

8<sup>th</sup> International conference (AIG) on  
**Geomorphology**

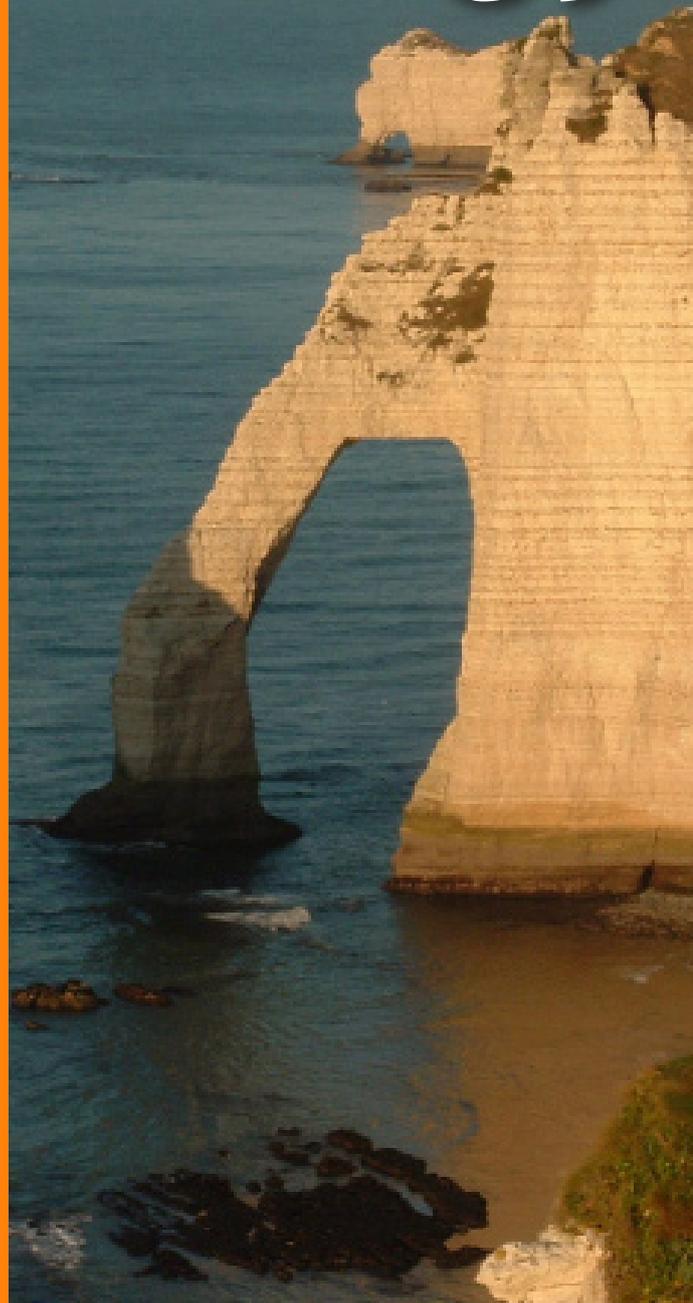
*ABSTRACTS VOLUME*

**PARIS - 2013**

27-31 august

« *Geomorphology and  
sustainability* »

[www.geomorphology-IAIG-paris2013.com](http://www.geomorphology-IAIG-paris2013.com)



## ACKNOWLEDGEMENT

The Organizing Committee would like to thank its partners for their support

### Institutional partners

---



### Bronze Partners

---



### Other Partners

---



Réalisé avec l'aide du Ministère de l'Enseignement supérieur et de la Recherche  
Action soutenue par la Région Ile-de-France (08 10 18 18 18)

## **CONTENTS**

Organizing Committee.....	Page 3
Scientific Committee.....	Page 4
Prologue.....	Page 7
Program Overview.....	Page 9
General Scientific Program (List of Sessions).....	Page 10
Program Schedule.....	Page 11
Detailed Scientific Program and Index of Abstracts.....	Page 15
Alphabetical Index of Presenting Authors.....	Page 1203
IAG Executive Committee.....	Page 1209



**ORGANIZING COMMITTEE**

<b>NAME</b>	<b>ROLE IN THE ORGANIZING COMMITTEE</b>	<b>INSTITUTION</b>
Stéphane COSTA	President	Univ. Caen Basse-Normandie
Marie-Françoise ANDRÉ	Co-president of the Scientific Committee	Univ. Clermont Ferrand
Gilles ARNAUD-FASSETTA	In charge of the Journal «Géomorphologie»	Univ. Paris Diderot (Paris VII)
François BETARD	Secretary of the French Federation of Geosciences	Univ. Paris Diderot (Paris VII)
Nathalie CARCAUD	In charge of Paris 2013 Excursions Commission Paris 2013	Univ. Angers
Etienne COSSART	Jointly in charge of the Paris 2013 Young Geomorphologists Meeting	Univ. Panthéon-Sorbonne (Paris I)
Monique FORT	Co-president of the Scientific Committee	Univ. Paris Diderot (Paris VII)
Matthieu GHILARDI		CNRS ; Lab. CEREGE, Aix-Marseille
Christian GIUSTI		Univ. Paris-Sorbonne (Paris IV)
Nicolas JACOB-ROUSSEAU	GFG treasurer	Univ. Lyon 2
Yann LE DREZEN	Co-responsible for excursions	Univ. Panthéon-Sorbonne (Paris I)
Charles LECOEUR		Univ. Panthéon-Sorbonne (Paris I)
Laurent LESPEZ	GFG treasurer	Univ. Caen Basse-Normandie
Denis MERCIER	Coordinator of the book <i>Geomorphology of France</i> Paris 2013	Univ. Nantes
Nathalie VANARA		Univ. Panthéon-Sorbonne (Paris I)

**SCIENTIFIC COMMITTEE**

<b>NAME</b>	<b>INSTITUTION</b>
<b>Presidents</b> FORT Monique ANDRÉ Marie-Françoise	Univ. Paris Diderot, France Univ. Clermont Ferrand, France
ALCÁNTARA-AYALA Irasema	UNAM Mexico, Mexico
ALLÉE Philippe	Univ. Limoges, France
ANTHONY Edward	Univ. Aix, France
ARNAUD-FASSETTA Gilles	Univ. Paris 12, France
ASRAT Asfawossen	Univ. Addis-Ababa, Ethiopia
AUDEMARD Franck	Univ. Caracas, Venezuela
AUDRA Philippe	Univ. Nice, France
BAKER Vic	Univ. Arizona, Tucson, USA
BALTEANU Dan	Acad. Sciences Bucarest, Romania
BENAZZOUZ Mohamed	Univ. Alger, Algeria
BRIERLEY Gary	Univ. Auckland, New-Zealand
BRUNSDEN Denys	King's College, London, United Kingdom
BURBANK Doug	Univ. Santa Barbara California, USA
CALVET Marc	Univ. Perpignan, France
CHRISTIANSEN Hanne	UNIS Svalbard, Norway
COELHO NETTO Anna Luisa	IGEO/UF Rio de Janeiro, Brasil
DECAULNE Armelle	CNRS Clermont-Ferrand, France
DELAHAYE Daniel	Univ. Caen, France
DELANNOY Jean-Jacques	Univ. Chambéry, France
DIKAU Richard	Univ. Bonn, Germany

EMBLETON-HAMANN Christine	Univ. Wien, Austria
EVANS Ian	Univ. Durham, United Kingdom
FREDI Paola	Univ. Roma, Italy
GAUTIER Emmanuèle	Univ. Paris 8, France
GOUDIE Andrew	St Cross College, Oxford, United Kingdom
GUNNELL Yanni	Univ. Lyon 2, France
GUTTIÉREZ Francisco	Univ. Zaragoza, Spain
HEQUETTE Arnaud	Univ. Dunkerque, France
HOOKE Janet	Univ. Liverpool, United Kingdom
KUZUCUOGLU Catherine	CNRS Meudon, France
LAGEAT Yannick	Univ. Brest, France
LANE Stuart	Univ. Lausanne, Switzerland
LANG Andreas	Univ. Liverpool, United Kingdom
LAOUINA Abdellah	Univ. Rabat, Morocco
LAVIGNE Franck	Univ. Paris 1, France
MAIRE Richard	CNRS Bordeaux, France
MALET Jean-Philippe	CNRS Strasbourg, France
MAQUAIRE Olivier	Univ. Caen, France
MARSTON Richard	Kansas State University, USA
MORHANGE Christophe	Univ. Aix, France
OGUCHI Chiaki	Univ. Saitama, Japan
PANIZZA Mario	Univ. Modena, Italy
PEIRY Jean-Luc	Univ. Clermont-Ferrand, France
PENVEN Marie-Josée	Univ. Rennes, France
PEULVAST Jean-Pierre	Univ. Paris 4, France

PFEFFER Karl-Heinz	Univ. Tübingen, Germany
PIEGAY Hervé	CNRS Lyon, France
RACZKOWSKA Zofia	Acad. Sciences Kraków, Poland
REYNARD Emmanuel	Univ. Lausanne, Switzerland
RODRIGUES Maria Luisa	Univ. Lisboa, Portugal
SALVADOR Pierre-Gil	Univ. Lille, France
SCHROTT Lothar	Univ. Salzburg, Austria
SELLIER Dominique	Univ. Nantes, France
SLAYMAKER Olav	Univ. Vancouver, Canada
STANLEY Jean-Daniel	Smithsonian Institution, Washington, USA
STARKEL Leslek	Acad. Sciences Kraków, Poland
STEPHENSON Wayne	Univ. of Otago, New Zealand
STIROS Stathis	Univ. Patras, Greece
SUNIL Kumar De	Univ. Tripura, India
TCHINDJIANG Mesmin	Univ. Yaounde, Cameroon
THORN Colin	Univ. Illinois, USA
THOURET Jean-Claude	Univ. Clermont-Ferrand, France
TRENHAILE Alan	Univ. Windsor, Canada
Van ASCH Theo	Univ. Utrecht, Netherlands
VÖTT Andreas	Univ. Mainz, Germany
WEISROCK André	Univ. Nancy, France
WILLIAMS Martin	Univ. Adelaide, Australia
YANG Xiaoping	Chinese Acad. Sciences, Beijing, China

## PROLOGUE

Dear colleagues, dear friends,

This is a great pleasure to welcome you at the 8<sup>th</sup> International Conference on Geomorphology of the International Association of Geomorphologists (IAG), held in Paris (27-31 August 2013). This volume includes the 1936 abstracts accepted for oral (931) and poster (1005) presentations. These were dispatched within 27 sessions covering the majority of geomorphological topics. All abstracts have been reviewed by the 105 co-chairs of the sessions. In addition, five keynotes punctuate the Conference Programme: they will be delivered by Denys Brunsten, Vic Baker, Ana Luiza Coelho Netto, Asfawossen Asrat, Xiaoping Yang. Finally, 7 inter-conferences and 6 post-conference field trips have been organized by geomorphologists from more 17 French Universities, and 3 from abroad (Switzerland, Italy).

This Abstract volume, which provides an excellent overview of current research trends in geomorphology, is complemented by two books dealing with the Geomorphology of France: the first one, “**Géomorphologie de la France**” is coordinated by D. Mercier (Dunod), and the second one, “**Landscapes and Landforms of France** “ edited by M. Fort and M.F. André, is the first of the new Springer series directed by P. Migón.

I would like to express my deep gratitude to the members of the Organizing committee for dedicating so much of their time to the organization of the conference: M. Fort, M.-F. André, E. Cossart, F. Bétard, Y. Le Drézen, N. Carcaud, D. Mercier, C. Le Coeur, L. Lespez, C. Giusti, N. Vanara, M. Ghilardi, Nicolas Jacob, G. Arnaud-Fassetta.

On behalf of the Organizing Committee, I wish to thank warmly the International Association of Geomorphologists (IAG) and its Executive Committee for putting their trust in the French community of geomorphologists.

Collectively, we are all very grateful to the Institutions: Marie de Paris, Conseil Régional d’Ile de France, CNRS, Ministère de la Recherche, and to all sponsors that have kindly provided financial and logistical support in a difficult economic period.

**Stéphane Costa** (University of Caen. LETG Géophen)  
*Chair of the Organizing Committee of the  
8<sup>th</sup> International Conference on Geomorphology*



## **PROGRAM OVERVIEW**

### **Monday, August 26**

---

14:30 - 18:30	Pre-registration
15:00 - 19:00	IAG meeting (Executive committee meeting of the outgoing EC)

### **Tuesday, August 27**

---

8:00 -	Registration
9:30 - 11:00	1 <sup>st</sup> IAG General Assembly
11:00 - 11:30	Opening Session
11:30 - 12:30	Keynote Lecture by Prof. Denys Brunsten
12:30 - 13:45	Break & Poster Session
13:45 - 16:30	Parallel Sessions
16:30 - 17:00	Coffee Break & Poster Session
17:00 - 18:00	Keynote Lecture by Prof. Victor Baker
19:00 - 21:00	Welcome Cocktail at Paris City Hall (Hôtel de Ville)

### **Wednesday, August 28**

---

8:00 - 10:15	Parallel Sessions
10:15 - 10:45	Coffee Break & Poster Session
10:45 - 12:30	Parallel Sessions
12:30 - 13:45	Break & Poster Session
13:45 - 15:45	Parallel Sessions
15:45 - 16:15	Coffee Break & Poster Session
16:15 - 18:30	Parallel Sessions
18:30 - 19:30	Keynote Lecture by Prof. Ana Luiza Coelho Netto
19:30 - 20:30	Wine & Cheese

### **Thursday, August 29**

---

One-day intercongress fieldtrips

### **Friday, August 30**

---

8:00 - 10:30	Parallel Sessions
10:30 - 11:00	Coffee Break & Poster Session
11:00 - 12:45	Parallel Sessions
12:45 - 14:00	Break & Poster Session
14:00 - 16:00	Parallel Sessions
16:00 - 16:30	Coffee Break & Poster Session
16:30 - 18:15	Parallel Sessions
18:15 - 19:15	Keynote Lecture by Prof. Asfawossen Asrat
20:00 - 23:30	Gala Evening on the Seine River (Péniche "Le Boréas")

### **Saturday, August 31**

---

8:00 - 10:15	Parallel Sessions
10:15 - 10:45	Coffee Break & Poster Session
10:45 - 12:30	Parallel Sessions
12:30 - 13:45	Break & Poster Session
13:45 - 16:15	Parallel Sessions
16:15 - 16:45	Coffee Break & Poster Session
16:45 - 17:45	Keynote Lecture by Prof. Xiaoping Yang
17:45 - 18:45	2 <sup>nd</sup> IAG General Assembly
18:45 - 19:15	Closing Session

### **Sunday, September 1**

---

Beginning of:

- Post-Conference Excursions
- Intensive Course for Young Geomorphologists

**GENERAL SCIENTIFIC PROGRAM (LIST OF SESSIONS)**

<b>Sessions</b>		<b>Convenors</b>
S1	History and epistemology of geomorphology	Victor BAKER
S2	Geomorphology and earth system science (IAG-WG)	Nick CLIFFORD
S3	Planetary geomorphology (IAG-WG)	Mary BOURKE & Nicolas MANGOLD
S4	Mega-geomorphology	Jorge RABASSA & Clifford OLLIER
S5	Tectonic geomorphology (including neotectonics and paleoseismology)	Doug BURBANK & Francisco BEZERRA
S6	Volcanic geomorphology: towards a quantitative assessment of volcanic landforms, processes and hazards	Jean-Claude THOURET & Paola FREDI
S7	Magnitude and frequency in geomorphology including: S7A - Extreme events in geomorphology (IAG-WG)	Stuart LANE & Thomas GLADE Samuel ETIENNE & James P. TERRY
S8	Geomorphic processes and long term landscape evolution	Yanni GUNNELL & Leszek STARKEL
S9	Rock control on geomorphic processes and landforms including: S9A - Sandstone geomorphology (Danxia IAG WG), extended to quartzites S9B - Karstic geomorphology: from hydrological functioning to palaeoenvironmental reconstructions	Piotr MIGÓN Piotr MIGÓN Philippe AUDRA, Francisco GUTIÉRREZ & Jo DE WAELE
S10	Quaternary geomorphology, including : S10A - FLAG-GLOCOPH	Margot BÖSE Gerardo BENITO, David BRIDGLAND, Stéphane CORDIER & Thomas HOFFMANN
S11	Geomorphology and global environmental change	Olav SLAYMAKER
S12-16	<b>Anthropocene geomorphology</b> S12. Geoarchaeology (IAG-WG) S13. Human impacts on landscapes (IAG-WG) S14. Geomorphic hazards, risk management and climate change impact (IAG-WG)  S15. Geoconservation, geotourism and education including: S15A - Anthropogenic and climatic drivers of cultural stone deterioration and conservation S15B - Geomorphosites (IAG-WG) including geoparks and WHS S15C - Managing landscape dynamics in protected areas S15D - Teaching and disseminating geomorphology S16. Forum francophone : la géomorphologie au service du développement durable	Andrew GOUDIE Kosmas PAVLOPOULOS & Vanessa HEYVAERT Asfawossen ASRAT, Andrew GOUDIE, Paul HUDSON, Denes LOCZY Irasema ALCÁNTARA AYALA, Sunil Kumar DE & Adriana NIZ  Patricia WARKE & Stephen McCABE  Emmanuel REYNARD, Paola CORATZA & Dominique SELLIER Maria Luisa RODRIGUES & Tim BADMAN David HIGGITT Jules ALONI, Jean-Louis BALLAIS, Mohamed Raouf KARRAY, André OZER, Mario PANIZZA, André ROY & PHAN TRONG Trinh

<b>S17</b>	<b>Geomorphology and the Critical Zone (including weathering, soils and biogeomorphology)</b>	Heather VILES & Junun SARTOHADI
<b>S18</b>	<b>Hillslope processes and mass movements</b> S18A - CERG Subsession: Methods for landslide hazard and risk assessment	Mauro SOLDATI, Mihai MICU & Jordi COROMINAS Jordi COROMINAS, Thomas GLADE, Jean-Philippe MALET
<b>S19</b>	<b>Fluvial geomorphology and river management including:</b> S19A - Large rivers (IAG-WG) S19B - Small catchments (IAG-WG) S19C - Sediment fluxes and morphodynamics of stream channels S19D - Other subsessions	Janet HOOKE & Gary BRIERLEY Avijit GUPTA & Zhongyuan CHEN Andrzej KOSTRZEWSKI Alain RECKING, John PITLICK, Mike CHURCH & Nicola SURIAN Janet HOOKE & Gary BRIERLEY
<b>S20</b>	<b>Sediment budgets (IAG-WG covering all environments)</b>	Achim A. BEYLICH & Armelle DECAULNE
<b>S21</b>	<b>Coastal geomorphology and management including:</b> S21A - Reef forms (IAG-WG) S21B - Rocky coasts (IAG-WG) S21C - Other subsessions	Edward ANTHONY & Julian ORFORD Chris PERRY, Paul KENCH & Scott SMITHERS David KENNEDY & Wayne STEPHENSON Edward ANTHONY & Julian ORFORD
<b>S22</b>	<b>Submarine geomorphology</b>	Klaus SCHWARZER & Sebastian KRSTEL
<b>S23</b>	<b>Aeolian systems and arid geomorphology (including subarid margins)</b>	Xiaoping YANG & Martin WILLIAMS
<b>S24</b>	<b>Tropical geomorphology</b> S24A - Tropical Rivers: Hydro-Physical Processes, Impacts, Hazards and Management (IGCP 582 and IAG Working Group on Tropical rivers)	Vishwas KALE, Robert WASSON  Edgardo LATRUBESSE, Jose C. STEVAUX, Rajiv SINHA
<b>S25</b>	<b>Cold region geomorphology including:</b> S25A - Glacial and paraglacial geomorphology S25B - Permafrost and periglacial geomorphology (in coop. with IPA) S25C - Mountain geomorphology	Jasper KNIGHT & Stephan HARRISON François COSTARD & Hugues LANTUIT  Francesco BRARDINONI & Lothar SCHROTT
<b>S26</b>	<b>Methods in Geomorphology including:</b> S26A - Modelling in geomorphology S26B - Remote sensing (including laser scanning, applications of radar, etc.) S26C - DEMs, GIS and spatial analysis S26D - Statistics in geomorphology S26E - Dating methods (including cosmogenic nuclides) S26F - Applied geomorphological mapping (IAG-WG)	John WAINWRIGHT Thomas DEWEZ & Dirk RIEKE-ZAPP  Takashi OGUCHI & Christopher GOMEZ Ian EVANS & Delphine GRANCHER Andreas LANG & Susan IVY-OCHS Michael SMITH, Paolo PARON & Jim GRIFFITHS
<b>S27</b>	<b>Young Geomorphologists Session</b>	Etienne COSSART, Johnny DOUVINET & Stuart LANE

**PROGRAM SCHEDULE**

<b>TUESDAY AUGUST 27</b>									
	Amphitheater Gaston Berger	Amphitheater Louis Armand Est	Amphitheater Louis Armand Ouest	Room 1	Room 2	Room 3	Room 4	Room AB	Room CD
9:30 11:00	<b>IAG General Assembly</b>	<i>IAG General Assembly*</i>	<i>IAG General Assembly*</i>						
11:00 11:30	<b>Opening Session</b>	<i>Opening Session*</i>	<i>Opening Session*</i>						
11:30 12:30	<b>Keynote lecture by Denys Brunsten</b>	<i>Keynote lecture by Denys Brunsten*</i>	<i>Keynote lecture by Denys Brunsten*</i>						
12:30 13:45	Break & Poster Session								
13:45 16:30	S21C	S19D	S14	S08	S12	S24	S15B	S25A	S22
16:30 17:00	Coffee Break & Poster Session								
17:00 18:00	<b>Keynote lecture by Victor Baker</b>	<i>Keynote lecture by Victor Baker*</i>	<i>Keynote lecture by Victor Baker*</i>						

<b>WEDNESDAY AUGUST 28</b>									
	Amphitheater Gaston Berger	Amphitheater Louis Armand Est	Amphitheater Louis Armand Ouest	Room 1	Room 2	Room 3	Room 4	Room AB	Room CD
8:00 10:15	S21C	S19D	S14	S08	S12	S26C	S15B	S25A	S24A
10:15 10:45	Coffee Break & Poster Session								
10:45 12:30	S21C	S19D	S14	S08 S04	S12	S26C	S15B S15C	S26E	S24A
12:30 13:45	Break & Poster Session								
13:45 15:45	S21C	S19D	S14	S01	S5	S26C	S19A	S25B	S24A S16
15:45 16:15	Coffee Break & Poster Session								
16:15 18:30	S21C	S19D	S18	S21A	S5	S2	S19A	S25B	S16
18:30 19:30	<b>Keynote lecture by Ana Luiza Coelho Netto</b>	<i>Keynote lecture by Ana Luiza Coelho Netto*</i>	<i>Keynote lecture by Ana Luiza Coelho Netto*</i>						

<b>FRIDAY AUGUST 30</b>									
	Amphitheater Gaston Berger	Amphitheater Louis Armand Est	Amphitheater Louis Armand Ouest	Room 1	Room 2	Room 3	Room 4	Room AB	Room CD
8:00 10:30	S21C	S19D	S18	S23	S5	S26A	S19A	S25C	S9B
10:30 11:00	Coffee Break & Poster Session								
11:00 12:45	S21C	S19C	S18	S23	S5	S26A	S7A	S25C	S9B
12:45 14:00	Break & Poster Session								
14:00 16:00	S13	S19C	S18	S23	S3	S26A	S10	S6	S9B S9
16:00 16:30	Coffee Break & Poster Session								
16:30 18:15	S13	S19C	S18	S23	S3	S26D	S10	S6	S9A
18:15 19:15	<b>Keynote lecture by Asfawossen Asrat</b>	<i>Keynote lecture by Asfawossen Asrat*</i>	<i>Keynote lecture by Asfawossen Asrat*</i>						

<b>SATURDAY AUGUST 31</b>									
	Amphitheater Gaston Berger	Amphitheater Louis Armand Est	Amphitheater Louis Armand Ouest	Room 1	Room 2	Room 3	Room 4	Room AB	Room CD
8:00 10:15	S13	S19C	S18 S18A	S21B	S20	S26B	S10A	S7	S17
10:15 10:45	Coffee Break & Poster Session								
10:45 12:30	S13	S19C S19B	S18A	S21B	S20	S26B	S10A	S11	S17
12:30 13:45	Break & Poster Session								
13:45 16:15	S13	S19B	S18A	S21B	S20 S15A	S26F	S10A S15D	S11	S27
16:15 16:45	Coffee Break & Poster Session								
16:45 17:45	<b>Keynote lecture by Xiaoping Yang</b>	<i>Keynote lecture by Xiaoping Yang*</i>	<i>Keynote lecture by Xiaoping Yang*</i>						
17:45 18:45	<b>IAG General Assembly</b>	<i>IAG General Assembly*</i>	<i>IAG General Assembly*</i>						
18:45 19:15	<b>Closing Session</b>	<i>Closing Session*</i>	<i>Closing Session*</i>						



## DETAILED SCIENTIFIC PROGRAM AND INDEX OF ABSTRACTS

### KEY-NOTE LECTURES

Tuesday, August 27 (11:30 - 12:30 - Amphitheater Gaston Berger) <b>Prof. Denys Brunsten</b> (King's College, London, UK) <i>Tales from the Deep</i> .....	127
Tuesday, August 27 (17:00 - 18:00 - Amphitheater Gaston Berger) <b>Prof. Victor Baker</b> (University of Arizona, USA) <i>Geomorphology of Earth-Like Planetary Surfaces</i> .....	128
Wednesday August 28 (18:30 - 19:30 - Amphitheater Gaston Berger) <b>Prof. Ana Luiza Coelho Netto</b> (Universidade Federal do Rio de Janeiro Janeiro, Brazil) <i>Spatially Non-Uniform Landscape Evolution and Process-Operations around the Tropic of Capricorn: the Role of Extreme Rainfall Events</i> .....	130
Friday August 30 (18:15 - 19:15 - Amphitheater Gaston Berger) <b>Prof. Asfawossen Asrat</b> (Addis Ababa University, Ethiopia) <i>Geomorphology of Ethiopia and Human Origins</i> .....	131
Saturday August 31 (16:45 - 17:45 - Amphitheater Gaston Berger) <b>Prof. Xiaoping Yang</b> (Institute of Geology and Geophysics, China) <i>Geomorphology and palaeoenvironmental changes in arid Asia</i> .....	132

### S01. HISTORY AND EPISTEMOLOGY OF GEOMORPHOLOGY

Convenor: *Victor R. BAKER*

#### **Oral presentations** .....135

FERRAZ M., VITTE A.

The relationship between art and the consolidation of american geomorphology during the nineteenth century

SCHOENEICH P.

The glacial trough - an attempt at theoretical geomorphology

FURLANI S., NINFO A., CANDELA A

Is the present the key to the future?

VAN DE WIEL M., DESJARDINS E., MARTEL T., ROUSSEAU Y., ASHMORE P.

Philosophical Reflections on Computational Geomorphology

RICHARDS K.

What's the point of fieldwork?

GRANT G., O'CONNOR J., WOLMAN M.G.

A river runs through It: Conceptual Models in fluvial geomorphology

CARLING P., JANSEN J., MESHKOVA L.

What's in a name? Unravelling the inosculate definitions of multichannel river networks

BAKER V.

Geosemiosis of planetary surfaces

#### **Poster presentations**.....139

RUDOYA A.

Rise of the Theory of Diluvial Morpholithogenesis in Russia: Opposition to the Recognition of late Pleistocene megaflooding in northern Eurasia

NEVSKY V.

**On Postmodern Geomorphology**

LAURETI L.

**From the Physical Geography, through Dynamic Geology, towards the Geomorphology. An historical itinerary, bridging the XIX and the XX century, of the Italian naturalists's contribute**

INKPEN R.

**The Primacy of Fieldwork**

## **S02. GEOMORPHOLOGY AND EARTH SYSTEM SCIENCE (IAG-WG)**

Convenor: *Nick CLIFFORD*

### **Oral presentations .....143**

CLIFFORD N.

**Geomorphology and Earth System Science: some thoughts on scale, place and method**

WILCOCK D., BRIERLEY G.

**Ethnogeomorphology**

BLUE B., BRIERLEY G.

**'But what do you measure?' Contextualising geomorphic understandings of the upper Yellow River**

DADSON S.

**Representing Geomorphology in Models of the Earth System**

MASSON E., KEILER M.

**Geomorphology 6.0: a framework for complexity elicitation**

LASTOCHKIN A., ZHIROV A.

**Geomorphologic fundamentals of system geologic and geographic studies**

FRENCH J., BURNINGHAM H.

**Conceptualising and formalising the structure of coupled estuary-coast-offshore systems**

DONADIO C., MAGDALENO F., KONDOLF G.M., MAZZARELLA A.

**Fractal dimension of drainage network geometry of some Mediterranean-type river basins in California, Spain and Italy: a geomorphologic key to interpretation**

ZHIJIU C., ZHANG W., LIU G., LI C.

**Preliminary study of the coupled control of tectonic uplift and the glaciations in the Tibetan Plateau**

### **Poster presentations .....**

BENNIA A., SRIVASTAV S.K., CHATTERJEE R.S.

**Groundwater investigations using optical and microwave remote sensing data in Solani watershed, India**

SAAD A.Z.E., KEBIR L., ZEBBAR Z.E., MAHI H., BENNIA A., DIF A., DJAAFAR Y.

**Hydrogeologic prospection in the basin of Tindouf. Contribution of the satellite images in the characterization of the fracturation**

GUIMARAES S., FRANCO B., GOMEZ T.

**Analysis of environmental fragility - Letter from Santa Maria da Vitoria - Bahia**

XU S.

**The Progress and Prospect of Daigu Landform Research**

FRANKL A., NYSSSEN J., POESEN J., ZWERTVAEGHER A.

**Using Google Earth to map and understand gully development**

ZHIROV A., LASTOCHKIN A.

**Applications of analytical geomorphologic maps in geography and geoecology**

BOLTRAMOVICH S., LASTOCHKIN A., ZHIROV A.

**On the new geomorphologic studies of Polar Regions**

D'AGATA C., MARAGNO D., SMIRAGLIA C., BOCCHIOLA D., DIOLAIUTI G.

**Half a century of glacier changes by analysing different data sources: The 1954-2007 glacier variations in the ortles-cevedale group(Stelvio National Park, Lombardy, Italian Alps)**

KAZHOKINA V.

**The ratio between river-bed erosion and river-basin denudation in natural and natural-anthropogenic landscapes on plains of Northern Eurasia according to suspended sediment runoff of the rivers**

MENAD W., ARNAUD-FASSETTA G., DOUVINET J., BELTRANDO G.

**Mechanisms of urban flood and surface runoff genesis in Oued Koriche catchment (Massif of Bouzaréah, western part of Grand Algiers, Algeria)**

BRANCIER J.

**A Micromorphological Assessment of Anthropogenic Features in Pre-Columbian Archaeological Layers: First Results for Crowned Mountains Sites in French Guiana**

DONADIO C., MAGDALENO F., KONDOLF G.M.

**Hydrogeomorphic features and improvement strategies of some Mediterranean rivers in California, Spain and Italy: a comparison between the Russian, Ebro and Volturno rivers**

SARMA J.N., ACHARJEE S.

**Variation of confluences of some large rivers in Brahmaputra basin, Assam, India**

BENYASSINE E.M., DEKAYIR A., DESRUELLES S.

**Geomorphological and environmental studies of high Moulouya watershed by ArcGis and ASTER Imaging**

MENDOZA M.E., GRATIOT N., LÓPEZ-GRANADOS E., ARNAUD F., MAGAND O., PRAT C., STEVES M.

**Relationships between land cover, land use change and erosion-sedimentation processes at the watershed level: A multitemporal study in the Cointzio watershed, Mexico**

YAN W., WEI E., LIU J., LI C., LIU J., FENG J.

**Improvement of Chang'E-1 Orbit Determination Accuracy by Space VLBI**

### **S03. PLANETARY GEOMORPHOLOGY (IAG-WG)**

Convenors: *Mary BOURKE & Nicolas MANGOLD*

#### **Oral presentations .....159**

DE VET S., MERRISON J., CAMMERAAT E.

**Understanding the environmental fate of glaciovolcanic glass using the parallels between subglacial volcanism in Iceland and on Mars**

CRADDOCK R., ANDREWS B., NANSON G., ROSE T., TIRSCH D., TOOTH S.

**Characteristics Of Basaltic Sand: Age-Dating Techniques And Understanding Size, Shape, And Composition As A Function Of Transport Process And Distance**

HERNY C., CARPY S., BOURGEOIS O., PERRET L., LE MOUJELIC S.

**Action of sublimation in the formation of spiral-shaped ice megadunes on the martian polar caps**

SCHMIDT F., ANDRIEU F., GARGANI J., COSTARD F., MASSOL H.

**Active geysers, dark flow and 'Spiders' in the Martian polar region**

GOURRONC M., BOURGEOIS O., MÈGE D., POCHAT S., BULTEL B.

**Remnants of an equatorial glaciated valley landsystem in Valles Marineris (Mars)**

KROMUSZCZYNSKA O., MAKOWSKA M., GUEYDAN F., GURGUREWICZ J., MEGE D.

**Deep-seated gravitational spreading in Valles Marineris ' observations and modeling**

BARRETT A., BALME M., PATEL M., HAGERMANN A.

**The latitudinal distribution of putative periglacial sites on the northern plains of Mars**

LE DEIT L., HAUBER E., FUETEN F., PONDRELLI M., ROSSI A.P., JAUMANN R.

**Investigation of possible coastal and periglacial landforms in Gale Crater, Mars**

HOWARD A., MOORE J., MORGAN A., HOBLEY D., WILLIAMS R., BURR D., DIETRICH W., WILSON S., MATSUBARA Y.

**Depositional Environment of Large Alluvial Fans in Saheki Crater, Mars**

CORNET T., BOURGEOIS O., LE MOUÉLIC S., SOTIN C., FLEURANT C., LEFÈVRE A., RODRIGUEZ S., MALASKA M., BARNES J.W., BROWN R.H., BAINES K.H., BURATTI B.J., CLARK R.N., NICHOLSON P.D.

**Surface dissolution on Titan: Ontario Lacus, Sikun Labyrinth and other karst-like landscapes**

MOORE J.M., HOWARD A.D.

**Climate Change on Titan: Hypotheses and the Geological Record**

MISIURA K., CZECHOWSKI L.

**Evolution of terrestrial and Titan's rivers**

ANSAN V., MANGOLD N.

**Martian valley network geometry from mars express stereo images topography: implication for martian climate.**

CONWAY S.J., BALME M.R.

**The third dimension of surface process: using hydrological analysis of high-resolution elevation data on the Moon, Mars and Earth to evaluate the action of water**

ZOU X., LIU J., ZHAO J., WANG W., LI C.

**The morphology and distribution research of boulders in Lunar Sinus Iridum**

## **Poster presentations .....169**

DEBNAK K., MEGE D., GURGUREWICZ J., MASSE M., FORGET F., LUCAS A., SPIGA A.

**A Valles Marineris synthesis**

BAIONI D., SGAVETTI M.

**Karst landforms as a geomorphic marker to record stratigraphic and litologic units in Sinus Meridiani (Mars)**

GARGANI J., JOUANNIC G., COSTARD F., BOURGEOIS O., MASSÉ M., CARTER J., MARMO C., NACHON M., ORI G.

**Morphological characterization of landforms produced by springtime seasonal activity**

YURY E.

**Impactive processes and morpholitogenes**

WITEK P.

**Formation and evolution of river deltas on Titan and Earth**

BALME M., GALLAGHER C., CONWAY S.

**The Geomorphology of Lyot Crater, Mars**

CZECHOWSKI L., WITEK P., MISIURA K.

**Numerical model of flow in some martian valleys**

NACHON M., GARGANI J., JOUANNIC G., COSTARD F., CONWAY S., BALME M.

**Geomorphological study of martian seasonal activity on the Kaiser crater dune field (46°10'S ; 18°50'E)**

WANG W., LIU J., ZOU X., LI C.

**Mare Basalt thickness Model of Lunar Polar Regions**

BOURKE M., PARTELI E., BYRNE S., BERMAN D.

**Rates of Dune Migration in a Polar Cavi on Mars**

MORGAN A., HOWARD A., HOBLEY D., MATSUBARA Y., MOORE J., PARSONS R., DIETRICH W., BURR D., WILLIAMS R., HAYES A.

**The alluvial fans of northern Chile as a terrestrial analog of the fan systems on Mars**

PARTELI E., DURAN O., BOURKE M., TSOAR H., HERRMANN H.

**Modeling barchan dune asymmetry**

## **S04. MEGAGEOMORPHOLOGY**

Convenors: *Jorge RABASSA & Clifford OLLIER*

### **Oral presentations .....175**

CHAMPAGNAC J.

**Late-Cenozoic relief evolution under evolving climate: A review of quantitative arguments**

RABASSA J.

**Gondwana paleosurfaces: large-scale and long-term landscape evolution in cratonic areas of Argentina**

DEGIOVANNI S.

**Geomorphological characterization of relictic Gondwanic paleosurfaces in the Comechingones range, Central Pampean Mountains, Argentina**

FLUGEL T.J., ECKARDT F.D., COTTERILL F.P.D.

**The Neogene evolution of the Congo and Kalahari basins, with a focus on the Congo-Zambezi watershed**

LADEIRA F.S.B., LEONARDI F., SANTOS M.

**The lateritic materials occurrence in Brazil - geographic distribution and association to the paleosurfaces**

### **Poster presentations .....177**

GRIMAUD J., CHARDON D., ROUBY D., BEAUVAIS A.

**Long-term evolution of West African drainage, denudation and paleo-river long profiles using the lateritic record from the Cenozoic**

OLLIER C.

**The neotectonic period and geomorphology**

RABASSA J., ACEVEDO R.D., PONCE J.F., MARTÍNEZ O.A., ORGEIRA M.J., PREZZI C., CORBELLA H., GONZÁLEZ-GUILLOT M., ROCCA M., SUBÍAS I., VÁZQUEZ C.

**Bajada del Diablo impact crater-strewn field: the largest crater field in the Southern Hemisphere**

## **S05. TECTONIC GEOMORPHOLOGY (INCLUDING NEOTECTONICS AND PALEOSEISMOLOGY)**

Convenors: *Doug BURBANK & Francisco BEZERRA*

### **Oral presentations .....181**

NIWA Y., SUGAI T., OGAMI T.

**Tectonic tilting toward the west during the past 7000 years indicated by spatial difference in relative sea-level changes across the Nobi Plain, on the footwall of the Yoro fault system, central Japan**

WHITNEY B., HENGESH J.

**Geomorphological evidence for a 2000 km long intracontinental fault system in the 'Stable Continental Region' of Western Australia**

BARCHI M., POZZOVIVO V., GALBIATI M., ROCCHINI P., CAIRO E.

**Passive vs. active control of tectonic structures on the recent sedimentary evolution of a turbidite system: a tectonic geomorphology study from the Po Plain (Northern Italy)**

DEFFONTAINES B., FORTUNATO G., MAGALHAES S.

**Seismic and Eustatic cycles in the southern Apennine deformation front (Basilicate -Southern Italy)**

FITZSIMONS S., HOWARTH J., JACOBSEN G., NORRIS R.

**The sedimentary response of mountain environments to large earthquakes: an example from south Westland, New Zealand**

PIRAZZOLI P., EVELPIDOU N., KARKANI E.

**Fossil shorelines at Corfu and surrounding islands deduced from erosion notches**

GORI S., FALCUCCI E., LADINA C., MARZORATI S., VALENSISE G.

**Fault activity, basin architecture and structural evolution of extensional tectonic depressions: case studies from central Apennines (Italy), investigated through geological and geophysical surveys**

PILLANS B.

**Dating fault movement in southeastern Australia, using paleomagnetism**

DEVI DATT D.

**Evolution of Neotectonic Landforms between Srinagar and Bagwan in Lower Alaknada Valley, Garhwal Himalaya, India**

BHATTACHARYA SOMA S.

**Neo-tectonics in the Genesis of Terraces in the Eastern Himalayan Foothills between River Gish and Jaldhaka, North Bengal, India**

NEPOP R., AGATOVA A., MYGLAN V., BARINOV V.

**New techniques within paleoseismological study of mountain terrains based on dendrocronological analysis and statistical approach by the example of SE Altai (Russia)**

FERRY M., SCHLUPP A., MUNKHUU U.

**Tectonic Geomorphology of Slow Faults in Northern Mongolia: Implications for Seismic Hazard in Ulaanbaatar**

LI Y., LV S.

**Paleoseismicity of the North Zhongtiaoshan Fault zone, Shanxi Graben System, China**

GHOSH P.

**How old are the Himalayan river valleys?**

MERIAUX A., VAN DER WOERD J., TAPPONNIER P., RYERSON F., FINKEL R., LASSERRE C., XU X.

**The Pingding segment of the Altyn Tagh Fault (91°E): Holocene slip-rate determination from cosmogenic radionuclide dating of offset fluvial terraces**

KUMAR A., SRIVASTAVA P.

**Late quaternary landform evolution along the Indus River, Ladakh, NW Himalaya**

HU X., PAN B., WANG J., LI Q., HU Z., CAO B., JIANG S.

**Deforming rate and kinematics of a potential part of the Tibetan Plateau on the mid-portion of the Qilian Shan Moutian, China**

GUTIERREZ F., CARBONEL D., LINARES R., ROQUE C., ZARROCA M., GUERRERO J., MCCALPIN J.

**Differentiating between gravitational faults related to evaporite dissolution and tectonic faults by means of geomorphological mapping, trenching and geophysical surveys**

SANDERSEN P.B.E., JØRGENSEN F., MØLLER R.R.

**Neotectonic deformation of a Late Quaternary glaciofluvial outwash plain in Southern Denmark caused by glacio-isostatic fault reactivation**

SCOTTI V., FACCENNA C., MOLIN P., SOLIGO M.

**The topography of the Iberian Chain (Spain): tectonic and surface processes interaction in landscape evolution**

DUPERRET A., VANDYCKE S., COLBEAUX J.P., VAN VLIET-LANOE B., DROMELET E., CANCOUET R.

**Morphotectonic analysis of coastal chalk cliffs in Picardy (NW France): field evidence of neotectonic fault systems occurrence in step-graben structure**

SANKARAN B.

**Remote Sensing and Ground Penetrating Radar in the characterization of Tectonic Geomorphology of South Andaman Islands, India ' A step towards hazard preparedness and mitigation**

FOROUTAN M., LE DORTZ K., MEYER B., SÉBRIER M., NAZARI H., FATTAHI M., RASHIDI A., BATEMAN M.D., BRAUCHER R., BOURLÈS D., BENEDETTI L., SIAME L., TALEBIAN M., GHORAISHI M.

**Prehistoric large earthquakes produced by slip on the Central Iran strike-slip faults**

ASCIONE A., CAPALBO A., CAPOLONGO D., MAZZOLI S., PAZZAGLIA F.J., VALENTE E., ZATTIN M.

**Uplift vs. denudation in the southern Apennines (Italy): geomorphologic evidence and constraints from terrestrial cosmogenic nuclides and apatite (U-Th)/He data**

BELLIN N., VANACKER V., KUBIK P.

**Linking topographic indices and rock uplift rates to denudation in a low uplift rate setting: Betic Cordillera, SE Spain**

MEGHRAOUI M.

**Long Term Evolution of Active Folding in North Africa: Surface deformation and modeling**

ROSSETTI D., ROSSETTI D., HYAKAWA E., BERTANI T., ZANI H., CREMON É.

**The role of tectonics on the evolution of late Quaternary Amazonian landscape**

REGARD V., MARTINOD J., CARRETIER S., SAILLARD M., PEDOJA K., RODRÍGUEZ M.P., RIQUELME R., HÉRAIL G., BENECH N., GUILLAUME B., AGUILAR G.

**Uplift history of the coastal Central Andes deduced from morphology**

AUDEMARD F., LEAL A.

**Local tsunamigenic earthquakes off northeastern Venezuela, in the southern Caribbean realm**

BERTI C., PAZZAGLIA F.J., MELTZER A.S.

**Active deformation of a passive margin: geomorphic evidence for persistent faulting consistent with the 23 August, 2011 Louisa County, VA earthquake**

## **Poster presentations .....196**

LU H., ZHANG T., LI Y., SI S., ZHENG X.

**Quaternary tectonic deformation in the front of the northern Tian Shan, northwestern China revealed by sedimentary and geomorphic evidences of the Urumqi River**

ELHABAB A., EL ADSANI I.

**Sequence stratigraphic analysis and hydrocarbon prospects of the late Neogene-Quaternary off shore sediments north west of Sinai, Egypt**

FUBELLI G., FALCUCCI E., GORI S., DELLA SETA M., FREDI P.

**Landscape evolution in a active tectonic context: the case of the Aterno river basin (L'Aquila, Abruzzo, Italy)**

HIRE P.S., PATIL A.D.

**Application of Geomorphic Indices of Active Tectonics (GAT) in Morphotectonic Analysis of the Par River from Western India**

BUCCI F., CARDINALI M., FIORUCCI F., GUZZETTI F., SANTANGELO M.

**Evolution of large-scale gravitational deformations in tectonically-controlled mountain slopes**

PERUCCA L., RUIZ F.

**Neotectonic structures in the precordillera geological province. Structural setting from geomorphologic, gravity and magnetic data**

CALVET M., GUNNELL Y., HEZ G., BRAUCHER R., GUILLOU V., BOURLES D., DELMAS M., SORRIAUX P.

**Capturing the timing and rates of valley incision through cave dating in the Eastern Pyrenees: geodynamic implications**

KEZOVIC M., DRLJEVIC N.

**Geomorphologic correlation of the reconstructed and contemporary relief in Kolubara - Tamnava Coal Basin**

MORALES N., FELIPE L.B., SOARES JR. A.V.

**Tectonic influence on the geomorphologic evolution of Tocantins river near Marabá, South Amazonia**

CICCACCI S., FALCUCCI E., FREDI P., LUPIA PALMIERI E.

**Recent tectonics control on the morphological evolution of the eastern sector of the Monti Sabatini Volcanic District (Lazio, Italy)**

OLIVETTI V., MOLIN P., CYR A., FACCHENNA C.

**Spatial variation in erosion rates and river longitudinal profiles along the Calabrian Arc**

MARTINEZ-GUTIERREZ G.

**Quaternary landscape response to neotectonics and fluvial processes: an example from the San José del Cabo basin, Baja California, México**

ZHANG S., DING R., MAO C., LI T., LV Z.

**Uplifts of the Longmenshan mountain in the eastern margin of Tibetan Plateau constrained by geomorphic evidences**

MIRABELLA F., BUCCI F., CARDINALI M., GUZZETTI F.

**Morpho-structural features and drainage pattern related to extensional faulting: an example from the Northern Apennines (Italy)**

MIRABELLA F., PUCCI S., DEMARTINI P.M., CIVICO R., BURATTI N., BAGLIONI S., SMEDILE A.

**Morphological and hydrological response to extensional faulting. An example from the Northern Apennines of Italy**

GODARD V., SPINABELLA F., BOURLÈS D., BURBANK D., BOOKHAGEN B., FISHER B., MOULIN A.

**Tectonic versus climatic controls on landscape denudation: A test in the central Himalayas**

BEZERRA F., ROSSETTI D., ANDRADES FILHO C., NOGUEIRA F., GÓES A.M., MEDEIROS W.E., OLIVEIRA R.G., FUCHS R.A.

**Role of Neogene-Quaternary faults on landform evolution in the continental margin of northeastern Brazil**

SANTANGELO N., ASCIONE A., IANNACE A., IMBRIALE P., SANTO A.

**Travertines distribution in Southern Italy: tectonic and geochemical implications**

ANSBERQUE C., GODARD V., BELLIER O., DE SIGOYER J., LI Y., LIU-ZENG J., REN Z., BOURLÈS D.

**Denudation rate spatial variation across the Eastern Tibetan margin**

BAIONI D., CAVITOLLO P., DELLA SETA M., FREDI P., GIANGIOLINI F., NESCI O., SAVELLI D., SGAVETTI M., SPIGARELLI A., TRAMONTANA M., TROIANI F.

**Channel-profiles metrics in tectonic geomorphology: new insights from a continental piedmont area, a sub-marine canyon system and analogues on Mars**

VANDYCKE S., DUPERRET A., COLBEAUX J.P.

**Relationships between tectonic fractures and cliffs morphologies: examples along chalk coast in France (Normandy, Picardy, Boulonnais)**

BLAHUT J., BALEK J., FUCIK Z., KAPLAN Z., KLIMES J.

**GEONAS GNSS network for geodynamic observations of surface development in Czechia**

PAVANO F., CATALANO S., ROMAGNOLI G., TORTORICI G.

**Regional vs. local morphological effects of the late quaternary deformation of NE Sicily**

SIMOU E., KARAGKOUNI V., PAPANTONIOU G., PAPANIKOLAOU D., NOMIKOU P.

**Morphotectonic analysis of Kozani Basin (Western Macedonia, Greece)**

SANTOS M.

**Morphotectonics and Cenozoic Sedimentation on Aiuruoca Region - Mantiqueira Range (MG), Brazil**

COUTO E., SANTOS L.J.C., GONTIJO A.H.P.

**Morphogenesis and Pedogenesis Relationship as Evidence of Neotectonics in Sedimentary Rocks in the Upper Cretaceous - Portion Center-South of the South American Platform - Brazil**

COUTO E., LUCIANE MARIA V., FORTES E.

**SL index as indicator of anomalies in the longitudinal profile of the Alonzo River, Southern Brazil**

GURGEL S.P.D.P., BEZERRA F.H.R., CORRÊA A.C.D.B., MARQUES F.O., MAIA R.P.  
**Evolution of uplifted structural landforms in northeastern Brazil**

LIANG H., LI S., ZHANG K.

**The neotectonics and its impact on the evolution of the Yellow River at the northeastern margin of the Tibetan Plateau, China**

CHAMPAGNAC J.D., VALLA P., HERMAN F., LOWICK S., GURALNIK B., FELLIN G.

**Fracture density as a controlling factor of erosion and exhumation over glacial-interglacial cycles: Insights from low-temperature thermochronology (AHe & OSL) and remote sensing, Granite Range, AK**

BALYAN H.

**Some remarks and additions to legend about neotectonics map**

GHEDHOU R., DEFFONTAINES B., ZETRINI H., RABIA M.C.

**Neotectonics of Jerba (S. Tunisia): A pull-apart on a NW-SE right lateral transtensive fault zone**

COLON S., BECK C., AUDEMARD F., PADRON C., DE BATIST M.

**Drastic late Pleistocene-Holocene faceting of the continental shelf off Central Venezuela by eustatism and local active tectonics**

ELIAS Z.

**The influence of tectonic movements upon river changes on the example of Lower Khazir river**

CASTALDINI D., DI MANNA P., GUERRIERI L., VITTORI E., PICCARDI L., BERLUSCONI A., LIVIO F., MICHETTI A.M., COMERCI V., TOSATTI G.

**Geological and geomorphological effects induced by the Emilia seismic swarm of May 2012 (northern Italy)**

GOSWAMI U., BEZBARUAH D.

**Morphotectonic analysis and some geo-environmental implications of the Gai River basin, North-East India**

AKKOPRU E., SENGUL A., GURAY E.

**The earthquake of Van on 23 October 2011 and its geomorphological effects**

EFE R., SOYKAN A., CUREBAL I., SONMEZ S.

**The Effect of Tectonics on Geomorphologic Evolution of Kalkım Basin (NW Turkey)**

BERTI C., PAZZAGLIA F.J., RAMAGE J.M., MICCADEI E.

**Geomorphic development of an actively uplifting footwall: integration of short-term co-seismic deformation (InSAR) and river network evolution. Examples from l'Aquila earthquake (April 2009), Italy**

**The Pliocene basalt and the history of the modern Longchuanjiang River in Tengchong, SW China**

LIU F., ZHAO Y., YANG Z.Y.

GIOIA D., DANESE M., LAZZARI M., SCHIATTARELLA M.

**Morphotectonic indicators of late Quaternary faulting in the Mercure River basin, southern Italy**

GENTI M., CHÉRY J., CATTIN R., VERNANT P.

**Erosion-induced isostatic rebound triggers extension in Pyrenees: insights from numerical modeling**

TSODOULOS I., GALLOUSI C., KOUKOUVELAS I.

**Geomorphic evidence of active fold growth along the Ainos Thrust Fault (Cephalonia Island, Greece)**

GONTIJO-PASCUTTI A., BEZERRA F.H.R.

**Tectonic evolution of the Paleogene to Quaternary Rio Santana Graben in the Ribeira Belt, continental margin of Brazil**

LAVARINI C., MAGALHÃES JR A.P., OLIVEIRA F.S.

**Neotectonic activity hypothesis in the SE Brazilian highlands supported by morphometric and statistical analysis: an initial approach**

TRIPATHI M.

**Neo-Tectonics and Landform Assemblage in the Middle Valley of Ramganga River (W), Kumaun Lesser Himalaya, India**

ABRAHAMI R., HUYGHE P., VAN DER BEEK P., CARCAILLET J., CHAKRABORTY T.

Using detrital thermochronologic and cosmogenic data to understand the evolution of modern Himalayan megafans

BARROS A.C.M., TAVARES B.A.C., MONTEIRO K.A., CORRÊA A.C.B.

The application of the slope x length index at the riacho grande watershed, northeast of Brazil

HARBOR D., RAHL J., BOVAY A.C., GALLI C., SBERNA D., HARTMAN R.

Drainage rearrangement and sediment production in response to uplift of the Andean Eastern Cordillera, NW Argentina

SILVA S.L.S., SILVA T.M.

Structural controls landscape in the south of Rio de Janeiro (Brazil): Morphotectonics evidences

GHATAK S., GHATAK M.

Geomorphometric Insights into Tectonically Active Intraplate Gavilgarh Fault Zone, Central India

MCINTOSH R., KOZÁK M.

Tracking tectonics in relief in selected model areas in the Bükk Mountains, NE Hungary

AUTHEMAYOU C., PEDOJA K., HEDDAR A., YELLES K., DJELLIT H., DEVERCHERE J., BOUDIAF A.

Geomorphologic analyses of coastal Uplift coupling the marine terraces and the drainage pattern : the case of the Sahel ridge, Algeria

YANG Z., LIN A.

Miocene Tectono-geomorphic evolution of the eastern Tibetan plateau and the course change of the Yangtze River

VALKANOU K., KARYMBALIS E., PAPANASTASSIOU D., CHALKIAS C., GAKI PAPANASTASSIOU K.

Morphotectonic study of the north Evia Island, Central Greece

SAMPAIO A., GONTIJO-PASCUTTI A., MOURA J.R.

Proposition of a morphotectonic subdivision of Sepetiba's Bay (Guanabara Graben, Rio de Janeiro, Brazil) based upon MDT of nautical charts and high resolution seismic profiles

MELLO C., SILVA C.G., METELO C.M.S., HATUSHIKA R.S., SUGUIO K.

Neotectonic control on evolution of quaternary lake systems in southeastern Brazil

STEPANCIKOVA P., NYVLT D., ROCKWELL T., HARTVICH F., HOK J., TABORIK P.

Late Quaternary faulting on the Sudetic Marginal Fault in intraplate Bohemian Massif (Central Europe)

FERRY M., AKSOY E., MEGHRAOUI M.

Geomorphology along Major Continental Faults: Slip rate constraint from climatic fluctuations

KANAKAKI S., CAMIZ S., POSCOLIERI M., PARCHARIDS I.

Morphostructural analysis of a subarea of Haiti, struck by the 2010 Earthquake, seated along the the Enriquillo-Plantain Garden Fault

SARIKAYA M., YILDIRIM C., CINER A.

Cosmogenic CL-36 dating of alluvial fans: implications for the late quaternary slip rates of the Ecemis fault in Turkey

## **S06. VOLCANIC GEOMORPHOLOGY: TOWARDS A QUANTITATIVE ASSESSMENT OF VOLCANIC LANDFORMS, PROCESSES AND HAZARDS**

Convenors: Jean-Claude THOURET & Paola FREDI

### **Oral presentations .....229**

PROCTER J., ZERNACK A., CRONIN S., PATRA A., SHERIDAN, LEONARD G., JOLLY G., KEYS H.

Geomorphic analysis of eruptive vents, landslide and debris flows of the 2012 Te Maari eruption from Mt. Tongariro, New Zealand

LAVIGNE F., DEGEAI J.P., LAHITTE P., ROBERT V., KOMOROWSKI J.C., VIDAL C.M., METRICH N., SRI HADMOKO D., ARYA DIPAYANA G., PRATOMO I., WASSMER P., DE BÉLIZAL E.

**The geomorphology of the Rinjani volcanic complex, Lombok Island, Indonesia: a result of a major historic eruption**

JOYCE E.B.

**Using volcanic landforms, their ages, bedrock and tectonic setting across the very large monogenetic field of the Newer Volcanic Province of southeastern Australia to assess future eruptions**

HADMOKO D.S., DIPAYANA G.A., SARTOHADI J., LAVIGNE F., MARFAI M.A., SURATMAN S.

**Lahars at Merapi Volcano following 2010 eruption: geomorphic impacts and hazards assessment**

VAN WYK DE VRIES B., MARQUEZ A., PETRONIS M., DELCAMP A., KERVYN M., PABLO G.

**Intrusion generated topography in monogenetic volcanoes**

GUILLÉN-MARTÍN C., ROMERO-RUIZ C., ROBERT A., DÓNIZ-PÁEZ J.

**Morphological changes associated with the emplacement of lava flows in coastal environments on the island of El Hierro (Canary Islands)**

RICCI J., LAHITTE P., QUIDELLEUR X.

**Evaluation of mechanical erosion and volcanic construction rates in the Basse-Terre Island (Guadeloupe, Lesser Antilles)**

CAMIZ S., POSCOLIERI M., ROVERATO M.

**Comparison of Andean Volcanoes landforms through geomorphometric analysis**

NEMETH K., KERESZTURI G., AGUSTÍN-FLORES J., CRONIN S.

**Quantitative assessment of external environmental controls on the style of monogenetic volcanic eruptions**

GROSSE P., KERVYN M., VAN WYK DE VRIES B.

**Towards a comprehensive morphometric classification of composite volcanoes**

KERVYN M., POPPE S., ALBINO F., SMETS B., KERVYN F.

**Mapping and quantifying the morphometry of volcanic features using high resolution Tandem-X DEM: the Virunga Volcanic Field, DR. Congo**

SIBRANT A.L.R., HILDENBRAND A., MARQUES F.O., BOULESTEIX T., COSTA A.C.G.

**Morpho-structural evolution of a volcanic island developed inside an active oceanic rift: São Miguel Island (Terceira Rift, Azores)**

NOMIKOU P., CAREY S., PAPANIKOLAOU D., PYLE D., PARKS M., BELL K., MATHER T., LIVANOS I., BEJELOU K., PERROS I.

**The volcanic morphology of the intra-caldera Kameni islands, Santorini, based on high resolution bathymetry and LiDAR data**

THOURET J.C., OEHLER J.F., SOLIKHIN A., GUPTA A., LIEW S.C.

**Multi scale patterns of aggradation and degradation on persistently active composite cones: the case study of Semeru, Indonesia, mapped and measured from satellite imagery, aerial photographs, and DEMs**

COSTA A., HILDENBRAND A., MARQUES F., SIBRANT A., CATALÃO J., CATITA C.

**Morpho-structural evolution of an active large-scale slump on the flank of an unstable volcanic island (Pico, Azores)**

**Poster presentations .....236**

NKOUATHIO D.G., KAGOU DONGMO A., ZANGMO TEFOGOUM G., MEWOULOU NDI Y., ABOUBAKAR B., GUEDJO SUH C.

**Landslides in the Western Highlands of Cameroon: environmental impact.**

THOURET J., GUPTA A., LIEW S.C., KASSOUK Z., OEHLER J.F., SOLIKHIN A.

**Pyroclastic density current and lahar deposits at Merapi, Indonesia, identified and measured with GeoEye and Pléiades imagery**

RASHIDOV T.

**Mud volcanoes of Azerbaijan as the relief unite: natural phenomenon and hazard**

YOSHIDA H.

Long-runout volcanoclastic sediments from Asama volcano due to the catastrophic sector-collapse in the Pleistocene, Japan

ROMERO RUIZ C., GUILLÉN-MARTÍN C., DÓNIZ-PÁEZ J., SÁNCHEZ-JIMÉNEZ N., ROBERT A.

The Degradation Of Recent Volcanic Landscapes Associated To The passage Of People. The Example Of Canary Islands, Spain

INBAR M.

Geomorphic Degradation of Volcanic Cinder Cones in Different Climatic Zones

BALYAN H.

Quaternary evolution of the waste mantle of the central volcanic Armenian highland

DE BELIZAL E., LAVIGNE F.

Geomorphic impacts and socioeconomic consequences of rain-triggered lahars at Merapi volcano (Java, Indonesia) following the 2010 eruption

LAHITTE P., GERMA CHARBONNIER A., LAVIGNE F.

Construction and destruction rates of volcanoes constrained from a DEM-based geomorphological reconstruction

HADMOKO D.S., THOURET J.C., SOLIKHIN A., WIBOWO S.B., WACANO D., KIKY P.

Lahar characteristics and erosion in the Gendol catchment after the centennial 2010 Merapi eruption

WIBOWO S.B., MOUROT P., LAVIGNE F., HADMOKO D.S.

Lahar flow characteristics on Putih River during 2012-2013 rainy season after centennial eruption of Merapi

VAN WYK DE VRIES B., KERVYN M., DELCAMP A., MOSSOUX S., LAGMAY M., GROSSE P.

The morphology of the Chaîne des Puys and Limagne Fault: a Linked Volcanic and Tectonic landscape

LABAZUY P., VAN WYK DE VRIES B., BOIVIN P., MIALLIER D.

Volcanic features of the central part of the Chaîne des Puys (Massif Central, France) revealed from the morphoquantitative analysis of a high resolution LiDAR-derived Digital Terrain Model

LAVIGNE F.

The SEDIMER Project: Sediment-related Risks and Disasters following the 2010 eruption of Merapi Volcano, Indonesia

## **S07. MAGNITUDE AND FREQUENCY IN GEOMORPHOLOGY**

Convenors: *Stuart LANE & Thomas GLADE*

### **Oral presentations .....247**

KORUP O.

Magnitude and frequency in geomorphology on changes and choices

VANACKER V., BELLIN N., KUBIK P.W.

Human-induced changes in geomorphic process rates: Can we gain new insights when analysing magnitude-frequency distributions?

GARES P., SWANN C., HILL S.

Event based magnitude/frequency analysis in geomorphology

KEILER M., FUCHS S.

The concept of frequency-magnitude relationship versus system dynamics in mountain catchments

MANI P., LIENER S., TOBLER D., HAEHLEN N.

Magnitude and frequency scenarios for a changing alpine environment

CROKE J., THOMPSON C., PIETSCH T., SHARMA A.

Flood Reconstruction and Implications for Magnitude-Frequency

GARCIA R.A.C., OLIVEIRA S.C., ZEZEZE J.L.

Landslide frequency-area distribution in the region north of Lisbon (Portugal)

**Poster presentations .....250**

STARKEL L.

Clusters of heavy rains at orographic barriers-geomorphic effects

RAVANEL L., EGLI M., BRANDOVA D., KUBIK P., DELINE P., GRUBER S.

Frequency of rockfalls in the permafrost-affected rock walls of the Mont Blanc massif in relation with post-glacial warm periods

BAARTMAN J., TEMME A., VELDKAMP T., JETTEN V., SCHOORL J.

Linking events to landscape evolution - comparing two models

CAVIEZEL C., HUNZIKER M., KUHN N.J.

Green alder encroachment on alpine pastures: potential for changing type, magnitude and frequency of erosion processes

RICHARDS K.

Restoring the geomorphology to magnitude-frequency analyses

MA Y., HUANG H.Q., NANSON G.C.

Has sediment transport regime been changed by climate change and human activities?-An analysis of a large semi-arid river basin

COLANGELO A.

The Spatial Magnitude-frequency Analysis Applied to Holocene Mass Movements in an Humid Tropical Brazilian Plateau

SCHILLEREFF D., CHIVERRELL R., MACDONALD N., HOOKE J.

Extracting quantitative palaeoflood data from lake sediments: a case-study from Brotherswater

FERK M., KOMAC B., ZORN M., ERHARTIC B.

Late Quaternary extreme floods in the junction between the Alps and the Balkans

DONNARUMMA A., REVELLINO P., GUERRIERO L., GRELE G., GUADAGNO F.M.

A slope evolution index to estimate adjustments of hillslope morphology in relation to landslide processes

MILAN D.

Modelling differences in catchment-scale sensitivity in neighbouring sub-catchments to the River South Tyne, UK

**57A - EXTREME EVENTS IN GEOMORPHOLOGY (IAG-WG)**

Convenors: *Samuel ETIENNE & James P. TERRY*

**Oral presentations .....259**

TERRY J.

How does 'reshaping' Darwin's 'Subsidence Theory of Atoll Formation' broaden the scope of tsunami hazard assessment for the Pacific Islands?

BIOLCHI S., FURLANI S., ANTONIOLI F., SCICCHITANO G., CUCCHI F., DRAP P., GAMBIN T., DEVOTO S., SALIBA D.

Large boulders accumulation along the NE Maltese coast: stormwaves or tsunami event?

RIXHON G., PARIS R., MAY S.M., ENGEL M., BRÜCKNER H.

Dating tsunami deposits triggered by the catastrophic flank collapse of Fogo Island, Cape Verde Islands: insights from ESR, U/Th and <sup>36</sup>Cl ages

GRACIA PRIETO F., ALONSO VILLALOBOS C., MENANTEAU L., BENAVENTE J., DEL RIO RODRÍGUEZ L., MÁRQUEZ CARMONA L.

**Effects of the 1755 tsunami on the southern coast of the city of Cadiz (Spain)**

SWITZER A., GOURAMANIS C., LEE Y.S., RUBIN C.M., BRISTOW C.B., JANKAEW K., PILE J., PHAM D.T.  
**The application of Ground Penetrating Radar analysis to investigate the impact and recovery of a coastal dunes and the recurrence interval of palaeotsunami events on the coast of Phra Thong Island, Thailand**

BAYNES E.R.C., ATTAL M., DUGMORE A.J., KIRSTEIN L.A., NIEDERMANN S., CODILEAN A.T.  
**Constraining bedrock erosion rates and processes during extreme flood events: case study in Iceland**

WALSH R., ELLISON S., JENKINS M., BIDIN K.  
**Geomorphic implications of differential changes in the frequency of large rainstorms of varying return period: evidence from tropical and temperate environments, Borneo and South Wales 1906-2012**

**Poster presentations .....262**

GIENKO G., TERRY J.  
**3D modelling of boulder shape and volume using digital photogrammetric techniques. Applications in coastal geomorphology**

SETO M., ASAI T., KITAZAWA T., NAKAMURA Y., OGUCHI T. C., TAMURA T.  
**Identification of liquefied layers in a liquefaction induced by The 2011 Off the Pacific Coast of Tohoku earthquake in central Japan**

TAMURA T.  
**Some geomorphological remarks on the 2011 mega-earthquake in Northeast Japan**

GARGANI J.  
**Extreme Environment and Geomorphological Crisis : the case of the Messinian Crisis**

ETIENNE S.  
**Extreme events and geomorphic crises: are they a kind of environmental crisis?**

RAMOS-PEREIRA A., TRINDADE J., COSTA A., MARTINS J.  
**Historical embayed coastal evolution under a high energetic hydrodynamic event**

RIXHON G., BRÜCKNER H., ENGEL M., MAY S.M., BINNIE S., DUNAI T.  
**Dating tsunami-induced transport of coral reef megaclasts on Bonaire (Leeward Antilles): a cosmogenic nuclide dating approach (36Cl)**

LANA-RENAULT N., NADAL-ROMERO E., SERRANO-MUELA M.P., GONZÁLEZ HIDALGO J.C., ALVERA B., SANJUAN Y., GARCÍA-RUIZ J.M.  
**Response of different land covers to an extreme event in the Spanish Pyrenees**

MILAN D., HERITAGE G., TOOTH S.  
**Use of repeat aerial LiDAR to assess geomorphic impacts of the January 2012 Cyclone Dando floods on the Sabie River, South Africa**

HONG T., BAI S., WANG J.  
**Reconstruct the spatio-temporal distribution of Xiakou landslide using Dendrogeomorphological method**

BOCHENEK W., GIL E., KIJOWSKA-STRUGAŁA M., KISZKA K., WIEJACZKA Ł., RACZKOWSKA Z.  
**Geomorphological effects of extreme precipitation in 2010 in selected parts of the Polish Carpathians**

FORT M.  
**Extreme or ordinary processes? Facts and thoughts on geomorphic scales in the Himalayan Mountains**

**S08. GEOMORPHIC PROCESSES AND LONG TERM LANDSCAPE EVOLUTION**Convenors: *Yanni GUNNELL & Leszek STARKEL***Oral presentations .....271**STARKEL L.**The Quaternary transformation of inherited older mountain landscapes**VAN DER BEEK P.**Impact of late-Cainozoic climate change on orogenic relief development**EBERT K., HALL A., KLEMAN J.**Factors determining the impact of glacial erosion on shield surfaces**TAVARES B.A.C., BARROS A.C.M., CORRÊA A.C.B.**Duricrusts in the Borborema highlands, northeastern Brazil: a climatic and structural approach**BESSIN P.(1), GUILLOCHEAU F.(1), ROBIN C.(1), BAUER H.(2), SCHROËTTER J.M.(3)**Geomorphological evolution of the Armorican massif (Western France): a base Upper Cretaceous wave-cut platform degraded in a tropical setting until Late Miocene**FARINES B., CALVET M.**Paradoxical topographies: the example of Betic chains**GIACHETTA E., SCOTTI V.N., FACCENNA C., MOLIN P.**Numerical simulations of Plio-Quaternary landscape evolution of the Iberian Chain (Spain)**RIFFEL S.B., VASCONCELOS P.M., CARMO I.O., FARLEY K.A.**Geochronological constraints on the weathering, exposure, and erosional histories of the Second Paraná Plateau, Southern Brazil**PEULVAST J., BETARD F.**Basin inversion, scarp retreat and soil distribution in the Araripe basin (northeast Brazil): implications for denudation history**GERMANOSKI D.**Structural and Lithologic Control on Topography in a Post-Orogenic Landscape: East-central Appalachians, Pennsylvania**BIERMAN P., ROOD D.**Cosmogenic evidence for profound landscape disequilibrium and pre-Pleistocene landscapes in South Africa**SCHARF T., CODILEAN A., DE WIT M., JANSEN J., KUBIK P.**Robust lithologies preserve ancient alpine-like topography in southern Africa**CALVET M., GUNNELL Y., FARINES B.**Are flat-topped orogens robust indicators of non-equilibrium mountain topography?**LANGSTON A., TUCKER G., ANDERSON R.**Using landscape evolution models to interpret climatic drivers of cyclic aggradation and incision along the fringes of a decaying mountain range**LEONARD E., MCMILLAN M., OUIMET W.**The post-orogenic Rocky Mountain Surface on the front ranges of Colorado, USA - its character and possible causes of its deformation**PEDERSON J.**The Colorado Plateau of the American Southwest where patterns of river incision are decoupled from topography and proposed mantle sources of uplift**ASLAN A., KARLSTROM K., KIRBY E., HEIZLER M., LAZEAR G., ROSENBERG R.**Late Cenozoic River Incision in the Rocky Mountain region and implications for Neogene uplift in the western U.S.**

AGUILAR G., RIQUELME R., MARTINOD J., CARRETIER S., DARROZES J., REGARD V.  
**Role of climate and tectonics in the geomorphologic evolution of the Semiarid Chilean Andes between 27-32°S**

PAN B., HU X., GENG H., LI Q., GAO H.  
**Erosion rates and their controlling factors along the eastern Qilian Shan Mountain, China**

PORTENGA E., BIERMAN P., DUNCAN C.  
**Rain, water, and ice: driving forces behind rapid erosion in western Bhutan**

BLÖTHE J., MUNACK H., KORUP O.  
**Spatial distribution and residence time of large valley-fills along the Himalayan arc**

**Poster presentations .....281**

GINESU S., DUNCAN R.  
**Significance and age of "megakarrens" in Sardinia (Italy)**

BOZZANO F., CIPRIANI I., DELLA SETA M., MARTINO S.  
**Valley slope evolution in a southern thyrrenian coastal area (Calabria, Southern Italy) as a coupled effect of quaternary sea-level changes and river erosion**

BAZHENOVA O.  
**Mechanism and structure of denudation in Island Steppes of Siberia**

RICCIONI DE MELOS A., FERREIRA BESERRA S., MENDES J.C., COELHO NETTO A.L.  
**Differential weathering in the Turvo River Basin**

CONCEICAO F., DIEGO S., MATHIAS C., LETÍCIA G.  
**Chemical dynamics, weathering rate and atmospheric/soil CO<sub>2</sub> uptake of basalts at São Paulo State, Brazil**

YAIR A.  
**The resilience of a badlands area to climate change**

SHI C., SHAO W., QI D.  
**Characteristics of hypsometry and valley geometry of the Suoshui basin in Zhangjiajie and their implications in landform evolution**

DELMAS M., GUNNELL Y., CALVET M.  
**Are cirques exclusively cold-climate landforms? Allometric growth revisited in the Eastern Pyrenees**

SEMBRONI A., GIACHETTA E., MOLIN P., FACCEENNA C.  
**GIS-based morphometric analysis of the Blue Nile and Tekeze watersheds (Ethiopia)**

RICHARDSON J., TOOTH S., GRIFFITHS H.  
**Processes and rates of bedrock erosion in Welsh rivers, and the implications for long term landscape development**

YURY E.  
**Mudflow morpholitogenesis((MMLG) on the Greater Caucasus**

GUILLOCHEAU F.  
**The very long wavelength (x1000 km) relief of the Congo Cuvette: a local base level controlled by upstream (EAR) and downstream (Atlantic bulge) uplifts during Miocene times**

GHOSH P., MISRA A., SINHA S., SENGUPTA I., HATUI K.  
**Evolution of catchment basins in the Himalayas: New observations**

MBEUGANG TCHEUBONSOU E.M., TCHINDJANG M.  
**The Yangben inselberg and planation surface**

BONNET N.  
**Long-term evolution of Southwest Indian landscapes by 40Ar-39Ar dating of K-Mn oxides in supergene Mn-ore deposits**

DORANTI-TIRITAN C., HACKSPACHER P.C., GLASMACHER U.A., POÇAY M.A.H.

**Long-term landscape evolution of the southeast Brazilian highlands: analysis of Poços de Caldas Alkaline Massif region**

NEXER M., AUTHEMAYOU C., PEDOJA K., DELCAILLAU B.

**Toward a quantification of long-term evolution of coastal landscapes? Drainage developed on marine terraces sequences on the North Cotentin peninsula (France)**

CSILLAG G., SEBE K., FODOR L.I.

**Piedmonts of the Transdanubian Range, Hungary: Limited slope retreat of the pediments?**

FLUGEL T.J., ECKARDT F.D., COTTERILL F.P.D.

**The spatial distribution of knickpoints in south-central Africa: implications for longterm landscape evolution**

HARBOR D., MEYER R., CONNORS C.

**Constraining Cenozoic uplift of the central Appalachians using river profiles and relict surfaces**

BRAGANÇA M.T.R., OLIVEIRA D.D.

**Correlations between geology and erosion surfaces in the central eastern sector of Paracatu river catchment, State of Minas Gerais, Brazil**

RODRIGUEZ GARCIA A., GARCIA-MELENDZ E., MARTIN-SERRANO A., SUAREZ RODRIGUEZ A., MINGUEZ A.

**Relief evolution of the eastern part of the Bierzo Basin (NW Spain): Response of erosion surfaces and fluvial network to Cenozoic Tectonic Activity**

MONTEIRO K., CORREA A.C.B.

**Applying hack index in drainages to define slope levels: a case study of the Eastern Borborema plateau Rivers**

N. BARRETO H., A. C. VARAJÃO C., BRAUCHER R., BOURLÈS D.L., A.R. SALGADO A., F.D.C. VARAJÃO A.

**Denudation rates of the Southern Espinhaço Range, Minas Gerais, Brazil, determined by in situ-produced cosmogenic beryllium-10**

SANCHEZ C., TAPIA M., RIQUELME R., CARRETIER S., BRICHAU S., MARQUARDT C.

**Reconstruction of long-term (last 35 Ma) pediment evolution in the Atacama Desert using a multidisciplinary approach**

LADEIRA F.S.B., LEONARDI F.

**The main elevation levels of the northeastern quadrilatero ferrifero region, Minas Gerais, Brazil and their relation with the different parent materials**

DE SOUZA MARTINS E., VASCONCELOS V., CARVALHO JÚNIOR O.A., REATTO A., COUTO JÚNIOR A.F.

**Self-organisation of geomorphological evolution in the brazilian Central Plateau**

RODRIGUES DE MORAES G., SÉRGIO BERNARDES LADEIRA F.

**Correlation between iron and laterite layers paleosurfaces Minas Gerais, Brazil**

BROCARD G., WILLENBRING J.K., SCATENA F.

**Use of detrital cosmogenic <sup>10</sup>Be and LIDAR DEM to evidence and quantify the propagation an erosion wave in steep tropical watersheds, Luquillo Critical Zone Observatory, Puerto Rico**

## **S09. ROCK CONTROL ON GEOMORPHIC PROCESSES AND LANDFORMS**

Convenor: *Piotr MIGÓN*

### **Oral presentations .....299**

DYKES A., DEVOTO S., SOLDATI M.

**Lithological controls on patterns of landsliding in northwest Malta**

CUREBAL I., EFE R., SOYKAN A., SONMEZ S.

**Factors that Affect the Formation and Development of Gölcük Uvala in Western Turkey**

MAIRE R., BINI A., BRUXELLES L., CAMUS H., DANDURAND G., DEVES G., DUBOIS C., LANS B., ORTEGA R., ROUDEAU S., QUINIF Y.

**A new paradigm in geomorphology and geology of reservoirs: The deep alteration of rocks by « ghost-rock » process**

ALVAREZ DE BUERGO M., GARCIA RODRIGUEZ M., FORT GONZALEZ R., CENTENO J.D., GOMEZ-HERAS M., SANZ M.A.

**Twidale's Rock: a granite block showing linked rock basins, channels and relief inversion**

**Poster presentations .....236**

OLIVA M., GÓMEZ ORTIZ A., SALVADOR FRANCH F., SALVÀ CATARINEU M., VIDAL MACUA J.J.

**The use of the Schmidt hammer as a complementary tool for cosmogenic dating in Sierra Nevada (Southern Spain)**

CAPPADONIA C., ANGILERI S.E., ROTIGLIANO E., BUCCOLINI M., COCO L.

**Subsurface erosion in a badlands area in Southern Italy: controlling factors analysis, types and frequency of pipes**

BURSZTYN N., PEDERSON J.

**Bedrock Strength and River Metrics: Spatial and Statistical Correlations on the Incision of the Colorado Plateau, Southwest USA**

BANERJEE A., BANERJEE A.

**Impact of rock structure on drainage development: a case study from south-western pedimental region of West Bengal, India**

QI D., HUANG H., CHEN A., CUI Z., ZHAI F., CHEN D.

**Temporal and Spatial Characteristics of Different Sandstone Geomorphology Types: from Zhangjiajie to China**

GARCIA RODRIGUEZ M., CENTENO J.D., GOMEZ-HERAS M., FORT GONZALEZ R., ALVAREZ DE BUERGO M.

**Thermal and structural controls on polygonal cracking in granite of La Pedriza de Manzanares (Spain)**

LANS B., MAIRE R.

**Genesis of incipient karst systems in saturated/semi-saturated and altered context: the example of « Graves » area (Gironde, France)**

**S9A - SANDSTONE GEOMORPHOLOGY (DANXIA IAG WG), EXTENDED TO QUARTZITES**

Convenor: *Piotr MIGÓN*

**Oral presentations .....307**

PAN Z., PENG H., SIMONSON S., YAN L.

Primary study on the global distribution and geomorphic development of red beds

HUANG J., CHEN Z., ZHANG R., PENG H., QI D.

Preliminary Study on Danxia Landform in China

REN F.

Study on the genesis of danxia landform in Longhushan area, southeast China

HUANG H., GU J., SONG H., XIAO S., TIAN S.

Contraverses over naming landscapes and implications ' Case of Zhangjiajie Global Geopark of China

SAMINPANYA S., DUANGKRAYOM J., JINTASAKUL P., HANTA R.

'Mo Hin Khao' a sandstone geotourism site in Thailand

GIUSTI C.

'Rougiers' and 'Ruffes' of southern France. A comparative study of geology, landforms and landscapes in the Permian basins of Lodève and Saint-Affrique (Aveyron, Hérault)

MIGON P.(1), WRAY R.(2)

Sandstone versus conglomerate erosional landscapes - Why similarities? Why differences?

**Poster presentations .....301**

MECCHIA M., SAURO F., PICCINI L., DE WAELE J.

A model simulation of the 'arenisation' weathering process in quartz-sandstones: a key factor for speleogenesis in the quartzite environment

SIMONSON S.

Distribution of red beds and classification of their erosion intensity in Guangdong Province, P.R.China'a remote sensing and GIS approach

PENG H., QIU Z., PAN Z.

Experimental geomorphology study on bedding caves at Mt. Danxiashan

PENG H., PAN Z., YAN L., SIMONSON S.

China will start a national basic data survey on Danxia landform  
Sun Yat-sen University, GUANGZHOU, CHINA

ZERBONI A., VERRECCHIA E.

Inherited evolution of sandstone landforms in the Tadrart Acacus massif (central Sahara) and associated formation of banded iron speleothems and crusts

HUANG J., CHEN Z., ZHANG R., QI D., WANG S., WANG Z.

Study on the geosciences and geotourism value of Kongtongshan Danxia Landscape in Pingliang, Gansu Province, China

SCHWEIGSTILLOVA J., SOUKUP J., BRUTHANS J., VACULIKOVA J., MAYO A.

Origin of "Rock Cities", pillars and clefts in friable sandstone: new insight from study in Sandstone Quarry where landforms recently evolve

## **S9B. KARSTIC GEOMORPHOLOGY: FROM HYDROLOGICAL FUNCTIONING TO PALAEOENVIRONMENTAL RECONSTRUCTIONS**

Convenors: *Philippe AUDRA, Francisco GUTIÉRREZ & Jo DE WAELE*

### **Oral presentations .....317**

*AUDRA P., BIGOT J.Y.*

**Rare sulfate minerals (fibroferrite) and hypogene sulfuric speleogenesis in Baume Galinière Cave (Alpes-de-Haute-Provence, France)**

*BALLESTEROS D., JIMÉNEZ-SÁNCHEZ M., GIRALT S., GARCÍA-SANSEGUNDO J., MELÉNDEZ M.*

**Interaction between the fluvial incision and the geological structures: the Torca La Texa shaft (Picos de Europa, Spain) case**

*DANDURAND G., MAIRE R., DUBOIS C., VANARA N., QUINIF Y.*

**Alteration of the Jurassic limestones series in the Charente karst basin: Impacts for the speleogenesis by ghost-rock process and the genesis of the large Touvre aquifer**

*DE WAELE J., FORTI P., MARABINI S., PICOTTI V.*

**Epigenic gypsum caves as indicators of climate-driven river incision and aggradation in a slowly uplifting region (Emilia Romagna, North Italy)**

*GÁZQUEZ F., CALAFORRA J.M., SANNA L., FORTI P., DE WAELE J.*

**The role of condensation in the evolution of dissolutional forms in gypsum caves: an example from the karst of Sorbas (SE Spain)**

*JIMENEZ-SANCHEZ M., STOLL H., GIRALT S., MORENO CABALLUD A., DOMINGUEZ-CUESTA M.J., ARANBURU A., MENDEZ-VICENTE A., BALLESTEROS D., VALERO B., CHENG H., EDWARDS L.*

**Cave geomorphology as a record of environmental changes: the El Pindal Cave (Cantabrian Coast, N Spain) case study**

*NEHME C., DELANNOY J.J., GÉRARD J., JAILLET S.*

**Morphogenesis reconstitution on Kelb valley, Lebanon: contribution of Jeita cave speleogenesis and karst landforms study**

*TEMOVSKI M., AUDRA P.(2), SPANGENBERG J., MIHEVC A., BIGOT J.Y.*

**Thermal Carbonic and Sulfuric Acid Speleogenesis in Cave Provalata, Republic of Macedonia**

*WHITE S.*

**Flank margin caves on a passive continental margin: naracoorte and the other southern australian examples**

*TONELLI C., GALVE J.P., SOLDATI M., GUTIÉRREZ F.*

**New perspectives on the genesis of the Miocene collapse structures of the Island of Gozo (Malta)**

*JARRY M., BRUXELLES L., BON F., FRITZ C., LACOMBE S., LELOUVIER L.A., MARTIN H., PALLIER C., RABANIT M., TOSELLO G., WATTEZ J., ARRIGHI V., SALMON C.*

**Karstic evolution and Human occupation in the Mas d'Azil Cave (Ariège, Pyrénées, France): new research and new results**

*VANARA N., GARATE D., BIGOT J.Y., CANEROT J., LANS B., MAIRE R., MAGNE L., DANDURAND G., PARENT G., LAUGA M., DOUAT M., BRAMOULLE Y., LABARGE A., RIVERO O., DARRICAU J., NORMAND C.*

**Isturitz, Oxocelhaya and Erberua Caves (Pyrénées-Atlantiques, France): geoarchaeological studies**

*BOCIC N., PAHERNIK M., MIHEVC A.*

**Geomorphology of the paleo and recent hydrographic network on the karst plateau (example Una Korana plateau, Croatia)**

*FORD D.*

**Canol, a proposed new karst international geopark in the Northwest Territories of Canada**

*HATTANJI T., AKIYAMA S., MATSUSHI Y., MATSUKURA Y.*

**Dissolution rate of limestone under doline in the Akiyoshidai karst plateau: Evaluation from weathering experiment and hydrological observation**

SHTOBER-ZISU N., AMASHA H., FRUMKIN A.

**Origin and nature of notches on the carbonate slopes of the Carmel Mountain, Israel**

ANDREO B., LINARES L., CARRASCO F., RENDÓN M.

**Hydrogeological characterisation of evaporite Karst Wetlands in southern Spain**

CHEDEVILLE S., LAIGNEL B., RODET J., TODISCO D., HAUCHARD E., MASSEI N., HANIN G.

**Conceptual model of the hydro-sedimentary behaviour of an estuarine karst: Example of Radicatel springs in the Seine Estuary (Normandy, France)**

TAVER V., JOHANNET A., BORRELL V., PISTRE S., VINCHES M.

**Towards a better comprehension of rainfall-runoff relation in karst system at various time scales. Case study on the Lez aquifer (Southern France)**

ZINI L., CALLIGARIS C., GRILLO B., CUCCHI F.

**Groundwater monitoring network in the classical Karst (NE Italy, SW Slovenia)**

## **Poster presentations .....327**

KHEZRI S.

**The evaluation of geomorphological features of the karstic cave discovered in Rabat, Sardasht, north-west of Iran**

KHEZRI S., ZAHERI S.

**Exploration and recognition of the 'Dolaneh' cave, Sardasht, Iran**

AUDRA P., NOBÉCOURT J.C.

**Hydrodynamic of the Coulomp karst spring, the largest in French Southern Alps**

ZARROCA M., PELLICER X.M., GUTIÉRREZ F., CARBONEL D., ROQUÉ C., LINARES R.

**Characterising tufaceous accumulations in groundwater discharge zones by means of geophysical surveying (ERT, GPR) and trenching. The Isona-Basturs complex (Pyrenees, NE Spain)**

FRANCISCO G., GALVE J.P., CASTAÑEDA C.

**Comparison of DInSAR derived displacement maps for sinkhole activity detection in the Ebro Valley mantled evaporite karst (NE Spain)**

CARBONEL D., GUTIÉRREZ F., MCCALPIN J., GUERRERO J., ROQUÉ C., LINARES R., ZARROCA M., GALVE J.P.

**Application of the trenching technique to sinkhole hazard analysis**

GONCALVES F., MAGALHÃES JR. A., RODET J.

**Contribution to the studies about the Brazilian Karstic areas: the geomorphological cartography as a subsidy to the analysis of the evolution of the Karst in the Karstic region of Currais de Pedras (KRCP)**

PARISE M., PEPE M.

**Mapping and interpretation of karst landforms: dolines and depressions, their significance and hydrological functioning**

KNEZ M., SLABE T., URUSHIBARA-YOSHINO K.

**Lithology, rock relief and karstification processes in coral minamidaito island in the nansei archipelago, Southeast Japan**

MAKHNATOV S., TOLMACHEV V.

**Using stochastic laws of sinkholes formations at solving construction engineering problems in karst aeras**

DOBROWOLSKI R., MROCZEK P.

**Clay cortex in epikarst as an indicator of age and morphogenesis - case studies from Lublin-Volhynia Chalkland (East Poland, West Ukraine)**

CUCCHI F., ZINI L., CALLIGARIS C., FORTE E., PETRONIO L., ZAVAGNO E.

**Gypsum's role in the sinkholes of the tagliamento River Valley (NE Italy)**

JAILLET S., SADIÉ B., DELANNOY J.J.

### 3D researches on conduits and karsts networks

LIGUORI V., MANNO G.

Dissolution phenomena and subsidence in Bosco-San Cataldo Mine (Sicily)

DO T., NGUYEN XUAN N.

Understanding of the nature and evolutionary history of the karst of Ha Long bay

FRAUSTO MARTINEZ O., IHL T., BUATISTA F., AGUILAR Y., FRAGOSO P.

Geomorphological analysis of karst depression in the Yucatan Peninsula, Mexico

PERRIN J.

Towards a multicriteria approach to subsidence hazards in karst with application to French case studies

ZIELIŃSKI A., ZAGÓRSKI P., SHCHERBA V.

Fluctuations of water levels in karst lakes near Staszów (Niecka Nidziańska, Poland)

GUERREIRO P., CUNHA L., RIBEIRO C.

Central Algarve tufa platforms, Southern Portugal. Geomorphological characterization and genesis

RENOUARD L.

The karst of Vang Vieng, Lao P.D.R.

BALLESTEROS D., DOMINGUEZ-CUESTA M.J., JIMÉNEZ-SANCHEZ M., GONZALEZ-PUMARIEGA P.

Tape-compass-clinometer, DistoX or total station, what is the best method to elaborate a cave survey? A case study in El Pindal Cave, Spain

DENNISTON R., HOUTS A., HAWS J., POLYAK V., WANAMAKER, JR. A., ASMEROM Y., BENEDETTI M., BICHO N.

A stalagmite record of western Iberia climate from the last glacial cycle

## S10. QUATERNARY GEOMORPHOLOGY

Convenor: Margot BÖSE

### **Oral presentations ..... 341**

BÖSE M.

From Morphostratigraphy to Chronostratigraphy - Modern Quaternary Geomorphology as a Basis for Climatic Research

WACHECKA-KOTKOWSKA L., CZUBLA P., GÓRSKA-ZABIELSKA M., KRÓL E., BARCZUK A.

Morphogenesis of SE part of the Lodz region, Central Poland, during late Saalian (MIS 6, WARTANIAN STAGE)

HIRSCH F., RAAB T.

Distribution, formation and chronology of Late Quaternary sediments in the Central Spanish Pyrenees

GUIER F., BRISSET E., BOURLES D., BRAUCHER R., ANTHONY E.

Overview of Last Deglaciation sedimentological, palynostratigraphical and <sup>14</sup>C chronologies in mountain lake sediments: Towards improved knowledge of the MIS2/MIS1 transition in the Mediterranean Alps

LAJCZAK A.

Changes in relief of the Azau Valley in Central Caucasus Mts resulting from impact of volcanic activity and glaciers' oscillations during the last 1100 years

OLIVA M., NEVES M., VIEIRA G., PINA P., CARDOSO M., FREITAS C.

Late Holocene environmental and climatic conditions in Adventalen valley (Svalbard) based on sedimentological studies of ice-wedge polygon terrain

CHRISTOL A.

Typology and chronology of terraces around the lake Van: highlighting changes in palaeogeography of the lake basin during the Late Pleistocene

RAJ R., SHARMA A., PRASAD V., VERMA P., TRIPATHI J.

**Late Quaternary climate and landscape evolution in north Gujarat: a multiproxy study of the Pariyaj Lake archive, western India**

ORKHONSELENGE A., KRIVONOGOV S.K., MINO K., KASHIWAYA K., YAMAMOTO M., NAKAMURA T.

**Landform Evolutions: Sedimentary Records from Lake Borsog, Eastern Shore of Lake Khuvsgul, Mongolia**

MOREAU J.

**New insights on the Quaternary stratigraphy of the coarse-grained Golo river alluvial plain (east-Corsica margin)**

JAMET G., DELCAILLAU B., DUGUÉ O.

**Influence of bedrock on the fluvial morphodynamics in the Pleistocene Dives River (NW France)**

GEBICA P.

**Late Holocene flood phases in the Upper Dniester river basin: response to climate change and human impact in the Carpathian Foreland**

BENEDETTI M.M., DANIELS J.M., HAWS J.A., FORMAN S.L.

**Heinrich Events and Late Pleistocene geomorphic instability on the central Portuguese coast**

FLAUX C., CLAUDE C., MARRINER N., MORHANGE C.

**Holocene record of hydrological changes in the Nile delta using Sr isotopes: an exemple of climatic forcing, societal management and local geomorphological responses (Maryut lagoon, Egypt).**

**Poster presentations .....348**

GILES D., MARTIN C., GRIFFITHS J., MORLEY A., LUKAS S., EVANS D., MURTON J., CULSHAW M., DONNELLY L., DE FREITAS M., WINTER M.

**The Geological Society of London Engineering Group Working Party on Periglacial and Glacial Engineering Geology**

DIAS R.L., PEREZ FILHO A.

**Geochronology of the planning surfaces in the Center-Western portion of the Paulista Peripheral Depression (Brazil) using Optically Stimulated Luminescence**

YANG D.Y., LIM J., LEE J.Y., KIM J.Y., YI S., KIM J.K.

**Mid-Holocene Wetland Evidences in West Coast Zone, Korea**

DOBROWOLSKI R., MAZUREK M.

**Geochemical record of biogenic-carbonate sedimentation in deposits of spring mires in Poland**

DELMAS M., CALVET M., GUNNELL Y., BRAUCHER R., GUILLOU V., BOURLES D.

**Are fluvial terraces reliable chronological markers in the history of valley development? The Ariège, north-Pyrenean piedmont, France**

MASHUKOV A., MASHUKOVA A.

**The complex studies of quaternary sediments in the Yenisei River**

ITO Y., OGUCHI T., MASUDA F.

**Late Quaternary depositional sequences and landforms in relation to sea-level changes in the Osaka intra-arc basin, Japan: a borehole database analysis**

FLAUX C., MARRINER N., MORHANGE C., KANIEWSKI D.

**The Nile delta : climate pacing and vulnerability to Holocene change**

HETU B.

**Deglaciation and postglacial evolution of relative sea level in the western part of the Saint-Lawrence River estuary and in the Gulf of St. Lawrence, Canada**

GRECU F., GHITA C., BENABAS C.

**Interfluvial negativ microform in Romanian Plain. Morphometric and genetic analysis**

M. RÉMILLARD A., HETU B., BERNATCHEZ P., ST-ONGE G.

**Relative sea level changes in the Magdalen Islands (Québec, Canada) since the last glaciation**

SAPELKO T., LUDIKOVA A., KUZNETSOV D., NAUMENKO M.  
**The use of geomorphology in the paleolimnological studies**

KADEREIT A., MÜLLER C., HOLZHAUER I., MEISENBERG O.  
**Chronological framework for late-Pleistocene to Holocene landscape evolution in the Upper Rhine rift valley near Heidelberg/SW-Germany as based on optically stimulated luminescence (OSL) dating**

MARCAL M., RAMOS R., HINGEL R., FEVRIER P.  
**Fluvial quaternary sedimentation in high valley of Macaé River, state of Rio de Janeiro, Brazil**

NASCIMENTO D., PEREZ FILHO A.  
**Evolutionary analysis of a slope at the right margin of Mogi Guaçu river in Conchal ' SP**

ZERBONI A., TROMBINO L., LIVIO F., BERLUSCONI A., MICHETTI A.M., SPÖTL C., RODNIGHT H.  
**The Monte Netto (Northern Italy) loess-paleosol sequence: implication for the Upper Pleistocene geomorphologic and palaeoenvironmental evolution of the central Po Plain**

CALISE G., BELLOTTI P., DAVOLI L., PELINO V.  
**Analysis of long term anemometric data relating to coastal stations of Calabria**

SCAPOZZA C., AMBROSI C., CASTELLETTI C., SOMA L., DALL'AGNOLO S.  
**Timing of deglaciation on the Southern Swiss Alps**

JOHN M., EYLES C.  
**Quantitative geomorphological analysis of drumlins in four Ontario, Canada drumlin fields**

COE H.  
**Phytolith and isotopic studies applied to geomorphologic analysis in the Southern Espinhaço Mountain Range, Brazil**

HOUDE-POIRIER M., HÉTU B., BERNATCHEZ P.  
**Glacial flows and deglaciation stages during the Late Wisconsinan in the Gaspé area, Québec (Canada)**

KIM S., TANAKA Y.  
**Palaeoflood history recorded by the slackwater deposits of the Dong River, Korea**

TANAKA Y., KIM S.H., KASHIMA K.  
**Slackwater deposits indicating paleoflood of Kherlen river, Mongolia**

ROCHA L., AUGUSTIN C., FIGUEIREDO M.  
**Interaction between geochemical processes texture and PH in the podzolization of arenosols in the Espinhaço Mountain Range - Brazil**

KOBYLKIN D., RYZHOV Y.V.  
**Exogenous processes and soil formation during MIS 2 and MIS 3 on geoarchaeological sites in the Angara region and Cisbaikalia**

SMOLKOVA V., PANEK T., HRADECKY J.  
**Information decoded from the Late Holocene sedimentary records in the Outer Western Carpathians, Czech Republic**

MELLO C., PEIXOTO M.N.O., MOURA J.R.S.  
**Late pleistocene and holocene morphostratigraphic and allostratigraphic records in southeastern Brazil**

VILANO W.F., SOUZA C.R.G., CANTARELI C.V.C., SILVA W.W.D.B.  
**Sea urchin burrows in Rocky Shores as indicator of Holocene Sea-Levels at the Northern Coast of the State of São Paulo, Brazil**

ABU GHAZLEH S., KEMPE S.  
**Fluctuations of Lake Lisan level during Marine Isotope Stage 2: implications for palaeoclimatic changes of the Jordan Valley**

**S10A. FLAG, GLOCOPH and PAGES-LUCIFS**

Convenors: Gerardo BENITO, David BRIDGLAND, Stéphane CORDIER &amp; Thomas HOFFMANN

**Oral presentations .....365**PASTRE J.F., GUILLOU H., NOMADE S., DEGEAI J.P.

Plioquaternary morphosedimentary evolution of the Allier valley (Massif Central, France). New contribution of K-Ar and 40Ar/39Ar datings

BRIDGLAND D.

Links between geomorphology and Quaternary geology: evidence from fluvial archives

PANIN A., ADAMIEC G., BUYLAERT J.P., MATLAKHOVA E., MURRAY A.

Incision/aggradation events in river valleys of the Central Russian Plain in the Valdaian (Weichselian) ' Holocene climatic cycle

CORDIER S., RIXHON G., HARMAND D., BRÜCKNER H., KELTERBAUM D., DUNAI T., BINNIE S.

Unraveling the Quaternary river incision in the Moselle and the Sarre valleys (Rhenish Massif, Germany): insights from cosmogenic nuclide dating (10Be/26Al) of fluvial terraces

SINHA S., DENSMORE A.L., SINHA R.

Sediment storage and evacuation episodes during the Late Quaternary in the intermontane basin of Dehradun, NW India

ADAMSON K., WOODWARD J., HUGHES P.

River system response to Pleistocene glaciation within a Mediterranean landsystem

MOZZI P., FONTANA A., MARCHETTI M.

Alluvial megafans along the Italian Southern Alps

CASTANET C., DEGEAI J.P., DESRUELLES S., ROBERT V.

Fluvial responses to climate changes, eustatism, neotectonics and anthropogenic impacts during the last 50 000 years in the Northwestern Africa: Gharb plain, Oued Sebou watershed (Morocco)

PIANA J., CARCAUD N., CYPRIEN-CHOUIN A.L., GANDOUIN E., LEROY D., VISSET L.

The Loir River fluvial dynamics during the Lateglacial and the Holocene (France): multi-scaled and multi-proxy approach

NOTEBAERT B., BERGER J.F., BROCHIER J.L.

Contrasting influences from land use changes and climatic variations on alluvial and colluvial deposition in Southern France

GHILARDI M., CAROZZA J.M., CORDIER S., PSOMIADIS D., ZOMENI Z., DEMORY F., SABATIER D., VELLA M.A., BONY G., MORHANGE C.

Evidence for a continuous fluvial activity of the Tremithos River (South Central Cyprus) during the Early to Mid-Holocene

GARNIER A., LESPEZ L., BALLOUCHE A., LE DREZEN Y., RASSE M., HUYSECOM E., DELAHAYE D.

Late to final Holocene fluvial system dynamics in the Yamé valley (Mali): climatic change or human impact ?

LAIGRE L., ARNAUD-FASSETTA G., REYNARD E.

A 7300 year record of palaeohydrology in the Swiss Rhône River floodplain (Valais, Switzerland)

PERȘOIU I., FEURDEAN A.

Late Quaternary floodplain evolution in the low tableland of Transylvanian Depression, Romania

ENZEL Y., AMIT R., GRODEK T., AYALON A., LEKACH J., PORAT N., BIERMAN P., BLUM J., EREL Y.

Late Quaternary weathering, sediment production, erosion, and alluvial fan deposition in hyperarid Nahal Yael, Israel

JONES A.F., TURNER J.N., DALY J.S., EDWARDS R.J., FRANCUS P., GOODHUE R., REID I.

Extending flood records in Irish and Welsh river catchments using high-resolution geochemical analysis of floodplain sediment sequences

HERGET J., EULER T.

**Obstacle marks as palaeohydrologic indicator**

SCHULTE L., PEÑA J.C., CARVALHO F., BURJACHS F., JULIÀ R., LLORCA J., RUBIO P., VEIT H.  
**Late Holocene periodicities of Alpine floods inferred from multi-proxy data**

BENITO G., MACHADO M.J., RICO M.T., SÁNCHEZ-MOYA Y., SOPEÑA A.

**Floods, droughts and people: historical palaeohydrology and landscape resilience of a Mediterranean rambla (Castellón, NE Spain)**

BALLESTEROS CANOVAS J., BODOQUE J.M., EGUIBAR M.A., RUIZ-VILLANUEVA V., DíEZ-HERRERO A., STOFFEL M., SÁNCHEZ-SILVA M.

**Progress on the estimation of past flood discharge from dendromechanical analyses of tilted trees**

**Poster presentations .....375**

FAUST D., WOLF D.

**Tectonic signals in fluvial archives Jarama River in central Spain**

BKHAIRI A.

**A palaeo-sebkha sequence near Kasserine (Central Tunisia): palaeohydrology and palaeoenvironment at the Upper Pleistocene- Holocene transition**

LAIGRE L., BÄTZ N., LANE S.

**Contribution of OSL signals for reconstructing the debris flow activity for two tributaries of the Swiss Rhône River: the Fully and Charrat torrents (Valais, Switzerland)**

DÍEZ-HERRERO A., FERRIO J.P., BALLESTEROS J.A., VOLTAS J., BODOQUE J.M., AGUILERA M., RUIZ-VILLANUEVA V., TARRES D.

**Using tree-ring oxygen stable isotopes for studying the origin of past flood events: first results from the Iberian Peninsula**

MATLAKHOVA E., DUBIS L., PANIN A.

**The use of microscopic study of quartz grains for establishing the origin of the Late Pleistocene river terrace deposits in the Central Russian Plain**

BENITO G., MACKLIN M.M., COHEN K.M., HERGET J.

**Hydrological EXtreme Events in Changing Climate: The HEX Events project**

PERȘOIU A., PERȘOIU I.

**Fluvial response to Holocene climate and environmental changes in NW Romania**

CAROZZA J.M., VALETTE P., CAROZZA L., LLUBES M., FERDINAND L., SEVEGNES L., DANU M., GALOP D., PYV.

**The geoarchaeology of the Middle Garonne valley: first results**

CASTANET C., CARCAUD N.

**Geoarchaeological approach of river-societies interactions: new developments in fluvial dynamics and embankments of the Loire River during the last 2000 years (Val d'Orléans, France)**

BRIANT R., WAINWRIGHT J., MOTTRAM G.

**Understanding Quaternary landscape development using numerical modelling: issues associated with making models and data 'meet in the middle'**

**S11. GEOMORPHOLOGY AND GLOBAL ENVIRONMENTAL CHANGE**Convenor: *Olav SLAYMAKER***Oral presentations .....383**SLAYMAKER O.**The role of geomorphology in global environmental change**GUERRA A., BEZERRA J., FULLEN M., JORGE M.**A Protocol to develop an environmental fragility map: a case study from angra dos reis and paraty municipalities, Rio De Janeiro State, Brazil**V. ELVERFELDT K., EMBLETON-HAMANN C., EGNER H.**Self-organising change? Considerations on causality**JACOB M., FRANKL A., BEECKMAN H., GUYASSA E., MELES K., NYSSSEN J.**Can treeline dynamics in the afro-alpine north Ethiopian highlands be used as proxy to study climate change?**BRUSCHI V., FORTE L.M., HURTADO M., BONACHEA J., DANTAS-FERREIRA M., RIVAS V., GÓMEZ-ARZAMENA J.E., REMONDO J., CENDRERO A.**Increasing frequency of geomorphic disasters: climate change or geomorphic change?**QUERCHEFANI D., CALLOT Y., DELAITRE E., ABDELJAOUED S.**La méthode du transect fixe pour la détermination du bilan sédimentaire et la caractérisation de sa variation spatio-temporelle : application dans une région aride du Sud tunisien**BARONI C., ANZIDEI M., DALLA FONTANA G., DEL MONTE M., FREPPAZ M., MASTRONUZZI G.A., SMIRAGLIA C., SOLDATI M.**Response of morphoclimatic system dynamics to global changes and related geomorphological hazards: outline and perspectives of a national Italian research project**VERSTRAETEN G., VAN OOST K., BROOHTHAERTS N., NOTEBAERT B., DOETTERL S., WIAUX F., SIX J.**Humans have impacted atmospheric C-exchange since the introduction of agriculture by changing the geomorphic cascade**JAMES A.**Pre-Columbian Anthropogeomorphic Impacts in North America**ZOMENI Z., NOLLER J.-S., IACOVOU M.**Quaternary Marine Terraces on Cyprus: Constraints on Uplift and Pedogenesis, and the Geoarchaeology of Palaipafos**BROOKS S., SPENCER T.**Sea Level Variability, Shoreline Response and Global Environmental Change: Observations from Eastern England**LE COZANNET G., GARCIN M., CAZENAVE A., THOMAS Y.F., LAVIGNE F.**The implications of last decades sea level variations for coastal erosion: a review**BRISTOW C., ARMITAGE S., DRAKE N.**Rise and Fall of Palaeolake Megachad**DRAMIS F., FUBELLI G.**Aggradation/erosion stages of tufa dams during Holocene: a palaeoclimatic comparison between northern Ethiopia and central Italy**RAMOS-PEREIRA A., RAMOS C., TRINDADE J., DANIELSEN R., MONGE-SOARES A., PORTELA P., MARTINS J.**Infilling constraints of the Estuary of River Alcabrichel since Middle Holocene**BECHT M., HILGER L., DUSIK J.M., NEUGIRG F., HECKMANN T., HAAS F.**Sediment fluxes on steep LIA moraine slopes in the Central Austrian Alps**

MEADOWS M.E., SLAYMAKER O., MOREIRA-MUNOZ A., BRIERLEY G., CLIFFORD N., ALCANTARA-AYALA I.

Physical Geography, Geomorphology and Global Environmental Change: Perspectives from the Developed and Developing World

**Poster presentations .....391**

DELINE P., RAVANEL L.

Seven years of rockfall monitoring in the Mont Blanc massif to validate the relationship between permafrost degradation and rockfall

ROBITAILLE A.

Role of wind activity in the forest opening in Québec's southern portion of the spruce lichen woodland, Québec, Canada

LU R., JIA F., SHANG Y., GAO S., CHEN Y.

Responses of *Pinus tabulaeformis* tree-ring to climatic metrics in Hasi Mountain, China

WU Y.(1), ZHENG Y.(2), TAN L.(3)

Aeolian activities during Holocene in the Qinghai-Tibet Plateau, China

GAO S., JIA F., LU R., SHANG Y., CHEN Y.

Tree-ring based PDSI reconstruction from AD 1804 for the Hasi Mountain, northwestern China

HALIUC A., HUTCHINSON S., FRANTIUC A., MINDRESCU M., ROMANESCU G.

Assesing lacustrine sediment for environmental changes, Red Lake(Romania)

MA Y., MENG H., LIU K.B., TAO M.

Vegetation changes and associated climate variations during the past ~40,000 years reconstructed from the Shaamar eolian-paleosol section in northern Mongolia

YU M.

The grain size component of winter sand and summer sand of the red sand dunes in the coast of southern China and its paleoclimatic significances

POIRAUD A.

Landslide inventory bimodality in volcanised tertiary basin of Puy-en-Velay (France): a geoinicator of climate change

ZHANG D., TIAN L., WU W.

Sandy Desertification and its Control in Qinghai Plateau, China

BARONI C., ANZIDEI M., DALLA FONTANA G., DEL MONTE M., FREPPAZ M., MASTRONUZZI G.A., SMIRAGLIA C., SOLDATI M.

Preliminary results of a national Italian research project: Response of morphoclimatic system dynamics to global changes and related geomorphological hazards

FONSECA G.

A synthesis of landscape the Pantanal of Mato Grosso from theoretical and methodological sketch of G. Bertrand

**S12. GEOARCHAEOLOGY (IAG-WG)**

Convenors: *Kosmas PAVLOPOULOS & Vanessa HEYVAERT*

**Oral presentations .....401**

MORHANGE C.

Relative sea level changes during Roman times in the NW Mediterranean, a geoarchaeological approach

DESRUELLES S., PAVLOPOULOS K., APOSTOLOPOULOS G., FOUACHE E., ETIENNE R., HASENOHR C., COSTA L., TRIANTAPHYLLOU M.

Hellenistic landscapes of the sacred harbour of Delos (Cyclades, Greece): new reconstruction based on sedimentological and geophysical data

SEELIGER M., BARTZ M., FEUSER S., PIRSON F., KELTERBAUM D., VOETT A., BRUECKNER H.  
The evolution of the Bay of Elaia and the fate of the former harbour of ancient Pergamum (Western Turkey)

FAIVRE S., BAKRAN-PETRICIOLI T., HORVATINCIC N.  
Relative sea-level change in the Central Adriatic during the last 2 ka years - a pluridisciplinary approach

BARYSHNIKOV G.  
Geomorphic hazards and ancient human occupation: the Russian Altai case study

MURU M., ROSENTAU A., AUNAP R.  
Geomorphological development and early human settlement pattern of Ruhnu Island in the Gulf of Riga eastern Baltic Sea

PORTALIER N., PURDUE L.  
From the hillsides to the port : evolution and management of agrarian and maritime landscapes in the territory of Frejus since the Antiquity (Var, France)

TALLÓN-ARMADA R., COSTA-CASAS M., LÓPEZ-MERINO L., BLANCO CHAO R., MARTÍNEZ CORTIZAS A.  
Study of a coastal sedimentary sequence containing the remains of a Roman salt-mine in NW Spain

CAROZZA J.(1), CAROZZA L.(2), MICU C.(3), BURENS A.(2), DANU M.(4), MESSEGER E.(5), RADU V.(6), LEVÉQUE F.(7), OPREANU G.(8), BALASESCU A.(9)  
The submerged chalcolithic lanscape of Taraschina: a key data to understand early Danube delta evolution

GOIRAN J.P., SALOMON F., MAZZINI I., BRAVARD J.P., PLEUGER E., VITTORI-VILLETTE C., BOETTO G., ARNAUD P., PELLEGRINO A.  
Geoarchaeology of the ancient harbour of Ostia at the river mouth of the Tiber: chronology, stratigraphy and palaeoenvironmental reconstruction

CHABROL A., KAPSIMALIS V., FOUACHE E., LECOEUR C.  
Human occupation and geomorphological evolution of the Corfu strait (NW Greece) during the Holocene: submarine seismic profiles and sedimentological proxies

PANYUSHKINA I., MACKLIN M., TOONEN W., CHANG C.  
The geoarchaeology of the Talgar River alluvial fan and Iron Age history in the Semirech'ye region, Kazakhstan

BARTZ M., EIWANGER J., HILGERS A., MIKDAD A., BRUECKNER H.  
Luminescence dating and sedimentological investigations of alluvial archives in the Mediterranean: A case study of a prehistoric site in Morocco, Ifri n'Ammar

SALOMON F., BRAVARD J.P., GOIRAN J.P., ROSA C., PANNUZI S., KEAY S.  
Alluvial geoarchaeology of the palaeomeander of Ostia, Tiber delta, Italy

STEINMANN R., GARCIA J.P., DUMONT A.  
Dynamic changes in Loire, Saône and Doubs rivers in Burgundy (France) forced by the Little Ice Age: impact on archaeological site record

NOWACKI D., WUNDERLICH J.  
Mid-Holocene inundation of the Lower Danube Valley - Lake sediments reflecting changing environmental conditions and human impact

VANDARAKIS D., PAVLOPOULOS K., VOVALIDIS K., FOUACHE E.  
Lithostratigraphic evidence of the paleogeographic evolution of the Athenian basin during Holocene (6.000 YBP)

GAMBIN B., MEDAIL F., ANDRIEU-PONEL V., DJAMALI M., MARRINER N., MORHANGE C., GAMBIN T.  
Mid-Holocene Environmental History of a Central Mediterranean Island

CUPPER M., SWIFT J., GREIG A., CARTER C., WESTAWAY M., JACOBSEN G., WOOD R., SANTORO C.  
Arsenic Exposure in Pre-Columbian Populations of Caleta Vitor, Northern Chile

BINI M., ANICHINI F., BINI D., DUBBINI N., FABIANI F., GATTIGLIA G., GIACOMELLI S., GUALANDI L., NOTI V., PAPPALARDO M., ROSSI V., SARTI G., STEFFÈ S.

**A geoarchaeological approach for assessing the archaeological potential in the city of Pisa (NW Italy)**

RAAB T., RAAB A., NICOLAY A., TAKLA M., BÖNISCH E., RÖSLER H.

**Open cast mines in South Brandenburg (Germany) - Archives for Late Holocene anthropogenic landscape development**

AGATOVA A., NEPOP R., SLYUSARENKO I., MYGLAN V., BARINOV V., NAZAROV A.

**The late Holocene palaeoenvironment forcing on human existing and migration within SE Altai (Russia)**

FOUACHE E., CEZ L., WATTEZ J., BESEVAL R., FRANCFORT H.P., BUYLAERT J.P., MURRAY A.

**Irrigation on the proto-urban site of Sarazm during the Bronze Age (Zerafshan Valley, Tadjikistan): Method and results**

CALLANAN M.

**Alpine Snow Patches as Archaeological Sites**

JARRETT L., VATNE G., BERTHLING I.

**Characteristics of Norwegian ice patches and glaciers with archeological finds**

DELANNOY J., DAVID B., GENESTE J.M., KATHERINE M., SADIÉ B., WHEAR R.L.

**Archaeomorphology and the social construction of rockshelters : Nawarla Gabarnmang (Australia)**

BOURGÉS F., GENTHON P., GENTY D., MANGIN A), D'HULST D.

**New concepts and evaluation tools in conservation of prehistoric caves, hints from Chauvet and other French cavities**

## **Poster presentations .....414**

GHILARDI M., PSOMIADIS D., LONGO F., AMATO V., ROSSI A., DEMORY F., SABATIER D., COLLEU M., SINIBALDI L., FLEURY J., CARAYON N.

**Palaeoenvironmental reconstruction of the Mid to Recent Holocene landscape surrounding the Minoan site of Phaistos (Crete, Greece)**

LESCURE S., ARNAUD-FASSETTA G., COLIN A., FARAVEL S., CAROZZA J.M., MATHE V., LE COEUR C., CORDIER S.

**Fluvio-Estuarine Paleoenvironments and Geoarcheology in the lower garonne valley: example of the mediaval site of Iangoiran (Gironde, SW France)**

BELLOTTI P., DALL'AGLIO P.L., DAVOLI L., D'OREFICE M., DI BELLA L., ESU D., FERRARI K., MAZZANTI M., TORRI P.

**Landscape change around Minturnae and Garigliano river mouth**

LANCZONT M., HOLUB B.

**Magdalenian open-air site location preferences in the Carpathian and peri-Carpathian landscapes (SE Poland)**

PEULVAST J.(1), TALLET P.(2)

**Time scales and geoarcheology: stability vs instability of the ancient maritime site of Ayn Sukhna, Gulf of Suez, Egypt**

ERTEK T.(1), KILIC E.(2), ERGINAL E.(3)

**A reconnaissance study of a prehistoric settlement in Koyun Island, Southern Marmara Archipelago, Marmara Sea, Turkey**

YOON S.O., HWANG S.

**Characteristics of ruins in the Neolithic Age in Bibong-ri, Changnyeong and their implications for sea level fluctuations**

DELANNOY J., GENESTE J.M., JAILLET S., SADIÉ B., BOCHE E.

**The social construction of rock art caves. Contributions of the geomorphological approach in Chauvet cave**

PELLEGRINI L., DALL'AGLIO P.L., ZIZIOLI D., FRANCESCHELLI C.

**Relations between ancient settlement and the physical environment: a case study of the area from Dora Baltea river to Scrivia river (Western Po Plain - Italy)**

NGUYEN T., FUJIMAKI T., NAKAYAMA T., OSAWA Y., OGUCHI C.T., THOMACHOT-SCHNEIDER C., GOMMEAUX M., DEMURA H.

**Study on the properties of reconstituted stones of the Orval Abbey, Belgium**

SECHI S., LAIGNEL B., LEPERT T., MELIS R.T.

**Erosional-detrital phases in the lower Seine Valley catchments (Normandy, France) using a geoarchaeological approach**

GAYNULLIN I., USMANOV B.

**Destructive abrasion processes of archaeological site Ostolopovskoe**

JIMENEZ-SANCHEZ M., DOMÍNGUEZ-CUESTA M.J., FARIAS P., FERNANDEZ-VIEJO G., RODRIGUEZ-RODRIGUEZ L., OLONA J., BALLESTEROS D., NAVES B.

**Geoarchaeology in Cantabrian Mountains (NW Spain): human activity prior to Roman occupation in the Roman Camp Site of Via Carisa?**

BAIBATSHA A.

**Geoarchaeological aspects of quaternary geomorphology of Kazakhstan**

MOURALIS D.

**Using geomorphology and physical geography in obsidian sourcing**

DE DONATIS M., LEPORE G., SAVELLI D., SUSINI S., SILANI M., BOSCHI F., NESCI O.

**Holocene fluvial and coastal processes, landforms and human settlement: the case of the roman town of Sena Gallica (Marche, Italy)**

MOTTE E., REGNAULD H., RUAULT R., DAIRE M.Y.

**What does art can teach us about coastal geomorphological environment ?**

GLAIS A., LESPEZ L., LOPEZ-SAEZ J.A.

**The environment of tell of Dikili Tash: anthropogenic and climatic changes**

CHAUSSE C., SCHWENNINGER J.L., DEBENHAM N., BLASER F.

**The Middle and Upper Pleistocene loess record and Acheulean-Mousterian industries of Saint-Illiers-la-Ville (78 - France)**

BEBERMEIER W., HOELZMANN P., SCHIMPF S., SCHÜTT B.

**Iron as raw material: Introduction of iron metallurgy and spatial implications on landscapes. A case study from the forelands of the Harz Mountains, NE Germany**

RUSSO ERMOLLI E., PACCIARELLI M., ROMANO P., CICALA L., DI DONATO V., RUELLO M.R., TERRASI F.

**Mid-Holocene changes in morphodynamics along the western Calabria coasts (Italy): geoarchaeological implications**

LEIGH D.S., KOWALEWSKI S.A., HOLDRIDGE G.H.

**Lama-bordos and late Holocene agricultural engineering systems controlling sediment yield in the Mixteca Alta, Oaxaca, Mexico**

KUZUCUOGLU C.

**Geomorphological and sediment records of an intense climate change at the end of the late bronze age (1250-950 BC) in Anatolia: relationships with the end of the Hittite Empire**

HEYVAERT V.M.A., FUJIWARA O., UMITSU M., SATO Y., ONO E., YATA T.

**Studying the impact of the Meio 1498 earthquake and tsunamis on the geomorphology of the Hamana floodplain: a geoarchaeological approach**

MOZZI P., ABBÀ T., FERRARESE F., FONTANA A., GAMBA M., NINFO A., PIOVAN S., ROSSATO S., ZANGRANDO D.

**From point to surface. Reconstruction of a riverine urban settlement in Padova (NE Italy)**

MELIS R., SECHI S., DEPALMAS A., ZEDDA M.

**Holocene landscape reconstruction of the Southern Sinis Peninsula area (Central-Western Sardinia, Italy): Geoarchaeological approach**

BEUZEN T., FOUACHE E., LEMÉE M., GERNEZ G., GIRAUD J.  
Geomorphological investigation in Adam Oasis (Sultanate of Oman) and the implication for the archaeology - The example of the Neolithic site Jebel al-Aluya

DEFIVE E., GUNNELL Y., GUILBERT J., POIRAUD A., MIRAS Y., BERGER J.F., CUBIZOLLE H.  
Response of upland catchments to environmental change in a temperate highland setting: initial results from the velay, Massif Central, France

CREPY M., CALLOT Y.  
Eolian dynamics and landforms in South Kharga oasis (Western Desert of Egypt): evidence for two different models before and after farming settlements in Antiquity

GONNET A.  
The Holocene sedimentary records of the Lower Seine Valley tributaries as indicators of the landscape evolution during 10 000 years in Normandy: the example of the archaeological settlement of Brionne (Eure, France)

LE DREZEN Y., LETANG M., BALLOUCHE A., EL KHALKI Y., LE COEUR C.  
First data on Holocene hydro-geomorphological dynamics in the valley of Wadi Tassa (Azilal, High Atlas, Morocco).

ARA JO-GOMES J.  
The Ribeira de Bensafrim Estuary, Lagos (Portugal) - human establishment and geomorphological evolution in the late holocene

VAN NIEULAND J., VANDENBERGHE D., DERESE C., GELORINI V., CROMBÉ P., VAN DEN HAUTE P.  
Late-Glacial aeolian activity in North-West Belgium: A contribution of OSL dating near the Moervaert paleolake

KOTAPALLI S.M.  
Geomorphology and geoarchaeology: The Indian context

STOCK F., LAERMANN H., STESKAL M., LADSTAETTER S., BRUECKNER H.  
New insights into the development of the Roman Harbour of Ephesos, Western Turkey

### **S13. HUMAN IMPACTS ON LANDSCAPES (IAG-WG)**

Convenors: *Asfawossen ASRAT, Andrew GOUDIE, Paul HUDSON & Denes LOCZY*

#### **Oral presentations .....435**

BOARDMAN J., FOSTER I.D.L.  
The significance of small farm dams in the Karoo, South Africa

HUDSON P., HEITMULLER F.T., KESEL R.H.  
Flood sedimentation during the extreme 2011 flood along the Lower Mississippi River, USA

LOCZY D.  
Human impact and rehabilitation potential on a floodplain in Hungary

BROOHTAERTS N., VERSTRAETEN G., NOTEBAERT B., KASSE C., BOHNCKE S., ASSENDELFT R., VANDENBERGHE J.  
Human impact on floodplain geocology. A Holocene perspective for the Dijle catchment, Central Belgium

LARSEN A., JOSHUA R.L., FUELLING A., BORK H.R.  
The legacy of mill dams in low-order streams in central Europe

BRIZGA S.  
Predicting and Managing Fluvial Processes: Opportunities for a Non-structural Approach

SHUTTLEWORTH E., EVANS M., ROTHWELL J.  
Understanding sediment provenance during storm events in an eroding blanket peat catchment in the Peak District National Park, UK

RODRIGUES S.C.

**Changes of land use between 1979 to 2009 in the lower medium Araguari River Valley - Brazil**

DOOLITTLE W.

**The Environmental Impact of Feeding One's Family**

BEACH T., LUZZADDER-BEACH S., DUNNING N.

**Geomorphic Impacts of Maya Civilization**

KOTHIERINGER K., LAMBERS K.

**High impact: 10 000 years of human-environment interaction in the Silvretta Alps**

NYSSSEN J., FRANKL A., MOHAMED S., PETRIE G., GEBREMESKEL G., SEGHERS V., HADGU K.M., DE MAEYER P., HAILE M.

**Ethiopia in the 1930s: historical aerial photographs and their fusion with current remotely sensed imagery for retrospective landscape analysis**

SAYAGO J.M.

**Landscape resilience and sustainability in subtropical Argentina**

MENANTEAU L., GAILLARD S.

**Geomorphological and landscape impacts of the development of the port of Veracruz (Gulf of Mexico) between the 16th and 21st centuries**

LATOCHA A.

**Old hydrotechnical constructions - their impact on present landscape and morphological processes in depopulated areas; Central Sudetes Mts., SW Poland**

PRICE S., FORD J., COOPER A.

**Humans as geological and geomorphological agents in the Anthropocene**

WALKER H., MCGRAW M.

**Maintaining the Integrity of the Environment in an Arctic Delta During Modernization**

AUBAULT H., MCTAINSH G., STRONG C., LEYS J.

**Measuring the impacts of pastoral activities on wind erosion using a grazing gradient: case study in Western New South Wales, Australia**

GARCIA-RUIZ J.M., LANA-RENAULT N., NADAL-ROMERO E., SANJUAN Y., BEGUERIA S.

**Are erosion rates relevant for soil erosion studies?**

HOFFMANN T., STRAUCH A.

**Human impact on erosion and burial of soil carbon through time**

LEIGH D.S., GRAGSON T.L., COUGHLAN M.R.

**Pedogenic Effects of Mid to Late Holocene Conversion of Forest to Pasture in the Western French Pyrenees**

BARTLEY R., CROKE J., THOMPSON C., FIFIELD K., TIMS S., WILKINSON S., KINSEY-HENDERSON A., HAWDON A.

**Comparing geologic and contemporary erosion rates: implications for land management in the Great Barrier Reef catchments, Australia**

FORGET M.

**Fluvial geomorphology and landscape evolution analyzed through the cartography of a large river. The case of the Argentinian Paraná**

DANIELSEN R., RAMOS-PEREIRA A., MENDES P., RAMOS C., ALEIXO C.

**Palynological signals of mid-Holocene natural or human induced erosion episodes in the Alcabrichel estuary, central littoral Portugal**

LUZ R., RODRIGUES C.

**Anthropogenic Geomorphology of a highly urbanised fluvial plain: Pinheiros River, Sao Paulo, Brazil.**

ASHMORE P.

**On explaining urban river morphology**

CENDRERO A., HURTADO M.H., FORTE L.M., DANGVAS N.V., GIMÉNEZ J.E., M. DA SILVA M., BRUSCHI V.M.

**Positive impacts of global geomorphic change: generation of renewable geologic materials?**

VIETZ G., RUTHERFURD I., FLETCHER T., WALSH C.

**Stream geomorphology is dramatically altered by small amounts of urbanisation**

PARDESHI S., PARDESHI S.

**Human induced land surface alteration in and around Pune city, India**

GILCHRIST D.

**Water and wastewater pipelines - geomorphological challenges**

DE BRUE H., VERSTRAETEN G.

**Impact of the quality and spatial resolution of Holocene land cover reconstructions on geomorphic model results**

KOBYLKIN D., RYZHOV Y., ANDREEV S.

**Dynamics of eolian processes in the geosystems of the Western Transbaikalia (South Siberia)**

LIU J.

**Study on vegetation-cover change and grazing intensity in the Alai Valley, the southern Kyrgyz Republic**

EMBLETON-HAMANN C.

**An exploration of the role of human activity in the generation and maintenance of hummocky meadows ('Buckelwiesen' landscapes) in the European Alps.**

SVOBODOVA E., JAKUBINSKY J., BACOVA R., HERBER V., KUBICEK P.

**GeoRISK: Geo-analysis of landscape level degradation and natural risks formation**

SANTOS W., AUGUSTIN C.

**Water and sediment loss from superficial runoff in areas of forest and pasture cover in southwest Amazonia Area-Acre, Brazil**

SMOLIKOVA J., KAPICKA J., ZIZALA D., VANOVA V.

**Monitoring of Erosion and Slope Deformation on Agricultural Land in the Czech Republic**

SONNEVELD M., HENDRIKS C., WALLINGA J.

**Drivers of drift sand dynamics; a reconstruction for the Wekeromse Zand, the Netherlands**

MILEVSKI I., LUKOVIC J.

**Human impact on the mountains landscape in Macedonia and Serbia**

## **Poster presentations .....454**

THOMAZ E.

**Slash-and-burn agriculture: establishing scenarios of runoff and soil loss for a five-year cycle**

ROSKIN J., KATRA I., BLUMBERG D.G.

**Late Holocene dune mobilizations in the northwestern Negev dunefield, Israel: A response to combined anthropogenic activity and short-term intensified windiness**

FERNANDEZ S., GONZALEZ M., ALVAREZ M., RODRIGUEZ C.

**Factors promoting heavy metals leaching in Cantabrian seaboard estuaries. Bay of Biscay.**

REHBEIN M., ROSS J.

**Morphodynamics studies of the relief in the watershed of the stream Feijó/ Metropolitan Region of Porto Alegre / Brazil**

HERMELIN M.

**Successive human impacts in a tropical Andean valley: the case of Medellin, Colombia**

DAIMARU H., MURKAMI W., KUOKAWA U.

**Effect of past land degradation on the present shallow landsides in Yamaguchi Prefecture, western Japan**

RAMIREZ NUNEZ C., PARROT J.F.

**Urban constructions in deep zones. A diachronic analysis of Mexico City**

PASCHOAL L.G., CUNHA C.M.L.

**Dynamics of land use and your interference in morphohydrographic system in aera of limestone mining: a case study in the inland of Sao Paulo, Brazil.**

LIKHACHEVA E., ANIKINA N., VOLOBOY A., CHESNOKOVA I.

**Integrated geomorphological study of the center of Moscow**

ROY H., FOX D.M., EMSELLEM K.

**Land use change in a Mediterranean catchment: implications for soil erosion**

GODLEWSKA A., RODZIK J., TERPILOWSKI S.

**Human impact on runoff forming and gully development in the Bug River valley side (E Poland)**

CIANCIO M.E., TCHILINGUIRIAN P., ZULETA G.A.

**Changes in trends of development of microtopography: effects of oil exploration and production in NorPatagonia, Argentina**

MARTÍN DUQUE J.F., HOOKE R.L., PEDRAZA J.

**Transformation of Earth's surface by humans**

NEUBERGOVA K., HYKS O.

**Suburbanization of the village Cernosice depending on the geomorphology of the terrain and transport services**

PATEAU M., FORT M., BEN MOUSSA A.

**The "Tanger Med" harbor complex: impacts of its construction on its landslide prone hinterland (Rif Mountains, Morocco)**

LESPEZ L., GLAIS A., LOPEZ-SAEZ A., LE DREZEN Y., TSIRTSONI Z., DARQUE P.

**Environmental and Social changes in the southern Balkans from the Neolithic: questions and methods of investigation**

LE COEUR C., LE COEUR C., FEISS-JEHEL C.

**Emptied beaches : example from Lebanon**

SAIJO K., MATSUBAYASHI T.

**Relationship between forest use for charcoal production and landform units**

BUCALA A., BUDEK A., KOZAK M.

**The anthropogenic influence on vegetation and soil properties in Gorce Mts. (Polish Carpathians) during last 50 years**

VOELKEL J.

**Anthropogenic genesis and age of the Lower Bavarian sand dune landscape around Abensberg and Siegenburg**

GARCÉS-ESCAMILLA I., PARROT J.F., RAMÍREZ-NÚÑEZ C.

**Peri-urban growth in Mexico-City. A local evaluation of the landscape damage due to a massive house production**

GONZALEZ-AMUCHASTEGUI M.J., SERRANO E.

**Holocene Tufa changes as response to human impact on landscape (High Ebro Basin. Nothern Spain)**

RODZIK J., REJMAN J., PALUSZEK J.

**Transformation of relief in the loess areas of small denivelation under agricultural land use on the basis of soil profiles analysis (Lublin Upland, Poland)**

NOVÁK T.J., INCZE J., RÓZSA P.

**Quantifying anthropogeomorphological transformation by using the concept of "hemeromorphy" a case study from Hungary**

STURMOVA I., KOCARKOVA D.

**The effect of the geomorphology of terrain on transport development in the context of suburbanization**

SILVA V., PEREZ FILHO A., GIGLIOTTI M.D.S., SANTOS P.S.

**Anthropogenic geomorphology: Changes in the Hydrographic basins of river Jequitinhonha lower course main channel drainage pattern and delta**

SATPATI L.

**Urban geomorphology of Kolkata megacity: an interpretation of anthropocene landscape of humid tropics**

HARNISCHMACHER S.

**Detection of mining subsidence in the Ruhr district (Germany) using historic maps and DEMs**

KOLODYNSKA-GAWRYSIAK R., MROCZEK P., CHODOROWSKI J., ZGLOBICKI W., KIEBALA A., PLAK A., CHABUDZINSKI L.

**Conditions and stages of Holocene evolution of closed depressions in loess area reflected on soil-sediment sequences. A case study from Nałęczów Plateau (E Poland)**

HERNANDEZ-CRUZ G.B., PARROT J.F., RAMIREZ-NUÑEZ C.

**Mine tailings dispersion and arsenic concentration. The San Antonio-El Triunfo district, Baja California Sur, Mexico**

INBAR M., ANKER Y.

**Urban Runoff and Environmental Impact in a Mediterranean Climate Area, Ariel, Israel**

IRENE B., REYNARD E., PELFINI M.

**Hydrological influence of an artificial channel on trees of picea abies (L.) Karst. Along a tourist trail. The case of the "torrent-neuf" (Valais, Switzerland)**

SILVA A.

**Terracing slopes to make a living in the Darjeeling Hills**

RUIZ-FLAÑO P., LANA-RENAULT N., ORTIGOSA L., GALILEA I., LLORENTE J.A., ARNÁEZ J.

**The effect of terrace abandonment on the restitution of the drainage network and soil erosion**

KASHIRO M.

**Anthropogenic relief of urban areas as a factor of changes of lake landscapes**

BRISSET E., MIRAMONT C., GUITER F., CARTIER R., ANTHONY E., POULENARD J., DELHON C., ARNAUD F., MEUNIER J.D., SYLVESTRE F., PAILLES C.

**5 millennia of Mediterranean mountain disturbance: soil erosion and vegetation dynamics recorded in Lake Petit (2200 m, South-Western Alps)**

LANA-RENAULT N., GALILEA I., LLORENTE J.Á., NADAL-ROMERO E., SERRANO-MUELA M.P.

**Assessing the diversity of the hydro-geomorphological response of marginal territories in Mediterranean mountain areas**

CASTALDINI D., CORATZA P., LIBERATOSCIOLI E., TOSATTI G.

**Human impact in the Apennine area of the Municipality of Fiorano Modenese (Northern Italy)**

LAQUINA A.

**Sustainable Land Management of the agro-pastoral plateaus, Atlantic Morocco**

SILVA C.F.A., VALADÃO R.C., SILVA J.R., SILVEIRA J.S.

**Human impact on slopes and valley bottoms in iron ore exploitation areas in Minas Gerais - Brazil**

PIJET-MIGON E.

**Landform change due to airport building**

VALENZUELA P., DOMINGUEZ-CUESTA M.J., JIMENEZ-SANCHEZ M., MELÉNDEZ-ASENSIO M., SÁENZ DE SANTA MARÍA J.A.

**Active collapse dolines: a geomorphological impact from a high-speed railway tunnel crossing the Cantabrian Mountains (NW Spain)**

ZORN M., KOMAC B., FERK M., ERHARTIC B.

**Erosion processes in flysch: An example from the Istria Peninsula (NE Adriatic)**

ARINGOLI D., BUCCOLINI M., DRAMIS F., FARABOLLINI P., GENTILI B., MATERAZZI M., PAMBIANCHI G., SCIARRA N.

**Early holocene to present fluvial-coastal morphodynamics in the adriatic sector of Central Italy**

CHAKRABORTTY D.

**River regulation and associated degradation of landscape ecology of flood plain: case study from a subtropical controlled drainage in para-deltaic tract of Southern Bengal, India**

JOARDAR R.

**Importance of Slope in City Planning Case Study: Southwestern Suburban Area of Kolkata, India**

VIEIRA GOMES R.

**The effects of land use changes and morphometric parameters in the gullies erosion, São Paulo, Brazil**

SMOLOVA I., DUSKOVA M., MACHACEK J.

**The distortion of alluvial plains by the mining of gravel sand**

JONES A.F., TURNER J.N., DALY J.S., GOODHUE R., EDWARDS R.J., FRANCUS P., REID I.

**Rapid assessment of floodplain storage of contaminant metals using high-resolution XRF core scanning**

BEERTEN K., VANDERSMISSEN N., DEFORCE K., LETERME B., MALLANTS D., VANDENBERGHE N.

**Land-use changes and geomorphological development during the last millenium in the Campine area, north-eastern Belgium**

MILEVSKI I.

**Types of badlands and earth pyramids in the republic of macedonia**

GOMES F., MANIESI V., BASTOS A.

**Erosion vulnerability evolution processes associated with the deforestation settlements in Western Amazon**

TRIVELLATO F., PEREZ FILHO A.

**Human activities and changes in flow, width and depth in cross sections at the top, middle and lower course of the river Peixe - Western Plateau Paulista (Brazil), 1906 and 2012**

SILVA R., BRITO É.

**Evaluation about the use and human occupancy in the west edge's geomorphologic unit of Potiguar Basin, Northeast of Brazil, CE**

MATOS-FIERZ M., REZENDE S., ROSS J.

**The landscape concept in studies or the transformations of the land surface: reading geomorphologic and biogeographyc**

KRAUSHAAR S., WILKINSON S., OLLESCH G., SIEBERT C., VOGEL H.J.

**Understanding erosion better in a data scarce catchment in NW Jordan - A multiple response approach**

**S14. GEOMORPHIC HAZARDS, RISK MANAGEMENT AND CLIMATE CHANGE IMPACT (IAG-WG)**

Convenors: *Irasema ALCÁNTARA AYALA, Sunil Kumar DE & Adriana NIZ*

**Oral presentations .....485**

STOFFEL M., STOFFEL M., TRAPPMANN D., CORONA C.

**Rockfalls triggered from a rock-glacier front as a mirror of multi-centennial permafrost dynamics in the Valais Alps?**

TOBLER D., MANI P.

**Predicting Massmovement Processes induced in Periglacial Areas**

GIARDINO M., PEROTTI L., BACENETTI M.

**Understanding geoenvironmental dynamics and hazards of high mountains: the Geo-Morpho-Structural assessment of Veny Valley (W-Alps, Italy)**

MEYER N.K., SCHWANGHART W., KORUP O., ROMSTAD B., ETZELMÜLLER B.  
**The impact of debris flows on the transport infrastructure in NW-Norway**

DAS A.K., HAZARIKA N., SAH R.K.  
**Changing nature of riverine hazards in Brahmaputra Valley, India**

FURDADA G., MARQUES M.A., MASCAREÑAS P.  
**Flood hazard maps of ephemeral streams (NE Spain): the Multibasin-Multifunction approach**

BANDYOPADHYAY S., DE S.K.  
**A Proposed Method of Bank Erosion Hazard Zonation and Its Application on the River Haora, Tripura, India**

WERREN G.  
**Flood hazard mapping as a risk mitigation tool in a Moroccan urban catchment**

GHANBARI H.  
**Estimation of flooding potential for Chakrood catchment by SCS method**

NAGARALE V., MORE P.  
**Flood Risk Management - A Case Study of Savitri River Basin, Maharashtra (India)**

UNDE M., JAWARE D.  
**Flood Recurrence Analysis of River Bhima at Pandharpur in Part of Maharashtra**

SAHA F., TCHINDJANG M.  
**Vulnerability to natural hazards in the city of Bamenda**

COLLANTES M., GONZALEZ L.M.  
**Climatic and anthropogenic mechanisms of the desertification process in the Santa Maria Valley, Northwestern Argentina**

COUURIER S., HUERTA-LUNA R., GARNICA R., ALCÁNTARA-AYALA I., HERNÁNDEZ G., OSORNO J.  
**The socialization of threat information in hazardous areas: a method for the representation of susceptibility to landslides at landholder parcel scale**

CREACH A.  
**How to evaluate the extreme vulnerability of human exposure to sea flood risks? The example of Noirmoutier island (Vendée, France)**

ZEZERE J., PEREIRA S., QUARESMA I., SANTOS P., SANTOS M., VERDE J.  
**DISASTER: a GIS database on hydro-geomorphologic disasters in Portugal**

UTASSE M., JOMELLI V., LEONE F., BRUNSTEIN D., GRANCHER D.  
**Assessment of direct and indirect vulnerabilities of transportation networks impacted by debris flows in the French Alps**

SOLDATI M., GHINOI A., MENONI S., PATTUZZI E.  
**A methodological framework to assess landslide vulnerability and resilience across different temporal and spatial scales**

MARSTON R., BUTLER W.  
**Spatial Distribution of Slope Failures, Grand Teton National Park, Wyoming, USA**

IWAFUNE M.  
**Dynamics of Tsunami Flood related with Evacuation Behavior in the City Area Enclosed with Embankments - Analysis of 'the Tsunami Movie' recorded in Miyako City on 11 March 2011 -**

LIN J.  
**Resilience of huge earthquake in Taiwan ---12 years after Chi-Chi Earthquake**

SUZUKI T.(1). SHIMAMURA M.(2)

**EADaS: A reference system for predicting possible geomorphic disasters in Japan**

TAKEZAWA N., UCHIDA T., ISHIZUKA T., HONMA S., KOBAYASHI Y.

**Earthquake induced landslides susceptibility assessment: Roles of topography, geology and seismology**

KUTOGLU S.

**Hazard Risk Assessment in North Cyprus: Sheet Floods, Flash Floods and Floods**

GHOMSI H.D., TCHINDJANG M.

**Urban risk in the Yaoundé VII district**

CHEN R., WU R.Y., KUO C.Y., CHANG K.J.

**Application of digital orthophotos and digital terrain models to investigate of surface evolution in Tsaoling landslides, Taiwan**

MURILLO GARCIA F., ARDIZZONE F., FIORUCCI F., CARDINALI M., MONDINI A., ROSSI M., GUZZETTI F., ALCÁNTARA AYALA I.

**Landslide identification and mapping based on the interpretation of a stereo pair of Very High Resolution satellite images (VHR) for the production of a landslide inventory for the municipality of Pahuatlan, Mexico.**

BONACHEA J., FORTE L.M., HURTADO M., BRUSCHI V.M., RIVAS V., GÓMEZ-ARZAMENA J.E., REMONDO J., CENDRERO A.

**Geomorphic risk assessment and management in the context of global change**

SIDDIQUI A.

**Integrating Environmental Indicators to Diagnose Desertification Risk Zone in Indian Arid Lands using Geo-Spatial Approach**

CANIL K., MACEDO E.S.D., GRAMANI M.F., MIRANDOLA F.A., SILVA F.C., CORSI A.C.

**Methodological approach for mapping landslide risk areas, based on brasilian public policy**

MONTANE A., VINET F., BUFFIN-BELANGER T., VENTO O.

**Hydrogeomorphological mapping: current uses and perspectives for floodplains management**

DIEZ-HERRERO A., GENOVA M., MAYER P., BALLESTEROS J.A., RUBIALES J.M., SAZ M.A., BECERRIL L., HERNANDEZ M., GUTIERREZ-PEREZ I., BODOQUE J.M., RUIZ-VILLANUEVA V.

**Dendrogeomorphological research applied to flood hazard analysis in the 'Caldera de Taburiente' National Park (La Palma, Canary Islands, Spain)**

MALIK I., OWCZAREK P., YONGBO T., WISTUBA M., PILORZ W.

**Protective role of planted alder trees in capturing debris flow material, Moxi Basin, Sichuan Province, China**

**Poster presentations .....502**

KULL I., TOBLER D.

**Hazard Management in a Debris Flow Affected Area ' Spreitgraben, Switzerland**

OSINTSEVA N., KWASNIKOWA Z.

**The assessment of the risks of gully erosion activation in urbanized areas**

MUJIA FOFAK G.G., TCHINDJANG M.

**Susceptibility to natural hazards in two peri-urban neighborhoods Yaoundé: case study of Akok-Ndoué and Mvog Betsi**

VOUNDI E., TCHINDJANG M.

**Characterization of natural hazards in peri-urban areas: the case of Mont Febe (Yaoundé)**

MURAKAMI W., DAIMARU H.

**Influence of deforestation and reforestation to landslide occurrences in the granite region—Case in Mt. Ichifusa area, in central Kyusyu, Japan**

ITURRIZAGA L.

**A genetic typology of glacial lakes in regard to their hazard potential in the Cordillera Blanca (Peru)**

WICKRAMASOORIYA A.

**Demarcation of landslide risk in highland of Sri Lanka using geomorphological setting, environmental and climatic conditions**

DE OLIVEIRA MAGALHAES A., PEULVAST J.P., BETARD F.

**High- and low-frequency morphodynamic events and natural risks in mountain catchments of the semi-arid Brazilian 'Nordeste': Crato (Ceará)**

RAVANEL L., DELINE P., LAMBIEL C.

**Stability monitoring of high Alpine infrastructure by terrestrial laserscanning**

MORAES I., CONCEIÇÃO F., CUNHA C., MORUZZI R.

**The Soil Conservation Service Method (SCS) applied to hydrological modeling: a contribution for urban flooding studies**

COLLANTES M.

**Geomorphological hazards in the Tucuman Province, Northwestern Argentina**

MEDEIROS W.D.A., CUNHA L., ALMEIDA A.C.

**Environmental risks in the Coast: comparative study Brazil-Portugal**

UCHIYAMA S., SUZUKI H., HOTTA Y.

**Predictive value of the geographical distribution of shrines undamaged by the 2011 Tohoku earthquake and tsunami: Identifying previous maximum disaster ranges from the distribution**

OWCZAREK P., MALIK I., TIE Y.

**Dendrochronological dating of debris flow activity in the Minya Konka massif (Sichuan, China)**

VELLA S.

**Climatic trend in Central Calabria (Italy) during the last 100 years**

PAPATHOMA-KOEHLE M.

**Validating an indicator-based vulnerability assessment methodology for debris flow hazards**

PROMPER C., GASSNER C., GLADE T.

**Spatial and temporal patterns of landslide risk - a case study in Lower Austria**

SANTANGELO N., DI CRESCENZO G., ROMANO P., SANTO A., SCORPIO V.

**Alluvial fan flooding hazard in Southern Apennines: the state of knowledge**

GAKI-PAPANASTASSIOU K., BATHRELLOS G., KARYMBALIS E., SKILODIMOU H.

**Urban flood hazard assessment model using multi-criteria analysis: the case of Kifissos River (Athens, Greece)**

TARRAGONI C., BELLOTTI P., DAVOLI L., LUPIA PALMIERI E.

**Recent evolution of the Tiber River delta and future scenarios of coastal vulnerability**

TCHINDJANG M., KAH FANG E.

**Lake Nyos, a multirisk and vulnerability appraisal**

DE LUIZ ROSITO LISTO F., VIEIRA B.C.

**Analyze of shallow-landslide risk and susceptibility in São Paulo city, Brazil**

XIE H., YU B.

**Research on the lithology response on the rock falls in the earthquake in the downstream of Yuzixi River, Sichuan, China**

ERSAN A., ÇOSKUNLU E., UÇARLI L., AYSU Y., ÇALISKAN K., TEKIN E., KOPARMAL E.

**Disaster management of regional disasters occurred on 9 July 2012 in Samsun City, (North Turkey)**

BERNARDIE S., GRANDJEAN G., PUISSANT A., MALLET J.P., HOUET T., BERGER F., FORT M., PIERRE D.

**Society Adaptation for coping with Mountain risks in a global change Context**

DE S., GHOSH G.K., ALCANTARA AYALA I., SENGUPTA A., JOSHI V.

**Landslide Susceptibility in the North District of Sikkim, India**

TSANAKAS K., GAKI-PAPANASTASSIOU K., MAROUKIAN H., CHALKIAS C., KATSAFADOS P., KALOGEROPOULOS K.

**An integrated appraisal of flood causes in Xirolaki Torrent, Northern Greece based on geomorphological and meteorological data**

*DI LUDOVICO A., CUCULO F., IZZO M.P., DI NIRO A., SCAPILLATI N.*

**The fortore river mouth: a data processing methodology for quaternary evolution trend interpretation (Puglia Region - Southern Italy)**

*NIZ A.E., OVIEDO J.A., LAMAS C.A.*

**Erosion of slopes and sedimentation in streams due to forest fires Rio Los Puestos basin, Catamarca, Argentina**

*NIZ A., OVIEDO J.A., LAMAS C.A.*

**The advance of the dunes and your influence in the migration of the human settlements in the village of Medanitos Catamarca - Argentina**

*REGMI D., KARGEL J.S., LEONARD G., THAPA B.*

**Cause and consequences of the Seti River disaster (May 5, 2012) and assessment of a possible early warning system**

## **S15A - ANTHROPOGENIC DRIVERS OF CULTURAL STONE DETERIORATION AND CONSERVATION**

Convenors: *Patricia WARKE & Stephen McCABE*

### **Oral presentations .....521**

*ALLEN C.D., GROOM K.M.*

**Geologic Analysis of Grenada's Carib Stones and Implications for Future Management**

*TAPETE D., GIGLI G., MORELLI S., VANNOCCI P., PECCHIONI E., MUGNAI F., CASAGLI N.*

**Assessing mutual influences of environment and petrography to address the conservation of weathered Maltese stone-built heritage based on interdisciplinary materials characterization**

*OGUCHI C., TAGUCHI N.*

**Experimental study on cement mortar deterioration in sulfate environment**

*SONG W., OGUCHI C.T., WARAGAI T.*

**Chemical analysis of black crust on the Angkor sandstone at the Bayon temple, Cambodia**

### **Poster presentations .....523**

*WARAGAI T., HIKI Y., HADA A., MORISHIMA W.*

**The formation of hollow of sandstone pillar and heated Angkor Wat temple, Cambodia**

*INKPEN R.*

**Reconstructing Past Pollution Environments Using Gravestones**

*ANDRÉ M.F.(1), PHALIP B.(2), ROUSSEL E.(3), VAUTIER F.(3), VOLDOIRE O.(1)*

**Impact of cement repointing on rates of sandstone deterioration in medieval churches of the French Massif Central**

*ILIES M.(1), IRIMUS I.A.(2), ROSU C.(2), RUS M.(2)*

**A study on anthropogenic and climatic induced deterioration of some stone built churches in the Transylvanian Depression**

*TOROK A., TURI N.*

**Linear expansion and thermal cycling of sandstones: key factors of weathering**

*GENET P.E.*

**Quantitative assessment of decay in Mayan cultural limestone**

*TEFOGOM G.Z., DONGMO A.K., NKOJATHIO G.D., WANDJI P., DEDZO M.G.*

**The geomorphological Units of Mount Bambouto Caldera (Cameroon Volcanic Line): an asset for geoeducation and geotourism**

**S15B - GEOMORPHOSITES (IAG-WG) INCLUDING GEOPARKS AND WHS**

Convenors: *Emmanuel REYNARD, Paola CORATZA & Dominique SELLIER*

**Oral presentations .....529**

GRAY M.

**Drawing the Line: Boundary Issues at the National Parks of the SW USA**

ERHARTIC B., ZORN M., FERK M., KOMAC B.

**Geomorphosites: Individual landforms or areas of geomorphological heritage**

SELLIER D.

**A deductive method for selection of geomorphosites**

KIRCHNER K., KUBALIKOVA L.

**Assessment of geomorphosites: methodological approach on examples of the Moravia (eastern part of the Czech Republic)**

CAPPADONIA C., AGNESI V., ANGILERI S.E., CORATZA P., COSTANZO D., DI PATTI C., SOLDATI M., TONELLI C.

**Bridging Malta and Sicily through geoheritage exploitation: Identification and assessment of geosites for territorial enhancement**

BLINOVA I., BREDIKHIN A.

**Assessment of geomorphosites for recreational purposes: Case of Nalychevo Nature Park (Kamchatka, Russia)**

MELELLI L.

**Quantitative Geodiversity Index: GIS & spatial analysis for assessment and selection of geomorphosites**

PEREIRA P., PEREIRA D., BRILHA J., SANTOS L., HENRIQUES R.

**Assessment of Mainland Portugal geodiversity**

HOBLEA F., JAILLET S., MAIRE R., MALARD A., MOREL L., FAGE L.H., MARBACH G., TOURTE B.

**The geomorphosites of Madre de Dios island (Patagonia, Chile): "marble glaciers", painting caves and hydro-aeolian karst landforms. A singular heritage unique in the world**

BUZJAK N., PAHERNIK M.

**Geomorphological heritage of Samobor karst area (Croatia)**

STEPHENS M., HODGE S., PAQUETTE J.

**Geoconservation of caves in Fiji: a case study from Volivoli Cave, SW Viti Levu Island**

GAUCI R., CORATZA P., SCHEMBRI J.A., SOLDATI M., TONELLI C.

**Understanding the geo-heritage value of Dwejra (Gozo) as a geomorphosite**

KIM C.

**Geopark's Activities and the Role of Geomorphology in South Korea**

OSORNO J., ALCÁNTARA-AYALA I., RAMOS S., COUTURIER S., GARNICA R., LOPEZ J.

**An online atlas as a collaborative and visualization tool for the geopark proposal of the Chichonal volcano area**

CORATZA P., CASTALDINI D., CONVENTI M., LIBERATOSCIOLI E.

**The appraisal of geoheritage through different approaches: the lesson from the Salse di Nirano Nature Reserve (Italy)**

GHIRALDI L., BALESTRO G., PEROTTI L., GIORDANO E., GIARDINO M.

**Collecting and sharing geoheritage information in the digital Age**

GRIFFITHS H., SALISBURY E.

**In search of the cultural geomorphosites of Wales: evidence from medieval poetry**

NESCI O., BORCHIA R.

**The Da Vinci Landscape Code; Exploring the Panorama behind La Gioconda**

FARABOLLINI P., LUGERI F.R., GRECO R., BOCCI C.

**The geological characterization of the Landscape in movies and fictions: a suggestion to involve the society in the WHS sustainable development**

PICA A., VERGARI F., DEL MONTE M., FREDI P.

**The Aeterna Urbs geomorphological heritage (Rome, Italy)**

UNJAH T., CHOUN SIAN L., ALI C.A., KOMOO I., LEMAN M.S.

**Towards holistic landscape conservation within urban area: a case study of klang gate geoheritage site in Kuala Lumpur, Malaysia**

**Poster presentations .....539**

LIU X.P., DONG Y., ZHOU L.P., DONG X.C., ZHU X.Z., QIU F.Y., CAO X.J., CHEN Z.H., ZHOU H.Y.

**Geoheritage of Fluvial Geomorphology in the Middle and Lower Reaches of the Yellow River: A Survey by Means of Remote Sensing**

GODOY L.H., SARDINHA D.S., CONCEIÇÃO F.T.

**Geopark potential in the plateaus of Parana sedimentary basin, Uberaba City (Minas Gerais), Brazil: geodiversity and geoconservation**

EKINCI D., DOGANER S.

**Assessment of geomorphosites in the Celil Gorge (Cihanbeyli Plateau, Turkey)**

BETARD F.

**Conservation, management and valorization of geomorphological heritage in 'geological' nature reserves: the case of the Vigny quarry (Vexin, France)**

NEMETH K., MOUFTI M.

**Geosites of the Al Madinah Volcanic Geopark as the first geopark proposed to develop in the Kingdom of Saudi Arabia**

CORATZA P., GALVE J.P., SOLDATI M., TONELLI C.

**Sinkholes in the Island of Gozo (Malta): Geomorphosites to be protected and enhanced**

SERRANO E., GONZÁLEZ-AMUCHASTEGUI M.J.

**Tufa and Heritage: Geomorphosites as main elements of Cultural and Historical Monuments (High Ebro River, Spain)**

PALACIO-PRIETO J.

**Cantona, one of the largest prehispanic cities in the mesoamerican region; relations to geosites and geomorphosites**

PICA A., BAZZOLI G., DEL MONTE M., MASÈ V.

**The enhancement of a geotourist trail in the Adamello Brenta Nature Geopark (Rhaetian Alps)**

JOYCE E.B.

**Volcanic Geomorphosites within the large Kanawinka Geopark of southeastern Australia; identifying, describing, evaluating and managing Geomorphosites for future use in Geotourism**

IRENE B., REYNARD E., LUPIA PALMIERI E., PELFINI M.

**Runoff impact on active geomorphosites in unconsolidated substrate. a comparison between earth pyramids in the swiss alps and badlands in the italian apennines**

RODRIGUES M.

**Urban geotourism**

TCHINDJANG M.

**Evaluation of a geotope of exceptional importance within the Cameroon coast: the Lobe Falls**

REYNARD E.

**Geomorphic context and active processes influencing a cultural heritage: irrigation channels in Valais, Switzerland**

REYNARD E., BOLLATI I., CAYLA N., CORATZA P., GIUSTI C., HOBLÉA F., ILIES D., MARTIN S., MEGERLE H., PELFINI M., REGOLINI G., SELLIER D., ZORN M.

**A new network on mountain geomorphosites**

PANIZZA V., CORATZA P.

**The Sulcis Iglesiente mining compound (Sardegna, Italy) inside the UNESCO World Heritage Tentative List**

COMANESCU L., NEDELEA A., DOBRE R.

**Mapping geomorphodiversity. Case study: Bucegi Mountains**

SKENTOS A., MITROU A., PAVLOPOULOS K., ANAGNOSTOPOULOU O.

**Geotopes portal; A methodological approach from the field to the Web**

IOSIF D., FOUACHE E., GRECU F., GIUSTI C.

**Typology and repartition of geosites in Danube Gorges (Romania)**

KOMAC B., ZORN M., ERHARTIC B., FERK M.

**Alpine geomorphosites in protected areas and mitigation of natural hazards**

TOMA B., IRIMUS I.A., PETREA D., ROSIAN G.

**Assessment of the geomorphosite on salt from Ocna Sibiului (Transylvanian Basin, Romania)**

FERK M., ERHARTIC B., ZORN M., KOMAC B.

**The Rakov Skocjan Karst Basin: Exceptional natural heritage**

TESTA B., ALDIGHERI B., DI BONA A.

**3D exploration of the San Lucano Valley: virtual geo-routes for everyone who want to understand the Dolomites landscape**

GIORDANO E., GIARDINO M., BARAL G., GHIRALDI L.

**Following the tracks of Charlemagne in the Cottian Alps. The cultural and geological heritage of the Franks trail (Susa Valley, Piemonte, NW Italy)**

PELLITERO R., GONZÁLEZ-AMUCHASTEGUI M.J., SERRANO E., MANOSSO F.

**Geodiversity map of Valderejo Natural Park (Northern Spain)**

HERNÁNDEZ MORENO M.G.

**Setting out the boundaries of geomorphosites on the region of the Chichón volcano in Chiapas, Mexico**

GIUSTI C., PEULVAST J.P., BETARD F.

**A large fluvial geomorphosite: the Seine River downstream Mantes-la-Jolie (France)**

WHITE S., WAKELIN-KING G.

**Assessing worth in geomorphology: Earth Sciences Comparative Matrix (ESCoM) a comparative tool for nominations to the Australian National Heritage List**

GIARDINO M., BRANDOLINI P., RE FIORENTIN G., PEROTTI L., TORRENO F.

**Proposals for the valorisation of alpine geoheritage and mountain cultural landscapes: the Valli di Lanzo's Geosites and the Val Grande's Geotouristical Trail**

RODRIGUEZ RODRIGUEZ L., JIMÉNEZ-SÁNCHEZ M., DOMÍNGUEZ-CUESTA M.J.

**Quaternary glacial geomorphosites from the Redes Natural Reservation and Picos de Europa Regional Park (Cantabrian Mountains, Iberian Peninsula)**

PEREIRA P., PEREIRA D., CRISPIM J., NUNES J.C., BRUM DA SILVEIRA A.

**Geomorphosites within the inventory of geosites with national and international relevance in Portugal**

ROSSKOPF C., FILOCAMO F., AUCELLI P., DI PAOLA G., CESARANO M.

**Geomorphosites as a tool for understanding the geological history: a proposal of geo-itineraries for the National Park of Abruzzo, Lazio and Molise and Matese areas (Molise region, Italy)**

BIALY S.

The remains of mining and metallurgy industry as examples of geomorphosites in the Tatra Mts. Assessment, their role in education and geotourism

## **151C. MANAGING LANDSCAPE DYNAMICS IN PROTECTED AREAS**

Convenors: *Maria Luisa RODRIGUES & Tim BADMAN*

### **Oral presentations .....559**

BRANDOLINI P., CEVASCO A., FIRPO M.

The landscape of man-made terraced slopes in Cinque Terre (Liguria, Italy): a world heritage site at geomorphological risk

BASTOS A., MANIESI V., GOMES F.

Environmental fragility in the southwest amazon associated with its occupation modes the surrounding Jamari National Forest Case

NAVARO B., LEROUGE G., NETTER C., ROUSSELIN T.

In situ biophysical data analysis establishing the draining process of Central African lakes whose origins are hypothetical: complementarities with an original small scale satellite based study

RAPISARDI E., GIARDINO M., CRISCI A., MASCAGNI S.

The hazard, the geomorphologist and the lawmaker - Geomorphological dynamics as a perspective for a resilience legislations in the domain of natural hazards

TOMCZYK A., EWERTOWSKI M.

Planning of the recreational trails in protected areas: application of the regression tree analysis and GIS

### **Poster presentations .....561**

RANGEL L., GUERRA A.

Trail impact assessment - Cairuçu Protection Area case study, Paraty Municipality - Rio de Janeiro State ' Brazil

KHABIDOV A., FEDOROVA E., MARUSIN K., KHOMCHANOVSKII A.

Multiannual Variability of Novosibirsk Reservoir's Morphometry

GRIFFITHS H., YORKE L., GRIFFITHS S.

Historical channel change and sediment dynamics in a heavily managed and protected small catchment: the Afon Dysynni, North Wales

CHIROL A., OLIVEIRA R.R., CATALÃO C.G., ERTHAL L.

Impacts of Mountain Bike activity in Atlantic Forest, Rio de Janeiro

LATOCHA A., PARZÓCH K.

Trail morphodynamics in the Stolowe Mountains National Park (SW Poland) - how nature helps managing erosion

ROSU C., IRIMUS I.A., ILIES M., TOGANEL C.

Geomorphological restriction in urban landscape management. Case study: Piatra-Neamt - Romania

TESTA B., ALDIGHERI B., CAIELLI G., DEFRANCO R.

Stream recovery in protected areas: planning with a geomorphological approach

SHUTTLEWORTH E., EVANS M., ROTHWELL J., HUTCHINSON S.

Sediment movement and storage in small headwater catchments in an eroding peatland, Peak District National Park, UK

VERDUM R., GASS S.L.B.

Areas of permanent preservation and their usage planning in the watersheds context: methodology for legal pattern adjustments applied in a pilot area in Northwestern Rio Grande do Sul, Brazil

## **S15D. TEACHING AND DISSEMINATING GEOMORPHOLOGY**

Convenor: *David HIGGIT*

### **Oral presentations .....569**

*PARON P., GOUDIE A., SMITH M.J.*

**Geomorphological Virtual Tours: multimedia e-books for undergraduate education**

*LUGERI F., FARABOLLINI P., GRAZIANO G.V., LUGERI N.*

**Landscapes, Geology and Sport: the Earth Sciences at the 'Giro d'Italia'**

*PRATOMO I., PERMANADEWI S.*

**Batur Caldera Complex, the first land-form volcanic laboratory in Indonesia**

*GALANI L., KRITIKOS G., THEODORAKOPOULOU K., SKENTOS A., PAVLOPOULOS K.*

**Sharing the past with students: teaching geography and history through digital palaeogeography**

*ECOCHARD E.*

**Physical Geography Must Reclaim French High-school Geography**

### **Poster presentations .....571**

*WICKRAMASOORIYA A.*

**Importance of introducing visual aids and 3D models in teaching geomorphology at secondary schools in Sri Lanka**

*PIOTROWSKA I.*

**Significance of selected teaching strategies and bilingual education in the teaching and popularisation of geomorphology**

*HIGGITT D.*

**Participatory GIS to investigate urban river habitat quality in Singapore**

*SOUZA C.J.O., VALADÃO R.C.*

**Difficulties encountered by professionals in training regarding geomorphology contents: a brazilian university case study**

*SOUZA C.J.O., VALADÃO R.C.*

**Recognition and development of fundamental skills and competencies for the construction of geomorphological knowledge in higher education in Brazil**

*ALMEIDA E., PENIDO F.*

**Geomorphology teaching for environmental engineering from the fieldwork - theory and practice**

*LUGERI F., ALDIGHIERI B., FARABOLLINI P., GIANNELLA G.*

**Geology and Wine: Landscapes in a bottle (remembering Lucilia Gregori)**

*TELLEZ M., SPELTZ R., FLESSA K., ARANDA F.*

**Geodiversity of the Colorado River Delta, Baja California, México**

## **S16. FORUM FRANCOPHONE : LA GEOMORPHOLOGIE AU SERVICE DU DEVELOPPEMENT DURABLE**

Convenors: *Jules ALONI, Jean-Louis BALLAIS, Mohamed Raouf KARRAY, André OZER, Mario PANIZZA, André ROY & PHAN TRONG Trinh*

### **Oral presentations .....579**

*PANIZZA M.*

**Géodiversité et Géomorphodiversité: exemples en Italie**

DAOUDI M.

**Modélisation et géomorphologie dynamique dans le nord de l'Algérie**

KONAN E., AKA K., ABE J., NEUMEIER U., NYSSSEN J., OZER A.

**Erosion et impact des vagues exceptionnelles sur le littoral ivoirien à l'est d'Abidjan**

EL ABDELLAOUI J.E.

**Etude de la morphodynamique et de la dynamique sédimentaire de la côte atlantique de Tanger (Maroc) par l'imagerie aérospatiale**

HACHEMI K., OZER A.

**Apports et résultats de l'imagerie radar SAR et l'interférométrie InSAR/DinSAR dans les études géomorphologiques dans la région subcarpatique de Buzău (Roumanie)**

OZER P.

**Tourisme, privatisation des littoraux et érosion des côtes: cas de Phan Thiet, Vietnam**

PATEAU M., FORT M., BEN MOUSSA A.

**Une cartographie du risque "instabilités de terrain" au service du développement durable : l'exemple du complexe portuaire "Tanger Med" et de son arrière-pays (Rif septentrional, Maroc)**

MAKANZU IMWANGANA F., MOEYERSONS J., NTOMBI M.

**Seuils topographiques des ravins dans la haute ville de Kinshasa (RD. Congo)**

BALLAIS J.L., CHAVE S., DELORME V., ESPOSITO C.

**Quatre lits pour un cours d'eau. Conséquences pour le risque d'inondation et l'aménagement**

GRIVEL S., NGO A.T., ZANINETTI J.M., LUONG T.V.

**Vulnérabilité de la plaine d'inondation du fleuve Hathanh (Centre Viêt-Nam) face aux changements environnementaux**

WULAMU M., BALLAIS J.L., DELORME V.

**Hydrogéomorphologie et risque d'inondation dans la vallée de la Karakash Darya (Xinjiang, Chine)**

NIANG A.J., OZER A.

**Etude des processus morphodynamiques et leur impact sur le modelé dunaire dans le sud-ouest de la Mauritanie par imagerie satellitale optique et radar**

SAHANI M., OZER P., MOEYERSONS J.

**Le contexte urbain et climatique des risques hydrologiques de la ville de Butembo (Nord Kivu/ RDC)**

## **Poster presentations .....585**

PANIZZA M., CORATZA P.

**Le « Voyage en Italie » de J.W.Goethe et le paysage de la géologie**

ALDIGHIERI B., DI GREGORIO F., CHARRIÈRE A., OUARHACHE D., EL HAMZAOUI O., HESSANE M.A.

**Taferdoust: la merveille du méandre et du douar perché sur le "Calcaire-corniche" (Moyen Atlas plissé, Maroc)**

ALDIGHIERI B., DI GREGORIO F., EL WARTITI M., ZAHRAOUI M., FADLI D.

**Paysages, géosites et patrimoine géologique dans le Massif Central du Maroc comme nouvelles ressources pour le géotourisme**

DAOUDI M.

**Téledétection géomorphologique au nord-est de Jeddah (Arabie Saoudite)**

ZITOUNI S., FORT M.

**Le risque d'effondrement de carrières souterraines dans la région parisienne : quelle gestion pour demain ?**

BIRHENJIRA M.

**Cartographie, pétrographie, géochimie et dynamisme de mise en place des coulées basaltiques cénozoïques: cas de la ville de Bukavu et ses environs. (Sud-kivu,RDCongo)**

OZER P., HOUNTONDJI Y.C., DE LONGUEVILLE F.

**Erosion littorale et migrations forcées de réfugiés environnementaux. L'exemple de Cotonou, Bénin**

NAPARUS M., GOLAY F., PATRU-STUPARIU I.

**Evaluation des processus géomorphologiques en région montagneuse: utilisation des ondelettes pour la modélisation du terrain à de multiples échelles**

BOUMEAZA T.

**Contexte d'évolution des terrasses limoneuses quaternaires du bassin inférieur de l'oued Moulouya comparés aux étagements quaternaires aperçus sur ses affluents (Maroc oriental)**

EL BOUQDAOUI K., EZZINE H., ZAHRAOUI M., LOUKILI M., OZER A.

**Approche méthodologique de cartographie des zones à risque potentiel d'érosion des sols du bassin versant du Srou (Moyen Atlas, Maroc)**

**S17. GEOMORPHOLOGY AND THE CRITICAL ZONE (INCLUDING WEATHERING, SOILS AND BIOGEOMORPHOLOGY)**

Convenors: *Heather VILES & Junun SARTOHADI*

**Oral presentations .....593**

KIRKBY M.

**Landscape evolution models and the critical zone**

LUKENS C., RIEBE C., SKLAR L., SHUSTER D.

**Altitudinal variations in the size and flux of eroded sediment revealed by cosmogenic nuclides and detrital thermochronometry**

GUIDEZ S.

**Impact of biological soil crusts on the infiltration / runoff balance along a rainfall gradient in south-eastern Tunisia**

BETARD F., PEULVAST J.P.

**Non-lateritic red soils of the Brazilian drylands: pedogenic processes and landscape evolution**

VERDUM R., CORBONNOIS J., MESSNER F., LAURENT F., SOARES V.G.

**Sandization in Southern Brazil Campos (Ibicui Basin, Rio Grande do Sul State)**

STOATE K., HILL S.M., BAROVICH K.

**Cenozoic evolution of the critical zone on Kangaroo Island, South Australia: a framework of landscape geochemical and biogeochemical evolution and the effect of contemporary anthropogenic landscape change**

NADAL JUNQUEIRA VILLELA F., ROSS J., MANFREDINI S.

**Analysis of Relief-Rock-Soil Relationship in the Contact Atlantic Plateau - Peripheral Depression of Sao Paulo**

PULUNGAN N., SARTOHADI J., STOETTER H.

**Relation of soil depth and slope degree in Loano District, Central Java Province, Indonesia**

VOELKEL J.

**The layered Critical Zone (CZ)' established geomorphic concepts but a novelty for Critical Zone Observatory (CZO) Science?**

LEONELLI G., PELFINI M.

**$\delta^{18}\text{O}$  isotopic signature of glacier meltwaters in the tree rings: basis for long-term high-resolution hydrological reconstructions in glacial environments**

HAHM W., RIEBE C., ARAKI S.

**Effects of bedrock nutrient density on life and topography in granitic landscapes**

DOETTERL S., OPFERGELT S., CORNELIS J.T., VAN OOST K., SIX J.

**Variability of SOC stabilization with the mineral phase along a slope transect**

PAWLIK L., MIGON P., KACPRZAK A.

**Contribution of tree uprooting to the evolution of hillslopes and soils - on the examples from the Sudetes Mts., SW Poland**

COOMBES M., NAYLOR L., VILES H., GOWELL M.

**What do organisms do on rocks? A multi-methods approach to evaluating biodeterioration and bioprotection in the critical zone**

TEMMERMAN S., VANDENBRUWAENE W., DIJKSTRA J., VAN DUREN L., DE VRIES M., VAN DE KOPPEL J., HERMAN P., BOUMA T.

**Landscape self-organization of tidal floodplains by bio-geomorphic feedbacks between vegetation growth, flow hydrodynamics and sedimentation-erosion**

NAYLOR L., COOMBES M., VILES H., GOWELL M., THOMPSON R.

**How biogeomorphic approaches can be used to identify ecosystem processes and services: using rock weathering studies as an example**

**Poster presentations .....601**

SCATENA F.

**Landscape morphology and the spatial variation of critical zone processes in the luquillo critical zone observatory of Puerto Rico**

RAAB T., SCHNEIDER A., GERKE H.H., MAURER T., NENOV R.

**Drainage network evolution during the initial phase of ecosystem development - observations from an artificially-created catchment**

MENENDEZ-DUARTE R., SANTIN C., FERNANDEZ S., NAVAS A., GASPAR L.

**Soil erosion and carbon redistribution in slopes under different lithologies and land uses: the effect of fires.**

BÄTZ N., LANE S.

**Biogeomorphological interactions in formerly glaciated terrain: the overlooked role of disturbance processes.**

HATTANJI T., MATSUSHI Y., KITAMURA Y., OGUCHI C.T., HACHINOHE S., MATSUZAKI H.

**Chemical weathering rate in a steep mountain basin of Northern Japanese Alps: Estimation from in situ cosmogenic nuclides and geochemical mass balance model**

BORGEAUD L., LANE S., VITTOZ P.

**Interactions between floristic diversity and organisation and alluvial fan morphodynamics**

MIASNIKOV Y.

**Sustainability, vulnerability and geodynamic hazard in geomorphologic systems of urban territories of the Russian Far East**

HUBER J., VOELKEL J.

**Periglacial Slope Deposits and the CZ - on their genesis and influence on soil water content by a case study from the Bavarian Forest, Germany**

TODA M.(1), WATANABE T.(2), KOBAYASHI S.(3)

**Estimation of Soil Formation Rate from Vegetation on Tertiary Rock Area in Japan**

TURKINGTON A.

**Bedrock weathering and Biogeomorphic processes in the Ouachita National Forest, USA**

RAJIB M.

**Redox front effect on the adsorption of cesium and strontium on pumice tuff**

WINKELBAUER J., VOELKEL J.

**Retracing signals of historical soil erosion in peatbog archives as an indicator for landscape resilience in the context of future landuse changes and weather fluctuations (TUM-CZO, Ammer Mts.)**

TRUEMAN A., WAINWRIGHT J., DENSMORE A., TURNBULL L.

**Simulating vegetation dynamics within Landscape Evolution Models: a simplification too far?**

STOFFEL M., STOFFEL M., BALLESTEROS CANOVAS J.A., CORONA C., LUCIA A., MARTÍN-DUQUE J.F., BODOQUE J.M.

**Four-dimensional reconstruction of gullying processes in a sandy badland of the Spanish Central System**

GHOSH C.

**Biofilm Formation on Sediments is an Adaptive Feature for *Vibrio cholerae*: A Bio-Geo Interaction Phenomenon**

FURQUIM S.A.C., SAKAMOTO A., BONOMO B.C.M., SOBREIRA M.S.

**Saline lakes degradation in the Pantanal wetland, central-western Brazil**

MARTIN Y., JOHNSON E., KROEKER S.

**Time and Again: Fire, Tree Root Decay and Slope Stability**

BACHRI S., STÖTTER J., SARTOHADI J.

**Volcanic hazard assessment in the bromo volcano area, East Java (Indonesia)**

AGHAJANY K., ROOSTAEI S., POURASGHAR F., REZAEI MOGHADAM M.H.

**Urmia Lakes, affected with the water level vacillations and critical increase the salt deserts, expectant of aid for again birth**

COSTA F., BACELLAR L.D.A.P., CASTRO S.S., RESENDE F.R.M., SILVA S.F.

**Morphological, micromorphological and analytical properties in a toposequence with haplic cambisols in the Nova Lima group - Quadrilátero Ferrífero, Minas Gerais state, Brazil**

CORDEIRO SANTOS L., GONÇALVES MANGUEIRA C., VITOR DO COUTO E.

**Relationship between soil, relief and the distribution of gullies in Northwestern Paraná - Brazil**

OLIVEIRA F., SCHAEFER C., ABRAHÃO W., CLEMENTE E., SIMAS F.

**Ornithogenic soil toposequence on Rata Island, Fernando de Noronha Archipelago, South Atlantic and quaternary paleoclimatic implications**

EICHEL J., SCHMIDTLEIN S., DIKAU R.

**Paraglacial adjustment and vegetation succession in the forefield of an actively retreating glacier - a biogeomorphological perspective**

## **S18. HILLSLOPE PROCESSES AND MASS MOVEMENTS**

Convenors: *Mauro SOLDATI, Mihai MICU & Jordi COROMINAS*

### **Oral presentations .....615**

SUWA H.

**Rainfall control of debris-flow behavior: motion and deposition at Mount Yakedake, Japan**

BOCCALI C., CALLIGARIS C., LAPASIN R., ZINI L.

**Developing of a standard methodology to characterize and modeling debris flows**

LIN J.

**Debris Flow Process Reconstruction Based on UAV Remote Sensing Imagery of Disastrous Scenario**

SAEMUNDSSON T., HELGASON J., PETURSSON H.

**The debris slide in the Móafellshyrna Mountain on the 20th of September 2012. Was it triggered by intense precipitation and earthquake activity or simply by melting of the permafrost?**

WASSMER P., W.M. ISKANDARSYAH T.Y., GOMEZ C., LAVIGNE F., HART D., PRATOMO I., BEL J.

**When Debris Flows Run Upslope: Tsunami Induced Debris Flows**

ZHOU G.

**Scale Amplification of Natural Debris-Flows Caused by Cascading Landslide Dam Failures**

MIZUNO H.

**Study on Surge Triggered by Debris flow Plunging into Reservoir**

NG K.Y., MILLIS S.W.

**Development of a geomorphological model for field instrumentation design, Tai O, Hong Kong**

MICHELETTI N., LANE S.N.

**Quantification of mass movement and sediment flux at the decadal scale for Alpine mountain basins: the critical role of sediment connectivity**

SANDRIC I.(1), CHITU Z.(2)

**Bayesian modeling of rainfall-triggered landslides using weather forecasting systems**

WISTUBA M., MALIK I.

**Relations between landslide activity and fluvial erosion: slope-channel coupling recorded in tree rings and relief (Western Carpathians and Eastern Sudetes, Czech Republic)**

BOGAARD T.

**Landslide hydrology: modelling the dynamic interactions between slope deformation, preferential flow and hydrology**

VILLAÇA GOMES M., VIEIRA B.C.

**Variations in soil hydraulic conductivity as triggering factors of shallow landslides in the Serra do Mar, Brazil**

BAUZYS F., EGAS H.M.

**Mass movements characterization in the disaster occurred in the Morro do Baú Complex, Santa Catarina, Brazil, in November, 2008**

AMARAL C., SILVA A., LIMA I., RAMALHO J., VAREJÃO L., RODRIGUES J., LAGO L., CORREIA R., CORRÊA S., PORTOCARRERO H., MOTTA M., VARGAS JR. E., DE CAMPOS T., DOURADO F., SILVA L., ARAÚJO J., FERNANDES N.F., VIEIRA B.

**The Catastrophic Landslide Event of January 2011 in Rio de Janeiro: Geomorphological and Geological Controls**

CARDOSO-LANDA G.

**Relation between the precipitation intensity and duration that originated the debris flows in Puebla, México**

GORUM T., VAN WESTEN C., KORUP O., VAN DER MEIJDE M., FAN X., VAN DER MEER F.D.

**The combined effect of complex rupture mechanism and topography in regional distribution pattern of the landslides triggered by the 12 January 2010 Haiti earthquake**

CHELLI A., VESCOVI P., CARLINI M., CLEMENZI L., ARTONI A., TELLINI C., TORELLI L., BALESTRIERI M.L.

**Relationships between large landslides and late orogenic antiforms in the Northern Apennines (N Italy): geomorphological, structural and thermochronological data**

GONZALEZ-DIEZ A., FERNANDEZ-MAROTO G., DOUGHTY M.W., DIAZ DE TERAN J.R., REMONDO J., CARDENAL J.

**The apply of digital photogrammetric techniques in the generation of landslide inventories of high temporal frequency for villafufre area (Cantabria, Spain)**

EISANK C., HÖBLING D., FRIEDL B., BLASCHKE T.

**Defining digital signatures of landslide types for semi-automated landslide mapping**

BELL R., PETSCHKO H., BRENNING A.

**Age-dependent footprint of landslides in airborne laser scanning digital terrain models**

DEVOTO S., FORTE E., MANTOVANI M., MOCNIK A., PASUTO A., PIACENTINI D., SOLDATI M.

**Long-term monitoring of slow-moving landslides: examples from the Island of Malta (Central Mediterranean Sea)**

BLAHUT J., KLIMES J., YEPES J., GALINDO I.

**Monitoring of large mass movements on El Hierro, Canary Islands, Spain**

VILIMEK V., KLIMES J.

**Landslide monitoring, temporal analysis and susceptibility assessment at Machu Picchu, Peru**

MBATCHOU MBATCHOU S., TCHINDJANG M., WAKPONOU A.

**Landslides and erosion times on the Batchingou massive (West Cameroon)**

AGNESI V., ARINGOLI D., BUCCOLINI M., COCO L., DEL MONTE M., GENTILI B., MATERAZZI M., PAMBIANCHI G., SCIARRA N.

**Geomorphological evolution in some clayey small catchments of central and Island Italy during the last 15,000 years**

COSSARTE E., MERCIER D., DECAULNE A., FEUILLET T., JONSSON H., SAEMUNDSSON P.

**Impacts of post glacial rebound on landsliding at a regional scale in Northern Iceland (Skagafjörður): spatial distribution and mechanisms involved**

HRADECKI J., PÁNEK T., SMOLKOVÁ V., ŠILHÁN K., LENART J.

**Long-term slope instabilities of southern slopes of the Crimean Mountains (Ukraine), the role of karstification and slope-disequilibrium phases of the Late Quaternary**

COROMINAS J., PLANAS X.

**The 'El Forn' landslide, Principality of Andorra: a survivor of the late Pleistocene glacier activity**

MICU M., JURCHESCU M., MICU D., BALTEANU D., ZAREA R., LEAU L.

**The morphogenesis of deep-seated landslides in the Romanian Curvature Carpathians as a proxy in regional landslide hazard assessment**

DELINE P., AKÇAR N., IVY-OCHS S., KUBIK P.W.

**Repeated rock avalanches onto the Brenva Glacier (Mont Blanc massif, Italy) during the Holocene**

PANEK T., HRADECKY J., MINAR J.

**Giant landslides at Late Pleistocene highstands of the Caspian Sea**

MAQUAIRE O., AFCHAIN P., COSTA S., DAVIDSON R., FRESSARD M., LETORTU P., LISSAK C., THIRARD G., THIERY Y.

**Long term evolution of 'Les Vaches Noires' cliffs and spatio-temporal occurrence of landslides (Calvados, Basse-Normandie, France)**

HURST M.D., ELLIS M.E., ROYSE K.R., LEE K.A., FREEBOROUGH K.

**Magnitude-frequency scaling of a long-term inventory of landslides in Great Britain**

ŠILHÁN K., PÁNEK T., HRADECKÝ J.

**Tree-ring analysis in the reconstruction of slope instabilities associated with earthquakes and precipitation (the Crimean Mountains, Ukraine)**

LIMA R., MARÇAL M.

**Analysis of high magnitude mass movements on January 2011 rainstorm - Nova Friburgo, Brazil**

RIEDLER R.A., FULLER I.C., GLADE T., BELL R., MARDEN M.

**Spatio-temporal landslide dynamics and their contribution to the channel system from 1946 to 2011, Southern Ruahines, New Zealand**

PARISE M., VENNARI C.

**Slope movements shaping the landscape in the Daunia Apennines (Southern Italy), and their effects on the built-up environment**

KACPRZAK A., MIGON P.

**Constraining relative chronologies of mass movements using soil characteristics**

LENART J., PÁNEK T.

**Crevice-type rockslide caves and their relation to the slope deformations**

RICHARDS K., BITHELL M.

**Cliffs and screes: the Reverend Fisher, Bakker and Le Heux, Statham and Kirkby and DEM**

SHRODER J., BISHOP M.

**Geomorphometric assessment of large mass movements in Afghanistan and Pakistan**

MARGOTTINI C., FIDOLINI F.

**Geomorphological processes affecting the conservation of the Shahr-e Zohak archaeological site (Central Afghanistan)**

**Poster presentations .....637**

BOARDMAN J., FAVIS-MORTLOCK D.T., FOSTER I.D.

**A 10-year record of erosion on badland sites in the Karoo, South Africa**

VENCES SANCHEZ D.A., OCHOA TEJEDA V., OROPEZA OROZCO O., PARROT J.F.

**Le site archéologique El Tajin (Etat de Veracruz, Mexique) serait situé sur un ancien dépôt gravitationnel pouvant être à nouveau affecté par de futurs glissements de terrain**

FORT M., RIMAL L.N., BOURLES D., GUILLOU V., BALESCU S., HUOT S., LAMOTHE M.

**Large Landslides in the Nepal Himalayas and their significance: The Phoksundo lake (Dolpo District, Western Nepal)**

BOCCALI C., DEVOTO S., KEIM L., STRADA C., ZINI L.

**Geomorphological characterization and long-term monitoring of slope movements between Salurn and Neumarkt (Adige Valley, Italy)**

SAWABE K., KARIYA Y.

**Features of gravitational slope deformation in Mizunesawa Basin, west Tokyo, Japan**

KARIYA Y.

**Historical rock avalanche in the east side of Mount Jizo, the Southern Japanese Alps, central Japan**

MARCATO G., DIXON N., SPRIGGS M., PASUTO A.

**Optimisation of Landslide monitoring based on geomorphological characterization**

LAUTE K., BEYLICH A.A.

**Contemporary hillslope processes sediment budgets in two glacier-connected drainage basins in western Norway**

BUCALA A., ZYDRON T., DEMCZUK P., GRUCHOT A.

**Analysis of rainfall-induced shallow landslides in Jamne and Jaszcz stream valleys (Polish Carpathians)**

BIL M., DLUGOSZ M., MICU M.

**An outline of landslide-triggering rainfall thresholds in the Flysch Carpathian Chain**

BERNATEK A.

**Analysis of spatial distribution of piping forms in Bieszczady Mts., Carpathians**

LOPEZ SAEZ J., CORONA C., STOFFEL M., BERGER F.

**Impact of climate change on landslide reactivations in the French Alps**

CORONA C., STOFFEL M., KAITNA R., HÜBL J.

**Hydrometeorological triggers of debris flows in the Tyrol region (Austria) since 1910**

NIACSU L., IONITA I.

**Landslide development within the Barlad Plateau of Eastern Romania**

SATO G., HAYASHI K., YAGI H., HIGAKI D.

**Landslide Distribution Induced by Large-scale Earthquakes in 2011, in Iwaki City, Japan**

FERNANDEZ MAROTO G., GONZALEZ-DIEZ A., DOUGHTY M., MARTINEZ CEDRUN P., DIAZ DE TERAN J.R., REMONDO J., CARDENAL J.

**The unstable area of Ajanedo, Cantabria (Spain): A proposal for inclusion in Global Landslide Database**

BOLLOT N., PIERRE G., SAMYN K., FRANCOIS B., MARRE A., GRANDJEAN G., ZORNETTE N., GARCIA O.

**Anatomy of a landslide: a study case in the vineyard of Champagne (France)**

FRESSARD M., MAQUAIRE O., AMORESE D., FONT M., DAVIDSON R., THIERY Y.

**Internal structure and triggering conditions of two recent shallow landslides in the Pays d'Auge plateau (Normandy, France)**

DIAS V.C., VIEIRA B.C.

**Morphometric and morphologic parameters and the occurrence of debris flow in Serra Do Mar (SP, Brazil)**

NKURUNZIZA P.

**Mass movements, landscape and river morphology evolution around Bujumbura City in Burundi**

PEREIRA NETO M.C., FERNANDES E.

**Environmental fragility of watershed of Serido River (RN/PB - Brazil): subsidies for territorial environmental planning**

NISHII R., IMAIZUMI F., UENO K., KUROBE K.

**Monitoring of sediment movement in an artificial forest, Japanese steep mountain**

OKAMOTO A., UCHIDA T., HAYASHI S.I., CAVALLI M., MARCATO G., PASUTO A.

**Assessing of soil loss caused by active landsliding at the catchment scale: comparison of two different methods in Japan and Italy**

PALOMBA M., GIARDINO M., RATTO S., POGLIOTTI P.

**Statistic/cartographic approach to the geomorphological analysis of slope instabilities in the periglacial environments of the Aosta valley (Western Alps, NW-Italy)**

SILVA L., ARAÚJO J., BRAGA B., FERNANDES N.

**Topographic controls and mathematical modeling of landslides in Southern Brazil**

CHITU Z., ISTRATE A., SANDRIC I.

**Landslide Inventory in Ialomita Sub Carpathians, Romania**

BELL R., MICU M.

**Geomorphic coupling of deep-seated landslides and channels: Paltineni case-study (Buzau Carpathians, Romania)**

IBISATE A., ORMAETXEA O., DÍAZ E., SÁENZ DE OLAZAGOITIA A.

**A complex landslide: the case of Andoin (Basque Country, Spain)**

ISOGAI N., MORITA K., ISHIZUKA T.

**Method for estimating the volume of sliding soil mass generated by deep catastrophic landslide: Application to the disaster in the Kii mountain range, 2011**

FERNANDES N., SANTOS A.C.F., PINTO C.S.B., BHERING S., GODOY J.M., FONTES R.L.P.

**Using fallout <sup>210</sup>Pb, <sup>7</sup>Be, sediment yield and modeling to assess soil erosion at different temporal and spatial scales in southeastern Brazil**

SOUZA J.M.D., ASEVEDO L.A., BERTOLINO A.V.F.A., FREITAS M.M.D.

**Mass movements in mountainous region in southeastern Brazil from the disaster of January 2011 as landscape transformers in the Atlantic forest Biome**

TÁBOŘÍK P., PÁNEK T.

**Resistivity measurements in slope geomorphology: recognition of deep-seated mass movements**

SMOLIKOVA J., BLAHUT J., ZIZALA D., VILIMEK V.

**Shallow slope deformations triggered by extreme rainfall: case studies from Czech Republic**

CARVALHO ARAUJO J., MARIA DA SILVA L., DOURADO F., FERREIRA FERNANDES N.

**Morphometric analysis of landslides using Gis: the case of d'antas watershed in Serrana region in the state of Rio De Janeiro, Brazil**

COMBAUD A., BOLLOT N., CHALUMEAU L., BATAILLER A., CHARBONNIER K., DOURLAT E., EMERIAU G.

**Influence of the mass movement on the vineyard fragmented. Case study of the Côte de l'Île de France (Champagne - France)**

TEFOGOM G.Z., NKOUATHIO G.D., DONGMO A.K., WANDJI P., DEDZO M.G.

**Study of Landslide hazards and Assessment of Associated Risks in the West-Cameroon Highlands (Central Africa)**

STEPHENS M.

**Recent landslide hazards in the Ba catchment, NW Viti Levu Island, Fiji**

MESSENZEHL K., HOFFMANN T.

Storage coupling and sediment connectivity in a high-alpine cascading system (Val Mütschans, Swiss National Park)

**S18A - CERG SUBSESSION: METHODS FOR LANDSLIDE HAZARD AND RISK ASSESSMENT**

Convenors: *Jordi COROMINAS, Thomas GLADE & Jean-Philippe MALET*

**Oral presentations .....659**

**The use of engineering geomorphology in landslide assessments: a Hong Kong case study**  
*PARRY S.*

*LISSAK C.(1), MAQUAIRE O.(1), MALET J.P.(2), BITRI A.(3), BOURDEAU C.(4), DAVIDSON R.(1), GRANDJEAN G.(3), REIFFSTECK P.(5)*

**Characterizing the complex morpho-structure of coastal landslides combining airborne and ground-based investigations**

*MOYA J., COROMINAS J., MAVROULI O.C.*

**A geomorphologic and probabilistic approach to the number and size of blocks of fragmental rockfalls**

*VAN ASCH T., XU Q.*

**A modelling approach of the large, rapid Yigong rockslide ' debris avalanche, Southeast Tibet**

*CARVALHO VIEIRA B., SOUZA FERREIRA F.*

**Physical and geotechnical properties of soils and shallow landslides, Serra Do Mar Mountain Range, Brazil**

*GHINOI A.*

**A reappraisal of field geomorphology in landslide hazard investigation**

*LOMBARDO L., CAMA M., CONOSCENTI C., HOCHSCHILD V., MÄRKER M., ROTIGLIANO E.*

**Comparing binary logistic regression and stochastic gradient boosting techniques in debris-flows susceptibility modelling: application in North-Eastern Sicily**

*ROTIGLIANO E., CAMA M.E., CONOSCENTI C., LOMBARDO L.*

**Landslide susceptibility modelling for extreme rainfall-triggered multiple landslides: a key study from the 2009 event in the Giampilieri Aera (Sicily, Italy)**

*PIACENTINI T., MICCADEI E., DI MICHELE R.*

**Assessment of rockfall susceptibility in different morphostructural frameworks, Abruzzo Region, Central Italy**

*MORITA K., ISOGAI N., ISHIZUKA T., UCHIDA T., OCHI H.*

**Assessing for deep-seated catastrophic landslide susceptibility of Japan: Application and verification for Kii mountain range, Japan**

*FERNANDES N., AMARAL C., BIERMAN P., SILVA L.M., ARAÚJO J.P., VARGAS JR. E., DE CAMPOS T., DOURADO F., LOPES M., PEIXOTO M.N., NUNES A.*

**Debris Flows in Rio de Janeiro: Mapping, Modeling and Dating**

*GRUNERT J., KRAUTER E., KUMCERICS C.*

**Accelerated landsliding due to climate warming? Modeling results from western Germany**

*OLIVEIRA S.C., ZÉZERE J.L.*

**Update of rainfall thresholds for landslide activity in the Lisbon area (Portugal)**

*FRESSARD M., THIERY Y., MAQUAIRE O.*

**Quantitative landslide hazard assessment in the hilly valleys of the Pays d'Auge plateau (Normandy, France)**

*PEREIRA S., SILVA M., GARCIA R.A.C., ZÉZERE J.L.*

**Quantitative Risk Analysis for shallow slides: the case of S. Marta de Penaguião (Douro Valley, Portugal)**

*CIUREAN R., HUSSIN H., FRIGERIO S., GLADE T.*

**Probabilistic modelling of uncertainties in vulnerability assessment - application to hydro-meteorological hazards in the municipality of Malborghetto-Valbruna, Italy**

REMONDO J., BONACHEA J., BRUSCHI V.M., GONZÁLEZ-DÍEZ A., DÍAZ DE TERÁN J.R., CENDRERO A.  
**Landslide risk models on the basis of recent occurrences**

SPIZZICHINO D., MARGOTTINI C., SOLDATI M.  
**Landslide risk assessment and management in the archaeological site of Machu Picchu Inca citadel (Peru)**

IASIO C., MULAS M., PETITTA M., CORSINI A.  
**Retrieving high resolution deformation patterns of slow moving landslides by COSMO-SkyMed SAR data: a sustainable long term monitoring system using artificial reflectors**

GUI L., YIN K., GLADE T.  
**Landslide monitoring: Analysis of displacement data of different landslides in Wanzhou District, Three-Gorges Reservoir, China**

MEISINA C., ZIZIOLI D., BORDONI M., VALENTINO R., BITTELLI M., CHERSICH S.  
**Continuous monitoring of a slope affected by shallow landslides in North'Eastern Oltrepo Pavese (Northern Apennines, Italy) for landslide susceptibility assessment: preliminary results**

**Poster presentations .....670**

ZAIDAN R., FERNANDES N.  
**Zoning and analysis of landslide risk in the urban watershed of the stream of independencia, in the city of Juiz De Fora (MG/BR)**

DOSHIDA S.  
**Assessment of landslide susceptibility using landslide map in Japan**

DOSHIDA S., UCHIYAMA S.  
**The characteristic features of landslides in the 2011 off the Pacific Coast of Tohoku Earthquake**

DELLA SETA M., ZANIBONI F., TINTI S., PAGNONI G., FREDI P., MAROTTA E., ORSI G.  
**Slope instability at Ischia Island (Gulf of Naples): scenarios for tsunamigenic landslides and coastal vulnerability**

IRIMUS I.A., MAGUT F., ZAHARIA S., POP O.T.  
**The impact of landslides in urban areas. Case study ' the city of Baia Mare**

DE S., GHOSH K.  
**A comparative study between Weight-rating and Analytical Hierarchical Methods of Landslide Susceptibility Zonation and Geotechnical Investigation of Some Individual Landslides in Dhalai District, Tripura, India**

MURILLO GARCÍA F., ROSSI M., REICHENBACH P., MARCHENSINI I., ARDIZZONE F., GUZZETTI F., ALCÁNTARA AYALA I.  
**Landslide susceptibility analysis and mapping: Pahuatlán-Puebla, Mexico**

FUCHS S.  
**Fluvial sediment transport: the effect of deposition behaviour on vulnerability of elements at risk exposed**

GOURNELOS T., TSAGAS D.  
**Structural Control of landslides movements in the uplifted area of NW Peloponnese (Greece)**

GIANNECCHINI R., GALANTI Y., D'AMATO AVANZI G., BARSANTI M.  
**Critical rainfall thresholds for triggering debris flows in a human-modified landscape: the case of Carrara Marble Basin (Italy)**

SOLDATI M., MAQUAIRE O., MICALLEF A., COSTA S., DELACOURT C., FOGLINI F., JABOYEDOFF M., LETORTU P., LISSAK C., PASUTO A., PRAMPOLINI M., TONELLI C.  
**Coupling terrestrial and marine datasets for coastal hazard assessment and risk reduction in changing environments - A EUR-OPA Major Hazards Agreement Project**

BRANDOLINI P., GALVE J.P., CEVASCO A., SOLDATI M.

**Evaluation of mitigation measures to reduce shallow-landslide hazard induced by extreme rainfall events: analysis of the road network in the Vernazza catchment (Cinque Terre, Italy)**

NICULITA M., MARGARINT C.

**Landslide susceptibility validation using multitemporal inventory of landslides in the Moldavian Plateau, Romania**

VAN ASCH T., TANG C.

**An integrated model to assess rain fall thresholds for critical run-out distances of debris flows in the Wenchuan Earthquake area, SW China**

LIBERATOSCIOLI E., SOLDATI M., VAN WESTEN C.J.

**Assessment of susceptibility for small landslides in the Secchia Basin (Modena Province - Italy) by means of statistical analysis**

FERNANDES E., CESTARO L.A., PEREIRA V.H.C.

**Dunes dynamics and potential risks of mass movements in Natal-RN City, Brazil**

HECKMANN T., GEGG K., BECHT M.

**Between spatial autocorrelation and representativity: Seeking the 'optimal' sample size for a statistical spatial prediction model of debris flow initiation**

MALET J., BÉGUERIA-PORTUGUÈS S., PROMPER C., GLADE T., PUISSANT A., REMAÎTRE A.

**Changing RISKS: Assessment and communication on possible effects of global changes on landslide risks**

PETSCHKO H., BELL R., GLADE T., GRANICA K., HEISS G., LEOPOLD P., BAUER C., PROSKE H., POMAROLI G., SCHWEIGL J.

**Methods for landslide susceptibility assessment, concepts and applications for spatial planning in Lower Austria**

SALVATORE M., BARONI C., CARLONI I., DELLA SETA M., DEL MONTE M., VERGARI F.

**Debris flow susceptibility assessment in the avio valley (adamello-presanella massif, Central Alps) through multitemporal and conditional analysis**

LI D., YIN K., CHEN L.

**Deformation and prediction of landslides with step-like deformation in the Three Gorges Reservoir**

NERY T., VIEIRA B.C.

**Landslide Susceptibility Mapping Using SINMAP model, Serra do Mar, Brazil**

ROTIGLIANO E., AGNESI V., ANGILERI S.E., ARNONE G., CALÌ M., CALVI F., CAMA M.E., CAPPADONIA C., CONOSCENTI C., COSTANZO D., LOMBARDO L.

**Multi-scale regional landslide susceptibility assessment in Sicily (Italy): The Sufra Sicilia Project**

MICCADEI E., MARSALA V., PIACENTINI T., ROCCA M., SCIARRA M.

**Landslide susceptibility map of the Mauritius Island**

CREMA S., CAVALLI M., MACCONI P., MARCHI L.

**Regional-scale debris-flow modelization for hazard mapping in alpine basins using a high-resolution DTM and events geodatabase**

BOSSI G., CAVALLI M., QUAN LUNA B., FRIGERIO S., MANTOVANI M., MARCATO G., SCHENATO L., PASUTO A.

**Multi temporal LiDAR-DTMs as a tool for modeling a complex landslide: a case study in the Small Dolomites (Rotolon catchment - Italy)**

CHENG C., BAI S., WANG J., WEI Y.

**Comprehensive Utilization of SAR and Optical Data for Landslides Investigation in the Bailongjiang Basin, China**

CHHABRA N., ROY N.G.

**Hydroelectric power generation, tropical river flood hazards and mitigation plan for better investment in Uttaranchal, India**

BOGAARD T., WENKERS K.

How can fiber optic technology be used in early warning systems for natural hazards?

*LISSAK C., MAQUAIRE O., MALET J.P.*

Critical hydro-climatic thresholds for triggering slow-moving landslides along Normandy coasts (France)

## **S19A - LARGE RIVERS (IAG-WG)**

Convenors: Avijit GUPTA & Zhongyuan CHEN

### **Oral presentations .....687**

*AALTO R.*

Sedimentary Processes in Large Source-to-Sink Systems Forced by ENSO

*GUPTA A., LIEW S.C.*

Climate change and large tropical rivers

*GAUTIER E., FEDOROV A., COSTARD F., KONSTANTINOV P., BRUNSTEIN D.*

Interactions between global warming, flooding and fluvial form adjustment on the Lena River, Central Siberia

*BRUNIER G., ANTHONY E.J., PROVANSAL M., DUSSOUILLEZ P., GOICHOT M.*

Recent changes in the morphology of river channels in the Mekong delta: natural or anthropogenic?

*BALTHAZAR V., VANACKER V.*

Regional scale analysis of natural vs. anthropogenic controls on sediment fluxes

*BRONSTERT A., ARAÚJO J., BATALLA R., GÜNTNER A., FÖRSTER S., FRANCKE T., MÜLLER E., BROSINSKY A., DELGADO J., LÓPEZ-TARAZÓN J., SOMMERER E., VERICAT D., WEBB S.*

Quantification and Modeling of Runoff and Suspended Sediment Transfer Paths in Instrumented Mesoscale Catchments in Spain and Brazil

*JOUBERT R., ROWNTREE K., ELLERY W.*

Understanding recent change in river-floodplain connectivity in the Baviaans catchment, Eastern Cape: implications for floodplain restoration

*FINLAYSON B., CHEN J., WU X., WEI T., LI M., CHEN Z., WEBBER M.*

The Hydrology of the Yangtze (Changjiang) River, China

*CHEN Z., YUAN W.H.*

Post-dam assessment for change in riverbed and delta-coast morphology following impoundment of Three Gorges Dam of the Yangtze (Changjiang) River

*YANG X.K., LU X.X.*

Model of reservoir regulations and their impacts on river fragmentation in the Yangtze River Basin, China

*SHAO L., LI C.(2), YUAN S.*

Geochemical compositions of the late Cenozoic sediments in the Jiangnan Basin: Implications for sediment source and evolution of the Yangtze River

*HIGGITT D., ZHANG X.B., HE X.B.*

Declining Sediment Yields in the Upper Yangtze: Dams, Degradation Control or Delivery?

*YANG D.*

Geomorphologic process of the first bend of the Yangtze River

*YU G.A., HUANG H.Q., LIU X.F., NANSON G., FAN B.L., LIU T.H.*

Characteristics and self-adjusting behavior of anabranching channel patterns along the middle and lower reaches of the Yangtze River

*RAMOND S., ROBERT V., GAUTIER E., DEPRET T., MARLIN C., DURAND V., MONVOISIN G., NORET A., MASSAULT M.*

Impacts of meander landforms evolution on hydrological functioning of a floodplain: the Loire Meander at Guilly (Central France)

RIQUIER J., PIÉGAY H.

**Predicting life span of restored secondary channels and backwaters (Rhône river, France)**

NAGUMO N., SUGAI T., KUBO S.

**Severe monsoon floods and floodplain development in the lower reach of the Stung Sen River, Lower Mekong Basin**

KIM V., MAKHINOV A.

**Morphodynamics and stability of the amur riverbed**

BHATTACHARJEE S.

**River bank erosion, shifting of off-take point: a case study of river Bhagirathi, West Bengal, India**

SALIT F., ARNAUD-FASSETTA G., ZAHARIA L., MADELIN M., BELTRANDO G.

**Morphological changes of the Lower Siret River from 1891 to 2010: the decisive impact of engineering works and water management strategy**

VALENTE A., MAGLIULO P.

**Short-term channel adjustments in an anthropized stretch of the Calore River (Southern Italy)**

MARAGA F., BELLARDONE G., TURCONI L.

**Present changing in river system of the upper Po River Plain (Italy)**

LIEDERMANN M., TRITTHART M., GMEINER P., HABERSACK H.

**Sediment transport measurements providing insights on initiation of motion and high flow bedload transport at the Austrian Danube**

TIAN S.M., WANG W.H., LI Y., ZHANG X.H.

**The evolution of the fluvial process in the lower Yellow River since 1960**

HU Z., PAN B., GAO H., HU X.

**Tracking the middle reach of the Yellow River running eastward across the Ordos Plateau and North China Plain**

BANDYOPADHYAY S., MUKHERJEE D., KAR N.S.

**Geomorphic Changes in the Indian Sundarban between 1917-23 and 2012: Evidences from Maps, Images and Hydrography**

**Poster presentations .....700**

ZHAO X., WU Z., YE P., TONG Y., HU D.

**Neogene gravels and dammed-lake sediments newly discovered in Nujiang (Salween) River valleys, Yunnan**

ALVES N.S., RODRIGUES C.

**Hydromorphodynamic of Anavilhanas Fluvial Archipelago - Amazon- Brazil**

ZHANG K.

**Fluvial competition exemplified by formation and evolution of the Fen River and Jinshan Yellow River, North China**

TANANAIEV N.

**Permafrost-cored alluvial bedforms and related channel morphology of the Lena River, Central Yakutia**

CHERNOV A.

**Geomorphological and geocological mapping of river valleys, floodplains and channels**

SHI C., SHAO W., FAN X.

**A study on phasic changes of sediment erosion and accumulation in the Inner Mongolian reach of the upper Yellow River and contributions of main factors**

DAS S., BANDYOPADHYAY S.

**Evolution of River Systems in the Indian Part of Upper Ganga Delta: Evidences from Maps and Satellite Images**

FERNANDES E., QUEIROZ NETO J.P.

**Spatial organization of Pantanal lagoons in Matogrosso Do Sul, Brazil**

YAN Y.

**Similarity analysis of scale effects of specific sediment yield in the Yangtze River basin, China**

SILVA J., RODRIGUES C., PEREIRA D.

**Fluvial patterns and its use for the assesment of amazonian geodiversity, discussion and application ont the Xingu River Basin**

YANG I.

**Developmental History of the World's Longest Rivers**

ATIF S., ARNAUD-FASSETTA G., FORT M.

**The lower Indus Basin: an anthropogenically modified hydrosystem under the influence of extreme events**

HENAFF Q., BELTRANDO G., ARNAUD-FASSETTA G.

**Simulation of floods in the Rhône valley from Lidar DEM: Assessing impacts of hydraulic structures on the floodplain dynamics faced new regulation of 2014**

DAVID M., CAROZZA J.M., VALETTE P.

**A quantitative approach of the morphological changes in the Middle Garonne river (South-west France) during the last 300 years**

**S19B - SMALL CATCHMENTS (IAG-WG)**

Convenor: *Andrzej KOSTRZEWSKI*

**Oral presentations .....709**

KOSTRZEWSKI A.

**The monitoring of small rivers catchments in various climatic zones - assumptions of methodological and methodical studies**

JAKUBINSKY J.

**Geomorphological features of small watercourses in a context of river landscape sustainability in the Czech Republic**

AUGUSTIN C., CRUZ L., FABRIS J., ROCHA L.

**Geochemical and physical loss from a small catchment area in the sub-humid 'tropics: contribution of gullies**

MYKHNOVYCH A., KOVALCHUK I., KRAVCHUK Y., PYLYPOVYCH O., CHIKOVA I.

**Extreme land-forming processes development and distribution in the Ukrainian Carpathians under natural and man-made factors**

KARALIS S., KALOGEROPOULOS A., KARYMBALIS E., CHALKIAS C.

**Assessment of the relationships among morphometric parameters and hydrologic indices**

NAMDEO S.

**Quantitative Morph metric Analysis of Machna River basin Management, M.P.(India)**

SMOLSKA E.

**Variability of soil erosion in the last-glacial areas on the example of NE Poland**

NADAL ROMERO E., CORTESI N., GONZÁLEZ HIDALGO C.

**Weather times and flood generation in the Araguás catchment (Central Spanish Pyrenees)**

MAILLARD B., REYNARD E., THELER D.

**Typology of torrential systems prone to debris flows occurrence in the Hérens valley (Switzerland)**

SOUZA J., CORREA A.

**Damming in semiarid, relation between landscape connectivity and effective catchment area on sacco creek watershed brazilian semiarid**

MAKHINOV A., KIM V.

**Debris dams on the far eastern rivers and their impact on the dynamics of riverbed transformations**

POEPPL R.E., KEILER M., COULTHARD T.

**Investigating morphodynamics and sediment fluxes in a river reach impacted by a series of dams using landscape evolution modelling with CAESAR-Lisflood**

SELCUK BIRICIKA., EKINCI D.

**Embedded Dam Technique on River Basins in Rehabilitation Studies: The Case of the Afyonkarahisar Dort River**

HARTVICH F., LANGHAMMER J., STYCH P.

**Coarse sediment study in small mid-mountain catchments: a multidisciplinary attitude**

**Poster presentations .....716**

PLACZKOWSKA E.

**The magnitude and frequency of morphogenetic processes in small catchments (Western Tatra Mts., Poland)**

KOSTRZEWSKI A., TYLKOWSKI J.

**The specificity of energy and matter circulation in the coastal, forested lake gardno catchment on Wolin Island (NW Poland)**

RODZIK J., JANICKI G., CHABUDZINSKI L., FRANCAZAK L., SILUCH M., STEPNIEWSKI K., DYER J., KOLODZIEJ G., MACIEJEWSKA E.

**Monitoring programme of sediment flux in small upland catchments, SE Poland**

KIM J.K., NAHM W.H., KIM M.S., YANG D.Y., JEONG G.S.

**The effect of landuse changes on sediment transportation in a small catchment during last 60 years**

LIM Y., KIM J.W., KIM J.K.

**Changes of size distribution of the raindrops against rainfall intensity in Daejeon, Korea**

LESENCIUC C.

**The GPR (ground penetrating radar) use to estimate the annual rate of sediment delivery in small catchments from Obcinele Bucovinei (the Romanian Carpathians)**

SLATTERY M., LLADO L.

**Soil moisture dynamics of a Muhly grass hillslope seep system**

CERMINARO A., OLIVEIRA D.D.

**Physic Characterization of Watershed of Reibeirão do Feijão, in the counties of São Carlos, Itirapina and Analandia ' Sao Paulo, Brazil ' as Morphopedology Compartmentation subsidy**

VIEL V., LESPEZ L., DELAHAYE D., LE GOUÉE P.

**Holocene sediment dynamics for two small river catchments in Normandy (Western France)**

RYSIN I.

**The results of ravine erosion monitoring in the territory of Udmurt Republic**

SERRANO MUELA P., REGÜÉS D., NADAL-ROMERO E.

**Influence of soil and vegetal cover on hydrological behavior of a forested catchment in a mid mountain environment**

SERRANO MUELA P., REGÜÉS D., NADAL-ROMERO E., LANA-RENAULT N.

**Groundwater dynamics in a forests submediterranean environment**

WIBOWO S.B., MAJOR J.J., PIERSON T.C., MOUROT P., HADMOKO D.S., LAVIGNE F.

**Lahar initiation on small upstream catchments of Merapi volcano during 2012-2013 rainy season**

TESTA P.M.C., RODRIGUES BARBOSA D., VIEIRA DE MELLO E., GUNDIM SILVA F., MACEDO RODRIGUES N.

**Land use in floodplains: a study on the Riparian Buffer in Sub-basin river Ipiranga - River tributary guandu / Brazil**

MASSELINK R., KEESSTRA S., GIMÉNEZ R., CASALÍ J., SEEGER M.

**Determining catchment-scale connectivity using hysteresis analysis of discharge and suspended sediment**

LAJCZAK A.

**Contemporary functioning of peat catchments on a glaciofluvial fan. Case study: Orawska Basin, Polish Carpathians**

## **S19C - SEDIMENT FLUXES AND MORPHODYNAMICS OF STREAM CHANNELS**

Convenors: *Alain RECKING, John PITLICK, Mike CHURCH & Nicola SURIAN*

### **Oral presentations .....727**

HEYMAN J., METTRA F., MA H.B., ANCEY C.

**Time scale analysis of bedload discharge over steep slopes: from intermittency to white noise**

METTRA F., HEYMAN J., MA H., ANCEY C.

**From bedform evolution to channel slope fluctuations in steep-slope streams**

MOLNAR P., SALETTI M.

**On grain blocking, step formation, sediment transport dynamics and self-organized criticality in steep streams**

GALIA T., HRADECKÝ J.

**Critical conditions for beginning of coarse sediment transport in headwater channels based in flysch rocks (Moravskoslezské Beskydy Mts., Western Carpathians)**

LINDSAY O., JOHNSON J.P.L.

**Evaluating bedload transport in coarse alluvial streams with RFID and motion tracers**

LIEBAULT F., LARONNE J.B., KLOTZ S., JANTZI H., RAVANAT X., FAVARIO J.

**Bedload transport monitoring in a small upland catchment**

DEPRET T., GRANCHER D., GAUTIER E., HOOKE J.

**Morphodynamic and bedload displacement on a meander loop (Cher River)**

MARQUIS G.A., ROY A.G.

**Linking process and form using a field data set: issues, challenges and prospects**

SLATTERY M., MELCHORS M.

**The impact of impoundment on sediment transport and channel bar dynamics on the Brazos River, Texas**

ROJAN E., DLUZEWSKI M., KRZEMIEN K., BIEJAT K.

**Morphodynamics of small wadis on the southern slopes of High Atlas Mountains (on the example of upper Dades catchment, Morocco)**

CHIODI F., ANDREOTTI B., CLAUDIN P.

**Revisiting the river bar instability**

ROUSSEAU Y., VAN DE WIEL M., BIRON P.

**Combining Geotechnical and Hydro-Morphological Modelling to Investigate the Dynamics of Meandering Rivers**

LEDUC P., RECKING A., NAAIM M.

**An experimental study of the grain sorting effect on braided pattern**

TAL M., GRAN K.

**Riparian vegetation as a primary control on channel width: results and insights from the laboratory to the field**

KLOESCH M., TRITTHART M., BLAMAUER B., HABERSACK H.

**Effects of bedload input on channel widening in a restored section of the Drau River, Austria**

ARNAUD F., BÉAL D., PIÉGAY H., ROLLET A.J., SCHMITT L.

**Experimental sediment reintroduction into the Rhine River downstream the Kembs dam: feedbacks from repeated field measures and high resolution imagery**

VATNE G.

**Relationships between bank protection and forced pool characteristics in a low gradient flood prone river, Central Norway**

HUGHES M.

**Spatial and temporal patterns of channel change and bedload transport of the Wood River, Upper Klamath Basin, USA: implications for assessing river management and restoration**

GROSPRETRE L., SCHMITT L., JACOB N., DELILE H., PRIVOLT G., PREUSSER F., COTTET M.

**Contemporary channel adjustments in a periurban catchment in the frame of a long-term sediment cascade history (Yzeron, City of Lyon, France)**

ZORRIASATEYN N., STEWARDSON M., VIETZ G., RUTHERFORD I., FLETCHER T.

**What Impact Does Urbanisation Have on the Depth of Bedload Sediment in Streams?**

GOB F., JACOB-ROUSSEAU N., LE DREZEN Y., HOUBRECHTS G.

**Stream incision and sediment wave consecutive to three centuries of timber floating in the Morvan Massif (Central France)**

LANDEMAINE V., GAY A., CERDAN O., SALVADOR-BLANES S., RODRIGUES S.

**Recent morphological evolution of a headwater stream in agricultural context after channelization (Ligoire River, France)**

TUNNICLIFFE J.

**The post-glacial evolution of Cordilleran rivers in southwestern British Columbia: timescales, texture and topography**

SRIDHAR A.

**Aggradation and incision of the fluvial terraces in response to the change in the river regime and pattern during the Holocene in Gujarat Alluvial Plain, western India**

NICOLL T., BRIERLEY G.

**Quantifying the influence of landscape connectivity on alluvial sediment flux in the upper Yellow River**

SLATER L.J., SINGER M.B.

**Trends in alluvial channel geometry: an indicator of decadal fluctuations in regional sediment supply and local flood risk**

ALCAYAGA SALDIAS H., BELLEUDY P.

**A simple approach to understand the kinetics of the responses of the river beds to changes in the sediment supply and hydrological regimes at the watershed scale**

RAMONELL C., MARCHETTI Z., PEREIRA S.

**Within-channel levees: a new-recognized fluvial form in the floodplain of a large river (Paraná River, South America)**

PARROT E., PIÉGAY H., TAL M.

**A comprehensive analysis of bedform evolution on the Rhône River, France**

HALLOT E., GUYON F., ZANGRE A., DABIRE F., DE THYSEBAERT D., PETIT F.

**Establishment of a sedimentation monitoring system of irrigation dams in Burkina Faso: The PADI project**

GUSAROVA A.

**Evaluation of genetic structure of erosion intensity in river basins according to the analysis of river suspended sediment flux**

EGOZI R.

**Anomaly suspended sediment loads and channel morphology changes in a Mediterranean catchment: the effects of land cover and land use changes**

FRYIRS K., GORE D.

**Sediment tracing in the upper Hunter catchment using elemental and mineralogical composition: Implications for catchment-scale suspended sediment (dis)connectivity and management**

BROOKS A., SPENCER J., OLLEY J., PIETSCH T., CURWEN G., BOROMBOVITS D., SHELLBERG J.  
**Sediment budget modelling in the northern Great Barrier Reef, Australia; without empirical data ' don't bother!**

**Poster presentations .....744**

SARDINHA D.S., CONCEIÇÃO F.T., GODOY L.H.  
**Mechanical and chemical erosion in three basins located in different geomorphologic provinces of Sao Paulo State, Brazil**

LAVAL F., VENTO O., ESCORIHUELA F., JOUSSE C., KOULINSKI V., BREILH B., MONTANE A.  
**Upper Drac River restoration project : restoration of a braided river bed incised in clay substratum through sediment reloading and bed widening**

BEYLICH A.A., LAUTE K.  
**Combining field measurements and flume experiments for analysing fluvial bedload transport and morphodynamics in steep mountain streams**

WYZGA B., MIKUS P., KACZKA R., WALUSIAK E., ZAWIEJSKA J.  
**Islands in a European mountain river: linkages with large wood deposition, flood flows and plant diversity**

CLARKE L., WERRITTY A.  
**Geomorphological changes associated with avulsion: a case study of the feshie fan, SCOTLAND**

LAMBERET T.  
**River Preservation Project : Evaluating the erosion surface rate of river banks using temporal and spatial analysis on 4 pilot sites of the Lanterne's Basin**

SPATTI JR. E., CONCEIÇÃO F.T., PINTO S.D.A.F., PEREIRA L.H.  
**Sediment transport in a small watershed by Agricultural activities in Sao Paulo State, Brazil**

BEL C., RORSMAN K., FREY P.  
**Experiments and modelling of size segregation in bedload transport**

PITLICK J., RECKING A.  
**Development of Basin-Scale Models to Estimate Bed Load Sediment Flux**

DUMITRIU D., NICULITA M., OBREJA F.  
**Lateral channel migration and bank erosion along the Trotus River (Eastern Carpathians)**

BROOthaerts N., NOTEBAERT B., VERSTRAETEN G.  
**Asynchronicity in floodplain processes. An example from the Dijle catchment, Central Belgium**

CHAPUIS M., DUFOUR S., MACVICAR B., ROY A., COUVERT B.  
**Sediment transport and morphodynamics of two highly modified rivers: valley management issues and keys for river stakeholders**

ANTONELLI C., ZBRACKI M., SABATIER D., GAIROARD S., LAUNAY M.  
**High frequency measurements of suspended sediment particles of the Rhone River, France**

VALEZIO É.V., PEREZ FILHO A.  
**Interpretation of the fluvial dynamic from Tucum stream/SP, Brazil: sedimentary load balance and transformations of the alluvial forms**

DE OLIVEIRA D.  
**The relationship between wind gaps and histosols in the Atlantic Plateau Paulista, Southeastern Brazil**

PASA V., DE OLIVEIRA D.  
**The stream capture process between the rivers Tiete and Paraíba Do Sul in the Atlantic Plateau Paulista: The case of Guararema's Elbow**

CROKE J., THOMPSON C., FRYIRS K.

**Sediment Dynamics and catchment connectivity at the catchment**

MARQUIS G.A., VENDITTI J.G., CHURCH M., KOSTASCHUK R.A., ATTARD M.E., RENNIE C.D.  
**Intermittent suspension of sand from the bed in the Fraser River**

PEREZ FILHO A., VALEZIO E.V., CARPI JUNIOR S.  
**Effects of human action on the transportation of Tucum Stream Channel in Sao Pedro, Brazil**

DOWNES P., DUSTERHOFF S.  
**Event-scale sediment fluxes and morphodynamics of a semi-arid river: the influence of climate drivers and human actions in the Lower Santa Clara River, California, USA**

LIRO M.  
**The changes in riverbed plant cover in two rivers upstream the dam reservoir. A case study of the Czorsztyn Reservoir in southern Poland**

REDIN VESTENA L., KOBIYAMA M.  
**Analysis of the relationship between the dynamics of saturated areas and sediment transport in a basin in Southern Brazil**

GILYAZOV A.  
**Theoretical and methodical basis of study of granulometry as an indicator of formation conditions of modern and ancient alluvial deposits**

OLIVEIRA L., MAGALHÃES JÚNIOR A.  
**The fluvial dynamic influences on evolution of the relief in the Pomba River Depression, Southeastern Brazil**

SATDAROV A.  
**Geomorphological analysis of longitudinal profiles of the river valleys in the Northern Hemisphere**

BERTOLDI W., GARCIA LUGO G.A.  
**Experimental assessment of the effectiveness of sediment transport estimates from morphological changes**

KIRKBY M., HOOKE J., SMITH M., BARBERA G., GARCIA-PINTADO J., BRACKEN L.  
**Hydrological impacts of floods in SE Spain, September 2012**

SKARPICH V., HRADECKY J., DUSEK R.  
**Man activity affecting the river (dis)continuum system in the Moravskoslezské Beskydy Mts. and their forefield**

SURIAN N., ZILIANI L.  
**Channel adjustments in a large gravel-bed river (Tagliamento River, Italy): what's the role of different sediment sources?**

LE BOUTEILLER C., VENDITTI J.  
**Influence of bottom vegetation on sediment transport and morphodynamics**

AMADEU P., CABRAL J., LUCAS C., MÔNICA M.  
**Sediment transfer assessment in Macaé River, Rio de Janeiro, Brazil**

SASS O., STANGL J., SCHNEIDER J., HARB G.  
**Quantifying fluvial sediment transport in a mountain catchment in Upper Styria (Austria) using sediment impact sensors**

BERTHET J., ASTRADE L., JAILLET S., PLOYON E.  
**Dynamic of sediments monitoring by terrestrial laserscanner, application to quantify sediment yield of four torrents in French Alps**

OLIVEIRA F., HAAK L.  
**Suspended Sediment Yield in a Subtropical Watershed**

KEESSTRA S., VAN MINNEN J., DE DIE L., KHAN S.A., WESTER F.  
**Sediment transport by tidal river management**

PIMENTEL MARINHO T., FILIZOLA N., SANTOS A.L., NASCIMENTO A., JEAN-MICHEL M., COCHNEAU G.  
**Analysis of the flow of suspended sediments from the behavior of the variation of water stain in the region of the confluence of the Negro and Solimoes-Amazonas Rivers, Amazonia, Brazil**

BILLI P., CIAMPALINI R.  
**Geomorphic analysis of the ephemeral stream distributary systems of the Kobo basin (northern Ethiopia)**

LALLIAS-TACON S., LIEBAULT F., PIEGAY H.  
**Reach-scale morphological changes of a braided river following a 15-year flood with multirate airborne LiDAR**

## **S19D. OTHER SUBSESSIONS**

Convenors: *Janet HOOKE & Gary BRIERLEY*

### **Oral presentations .....767**

NANSON G., HUANG H.Q.  
**A philosophy of rivers**

PETIT F., HALLOT E., PEETERS A., LEVECQ Y., HOUBRECHTS G.  
**Bedload dynamics in gravel bed rivers**

SZABO T., FITYUS S., DOMOKOS G.  
**Measuring and modeling of basalt pebble abrasion in the Williams River, Australia**

STEWARTSON M., RUTHERFURD I.  
**In-Channel Fine Sediment Retention and Dynamics: A Review**

LANE S.N., BALIN D., LOVIS B., MICHELETTI N.  
**The impacts of climatically-driven hydrological change upon sediment flux in Alpine river basins**

GAO P., NEARING M., HICKS M.  
**Quantifying spatial and temporal variations of specific event sediment yields in different climatic zones**

KERMODE S.J., COHEN T.J., REINFELDS I.V., NANSON G.C., JONES B.G.  
**Modern depositional processes in a confined, flood prone setting: benches of the Shoalhaven River, NSW, Australia**

SMITH-ADAO L., ROWNTREE K., NEL J.  
**Valley floor changes along and adjacent to the Baviaanskloof River, Eastern Cape Province, South Africa: Testing confinement**

WAWRZYNIAK V., PIÉGAY H., ALLEMAND P., VAUDOR L., GRANDJEAN P.  
**Is braided river index only related to discharge and geomorphic activity? Feedbacks from thermal infrared remote sensing**

CLARKE L., MCLELLAND S., COULTHARD T.  
**Experimental investigation into the impact of vegetation on fan morphology and flow**

BÄTZ N., LANE S., VERRECCHIA E.  
**The Fluvial Critical Zone ' the co-evolution of a geomorphic-vegetation-soil system**

WYZGA B., ZAWIEJSKA J., RADECKI-PAWLIK A.  
**Identifying channel incision and its hydraulic importance: examples from Polish Carpathian rivers**

CHUDANICOVA M., HRADECKY J., PANEK T.  
**Anthropogenic intervention into the river pattern as a cause of the Ol'e River floodplain development change (with the use of magnetic susceptibility for the sedimentary record interpretation)**

SLOWIK M.  
**Changes of channel planform within anastomosing river system transformed by hydro technical works (the Odra River, W Poland)**

BELLETTI B., DUFOUR S., PIÉGAY H.

**Spatial and temporal variability of braided river bio-geomorphic patterns at the regional scale, the case of the French Rhône basin**

SCORPIO V., AUCELLI P., GIANO I., PISANO L., ROBUSTELLI G., ROSSKOPF C., SCHIATTARELLA M.

**Recent channel adjustments of major rivers in southern Apennines (Italy): a contribution to the understanding of fluvial response to human impact and climate change**

CAMPANA D., COMITI F., GIAMMARCHI F., TONON G.

**Morphological degradation and restoration of the Ahr river (Italian Alps) and their effect on riparian vegetation**

TURNER J.N., JONES A.F., HARVEY E.

**Historical river channel change and stability in Irish catchments: implications for river management under the EU Water Framework Directive**

TEOUGAM N., TCHAWA P., TCHINDJANG M.

**Detecting the Fluvial Channel Mobility and the Erosion Process Development for a Sustainable Management of the Mayo Tsanaga (North Cameroon)**

MARREN P., ZOLJAN S., SMITH H., TEO E.

**Catchment-scale versus site-scale controls on flood impact: Flooding in northern Victoria, Australia in 2010 to 2012**

HOOKE J.

**Geomorphological impact and feedback effects of occurrence and sequences of flood events of differing characteristics**

SEAR D., DEARING J., WHEATON J., BATES P., NEAL J.

**Flooding from extreme rainfall: Geomorphological effectiveness as a vehicle for flood risk management and whole river restoration**

RÄPPLÉ B., PIÉGAY H., MUTZ M., STELLA J.C., TRÉMÉLO M.L., WILCOX A.

**Physical controls of vegetation recruitment patterns on the Drôme River (SE France): An analysis based on a chronosequence of high resolution aerial imagery**

BOIVIN M., BUFFIN-BELANGER T., PIEGAY H.

**Assessment of the annual dynamics of large woods along a 60 km semi-alluvial river section of the Gaspé Peninsula, Quebec, Canada, feedbacks from 3 year field surveys combined with airborne and ground images**

CORENBLIT D., BORNETTE G., STEIGER J., DAVIES N.

**Necessity of linking paleontological and contemporary approaches for understanding river dynamics**

GOSWAMI U., ACHARJEE S.

**Downstream channel changes of a tropical alluvial river due to construction of a dam: The example of the Subansiri in Assam, India**

CASADO A., PEIRY J.L., CAMPO A.M.

**Geomorphic changes of a dry-temperate meandering river highly disturbed by a large dam, Sauce Grande River, Argentina**

MAGILLIGAN F., NISLOW K., RENSHAW C., GARTNER J.

**Geomorphic Impacts of Riparian (Dis)Connectivity: Dams and Dam Removals as 'Natural' Geomorphic Experiments**

WHITFIELD G., WHITFIELD E.

**Geomorphological response to weir removal: the River Twymyn, mid Wales, UK**

IBISATE A., ACÍN V., BALLARIN D., DIAZ E., GRANADO D., MORA D., OLLERO A.

**Geomorphological monitoring after dam removal**

JUGIE M., GOB F., SLAWSON D., LECOEUR C.

**Hydromorphological adjustments and re-adjustments of low energy rivers in a sub-urban catchment following historical engineering and recent urbanization**

REGAMEY B., LANE S.N., MICHELETTI N.

**Long term impacts of flow abstraction upon basin scale sedimentation processes in an Alpine valley system**

DEMERS S., OLSEN T., BUFFIN-BÉLANGER T., BIRON P.

**On the use of floodplain landforms to generate flood risk maps**

LESPEZ L., VIEL V., GERMAIN-VALLÉE C., ROLLET A.J., GERMAINE M.A., CADOR J.M., DELAHAYE D.

**Inherited rivers. Anthropogenic changes in the low energy rivers in W France from 1500 BC and implications for their current management**

PEIXOTO M., DEL POZO I.F.

**Landscape Connectivity in Hilly Catchments on Middle Paraíba do Sul River Valley, Southeastern Brazilian Plateau**

VAN DER WAAL B., ROWNTREE K.

**Sediment connectivity in the upper Thina River, Eastern Cape, South Africa**

GURNELL A.

**Characterising Urban Rivers to support their Sustainable Management**

GUSMAROLI G., CEDDIA M., SOGNI D., MANNUCCI G., DOTTI N., PARINI M.

**Geomorphological assessment of urban river reaches: results and discussion of five case studies (North Italy)**

COTTON G.

**Reach-Scale Index for Sand-Bed Channels**

BUFFIN-BELANGER T., BIRON P., LAROCQUE M.

**Reflections on the application of the 'Freedom space' river management approach to help mitigate climate change impacts on three rivers of southern Québec, Canada**

BRIERLEY G., FRYIRS K., TADAKI M.

**Fluvial Geomorphology in Practice: Lessons learnt in the development and application of the River Styles framework**

RINALDI M., SURIAN N., COMITI F., BUSSETTINI M.

**A methodological framework for hydromorphological analysis of Italian streams (IDRAIM) aimed to an integrated management of fluvial hazard and river restoration**

RUTHERFURD I.

**Making space for geomorphic processes: the example of buffers for rivers**

POLVI L.E., NILSSON C.

**Potential and actual geomorphic complexity of restored streams in headwater streams of northern Sweden**

DIXON S., SEAR D., ODONI N.

**The effects of river restoration on flood risk and flood hydrology**

STOUT J., RUTHERFURD I., WEBB A.

**The role of geomorphic processes in the sustainability of large wood loads in rivers: A Bayesian approach**

PEETERS A., VERNIERS G., DE LE COURT B., HALLOT E., HOUBRECHTS G., PETIT F.

**Assessing the success of river restoration projects through Geomorphology**

THOMMERET N., BILODEAU C., GOB F., BAUDOIN J.M., ALBERT M.B., BELLIARD J.

**Morphological descriptors and typologies of French rivers as tools for managing river restoration**

O'DONNELL J., FRYIRS K., LEISHMAN M.R.

**Investigating the potential of seed banks as a regeneration niche in riparian systems: Implications for vegetation-based river rehabilitation**

MELUN G., ARNAUD-FASSETTA G., FORT M., CHALAUX E., LUCAS E., FOUREL S., GUESDON L.

**Hydromorphological impacts of hydrosedimentary and ecological continuity's restoration. Example of the Yerres RIV., seine catchment, France**

**Poster presentations .....792**KURASHIGE Y.**Measurement of Hydraulic Head Distribution below River Bed at around Alluvial Fan End: Case Study in the Inukami River, Central Japan**CYFFKA B., FISCHER P., HAAS F.**Restoration of Dynamic Processes - Hydro-geomorphological Research in the Riparian Forest between Neuburg and Ingolstadt**MORAIS E., HOOKE J., ROCHA P.**Spatial distribution of cutoffs on the Peixe River, Brazil**GREENWOOD P., KUHN N.**Determining soil flux from small riparian areas colonised by the invasive plant, *Impatiens glandulifera* on a small watercourse in northwest Switzerland**GRECU F., IOANA-TOROIMAC G., DOBRE R., ZAHARIA L.**River channel recent dynamics in relation to floods in the Curvature Carpathians (Romania)**MANYARI W.**Flow variability in large tropical river systems in the Amazon**VÁQUEZ-TARRÍO D., ROSANA M.D.**Comparison between bedload transport rates estimated with tracer-clasts and results given by theoretical equations in an atlantic mountain stream (Pigüeña rivers, NW Spain)**GURNELL A.**A multi-scale framework for assessing processes and forms within European Rivers**HOUBRECHTS G., DENIS A.C., JUVIGNÉ E., PETIT F.**Time-history of the gravel sheet in Ardennian rivers over the last 100,000 years**HORACIO J., PÉREZ-ALBERTI A., OLLERO A., CANOSA J.F.**Lithotopo units as ecoregions of fluvial systems: methodology and application**HAJDUKIEWICZ H., WYZGA B., MIKUS P., ZAWIEJSKA J., RADECKI-PAWLIK A.**Effects of a major flood on a mountain river on physical habitat conditions for river biota, channel morphology and valley-floor infrastructure**KHANCHOUL K., TOURKI M., LE BISSONNAIS Y.**Sediment yield prediction in river basins by means of geomorphic parameters and regression- ANN relationships**ZAWIEJSKA J., HAJDUKIEWICZ H., WYZGA B., RADECKI-PAWLIK A., MIKUS P.**Longitudinal and temporal variation of bed-material grain size in a mountain river disturbed by gravel extraction and channelization, the Czarny Dunajec, Polish Carpathians**ROCHA P., HOOKE J.M.**The Interannual regime of rivers: a comparison between peixe (western Sao Paulo State, Brazil) and dee river (UK) and the sea index influences**AUDISIO C., TURCONI L.**Morphological changes along alpine river reaches affected by natural et human impact: examples on river pellice and chisone (NW Italy)**SHIMAZU H.**Annual landform changes and their effects on pioneer species in the active braided gravel-bed river in the upper reaches of the Azusa River, central Japan**OLDKNOW C., HOOKE J., LANG A., MAUZ B.**Towards understanding spatial and temporal variations in landscape response to climate change at an upland Karoo site, South Africa.**

STORANI D.L., PEREZ FILHO A.

**Regional scenario of Quaternary climatic oscillations: low river terraces and flood plains in the current context of Depressão Periférica Paulista**

FACINCANI E.M., BACANI V.M., SANTOS R.M., PEREIRA W.

**Quaternary Basin of the Pantanal Mato-Grossense, Brazil: fluvial Megafans**

FACINCANI E.M., BACANI V.M., SANTOS R.M., QUIRINO P.B., CORDEIRO B.M., PEREIRA W.

**Negro River: fluvial megafan. Southeastern border of the Pantanal Basin, Brazil**

LEJEUNE Q., SCHMITT L., ZIMMERMANN A., ESCHBACH D.

**Evaluating a functional hydromorphological restoration of a lateral channel of the Upper Rhine (France): first results and implications of the temporal trajectory to restoration sustainability**

BESN P., IBISATE A.

**Fluvial geomorphological adjustments to global change in Iberian Rivers**

GAMBOA-ROCHA A., STEWARDSON M., RUTHERFURD I., FINLAYSON B.

**Elucidating the level of influence of key factors on the spatial distribution of overbank deposition**

WANG S., YAN Y., HE L., YAN M.

**Variation trend of the sedimentation rate in the Yinchuan Plain of the upper Yellow River since 0.7 Ma B.P. and its main influencing factors**

CHEN X., LIN M., LIN B.

**Velocity distribution of turbulent open-channel flow over permeable rough bed**

OGAMI T.

**Knickpoint initiation and migration rate of bedrock rivers dissecting the Middle to Late Pleistocene marine terraces at North Sanriku coast, NE Japan**

BATHRELLOS G., SKILODIMOU H., MAROUKIAN H., GAKI-PAPANASTASSIOU K.

**Late Quaternary evolution of the lower reaches of Ziliana stream in south Mt. Olympus (Greece)**

HOOKE J.

**Spatial and temporal variability in cut-off sedimentation**

BERA B.

**The decay and related environment problems of the deltaic rivers in West Bengal, India**

EKASSI ONDOUA L., TCHINDJANG M., WAKPONOU A.

**Quaternary Paleolandforms at Sanaga-Mbam confluence between geography and historical palaeoenvironmental approach**

DOUDJE K., TCHINDJANG M., MOUPENG B.

**Current development of the bed and major Chari river bank at N'Djamena since Holocene**

DOUDJE K., TCHINDJANG M., MOUPENG B.

**Development of the Chari river bank from Mandjaffa to Milezi (1970 - 2008) at N'Djamena (Tchad)**

PETERSEN C., JOVANOVIC N.

**Linking land use, riparian vegetation and channel changes in two catchments in the Upper Olifants River, Mpumalanga Province, South Africa**

RINALDI M., NARDI L.

**Morphological effects of a large flood: the case study of the Magra River (Italy)**

IOANA-TOROIMAC G., GRECU F.

**Abandoned borrow pits from Buzau River's floodplain (Romania) - evolution and management**

NUNES PATUCCI N., OLIVEIRA D.

**Evaluation of morphometric and morphological variables: analyses of topographic, geological and partitioning maps of Guaratuba basin ' Boraceia ' São Paulo ' Brasil**

DEGIOVANNI S., ANDREAZZINI J.

**Morphodynamic and morphologic changes analysis in rivers of the Sierra de Comechingones piedemont, Cordoba province, Argentina, during the Late Holocene-present. Environmental implications**

BERTOLDI W., MAO L., COMITI F., GURNELL A., MCLELLAND S., RAVAZZOLO D., TAL M., WELBER M., ZANELLA S.

**The effect of input load on large wood dynamics in braided streams: preliminary results from physical modelling**

CONESA-GARCÍA C., GARCÍA-LORENZO R.

**Fluviomorphological hazards in roads crossing ephemeral channels on the South East coast of Spain**

THAKRE D.

**Geospatial Mapping Ancient Phad Irrigation System in Mousam Basin, Maharashtra (INDIA): A GIS Approach**

WIEDERKEHR E., DUFOUR S., PIÉGAY H.

**Contribution of geomatic for multiscale characterisation of river systems: application to the Rhone basin**

NIKAM S.

**Hypsometric Analysis for Prioritization and Conservation Planning of Sub Watersheds; a Case study of Arjunsagar Lake Catchment, North Maharashtra, India**

GILES P., WHITEHOUSE B., KARYMBALIS E.

**Examination of the morphological characteristics of alluvial fans modified by interactions with rivers in broad axial valleys in Yukon Territory, Canada, and Alaska, U.S.A.**

SOUZA J., BARROS A.C.M., CORREA A.C.B.

**Small catchment river styles® in Brazilian dryland, sacco creek watershed**

KARYMBALIS E., GILES P., PAPANASTASSIOU D., FERENTINO M., GAKI-PAPANASTASSIOU K.

**Analysis of relationships among alluvial fans and source basins in Lake Trichonis (Western Greece)**

DINH Q., BIZZI S., BERNARDI D., PAVAN S., CASTELLETTI A., SCHIPPA L., SONCINI-SESSA R.

**Integrating river geomorphic processes into optimal planning of reservoir operations**

MCDOWELL P.

**Sedge as an influence on channel form: case study of Carex nudata in gravel-bedded John Day River, Oregon, USA**

NIKAM C.

**Diversion of running water discharge from par river to girna river valley**

PERSOUI I., ROBU D.

**Historical planform adjustments of rivers from the Eastern part of Pannonian Basin, as indicators of neotectonic features**

## **S20. SEDIMENT BUDGETS (IAG-WG COVERING ALL ENVIRONMENTS)**

Convenors: Achim A. BEYLICH & Armelle DECAULNE

### **Oral presentations .....819**

VALE S.

**Development and application of a fingerprinting technique for quantitative source ascription of fine sediment in a large dynamic fluvial environment: Manawatu, New Zealand**

VIEL V., DELAHAYE D., ROLLET A.J., LESPEZ L., REULIER R., CADOR J.M., DAVIDSON R.

**The sediment budget: a tool to evaluate scale effect on sediment dynamics into a catchment**

PELACANI S., MAERKER M., SCHMITT F.G.

**Application of the physically based model, power spectral analyses and cross correlation analyses to estimate the sediment budget and the delay time for an impacted stream: case study of Italy**

DEVATY J., DOSTAL T., KRASA J.

**Modeling of rainfall-runoff and soil erosion processes in various scales and using various DEM - assessment of effects**

TANANAEV N.

**Geological and geomorphological controls of suspended sediment fluxes in periglacial environments of Russian Arctic**

SMITH H., BLAKE W.

**Spatial patterns and timescales of fine sediment redistribution in river basins: application of a sediment budget model with fallout radionuclide tracers**

HOBGEN S., WASSON R., MYERS B., FISHER R.

**Sediment Budgets in data poor environments: Case of the Kambaniru Catchment, Indonesia**

GAY A., CERDAN O., DELMAS M., DESMET M., DEGAN F.

**Contributions of on-land sediment sources and transfer to the overall Loire river basin sediment budget**

FOUCHER A., DESMET M., SALVADOR-BLANES S., CERDAN O., EVRARD O., LEFEVRE I.

**Using suspended sediment records and lake deposits to reconstruct current and past sediment dynamics in a small agricultural catchment**

DOWNS P., DUSTERHOFF S., LEVERICH G.

**A spatially-distributed sediment budget for a regulated catchment in coastal California, USA**

BELYAEV V., EVRARD O., MARKELOV M., SHAMSHURINA E., IVANOVA N., GOLOSOV V., PARAMONOVA T., OTTLE C., LEFEVRE I., BONTE P.

**Quantification of the fluvial sediment budget and associated particle-bound pollutant redistribution in an agriculture-dominated river basin of the European Russia: the problem of upscaling**

GUNS M., VANACKER V., DEMOULIN A.

**Role of landslides in sedimentary fluxes in tropical mountain regions**

JENSEN E.

**Sediment budget of two glacial rivers in Iceland**

ZWOLINSKI Z.

**Geocological functions of polar river systems**

BRARDINONI F., MAYNARD D., ROLLERSON T.

**Response of Landslide Sediment Dynamics to Forest Clearing in Coastal British Columbia, Canada**

LAUTE K., BEYLICH A.A.

**Controls of snow avalanche distribution and geomorphic avalanche activity at hillslopes in steep mountain valleys in western Norway**

FUCHS M., WILL M.

**The Temporal and Spatial Quantification of Holocene Sediment Dynamics in a meso-scale catchment in northern Bavaria / Germany**

HILGER L., HECKMANN T., HAAS F., BECHT M.

**Regionalization of geomorphic processes in the proglacial area of Gepatsch and Weißsee glaciers, Oetztal Alps, Austria**

MUELLER J., GAERTNER-ROER I., KENNER R., MORCHE D.

**Sediment transfer and geomorphic work on a periglacial mountain slope**

STROMSOE N., CALLOW N., MCGOWAN H., MARX S.

**Sediment sources, yield and connectivity in a low relief alpine catchment, Snowy Mountains, New South Wales, Australia**

**Poster presentations .....829**

LU X., YANG X., RAN L.

**Estimate of Reservoirs Storage Capacity and Total Sediment Trapped in China**

BEYLICH A.A., LAMOUREUX S.F., DECAULNE A.

**The I.A.G./A.I.G. SEDIBUD (Sediment Budgets in Cold Environments) Programme: Scientific key issues and future tasks**

SULTANA D.

**Holocene human impacts on fluvial sedimentary budgets in Malta, Central Mediterranean**

DECAULNE A., EGGERTSSON Ó., LAUTE K., BEYLICH A.A.

**The main snow-avalanche winters of the last 100 years documented by dendrogeomorphology in the Bødalen and Erdalen valleys, inner Nordfjord, western Norway**

LANDEMAINE V., CERDAN O., LAIGNEL B.

**A sediment budget of an intensively cultivated downslope area of the Seine River: The Pays de Caux loess plateaux**

ANGHEL T., STOFFEL M., POP O., BUIMGA-IARINCA S., IRIMUS I.A.

**Relationship between Norway spruce (*Picea abies* (L.) Karst.) growth anomalies and sedimentation rates in the sulphur mining area of Calimani Massif, Romania**

POP O., MUNTEANU A., GAVRILA I., ANGHEL T., PETREA D.

**Spatio-temporal variation of snow avalanche activity in Piatra Craiului Mountains (Romanian Carpathians) assessed by dendrogeomorphological methods**

FOUCHER A., SALVADOR-BLANES S., DESMET M., CERDAN O., EVRARD O., LEFEVRE I.

**The experimental Louroux lake catchment: continuous records of discharge and suspended sediment flux in a small agricultural catchment**

GUITER F., BRISSET E., MIRAMONT C., ANTHONY E., BRUNETON H.

**Lateglacial to Holocene sediment budget of a small subAlpine river catchment: using 3D palaeotopographic reconstructions for volume quantification**

DIXON J.

**Sediment Fluxes in Karkevagge, Swedish Lapland: A compilation of Previous Studies**

MERCIER J.

**How Far was this Sediment Origin? A Granulometry May Tell**

NAZAROV N.N., FROLOVA I.V.

**Morphodynamics of reservoir banks in the Kama River: "accessory" geomorphic processes**

## **S21A - REEF FORMS (IAG-WG)**

Convenors: *Chris PERRY, Paul KENCH & Scott SMITHERS*

### **Oral presentations .....837**

*RIEGL B., PERRY C., SMITHERS S., KENCH P.*

**Biotic dynamics as a driver of coral reef geomorphology**

*SMITHERS S., PERRY C., ROCHE R.*

**Holocene growth of King Reef - the largest mainland fringing reef on Great Barrier Reef, Australia**

*KAN H., URATA K., NAGAO M., HORI N., OHASHI T., NAKASHIMA Y., GOTO K., YOKOYAMA Y., SUZUKI A.*

**Discovery of submerged karst terrain in modern reef area by broadband multibeam bathymetric survey in the southern Ryukyu Islands, Japan**

*MORGAN K., KENCH P.*

**Calcium carbonate budget of a Maldivian reef platform**

*MANDLIER P., KENCH P.*

**Hydrodynamic process controls on reef platform sedimentation and island formation**

*KENCH P., PERRY C., SMITHERS S., YAMANO H., O'LEARY M.*

**Infill of Faro Lagoons: Size Thresholds and Controls on Island Formation in the Maldives**

*COSTA M., MACEDO E., SIEGLE E.*

**Morphological response of reef island on rocas atoll (South Atlantic Ocean) to Seasonal energetic wave conditions**

*JAVIER L., WOODROFFE C., PHINN S., HAMYLTON S.*

**A sediment budget for Lizard Island, northern Great Barrier Reef**

*MCLEAN R.*

**Atoll Island Geomorphology and Stability: Nukulaelae Atoll, Tuvalu, Central Pacific**

### **Poster presentations .....841**

*PERRY C., MURPHY G., KENCH P., SMITHERS S., EDINGER E., STENECK R., MUMBY P.*

**Quantifying the impacts of regional scale reef ecosystem decline on the geomorphic performance and growth potential of Caribbean coral reefs**

*SWITZER A., MELTZNER A.J., WU C.C., CHIANG H.W., SHEN C.C., GONG S.Y., SUWARGADI B.W., NATAWIDJAJA D.H., HORTON B.P.*

**Precise timing and elevation of the mid-Holocene highstand at Belitung Island, Indonesia, on the Sunda Shelf, from coral microatolls**

## **S21B. ROCKY COASTS (IAG-WG)**

Convenors: *David KENNEDY & Wayne STEPHENSON*

### **Oral presentations .....845**

*STUIVER C., NICHOLLS R.J., RICHARDS D., BARTON M.*

**The influence of inter-tidal shore platforms on soft cliff recession rates and headland formation on the southwest coast of the Isle of Wight**

*NORMAN E., ROSSER N., BRAIN M., PETLEY D., WAUGH S.*

**Alongshore variations in hard rock coastal cliff erosion**

*E LINEAU S., DUPERRET A., MERRIEN-SOUKATCHOFF V.*

**Pluri-decadal evolution of cretaceous coastal cliffs along the eastern English Channel in Upper-Normandy (NW France), as evidenced by aerial photographs and Lidar**

LETORTU P., COSTA S., CADOR J.M., CANTAT O., MAQUAIRE O., BONNET E.

**Fall of coastal chalk cliffs in Upper Normandy: Towards the determination of triggering factors**

ROHMER J., DEWEZ T.

**Analyzing the spatial structure of sea cliff instabilities through repeated high resolution terrestrial laser scanning surveys and point processes statistics**

DICKSON M.

**A new approach to coastal cliff landslide hazard assessment**

SWIRAD Z., REES W.G.

**Application of GNU Octave tools to analyse the shape of a rocky shoreline - an example from Hornsund area (SW Spitsbergen, Svalbard)**

SAPOVAL B., BALDASSARRI A.

**A feedback model relates rocky coast erosion to percolation theory, a new perspective on the statistics of erosion events**

FICHAUT B., SUANEZ S.

**Set up and evolution of cliff-top storm deposits on the western coast of Baneg island in the Molène archipelago, Brittany, France**

MARINO A., CIUCCI M.

**Geomorphic hazard along southern Abruzzo coast (central Italy)**

MOTTERSHEAD D., BRAY M., FARRES P., SOAR P.

**Geomorphological evidence of extreme wave events in the Maltese Islands**

ABAZOVIC A., STEPHENSON W.J.

**Evidence of storm wave induced shore platform boulder dynamics at Timaru, New Zealand**

YOUNG A., GUZA R., DICKSON M., FLICK R., WILLIAM O.

**Microseismic observations of coastal ground motion and geomorphic implications**

MOSES C., ROBINSON D., WILLIAMS R.

**Towards an improved understanding of tidal notch development: ten years of micro-erosion meter rates, Phang Nga Bay, Thailand**

TRENHAILE A., PRESTANSKI K., PORTER N., GAGNON J.

**Shore Platform and Cliff Notch Transitions along the La Paz Peninsula, Southern Baja, Mexico**

GABRIEL S., OLIVEIRA S., HORTA J., MOURA D.

**Rocky coast dynamics - comparison between shore platform and adjacent sandy beach**

LIMBER P., MURRAY A.B., ADAMS P., GOLDSTEIN E.

**Using beach and sea cliff dynamics to understand rocky coastline morphology, sea stacks, and headland amplitude**

NUNES M., FERREIRA Ó., BAILY B., CALVÃO J.

**Beach nourishment impact in receding soft rock coastal cliffs using remote sensing techniques (Forte Novo, south Portugal)**

PEREZ-ALBERTI A.

**Boulder mobility and shore platform erosion in southern Galicia, Northwestern Spain**

PAPPALARDO M., CHELLI A., PANNACCIULLI F.G.

**The role of biota in the weathering of microtidal shore platforms: first results from a new approach through case studies along the coast of NW Italy**

STEPHENSON W., NAYLOR L., CHEN B.

**Wave transformations across a macro-tidal shore platform**

ROBINSON D., MOSES C.

**Comparative rates of surface erosion of coastal engineering materials and of chalk and sandstone platforms, East Sussex, southeast England**

SALEEM A., MAHMOUD A.M.

**Rocky shore platform's evolution in the North-West Coast of Egypt**

FURLANI S., CUCCHI F.

**260 km of snorkel-geomorphological surveying along the Istrian rocky coast (Croatia, Slovenia, Italy): results from the 'Geoswim project'**

**Poster presentations .....857**

PEREZ-ALBERTI A., PIRES A., LÓPEZ-SÁNCHEZ M.

**Photogrammetric evaluation of rocky coasts using UAV mapping system**

CAPLAIN B., REGARD V., ASTRUC D.

**Cliff erosion in a monochromatic wave flume: analysis of cliff recession and collapse events**

REGARD V., DEWEZ T.J., BOURLÈS D.L., ANDERSON R.S., DUPERRÉ A., COSTA S., LEANNI L., KEVIN P., MAILLET G.M.

**Late Holocene sea-cliff retreat recorded by <sup>10</sup>Be profiles across a coastal platform: Theory and examples from the English Channel and Korea**

GAUCI R., INKPEN R., SCHEMBRI J.A., FURLANI S.

**Identification and quantification of rates of surface erosion on shore platforms in Malta and their relationship to environmental change**

STRZELECKI M.

**Rock resistance variability across High Arctic rocky coastal zones - case studies from sheltered fjords of Svalbard and tsunami-affected coasts of Western Greenland**

PIRES A., PÉREZ-ALBERTI A., CHAMINÉ H.

**Geo-engineering mapping of Aguiño groyne (Galicia, NW Spain): a rocky platform as a foundation?**

ROVERA G., LOPEZ SAEZ J., CORONA C., STOFFEL M.

**Highly-resolution quantitative reconstruction of detritic quaternary cliffs retreat based on anatomical changes in exposed roots (Porquerolles island, France)**

ARAÚJO M., GOMES A.

**S. Paio (Labruge, Vila do Conde, Northern Portugal). A protected area and its geomorphologic value**

BRAYNE R., NAYLOR L., REINHARDT L., LORANG M.

**Investigating the interrelationship between boulder beach dynamics and storm events**

RAGARU E., MERCIER D., CHAIBI M., MAANAN M.

**Lithological control on coastal rock cliffs erosion of Safi, Morocco**

**S21C. OTHER SUBSESSIONS**

Convenors: *Edward ANTHONY & Julian ORFORD*

**Oral presentations .....865**

CHEN B., STEPHENSON W., HEMMINGSEN M.

**What is the contribution of abrasion to the sediment budget of a mixed sand and gravel beach?**

BOUAKLINE S., BOUTBA M., GUETTOUCHE M.S.

**Microtidal sandy beaches erosion: Diagnosis by DGPS measurements. Case study of the algeria west coast region- Algeria**

SUANEZ S., STÉPHAN P., FICHAUT B., CUQ V., BLAISE E., CARIOLET J.M., CANCOUËT R., DELACOURT C.

**Coastal monitoring and medium-term shoreline dynamics in Brittany (France)**

STEPHAN P., SUANEZ S., FICHAUT B.

**Long-, mid- and short-term morphological behaviours of gravel barriers: illustrations from the coast of Brittany (France)**

BULTEAU T., BAILLS A., PETITJEAN L., GARCIN M., DE LA TORRE Y., PALANISAMY H., LE COZANNET G.

**Potential and limitations of Bayesian networks for understanding shoreline mobility: an example in La Réunion island**

MORISSETTE A., JOYAL G.

**High resolution coastal evolution: dynamic profiles and geomorphological resilience beach index (GRBI)**

MATIAS A., CARRASCO A.R., PACHECO A., LOUREIRO C., NUNES M., FERREIRA Ó., ARMAROLI C., MASSELINK G.

**Longshore variation of overwash occurrence in a barrier island (Portugal)**

GREEN A.N., COOPER J.A.G., SMITH A.M., SALZMANN L.

**Longshore cell development in a boulder beach, Mission Rocks, South Africa**

TILLMANN T., WUNDERLICH J.

**Geomorphological development and sedimentary architecture and of two barrier islands (Sylt and Amrum/ German North Sea): Insights from ground-penetrating radar surveys and sedimentological data**

MOORE L., DURAN O., WALTERS D., YOUNG D., FAGHERAZZI S., MARIOTTI G.

**Ecomorphodynamic Feedbacks Determine Barrier Island Response to Climate Change**

GIBEAUT J.

**Projected Changes in Barrier-Island Wetland Distribution Caused by Sea-Level Rise**

LIN T.Y., LOU J.Y., LIOU J.Y., HWUNG H.H.

**Morphodynamics of barrier island evolution off SW Taiwan: An example from Wan-tzu-liao barrier, Tainan**

HEQUETTE A., RUZ M.H., ANTHONY E.J., MARIN D.

**Linking nearshore and coastal changes in the southwestern North Sea and Dover Strait: the role of tidal sand banks on coastline evolution**

SHAH-HOSSEINI M., MORHANGE C., NADERI BENI A., ANTHONY E.

**Study of strandplain evolution along the Iranian coast of Makran (north western Indian Ocean) with application of ground penetrating radar**

CESCON A.L., COOPER J.A.G., JACKSON D.W.T.

**Anegada Island, British Virgin Islands: a case study of beach ridges**

FERNANDEZ G., BAPTISTA DA ROCHA T., RODRIGUES A.

**Geomorphology and Internal Sedimentary Structure of Holocene Coastal Sandy Barriers along Rio de Janeiro Coast, Brazil**

ZAGÓRSKI P., STRZELECKI M., SUPERSON J.

**Post-Little Ice Age evolution of High Arctic paraglacial coasts in Svalbard**

BRILL D., BRUECKNER H., JANKAEW K., KELLETAT D., SCHEFFERS A.

**Morphogenesis of Phra Thong's beach-ridge plain (Thailand) ' the contribution of gradual processes and episodic events**

VAN VLIET-LANOE B., HENAFF A., DELACOURT C., FERNANE A., GOSLIN J., HALLEGOUËT B., PENAUD A.

**Middle to late holocene storminess record in western britany**

MAY S.M., ENGEL M., BRÜCKNER H., PINT A., KELLETAT D., SCHEFFERS A., SQUIRE P.

**Geomorphology, sedimentology and geochronology of cyclone-generated landforms and washover deposits along the coasts of NW Australia**

VESPREMEANU-STROE A., TATUI F., CONSTANTINESCU S., PREOTEASA L., ZAINESCU F.

**Storm Regime and Morphological Changes at Different Time Scales on the Romanian Black Sea Coast**

PSUTY N., SCHMELZ W., SPAHN A., CHRISTIANO M.

**Coastal Foredune Evolution Under Extreme Events: Superstorm Sandy**

MASSELINK G.

**New understanding and prediction of storm impacts on gravel beaches (NUPSIG project): roles of geomorphological investigation and numerical modelling**

WINOWSKI M.

**The impact of extreme and above average processes on morphodynamics of cliff slumps (Wolin Island - NW Poland)**

EL TALIBI H., ZAGHLOUL M.N., ABOUMARIA K., WASSMER P., MERCIER J.L.

**New insights on morphological and sedimentary evidences of high energy marine flooding along the Moroccan Atlantic coast**

HART D.E.

**Coastal multi-hazard cascades: how 12 seconds can reset baselines & trigger decades of coastal system adjustment**

LEMCKERT C., COOPER A.

**Extreme sea-level rise and adaptation options for coastal resort cities**

FLOOD R., ORFORD J., TURNER J.

**Holocene sedimentary processes in the West Bengal Sundarbans: facies dynamics in a peri-marine environment**

ARISANTY D., SARTOHADI J., MARFAI M., SRI HADMOKO D.

**The Influence of Tide for Suspended Sediment Transport in Barito River Delta, Southern Kalimantan, Indonesia**

HUSEIN S.

**Altération of delta morphology by channel abandonment processes at Mahakam delta, east Kalimantan, Indonesia**

ZHANG Y.

**Formation and evolution of the abandoned Yellow River delta**

ANTHONY E.

**Longshore drift and sand sequestering in river deltas**

MAGDIEL LYDIA B.R., ORTIZ PEREZ M.A.

**Temporal and spatial variability of coastal change on deltaic coast of Tabasco, Mexico**

MASSUANGANHE E., WESTERBERG L.O., ACHIMO M.

**Geomorphology and evolution of the Save River Delta plain, South-Centre Mozambique**

GOSLIN J., VAN-VLIET LANOË B., HENAFF A., DELACOURT C., FERNANE A., HALLEGOUET B., PENAUD A., SUANEZ S.

**A renewed Holocene relative sea-level envelope for Western Brittany (France): Global signal and local artefacts**

RUZ M.H.

**Incipient foredune development along macrotidal beaches, Northern France**

LABUZ T.

**Morphological types of foredunes in Poland as an indicator of coast trend changes**

CHOI K.H., KIM Y.M., JUNG P.M.

**Decrease of the supply of wind-blown sands in front of artificial pine forest in coastal dunes**

PINHO J., GRANJA H., ALMEIDA E., HENRIQUE A., TEIXEIRA A., VIEIRA S.

**Dune fences efficiency assessment on northern beaches of Portugal**

CARTIER A., HÉQUETTE A., LARROUDE P.

**The role of the inter-bar depressions in hydrodynamic and sediment transport processes of sandy macrotidal beaches**

DAS MAJUMDAR D., PURKAIT B., PAUL A.K.

**Dune Vulnerability and Management Strategy: A Case Study of West Bengal and Orissa Coasts, Bay of Bengal, India**

SILINSKI A., HEUNER M., DAUWE S., PUJALON S., TROCH P., BOUMA T.J., VAN BELZEN J., SCHÖDER U., FUCHS E., MEIRE P., TEMMERMAN S.

**Interactions between waves, sediments and pioneer plants in tidal marshes: Results from a full scale flume experiment**

BALKE T., JEUKEN M.C.J.L., HERMAN P.M.J., BOUMA T.J.

**Biogeomorphic succession of mangroves: Basic knowledge to improve restoration and management of tropical mangrove coasts**

JEANSON M., DOLIQUE F., ANTHONY E.

**Mangrove evolution and morphodynamic processes in Mayotte Island (Indian Ocean)**

WHITE A., HANLEY M.E., MASSELINK G., BLAKE W.H., HOGGART S.P.G.

**A risky retreat: Fine-tuning projections of salt marsh development in managed realignment projects**

ORFORD J.D., PETHICK J., KUMAR S.

**Geomorphological responses of tidal islands and estuary channels to embankments: a paradox of sustainability and protection in the West Bengal Sundarbans**

REGNAULD H., DAIRE M.Y., LOPEZ ROMERO E.

**Evolution of the coastline of anthropised islands off Galicia and Brittany: Ons and Ushant**

RANDAZZO G., LANZA S.

**Shoreline evolution of Capo Peloro, the northernmost point of Sicily(Italy) : causes and temporary management**

ARAÚJO M., MONGE SOARES A., CUNHA P.P., GOMES A., VIEIRA M.

**Anthropic interference versus littoral dynamics: Aguda (Northern Portugal) breakwater, Holocene evolution and recent coastal erosion**

TRAVALINI V., CUNHA C.M.L.D.

**The relief cartography in coastal areas: a contribution to the environmental planning of Bertioga, Sao Paulo State, Southeastern Brazil**

ETIENNE L., BOUAZIZ R., DAHECH S., DAOUD A., BELTRANDO G.

**Coastline vulnerability in the Kerkennah archipelago between 1963 and 2010**

DREJZA S., BERNATCHEZ P., DUGAS S.

**Toward a prevention of coastal erosion in the Magdalen Islands, Quebec, Canada**

OLLERHEAD J.

**Geomorphic Changes at a Bay of Fundy Salt Marsh Restoration in New Brunswick, Canada**

REED D.

**Science in Support of Coastal Management: Developing Louisiana's 2012 Coastal Master Plan**

CUROY J., MOSES C., ROBINSON D.

**Influence of sediment recycling-recharging on mixed beach behaviour: a case study at Cayeux-sur-Mer, north France**

JOLICOEUR S., BÉRUBÉ D., DESROSIERS M., O'CARROLL S.

**Coastal squeeze: its assessment and integration within regional- and municipal-level planning tools**

LOUREIRO C., FERREIRA Ó., COOPER A.

**Embayed configuration and geological control on beach morphodynamics and management: an overview of contrasting responses in embayed beaches of southwestern Portugal**

CARPENTER N., NICHOLLS R.J., DICKSON M.E.

**Development of an Integrated Geomorphic Model of Soft Cliff Retreat: Investigating the effects of varying lithology in the vertical**

GOMEZ-PUJOL L., ROIG-MUNAR F.X.

**Cliff-top large boulders emplacement along the Southern coast of Menorca (Balearic Islands, Western Mediterranean): addressing the role of storm or tsunami wave processes in rock coast deposits**

KENNEDY D.

**Beach development on microtidal shore platforms**

BLANCO-CHAO R., FEAL-PEREZ A., DUARTE-CAMPOS A.

**Erosion, progradation and sediment transport between beach-dune systems and adjacent beaches on shore platforms**

**Poster presentations .....895**

SOUZA T.A., OLIVEIRA R.C.

**Analysis of the relief of the city of Ilha Comprida, south coast of São Paulo, Brazil**

REPKINA T.

**The White Sea Coasts' response to the extreme storm of 15-16 November 2011. Coastal Development Forecast**

BADYUKOVA E., ZHINDAREV L., LUKYANOVA S., SOLOVIEVA G.

**Evidences of sea-level oscillations on the coasts of Vistula and Curonian Spits (SE of Baltic Sea)**

COOMBES M.(1), FEAL-PÉREZ A.(2), NAYLOR L.(3)

**Detecting rapid changes in the hardness of engineering materials in the coastal built environment using the Equotip durometer**

KAIN C.(1), GOMEZ C.(1), HART D.(1), WASSMER P.(2), STARHEIM C.(1)

**River channels as conduits for high energy coastal events**

PAQUIER A., MEULÉ S., ANTHONY E.

**Current and wind-wave interactions with a low shoot-density *Zostera noltii* meadow in a fetch-limited micro-tidal setting, Berre Lagoon, Mediterranean France**

GIAIME M., ANTHONY E., DUSSOUILLEZ P.

**Beach morphodynamics under rock-armour breakwater protection in a microtidal, storm-dominated Mediterranean setting**

ISKANDARSYAH T., WASSMER P., SCHWARTZ D.

**Consequences of the coastal geomorphologic system to the tsunami deposits generated by 1883 Krakatau eruption in Ujung Kulon Peninsula, Indonesia**

BALDASSARRE M., BELLOTTI P., DAVOLI L.

**DGPS and high resolution SAR satellite data integration for coastline extraction and monitoring coastal assessment**

KODAMA Y., WATAKABE T.

**Restoration of the coastal geo-environment along Tottori Sand Dunes**

LIGUORI V., MANNO G., AGATE F.

**Coastal Dynamics in western Sicily**

FEDOROVA E.

**Spatial Variation of Grain-Size Composition of Artificial Beach at the Novosibirsk Reservoir**

KHOMCHANOVSKII A., KHABIDOV A.

**Study of annual equilibrium beach evolution at coastal of man-made lake**

PARK S., LEE G.E.

**Analyses of coastal geomorphology change in a macrotidal setting, west coast of Korea**

TAAQUATI M., ANTHONY E.J., EL MRINI A., NACHITE D.

**Field observations of morphological change on contrasting beaches: An investigation at two sites on the North Atlantic coast of Morocco**

JUIGNER M., ROBIN M., FATTAL P., MAANAN M., DEBAINÉ F., BAUDOIN V., LE GUERN C., GOUGUET L.

**Monitoring of the sandy shoreline changes on the Pays de Monts coast from the 1920s to 2010**

MONTREUIL A., BULLARD J., CHANDLER J.

**Multi-temporal scale development of embryo dunes on an accreting macrotidal beach: North Lincolnshire, UK**

TRINDADE J., RAMOS-PEREIRA A.

**Predicting storm erosion impacts on exposed beaches**

MARIE G., NEUMEIER U., LE ROUX A.

**Influence of coastal geomorphology on boulder transport by ice in the St. Lawrence estuary (Quebec, Canada)**

BISWAS B.

**Changing Water Resources of West Bengal, India: A Micro level Study**

ELMIMOUNI A., ANTHONY E., DAOUDI L.

**Complex rotation of an embayed beach, Essaouira, Morocco**

CLEMENTE SALAS L., MENANTEAU L., RODRÍGUEZ-RAMIREZ A.

**Holocene evolution of coastal formations in the estuaries of the Guadalquivir and Tinto-Odiel (Gulf of Cadiz, SW Spain)**

RAZAFIMBELO M.R., RATIARISON A.

**Morondava, town in danger**

SUANEZ S., FICHAUT B., COSTA S., DAVIDSON R., ARDHUIN F.

**Morphological changes and dynamics of comet-tails in the Molène archipelago (Brittany, France)**

LOCKOT G., HARTMANN K., WUENNEMANN B.

**Quantifying disturbances of lake terraces at two lakes on the NE Tibetan Plateau**

STEPHAN P., FICHAUT B., SUANEZ S.

**Morphological evolution of the Sillon de Talbert gravel barrier spit (Brittany, France) since the 17<sup>e</sup> century: a challenge for coastal management?**

TATUI F., VESPREMEANU-STROE A.

**Nearshore Sandbars Behavior on Danube Delta Coast**

LYGIN A., MARUSIN K., LYGIN A., KHABIDOV A.

**Prototype of the information system for coastal zone monitoring**

NICOLAE LERMA A., THOMAS Y.F., ANDRADE C.A.

**Water level modeling on micro-tidal beach, application of several wave breaking approaches**

RUVAULT R., REGNAULD H., TIERCELIN J.J., PROUST J.N., MOTTE E.

**Geomorphological Evolution of the coastline in Baie d'Audierne (Western Brittany, France) and relation with changes in the land use**

ALAM A.K.M., TALUKDAR A., AHSAN A.

**Geological Exploration in the Coastal Zone of Bangladesh**

CIAMPALINI A., FIDOLINI F., ANDRETTA A., CONSOLONI I., MORETTI S.

**Evolution of quaternary coastal landscape in the Giglio Island (Tuscany, Italy)**

PARK H.S., KWON M.S., JEON C.K.

**Survey and analysis of coastal geomorphology using Terrestrial LIDAR in Kosrae, Federated States of Micronesia**

FERNANDEZ G.

**Morphological Evolution along the North Part of Paraíba do Sul River Delta, Rio de Janeiro Brazil**

KARYMBALIS E., KOUGEMITROU E., GAKI-PAPANASTASSIOU K., TSANAKAS K., DRINIA H., ANTONARAKOU A., STATHOPOULOS V.

**Geomorphic evolution of the Pinios River delta, in Central Greece, in the Late Holocene**

DHORDE A., DHORDE A.

**Conceptual Models for Natural Mechanisms of Sediment Bypassing at the Tidal Inlets along the Konkan Coast of Maharashtra, India**

YOUNG E., DAWSON S., MCKENZIE B.

**A quantitative comparison of seasonal, annual, and decadal changes in coastal geomorphology in the southern Outer Hebrides, Scotland**

SANDER L., MORIGI C., FRUERGAARD M., JOHANNESSEN P.N., NIELSEN L.H., PEJRUP M.

**Reconstruction of coastal evolution and Holocene sea-level history from surface morphology and lagoon sediments of a regressive, micro-tidal environment**

MAQUAIRE O., LISSAK C., COSTA S., THIERY Y., FRESSARD M., DAVIDSON R.

**Landslide hazard zoning at large scale along Lower Normandy coast affected by slow-moving landslides (France)**

MAGKLARA M., KARYMBALIS E.

**Development of a Coastal Sensitivity Index for Elafonissos Island, Peloponnese**

LYGIN A., LYGIN A., KHABIDOV A.

**Verification of dean's equilibrium beach profile formula for large man-made lakes**

VALENTE A., PENNETTA M., SICA M.

**Rip channel patterns on the beach near the mouth of Sele River (southern Italy)**

KHOUAKHI A., SNOUSSI M.

**Vulnerability assessment of Al Hoceima bay (Moroccan Mediterranean coast): a coastal management tool to reduce potential impacts of sea-level rise and storm surges**

MATOS FIERZ M.

**Definition of geomorphologic coastal systems at the Sao Paulo's coast - a taxonomic proposal**

DE GOUVEIA SOUZA C.

**The Ubatuba Beachrock (State of São Paulo, Brazil): A New Evidence of a Mid-Holocene Negative Sea-Level**

PEDROSA F., NASCIMENTO F.

**Ge indicators and beach classification for coastal management in Arraial do Cabo, Rio de Janeiro, Brazil**

GONZALEZ-VILA F.

**Chronology of coastal progradation rates along the Santa Catarina litoral, Brazil**

SAYED M., SHAAABAN A.B., REGNAULD H., ABDEL HAMID A.

**Environmental Problems in coastal margins of Nile delta**

ZHIZHONG L., JIANHUI J., XIULING C., FANGEN H., XIANLI W., JIN X.

**Quaternary environmental evolution recorded by littoral deposits in China's southeast coast**

CHAUDHURI S.

**Ecological and Geomorphic Controls on Spatial Variation of Crab Burrows: A Case Study in Bakkhali Beach Area, West Bengal, India**

## **S22. SUBMARINE GEOMORPHOLOGY**

Convenors: *Klaus SCHWARZER & Sebastian KRSTEL*

### **Oral presentations .....923**

BURNINGHAM H., FRENCH J.

**Deriving long-term (multi-century) quantitative measures of marine geomorphological change using qualitative records**

MICALLEF A.

**Submarine geomorphology and the geomorphometric approach - Recent developments**

BRACCHI V., SAVINI A., MARCHESE F., CORSELLI C.

**Geomorphological expression of shallow water carbonate buildings in the Mediterranean Sea**

GARLAN T.

**Characterization of current sediment dynamics, obtained from the distribution and movement of underwater dunes: the example of the English Channel**

VITAL H., GOMES M., NOGUEIRA M., PIERRI G., LIRA H., SILVA J.P., ALMEIDA N.

**Submarine geomorphology of a tropical shelf: examples from the Rio Grande Do Norte Shelf, NE Brazil**

NIELSEN T., KUIJPERS A.

**Geomorphological response to North Atlantic Deep Water circulation: Examples from high-energy current environments at the Faroe and Greenland margins and abyssal southwestern North Atlantic**

BECKERS A., BECK C., HUBERT-FERRARI A., TRIPSANAS E., SAKELLARIOU D., DE BATIST M., DE RYCKER K., BASCOU P.

**Sea floor morphology of north-western Gulf of Corinth (Greece): combined impacts of Late Quaternary eustatism and active tectonics**

SAVINI A., VERDICCHIO G., MARCHESE F.

**Geomorphological mapping of complex submarine slides (Apulian ridge, eastern Mediterranean Sea): implication for geohazard assessments**

FONTANA A., CORREGGIARI A.M., SLAVEC P., REMIA A., MASELLI V., ZERJAL A., POGLAJEN S., CELARC B., BAVEC M., ROSSATO S.

**Holocene evolution of the Northern Adriatic Platform: morphologic and stratigraphic evidence**

HANEBUTH T., MERSMEYER H., KUDRASS H., WESTPHAL H.

**Aeolian to shallow-marine shelf palaeo-landscapes off a major desert since the Late Pleistocene (Northern Mauritania)**

KOKHAN A.

**Axial and off-axial morphology of Arctic and Polar Atlantic spreading ridges (analogous modeling)**

**Poster presentations .....928**

WANG Y., ZOU X., YIN Y., ZHANG Y., LIU S.

**River-Sea interaction and paleo-Yangtze giant delta system studies**

KOKHAN A., DUBININ E., GROKHOLSKY A.

**Geodynamical analyses of relief of rift zones of ultra-slow spreading ridges**

EVELPIDOU N., PIRAZZOLI P.

**Underwater geomorphological survey revealing past temporary standstills of the relative sea level in carbonate rock areas**

EVELPIDOU N., KARKANI A., PIRAZZOLI P.

**Late Holocene shorelines deduced from tidal notches on both sides of the Ionian Thrust: Fiscardo Peninsula (Cephalonia) and Ithaca Island**

PIE DADE A., ALVES T., ZÉZERE J.L.

**Raft Tectonics in SE Brazil as an example of large-scale gravitational collapse on continental margins**

NONNIS O., PAGANELLI D., PROIETTI R., PAZZINI A., NICOLETTI L., GABELLINI M.

**Morphological alterations of the seabed related to relict sand dredging for beach nourishment**

SKENTOS A., PAVLOPOULOS K., KAPSIMALIS V.

**Geomorphology of the Cyclades plateau (Aegean Sea, Greece)**

NORMANDEAU A.(1), LAJEUNESSE P.(1), ST-ONGE G.(2)

**Geomorphology of submarine canyons and channels in the St. Lawrence Estuary (Eastern Canada)**

PALAMARA S., SAVINI A.

**Seafloor undulations in the Policastro gulf (South-eastern Tyrrhenian Sea): description and possible genetic mechanism**

MARCHESE F., SAVINI A.

**Detached blocks from submarine slides investigated using quantitative geomorphological techniques**

## **S23. AEOLIAN SYSTEMS AND ARID GEOMORPHOLOGY (INCLUDING SUBARID MARGINS)**

Convenors: *Xiaoping YANG & Martin WILLIAMS*

### **Oral presentations .....937**

ZHANG D., YANG X., NARTEAU C., ROZIER O.

**Mean residence time in barchan dunes from numerical modelling**

YAIR A.

**Complex Geo-Ecological responses to climate change in dry-land areas: Northern Negev desert, Israel**

DIETZE M., KLEBER A.

**Dynamic stone pavements - insights from experiments and numeric modelling**

HESSE P.

**What makes Australian desert dunes so stable? Vegetation and sand transport response to variable rainfall**

PERKINS J., FINNEGAN N.J., DE SILVA S.L.

**The relative efficacy of wind and fluvial erosion of bedrock in northern Chile**

BIEJAT K., DLUZEWSKI M.

**Form-flow interaction of star dune arms**

DLUZEWSKI M., BIEJAT K.

**Sand bulk density as an indicator of form-flow interaction on barchan dunes**

CAMMERAAT E., KAKEMBO V.

**Vegetation change and geomorphological response of dryland hillslopes**

BOURKE M., VILES H., CONWAY S., GOUDIE A.

**Fog-induced slumping in a hyper-arid dunefield, Namibia**

PAILLOU P.

**The Kufrah paleodrainage system in Libya: Mapping the past from space**

VEIT H., PREUSSER F.

**The Southern Westerlies in Central Chile during the last glacial cycle as documented in coastal dunes and paleosols**

WILLIAMS M., DULLER G., WILLIAMS F., MACKLIN M., WOODWARD J., EL TOM O., MUNRO N.

**Causal links between Eastern Mediterranean sapropel formation, Nile floods and White Nile source-bordering dunes confirmed by OSL and radiocarbon dating.**

FAUST D., WILLKOMMEN T., YANES Y., ZOELLER L., RICHTER D.

**From dune accumulation to soil formation - Is climate change required?**

KASSE C.

**Climate change and sandy aeolian deposition during the Last Glacial Maximum and Late Glacial in northwest Europe with special reference to the Lutterzand type locality, eastern Netherlands**

SEBE K., ROETZEL R., FIEBIG M., LÜTHGENS C.

**Pleistocene cold-climate wind system in the foreland of the Pannonian Basin**

LEHMKUHL F.

**Timing and spatial distribution of loess-like sediments and late Quaternary alluvial fans in Mongolia and adjacent areas**

PAIN C.

**Landforms of the hyper-arid Northern Emirates, United Arab Emirates**

BENAZZOUC M., BOUREBOUNE L.

**Morphoclimatic significance of eolian plugs on the northern margins of Sahara desert**

SCUDERI L., WEISSMANN G., YANG X., KINDILIEN P.

**Mapping China's deserts and desert margins: A database approach to understanding form, process and causality**

ZHOU N., ZHANG C.

**Aeolian sand landforms in the Mainling Wide Valley of the Yarlung Zangbo River**

STAUCH G., LEHMKUHL F., HILGERS A., ZHAO H.

**Aeolian sediments on the north-eastern Tibetan Plateau**

EMBABI N.

**North Sinai Sand Sea, Egypt: Dune Types and Forms, Sediments, and Hazards**

HAMED W.

**Geomorphology of western desert Iraq**

LANCASTER N., SINGHVI A., GLENNIE K., TELLER J., PANDEY V.

**Complex dune patterns of the northern Rub' Al-Khali, UAE ' age and origins**

ROSKIN J., KATRA I., BLUMBERG D.G.

**Particle-size fractionation of eolian sand along the Sinai - Negev erg**

BEN FRAJ T.

**Windy silt deposits (or loess) in Southeast Tunisia (Northern borders of the Great Sahara): chronostratigraphy and paleoenvironments of their deposition**

AMIT R., ENZEL Y., ONN C., MUSHKIN A., JIGJIDSUREN B., GILLESPIE A.

**The role of active sand seas in forming desert loess sequences with implications to the Chinese Loess Plateau.**

WIGGS G., KING J., THOMAS D., WASHINGTON R., ECKARDT F., BRYANT R., NIELD J., VICKERY K.

**Dust emission dynamics and source area variability: field measurements for climate modelling**

STRONG C., WEBB N., CHAPPELL A., MARX S., MCTAINSH G.

**Soil organic carbon enrichment of dust emissions: magnitude, mechanisms and its implications for the carbon cycle**

ECKARDT F.

**Dust Sources of Southern African**

**Poster presentations .....952**

PAVLOVA M.

**Eolian terrain of the lower course of the river Vilyui (Central Yakutia)**

ZHAO X.

**Study on Arid Geomorphologic Features in the Queletag Mountain in Southern Piedmont of the Tianshan Mountains, Xinjiang, China**

ENZEL Y., AMIT R., CROUVI O., PORAT N.

**Intensified, gusty latest Pleistocene winds forced abrasion of Sinai/Negev sand into a continuum of finer grains downwind**

GALANIN A., URBAN A., PARFYONOV M., TANANAEV N.

**Tukulan Phenomena - Specific Cryoarid Landforms of Central Yakutia**

NAEIMINEZAMABAD A.

**Application of SRTM and ETM in identification of unknown geomorphologic forms, Case Study: Lut Plain in south east of Iran**

REN X., YANG X., ZHANG D., LI H.

**Hydrochemical characteristics of natural water and origins of dissolved salts in the eastern Hunshandake Sandy Land, Eastern Inner Mongolia, China**

SAYAGO J.M.

**Desertification and human impact in the arid region of Northwestern Argentina**

YOON S.O., HWANG S., PARK C.S.

**Geochemical properties of loess-paleosol sequence in the Haemi area, West Coast of South Korea**

TIUMENTCEVA E.

**Eolian denudation in the baikal region under conditions of climate aridity**

ZHENG Y., WU Y., LI S.

**Provenance analysis of aeolian sediments in the wide valleys of Middle Reaches of Yarlung Zangbo River in Tibet, China**

YAN P., ZHENG S., GUO J., LI X.

**Using a 3D laser scanner to monitor the wind erosion in wind tunnel test**

LUZÓN A., RODRÍGUEZ-LÓPEZ J.P., PÉREZ A., SORIANO M.A., GIL H., POCOVÍ A.

**Exceptional preservation of Pleistocene aeolian forms in an outwash plain. Central Ebro Basin (NE Spain)**

ZOU X., WU X., ZHANG C., WANG R., ZHAO J.

**The Effect of Wind Barriers on the Airflow Field in A Wind Tunnel**

**Active sand seas are a major source of desert loess**

CROUVI O., AMIT R., ENZEL Y., GILLESPIE A.

CLAUDIN P., WIGGS G., ANDREOTTI B.

**Field evidence for the upwind velocity shift at the crest of low dunes**

MUNRO R.

**Understanding the causes of increased sand influx at the Begrawiya (Meroe) pyramids archaeological site, Sudan: initial findings to support the implementation of a mitigation programme**

ZHANG X., SUN T., XU J.

**The Study of Relationship between Moving of the Farming-pastoral Boundary and Preaching of Catholic Church in Kalgan, Northern China**

PAN M., WU Y., ZHENG Y.

**Aeolian activity in DingJie area(southern Tibet, China)during Holocene**

SRIJONO S., HENDRATNO A., HUSEIN S., FRESKY Y.

**Recent development of coastal sand dunes, Parangtritis, Yogyakarta, Indonesia**

GABARROU S., LE COZANNET G., PARTELI E., PEDREROS R., OLIVEROS C., BRIVOIS O., MULLER H., GUEBER E., MALLET C.

**Modeling aeolian coastal dunes mobility in Aquitaine, South Western France**

WIGGS G., WASHINGTON R., KING J., THOMAS D., WOODWARD S., ECKARDT F., HAUSTEIN K., BRYANT R., NIELD J., VICKERY K., MURRAY J., BRINDLEY H., JONES R.

**Dust Observations for Models (DO4Models): Project Overview**

VERSTRAETEN G., MOHAMED I., NOTEBAERT B.

**More than 5000 years of interaction between aeolian, fluvial and anthropogenic systems in the central Egyptian Nile valley**

MAMADOU I., GAUTIER E., BOUZOU-MOUSSA I., DESCROIX L.

**Process and causes of neo-exoreism in Sahel: 'Koris' study case in the area of Niamey (Niger)**

BRISTOW C., DULLER G.

**The structure and development of a star dune, Lala Lallia, Erg Chebbi, Morocco**

KATSUKI A.

**Size distribution of barchan dunes with a cellular model**

DE VET S., CAMMERAAT E.

**Non-linear differentiation in fluid thresholds for wind-induced sediment mobilisation in low-pressure, high-altitude mountain environments**

LANCASTER N., HALFEN A.

**A Global Digital Database and Atlas of Quaternary Dune Fields and Sand Seas**

STONE A., GARZANTI E.

**Initial investigations of the age and provenance of the dunes of Rooisand in the Great Escarpment region of western Namibia**

BAOLI L., COULTHARD T., MCLELLAND S.

**Modelling the interaction between sand dunes and rivers, and the impact on geomorphology**

## **S24. TROPICAL GEOMORPHOLOGY**

Convenors: *Vishwas KALE & Robert WASSON*

### **Oral presentations .....969**

LATRUBESSE E.

**Anabranching patterns in large rivers: state of the art and clues from the tropics**

MAY J.H., NANSON G.C.

**Monsoonal rivers of Australia's "Top End" in the late Quaternary**

MESHKOVA L., CARLING P.

**The Quaternary Mekong River terraces: sediments, climate and former river courses**

YU Z., ZHANG K.

**Quaternary Evolution of the Pearl River Delta, China, Inferred from Terraces and Boreholes**

KALE V.S., MAGAR A., BASAVAIAH N., RAJSHEKHAR C.

**Sedimentary Records of Monsoon Variability from Historical Tanks in the rainshadow zone of the Western Ghat, Deccan Trap Region, India**

ACHYUTHAN H.

**Holocene alluvial records of the northeast monsoon dominated rivers of south India**

ROY N., SINHA R.

**Hydro-climatic trends of the Upper Ganga Plains how significant in water resources management**

JAIN V., TANDON S., SINHA R.

**An appraisal of geomorphic complexity of a large tropical river, Ganga River system, India**

RUNGE J., EISENBERG J.

**Long term geomorphic landscape evolution and gold deposits in the Central African Republic (CAR, Bandas Greenstone Belt)**

GARCIA-GOVEA C., GAUTIER E., BRUNSTEIN D., LARAQUE A., GUYOT J.L., ROSALES-SIERRA V.

**Hydro-geomorphologic comparison of two Amazonian rivers: Napo river and Beni river**

JOMELLI V., FAVIER V., KHODRI M., BRAUCHER R., BLARD P.H., RINTERKNECHT V., LEANNI L., BOURLES D., BRUNSTEIN D., GRANCHER D., FRANCOU B.

**Were tropical glacier fluctuations synchronous with mid-latitudes during the Holocene?**

### **Poster presentations .....974**

EISENBERG J., RUNGE J.

**Neo-tectonics in Central African river catchments evidenced by lineament analysis - Examples from Southern Cameroon**

ALVES G., QUEIROZ NETO J.P.

**Soil transformation system and lake Mandacarú formation in the Três Cantos compartment area, at Maracá, São Paulo, Brazil**

HENRIQUE F.M., FERNANDES E.

**Geomorphic processes in tropical environment: a study in piloes-pb city**

MARCAL M., RIBEIRO S.

**Ethnogeomorphology as a methodological resource, applied to land use planning, semiarid Ceara state, Brazil**

DANIELE E., VIEIRA B.C.

**The Erosional features of Espirado basin, São Paulo, Brazil**

HOSSAIN S., HASAN M.A., AHMED K.M.

**Geomorphological and Geological Control on the Chemistry of Groundwater: A Case Study from the Meghna Basin, Bangladesh**

GARNIER A., LESPEZ L., CAILLAULT S., DUFOUR S., EICHHORN B., NEUMANN K.

**The role of gallery forest in semi-arid fluvial system dynamics: case study from the Yamé River (Mali, West Africa) during the Holocene**

CAROZZA J., CORNU J.F., GUITET S., BRUNEAU O.

**Typology of tropical elementary landforms based on 30 m SRTM data: Example from the French Guyana shield**

CORNU J.F., GUITET S., BRUNEAU O., CAROZZA J.M.

**Multiconvex landform object-based segmentations: Regions vs. edge based approaches with different DEM**

LIND P., MCDOWELL P.

**Sediment distribution and flux patterns of active boulder bars in a montane tropical river ' Rio Pacuare, Costa Rica**

## **S24A. TROPICAL RIVERS: HYDRO-PHYSICAL PROCESSES, IMPACTS, HAZARDS AND MANAGEMENT (IGCP 582 AND IAG-WG)**

Convenors: *Edgardo LATRUBESSE, Jose C. STEVAUX & Rajiv SINHA*

### **Oral presentations .....983**

RUNGE J.

**Physiogeographic features and hydrological characteristics of the Congo and the Oubangui drainage basins, Central Africa**

FURUICHI T., WIN Z., LIN S., OGASAWARA M., YAMAMOTO M., OCHIAI S.

**Catchment-scale hydrology of and sediment transport by the Ayeyarwady (Irrawaddy) River and landforms of its catchment**

MWELWA E., CROSATO A., WRIGHT N., BEEVERS L.

**Analysis of the state of the flow and morphology interaction in the hydropower dominated Middle Zambezi subcatchment**

BAWA N., JAIN V., SHEKHAR S.

**Stream power based threshold identification for explaining channel morphological variability, Yamuna River system, India**

NG S., WOOD S.H., ZIEGLER A.D.

**Rivers in Northern Thai History: Implications for Management**

SINHA R., MOZUMDER C., JAIN V.

**Geomorphic considerations for environmental flow and habitat suitability in the Ganga river system, India**

GUPTA S., GHATAK S., SHARMA S., KATURI A.

**Fluvial Forms, Processes and Sediment Characteristics of River Teesta in India**

CASTELLANOS B., LARAQUE A., LOPEZ J., PEREZ J., RODRIGUEZ M., ROSALES J., STEIGER J.

**Homogeneous Sections of Suspended Matter in a heterogeneous large tropical river: the Orinoco river (Venezuela)**

FILIZOLA N., MARTINEZ J.M., FRAIZY P., ARMIJOS E., SOARES C., SAMPAIO F.P., MARINHO T., MARTINELLI A., ZUMAK A., SONDAG F., GUYOT J.L.

**Amazon River suspended sediment behavior on water surface - observations at the Manacapuru hydrometric station, Amazonas, Brazil**

BRAVARD J.

**The Mekong River, a reappraisal of sediment transfer based on geomorphology and grain size**

AALTO R., AUFDENKAMPE A.

**Processes of Sediment and Carbon Sequestration within Large Tropical Rivers**

STEVAUX J., LELI I., GON P., ASSINI M.

**Tropical multichannel rivers: processes, forms and evolution**

RESTREPO J.

**The Perils of Human Activity on Andean Rivers: Lessons from Colombia's Experience with Soil Erosion**

MONTERO J., LATRUBESE E.

**The igapó of the Negro River in central Amazonia: Linking late-successional inundation forest with fluvial geomorphology**

ALMEIDA CAVALCANTE A.

**Channel morphodynamics in semiarid areas: Jaguaribe River, Ceara, Brazil**

ZIEGLER A., LIM H.S., WOOD S.H.

**Moving forward, locking backwards: preparing for the next large Asian floods**

KEMP J., OLLEY J., MCMAHON J., ELLISON T.

**River response to European-style agriculture in a large, subtropical catchment: Brisbane River, Australia**

LISENBY P., WASKLEWICZ T., SLATTERY M.

**High-Resolution Characterization of a Tropical Montane Stream: Using Terrestrial Laser Scanning to Relate Channel Morphology to the Distribution of Stream Power and Shear Stress**

DA SILVEIRA FONTES L., LATRUBESSE E.M., STEVAUX J.C.

**Geomorphology and interaction river-sea changes after construction of large dams in Sao Francisco river, Brazil**

**Poster presentations .....992**

LAHA C., BANDYOPADHYAY S.

**Oscillation of River Ganges through time and its predicting tendency for vulnerability analysis with Remote Sensing and GIS**

SCATENA F.

**Geomorphology and Ecosystem Based Management of Tropical Montane Streams in Puerto Rico**

MESHKOVA L., CARLING P.

**Petrified wood as a tracer of the Mekong River palaeo-course**

BERNAL I., CHRISTOPHOUL F., DARROZES J., LARAQUE A.

**Channel Pattern variability along the Pastaza River (Ecuador and Northern Peru)**

WOOD S.H., ZIEGLER A.D., RITTENOUR T.M.

**Floods of the Mekong at Chiang Sean, northern Thailand: Archaeological and OSL dating of large floods**

SINHA R., LAHIRI S.

**Morphodynamics of the Brahmaputra River in upper Assam, India using a GIS based approach**

BEAN R., LATRUBESSE E.

**Continental-Scale Morphometric Analysis of Andean Basins**

BEAN R., LATRUBESSE E., STEVAUX J., ABAD J.

**The Ucayali depression, Peruvian Amazonia: Quaternary fluvial record and present day hydro-sedimentological dynamics**

CELARINO A., LATRUBESSE E., LADEIRA F.  
Fluvial morphometric analysis of the Pardo River basin (SP-MG, Brazil) and morphotectonic inferences

VIEIRA L., FROEHNER S.J., COUTO E.V.  
Historical Evaluation of the distribution of PAHs in samples from lakes in Southern Brazil

SOSA-GONZALEZ V., BIERMAN P.R., NICHOLS .K.K., ROOD D.H.  
Tropical erosion: the story of Panama

BONTHIUS C., LATRUBESSE E., ABAD J., STEVAUX J., FILIZOLA N., AQUINO S.  
Channel morphology and morphodynamics of the Madeira River in Brazil

DZANA J.G., KUATE S.  
Flood flows and their Implications in Humid Tropical and Urbanised Catchments: A Case-study of the Mfoundi River (Yaounde-Cameroon)

CREMON E., ROSSETTI D., ZANI H.  
Late Quaternary shifts in drainage morphology in the Demini River area, northern Amazonia: paleoenvironmental implications

FRANZINELLI E., IGREJA H.  
Characteristics of the Solimões-Amazon River bed: implication of neotectonics

RAMONELL C., LATRUBESSE E.M.  
Processes, forms and rates of floodplain building in a large South American river: the Middle Paraná River, Argentina

LINDOSO T., QUINTELA M.F., MIGUEZ M.  
Renaturalization of streams and rivers - Institutional arrangements in Urban Planning and Flood Mitigation

CHAKRABORTY A.  
Geomorphological-ecological-sedimentological evolution of Chuksar Island, hugly estuary, India: a neoichnological approach

WALSH R., ANNAMMALA K.V., NAINAR A., BLAKE W.H., BIDIN K., DOUGLAS I.  
Impacts of rainforest disturbance and conversion to oil palm on large river catchments in Borneo: evidence from sediment fingerprinting and long-term monitoring

MUNIZ L., FILIZOLA N., FRAIZY P., MELO E.  
The influence of standards morphometric on changes in the levels of water in Madeira Basin - Brazil: an assessment of damages under extreme conditions hydrological

## **S25A. GLACIAL AND PARAGLACIAL GEOMORPHOLOGY**

Convenors: Jasper KNIGHT & Stephan HARRISON

### **Oral presentations .....1005**

EVANS I.  
Glaciers, rock avalanches and 'the buzzsaw' in cirque development

VALCARCEL M., OTERO-OTERO M., MARTÍNEZ-CORTIZAS A., BLANCO-CHAO R.  
Glacial and paraglacial dynamics inside glacial cirques. A 3D morphometric analysis

BERENQUER F., JOSÉ JUAN DE SANJOSÉ BLASCO J.J., ATKINSON GORDO A., DE MATIAS J., SERRANO E., RICO I.  
Geomatics techniques applied to the rock glaciers, glaciers and ice-patches in Spain (1991-2012)

BERTHLING I., ETZELMÜLLER B.  
The role of glacial/permafrost interactions in patchy alpine landscape development

GUILLOH H., GODON C., GOUPY B., POHL A., BUONCRISTIANI J.F., MUGNIER J.L.

**Glacial and periglacial erosion rate inferred from five years of detrital flux monitoring (Bossons stream, Mont-Blanc massif, France)**

JARMAN D., HARRISON S.

**Rock slope failure in the mountains of Europe: paraglacial-parafluvial transitions**

DECAULNE A., MERCIER D., COSSART E., FEUILLET T., JÓNSSON H.P., SÆMUNDSSON Þ.

**The Vatn landslide, Skagafjörður, northern Iceland: early Holocene dating and Holocene palaeoenvironmental reconstitution potentialities**

GARDENT M., DELINE P., SCHOENEICH P.

**Geomorphological data for the recognition of mountain areas prone to glacial-related hazards, French Alps**

STRZELECKI M., LONG A., LLOYD J.

**Mechanisms controlling the post-Little Ice Age evolution of paraglacial coasts in Svalbard Archipelago**

HARRISON S.

**Geomorphological sensitivity: implications for landscape responses to climate change in glacial environments**

MERCIER D., COSSART E., DECAULNE A., FEUILLET T., COQUIN J., BOURGEOIS O., POCHAT S., JÓNSSON H.P., SÆMUNDSSON Þ.

**Toward a comprehensive paraglacial model: case studies from Iceland**

HARBOR J., STROEVEN A., BLOMDIN R., CAFFEE M., CHEN Y., CODILEAN T., FU P., GRIBENSKI N., HÄTTESTRAND C., HEYMAN J., IVANOV M., LI Y., LI Y., LIFTON N., LIU G., PETRAKOV D., ROGOZHINA I., USUBALIEV R.

**Spatial and temporal patterns of paleoglaciation across Central Asia**

BARR I.D.

**Topographic controls upon moraine distribution**

EWERTOWSKI M.

**Landform development at the High-Arctic valley glacier landsystem, Ragnarbreen, Svalbard**

RACHLEWICZ G.

**Character and rates of glacial sedimentary processes in the terrestrial part of Billefjorden basin (Svalbard)**

HUGHES P.

**Glacial geomorphology of the High Atlas, Morocco**

MINDRESCU M., EVANS I.

**Cirque development and the glaciation of the Romanian Mountains**

LE ROY M., DELINE P., CARCAILLET J.

**<sup>10</sup>Be exposure dating of onset and timing of Neoglacial glacier advances in the Ecrins massif, French Alps**

STOCKER-WALDHUBER M., SCHMIDT K.H., KUHN M., MORCHE D., LAMBRECHT A.

**Measurements of glacial and subglacial mass exchange of Gepatschferner (Ötztal Alps, Austria)**

ZANONER T., SEPPI R., CARTON A., NINFO A., BONDESAN A., FRANCESE R.

**Transition from glacial to periglacial processes in the Dolomites: the case of Cima Uomo area (Eastern Italian Alps)**

**Poster presentations .....1015**

EMBLETON-HAMANN C., SLAYMAKER O.

**Paraglacial - a comparative study of German and Anglo-Canadian usage**

HUGUET F.

**The survival of preglacial landforms in basement complex areas**

KING E.

**Contemporary sub-glacial landscapes: case studies from three Antarctic ice streams**

KNIGHT J.

**Subglacial processes and drumlin formation in west Connemara, Ireland**

ITURRIZAGA L.

**Last Glacial Maximum to Holocene glacial and paraglacial landscape reconstruction in the Cachapoal valley (Southern Central Andes, 34°22'S/70°05'W)**

GALANIN A.

**The age of the Last Glacial Maximum in the Asian North-East**

GODLEWSKA A.

**Differentiation of the younger saalian ice-sheet dynamics in the interfluvium of the Krzna and Bug Rivers (E Poland)**

BUSNELLI J.

**The overlapping problem of paleoglacial and periglacial landforms under an evident scenario of global warming but a tectonic uplifting in the central Andes (Northwestern Argentina)**

MARREN P., TOOMATH S.

**Fluvial adjustments in response to glacier retreat: Skaftafellsjökull, Iceland**

HIRSCH F., RAAB T.

**Micromorphology and macrofabrics of Late Quaternary sediments in the Aragonese Pyrenees, Spain**

GODON C., MUGNIER J.L., FALLOURD R., PAQUETTE J.L., POHL A., BUONCRISTIANI J.F.

**The Glacier des Bossons protects Europe's summit from erosion**

SANTOS-GONZALEZ J., REDONDO-VEGA J.M., GONZÁLEZ-GUTIÉRREZ R.B., GOMEZ-VILLAR A.

**Determination of La Bana Lake (NW Iberian Peninsula) Origin using clast macro-fabric analysis**

SANTOS-GONZALEZ J., SANTOS J., REDONDO-VEGA J.M., GONZÁLEZ-GUTIÉRREZ R.B., GÓMEZ-VILLAR A.

**Till fabric and grain size analysis of glacial sequences in a complex paleoglacial system, the case study of the upper sil valley, cantabrian mountains, NW Spain**

CARTURAN L., BARONI C., CARTON A., CAZORZI F., DALLA FONTANA G., DELPERO C., SALVATORE M.C., SEPPI R., ZANONER T.

**Reconstruction of Late Holocene fluctuations of La Mare Glacier (Eastern Italian Alps): a combined approach**

LEONELLI G., BOLLATI I., DIOLAIUTI G., MERLINI A., TROMBINO L., SMIRAGLIA C., ZERBONI A., PELFINI M.

**The largest Italian valley glacier with little ice during the Sub-Boreal: evidences from a buried log in the Forni Glacier forefield**

BATHRELLOS G., SKILODIMOU H., MAROUKIAN H.

**The spatial distribution of cirques during Quaternary glaciations in Greece**

BIERMAN P., CORBETT L., GRALY J., NEUMANN T., ROOD D., SHAKUN J., NELSON A.

**The Greenland Ice Sheet erodes its bed some places but not in others**

HAEMMIG C., KEUSEN H., HESS J., TOBLER D.

**Early Warning of Glacial Lake Outburst Floods and Climate Change Monitoring in the Karakoram Mountains, P.R. China**

HARRISON S.

**The Glaciation of southwest England**

ESKOLA T., PEURANIEMI V.

**Glacial erosion in northern Ostrobothnia, Finland**

ESKOLA T., PEURANIEMI V.

**Glaciomorphological depositional formations in northern Ostrobothnia, Finland**

ROSSATO S., MOZZI P., MONEGATO G.

**From minor to major: understanding the LGM Adige-Brenta-Astico glacial system in the eastern Southern Alps through the analysis of transfluence tongues**

GEIGER A., FABEL D., GLASSER N.

**Thickness constraints of the Patagonian Ice Sheet over the last glacial cycle using surface exposure dating**

MALOWANY K., OSBORN G., MARTIN Y., MARSHALL S.

**Modelling depth of river incision caused by meltwater discharge from the retreating Cordilleran Ice Sheet, Alberta, Canada**

WANG J., KASSAB C., HARBOR J.M., CAFFEE M.W., CUI H., ZHANG G.

**Cosmogenic nuclide constraints on Late Quaternary glacial chronology on the Dalijia Shan, northeastern Tibetan Plateau**

YESILYURT S., DOGAN U., SENKUL C.

**Glacier recession from 1955 to 2007 on Sat (Ikiyaka) Mountains, Southeastern Anatolia, Turkey**

RODRIGUEZ RODRIGUEZ L., JIMÉNEZ-SÁNCHEZ M., DOMÍNGUEZ-CUESTA M.J.

**The Quaternary glacial maximum in the center of the Cantabrian Mountains (northern Iberian Peninsula): Aller-Nalón-Porma catchments**

BERTHLING I., LANDSNES E., FREDIN O.

**The Norwegian strandflat - glacial or periglacial erosion?**

SAMYN D., GLASSER N.

**Ice shelf structural and (geo-)statistical mapping: a case study using satellite imagery**

GHEORGHIU D.M.

**Surface exposure dating of rock slope failures in Northern Romania**

## **S25B. PERMAFROST AND PERIGLACIAL GEOMORPHOLOGY (IN COOP. WITH IPA)**

Convenors: *François COSTARD & Hugues LANTUIT*

### **Oral presentations .....1031**

KOKELJ S., TUNNICLIFFE J., LACELLE D., LANTZ T.

**Assessing the factors that affect growth and propagation of 'mega-slumps' in Canada's Northwest Territories**

LANTUIT H., FRITZ M., KRAUTBLATTER M., ANGELOPOULOS M., POLLARD W.

**Retrogressive thaw slumps: structure, evolution and relevance to carbon cycle of the Arctic Ocean**

SEJOURNE A., FEDOROV A., COSTARD F., GARGANI J., SKORVE J.

**Important melting of ice-wedges and formation of thermocirques on slopes of thermokarst lakes in Central Yakutia (Siberia)**

MORGENSTERN A., GROSSE G., ARCOS D.R., GÜNTHER F., OVERDUIN P.P., SCHIRRMEISTER L.

**Thermo-erosional landforms in Siberian ice-rich permafrost**

COSTARD F., GAUTIER E., FEDOROV A., KONSTANTINOV P., DUPEYRAT L.

**A reassessment of the erosional potential of fluvial thermal process during ice breakups of the Lena river (Siberia)**

GAGARIN L.

**Features of suffosional processes in permafrost (Central Yakutia, Russia)**

DWIGHT R., SCOTT D., MEIKLEJOHN I., MATCHER G., LEE J.

**Thermal and Moisture Regimes in the Active Layer of Western Dronning Maud Land, Antarctica**

ETZELMULLER B., LILLEOREN K.S.

**Cold region geomorphology and Permafrost Evolution in the North-Atlantic region**

SCHROTT L., OTTO J.C., KELLER F.

**Modelling alpine permafrost distribution in the Hohe Tauern region, Austria**

MAGNIN F., DELINE P., RAVANEL L., GRUBER S., KRAUTBLATTER M.

**Permafrost investigation in the Mont Blanc massif steep rock walls: a coupled measurement, modelling and geophysical approach**

GAERTNER-ROER J., MUELLER J.

**Identification of geomorphic and climatic controls on degradation of Alpine rockglaciers**

URDEA P.

**Permafrost existence in rock glaciers of the Southern Carpathians (Romania)**

LE COEUR C.

**Rock glaciers debris accumulation for assessment of rockwall retreat**

OWCZAREK P., MIGALA K., NAWROT A., MALIK I.

**Dendrogeomorphology in the Arctic regions - methods and case studies**

RIBOLINI A., BINI M., CONSOLONI I., ISOLA I., PAPPALARDO M., ZANCHETTA G., FUCKS E., PANZERI L., MARTINI M., TERRASI F.

**Late pleistocene sand wedges along the Patagonian Coast (Argentina): chronological constrains and implication for coastal permafrost distribution**

BRUXELLES L., JORDA C., MOURRE V., RAUX A.

**New periglacial features on the ancient terraces of the lower Rhône valley (Costières, Gard, France): mapping, datings and implications for the taphonomy of the palaeolithic lithic remains**

**Poster presentations .....1039**

BRARDINONI F., SCOTTI R., CROSTA G.B.

**The Spatial Distribution of Rock Glaciers and Protalus Ramparts in the Central Italian Alps**

URBAN A.

**Age and structure of perennial frost mounds in Yakutia region**

MEIKLEJOHN I., HANSEN C., DWIGHT R., LEE J., SCOTT D.

**Characteristics and Development of an Autochthonous Blockfield, Western Dronning Maud Land, Antarctica**

SALVADOR-FRANCH F., OLIVA M., SALVÀ-CATARINEU M., GÓMEZ-ORTIZ A.

**Ground temperature regime and periglacial dynamics in three different sites from the summit area in Sierra Nevada (southern Spain) from 2006 to 2012**

PERRIER R., COSSART E., FORT M.

**Mapping the consequences of global change on permafrost extent: a case study from the Clarée valley, southern French Alps**

SLEE A.

**The distribution and climatic implications of granite tors on the Great Dividing Range, Australia**

KASPRZAK M., KONDRACKA M.

**Geophysical signatures of permafrost in SW Spitsbergen**

ZANONER T., FRANCESE R., BONDESAN A., GIORGI M., CARTON A., SEPPI R., NINFO A.

**3D geophysical imaging to study the evolution of a debris covered glacier in the Dolomites (South-Eastern Italian Alps)**

STROHMEYER V., HUC S., DESPLANQUE C., SCHOENEICH P., CECILLON L., HUSTACHE E., ROBERT Y.

**Biodiversity and thermal regimes on cold scree slopes**

BODIN X., KRYSIECKI J.M., SCHOENEICH P.

**Past and present dynamics of a potentially hazardous rock glacier (Dérochoir, Mont Blanc Massif, France)**

EWERTOWSKI M., KASPRZAK L., SZUMAN I.(2), TOMCZYK A.

Ice sheet - permafrost interactions inferred from landform and sedimentary structures, Weichselian Ice Sheet, Poland

VASILE M., VESPREMEANU-STROE A.

The influence of altitude, exposure and declivity on freeze-thaw processes in non-permafrost mountain areas: the Southern Carpathians, Romania

ANETAS G., BODIN X., SORUCO A.

Distribution and characteristics of mountain permafrost under the Tropics: insights from an inventory of rock glaciers on the Altiplano, Chile and Bolivia (20-22°S)

DEFIVE E., LE COEUR C., VIRMOUX C., PEIGNELIN C., POIRAUD A., GUNNELL Y.

Age and dynamics of blockstreams in the eastern velay highlands, Massif Central, France: preliminary findings

RAMAGE J., HUGELIUS G., PALMTAG J., LASHCHINSKIY N.

Phytomass and soil organic carbon inventories related to land cover classification and periglacial landscape features at Ari-Mas and Logata, Taimyr Peninsula

## **S25C. MOUNTAIN GEOMORPHOLOGY**

Convenors: *Francesco BRARDINONI & Lothar SCHROTT*

### **Oral presentations .....1049**

KNIGHT J., GRAB S., MAYET N.

Lightning strikes and their influence on mountain geomorphology and sediment supply

SERRANO E., SANJOSÉ J.J., GONZÁLEZ-TRUEBA J.J.

Debris talus and cones dynamic in a calcareous Atlantic high mountain (Picos de Europa, Northern Spain)

GÖTZ J., SCHROTT L.

Holocene rockwall retreat in an inner-alpine headwater catchment (Gardenmoos Basin, Schober Mountains, Austrian Alps)

PAVLOVA I., ECKERT N., GRANCHER D., JOMELLI V., BRUNSTEIN D.

Geomorphological and climate context of debris flow regional occurrence in the Northern French Alps

GOLDIN B., CAVALLI M., BRARDINONI F., COMITI F., MARCHI L.

Geomorphic change detection using LiDAR DTMs in two small basins of the Italian Alps

COMITI F., DELL'AGNESE A., MAO L., ENGEL M., LUCÍA A., PENNA D., BERTOLDI G.

Temporal variations of bedload transport in a glacierized mountain basin

ROVERA G., CORONA C., LOPEZ SAEZ J., STOFFEL M.

Root-exposure: a new tool to quantify medium term erosion rates in gypsum areas (Massif de la Vanoise, France)

ANGEL I., CARCAILLET J., CARRILLO E., AUDEMARD F., BECK C.

Glacial chronology in the Mérida Andes, Venezuela, deduced from cosmogenic <sup>10</sup>Be radionuclide dating

NISHII R., MATSUSHI Y., MATSUZAKI H.

Terrestrial cosmogenic nuclides dating of a sackung on a cirque in the Japanese Alps

PHARTIYAL B., SINGH R., NAG D., KOTHARI G.C.

Geomorphic landscape evolution along the river valleys in Ladakh region of NW Trans Himalayan range during Late Quaternary: implications to climate and tectonics

MORCHE D., BAEWERT H.

Consequences of a subglacial lake outburst flood for a proglacial fluvial system (Fagge River, Kaunertal, Austria)

BOSSON J.B., BODIN X., DELINE P., SCHOENEICH P., BARON L., GARDENT M., KRISIECKI J.M., LAMBIEL C.

**Ground ice distribution in a high mountain sedimentary environment and its influence on sediment fluxes and local hazards: results of geoelectrical tomography in the Rognes sector (Mont-Blanc, France)**

DRAEBING D., KRAUTBLATTER M.

**Influences of Snow Cover on Permafrost in unstable Rock Walls**

LAMBIEL C., DELALOYE R., DELUIGI N., SCAPOZZA C., BOSSON J.B.

**Mapping and modelling the discontinuity of mountain permafrost: a challenging task**

LILLEØREN K., GÄRTNER-ROER I., ETZELMÜLLER B.

**Permafrost landforms in the Tröllaskagi peninsula, northern Iceland - implications for the deglaciation pattern**

SCHIAVONE S., BODIN X., BRENNING A., AZOCAR G., QUENSE J.

**Possible climatic controls on the recent (2004-2013) variations of surface displacements of cryospheric landforms in an Andean environment (Chile, 33°S)**

SLEE A., HAWORTH R., GONTZ A., SHULMEISTER J.

**The climatic significance of relict periglacial landforms in the New England Tablelands, Australia**

## **Poster presentations .....1057**

BARR I.D.

**Hypsometry of glaciated basins upon the Kamchatka Peninsula**

TIE Y.

**Debris flow hazards in high mountain area, Moxi basin, Southwestern of China**

REINFELDS I., SWANSON E., COHEN T., NOLAN A., WILLIAMS S.

**Hydrospatial assessment of streamflow yields and effects of climate change in the Australian alps**

GARDENT M., DELINE P., SCHOENEICH P.

**An inventory of the glaciers in the French Alps at the end of the Little Ice Age**

TEMME A., DECHIER D., BIRKELAND P., SCHWERING M., DIEK S.

**Using soils to reconstruct geomorphological history of a puzzling cirque in the Colorado Front Range**

TEMME A., EGLI M.

**Can we make rockfall maps using climber's books? A semi-quantitative analysis**

KOTARBA A., RACZKOWSKA Z.

**Debris flows and relief evolution in the Tatra Mountains**

JARMAN D.

**Megafans and outsize fans in the Tirol Alps - incremental, episodic, or catastrophic ?**

VOICULESCU M., ONACA A., CHIROIU P.

**Recent dendrogeomorphic approaches in Romanian Carpathians. Spatio-temporal reconstruction and patterns of snow avalanche activity in Făgăraş massif and Bucegi Mountains (Southern Carpathians) - Romanian Carpathians.**

BAYRAKDAR C., ÇILGIN Z.

**Two Different Example for Glacio-Karstic Evolution in Western Taurus (SW Turkey): Akdag Mountain and Dedegol Mountain**

LILLEØREN K., ETZELMÜLLER B., GISNÅS K., SCHULER T.V., HUMLUM O.

**Relative age and Holocene distribution of permafrost in Norway**

ROUSSEL E., CHENET M.

**Postglacial rockfalls controls on environmental partitioning of the Haute-Romanche valley (Massif des Écrins, french Alps)**

YU B., ZHU Y., QI X.

The topographical factors in the formation of gully type debris flows in the upper reaches of Minjiang River

KLIMES J., VILIMEK V., EMMER A., COCHACHIN A.

Glacial lake outburst flood hazard assessment, example of the Palcacocha Lake, Cordillera Blanca, Peru

BOSSON J., UTZ S., LAMBIEL C.

Current evolution of high mountain glacier systems: the case of the Rognes and Pierre Ronde systems (St-Gervais, Mont-Blanc, France)

IKEDA A., ADACHI K., HATTANJI T.

Changes in hardness of rock surface as a result of weathering through the Holocene in an alpine area in Switzerland

SCAPOZZA C.

Evidence of paraglacial and periparaglacial crisis in the evolution of sediment transfer in the Southern Swiss Alps since the Last Glacial Maximum

STAUB B., DELALOYE R., LAMBIEL C.

Joint analysis of rock glacier kinematics and complementary permafrost monitoring elements observed in the Swiss Alps

ROJAN E., RACZKOWSKA Z., KALAFARSKI M., DLUGOSZ M., KACZKA R., GADEK B.

Avalanches in relation to relief of the Tatra Mountains

## **S26A. MODELLING IN GEOMORPHOLOGY**

Convenor: *John WAINWRIGHT*

### **Oral presentations .....1069**

CHAPUIS M., DUFOUR S., PROVANSAL M., COUVERT B., DE LINARES M.

Coupling 3D hydraulic numerical modeling and field survey to assess morphodynamics of a wandering gravel bed river (Durance River, Southern French Alps)

CLAUDIN P., DURAN O., ANDREOTTI B.

Numerical simulation of turbulent sediment transport

ZHANG W., SCHNEIDER R., KOLB J.

Morphogenetic modelling of coastal foredunes

BURKOW M.

Numerical simulation of current driven sediment transport processes

RUIZ-VILLANUEVA V., DÍEZ-HERRERO A., BODOQUE J.M., BLADÉ E., SÁNCHEZ-JUNI M.

2D-Hydrodynamic modelling of large wood transport in rivers

CIAMPALINI R., FOLLAIN S., LE BISSONNAIS Y., DAVID M., COUTURIER A., WALTER C.

Modelling soil erosion on medium-term: the application of a landscape evolution model in a Mediterranean catchment

DOUVINET J., ESCUDIER A., DELAHAYE D., LANGLOIS P.

Flash floods susceptibility assessment through cellular automata modelling: a case study in northern France

BARKWITH A., WANG L., JACKSON C.R., HURST M., ELLIS M.

The dynamic cellular automata landscape evolution modelling platform CDP

CERDAN O., LE M., ROUSSEAU M., CORDIER S., LUCAS C.

Physically based modelling of soil erosion from the plot scale to the catchment scale

A. ALMODARES S.A.

Space time substitution in geomorphology (modelling by rainfall)

SEPEHR A.

**Non-Linear Equilibrium Points in geomorphology**

OUCHI S.

**Development of experimental landforms with rainfall-erosion and uplift of various rates**

MONDY L., DUCLAUX G., SALLES T., THOMAS C., REY P.

**Modelling stratigraphic and surface dynamics processes on a coupled thermo-mechanical lithospheric model: an example in oblique continental rifting**

BENAICHOUCHE A., STAB O., COJAN I., BRULHET J., TIJANI M., TESSIER B.

**How stream piracies are initiated in landscape evolution models? Predictive study in the Meuse basin**

BAARTMAN J., MASSELINK R., KEESSTRA S.

**Relating landscape morphological complexity to catchment connectivity**

VAN GORP W., SCHOORL J., TEMME A., VELDKAMP A.

**Modelling response to local base level change using LAPSUS**

WILLIAMS R.D., HICKS M., MEASURES R., BRASINGTON J.

**Validating predictions of braided river morphodynamics: static and dynamical metrics**

IWASHITA F., BROOKS A., CURWEN G., SPENCER J.

**A machine learning approach to estimate river bank erosion through multi-temporal LIDAR and spectral imagery**

MARTEL T., VAN DE WIEL M.

**Massively parallel particle-based methods in landscape evolution modelling: geomorphic validity and performance**

MADDY D., MCGOUGH S., WAINWRIGHT J., TRUEMAN A.

**PARALLEM: A new parallel-coded Landscape Evolution Model**

ALVIOLI M., MARCHESINI I., ROSSI M., SANTANGELO M., CARDINALI M., REICHENBACH P., ARDIZZONE

**Parallel processing in WPS services for geological and geomorphological mapping**

TRUEMAN A., MADDY D., MCGOUGH S., WAINWRIGHT J.

**Multivariate Global Sensitivity Analysis of a Landscape Evolution Model: Multiple Model-Ensemble Deployment on a High Throughput Computing Grid**

ROUSSEAU M.(1), CERDAN O.(1), ERN A.(2), LE MAÎTRE O.(3), SOCHALA P.(1)

**Are 'Physically-based' soil erosion models physically-based? Some elements from a sensitivity analysis of the Hairsine and Rose model**

## **Poster presentations .....1081**

NAEIMINEZAMABAD A.

**Effect Meander Development at change land cover in Mond River with Spatial Data Modeler**

GILES D.

**The use of ground models for the integration of geomorphological, geoenvironmental and engineering geological data**

RAMIREZ NU EZ C., PARROT J.F.

**Regional characterization based on a new drainage network parameter. The case of the Coatzacoalcos fluvial system.**

ZHANG D., NARTEAU C., ROZIER O., COURRECH DU PONT S.

**Morphology and dynamics of star dunes from numerical modelling**

NARDINI A., GOMEZ MIGUEZ M., PITZER JACOB A.C.

**Predicting river morphology after restoration. Application to a Brazilian case of the methodology VALURI**

CORREA E.A., PINTO S.D.A.F., MORAES I.C.

**Analysis of methods of potential environmental fragility in a small sized watershed**

ROUSSEAU M.(1), CERDAN O.(2), DELESTRE O.(3), DUPROS F.(2), CORDIER S.(4), JAMES F.(4)

**Comparative study of overland flow modeling with different numerical resolutions**

SILVA A., FERNANDES N.

**Assessment of annual streamflow responses to different land use and land cover in a mountainous area of Rio de Janeiro, Brazil**

BORYSIK J., MAZUREK M., ZWOLINSKI Z.

**Concept of sustainable management involves landscape geodiversity of hydrogeomorphological units: the Dębnica River, Poland**

PINHEIRO L., CUNHA C.

**The Importance of the USLE L Factor in Erosive Modeling: a Brazilian perspective**

MERGILI M., GRUBER F.E., SCHNEIDER J.F.

**A GRASS GIS model for high-mountain multihazard assessment at the regional scale**

PASCULLI A., AUDISIO C., SCIARRA N.

**Modelling river evolution: conceptual and numerical model on the river pellice (North-Western Italy)**

DADSON S.

**Estimates of river flows, floodplain inundation and land-atmosphere feedbacks in tropical African wetlands**

MARCHESINI I., MERGILI M., SANTANGELO M., BUCCI F., CARDINALI M., ROSSI M., FELLIN W., GUZZETTI F.

**A GRASS GIS-based deterministic model for the analysis of deep-seated slope stability in complex geology**

ETTINGER S.

**Using field data to evaluate modeling input parameters and attempt to include spatial distribution of flow bulking of lahars in three valleys at Cotopaxi volcano, Ecuador**

WAINWRIGHT J., PARSONS A.J., COOPER J.R., LONG E.J., HARGRAVE G., KITCHENER B., HEWETT C., ONDA Y., FURUKAWA T., OBANA E., HAYASHI H., NOGUCHI T., PATIN J.

**Innovative Modelling Techniques to Upscale Novel Field and Laboratory Estimates of Soil Erosion**

MOHR C., ZIMMERMANN A., FRANCKE T., KORUP O., BRONSTERT A.

**Robust interpolation techniques for estimating suspended sediment yields in logged catchments, south-central Chile**

BRYSON L., HUGHES D.A., ROWNTREE K.M.

**A Conceptual Understanding of Sedimentation in South African Catchments by a Sediment Flow Model**

ANDERS N., SEIJMONSBERGEN H., BOUTEN W.

**Evaluating landscape evolution models with object-based landform classifications**

QUENEHERVE G., MÄRKER M., ZAKERINEJAD R.

**Gully Development Assessment with Google Earth, GIS and Statistics**

ROSCA S.M., PETREA D., IRIMUS I.A., SURDEANU V.

**Methodological comparative assessment of the landslide susceptibility - case study: The Niraj River Basin (Transylvania depression, Romania)**

FRANK F., MCARDELL B., DEUBELBEISS Y., HUGGEL C., KULL I.

**Modeling debris flow erosion in Alpine Holocene debris fans: application to the Spreitgraben catchment, Switzerland**

**S26B. REMOTE SENSING (INCLUDING LASER SCANNING, APPLICATIONS OF RADAR, ETC.)**

Convenors: *Thomas DEWEZ & Dirk RIEKE-ZAPP*

**Oral presentations .....1095**

*BARBOUX C., DELALOYE R., LAMBIEL C., STROZZI T., COLLET C., RAETZO H.*

**Differential SAR Interferometry in alpine geomorphology: Potential of this high precision technology for detecting and surveying landforms in mountain environment**

*GIULIANO J., DEWEZ T., GODARD V., LÉBOURG T., MARCOT N.*

**Sea cliff erosion monitoring by boat-borne Laser-scanning**

*RAZAK K., QUAN LUNA B.*

**Airborne laser scanning of forested rock extraction: Airborne parameterizations, quality assessment, and rockfall modeling**

*TOBLER D., MEIER L., GRAF K.*

**Predicting Rock-Movements by Interferometric Radar Measurements**

*MOORMAN B., WHITEHEAD K., HUGENHOLTZ C.*

**The application of UAV's for high-precision glacial, periglacial and hydrological monitoring**

*ECHÉLARD T., KRYSIECKI J.M., SCHOENEICH P., GAY M.*

**Rockglacier movement detection by D-InSAR in French Alps using ERS archive data and TerraSAR-X data**

*DEWEZ T., MOSER S.*

**Time-lapse stereo-photogrammetric monitoring of volcanic slopes**

*GANCE J., MALET J.P., DEWEZ T., TRAVELLETTI J.*

**Continuous tracking of objects for characterizing landslide displacements from terrestrial images**

*BODIN X., DEROUX B., VACHER P., THIBERT E.*

**High-resolution quantification of mountain permafrost displacements: insights from Terrestrial Laser Scanning and image correlation techniques**

*ALHO P., KASVI E., VAAJA M., FLENER C., LOTSARI E., KUKKO A., KAARTINEN H., HYYPPÄ J., HYYPPÄ H.*

**Change detection of river channel utilising laser scanning, sonar survey and UAV-photogrammetry based bathymetric model**

*BENACCHIO V., PIEGAY H., MICHEL K., VAUDOR L.*

**Identification of factors disrupting remote bathymetry: experimental approach from ground imagery on the lower ain river (France)**

*SMITH M., PARON P.*

**Kite aerial photogrammetry system for monitoring coastal change in the Netherlands**

*NINFO A., MOZZI P.*

**Integration of LiDAR and optical remote sensing for the study of fluvial and anthropogenic landforms in the Brenta-Bacchiglione alluvial plain (NE Italy)**

*DELGADO BLASCO J., MOHAMED I.L., VERSTRAETEN G., HANSSSEN R.F.*

**The application of radar and optical remote sensing to analyse dune dynamics at the dune-field scale**

*QU N HERV. G., MÄRKER M., BACHOFER F.*

**Geophysics and Remote Sensing Data for the Detection of Soil Texture Distribution**

*DHORDE A., DHORDE A., KUMAR K.*

**Estimation of Surface Runoff for an Urbanized Watershed Using Satellite Data: A Case Study of Ramnadi Basin, Maharashtra, India**

**Poster presentations .....1103**

FERNANDEZ S., ROCES P., RECONDO C.

**Ortophoto and satellite imagery to monitoring charcoal in mountain soils (NW of Cantabrian Range, Spain)**

LANE S.N., CHANDLER J.H., MICHELETTI N.

**Digital elevation modelling from a Smartphone**

NADAL ROMERO E., REVUELTO J., LÓPEZ-MORENO J.I., VICENTE-SERRANO S., GARCÍA RUIZ J.M.

**Testing a Terrestrial Laser Scanner and photogrammetric techniques for studying badland dynamics**

MICHELETTI N., LANE S.N., CHANDLER J.H.

**Reconstruction of past hillslopes morphology using aerial photographs: data quality and applications for the investigation of landscape changes at the decadal scale**

ROUSSEAU Y., ASHMORE P., BIRON P., VAN DE WIEL M.

**Surveying Channel Morphology Using Ground-Based Photogrammetry**

DUFRECHOU G., HOHMANN A., GRANDJEAN G., BOURGUIGNON A.

**Hyperspectral proximal and remote sensing applied to clay minerals identification and mapping**

MAYAMBA AIME M., TSETA FELICIEN M., KOMANDA JULES A.

**Gullies detection on satellite imagery in an intra urban catchment of tropical region. Methodological development in river Bumbu catchment (Kinshasa, RD Congo)**

YERMOLAEV O., USMANOV B.

**Terrestrial laser scanning methods as instrument of landslide and erosion processes study**

AL-DOAAN M., DAOUDI M.

**Use Of Remote Sensing to Locate Subsurface Shallow Waters in Al Madinah Al Munawwarah, Western Saudi Arabia**

CONESA-GARCÍA C., TOMÁS R., HERRERA G., LÓPEZ BERMÚDEZ F., CANO M., NAVARRO-HERVÁS F., PÉREZ-CUTILLAS P.

**InSAR as a complementary tool for identifying alluvial morphological units: Vega Media of the Segura River (SE Spain) case study**

PETROVIC D., PAVLOVIC R.

**Application of remote sensing for geomorphological mapping and reconstruction of geomorphological evolution**

PAPPALARDO M., RIBOLINI A., PASQUINUCCI M., BARONI C., BINI M., MENCHELLI S., MORELLI G., SALVATORE M.C., SANGRISO P.

**Vada Volaterrana (Italy). High-resolution Ground Penetrating Radar in Geoarchaeology: the application of STREAM X multichannel system**

GOMEZ-GUTIERREZ A., SCHNABEL S., RUBIO-DELGADO J., BERENQUER-SEMPERE F., LAVADO-CONTADOR F.

**Estimation of medium-term soil erosion rates by means of terrestrial laser scanner and exposed roots**

PANEK J., MACHACEK J.

**Using UAV as a source of DSM data in geomorphological 3D modelling**

DAMIANO E., BACENETTI M., BERTOTTO S., GIARDINO M., GODONE F., PEROTTI L., CHIARLE M.

**Integrated geomatic techniques for surveying glacial and recently deglaciated areas**

ANDERS N., KEESSTRA S., SEEGER M., SUOMALAINEN J., BARTHOLOMEUS H., KOOISTRA L.

**Monitoring geomorphological change with unmanned aerial vehicles**

DIAS ALVES PORTELA V., CARVALHO VIEIRA B.

**Vegetation and landslides in the Serra do Mar (SP), Brazil: evaluation by satellite images processing**

GAL A., BELL R., MICU M.

**An insight into the mud volcanoes morphodynamics. A Romanian case-study**

GARCIA-MELENDEZ E., BUZZI J., RIAZA A., CANTANO M., MINGUEZ A., RODRIGUEZ GARCIA A.

**Imaging spectrometry for the geomorphological and spectral characterization of the lower Odiel river course (Huelva, Spain)**

DIETRICH J., LIND P.

**The use of Structure for Motion for repeat topographic surveys of active boulder bars on a hydrologically dynamic tropical river**

SANTOS CORREA C., TAVARES DE MATTOS J., DIAS BRITO H.

**SRTM employment images in physiographic subdivision: a case study in the region of São José dos Campos - SP - Brazil**

GHAHROUDI TALI M.

**Application of principal components analysis (pca) to detect geomorphological faces, case study: meaghan lake**

MICHOUD C., CARREA D., AUGEREAU E., CANCOUËT R., COSTA S., DAVIDSON R., DELACOURT C., DERRON M.H., JABOYEDOFF M., LETORTU P., MAQUAIRE O.

**Acquisition, Resolution and Precision of Dieppe Coastal Cliffs Point Clouds from Mobile Laser Scanning**

## **S26C - DEMs, GIS AND SPATIAL ANALYSIS**

Convenors: *Takashi OGUCHI & Christopher GOMEZ*

### **Oral presentations .....1117**

STARHEIM C., GOMEZ C., DAVIES T., OWENS I., HADMOKO D.S.

**Generating high spatiotemporal resolution digital terrain models for debris flow deposits from 3D structure-from-motion imagery and an unmanned aerial vehicle**

HAYAKAWA Y.S., OGUCHI T., SAITO H., KOBAYASHI A., KOMATSU G., GOTO K., BAKER V.R., PELLETIER J.D., MCGUIRE L.

**Impact of tsunami erosion on coastal valley formation in northeastern Japan: an airborne and terrestrial laser scanning approach**

CLAPUYT F., VANACKER V., VAN OOST K.

**Accuracy assessment of DEMs derived from low-cost UAV-based remote sensing for geomorphic landform representation**

GOMEZ C., STARHEIM C.

**SfM vs. RTK: FIGHT! (Structure from Motion versus Global Navigation Satellite System Real Time Kinetic)**

KAIN C., GOMEZ C., HART D.

**Three dimensional reconstruction of paleotopography to assess the role of antecedent morphology before and after rapid deposition events**

ZIZIOLI D., NINFO A., MEISINA C., ZUCCA F., PELLEGRINI L.

**3D Mapping of liquefaction phenomena induced by May 2012 Emilia earthquakes (Po Plain, Northern Italy)**

SCHMITT T., BISCARA L., LOUBRIEU B.

**Digital Bathymetric Models (DBM) : multiple sources, multiple uses ... and multiple models. A comparison of known DBM for the Bay of Biscay**

HECKMANN T., SCHWANGHART W., PHILLIPS J.

**Graph theory - recent developments of its application in geomorphology**

OZDEMIR A.

**Spatial distribution of the sinkhole and sinkhole affecting factors in the vicinity of Karapınar (Konya, Central Turkey)**

MALTSEV K., MALTSEV K., YERMOLAEV O.

**River basins of Russian Plane: geomorphometrical analysis and geomorphological zoning**

CORNU J.F., CAROZZA J.M., OBERDORFF T.

**Active hydrological stream network extraction: a GIS approach based on DEM and climate data**

PERSENDT F., GOMEZ C.

**Assessing drainage network extractions in a low-relief area from Lidar-derived DEM and DEM-derived from other data sources: a case study from the Cuvelai Basin, Namibia**

VASCONCELOS V., CARVALHO JUNIOR O.A., MARTINS E.D.S., COUTO JUNIOR A.F., GUIMARÃES R.F., GOMES R.A.T.

**Semi-automated identification of landforms intensity by geomorphometric signature**

TANARRO L.M., CORONA C., STOFFEL M., LUCIA A., BALLESTEROS J.A., TRAPPMANN D.

**Do highly resolved DEMs improve the quality of rockfall model output? - A case study from Central Spain**

RUDAZ B., GAVILLET L., JABOYEDOFF M.

**Geomorphological assessment of alpine watersheds using SLBL and steady-state profiles**

LEROUGE G., ROUSSELIN T., NAVARO B.

**Geomorphologic analysis method using ASTER GDEM v2 digital elevation model over the tropical rainforest: implementation to lakes problematic in Sangha National Park (Central African Republic)**

BACANI V., SAKAMOTO A., QUÉNOL H., LUCHIARI A.

**Remote sensing and GIS for environmental fragility assessment in the upper Coxim River Basin, Brazil**

BERTRAND M., LIÉBAULT F., PIÉGAY H.

**GIS-based methods to evaluate morphometric characteristics of small catchments within a debris-flow susceptibility assessment approach at a regional scale**

REINFELDS I., BONETTI R., BUTLER G., BRODERICK T., CHISHOLM L.

**A multi-scale GIS and hydrodynamic modelling approach to fish passage assessment: Clarence River gorge, NSW Australia**

MORIOKA T., OGUCHI T., LIN Z., YOSHIDA H.

**GIS analysis of asymmetric valleys dissecting Pleistocene uplands in and around Tokyo, Japan**

LIN Z., CHEN J.

**Response of channel offsets to active strike-slip faulting of the Red River fault**

HERMUCHE P., GUIMARÃES R., CARVALHO JUNIOR O., GOMES R.

**Relationship between geomorphology and dry forest in Parana Valley, Goiás, Brazil, using sensor modis images and morphometric data**

CONOSCENTI C., CIACCIO M., GÓMEZ GUTIÉRREZ Á., ROTIGLIANO E., AGNESI V.

**Landslide susceptibility zonation by exploiting GIS tools and two statistical methods: binary logistic regression and multivariate adaptive regression splines. A test in western Sicily (Italy)**

LAHITTE P., LAVIGNE F., GERMA CHARBONNIER A.

**Evolution of volcanic landforms by construction and destruction events constrained from DEM-based numerical reconstructions**

## **Poster presentations .....1149**

RIZZETTO F.

**Use of aerial photograph interpretation and Geographic Information Systems to study tidal channel changes: an example from the Venice Lagoon (Italy)**

PARROT J., RAMIREZ NUÑEZ C.

**River flux modeling**

PARROT J., HERNÁNDEZ M., RAMIREZ NUÑEZ C.

**The logarithmic slope as a critical geomorphological parameter.**

EBERT K.

**GIS analysis as a tool for identification of preglacial large-scale landform assemblages and quantification of glacial erosional impact on northern shields**

SAITO H., MURAKAMI W., DAIMARU H., OGUCHI T.

**Effect of clear-cutting on landslide occurrences: Rainfall thresholds and topographic analysis at Mt. Ichifusa, Japan**

GOMES R., MENKE A., GUIMARÃES R., CARVALHO JÚNIOR O.

**Cluster analysis in watersheds using morphometric parameters in the state of Goiás, Brazil**

HOŁUB B.

**GIS application in morphometric-statistical analysis of relief in the upper Dniester River catchment (East Carpathian Foreland, Ukraine)**

HART D.E., GOMEZ C., BEALING P.

**Coastal Quakes: using global datasets to expose an underrated hazard**

ETZELMULLER B., HJORT J., LILLEOREN K.S.

**Landform prediction and environmental constraints ' examples and geomorphological implications**

ASMARYAN S.

**The ecological-geomorphological assessment of urban areas using GIS (a case study Yerevan)**

VAN DE WIEL M., TEMME A.

**Mass-Conservative Depression Removal from DEMs**

LABUZ T., OSOCH P.

**DTM models of coastal dune relief and dynamics as a tool for coast erosion and flooding prediction**

ALEIXO C., RAMOS-PEREIRA A., TRINDADE J.

**Dynamic effects of catchment morphology in the Alcabrichel estuary, Portuguese Estremadura**

GOMEZ C., WASSMER P., STARHEIM C., HADMOKO D.S., LAVIGNE F.

**Graph theory: the Ford and Fuklerson, and the Edmonds-Karp Algorithms to Model Dynamic Sedimentary Systems**

NAUMENKO M.

**Morphometric models of lake's bottom as necessary tool for limnological investigations**

OCHIAI S., OGUCHI T., HAYAKAWA Y.S.

**Morphometric analysis of alluvial fans and source basins for regions with different climates**

HAEDKE H.

**Multiscale Wavelet Analysis of ASTER DEM to detect geomorphologic and tectonic processes in the Gaxun Nur Basin, China**

DOMINGUEZ-CUESTA M.J., JIMENEZ-SANCHEZ M., RODRIGUEZ-RODRIGUEZ L.

**Visibility and optimal routes from the Roman Camp Site of Via Carisa, Cantabrian Mountains (Asturias, NW Spain)**

SOUZA VALLADARES G., AQUINO R.P., CUNHA COELHO M.F.

**Digital mapping of geomorphological features in a tropical semiarid climate of Ceará State, Brazil**

MIGON P., KASPRZAK M.

**Unexpected geomorphic features of a sandstone tableland revealed by LiDAR-derived DEM**

PRASICEK G., KRAUS A., OTTO J.C., SCHROTT L.

**Generation of morphometric semantics for automated mapping of geomorphological process domains**

WŁOSINSKA M., NIEDZIELSKI T., MIGON P.

**A new method for estimating ocean reference depth**

EISANK C., SMITH M., HILLIER J.

**Supervised testing of segmentation for automated delimitation of landforms in DEMs**

REULIER R., CAILLAULT S., DELAHAYE D., VIEL V.

**Multi-agent modeling as a tool of spatial analysis for monitoring sediment fluxes**

JAVIER L.(1), PHINN S.(2)

**Measuring coral reef terrain roughness from a very-high resolution Digital Elevation Model (DEM) derived from Structure from Motion (SfM) Point Clouds**

LAVARINI C., MAGALHÃES JR A.P., OLIVEIRA F.S.

**Cluster Analysis of Watersheds as a Guideline for the Study and Sampling of Regoliths**

GOMEZ-GUTIERREZ A., CONOSCENTI C., ANGILERI S.E., CARRASCO R.M.

**Determining the optimal pixel size of topographical parameters for the prediction of hazardous geomorphological phenomenons of different magnitude: gullies and landslides**

NINFO A., ZANONER T., GRUBER N., MASSIRONI M., CARTON A.

**DSGSDs diagnostic landforms: a morphometric LiDAR based approach**

MINGUEZ-MENENDEZ A., GARCIA-MELENDEZ E., MARTIN-SERRANO A., SUAREZ-RODRIGUEZ A., RODRIGUEZ-GARCIA A., RODRIGUEZ-FERNANDEZ R.

**Study of the reference levels of erosional surfaces in the western Cantabrian Mountains and Montes de León (northwest Spain) through Digital Elevation Models**

BYUN J., SEONG Y.B.

**New Algorithm to Extract Longitudinal Stream Profiles (LSPs) based on unfilled DEMs**

GHIRALDI L., BACENETTI M., MILLEMACI P., PEROTTI L., GIARDINO M.

**Morphometric and morphotectonic indexes for quantitative geomorphology analysis of the Cannobino drainage basin (Piemonte, NW Italy)**

AQUINO R.P., VALLADARES G.S., COELHO CUNHA M.F.

**Geomorphological units and the risk of erosion in the central hinterland of Ceara, Brazil**

DA SILVA SOUSA A., SOUSA A.

**Fragility environmental analysis of River Basin Caulim - Sao Paulo/SP/Brazil**

CARDOSO-LANDA G.

**Application of a geographical information system to debris flows**

**S26D. STATISTICS IN GEOMORPHOLOGY**

Convenors: *Ian EVANS & Delphine GRANCHER*

**Oral presentations .....1149**

UBER J.A., ZÉZERE J.L., SANTOS L.J.C.

**Susceptibility analysis of landslide in the Bacia Do Marumbi (Morretes/PR) using bivariate and multivariate statistical methods**

VERONESI F., HURNI L.

**Automated geomorphological classification for the creation of rigorous shaded relief maps**

VAUDOR L., PARROT E.

**Interpreting wavelet-based decompositions of geomorphological features: the example of the Rhone river bathymetry**

SCHMELTER M.

**Accounting for uncertainty in fluvial geomorphology using Bayesian statistics**

ECKERT N., LAVIGNE A., PAVLOVA I., THIBERT E., BEL L., GRANCHER D., PARENT E., JOMELLI V., NAVEAU P., BOREUX J.J.

**Hierarchical Bayesian modelling for hydrological spatiotemporal mountain climate proxies**

**Poster presentations .....1151**

ROSSI M., MONDINI A.C., MARCHESINI I., SANTANGELO M., BUCCI F., GUZZETTI F.

**Landslide morphometric signature**

RAMOND S., GRANCHER D., GAUTIER E.

**Statistical approach to analyze evolutions of statistical long-term hydrological data sets on the Loire river (France)**

DELUIGI N., LAMBIEL C., KANEVSKI M.

**The discontinuous spatial distribution of Alpine Permafrost: an application of exploratory spatial data analysis**

THOMMERET N., BAILLY J.S., BARDET J.M., KAISER B., PUECH C.

**Robustness of fractal dimension estimators for vector talweg network characterization**

DIETZE M., DIETZE E.

**A flexible open-source toolbox for robust end-member modelling analysis - The R-package EMMAgeo**

**S26E - DATING METHODS (INCLUDING COSMOGENIC NUCLIDES)**

Convenors: *Andreas LANG & Susan IVY-OCHS*

**Oral presentations .....1157**

AKCAR N., DELINE P., IVY-OCHS S., KUBIK P.W., SCHLÜCHTER C.

**Surface exposure dating of rock avalanche deposits in the Ferret Valley (Mont Blanc massif, Italy)**

MONGE SOARES A., CESÁRIO PORTELA P.J., MATOS MARTINS J.M., RAMOS PEREIRA A.

**Age modelling of Mid-Holocene sedimentary sequences using a Bayesian approach**

MUNYIKWA K., BROWN S., PLUMB E.

**The utility of portable optically stimulated luminescence (OSL) readers in providing temporal contexts in clastic depositional systems: opportunities in geomorphology**

SARIKAYA M., HIMMET H., ATILA Ç.

**Last Glacial Maximum glaciers on Akdağ, southwest Turkey, inferred from cosmogenic <sup>36</sup>Cl dating of moraines**

SEONG Y.B., LEE S.Y., KIM D.E., CHOI K.H., YU B.Y.

**A tragic flood but an invaluable opportunity to build a better model on catchment wide denudation rate (CWDR) using a pair of <sup>10</sup>Be and <sup>14</sup>C**

WIRSIG C., IVY-OCHS S., ZASADNI J., AKCAR N., DELINE P., KOBER F., SCHLÜCHTER C.

**Timing of ice decay after the LGM in the high Alps**

CORONA C., LOPEZ SAEZ J., STOFFEL M., BERGER F.

**A continuous high-resolution 700-yr snow-avalanche chronology from the Queyras massif recorded from tree-ring and historical archives**

**Poster presentations .....1160**

TILLMANN T., ZIEHE D., WUNDERLICH J.

**Amino acid racemization analysis (AAR) as a successful tool for dating Holocene barrier island spit accretion: Examples of Southern Sylt (North Sea/ German Bight)**

MAY S.M., BRÜCKNER H., HILGERS A., KELLETAT D., PÖTSCH S., RIXHON G., ZANDER A.

**Investigations on anthropogenic shell accumulations in the Longotoma dune complex (central Chile) ' geochronological data and palaeoenvironmental context**

CUNHA C., CONCEIÇÃO F.T.D., SIMON A.L.H., PEREZ FILHO A.

**The land use interference on geomorphological aspects and sedimentation rates in the low course of the Piracicaba River basin, São Paulo State, Brazil**

CLAUDE A., IVY-OCHS S., KOBER F., ANTOGNINI M., SALCHER B., KUBIK P.W.

**Surface exposure dating of the Chironico landslide (Leventina valley, southern Swiss Alps)**

CLAUDE A., AKÇAR N., IVY-OCHS S., GRAF H.R., KUBIK P., VOCKENHUBER C., DEHNERT A., MEINERT R., SCHLÜCHTER C.

**Cosmogenic nuclide dating of Swiss Deckenschotter**

REBER R., TIKHOMIROV D., AKÇAR N., YESILYURT S., YAVUZ V., KUBIK P.W., SCHLÜCHTER C.

**Late Pleistocene Glacier advances in North Anatolia deduced from cosmogenic <sup>10</sup>Be and <sup>26</sup>Al**

CSILLAG G., RUSZKICZAY-RÜDIGER Z., NOVOTHNY Á., THAMÓ-BOZSÓ E., FODOR L.I., BRAUCHER R.

**Geochronology of Danube terraces in Hungary, using cosmogenic <sup>10</sup>Be and luminescence dating**

TSODOULOS I., STAMOULIS K., PAPACHRISTODOULOU C., IOANNIDES K., PAVLIDES S., CHATZIPETROS A., KOUKOUVELAS I.

**Quantification of optically stimulated luminescence dating uncertainties based on the analysis of samples collected from a paleoseismological trench of an active fault in Central Greece**

MESSERLI M., IVY-OCHS S., MAISCH M.

**GIS-based geomorphological mapping, dating of selected landforms and landscape evolution during the Lateglacial and Holocene, in the region of Val Tuoi, Grisons, Switzerland**

HUANG H., MAY J.H., FINK D., WRAY R., GU J.

**Assessing processes and timescales of sandstone landscape formation in Zhangjiajie Geopark of China**

GOLOSOV V., WALLING D., BELYAEV V.

**Application of fallout radionuclides for investigating recent overbank sedimentation rates on river floodplains: potential and limitations**

## **S26F - APPLIED GEOMORPHOLOGICAL MAPPING (IAG-WG)**

Convenors: *Michael SMITH, Paolo PARON & Jim GRIFFITHS*

### **Oral presentations .....1169**

SZEFLER K., TEGOWSKI J., NOWAK J.

**Spectral properties of Southern Baltic bottom roughness**

GRIFFITHS J.

**Geomorphological mapping of an active landslide on the south-east coast of the Isle of Wight, U.K.**

PANI P.

**Geomorphological mapping of himalayan terrain using multi-sensor data: a case study of himachal pradesh, India**

BUCCOLINI M., COCO L., ARINGOLI D., MATERAZZI M.

**The influence of slope morphometry on erosion processes: the application of MSI (Morphometric Slope Index)**

BOURENANE H., BOUHADAD Y.

**Landslide susceptibility zonation using bivariate statistical analysis and GIS in Constantine city (North East of Algeria)**

ISLAMI N.

**Subsurface geomorphology of the North Kelantan Plain, as revealed by geoelectrical resistivity surveys**

BARBOSA SOARES NETO G., SOUZA MARTINS É., VASCONCELOS V., LLACER ROIG H., B. J. MENEZES P.H.

**Methodological procedures of digital geomorphological cartography in brazilian Central Plateau**

NICULITA M.

**Open Geomorphological Map. Romanian case study**

### **Poster presentations .....1173**

BEN FRAJ T.

**Geomorphological map of Northern Jeffara plain and North-eastern part of Matmata-Dahar plateau (Southeast Tunisia) 1/100 000**

RAMOS A., CUNHA L., CUNHA P.

**Geomorphological mapping applied to regional planning and geoheritage: study on Figueira da Foz Nazaré area (western central Portugal)**

CUNHA E., BACANI V., FACINCANI E., SAKAMOTO A., LUCHIARI A.

**Remote sensing and gis applied to geomorphological mapping of the watershed stream Indaia, MS, Brazil**

BUZJAK N., PAHERNIK M., FAIVRE S., BOCIC N.

**Geomorphological map of Croatia 1:100.000**

MAILLARD B., REYNARD E., KUMMERT M., LAMBIEL C., THELER D.

**The geomorphological map of the Hérens valley (Switzerland)**

SCHOENEICH P., LAMBIEL C., BOSSON J.B.

**Geomorphological map of the Diablerets massif - Swiss Alps**

LAMBIEL C., MAILLARD B., MARTIN S., PELLITERO ONDICOL R., SCHOENEICH P., REYNARD E.

**Adaptation of the geomorphological mapping system of the University of Lausanne for ArcGIS**

MOEINI A., ALIZADE A., AHMADI H., ETEMAD V.

**Survey the relationship between geomorphology and forest types (Case study: Kheirod forest, North of Iran)**

DZIEDUSZYNSKA D., WACHECKA-KOTKOWSKA L.

**The main geotouristic objects in the Lodz region (Central Poland)**

**Hydrogeomorphological mapping in hard-rock groundwater systems**

TEIXEIRA J., FREITAS L., AFONSO M.J., ROCHA F., PEREIRA A.J.S.C., MARQUES J.M., CHAMINE H.I.

NGUYEN XUAN N.

**Geomorphological analysis on the geological formations in downstream valley of the Da River, the Western Hanoi City, Vietnam**

PARRY S.

**Use the of engineering geomorphological mapping for landslide hazard assessments in Hong Kong**

COMANESCU L., NEDELEA A., ZAHARIA L., SAFTOIU L.

**Mapping flood vulnerability. Case study: Tecuci Town (Romania)**

PIACENTINI T., MICCADEI E., DI MICHELE R., RANALLI O., SCIARRA M., URBANO T.

**Multi-scale and multi-purpose Geomorphological Mapping for landscape evolution, geotourism, slope instabilities, and medical geology**

PLATONOVA S.

**Ecological-geomorphological features of transboundary interaction in the Irtysh river basin**

GUITET S., RICHARD-HANSEN C., BRUNAU X O., CORNU J.F., CAROZZA J.M.

**Geomorphology explains the regional beta-diversity of French Guiana rainforest and furnishes consistent maps to optimize forest management, regional planning and biodiversity conservation**

REVELLINO P., GUERRIERO L., COE J.A., GRELE G., GUADAGNO F.M.

**Multi-temporal mapping of a large, slow-moving earth flow for kinematic interpretation**

BINI M., BARONI C., RIBOLINI A., ANICHINI F., GATTIGLIA G., PARIBENI E.

**A new interdisciplinary approach to build a geomorpho-archaeological map: the case study of the Versilia plain (NW Italy)**

RODRIGUES S.C., MARTINS T.I.S.

**Geomorphological Map of Piumhi Topographical Sheet (1:50.000) - Minas Gerais - Brazil**

TERUGGI L.B., CHIAVERINI I., OSTUNI D., FARENGA M.

**Database development for mapping fluvial channel variations: case study Cecina River (Central Italy)**

BACENETTI M., PEROTTI L., GIARDINO M.

**Using geospatial mobile applications and devices for geomorphological field data collection in mountain areas: a comparison test**

*EL GHACHI M., EL KHALKI YAHIA*

**Les inondations urbaines dans la ville de Khénifra (pied du Moyen Atlas occidental, Maroc) : caractérisation et cartographie**

*PEREIRA D., SANTOS L., PEREIRA P., SILVA J., HENRIQUES R.*

**Geomorphological units of Mainland Portugal: definition and mapping**

*TERUGGI L.B., MARIN E., CAPORALI E., VACCARO C., SALA S., KRISTENSEN M.J.*

**A GIS based interdisciplinary analysis of Río Quequén Grande watershed in Argentina**

*ZWOLINSKI Z.*

**Geomorphological mapping in Poland**

*KEESSTRA S., MARRUEDO ARRIBITA A., LASSU T., SEEGER M.*

**Rainfall intensity, aggregate stability, shear stress resistance as parameters to evaluate soil erosion by water: an experimental study**

## **S27. YOUNG GEOMORPHOLOGISTS SESSION**

Convenors: *Etienne COSSART, Johnny DOUVINET & Stuart LANE*

### **Oral presentations .....1189**

*LELEN M.*

**Morphometry of talus slopes in the high mountains methodological problems**

*PERRIER R., COSSART E., FORT M.*

**Thermal regime of ground surface in the French Southern Alps: a case study from the Clarée and Ubaye valleys**

*LOPEZ SAEZ J.*

**Recent contributions of dendrogeomorphology for the study of mass movements in an Alpine context**

*D'ARCY M., WHITTAKER A., RODA BOLUDA D., ALLEN P.*

**New constraints on landscape sensitivity to glacial-interglacial climate change: A detailed and quantitative record from debris flow deposits in Owens Valley, California**

*REULIER R., DELAHAYE D., VIEL V., CAILLAULT S., ABDELKRIM B., DAVIDSON R.*

**Study of the spatial interactions in the hydrosedimentary transfers on agricultural watershed**

*CARABALLO ARIAS N., CONOSCENTI C., DI STEFANO C., FERRO V.*

**Morphometric analysis of two calanchi areas in Sicily (Italy) by exploiting high resolution Digital Elevation Models**

*NURWIHASTUTI D., NURWIHASTUTI D.W., SARTOHADI J., MARDIATNO D., NEHREN U.*

**Spatial Correlation between Geomorphological and Subsurface Characteristics: A Case Study of Bantul, Yogyakarta, Indonesia**

*SAMSONOVA S.*

**Geomorphic mapping for environmental management in urban areas (case study of Moscow parks)**

*SEKARSARI P., GURNEL A.M., HENSHAW A.J., ZOLEZZI G.*

**Exploring geomorphic and vegetational features of low energy rivers using Google™ Earth**

*CREPY M., CALLOT Y.*

**Typology of eolian landforms of South Kharga oasis (Western Desert of Egypt): original evolution models and local specificities of Saharan loess deposits**

### **Poster presentations .....1194**

*MANDAL S., SARKAR S., BOSE P.K.*

**Tectonic sway on alluvial fan trilogy at Himalayan foothills**

STARHEIM C., GOMEZ C., DAVIES T., OWENS I., HADMOKO D.S., WASSMER P., LAVIGNE F.  
**Identifying complex internal architecture in debris flow and lahar deposits using ground penetrating radar**

MAKANZU IMWANGANA F., MOEYERSONS J., NTOMBI M.  
**The use of a rain simulator as an infiltrometer at Kinshasa (D.R. Congo)**

CESCON A.L., COOPER J.A.G., JACKSON D.W.T.  
**Spatial distribution of beach ridges in the Intra-Americas Seas islands: a supervised manual investigation using Google Earth**

ZOUVA C., GAKI-PAPANASTASSIOU K.  
**A methodological framework for the spatial decision support of the management of coastal wetlands**

GIL H., SORIANO M.A., LUZÓN A., PÉREZ A., POCOVÍ A.  
**Interaction of tectonic, karstic and sedimentary processes in Early Pleistocene deposits (central Ebro Basin, NE Spain)**

BRISSET E., MIRAMONT C., GUITER F., TROUSSIER T., ANTHONY E., ARNAUD F.  
**Lake Allos: a 12,000 year reference record of past climate-Human-environment interactions in the Mediterranean French Alps**

HAQUE N., SHAMSUZZAMAN ..., RAHMAN M.A., EKRAM A.R., UDDIN N., HASAN F.  
**Geomorphology of Sylhet City, Bangladesh - for Sustainable Urban Planning**

ADAM A.  
**Assessing the impact of the pipeline on the swamp geosystems**

WERB S., DELGADO J.M., BRONSTERT A.  
**Modelling sediment transport: Evaluating the effects of spatially refined input data**

GO A., TANAKA Y., KASHIMA K.  
**Sedimentary environment of Hwajinpo lake using diatom analysis**

SANDER L., KABUTH A.K.  
**I just can't put my finger on it! Understanding coastal lagoon systems from remotely sensed data - A case-study comparison from Denmark and Argentina**

CHMIELOWSKA D.  
**Characteristics of loam deposits as indicators of their sedimentary environment in the Late Glacial, example from Nowy Targ-Orava Basin, southern Poland**

LINOIR D., THOMACHOT-SCHNEIDER C., FRONTEAU G., MALAM ISSA O., BARBIN V.  
**Hydric properties of carbonates accumulation horizons in Chalky Champagne (NE of Paris Basin, France)**

MAJEWSKI K.  
**Application of terrestrial digital photography and free computer software in generating digital terrain models and geomorphological analysis**

LI S., ZHANG K.  
**Research on the relationship between alluvial fans and the mountain uplift in Northwestern China based on GIS technique**

## Key-note lectures





## Geomorphology of Ethiopia and Human Origins

ASFAWOSSEN ASRAT

SCHOOL OF EARTH SCIENCES, ADDIS ABABA UNIVERSITY, P. O. BOX 1176, ADDIS ABABA, ETHIOPIA  
([asfawossen.asrat@aau.edu.et](mailto:asfawossen.asrat@aau.edu.et); [asfawossena@gmail.com](mailto:asfawossena@gmail.com))

Ethiopia is endowed with unique geomorphologic setting where the great East African Rift bisects the uplifted Ethiopian highlands, leading to diverse geomorphologic processes resulting in equally diverse landforms. Ethiopia has also proved to be the true "cradle of humanity" where more than 90% of the Australopithecus afarensis sp. discovered so far (including the famous A. Afarensis, "Lucy") are from Ethiopia. Furthermore, the earliest fossil remains of H. sapiens have been found in Ethiopia dating back to 195 ka, and to between 160 and 154 ka suggesting that East Africa was the likely region of the origin of our species. Many archaeological, palaeontological and geological evidences also suggest that Early Modern Humans expanded their geographical range throughout the rest of the world starting from eastern Africa as of ca. 125 Ka. However, the environmental context of these discoveries has not been fully assessed. This paper postulates and shows that the geomorphological setting of Ethiopia played a significant role in human origins and dispersal by modulating the environmental (ecological) setting and local climatic conditions. Geological, Geomorphologic, palaeoanthropological and archaeological data from all over eastern Africa are reviewed and presented. High resolution palaeoclimatic data from lake and speleothem archives are used to interpret the environmental context of human origins and dispersal. This paper further shows that geomorphology of the country, i.e., the isolation of the northwestern highlands (where the political centers of the country have been located) from the external world by the harsh Afar depression close to the sea, determined the route of Ethiopian civilization and history.

\*\*\*\*\*

## La Géomorphologie de l'Éthiopie et les Origines de l'Homme

ASFAWOSSEN ASRAT

SCHOOL OF EARTH SCIENCES, ADDIS ABABA UNIVERSITY, P. O. BOX 1176, ADDIS ABABA, ETHIOPIA  
([asfawossen.asrat@aau.edu.et](mailto:asfawossen.asrat@aau.edu.et); [asfawossena@gmail.com](mailto:asfawossena@gmail.com))

L'Éthiopie bénéficie d'un contexte géomorphologique exceptionnel. À cheval sur le grand Rift Est Africain qui scinde en deux les hauts plateaux éthiopiens soulevés, cette situation induit des processus géomorphologiques divers, se traduisant par des formes de relief tout aussi diverses. Il est désormais acquis que l'Éthiopie est le véritable «berceau de l'humanité», où plus de 90% des Australopithecus afarensis sp. ont été découverts à ce jour (y compris la célèbre «Lucy», A. afarensis). De plus, les premiers restes fossiles de Homo sapiens trouvés en Éthiopie remontent à 195 ka, d'autres sont d'âge compris entre 160 et 154 ka, ce qui laisse à penser que l'Afrique de l'Est est probablement bien la région d'apparition de notre espèce. De nombreux témoignages archéologiques, paléontologiques et géologiques suggèrent également que les premiers hommes modernes ont, à partir de ca. 125 ka, élargi leur emprise spatiale depuis l'Afrique orientale à travers le reste du monde. Toutefois, le contexte environnemental de ces découvertes n'a pas été pleinement évalué. Cette présentation émet l'hypothèse et montre comment le cadre géomorphologique de l'Éthiopie a joué un rôle important dans les origines de l'Homme et de sa dispersion, en offrant des conditions écologiques modulées par l'étagement des milieux et des conditions climatiques locales favorables. Les données géologiques, géomorphologiques, paléoanthropologiques et archéologiques de toute l'Afrique de l'Est sont examinées et présentées. Le recours aux archives paléoclimatiques de haute résolution telles que les sédiments lacustres et les spéléothèmes permet d'interpréter le contexte environnemental des origines de l'Homme et de sa dissémination. Cette présentation montre en outre comment la géomorphologie du pays, notamment l'existence en bordure de mer de la dépression de l'Afar, quasi inhabitable, a conduit à l'isolement du reste du monde de la région montagneuse du nord-ouest –là où se trouvent les centres politiques du pays–, déterminant ainsi la voie de la civilisation éthiopienne et de son histoire.

## Tales from the deep

BRUNSDEN DENYS  
KING'S COLLEGE, LONDON  
(brunsden@chideock.co.uk)

A conference entitled 'Seismic Geomorphology,' held in Houston, Texas in 2009, was organized by the geophysical profession, the petroleum industry and the Geological Society of London. It was advertised with the words:-

"We are poised to embark on a new era of discovery in the study of geomorphology. The discipline has a long and illustrious history, but in recent years an entirely new way of studying landscapes and seascapes has been developed."

This paper discusses this significant challenge to our discipline from outside our area of expertise. The central point is that we probably know more about the surface of the Moon or Mars than we do about the ocean floor. Of course we have an excellent general picture at a large scale but only where there are industrial, conservation or oceanographic imperatives have specifically commissioned detailed studies been carried out. Perhaps only < 2% of the sea floor is known at high resolution.

Yet, the sea floor occupies 71% of the Earth's surface, some 361,419,000 km<sup>2</sup>. It is truly the last geomorphological frontier. This paper attempts to describe some of the problems we face as we attempt to describe, in detail, this huge area, its landforms and processes for the first time.

Geomorphology is now routinely included in sea floor surveys but the work is mainly carried out by oceanographers, geophysicists, geologists, sedimentologists, geomechanics or geo-chronological experts. Few geomorphologists have the software or interpretation skills required.

Primary interests for geomorphological inputs are planning data acquisition programs, site characterization, interpreting ground conditions, sediment transfer systems, geohazards identification and risk evaluation all set within the frameworks of palaeo-oceanography and contemporary met-ocean research.

The lecture cannot cover all of these fields or indeed 71% of the planet. It therefore concentrates the morphological aspects that can be contributed to the inter-disciplinary teams. Any specialist will know that many spectacular technical advances are not discussed. Instead the lecture concentrates on geomorphological problems, grand visions and conceptual developments.

Brief examples of ocean floor discovery and current technical capability are followed by outlines of environmental, structural, tectonic controls of ocean landforms and sediment transfer systems; the nature of onshore-offshore connections, environmental change and biodiversity. Emphasis is placed on geomorphological mapping of the sea floor.

Critical discussions include:

- The types, distribution and scales of ocean floor processes.
- The process controls, causative factors, triggers and recurrence intervals of events.
- The nature of landform inheritance and multi-cyclicality.
- The influence depth of sea level change.
- The nature of high energy events, new benthic storm processes.
- Event calibration and
- The sea floor as a record of the continents.

World- wide examples are used in illustration.

The paper also outlines eight primary tasks for offshore process geomorphology.

\*\*\*\*\*

## Histoires des profondeurs

BRUNSDEN DENYS  
KING'S COLLEGE, LONDON  
(brunsden@chideock.co.uk)

La conférence intitulée «Géomorphologie sismique», qui s'est tenue à Houston (Texas) en 2009, avait été organisée par les géophysiciens professionnels, l'industrie pétrolière et la Société Géologique de Londres. On en avait fait la publicité en ces termes: "Nous sommes prêts à nous engager dans une nouvelle ère de découvertes grâce aux études de géomorphologie. Cette discipline a non seulement une histoire longue et illustre, mais elle a aussi, au cours des dernières années, développé une toute nouvelle façon d'appréhender les paysages terrestres et marins. "

Cet exposé aborde ce grand défi pour notre discipline, dans un champ jusque là en dehors de notre domaine d'expertise. Le point central est que nous en savons probablement plus sur la surface de la Lune ou de Mars que sur le plancher océanique. Certes, nous avons une excellente connaissance générale à petite échelle, mais seulement là où les impératifs industriels, océanographiques ou de conservation ont spécifiquement requis la réalisation d'études détaillées. Peut-être <2% seulement de la surface de la mer sont connus avec une haute résolution. Et pourtant, le fond des mers occupe 71% de la surface de la Terre, soit 361.419.000 km<sup>2</sup>, et c'est pourquoi il constitue vraiment la dernière frontière géomorphologique. Cette présentation vise à décrire quelques-uns des problèmes auxquels nous, en tant que géomorphologues, sommes confrontés alors que nous tentons de décrire, en détail et pour la première fois, ce vaste espace, ses reliefs et ses processus.

La géomorphologie est désormais systématiquement incluse dans les recherches sur le plancher océanique, mais le travail est principalement effectué par des experts océanographes, géophysiciens, géologues, sédimentologues, géomécaniciens ou géo-chronologistes. Rares sont les géomorphologues qui ont les compétences requises en terme de logiciels ou d'interprétation.

Dans le cadre de recherches contemporaines menées en paléo-océanographie et sur les relations météorologie-océanographie, les apports majeurs de la géomorphologie sont les suivants : la planification des programmes d'acquisition de données, la caractérisation du site, l'interprétation des conditions au sol, les systèmes de transfert des sédiments, l'identification des risques géologiques et l'évaluation des risques.

Cette conférence ne peut couvrir tous ces domaines, ni 71% de la planète. Elle se concentrera donc sur les aspects morphologiques qui peuvent contribuer de façon importante aux équipes interdisciplinaires. On ne discutera pas des nombreux progrès techniques spectaculaires réalisés. On insistera en revanche sur les problèmes géomorphologiques posés, les visions d'ensemble et les développements conceptuels.

Après l'exposé rapide d'exemples de découvertes actuelles du plancher océanique et des capacités techniques en cours, on présentera les facteurs environnementaux, structuraux et tectoniques qui conditionnent les reliefs océaniques, ainsi que les systèmes de transfert des sédiments, la nature des connexions continent-océan, les changements environnementaux et la biodiversité. L'accent sera mis sur la cartographie géomorphologique des fonds marins.

Plusieurs éléments de discussion critique porteront sur :

- Les types, la distribution et les échelles de processus agissant au niveau du plancher océanique.
- Les facteurs de contrôle des processus, les facteurs de déclenchement, et les intervalles de récurrence des événements.
- La nature des héritages géomorphologiques et de la multi-cyclicité.
- La profondeur de l'influence de la variation du niveau marin.
- La nature des événements à haute énergie et des nouveaux processus de tempêtes benthiques.
- L'étalonnage de l'événement et
- Le fond de la mer comme enregistrement de tous les continents.

La conférence sera illustrée par des exemples choisis dans le monde entier.

On terminera par la définition des huit principales tâches à mettre en œuvre pour une géomorphologie des processus sous-marins.

**Spatially non-uniform landscape evolution and process-operations around the Tropic of Capricorn: the role of extreme rainfall events.**

COELHO-NETTO ANA-LUIZA

LABORATORIO DE GEO-HIDROECOLOGIA, INSTITUTO DE GEOCIENCIAS, DEPARTAMENTO DE GEOGRAFIA,  
UFRJ-UNIVERSIDADE FEDERAL DO RIO DE JANEIRO JANEIRO, BRAZIL  
(ananetto@acd.ufrj.br)

Classical geomorphology valued the relationships between bio-climatic zoning and the dominant morphogenetic evolutionary pattern. Humid Tropical landscapes were seen as related to slow and progressive chemical denudation to form the so-called etchplanation. Long term field studies in SE-Brazil, however, provide evidences of highly discontinuous processes operations and evolutionary patterns both on space and time. At middle Paraíba do Sul river valley, i.e., stratigraphic data and absolute dating together with hillslope morphological characteristics and weathering-transport relationships, point out the dominance of mechanical denudation (by gullying due to delayed responses of seepage erosion relative to regional rainfall inputs and consequent landslides) over chemical denudation in some major tributary basins draining serra do Mar, but not at all major tributary basins draining serra da Mantiqueira where chemical denudation landforms still prevail. The underlying bedrock and inherited tectonic structures, together with basin relief seems to explain such variations in the hilly lowlands. In contrast, all mountainous compartments are quite vulnerable to mechanical denudation especially related to gravitational transport (mass movements). Wet seasons and extreme rainfalls are usually associated with fast movements by shallow landslides, rock fall and debris flows that may cause disasters. The very extreme landslide disaster from January 2011 spread over large areas of the mountainous domain in Rio de Janeiro state causing more than 1,500 deaths and intense social, environmental and economic losses. Facing the magnitude of landscape changes in response to this climatic event, one might consider the relevance of very extreme rainfall inputs on landscape evolution in mountainous areas but not necessarily in the complex hilly lowlands as it will be discussed in this lecture.

\*\*\*\*\*

**Evolution de paysage spatialement non-uniforme et action des processus autour du Tropique du Capricorne : le rôle des événements pluviométriques extrêmes.**

COELHO-NETTO ANA-LUIZA

LABORATORIO DE GEO-HIDROECOLOGIA, INSTITUTO DE GEOCIENCIAS, DEPARTAMENTO DE GEOGRAFIA,  
UFRJ-UNIVERSIDADE FEDERAL DO RIO DE JANEIRO JANEIRO, BRAZIL  
(ananetto@acd.ufrj.br)

La géomorphologie classique insiste sur les relations entre les zones bio-climatiques et le modèle dominant de l'évolution morphogénétique. Les paysages tropicaux humides ont été considérés comme étant le produit d'une dénudation chimique lente et progressive, ce que l'on a appelé "etchplanation". Des études de terrain sur le long terme, menées dans le SE-Brésil, ont cependant apporté la preuve qu'il existe des actions discontinues, dans l'espace et le temps, des processus et des séquences d'évolution. Dans la moyenne vallée du Paraíba do Sul, à partir des données stratigraphiques et de datations absolues, combinées aux caractéristiques morphologiques des versants et aux relations météorisation-transport, on a pu mettre en évidence la prédominance de la dénudation mécanique sur la dénudation chimique : érosion par ravinement, liée aux actions de soutirage différé par rapport aux entrées pluviométriques régionales, et érosion par glissements de terrain. Ceci a été observé dans certains bassins tributaires majeurs qui drainent la Serra do Mar, mais en revanche pas dans tous les grands bassins tributaires de la Serra da Mantiqueira, où la dénudation chimique l'emporte encore. Le socle rocheux sous-jacent et les structures tectoniques héritées, en même temps que l'amplitude topographique des bassins, semblent expliquer de telles variations dans les bas plateaux vallonnés. En revanche, tous les secteurs de montagne sont très vulnérables à la dénudation mécanique, en particulier au transport gravitaire (mouvements de masse). La saison des pluies et les précipitations extrêmes vont généralement de pair avec le développement de glissements de terrain rapides et superficiels, d'éboulements et de coulées de débris qui peuvent engendrer de vrais désastres. Tel fut le cas en Janvier 2011, où se produisit une catastrophe extrême caractérisée par des mouvements de terrain qui ont affecté de vastes zones du domaine montagneux de l'Etat de Rio de Janeiro, et ont causé plus de 1.500 morts ainsi que d'immenses pertes socio-économiques et environnementales. Face à l'ampleur des changements engendrés dans le paysage en réponse à cet événement climatique, on doit s'interroger sur le rôle des apports pluviométriques extrêmes sur l'évolution du paysage dans les zones de montagne, rôle pas nécessairement aussi important dans les bas plateaux vallonnés complexes, comme il sera discuté dans cette conférence.

## Geomorphology of earth-like planetary surfaces

BAKER VICTOR R.

DEPARTMENT OF PLANETARY SCIENCES, THE UNIVERSITY OF ARIZONA, TUCSON, ARIZONA, 85721, USA

([baker@email.arizona.edu](mailto:baker@email.arizona.edu))

Recent advances in astronomy hold the prospect for the discovery of a great many Earth-like planets, rich in both water and possible habitats for life. Nevertheless, until it proves possible to do the geomorphology for these potential exo-Earths, we can greatly advance the science of Earth-like planetary surfaces through studies in our own solar system. Recent discoveries from Mars missions reveal the extensive role of water in shaping ancient Martian landscapes, including the formation of channels and valleys, alluvial fans and deltas, aqueous weathering products (clay minerals and sulfates), glacial and periglacial features, paleolakes, and even a probable, though transient ancient ocean. The surface of Saturn's moon Titan has extensive networks of fluvial features, but the responsible fluid is methane, which seems to be cycled on Titan in much the same way that water is on Earth. Venus has a spectacular variety of volcanic features, including some that mimic aspects of fluvial landscapes. Such discoveries are leading to the recognition of the importance for Earth itself of processes, features and relationships that are better displayed on other planetary surfaces, including important roles for impact cratering, large-scale volcanism, and megaflooding.

\*\*\*\*\*

## Géomorphologie des surfaces planétaires telluriques

BAKER VICTOR R.

DEPARTMENT OF PLANETARY SCIENCES, THE UNIVERSITY OF ARIZONA, TUCSON, ARIZONA, 85721, USA

([baker@email.arizona.edu](mailto:baker@email.arizona.edu))

Les progrès récents de l'astronomie entretiennent la perspective de découverte d'un grand nombre planètes telluriques, riches en eau et recelant des habitats de vie possibles. Néanmoins, avant qu'il ne s'avère possible d'étudier la géomorphologie de ces exo-Terres potentielles, nous pouvons faire beaucoup progresser la planétologie à partir d'études dans notre propre système solaire. Les découvertes issues des récentes missions sur Mars révèlent le rôle important de l'eau dans le façonnement des paysages martiens anciens, avec notamment la formation de chenaux et de vallées, de cônes alluviaux et de deltas, de produits de météorisation hydratés (minéraux argileux et sulfates), des traces de façonnements glaciaires et périglaciaires, de paléo-lacs, et même un probable, bien qu'éphémère océan antique. La surface de Titan, lune de Saturne, possède de vastes réseaux de systèmes fluviaux, mais le fluide responsable en est le méthane, qui semble sur Titan être recyclé pour une large part de la même manière que l'eau l'est sur Terre. Venus présente une variété impressionnante de formes volcaniques, dont certaines prennent même les apparences de paysages fluviaux. Ces découvertes amènent à prendre en considération, pour la Terre elle-même, des processus, des formes et des interactions qui sont mieux mis en évidence sur d'autres surfaces planétaires, ceci afin de mieux comprendre en particulier leur rôle dans la formation des cratères d'impact, du volcanisme à grande échelle, et des crues géantes terrestres.

## **Geomorphology and palaeoenvironmental changes in arid Asia**

XIAOPING YANG

*INSTITUTE OF GEOLOGY AND GEOPHYSICS, CHINESE ACADEMY OF SCIENCES, P.O. BOX 9825,  
BEIJING 100029, CHINA.  
(xpyang@mail.igcas.ac.cn)*

Located in the interior of the largest continent, Eurasia, the arid regions of Asia are distributed in a wide range of tectonic settings, from 155 m below sea level to more than 5000 m above sea level. Under dynamic fluvial, aeolian, lacustrine processes and the interactions between those, a great diversity of landforms occurs in these arid regions, with a high percentage of active sand seas in the desert landscape. This lecture reviews our current understanding of formation and Quaternary changes of these desert landscapes, a key portion of the middle-latitude drylands on Earth. Combining earlier studies with our recent work, we aim to offer a comprehensive picture of the formation of the diverse desert landforms and their Quaternary changes and identify knowledge gaps. Here we focus on two aspects: formation of megadunes and late Quaternary environmental changes in the deserts of northern China. Our field sites refer mainly to the Tarim Basin of southern Xinjiang, the Alashan Plateau of western Inner Mongolia and the Hunshandake Sandy Land of eastern Inner Mongolia, all characterized by occurrences of sand dunes at present time. Our geophysical investigation of dune bodies in the Badain Jaran Desert of western Inner Mongolia reveals that the height of dunes is highly sensitive to local geology and interactions between changing climate conditions, both of these aspects have been neglected in the studies of the dune formation so far. Our recent palaeoenvironmental investigations confirm that great geomorphological, climatic and hydrological changes have taken place in these regions during the Late Quaternary, and the extent and intensity of human activities in these drylands during some periods of the Holocene were surprisingly greater than previously assumed. The acute risk of some potentially unsustainable land management practices in these drylands will be briefly discussed also.

\*\*\*\*\*

## **Géomorphologie et changements paléo-environnementaux dans l'Asie aride**

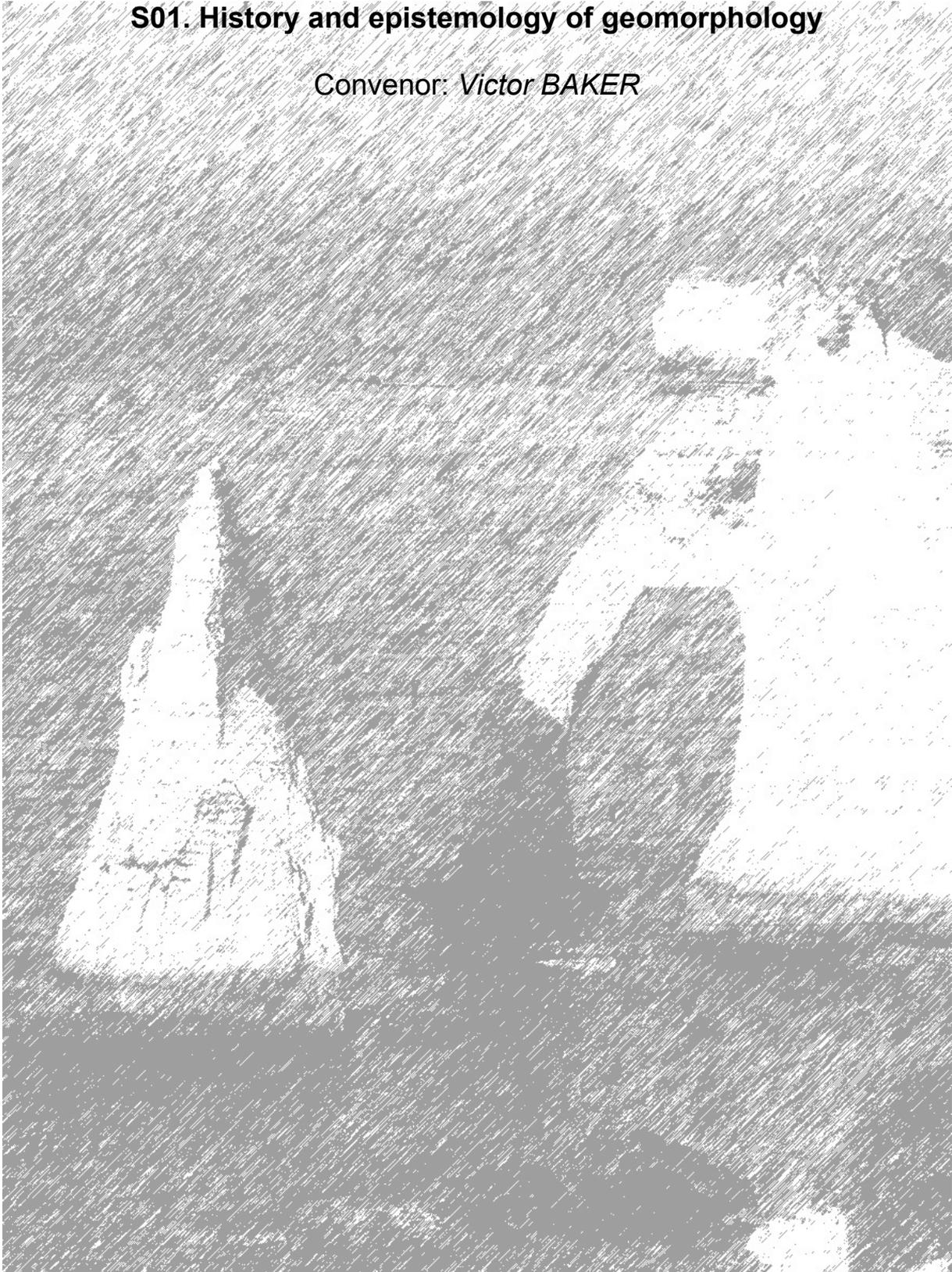
XIAOPING YANG

*INSTITUTE OF GEOLOGY AND GEOPHYSICS, CHINESE ACADEMY OF SCIENCES, P.O. BOX 9825,  
BEIJING 100029, CHINA.  
(xpyang@mail.igcas.ac.cn)*

Situées au milieu du plus grand continent, l'Eurasie, les régions arides de l'Asie couvrent un large éventail de contextes tectoniques, depuis -155 m en dessous du niveau de la mer à plus de 5000 m d'altitude. Grâce aux processus dynamiques fluviaux, lacustres, ou éoliens, ainsi qu'aux interactions de ces différents processus entre eux, des formes de relief très diverses ont pu se développer dans ces régions arides, avec notamment un pourcentage élevé de mers de sable actives. Cette conférence fait l'état de l'art de notre compréhension actuelle de la formation et des changements quaternaires de ces paysages désertiques, éléments clés des terres arides des latitudes moyennes sur Terre. Partant des études antérieures et de nos travaux récents, notre objectif est de présenter une synthèse globale de la formation des reliefs désertiques et leurs divers changements au cours du Quaternaire afin d'identifier les lacunes dans les connaissances. Nous nous concentrerons ici sur deux aspects : la formation des méga-dunes et les changements environnementaux quaternaire dans les déserts du nord de la Chine. Nos sites sur le terrain concernent principalement le bassin du Tarim au sud du Xinjiang, le Plateau d'Alashan à l'ouest de la Mongolie intérieure, et le Pays Sableux de Hunshandake de l'est de la Mongolie intérieure, tous ces sites étant actuellement caractérisés par la présence de dunes de sable. Nos recherches géophysiques sur les ensembles dunaires dans le désert de l'ouest de Badain Jaran en Mongolie intérieure révèlent que la hauteur des dunes est très sensible à la géologie locale et aux interactions entre des conditions climatiques changeantes, ces deux aspects ayant été négligés jusqu'à présent dans les études sur la formation des dunes. Nos dernières recherches de terrain confirment que de grands changements paléo-environnementaux, géomorphologiques, climatiques et hydrologiques, se sont produits dans ces régions au cours du Quaternaire tardif et que, au cours de certaines périodes de l'Holocène, les activités humaines ont eu dans ces terres arides une emprise et une intensité étonnamment plus grandes qu'on ne le pensait jusqu'à présent. Le risque aigu de certaines pratiques potentiellement non durables de gestion des terres dans ces régions arides sera également brièvement discuté.

**S01. History and epistemology of geomorphology**

Convenor: *Victor BAKER*





## **Oral presentations:**

### **The relationship between art and the consolidation of american geomorphology during the nineteenth century**

FERRAZ M., VITTE A.  
UNICAMP, CAMPINAS, BRAZIL

This essay intends to establish the relationships between the consolidation of North American geomorphology and the arts, especially landscape painting of the XIX Century. Currently, modern science is going through a revision of its paradigms, and the historic fragmentation of science is also being affected. This makes it possible for new perspectives, which are also interdisciplinary, to be adopted.

The concept of landscape art permits dialogue between geography and the arts because it was a fundamental concept for the systemization of the science of geography as well as the study of geomorphology. Landscape art was the artistic genre of greatest significance in the United States during this period.

The XIX Century was marked by deep changes in North American society and science. During that time a national identity was being sought, and since there were no great historic precedents, they exalted nature through landscape painting. This expanded and stabilized the scientific community. The same effect occurred with geomorphology.

The expeditions to explore the American West were made by explorers who relied on the help of artists to depict the "new" artistic landscaping, artists who adopted a new vision for the representation of landscapes, based on natural history and sciences, producing a new vision of nature. Likewise, the westward expeditions also contributed to the unfolding of new theories of geomorphology.

Some artists would collect patterns of rocks, fossils and ores. They also read scientific theories and incorporated concepts of geomorphology into their works. As some examples, we have Thomas Cole, Sanford Robinson Gifford and Albert Bierstadt. Robinson and Bierstadt participated in expeditions to the West.

In conclusion, the landscape art movement of the XIX Century integrates concepts of nature and culture.

\*\*\*\*\*

### **The glacial trough - an attempt at theoretical geomorphology**

SCHOENEICH P.  
Institut de Géographie Alpine - PACTE/Territoires, Université Joseph Fourier, GRENOBLE, FRANCE

In the late 19<sup>th</sup> century, geomorphology was part of geology and an almost empirical science. It is the theoretical synthesis of the « normal » erosion system by Davis which both established geomorphology as an independent science and separated it from the still empirical geology. Davis' erosional cycle theory provided not only an explicative framework, but also a predictive model, allowing geomorphological predictions to be searched in the field. In its beginning, geomorphology was a theoretically based science! If the history and fate of Davis' theories are well known, the most excessive tentative of theoretical approach in geomorphology remains largely unknown, mainly because it was almost confined to German-speaking geography: the glacial trough theory. Its main propagator was Hans Hess with his paper *Der Taltrug* in 1903. According to this theory, successive glaciations carve narrower and deeper troughs, which leave remnants in the form of embedded glacial troughs. In the early 20<sup>th</sup> century many geomorphologists searched for benches and examined slope profiles in order to find embedded troughs, four of them if possible, corresponding to the four Alpine glaciations defined by Penck and Brückner. Other authors tried to define troughs corresponding to the last deglaciation phases. Associated concepts like tongue basins and stepped glacial cirques were also used and led sometimes to opposite interpretations of the same features. Almost all studies based only on a topographical analysis – the most excessive relied even only on analysis of maps, without any field work. Criticisms arose from the beginning and developed in the 1920's. The interest for glacial troughs, and debate around it, disappeared after the 1930's. Today with the development of cosmogenic exposure dating, the question whether glacial troughs, like trimlines, could enjoy a revival arises.

We will expose a brief history of the concepts, and develop some examples mainly from the Swiss Alps.

### Is the present the key to the future?

*FURLANI S.(1), NINFO A.(2), CANDELA A.(3)*

*(1) Dept. of Mathematics and Geosciences, University of Trieste, TRIESTE, ITALY ; (2) Dept. of Geosciences, University of Padua, PADUA, ITALY ; (3) Dept. Of Theoretical and Applied Sciences, University of Insubria, VARESE, ITALY*

Earth sciences are largely based on the concept of the uniformitarianism, the assumption that the same natural laws and processes that operate today have always operated in the universe in the past. It summarizes and includes the gradualistic concept. Modern earth scientists do not apply this concept in the same way as in the past, since the present may not be long enough to study the past and geologic processes may have been active at different rates. Thus the forecast of future natural events is partly related to the knowledge of present-day processes.

Even the debate concerning the relations between the past, the present and the future in geomorphology has not been discussed as regarding an approach inside the theoretical philosophy, despite its importance for geomorphic models.

The concept that "the present is the key of the past" implies that we know the present, at least enough to be able to extend our knowledge back in time or forward to focus on the future. Therefore, even if the future remains always unknowable, the accumulation of new data will anyway allow a deeper knowledge. Prediction is realized by the improvement of theoretical models which are able to forecast the future trends. The abstraction of theoretical models occupies a largest space rather than the empiricism of measured data, since it is the sum of the space of actualism (measured data) and the space of possibility (the future).

A considerable number of studies in epistemology shows that natural systems fall into the category of complex phenomena within which it is very difficult to forecast future conditions. Recent rates of global deglaciation shows we are actual in a overscale discontinuity moment and present-day measures are probably not representative of past and future trends. It is therefore required a deep rethinking of the category of reductionist scientific determinism that should consider also out-of-scale events.

\*\*\*\*\*

### Philosophical Reflections on Computational Geomorphology

*VAN DE WIEL M., DESJARDINS E., MARTEL T., ROUSSEAU Y., ASHMORE P.*

*University of Western Ontario, LONDON, ONTARIO, CANADA*

Like many other scientific disciplines, geomorphology has over the last two decades witnessed a phenomenal rise in the use of computational modelling as a tool for predicting changes, testing hypotheses and generating new knowledge. This turn marks an especially important shift for geomorphology, which has traditionally employed empirical and observation-based methods of inquiry. Although promising for many of us, the rise of computational geomorphology raises several epistemological issues that need to be debated if the knowledge gained from this new tool is to be considered admissible. This paper focuses on two lines of inquiry. First, and most importantly, we compare the nature and value of the knowledge established through computational modelling with that obtained through more "traditional" empirical methods used in geomorphology. More specifically, we discuss if these methods generate knowledge of the same value, or if computationally-derived knowledge is subservient to empirical observation. We contend that computational modelling can indeed provide understanding of the causal structure of the world, and that it can improve our capacity to recognize and deal with the inherent complexity of geomorphological phenomena. Second, we highlight and reflect on two different modes of modelling, *i.e.* predictive and exploratory. The former is characterized by instances where the functioning of the modelled geomorphic system is well-understood and where specific state changes in that system are predicted, whereas the latter uses modelling to test hypotheses or to improve our understanding of the functioning of the modelled geomorphic system. These two types of modelling have different underlying epistemologies, and thus offer different challenges and opportunities in characterizing the complexity of geomorphological systems.

### **What's the point of fieldwork?**

RICHARDS K.

*University of Cambridge, CAMBRIDGE, UNITED KINGDOM*

This paper will explore questions about the changing role and epistemological status of "the field" in geomorphology. If field locations are an environmental scientist's equivalent of the physical scientist's laboratory, what does this mean for experiments and experimental design, and for explanation and understanding, in geomorphology (and indeed, in different areas of geomorphology)? If numerical models and remote sensing can today generate "data" at a rate unimaginable for field measurement, what does this mean for the epistemological status of the "field"? Does adherence to an image of fieldwork imply that it has a more social than a scientific purpose (although being no less important for that)? And do the epistemological peculiarities of field enquiry, surprisingly, gradually serve to undermine the autonomy of environmental science disciplines (including geomorphology), and to threaten their independent status?

\*\*\*\*\*

### **A river runs through It: Conceptual Models in fluvial geomorphology**

GRANT G.(1), O'CONNOR J.(2), WOLMAN M.G.(3)

*(1) USDA Forest Service, Pacific Northwest Research Station, CORVALLIS, OR, UNITED STATES ; (2) US Geological Survey, PORTLAND, OR, UNITED STATES ; (3) Johns Hopkins University, BALTIMORE, MD, UNITED STATES*

Fluvial geomorphology has a rich history of conceptual models to explain how rivers change and evolve. These models provide a framework for analysis, and the choice of models and the manner of their application will fundamentally affect the outcome of any geomorphologic study. Underlying the models themselves is a scaffolding of ideas and concepts that draws from Newtonian physics, and fundamental geological and geomorphic principles dating back to Playfair and before. The history of modern conceptual models in fluvial geomorphology can be viewed as a braided river of ideas that begins with a bifurcation in thinking between G.K. Gilbert's concept of landscape processes reflecting a balance among pertinent forces, and W.M. Davis's concept of the geographic cycle. Many of the conceptual models that have been developed subsequently are primarily fed by one or the other of these two master braids, although some of the most exciting ideas have emerged from cross-currents in thinking. Concepts such as the graded river, hydraulic geometry, dynamic equilibrium, geomorphic thresholds, magnitude and frequency of geomorphic processes, landscape and channel classification, and landscape evolution all find their places in this river of ideas. Conceptual models both reveal and conceal fundamental aspects of the fluvial system, and care should be taken to choose wisely and not follow blindly.

### **What's in a name? Unravelling the inosculate definitions of multichannel river networks**

CARLING P.(1), JANSEN J.(2), MESHKOVA L.(1)

(1) *University of Southampton, SOUTHAMPTON, UNITED KINGDOM* ; (2) *Stockholme University, STOCKHOLME, SWEDEN*

The etymology and historic usage of such terms as 'anabranching', 'anastomosing' and 'braiding' within river science are reviewed. Despite several decades of modern research to define river channel typologies inclusive of single channels and multiple channel networks, typologies remain ill-conditioned and consequently ill-defined: the history of usage of terms, in part, has conditioned the modern philosophical approach to defining channel typologies rather than the latter being physics-based. Conventionally employed quantitative planform characteristics of river networks possibly cannot be used alone to define channel types, yet the planform remains a central part of all modern classification schemes, supplemented by sedimentological and other qualitative channel characteristics. Planform characteristics largely have been defined using non-standardised metrics describing individual network components, such as link lengths, braiding-intensity and bifurcation angles; which data often fail to separate visually-different networks of channels. We find that existing typologies remain pragmatically utilitarian rather than fundamentally physics-based and too often fail to discriminate between two distinctive and important processes integral to new channel initiation and flow-splitting: i) in-channel bar accretion, and ii) channel avulsion and floodplain excision. It is suggested that, firstly, if channel planform is to remain central to river typologies, then more rigorous quantitative approaches to the analysis of extended integral channel networks at reach scales (rather than network components) are required to correctly determine whether 'visually-different' channel patterns can be discriminated consistently; and, secondly, if such visually-different styles do in fact differ in their governing processes of formation and maintenance.

\*\*\*\*\*

### **Geosemiosis of planetary surfaces**

BAKER V.

*University of Arizona, TUCSON, UNITED STATES*

Geosemiosis (Baker, 1999, *Geol. Soc. America Bull.*, v. 111, p. 633-645) involves the continuous interpretive flow of signs (semiosis) from the Earth to our thoughts about Earth. For geomorphology this flow of signs that leads to a fruitful course of hypothesis generation in regard to the causes of landforms and landscapes. The invention of geomorphological hypotheses involves both inductive inferences of the type G.K. Gilbert termed "empiric classification" and abductive inferences of a logical form made famous by the 19th century American logician Charles Sanders Peirce. The testing and corroboration of such geomorphological hypotheses relies less on the correspondence logic of theoretical/ experimental sciences, like physics, and more on the logic of consistency, coherence, and consilience that characterizes the investigative/historical sciences of interpretation exemplified by geological geomorphology. Geosemiosis focuses on what Earth says to us, thereby providing a complement to the accelerating mode of science that is focused on what we can say about Earth. While the latter uses mathematics to provide knowledge that aspires to be universal, necessary, and certain, the science of what Earth says to us focuses all the messy and uncertain realities of the nature's particulars. The science of what Earth says to us is more concerned with what actually does happen or has happened, as opposed to making a law-based, prediction of what should happen. This approach to science may well have more affinity with the commonsense view of the nonscientists who influence policy decisions. Human action seems to be more influenced by beliefs attached to experience of particulars than by adherence to abstract generalities.

## **Poster presentations:**

### **Rise of the Theory of Diluvial Morpholithogenesis in Russia: Opposition to the Recognition of late Pleistocene megaflooding in northern Eurasia**

RUDOYA A.

*Tomsk State University, TOMSK, RUSSIAN FEDERATION*

Cataclysmic flooding theories for the late Pleistocene landscapes of the northwestern United States were long regarded as unique and restricted to that region. However, beginning in the 1980s discoveries by the author and others identified the systematic effects of immense breakout floods from late Pleistocene ice-dammed lakes that filled intermountain depressions in the Gorny Altai region of central Asia, including the Chuya, Katun, Tchulishman, and Bashkaus valleys. Subsequent studies documented evidence for late Pleistocene cataclysmic flooding associated with depressions in the northern Mongolian region, and further work extended the recognition of possible great late Pleistocene floods in the Transbaikal and the Cisbaikal regions. Despite these discoveries, what is now known to be relief features and related sediments formed and emplaced by cataclysmic flood phenomena continued to be explained by many investigators in terms of very different and occasionally conflicting mechanisms. The lack of a general unifying theory for the phenomena meant that explanations that seemed to be more or less plausible for a particular valley are ineffective for explaining similar features in an adjacent valley, and of no use at all for explaining features on the drainage divides between valleys. Nevertheless, the new cataclysmic flooding theories will become more widely accepted when the investigative community comes to realize the insufficiency of previous explanations. The appearance of puzzling anomalies means that paradigms established by previously successful theories will be found to be lacking. As this lack of success is reinforced by the collection of new data, the stage will be set for theory change, whereby new explanatory theories successfully encompass both the phenomena that marked explanatory successes for the old theories, and also the discoveries that proved anomalous in regard to systems posed by the old theories.

\*\*\*\*\*

### **On Postmodern Geomorphology**

NEVSKY V.

*Pacific Geographical Institute FEB RAS, VLADIVOSTOK, RUSSIAN FEDERATION*

Thematic structure of publications for the last 20 years shows that geomorphology enters a period of semantic reorganization. Its status could be characterized as the entry in a modern cultural (and scientific) reality, i.e. Postmodern. It will be expected that the technological analytic mainstream of geomorphology will produce less and less new semantic information. The themes of all the scientific publications could be led to a limited number of principal patterns, such as “quantitative estimate of some exogenous geomorphic process”, “regional DEM and its application” and so on. Geomorphic information is becoming more specific and additional. New meanings are mainly formed in border scientific branches, such as ecological geomorphology and aesthetic geomorphology. The first fate feature of postmodern geomorphology is decrease in historical aspect, which has been given to paleogeography and geology. The second feature is a tendency to depletion of our visual object, i.e. the earth surface. Geomorphology is gradually depriving of endlessness and eternity, whereas the latter are the very main opponents of Postmodern. Thus, geomorphology is coming back to geology from which it singled out a century ago. It is a normal process, neither bad nor good. To keep independence, geomorphology should return itself historicity and evolutionism (according to W.M. Davis’s ideas). Geomorphology must take part in interdisciplinary project that has a general name “Evolutionism: synergetic approach”. If one follows the nomogenesis principle, then relief development will be involved (as well as climate development) into the framework of biological and human evolution. The contour of new geomorphologic paradigm will become evident in the field of interaction between geography, biology and social-human sciences.

**From the Physical Geography, through Dynamic Geology, towards the Geomorphology. An historical itinerary, bridging the XIX and the XX century, of the Italian naturalists's contribute**

LAURETI L.

*Univ. di Pavia, Dipart. di Scienze della Terra e dell'Ambiente, PAVIA, ITALY*

The aim of this paper is to retrace the initial stages of the historical evolution (both from the content and the methodology) turning, from the early descriptions of the physical surface of the Earth, towards the achievement of the Geomorphology as peculiar scientific discipline putting in evidence the contribute provided by the Italian geographers and geologists.

Surely under the influence of scientists such Lyell or Humboldt (whose works had in Europe a large reputation) together with the Kantian "Physische Geographie" (1801), the Italian text-books, for the use of both secondary schools and universities, revealed a mainly repetitive and descriptive character during all the first half of the XIX century. It is in this time that we see become stronger the dichotomy between the Physical Geography and the so-called Political Geography, peculiar in the Galanti's or Balbi's works. In this regard it is very symptomatic the great diffusion of the Italian translation of the Somerville's "Physical Geography" (1853). Luckily, during the second half of the XIX century, the rapid spread of the studies and researches in Italy, thanks to eminent scientists as Stoppani, Capellini, Taramelli and others, gave a strong support to the evolution and renewal of the Physical Geography, particularly by the development of the Dynamic Geology (to which is dedicated the first of the three volumes of the Stoppani's "Corso di Geologia", 1871).

As known, the word "Geomorphology" was used firstly at the end of the XIX century, probably by an American geologist (McGee 1891). After few years, also by an Italian geologist (Rovereto), entitling a work about the morphology of the Ligurian coasts (1902-03), followed, after twenty years, by a great treatise in two volumes: "Trattato di geologia morfologica (Geomorfologia)" (1924-25), again today a useful reference work.

\*\*\*\*\*

**The Primacy of Fieldwork**

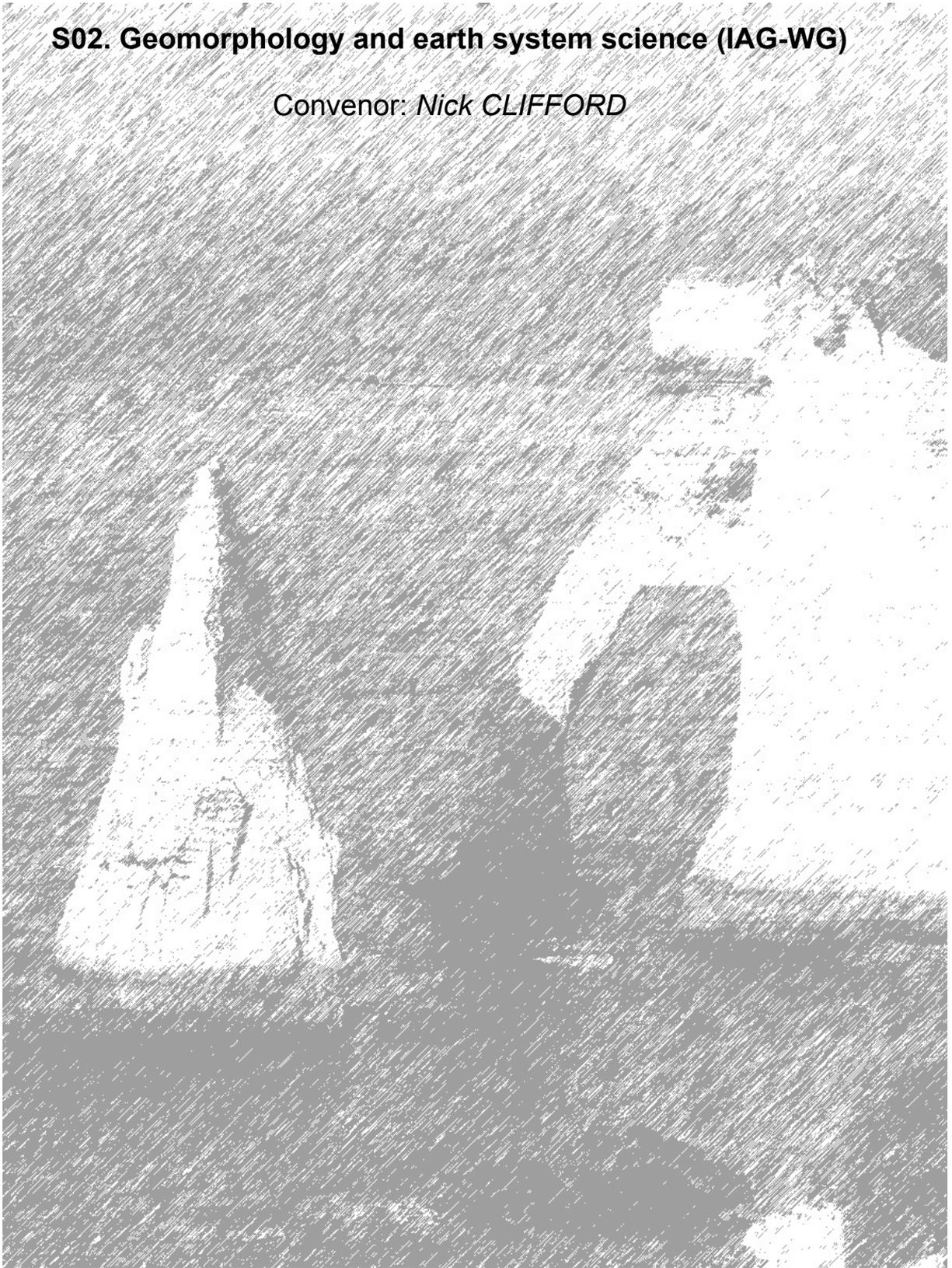
INKPEN R.

*University of Portsmouth, PORTSMOUTH, UNITED KINGDOM*

The practice of 'fieldwork' remains essential to the nature of geomorphology. Using examples from stone decay this presentation illustrates how fieldwork is the primary driver of conceptual and methodological developments. The term 'fieldwork' is explored and defined in relation to the practices undertaken by geomorphologists in this field. Likewise, the role of this expanded view of fieldwork in generating wonder and intrigue (or enchantment as others have suggested), essential and often under-rated stimuli to investigation, are discussed. Overall, this primacy of practice provides geomorphology with a particular conceptual and philosophical view of the physical environment within the sciences.

**S02. Geomorphology and earth system science (IAG-WG)**

Convenor: *Nick CLIFFORD*





## **Oral presentations:**

### **Geomorphology and Earth System Science: some thoughts on scale, place and method**

CLIFFORD N.

*King's College London, LONDON, UNITED KINGDOM*

Views on the relations between Geomorphology and ESS are varied, and span a range from very positive to very negative. The spectrum of views relates both to the epistemology of the two subject areas, and to disciplinary security and identity in a fast-changing academy and a fast-changing world.

Epistemologically, scientific investigation is marked by new technologies for information gathering, processing and sharing; by new means of simulation and modelling and potentially, synthesis; and environmental science is increasingly addressing questions which are hybrid between differing physical systems, and between these and social and political considerations. Beyond the science process, there are rapidly changing expectations in student experience and higher education; and there is questioning of the place of scientific research in social and political decision-making, especially relating to issues with inherently large uncertainties.

This paper offers some comment on the relations between Geomorphology and ESS, first, through considerations of 'conceptual contingency' (historical explanation) and place-based understanding of form-process interactions, and then through the methodologies which are adopted in these circumstances. It is argued that both a more contingent, local method and conceptualisation is characteristic of many forms of Geomorphology, past and present, which can be counterposed against more totalising approaches characteristic of ESS.

Geomorphological and ESS approaches are then reviewed against changing science-society relations. Here, the argument presents Geomorphology as one means of reducing uncertainty and 'downscaling' ESS to levels more suitable for practical policy uptake and to facilitate greater social and political acceptance of science input in key environmental questions.

\*\*\*\*\*

### **Ethnogeomorphology**

WILCOCK D.(1), BRIERLEY G.(2)

*(1) Victoria University, MELBOURNE, AUSTRALIA ; (2) University of Auckland, AUCKLAND, NEW ZEALAND*

Geomorphology offers an effective entry point into wider debates across geography and the sciences, framing understandings of landscapes as physical manifestations of complex and emergent relationships that can be used as a platform to support conversations among multiple and diverse worldviews. Physical geographers have much to contribute in moving beyond monological (one only) views of landscapes. This paper draws upon concepts of emergence, connectivity, and space-time relationality to develop an 'ethnogeomorphic' outlook upon biophysical-and-cultural ('living') landscapes. This perspective is grounded through ethnographic case studies with Indigenous [1] communities in Australia and Canada that examine knowledge production and concerns for environmental negotiation and decision-making. Extending beyond a traditional approach to ethnosciences, ethnogeomorphology seeks to move beyond crossdisciplinary scientific disciplines (and their associated epistemologies) towards a shared (if contested) platform of knowledge transfer and communication that reflects multiple ways of connecting to landscapes. Convergent perspectives upon landscape understandings are highlighted from Indigenous knowledges and emerging, relational approaches to geomorphic analysis. Ethnogeomorphology presents a situated, non-relativist response to people-landscape connections that reflects and advocates sentient relationships to place. Potential applications of ethnogeomorphology as an integrating theme of geographic enquiry are explored, highlighting important tensions in the knowledge production process.

[1] Indigenous' is deliberately capitalised, following discussion by Johnson et al. (2007) of decolonising discourse around Indigenous rights in the global context.

### **'But what do you measure?' Contextualising geomorphic understandings of the upper Yellow River**

BLUE B., BRIERLEY G.

*The University of Auckland, AUCKLAND, NEW ZEALAND*

As new technologies, measurement techniques and sources of information become available to geomorphologists, the importance of contextualising our expanding volume of information becomes ever greater. Geomorphic understandings are products of their specific physical, scientific and human contexts: local morphologies, controls and histories; the methods, scales and purposes of enquiry; and the philosophies, skills and background of the practitioner are all reflected in the knowledge produced by geomorphological research. These contextual factors exert a critical influence upon the application of geomorphic knowledge to new places and timescales, by other people, calling into question the development and communication of geomorphological knowledge both in terms of primary research and practical applications. Geomorphic classification provides a means of knowledge production and transfer, however it also has the potential to render that knowledge irrelevant or misleading if applied uncritically. Concerns for the role of spatial and temporal context, the ramifications of 'disciplining' unruly continua of form and process into 'simple' categories, and the selection of appropriate descriptors of form and process are central to the effectiveness of morphological classification: not all measures are relevant for all morphologies in all places. Using examples from the upper Yellow River, this paper explores the role of what, where, how and why we measure in shaping our understandings of the forms, processes and controls of riverine systems.

\*\*\*\*\*

### **Representing Geomorphology in Models of the Earth System**

DADSON S.

*School of Geography and the Environment, University of Oxford, OXFORD, UNITED KINGDOM*

Understanding the competing pressures on land and water resources requires detailed knowledge of the future climate and water balance under uncertain environmental change. For many years, Earth system models have represented land-surface processes including surface and subsurface hydrology, because they exert important influence on fluxes of water and energy between the land and the atmosphere. However, improvements in model resolution, and detailed research showing that land-surface heterogeneities can strongly influence land-atmosphere feedbacks has motivated a renewed interest in the representation of Earth surface processes in models of the Earth system. In practice, these representations may vary from the representation of finer-detailed orography for use in atmospheric models, to more sophisticated representations of sub-grid-scale features of the geomorphic environment in ways that interact dynamically with other Earth system components.

These challenges have invigorated debate around the representation of surface processes in simple models and have contributed to resurgence in the use of reduced-complexity models. This paper examines the role that land-surface models can play in providing a robust scientific basis for making resource management decisions against a background of environmental change, including climate and land-cover change. Some perspectives are given on Earth system models which represent hydrological and geomorphological systems, in particular: (i) the representation of surface, subsurface and floodplain hydrology in models, particularly at the scales relevant to land-surface modelling, (ii) the representation of human interventions such as dams and irrigation, and (iii) the role of geomorphic systems in the carbon cycle.

## Geomorphology 6.0: a framework for complexity elicitation

MASSON E.(1), KEILER M.(2)

(1) University Lille 1 Sciences and Technologies, VILLENEUVE ASCQ, FRANCE ; (2) Geographisches Institut Universität Bern, BERN, SWITZERLAND

Earth surface landforms are emerging from complex environmental systems. The observed pattern and structure may result by self-organisation, linear as well as nonlinear interactions and feedbacks between the elements in the systems. Studying geomorphic features and the processes dynamics, the relation and connectivity to other component parts in the Earth systems and to the human sphere become evident and are increasingly addressed. Both, Earth systems and geomorphological systems, are denoted as complex systems. However, in many fields the terms of complexity and complex systems are used as catchwords or in a general linguistic usage. Furthermore, the terms are equated with descriptions of geomorphological research without considering and/or defining the theoretical background. This situation hinders cooperation within geomorphology and especially trans-disciplinary approaches in Earth system sciences.

In contrast to highlighting the importance of more theoretical discussion we propose as a first step a framework for deconstructing complexity to make more explicit which part in a complex system is addressed and which part is missing in geomorphological studies. This framework should help to define boundary limits of the studied system complexity by describing and analysing following six dimensions: structures, functions, connections, phases, scales and adaptations. This six dimensions conceptual basis can be combined in a second step for a more detailed analysis.

To illustrate this theoretical framework, a case study considering the analysis of main influencing factors on sediment discharge in steep alpine catchments will be discussed. Moreover, this theoretical contribution and its case study will foster the discussion on trans-disciplinary approaches into geomorphological studies. Our proposition is indeed a framework for thinking and analysing complex catchment issues within Earth System Sciences.

\*\*\*\*\*

## Geomorphologic fundamentals of system geologic and geographic studies

LASTOCHKIN A., ZHIROVA.

St. Petersburg State University, ST. PETERSBURG, RUSSIAN FEDERATION

Numerous versions of system theories in natural science are based on morphological approach. In the Earth sciences which are closely tied to the Earth surface this approach is widely used when geotopological and structural geographic studies are involved.

Composition of the Earth surface is determined by means of tracing *structural lines* of 25 types. These lines connect points of extremum and zero points originating from the analysis of main geomorphic functions: altitude (depth), inclination, vertical and horizontal curvature. Intersections of structural lines present *characteristic points* of 20 types. Both structural lines and characteristic points serve as the borders of *elementary surfaces* of 52 types. Elementary surfaces fix definite locations (geotops, biotops, etc.), each with a number of exposures (gravitational, insolational, circulating, anthropogenic) that determine distinctive features such as physical, chemical, biological, environmental, etc. They can be mapped in different scales.

Structure of the Earth surface is studied through the reduction of topological models to mere structural networks, which patterns conform to the classical and dynamic symmetry. Measures of elements and symmetrical patterns reflect the aggregate result of day-surface material and energy flows since the relief acts as a distributor and concentrator of them, thus, influencing biota and mankind. The main ideas of this approach are stated in the monograph "General theory of geosystems" (SPb, publishing house Lema, 2011) published with support of the grant of the Russian government (№ 11.G34.31.00025).

## Conceptualising and formalising the structure of coupled estuary-coast-offshore systems

FRENCH J., BURNINGHAM H.

University College London, LONDON, UNITED KINGDOM

The concept of the coastal cell has endured for 50 years as an essentially geomorphological framework for coastal engineering and management. Cells are readily defined for coasts dominated by alongshore transport of beach-grade material, but struggle to accommodate longer range suspended sediment fluxes. Moreover, the challenges of predicting, understanding and mitigating climate change impacts at the coast demand a richer conceptualisation that embraces the connectedness of open coasts with estuaries and the offshore at broader scales and also acknowledges the extent of anthropogenic control. Accordingly, we present a new approach that re-engages with formal systems analysis and, importantly, restores a geomorphological focus to problems that have latterly become the preserve of the engineering community. At the heart of this approach is an ontology of landforms and interventions that is partly inspired by the coastal tract concept and its temporal hierarchy of sediment sharing systems, but which places more emphasis on a spatial hierarchy in scale, from coastal shelf, through landform complexes, to landforms and engineering interventions. A formal protocol specifies the mapping of important landform components and structural and non-structural constraints thereon, and their grouping into estuarine and coastal landform complexes. The complex web of interactions is represented through an influence network, which contains a sub-set of mass transfer pathways that define the sediment budget. This process constitutes a form of knowledge formalisation in which disparate sources of information (published research, data etc) are generalised into usable knowledge. System maps then act as a catalyst for structured discussion of geomorphic system behaviour and its implications for climate change impacts and their management. They also provide both a framework and a repository for more quantitative analyses and system-level modelling at the scales that really matter.

\*\*\*\*\*

## Fractal dimension of drainage network geometry of some Mediterranean-type river basins in California, Spain and Italy: a geomorphologic key to interpretation

DONADIO C.(1), MAGDALENO F.(2), KONDOLF G.M.(3), MAZZARELLA A.(1)

(1) Department of Earth Sciences, Environment & Resources, University of Naples Federico II, NAPOLI, ITALY ;

(2) CEDEX, Ministry of Public Works - Ministry of Agriculture, Food and Environment - Alfonso XII, 3, MADRID, SPAIN ; (3) Department of Landscape Architecture and Environmental Planning, University of California, BERKELEY, UNITED STATES

By applying fractal geometry analysis to the drainage network of three large river basins in America and Europe, 2D- and 3D-fractal dimensions through the correlation integral have been calculated. Preliminary results have been compared with classical geomorphic-quantitative indexes to highlight fluvial dynamics. The basins of Russian River in northern California, Ebro River in northeastern Spain and Volturno River in southern Italy, in present-day Mediterranean climate and with different geologic history and tectonic styles, have been analyzed. Preliminary results show an average fractal dimension slightly above unity. This suggests that basins have experienced concurrent overlay of secondary modeling processes, resulting from morphoselective erosion in a climate different from the present, on the primary tectonic processes, responsible for both the current structuration of inherited landscapes and degree of structural control. Tectogenesis was intense in the Plio-Pleistocene, although currently very active in some of these basins, while morphogenesis mainly occurred in the Late Quaternary and its effects are well preserved. The different fractal degree would indicate river basin evolution at certain periods was controlled by glacial fluctuations, at others by intense effects related to Plio-Quaternary tectonics and locally to Pleisto-Holocene volcano-tectonic activity. Finally, in historical times such phenomena appear to have been overlain by fluvial dynamics.

References: D'Alessandro L., De Pippo T., Donadio C., Mazzarella A. & Miccadei E. 2006: *Fractal dimension in Italy: a geomorphological key to interpretation*. Z. Geomorph. N.F., 50, 4, 479-499.

Kondolf G.M. & Piégay H. 2003: (Eds.) *Tools in Fluvial Geomorphology*. Wiley, UK, 688p.

Magdaleno F., Fernández J.A., Merino S. 2012: The Ebro River in the 20th century or the ecomorphological transformation of a large and dynamic Mediterranean channel. Earth Surf. Proc. Landf. 37, 5, 486-498.

### **Preliminary study of the coupled control of tectonic uplift and the glaciations in the Tibetan Plateau**

ZHIJIU c.(1), ZHANG W.(2), LIU G.(1), LI C.(1)

(1) Peking University, BEIJING, CHINA ; (2) Liaoning Normal University, DALIAN, GHANA

It has been noticed that the youngest glaciations in high Asia and the surrounding mountains occurred later than the high latitudes and polar region. The Kunlun-Huanghe tectonic movement around 1.1-0.7-0.6 Ma M.P. induced the Tibetan plateau and the bordering mountains extensively uplift to the height about 4000 m. The orbital configuration was also changed towards the dominance of the 100 ka cycle at around the same time, which led to further cooling of the Earth and resulted in the development of glaciers. The oldest glaciation, Kunlun Glaciation (0.71-0.78 Ma.B.P.), occurred in the Tibetan Plateau and the bordering mountains. Definitely glacial remains of the last glacial cycle (0.05-0.01 Ma B.P.) are preserved in the Siguniang Shan (6250 m) and the Xuebaoding Shan (5588 m) of the eastern Tibetan Plateau. However, complete glacial sequence including the penultimate, last glacial cycle and the glaciation in the middle stage of the Pleistocene occurred in the Queer Shan and Nianbaoyuze located in the inner part of the Tibetan Plateau, which is lower than the Siguniang Shan and Xuebaoding Shan in the same latitude, although the moisture is not beneficial for the Queer Shan and Nianbaoyuze Shan. This may be the result of the extensive tectonic uplift because the uplift rate is about 2 mm/yr during the middle and late Pleistocene in the Siguniang Shan and Xuebaoding Shan. Only glacial remains in the last glacial cycle are preserved in seventeen mountains with the altitude of 3500-400 m in the east margin of the Tibetan Plateau. Most absolute ages of the glacial remains are 0.03-0.01 Ma B.P. The glacial sequence in these mountains may be induced by three reasons, that is, first, the direction of the uplift of the Tibetan Plateau is from west to the east margin, second, the climate became cold and led to the snowline decrease, and finally, the coupled control of the tectonic uplift in these regions and the cold climate.

\*\*\*\*\*

### **Poster presentations:**

#### **Groundwater investigations using optical and microwave remote sensing data in Solani watershed, India**

BENNIA A.(1), SRIVASTAV S.K.(2), CHATTERJEE R.S.(2)

(1) Centre for spatial techniques CTS, ORAN, ALGERIA ; (2) Indian Institute of remote sensing, DAHRADUN, INDIA

This article describes general hydro-geological set for the Solani watershed. Satellite imagery obtained from Landsat-7ETM+ has been analysed to prepare the groundwater prospects map. By using SAR interferometry techniques, paleo-channels, geomorphic units, lineaments, could be identified and delineated at a reasonable level of accuracy.

In this study the following aspects have been covered: drainage map, geology, geomorphology, depth of water table map, water table contour map, EC (electric conductivity) distribution map etc. From these thematic maps ground water prospects map, has been prepared. As seen in these maps, the depth of water table in this area ranges from 2m from ground level to more than 100m; the EC of ground water varies from 284 $\mu$ S/cm to 2000 $\mu$ S/cm. Five different prospect zones: excellent, good, moderate, low and runoff zone are identified according to the integration of thematic maps.

**Hydrogeologic prospection in the basin of Tindouf. Contribution of the satellite images in the characterization of the fracturation**

*SAAD A.Z.E., KEBIR L., ZEBBAR Z.E., MAHI H., BENNIA A., DIF A., DJAAFAR Y.  
Centre des Techniques Spatiales, ARZEW, ALGERIA*

The study belongs to the sub watershed Saoura and is included in the large Saharan platform, and belongs to the North African craton. This platform includes a Saharan Precambrian basement on which rests unconformably overlain by a thick sedimentary Paleozoic structured into several basins separated by high zones, including the Tindouf Basin to the west. This Basin is characterized by the endoreic. It is a great a closed basin with a large east-west extension in oval shape. Its main outlet is the sabkha Tindouf, it is fed by a river system developed only in the northern part of the basin. The main stream el Maa, which is composed of two major tributaries that drain the northern part of the basin along the border with Morocco.

Hydrogeological prospecting area is mainly based on the structural aspect. For its characterization, we use the image data.

Areas of intersection of lineaments involve a large reserve of water. The intersection is the most favorable to drill to optimal production.

The study area is composed of faults and folds with a large radius of curvature. Lineaments are characterized different directions. Characterized most generally NE-SW to NNE-SSW. According to some authors, the allocation of this direction is to order Hercynian

This study represents a contribution to the understanding of the hydrogeological behavior of some of the Tindouf Basin, and offers a menu of potential groundwater. The overall results are a contribution to a better hydrogeological exploration in the region.

Keywords: Tindouf, hydrogeological, fracturation, satellite images

\*\*\*\*\*

**Analysis of environmental fragility - Letter from Santa Maria da Vitoria - Bahia**

*GUIMARAES S., FRANCO B., GOMEZ T.  
Universidade Federal da Bahia, BARREIRAS-BA, BRAZIL*

Motivated by the need to understand the existing processes contained in the spaces occupied by humans, they are sourced from environmental and social phenomena, the study was conducted, the result was achieved by performing analysis of the physical and socioeconomic aspects of the area between the Geographic coordinates: 13 °, 13 ° 30' South Latitude and 44 °, 44 ° 30' West Longitude. This part which includes the municipalities of Baianópolis, Canápolis Coribe, Correntina, Jaborandi, Santa Maria da Vitória Santana and São Felix do Coribe. Those that are located in the Far West Mesoregion Baiano. The study had as main objective the acquisition and interpretation of results in making maps, making it possible to do an analysis relating the physical limitations and confronting -the form in which man has occupied this space. Thus from these reviews was possible to obtain a map of environmental vulnerability of the same.

Keywords: Santa Maria da Vitoria, Environmental Fragility, West of Bahia, interpretation

## The Progress and Prospect of Daigu Landform Research

XU S.

*College of Resource and Environment, Linyi University, Shandong Province, China, LINYI, CHINA*

In August 2007, Professor Cui Zhijiu and other six geomorphologists, identified Daigu Landform as China's fifth modelling landform after Karst landform, Danxia landform, Zhangjiajie landform and Zhangshiyuan landform in the academic conference held in Mengyin county of Shandong province.

In the landform classification system, Gu is a type of mesa landforms, which is known as Gu in Yimeng Mountainous area in Shandong. Gu is an elevated area of land with a flat top and steep cliffs under the mountain top. The cliffs have a gentle slope near the foot of the mountain. There is a total of over 180 Gu in Yimeng Mountainous area. The formation of Daigu landform requires three conditions: the soft-hard interbedding gentle stratum, long-term gradual tectonic uplift and strong external erosion. The formation of Daigu landform in this region is due to the effect of erosion and corrosion of water flow and gravity collapse on large-area and gently sloping limestone and sand-shale layer of Cambrian system under long-term and gradual tectonic uplift in the context of local fault structure. Daigu landform, developed in the Cambrian neritic deposit marine sediment of dating back to about 500 million years ago, is attracting more and more attention with its structural typicality, type diversity, clustered concentrated distribution.

At present, there is still a lack of profound and systematic research into the formation and evolution pattern of Daigu landform. Therefore, the key topics of academic research is its distribution, morphological characteristics, evolution trend, etc. The research on Daigu landform can reverse current situation of weak mesa research in geomorphology field and enrich the research on continental weathering and terrestrial carbon cycle. Furthermore, it can provide scientific support for applying for National Geopark of China and the World Natural Heritage.

\*\*\*\*\*

## Using Google Earth to map and understand gully development

FRANKL A.(1), NYSSSEN J.(1), POESEN J.(2), ZWERTVAEGHER A.(3)

*(1) Geography Department, Ghent University, GHENT, BELGIUM ; (2) Department of Earth and Environmental Sciences, KU Leuven, HEVERLEE, BELGIUM ; (3) Department of Geology and Soil Science, Ghent University, GHENT, BELGIUM*

High-resolution images available on Google Earth are increasingly being consulted in geographic studies. However, most studies limit themselves to visualizations or on-screen measurements. Google Earth allows users to create points, lines and polygons on-screen, which can be saved as KML files. Here, the use of R statistics freeware is proposed to easily convert these files to the shapefile format [or '.shp file format'], which can be loaded into GIS-software (ESRI ArcGIS 9 in our example). The geospatial data integration in GIS strongly increases the analysis possibilities. We highlight our methodology and its accuracy by an applied study on gully network and volume development in the second half of the 20th century in the Northern Ethiopian Highlands.

Reference: Frankl, A., Zwertvaegher, A., Poesen, J., Nyssen, J., 2012. Transferring Google Earth observations to GIS-software: Example from gully erosion study. *International Journal of Digital Earth*. In press.

## **Applications of analytical geomorphologic maps in geography and geocology**

ZHIROV A., LASTOCHKIN A.

*St. Petersburg State University, ST. PETERSBURG, RUSSIAN FEDERATION*

Initial creation of analytical geomorphologic maps by tracing of structural lines of five principal types (convex crests, convex bends, concave bends, concave keels, morphoisographs) gives a morphological basis for the further studies and mapping, not only geomorphologic ones. Suggested by A. Lastochkin in the eighties, the system-morphological approach with its thorough, parametric and correlated, systematization of points, linear and areal relief elements makes it possible to do a precise map fixing of the morphological structure of any kind of surfaces: from day to subaquatic and subglacial ones and even to various interfaces. The analytical geomorphologic map presents all the elementary surfaces, each corresponding to one geotop, or location. Geotops house elementary landscapes and other geo-units: elementary soil areas, biocenoses, etc.

Analytically mapped relief represents a complete set of geotops (locations) which can be used as a fine basis for various applications. SPbU researchers and other Lastochkin' disciples have built a lot of analytical geomorphologic maps covering landscapes and soils, biocenoses and forests, some issues dedicated to forecasts of geomorphologic and geologic risks, natural distribution of anthropogenic pollution, including that of water-bearing strata, ferromanganese nodules at the ocean floor and many others. The most fruitful applications of the system-morphological approach can be found in the monograph "Applied geomorphology based on the general theory of geosystems" (SPbU, 2008) and in the "Geomorphologic Atlas of Antarctica" (SPb, publishing house Map, 2011) created by SPbU geomorphologists under the leadership of Prof. Lastochkin and granted by the Russian government (№11.G34.31.00025).

\*\*\*\*\*

## **On the new geomorphologic studies of Polar Regions**

BOLTRAMOVICH S., LASTOCHKIN A., ZHIROV A.

*St. Petersburg State University, ST. PETERSBURG, RUSSIAN FEDERATION*

"Geomorphologic Atlas of Antarctica" can be estimated as a unique issue dedicated to the relief of a single continent. It has been created by the team of researchers from R&D institutions of St. Petersburg (Russia) under the leadership of Prof. Alexander Lastochkin and granted by the Russian government (№11.G34.31.00025). The Atlas presents an integrated model of day-surface, subglacial and subaquatic relief of Antarctica.

The Atlas is based on the new morphological approach worked up by A. Lastochkin from the Department of Geomorphology at SPbU. This approach embraces Earth surface division into defined elements – 20 points, 25 linear and 52 areal – and their networks that serve as functioning geo-systems of different levels. Data are mined from various Russian and international sources: geophysical, geographic, geologic, etc. Application of new morphological approach has made it possible to detail the Antarctic subglacial-and-subaquatic surface and to get new information concerning dynamics of different structural stages of the ice continent.

The mapping of Antarctica is carried out both for the entire continent and its separate, well studied regions: Vostok Lake and Lambert Graben. A set of maps comprises analytical (element's), orographic and other geomorphologic models as well as morphometric and morphotectonic maps that allow to assess neotectonic and glacioisostatic movements. Glaciodynamic studies have revealed the strong correlation between ice movements and day-surface and subglacial relief. Relief forming processes of the present and pre-glacial epoch as well as detailed studies of coastal areas are also represented in the Atlas.

Now, the research team is in the process of creation of a similar "Geomorphologic Atlas of the Arctic", which will cover the territories and water areas up to latitude 65° north. New morphological approach will also serve as integration base for the data obtained by various Earth sciences.

**Half a century of glacier changes by analysing different data sources: The 1954-2007 glacier variations in the ortles-cevedale group(Stelvio National Park, Lombardy, Italian Alps)**

*D'AGATA C.(1), MARAGNO D.(1), SMIRAGLIA C.(1), BOCCHIOLA D.(2), DIOLAIUTI G.(1)*

*(1) Università milano, MILANO, ITALY ; (2) Politecnico, MILANO, ITALY*

By analysing aerial photos, orthophotos and digital elevation models (DEMs) and by collecting and analysing field data (glaciological and geomorphological evidence) we reconstructed and described the recent evolution of a representative subset of Alpine glaciers (i.e.: 43 glaciers located in the Ortles Cevedale Group, Stelvio National Park, Italy). Our data cover half a century of Alpine glacier history (from 1954 to 2007) thus permitting to describe glacier changes on a long and representative time window. The analysis led to a quantification of glacier changes and a description of the occurring geomorphological processes.

We found a glacier surface area change of **-19.43 km<sup>2</sup>**, ca. -40%, from 1954 to 2007. Small glaciers proved to contribute strongly to total area loss. The area change rate accelerated in the later period, with surface reduction between 2003 and 2007 amounting to ca. 8.7 %, equal to a mean area loss of ca. 0.693 km<sup>2</sup>/year; the mean yearly loss over the previous periods (1954-1981, 1981-1990 and 1990-2003) were found equal to **0.242km<sup>2</sup>/year**, **0.436km<sup>2</sup>/year** and **0.476km<sup>2</sup>/year**, respectively. The glacier volume change was evaluated in the time frame 1981-2007 and it resulted equal to  $-766 \times 10^6 \text{ m}^3$  which corresponds to a mean thickness change of  $-18 \text{ m}$  (-0.7 m/year). This value is in good agreement with glaciological data (mass balance evaluations) measured on the field in the same period on some selected glacier in the Ortles Cevedale Group and with geomorphological evidence like the youngest moraine ridges abandoned by the Ortles Cevedale glaciers since the end of the 1980s. From a geodynamical perspective Ortles Cevedale group is now experiencing transition from a glacial system to a paraglacial one. The areas where most recently the main shaping and driving factors were glaciers are now subject to the action of melting water, slope evolution, and dynamics and periglacial processes.

\*\*\*\*\*

**The ratio between river-bed erosion and river-basin denudation in natural and natural-anthropogenic landscapes on plains of Northern Eurasia according to suspended sediment runoff of the rivers**

*KAZHOKINA V.*

*Kazan Federal University, KAZAN, RUSSIAN FEDERATION*

Studies of suspended sediment load of rivers lead to the conclusion that it formed due to erosion of the river-bed and its banks (river-bed component) and the various processes of mechanical denudation on the surface of the river basin (basin component). Different researchers at different times have been proposed numerous methods of partitioning of suspended sediment runoff in the river-bed and river-basin components. All of these methods vary in methodology, source data, and accuracy.

For estimation of the ratio between intensity of river-bed erosion and denudation of river basins 350 basins have been selected. All basins are located in various landscapes on the plains of Northern Eurasia. This area is provided with published materials of observations in the hydrological stations. Studies show that in natural conditions river-bed washouts play the most important role in the formation of sediment load in the forest zone (river-bed component equals 61 – 76 % of total sediment volume). Closed vegetation cover of this zone prevents any manifestations of mechanical denudation on river basins where erosion is inactive. As area of forests reduces, the part of basin component increases to the north and south of the forest zone. Basin component reaches maximum in the semi-desert zone, where its part in sediment load achieves up to 81 – 89 %.

Denudation processes intensify on the surface of the river basins that strongly disturbed by human activities. The total value of suspended sediment load and part of basin component in such basins always increase. In forest zone the part of river-bed component may be reduced in 20 – 30 times (up to 2 – 5 %). Human activity in the treeless natural zones reduces the part of river-bed component in 1.5 – 2.5 times.

**Mechanisms of urban flood and surface runoff genesis in Oued Koriche catchment (Massif of Bouzaréah, western part of Grand Algiers, Algeria)**

MENAD W.(1), ARNAUD-FASSETTA G.(2), DOUVINET J.(3), BELTRANDO G.(2)

(1) 8586 (PRODIG) du CNRS à Université Paris-Diderot (Paris 7), CHOISY LE ROI, FRANCE ; (2) UMR 8586 (PRODIG) du CNRS ? Université Paris-Diderot (Paris 7), 5, RUE THOMAS MANN ? 75205 PARIS CEDEX 13, FRANCE ; (3) UMR 7300 (ESPACE) du CNRS, Equipe d'Avignon ? Université d'Avignon et des Pays du Vaucluse, 74, RUE LOUIS PASTEUR, CASE 19 ? 84029 AVIGNON CEDEX 1, FRANCE

Oued Koriche catchment is one of hydrographic units which constitute Massif of Bouzaréah (western part of Grand Algiers). In November 9-10<sup>th</sup>, 2001, the Massif of Bouzaréah and especially Oued Koriche catchment experienced one of the most catastrophic hydrometeorological events in the history of the Mediterranean. Historical analysis of climatic events of the Mediterranean shows that the meteorological scenario that triggered this event was unexceptional (Argence, 2008; Menad *et al.*, 2012), and the level of damages observed cannot be just explained through this factor. The mechanisms of the genesis and development of the hydrological response of Oued Koriche catchment are the key factors of disaster. Therefore, we made recourse to the numerical simulation tools (cellular automaton *RuiCells*). Our analysis strategy covers the following points. Several catchment parameters (meteorology, geomorphology, and anthropogenic actions) were progressively introduced in order to evaluate the hydromorphological effectiveness of Oued Koriche hydrosystem. The impact (in space and time) of urban pressure on the hydrological response of the 9-10<sup>th</sup> November event was quantified. This research clarifies how the urban pressure induces a polygenic hydrological response in Mediterranean, anthropised catchment.

\*\*\*\*\*

**A Micromorphological Assessment of Anthropogenic Features in Pre-Columbian Archaeological Layers: First Results for Crowned Mountains Sites in French Guiana**

BRANCIER J.

Universite Paris I, PARIS, FRANCE

Crowned Mountain sites are typical pre-Columbian settlements under rainforest, on hilltops, most often characterised by the presence of circular U-shape ditches. Such sites may have had a defensive or a symbolic role for necropolis. About forty sites were identified in Brazil, Suriname and in French Guiana. In most cases, 14C dates indicate that ditches were built around 1<sup>st</sup> cAD, but pottery remains reveal that different ethnic groups or cultures may have existed. In French Guiana, there is very few data on ancient human settlements on Crowned Mountain sites as only three of them were recently prospected and excavated by INRAP: MC 87 and MC 88 (near Regina) and Yaou (near Maripasoula). Applying a geoarchaeological approach combining stratigraphy and micromorphology, the objective of the present study is to identify anthropogenic features in the archaeological record. The aim is to distinguish between agricultural, habitation or necropolis activity areas in order to better understand site formation processes. Micromorphological study shows that archaeological layers are enriched in organic particle, charcoals and fine organic matter likely related to human occupation(s). In ditch infilling, rhythms of accumulation help to differentiate formation processes such as collapse or intentional backfill. In the enclosed area, both in ditch infilling and soils, yellowish unburnt oxic B horizon aggregates together with anthropogenic features related to fire such as charcoals and burnt soil fragments (rubefied and dark brown aggregates) stress that lateritic soil acted as support (i) for activities in the enclosure, and (ii) as reworked material in the ditch. These components may result from clearance for settlement, agricultural management and cultivation, or domestic activities. Locally, the presence of crescent clay coatings and infillings may indicate intentional fires (charcoals and ashes inputs) or bone inputs. Micro-laminated coatings could also suggest land clearance.

### **Hydrogeomorphic features and improvement strategies of some Mediterranean rivers in California, Spain and Italy: a comparison between the Russian, Ebro and Volturno rivers**

DONADIO C.(1), MAGDALENO F.(2), KONDOLF G.M.(3)

(1) *Department of Earth Sciences, Environment & Resources, University of Naples Federico II, NAPOLI, ITALY ;*  
 (2) *2CEDEX, Ministry of Public Works - Ministry of Agriculture, Food and Environment, MADRID, SPAIN ;* (3)  
*3Department of Landscape Architecture and Environmental Planning, University of California, BERKELEY, UNITED STATES*

The application of an interdisciplinary approach to river management in some fluvial environments is presented. Three large rivers in Mediterranean climate have been studied: Russian River in northern California (drainage area of 3,846 km<sup>2</sup>), Ebro River in northeastern Spain (85,530 km<sup>2</sup>) and Volturno River (5,550 km<sup>2</sup>) in southern Italy. The aim is to compare hydrological and geomorphic features to highlight natural and human-based evolution, considering climatic crises and river basin management in the last decades. Moreover, improvement strategies held in the last years to increase their ecological status and to reduce pressures on hydromorphological attributes are analyzed. These rivers have been facing increasing changes in hydrogeomorphic aspects, mainly due to river damming, coastal retreat and floodplain occupation. These changes have deeply altered the fluvial dynamics, modifying aquatic and riparian habitats and imposing large alterations in their geomorphological connectivity. However, they are being actively managed nowadays to improve their ecohydrological status: habitat restoration for protected species and amelioration of flow regime in Russian River, improvement of river connectivity and reduction of hydrologic alteration in Ebro River, river banks and mouth recovery to reduce erosion in Volturno River are some of those strategies. Application of these tools shows that an integrated, adaptive approach suitable for Mediterranean rivers improves their ecological status restoring natural processes.

References: De Pippo T., Donadio C., Guida M., Petrosino C. 2006: The case of Sarno River (southern Italy). Effects of geomorphology on the environmental impacts. *Environ. Sc. Pollut. Res.*, 13, 3, 184-191.

Kondolf G.M. & Piégay H. 2003: (Eds.) *Tools in Fluvial Geomorphology*. Wiley, UK, 688p.

Magdaleno F. 2011: *Manual de técnicas de restauración fluvial* (2nd ed.). Monogr. M-100, Secretaría General Técnica, Centro de Publicaciones, Min. de Fomento, Madrid, 300p.

\*\*\*\*\*

### **Variation of confluences of some large rivers in Brahmaputra basin, Assam, India**

SARMA J.N., ACHARJEE S.

*DIBRUGARH UNIVERSITY, DIBRUGARH, INDIA*

Confluences of the three large rivers, viz. Dihang, Dibang and Lohit, which constitute the mighty Brahmaputra River in Assam, India, have shown dynamic character for a period spanning 87 years (1924–2011). The Lohit River was flowing westerly along regional slope of the area. Both the Dihang and the Dibang, flowing southerly joined the Lohit near Kobo and their combined flow flowed westerly as the Brahmaputra. The study indicates that although the channel patterns of these three large rivers remained same, their confluence points have moved both upstream and downstream since 1950. During 1924-1972 the confluences between the Dibang and the Lohit migrated 7.2 km eastward and that of the Lohit and Dihang 20 km southwestward. By 2001 the Lohit avulsed diverting its flow south-westward to meet the Dihang at about 40 km west of its earlier confluence. Since 2005 the Dibang got separated from the Lohit and flowed independently in south-westerly direction to meet the Dihang near Kobo. The processes that have controlled the confluence movements include river capture, avulsion and neotectonic activity. River captures of streams the Dangori and the Dibru by the Lohit occurred through lateral bank erosion. Both the Dibang and the Lohit avulsed to flow from south to south-west and west to south-west, respectively. The diversion of the flow of the Lohit to the south-west is also correlated to a neotectonic fault, which created the 85 km long Oakland-Guijan-Laina topographic scarp and the rivers Dangori and Dibru were flowing along the base of the same. Recent activity along this fault might have diverted the Lohit towards the base of the scarp to capture those two small rivers, thereby shifting its confluence point with the Dihang by 40 km.

Keywords: Brahmaputra, Confluence, River capture, Avulsion, Neotectonics.

## **Geomorphological and environmental studies of high Moulouya watershed by ArcGis and ASTER Imaging**

*BENYASSINE E.M.(1), DEKAYIR A.(1), DESRUELLES S.(2)*

*(1) UR- Geoexploration & Geotechnics, Faculty of Sciences, ZITOUN, MEKNES, MOROCCO ; (2) Université de Picardie Jules Verne, AMIENS, FRANCE*

The use of GIS and remote sensing tools permit to display, to acquire and to manage all spatial reference informations, in order to model spatial and temporal phenomena. These new merely computer techniques became asked more and more concerning the studies of the impact on the environment. The morphogenesis survey of the the High Moulouya watershed is the product of a methodological approach based on the advanced geomatics. It allowed us to show at the same time the grounds deterioration as a consequence of several conjugated factors acting together, leading to a deterioration of this non renewable capital.

The objective of this work is to explain of the morphohydrographical and morphostructural variations of the high Moulouya watershed in regard to its geomorphological and geological characteristics. It is mainly founded on the combination of a surface numerical analysis and a traditional synthetic approach. The use of GIS on the basis of the topographic maps 1/50000 allowed us to get a digitized model by the river system of the studied zone for purpose to make a spatial distribution of the geochemical data of various environmental component of the Zeïda mining area.

The geomorphological study of the spatial analysis was made on the basis of SRTM data, especially to create a morphological maps such: the slope, ground digital model as well as the river system maps (built by the assembly of the flow accumulation and the flow direction) of the aforesaid zone.

The use of the spatial remote detection in the analysis of the ASTER 15m images using ENVI 4.7 software, allowed us to detect clayey formations which exist near the studied area, and the creation of the clays distribution map. Recognized their high potential to capture heavy metals, the spatial localization of clays is crucial to limit at least the most polluted zones.

Key words: GIS, ASTER 15m images, Zeïda mining area, High Moulouya watershed

Topic: Environnement, Gestion des Ressources en Eau

\*\*\*\*\*

## **Relationships between land cover, land use change and erosion-sedimentation processes at the watershed level: A multitemporal study in the Cointzio watershed, Mexico**

*MENDOZA M.E.(1), GRATIOT N.(2), LÓPEZ-GRANADOS E.(3), ARNAUD F.(4), MAGAND O.(5), PRAT C.(6), STEVES M.(2)*

*(1) UNAM, MORELIA, MEXICO ; (2) IRD, GRENOBLE, FRANCE ; (3) UMSNH, MORELIA, MEXICO ; (4) EDYTEM, LE BOURGET DU LAC, FRANCE ; (5) LGGE, GRENOBLE, FRANCE ; (6) IRD, MARSEILLE, FRANCE*

Changes in land cover and land use (LCLU) have a relevant role in current local and global change processes which are directly linked with water and soil quality, runoff and sedimentation rates. Soil erosion and sedimentation have been extensively studied at the experimental watershed or plot level, whereas in larger areas further research is needed for evaluating similar relationships. This paper aims to investigate LCLU change processes within the Cointzio watershed (Central Mexico) and its relationship to soil erosion and sediment transport processes. The analysis covers a 28-year time period from 1975 to 2003. LCLU changes were derived from a multitemporal remote sensing analysis (1975, 1986, 1996, 2000 and 2003) while long-term soil erosion was reconstructed based on lake sediment deposition data. We found that 46 % all of the LCLU changes occurred between 1986 and 1996. Sedimentation discharge remained stable over the 1975-2003 period ( $1.4 \pm 0.6 \text{ g.cm}^{-2}.\text{y}^{-1}$ ), with the exception of two peaks (1975-1977 and 1991-1994;  $3.1 \pm 0.6$  and  $2.6 \pm 0.6 \text{ g.cm}^{-2}.\text{y}^{-1}$ , respectively) caused by exceptional rainfall events. The processes did not lead to changes in soil erosion and sediment transport rate likely due to the simultaneous positive (forest transition and scrubland increase) and negative changes (deforestation and forest degradation). We concluded that the poor correlation of LCLU changes to sediment discharge can be explained by a balance between negative changes that promote land degradation processes (e.g., erosion, mass wasting) and positive ones that reduce these kind of processes.

### Improvement of Chang'E-1 Orbit Determination Accuracy by Space VLBI

*YAN W.(1), WEI E.(2), LIU J.(3), LI C.(1), LIU J.(1), FENG J.(1)*

*(1) National Astronomical Observatories, Chinese Academy of Sciences, BEIJING, CHINA ; (2) School of Geodesy and Geomatics, Wuhan University, WUHAN, CHINA ; (3) GNSS Center, Wuhan University, WUHAN, CHINA*

Chang'E-1 (CE-1) is China's first lunar probe and has been provided abundant information for China's lunar exploration (Ouyang et al.,2010). Precise orbit determination of CE-1 is crucial to lunar exploration because it is directly related to the implementation of various scientific researches such as determining lunar gravity field. However, the orbit determination accuracy of CE-1 can't meet the demand of high-precision applications like geodesy currently (Li et al.,2009, Cheng et al.,2011). How to improve probe orbit determination accuracy has become the main challenge of China's Lunar Exploration Program.

According to this background, Earth Orientation Parameters (EOP) and relativistic effect corrections are introduced into the orbit determination of CE-1 by a derived differential very long baseline interferometry ( $\Delta$ VLBI) time delay model (Yan et al.,2011 and 2012). The calculation results show that the accuracy of CE-1 orbit parameters and EOP can be improved obviously compared with their predicted values. However, more precise results can't be obtained because of the restriction of relatively low accuracy and poor geometrical structure of  $\Delta$ VLBI time delay observations under current monitoring conditions. New strategies are required to overcome these problems.

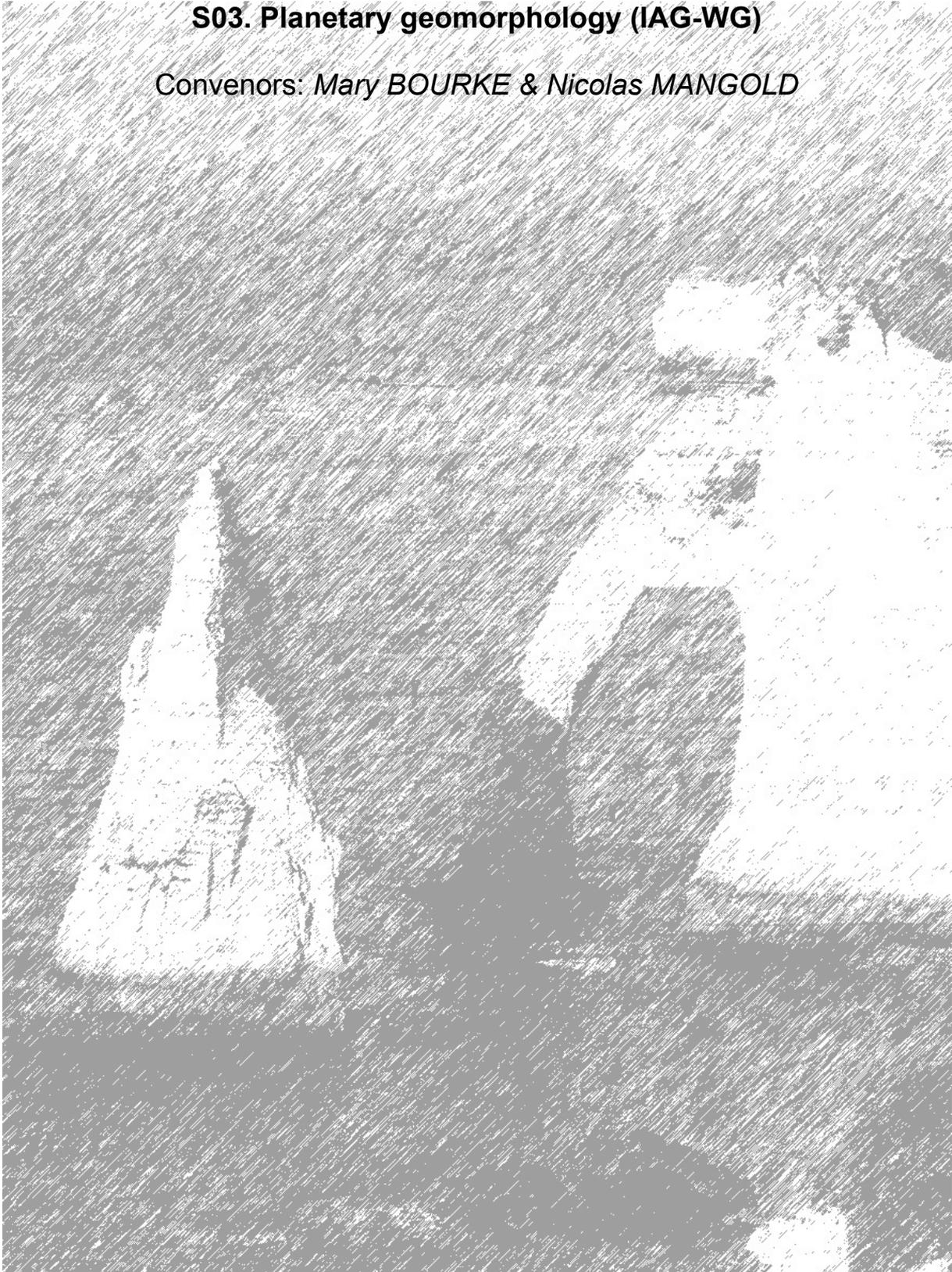
Space VLBI (SVLBI) is an extension of ground based VLBI to space, which has many advantages such as improving the accuracy and geometrical structure of time delay observations, interconnecting different coordinates systems, calculating orbit parameters and EOP simultaneously and so on. So the application of SVLBI in orbit determination of CE-1 is expected to further improve the accuracy of unknown parameters. In this paper, a relativistic SVLBI time delay observations model for CE-1 Transfer Orbit is derived and the estimability of unknown parameters is discussed. The optimal observation conditions are determined and some useful results are given by the calculation of simulated observations.

\*\*\*\*\*



**S03. Planetary geomorphology (IAG-WG)**

Convenors: *Mary BOURKE & Nicolas MANGOLD*





## **Oral presentations:**

### **Understanding the environmental fate of glaciovolcanic glass using the parallels between subglacial volcanism in Iceland and on Mars**

*DE VET S.(1), MERRISON J.(2), CAMMERAAT E.(1)*

*(1) IBED-Earth Surface Science, University of Amsterdam, AMSTERDAM, NETHERLANDS ; (2) Marslab, Department of Physics and Astronomy, University of Aarhus, AARHUS, DENMARK*

Recent discoveries of volcanic glass on Mars show that amorphous materials are a vital ingredient in surface sediments and aeolian landforms. Mobilisation of these materials still occurs today based on geomorphologic evidence of erosion patterns and dune migration. Measuring a realistic fluid threshold for rolling of fresh glassy sediment was therefore the main aim of our study. In order to determine this threshold, we simulated the removal of a terrestrial analogue material in a low-pressure wind tunnel experiment.

Volcanic glasses on Mars most likely originated from glaciovolcanic eruptions and therefore share similar properties with volcanic glasses formed, e.g. in Iceland. Properties of the Martian glass particles are difficult to measure from orbit and hence we selected an unaltered analogue material from Iceland. Wind tunnel simulations at various atmospheric pressures were used to determine the shear stress required for removal by rolling. A semi-empirical model was fitted to predict removal on Mars. Various material properties of the glass were measured to evaluate the goodness of the obtained fit as a function of the variation in material properties. We found that the model can be validly used to predict the removal on Mars. Large angular particles were found to be mobilised by rolling during strong winds and gusts in the present-day environment of Mars. Abrasion of particles during wind-induced rolling was simulated by rolling experiment for 15 weeks in rotating drums. As mobilisation of large particles is still at the limit of wind shears on Mars, their modification may have been much less than the textures that are commonly found in fine-grained aeolian sediments. This suggests that surface materials may have preserved a geochemical or physico-mechanical record of their subglacial eruption environment.

\*\*\*\*\*

### **Characteristics Of Basaltic Sand: Age-Dating Techniques And Understanding Size, Shape, And Composition As A Function Of Transport Process And Distance**

*CRADDOCK R.(1), ANDREWS B.(1), NANSON G.(2), ROSE T.(1), TIRSCH D.(3), TOOTH S.(4)*

*(1) Smithsonian Institution, WASHINGTON, DC, UNITED STATES ; (2) University of Wollongong, WOLLONGONG, AUSTRALIA ; (3) Institute of Planetary Research, German Aerospace Center (DLR), BERLIN, GERMANY ; (4) Institute of Geography and Earth Sciences, Aberystwyth University, ABERYSTWYTH, UNITED KINGDOM*

The chemical and physical characteristics of sedimentary material can provide valuable clues about transport processes, distance traveled, and provenance. For a typical sedimentary deposit on Earth, for example, it has been shown that the ratio of feldspar to quartz can be used to assess the maturity (or transport distance) of a terrestrial deposit, because feldspar is more vulnerable to weathering than quartz. Further, chemical analysis can also be used to determine potential sediment sources, and grain-size sorting can be used to distinguish aeolian sediments (typically well-sorted) from fluvial sediments (poorly sorted in high energy environments). It is also common to use the shapes of individual quartz particles to determine transport process and distance, all of which can help us better understand the history of a sample of sedimentary material and the geological processes that created and emplaced it.

These traditional sedimentological concepts are now being applied to our interpretation of Martian surface materials. While such an approach seems logical, the problem is that most of our current understanding is based on sediments derived from felsic materials (e.g., granite) primarily because that is the composition of most of the landmass on the Earth. However, the Martian surface is composed primarily of basalt, which generates much different sedimentary particles as it weathers. Instead of quartz, feldspar, and heavy minerals commonly found in most terrestrial sedimentary deposits, basaltic sediments are composed of varying amounts of olivine, pyroxene, plagioclase, and vitric and lithic fragments. We are currently documenting the physical and chemical changes that take place in basaltic sediments as they are transported by wind, water and ice over increasing distances. This will result in an improvement in our understanding of traditional sedimentological concepts when applying them to Martian surface materials.

### **Action of sublimation in the formation of spiral-shaped ice megadunes on the martian polar caps**

HERNY C.(1), CARPY S.(1), BOURGEOIS O.(1), PERRET L.(2), LE MOUÉLIC S.(1)

(1) *Laboratoire de Planetologie et de Geodynamique de Nantes, NANTES, FRANCE* ; (2) *Laboratoire de recherche en Hydrodynamique, Energétique et Environnement Atmosphérique, NANTES, FRANCE*

Orbital probes have revealed that martian polar caps comprise spiral-shaped ice megadunes. These dunes have a singular dynamic probably linked to their composition. Observations reveal that ice ablation occurs dominantly downstream of the megadunes, while ice condensation dominantly occurs upstream. Thereby the dunes move upwind. This phenomenon has been attributed to the combined action of katabatic winds and sublimation.

We propose to lead a physical downscaled experiment in an atmospheric wind tunnel to study the action of sublimation as a geomorphic control agent on the development of ice dunes. The experimental setup will comprise enable the generation of an air flow around a topographic object in order to study sublimation and condensation processes over time. The scaling of the experiment is based on a compilation of martian orbital observations available in the literature. We choose CO<sub>2</sub> ice as an analogue for the ice of martian caps in the experiment because of its ability to sublimate at terrestrial P/T conditions. An optical method (Particle Image Velocimetry) allows reconstructing the velocity field around the topographic object and a thermal method is used to estimate the rate of sublimation.

The first results of the experiment will be compared to orbital data on the Martian polar caps and to similar landforms on Earth, such as in Antarctica. This work will serve as a database to validate a numerical code taking into account ice phase changes and wind.

\*\*\*\*\*

### **Active geysers, dark flow and 'Spiders' in the Martian polar region**

SCHMIDT F., ANDRIEU F., GARGANI J., COSTARD F., MASSOL H.  
*CNRS UMR8148 IDES, ORSAY, FRANCE*

Discovered one decade ago with the high-resolution imaging camera, "spiders" are dendritic network, with a shape that looks like an arthropod. At the early spring, spiders are often associated with a dark fan that usually begins at the center of the feature. Later in the spring, dark flows develop episodically from these dark fans. These active processes have no analogues on Earth and may imply liquid water or CO<sub>2</sub> gas or other fluids. One class of model proposes that dark spots are formed in presence of liquid water below the CO<sub>2</sub> ice. Alternatively, the Kieffer model assumes a CO<sub>2</sub> jet formed by sublimation beneath a translucent slab ice.

Every year, during the polar winter, the surface temperature is low enough to condensate atmospheric CO<sub>2</sub> (140 K). In the springtime, a layer of condensed CO<sub>2</sub> drapes the whole landscape with a thickness up to 1 meter. The spiders' formation is most probably related to the CO<sub>2</sub> sublimation during the spring. According to Kieffer model, sublimation occurs at the bottom of a translucent CO<sub>2</sub> ice layer creating a trapped gas that goes into pressure. When pressure is large enough to crack the surface CO<sub>2</sub> layer, the gas escapes, carrying a large amount of dust and creating the vents and fans. The spiders are the cavities built in the regolith by this venting process.

Most recent studies using spectroscopic analysis, thermal measurements, geomorphologic studies imply a complex scenario of formation.

### Remnants of an equatorial glaciated valley landsystem in Valles Marineris (Mars)

*GOURRONC M.(1), BOURGEOIS O.(1), MÈGE D.(2), POCHAT S.(1), BULTEL B.(3)*

*(1) LPGNantes, Université de Nantes, CNRS, OSUNA, NANTES, FRANCE ; (2) Institute of Geological Sciences, Polish Academy of Sciences, WROCLAW, POLAND ; (3) Laboratoire de Géologie de Lyon, Université Claude Bernard Lyon 1, ENS Lyon, LYON, FRANCE*

Various ice-related features occurring on the floor of Valles Marineris suggest that this canyon system that stretches along the Martian equator has experienced a period of past glacial activity. Three regions of Valles Marineris were investigated, Coprates Chasma, Candor Chasma, and Ius Chasma. Geomorphological observations are based on images and altimetry analysis by using the Context Camera (CTX), the High Resolution Imaging Science Experiment (HiRISE) and MOLA PEDR single tracks. The study reveals some features reminiscent of a past glaciated valley landsystem in these regions. A line running along the base of valley wallslopes and associated with spur and gully morphology can be interpreted as a periglacial trimline. Other landforms on the floor of Candor Chasma can be interpreted as stagnant ice features such as polygonal terrains, chaotic terrains which look similar to terrestrial ablation moraines with kettle holes. Ancient ice probably also persists now in Candor Chasma in the form of a debris covered glacier with a surface elevation that is consistent with that of the trimline. In Coprates Chasma, hanging valleys provide additional evidence for the former existence of an extensive glacial filling of Valles Marineris. Terraced mounds resting on the floor of Coprates Chasma and around basement domes can be interpreted as stagnant remnants of stratified ice. Altogether, these landforms define a full glacial landsystem consistent with global climate models that predict glaciations in Valles Marineris during the Late Amazonian.

\*\*\*\*\*

### Deep-seated gravitational spreading in Valles Marineris ' observations and modeling

*KROMUSZCZYNSKA O.(1), MAKOWSKA M.(1), GUEYDAN F.(2), GURGUREWICZ J.(3), MEGE D.(4)*

*(1) WROONA Group, Institute of Geological Sciences, Polish Academy of Sciences, Research Centre in Wroclaw, WROCLAW, POLAND ; (2) Géosciences Montpellier, UMR 5243- CC. 60 Université Montpellier 2, MONTPELLIER, FRANCE ; (3) WROONA Group, Institute of Geological Sciences, Polish Academy of Sciences, Research Centre in Wroclaw & Space Research Centre, Polish Academy of Sciences, Bartycka Warszawa, WROCLAW & WARSZAWA, POLAND ; (4) WROONA Group, Institute of Geological Sciences, Polish Academy of Sciences, Research Centre in Wroclaw & Laboratoire de planétologie et géodynamique, UMR CNRS 6112, University of Nantes, France, WROCLAW, POLAND*

Deep-seated gravitational spreading (DSGS) of topographic ridges (sackung) has been interpreted in the Valles Marineris canyon on Mars on the base of identification of ridge-top splitting and uphill-facing normal fault scarps. DSGS features are much larger on Mars than on all documented DSGS instances on Earth. In order to quantify this difference, scarp dimensions obtained using Mars Reconnaissance Orbiter/CTX orbital images and stereo-derived DEMs have been compared with scarp dimensions at textbook terrestrial analogues in the Polish and Slovakian Tatra Mountains, obtained in the field using WADGPS and tape measurements. In the Tatras, the vertical offset of individual DSGS fault scarps does not exceed ~10 meters, whereas in Valles Marineris fault vertical offset is 40-1000 metres. Therefore, at least one order of magnitude of difference in scale exists between the terrestrial and Martian DSGS occurrences.

In both instances, DSGS has been interpreted to be a postglacial process. DSGS triggering, strain localization, and how ridge deformation proceeds in the terrestrial and Martian cases are investigated and compared using a finite element approach constrained by the observed distribution and quantification of ridge strain. Effect of ridge confinement by valley glaciers and viscous stress relaxation after deglaciation are accounted for. The rock weakening effects of water circulation and freezing/thawing cycles in the ridge on the evolution of rock mass strength is considered. The first results relating to DSGS triggering and strain localization will be presented.

### **The latitudinal distribution of putative periglacial sites on the northern plains of Mars**

BARRETT A., BALME M., PATEL M., HAGERMANN A.  
*The Open University, MILTON KEYNES, UNITED KINGDOM*

Periglacial landscapes are found in cold regions on Earth where the freezing and thawing of the permafrost active layer plays an important role in shaping the landscape. A variety of distinctive landforms such as sorted circles, thermokarst depressions and solifluction lobes are indicative of periglacial environments on Earth. It has been suggested that similar features on the northern plains of Mars could be the result of the same, or similar processes. Since the formation of a periglacial landscape requires the freezing and thawing of water their presence on Mars would indicate that the thawing of water-ice has occurred in the geologically recent past. Periglacial landforms could have formed in past periods of higher obliquity when the environment was more conducive to the action of liquid water or due to the depression of the freezing point by brines under current conditions.

We have conducted a survey of putative periglacial landforms across the northern Martian plains. Over 400 HiRISE images of the walls and floors of >1 km diameter craters have been examined to map the locations of these landforms across regions of Acidalia, Utopia and Arcadia Planitia between 30 and 80 °N. These data allow an assessment of the latitudinal distribution of these features. Variations between the types of landform found in different regions of the Northern Plains of Mars can also be assessed.

Scalloped depressions and gullies have a similar latitude range, and are frequently found south of 60°N. Similar features to the scalloped depressions of Utopia Planitia have been observed in both Acidalia and Arcadia Planitia, but are not found over as wide a range of latitudes in Acidalia. Possible sorted landforms (lobes, polygons etc.) can be found as far south as 40 and as far north as 70°N but most are found between 45-65 °N. They seem to occur over a wider range of latitudes in Utopia Planitia than in Acidalia.

\*\*\*\*\*

### **Investigation of possible coastal and periglacial landforms in Gale Crater, Mars**

LE DEIT L.(1), HAUBER E.(1), FUETEN F.(2), PONDRELLI M.(3), ROSSI A.P.(4), JAUMANN R.(1)  
*(1) DLR, BERLIN, GERMANY ; (2) Brock University, ST. CATHARINES, CANADA ; (3) IRSPS, PESCARA, ITALY ; (4) Jacobs University, BREMEN, GERMANY*

The martian surface water reservoir appears to have been affected by a major change at the Late Noachian/Early Hesperian Epoch. The 150 km diameter Gale crater (-5.4°N, 137.9°E) was formed at this time, ~3.6 Ga ago, and is currently investigated in situ by the Mars Science Laboratory (MSL) rover, Curiosity. Gale is filled by sedimentary deposits including a crescent-shaped mound of layered deposits, Aeolis Mons (informally also named Mount Sharp), up to 5 km high and 6000 km<sup>2</sup> in area. In order to reconstruct the paleo-environments and the associated hydrological systems that existed within Gale, and their evolution through time, we provide a geomorphological study of landscapes using CTX and HiRISE images, and a HRSC DEM.

Possible morphologic indicators of the existence of a paleolake include a Gilbert-type delta, terraces, possible shorelines, and layered deposits on the crater floor. They are all located in the same elevation range, between -4450 m and -3700 m. The more confident detections of sulfates and phyllosilicates are also located at these elevations, which would correspond to the ancient lake levels. Assuming that the lake floor elevation corresponds to the current floor elevation, its maximum volume would have been 3615 km<sup>3</sup> with an average water depth of ~590 m. Lobate and fan-shaped deposits lie along the flanks of Aeolis Mons and at its base. They likely result from slow movements such as creeping as for rockglaciers. Other fan-shaped deposits are located at the mouth of deep re-entrants with steep headwalls on the western and southern slopes of Aeolis Mons. They share morphologic similarities with retrogressive thaw slumps on Earth, which result from the thaw of ice-rich permafrost. These possible periglacial landforms suggest the former presence of ice-rich permafrost, possibly under high obliquity conditions during the Hesperian. Consequently, Gale crater would have been a periglacial region that once hosted a lake.

### Depositional Environment of Large Alluvial Fans in Saheki Crater, Mars

*HOWARD A.(1), MOORE J.(2), MORGAN A.(1), HOBLEY D.(1), WILLIAMS R.(3), BURR D.(4), DIETRICH W.(5), WILSON S.(6), MATSUBARA Y.(1)*

*(1) University of Virginia, CHARLOTTESVILLE, UNITED STATES ; (2) NASA Ames Research Center, MOFFETT FIELD, CA, UNITED STATES ; (3) Planetary Science Institute, TUCSON, AZ, UNITED STATES ; (4) University of Tennessee, KNOXVILLE, TN, UNITED STATES ; (5) University of California, BERKELEY, CA, UNITED STATES ; (6) Smithsonian Institution, WASHINGTON, D.C., UNITED STATES*

Alluvial fans extend up to 40 km into the interior of more than 110 Martian craters. The fans have gradients of about 2 degrees and are sourced from interior-rim drainage basins. Saheki crater contains the best exposures of fan stratigraphy due to selective post-deposition wind erosion that has raised gravel-floored distributaries into positive relief and exposed stratigraphic sections of interbedded fine deposits.

Distributaries generally extend from the crater apex to the fan terminus with sparse branching. Their tops are commonly paved with gravel estimated to have dominant grain sizes near the 25 cm/px resolution of spacecraft images; occasional meter-scale boulders are also seen. Wind erosion has resulted in distributaries becoming inverted by up to 80 m, exposing thick sections of bedded sediment on sideslopes. This bedded sediment is readily wind eroded, with visible layering of 1-3 m. Layers extend up to 1 km in the downslope direction, with local pinch-outs and possible unconformities.

We interpret the distributaries to have been formed by well-channelized fluvial flows depositing gravel in distributaries, with the thick layered wind-erodible sediment being deposited by overbank flows and dominated by granule-sized or finer grains. Alluvial fans in the Atacama Desert of northern Chile sourced from the Andean highlands are a potential analog.

Maximum discharges are estimated to range between 60-300 m<sup>3</sup>/s, depending on sediment density and concentration. Runoff rates of 0.5 to 3 mm/hr would be required from the 340 km<sup>2</sup> upland basin. The most likely climatic environment generating runoff on these ~ 3.2 Ga fans would be from melting during favorable orbital configurations of annual or epochal snow accumulations. Our calculated runoff rates match existing estimates of possible discharge rates from melting snow on Mars.

\*\*\*\*\*

### Surface dissolution on Titan: Ontario Lacus, Sikun Labyrinthus and other karst-like landscapes

*CORNET T.(1), BOURGEOIS O.(1), LE MOUÉLIC S.(1), SOTIN C.(2), FLEURANT C.(3), LEFÈVRE A.(1), RODRIGUEZ S.(4), MALASKA M.(5), BARNES J.W.(6), BROWN R.H.(7), BAINES K.H.(5), BURATTI B.J.(5), CLARK R.N.(8), NICHOLSON P.D.(9)*

*(1) LPGNantes - Université de Nantes - UMR CNRS 6112 - OSUNA, NANTES, FRANCE ; (2) JPL/LPGNantes, PASADENA, UNITED STATES ; (3) LETG - UMR CNRS 6554 - OSUNA, ANGERS, FRANCE ; (4) LAIM - CEA Saclay, GIF SUR YVETTE, FRANCE ; (5) JPL, PASADENA, UNITED STATES ; (6) University of Idaho, MOSCOW, UNITED STATES ; (7) LPL, TUCSON, UNITED STATES ; (8) USGS, DENVER, UNITED STATES ; (9) Cornell University, ITHACA, UNITED STATES*

Polar Regions of Saturn's major icy moon Titan are dotted with hundreds of closed depressions. Some of these are covered by liquid methane/ethane, which are metastable under Titan surface conditions (93 K, 1.5 bar). A karstic origin of these depressions seems highly likely [1,2].

Ontario Lacus, the widest depression of the southern hemisphere (235×75 km) is a flat-floored rounded depression lying within a wide and flat sedimentary basin. It appears to be liquid-covered over half of its surface, while the rest of the depression floor is probably composed of damp and smooth solid hydrocarbons. Landforms and climate of the area are close to those of the Etosha Pan [3], a karsto-evaporitic depression located in the southern part of the Owambo Basin (Namibia). This basin is covered by a superficial layer of calcretes that has formed and has been carved by repeated cycles of evaporitic crystallization and dissolution of calcium carbonates under a semi-arid climate. According to this analogy, Ontario Lacus may have formed by dissolution of a surface layer soluble in liquid hydrocarbons. Sikun Labyrinthus, a region located at similar latitudes, also exhibits landforms diagnostic of dissolution processes. Dissected plateaus, polygonal terrains, remnant ridges and empty depressions are interpreted as fluvio-karst, cockpit, tower karst and polje-like landforms [4,5].

Karst-like landforms are also observed in other regions, suggesting that the dissolution of a surface layer is a major land-shaping process on Titan. This surface layer may have formed by (1) precipitation of solid hydrocarbons produced in the atmosphere, or (2) evaporitic crystallization of hydrocarbons previously dissolved in an alkanifer.

[1] Bourgeois et al. (2008), 39th LPSC. [2] Mitchell et al. (2011), 1st Int. Plan. Cave Res. Work. [3] Cornet et al. (2012), Icarus, 218(2). [4] Malaska et al. (2010), 41st LPSC. [5] Malaska et al. (2011), 1st Intern. Plan. Cave Res. Work.

## Climate Change on Titan: Hypotheses and the Geological Record

MOORE J.M.(1), HOWARD A.D.(2)

(1) NASA ARC, MOFFETT FIELD, UNITED STATES ; (2) University of Virginia, CHARLOTTESVILLE, VA, UNITED STATES

On Titan climate dictates the intensity and relative roles of fluvial and aeolian activity from place to place and over geologic time. Hypotheses of Titan's climatic evolution fall into three broad categories, regulated and dominated by the role, sources, and availability of methane: Steady State, Progressive, and Cyclic. Preliminary mapping of putative basement rock indicates that it mostly appears within 30° of the equator. Equatorial ancient Uplands regions on Titan exhibit pronounced "crinkling" interpreted to be fluvially-dissected ridge and valley topography. We interpret smooth, dark areas within these uplands units as local sedimentary deposits, often apparently in old craters. Low mid-latitudes contain obvious concentrations of circular features that may be radar bright or radar dark. We provisionally interpret these regions as heavily degraded and partially sediment covered cratered terrains. High mid-latitude regions on Titan exhibit dissected sedimentary plains at a number of localities. Much of the high mid latitudes are otherwise relatively featureless, as are much the lake-dotted polar regions, consistent with these latitude belts being dominated by plains-forming fluvial and lacustrine sediment. The types of terrains seen on Titan may be difficult to reconcile with a simple steady-state scenario. For Titan to have still-recognizable cratered terrains *and* ongoing fluvial activity could imply one or more of at least three possible explanations: (1) alkane fluvial erosion on Titan is extremely inefficient relative to that by water on the Earth and Mars; (2) fluvial erosion very rarely (or briefly) occurs on some regions on Titan; and/or (3) it has started raining on Titan only in geologically recent times. We are currently investigating which climate scenarios best fit the suite of landforms found within given regions, and as well might explain the latitudinal arrangement of regions across the face of the satellite.

\*\*\*\*\*

## Evolution of terrestrial and Titan's rivers

MISIURA K., CZECHOWSKI L.

Warsaw University, WARSZAWA, POLAND

Titan is the only celestial body, beside the Earth, where liquid is present on the surface as lakes and rivers. In our research we use numerical model of the river to determine differences of evolution of rivers on the Earth and on Titan. We have found that transport of sediments on Titan is more effective than on Earth for the same river geometry and discharge.

Titan is a very special body in the Solar System. It is the only moon that has a dense atmosphere and flowing liquid on its surface. The Cassini-Huygens mission has found on Titan meandering rivers, and indicated processes of erosion, transport of solid material and its sedimentation. This paper is aimed to investigate the similarity and differences between these processes on Titan and the Earth.

The dynamical analysis of the considered rivers is performed using the package CCHE modified for the specific conditions on Titan. The package is based on the Navier-Stokes equations for depth-integrated two dimensional, turbulent flow and three dimensional convection-diffusion equation of sediment transport.

We considered our model for a few kinds of liquid found on Titan. The liquid that falls as a rain (75% CH<sub>4</sub>, 25% N<sub>2</sub>) has different properties than the fluid forming lakes (74% C<sub>2</sub>H<sub>6</sub>, 10% CH<sub>4</sub>, 7% C<sub>3</sub>H<sub>8</sub>, 8.5% C<sub>4</sub>H<sub>10</sub>, 0.5% N<sub>2</sub>). Other parameters of our model are: inflow discharge, outflow level, grain size of sediments etc. For every calculation performed for Titan's river similar calculations are performed for terrestrial ones.

We compare results of our calculation for flow of different liquids and for sediment transport for the Earth and for Titan. The basic statement is that on Titan the transport of sediment is more efficient than on Earth for rivers of the same geometry and total discharge.

We are very grateful to Yaoxin Zhang and Yafei Jia from NCCHE for providing their program – CCHE2D.

**Martian valley network geometry from mars express stereo images topography: implication for martian climate.**

ANSAN V., MANGOLD N.  
 LPGNnantes, NANTES, FRANCE

Since visible images have been acquired by Viking orbiter in 1976, valley networks have been mainly identified in the heavily cratered uplands dated Noachian (>3.5 Gyr). Valley networks on Mars have been the subject of considerable debates about their formation processes and their implications on the early Mars climate.

Based on orbital images, the branching valley networks could be classified in two groups: 1) dense valley networks with numerous tributaries and 2) valley networks with poor number of tributaries. The latter sometimes display small delta fans formed during a short time of fluvial erosion that requires episodic fluvial flows but likely not a globally different climate. For the dense valley networks, no erosion product is usually observed because they were subsequently eroded, or covered by later deposits (especially Hesperian lava flows). From crater counts, they seem to be mainly formed during the Late Noachian to the Early Hesperian.

Since 2004, the HRSC camera has acquired visual images in stereoscopic mode with typical spatial resolution of ~10m for the nadir images. Digital Elevation Models (DEM) can be generated with a spatial resolution of ~50 m. Based on this dataset, about 10 times better than the laser altimeter topography, we studied the branching valley networks in order to characterize the degree of erosion in different periods of Mars.

Our results show that the drainage density seems to be higher for younger terrains. The branching pattern is better preserved for young valley networks, even if the lithology and climatic proxy were not constant spatially and temporally during the Mars history. Second, although the young valley networks are more preserved, the power of fluvial erosion was higher during the Noachian with a higher vertical incision related to wider valleys. These results also show that 2D parameters cannot be used to derive the degree of incision and that the topography must be used to derive the actual degree of incision.

\*\*\*\*\*

**The third dimension of surface process: using hydrological analysis of high-resolution elevation data on the Moon, Mars and Earth to evaluate the action of water**

CONWAY S.J., BALME M.R.  
 Open University, MILTON KEYNES, UNITED KINGDOM

Planetary geomorphology commonly relies on comparison of the morphologies of surface features in two-dimensional image data. Such comparisons can suffer from problems of equifinality, where features formed by different processes look similar. A good example of this are gullies on Mars, which have been attributed to overland flow, debris flow, dry mass wasting and other exotic processes. On Earth, and ever increasingly on the Mars and the Moon, elevation data are being commonly used to provide stratigraphic relationships. With the growing availability of high resolution ~1 m/pix elevation data on all three bodies, avenues are opening for more detailed and complex investigation. Here we build on our previous work using terrain analysis techniques, previously primarily used in hydrological studies on Earth, to add the third dimension to the analysis of surface processes on planetary bodies.

We use stereo satellite images to build elevation models at 1-2m/pix on Mars and the Moon, and LiDAR data to build equivalent models on Earth. The terrain analysis relies on the analysis of local (e.g., slope, curvature) and far-field (i.e. those taking into account the upstream characteristics of the topography, such as distance from divide, upstream drainage area) terrain derivatives. We have already shown using these techniques that landscapes formed predominantly by overland-flow, debris flow and rockfall are distinguishable on Earth. We have also been the first to apply this work to Mars. Here we extend this work, to look at other surface processes and, for the first time, present analysis of the lunar surface.

## The morphology and distribution research of boulders in Lunar Sinus Iridum

ZOU X., LIU J., ZHAO J., WANG W., LI C.

National Astronomical Observatories, Chinese Academy of Sciences, BEIJING, CHINA

Boulders scattered all over the lunar surface were revealed by high-resolution cameras on current space crafts. The causes of boulders are mostly from cratering ejection, some are made by microsize impact or slope colapsions. The chinese first lunar lander/rover Chang'E-3 is planed to land in the Sinus Iridum landing area in 2013. Using the high resolution image data, we can analyze the topographic features of the area. The first goal of our reseach is to reduce the risk of the Chang'E-3 meeting boulders during its soft landing in the area. With recognizing and measuring, we can get the size (length, width, height and volume) and pozition (x, y, z within lunar control framework) of each boulder from Chang'E-2 1.5m and LRO 0.5m high-resolution images. After that we established the boulder database which is also a great tool to research the classification, intensity and timeline of the lunar surface evolution.

Using the boulder measurements we find out many facts about the morphology, gathering type and disribution of boulders. Firstly, we mapped 15.4 thousand boulder-groups of the area, sort them by their causes and distribution, and compare their difference in morphology. The boulder-groups covered about 10% of the area. Then, we calculate 211 boulders' height by measure their shadow lenth and the surface slope. We use different models to calculate different illumination cases to improve the accuracy. The statistics shows that most boulders are from secondary cratering causes and they are most fat-short rather than slim-tall. After all 17.0 thousand diameter measurements of boulders were made. The results shows that the biggest boulder is more than 23m long and the average size of detected boulders is 4.6m. In the last part of our research we used theoretical methods to research the morphology evolution of the region.

\*\*\*\*\*

## Poster presentations:

### A Valles Marineris synthesis

DEBNIAK K.(1), MEGE D.(1), GURGUREWICZ J.(1), MASSE M.(1), FORGET F.(2), LUCAS A.(3), SPIGA A.(2)

(1) Polish Academy of Sciences, WROCLAW, POLAND ; (2) Universite Pierre et Marie Curie, PARIS, FRANCE ; (3) California Institute of Technology, PASADENA, UNITED STATES

The Valles Marineris giant trough system opens an up to 10-km deep window into the geology of the Martian crust. Tectonic, volcanic, sedimentary, and erosional processes spanning a range of ~4 g.y. have been recorded along the trough walls and on their floor. They testify to a succession of paleo-environments and paleoclimates which have been a matter of debates since the Viking era. Far from being closed, these debates have been enriched and complexified by the accumulation of the subsequent datasets obtained by the Mars Global Surveyor (MGS), Mars Odyssey, Mars Express (MEx), and Mars Reconnaissance Orbiter (MRO) spacecrafts. The abundance of datasets, their diversity, very high resolution of visible imagery, as well as the small number of researchers involved in Valles Marineris exploration, contributed to thematic and geographic dispersion of studies to such a point that synthesis and correlation of previous works are necessary. From this point, new views and a new coherent framework for Valles Marineris evolution can emerge.

The undertaken study consists in the realization of a GIS of Valles Marineris that will include mosaics of selected datasets (MRO/CTX VIS images, Mars Odyssey/Themis night-time IR images, MGS/MOLA PEDR and DEM, MEx/HRSC images and DEMs, MRO/HIRISE images and DEMs), existing regional maps (MEx/OMEGA and MRO/CRISM mineral maps, gravity and magnetic maps), new regional or local maps (CTX DEMs, climate/paleoclimate models), basic geomorphologic description layers (in which geomorphology is not interpreted in terms of processes and environments), and advanced geomorphologic and geologic interpretation layers (in which processes and paleoenvironmental interpretations are proposed by the authors). The state of the art of this project, expected to be completed in 2015, will be presented.

### **Karst landforms as a geomorphic marker to record stratigraphic and litologic units in Sinus Meridiani (Mars)**

BAIONI D., SGAUETTI M.  
PARMA UNIVERSITY, PARMA, ITALY

Sinus Meridiani region is located next to Martian equator between 1°20' N to 2° 20' N latitude and 2° 50 ' W to 1°E longitude, covering an area of about 20,000 square kilometres, characterized by spectral signatures of evaporitic minerals.

A morphological and morphometric investigation of the study area through an integrated analysis of eighteen Reconnaissance Orbiter (MRO) High Resolution Imaging Science Experiment (HiRISE) was performed.

The analysis highlighted the presence of karst landforms that resemble similarly karst landforms that can be observed in different karst terrains on the Earth. In particular, four distinct karst terrains was observed in the study area characterized by different features displaying different kind and degree of karstification.

These differences seem to indicate the different relative karst susceptibility due to different solutional properties of these four units. Moreover, the results of this study suggest that the karst landforms can be used as useful geomorphic marker to record different units from the compositional and/or mineralogical point of view in the Sinus Meridiani area.

\*\*\*\*\*

### **Morphological characterization of landforms produced by springtime seasonal activity**

GARGANI J.(1), JOUANNIC G.(1), COSTARD F.(1), BOURGEOIS O.(2), MASSÉ M.(3), CARTER J.(4), MARMO C.(1), NACHON M.(2), ORI G.(5)  
(1) Univ. Paris-Sud, ORSAY, FRANCE ; (2) Univ. Nantes, NANTES, FRANCE ; (3) Polish Academy of Sciences, WROONA group, WROCLAW, POLAND ; (4) European Southern Observatory, VITACURA, CHILE ; (5) Univ. G. d'Annunzio, PESCARA, ITALY

On the basis of HiRISE images, we show that some perennial landforms on the Martian dune Russell are shaped by current seasonal viscous flows that occur during spring, after complete disappearance of the winter CO<sub>2</sub> ice layer, and are able to erode their substrate. These perennial landforms comprise a complex interconnected rills system that has morphological similarities with networks of meltwater channels on some terrestrial temperate glaciers. Activity has been recorded each year between 2007 and 2011 in this rill system, which grew at a rate of 10000 m<sup>2</sup>.yr<sup>-1</sup>. The morphology of the rill system is consistent with viscous flow of a material able to erode as well as to carry a non negligible quantity of sand. There are at least four processes that could explain the physical properties of these perennial rills estimated in this study: (1) brine flow, (2) liquid water flow mixed with sand, (3) liquid water flow mixed with snow or ice, (4) a combination of the previous three processes. The formation of these perennial rills occurred through multiple pulses probably in relation with a daily freeze/thaw cycle. Different methods have been used to estimate the velocity of flow required to form these perennial rills. The velocity estimated using image comparison ( $\sim 10^{-3} - 10^{-4} \text{ m.s}^{-1}$ ) is smaller than the one estimated using the mechanical threshold of motion for sand grains ( $\sim 10^{-2} - 10^{-3} \text{ m.s}^{-1}$ ) or to the one obtained by modeling the viscous flow dynamic ( $1 \text{ m.s}^{-1} - 20 \text{ m.s}^{-1}$ ).

## Impactive processes and morpholitogenes

YURY E.

*Kuban State University, KRASNODAR, RUSSIAN FEDERATION*

Meteorite craters are widespread on a surface of Earth and other planets. Crater landscapes of the Moon, Mars, Mercury and many satellites in Solar system were formed generally as a result of repeated blows of meteorites, fireballs, comets of various scale (Efremov, 1999).

Space bodies and terrestrial gravitational processes (avalanches, landslides, collapses and mud streams) transform a surface on which they fall. Thus there are the special genetic forms of a relief named as impact one. At such influence in rocks and friable deposits there are considerable changes. At blows of space bodies rocks and minerals transform in and move on the periphery of an explosion crater. Therefore we selected special impactive.

Consider various features of formation and transformation of impact relief and friable deposits it is necessary to allocate the next morpholitogenes classes: meteorite-shock, avalanche - shock, gravitational - shock.

*Meteorite – shock morpholitogenes.* Mechanism of influence of space bodies on a surface of Earth is well studied. At the same time varieties such morpholitogenes are a little known.

*Avalanche - shock morpholitogenes.* Formation of such forms of a relief possibly only under certain conditions. Shock forms are located in areas of the ancient glaciation being characterized by steep slopes of glacial trough valleys or deep erosive valleys. Formation of the specified forms of a relief occurs in areas to considerable moistening, a frequent descent of avalanches and a large number of fragments of rocks.

*Gravitational - shock morpholitogenes.* About shock impact of landslide, and mudflow masses on a spreading bed it is a little known. Thus, now it is possible to explain an origin of a Earth relief and other planets of Solar system not only result of action of gravitational, endogenetic and exogenous processes, but also cosmogenical factors - in blows of space bodies to spreading bed.

\*\*\*\*\*

## Formation and evolution of river deltas on Titan and Earth

WITEK P.

*Institute of Geophysics, University of Warsaw, WARSZAWA, POLAND*

River deltas are created as a result of transport and deposition of sediments by flowing liquids. These landforms are known to exist on Earth, Mars and Titan, the largest moon of Saturn. Titan is the only celestial body other than Earth where current surface conditions allow the fluids to exist and shape the surface. Lakes of liquid hydrocarbons and river valleys have been observed by Cassini probe. At the shore of Ontario Lacus, the largest lake of the southern hemisphere, there exist a feature interpreted as a two-lobed river delta. We simulate the flow and sediment transport to understand similarities and differences of sedimentary processes between Titanian and terrestrial rivers. We consider several possible chemical compositions of the flowing liquid and sediments for our models of Titanian rivers. We use two-dimensional depth-averaged hydrodynamic numerical model, based on the Reynolds approximation of momentum equations and the continuity equation. Additional equations are used to describe bed-load transport, suspended sediment transport and deposition.

## The Geomorphology of Lyot Crater, Mars

BALME M.(1), GALLAGHER C.(2), CONWAY S.(1)

(1) *Open University, MILTON KEYNES, UNITED KINGDOM*; (2) *University College Dublin, DUBLIN, IRELAND*

Lyot crater, Mars, is a relatively young (<3 Ga), deep (~ 7 km below Mars datum) impact basin situated at about 50°N, just north of the dichotomy boundary. The impact almost certainly penetrated the cryosphere, and would have exposed any groundwater zone existing beneath. Recent studies have linked large fluvial channels located outside Lyot's ejecta blanket with impact-release of groundwater or melting of ice [1], and small fluvial channels within the basin with much later climate-related events [2]. Thus the deposits and channel systems in and around Lyot crater provide an ideal study area for (i) investigations aimed at exploring the sediments and volatiles excavated during impact and perhaps a way of testing whether there was a groundwater zone, and (ii) studies of glacial and periglacial environments useful for understanding water on Mars throughout its history.

We present preliminary mapping of the various ice- and water-related landforms found in and around Lyot crater. Of particular interest are polygonal networks of metre-scale clasts, and a variety of channels, fans and lobate flows. The lobate flows exist within the crater rim and in high relief areas outside the crater. Fluvial-like channels and fans are seen both within the crater and on the ejecta blanket. The networks of polygonal clasts occur only on the eastern margins of the continuous ejecta blanket, at a radial distance of about 300 km from the crater centre. This pattern suggests that the emplacement of these landforms is genetically related to the impact.

Our working hypothesis is that the lobate flows, fans and channels represent glacial/fluvial assemblages. The polygonal clast network is harder to explain, but could reflect the location of water-ice-rich zones in the ejecta blanket. Hence, this could be material excavated from the cryosphere during impacts and then reworked by periglacial processes at a much later time.

[1] Harrison, T.N., et al., GRL 2010. [2] Dickson, J.L., et al., GRL 2009.

\*\*\*\*\*

## Numerical model of flow in some martian valleys

CZECHOWSKI L., WITEK P., MISIURA K.

*University of Warsaw, WARSZAWA, POLAND*

On the surface of Mars, under current conditions, liquid water could exist only occasionally in lowest regions of the planet. This water contains probably some components that decrease its freezing point and raised its boiling point. However billions years ago more dense atmosphere on the Mars allows for the presence of large volume of liquid water. There are a number of structures apparently resulting from owing liquid water in the past. They are of two types: outflow channels and valley networks. The Curiosity rover landed close to ancient river's valley, so some details concerning of the rivers flow on Mars will be known in the near future. In our research we investigate the possible flow in some chosen valley networks on Mars. The numerical model based on equations of turbulent flow is used. The erosion and transport of the solid material is described by another equation. We try to determine the basic properties of the flow, its erosion as well as the transport efficiency of the solid material. The comparison with the terrestrial rivers indicates some important differences that concern mainly the rate of erosion and sedimentation.

### Geomorphological study of martian seasonal activity on the Kaiser crater dune field (46°10'S ; 18°50'E)

NACHON M.(1), GARGANI J.(2), JOUANNIC G.(2), COSTARD F.(2), CONWAY S.(3), BALME M.(3)

(1) Université de Nantes - Laboratoire de Planétologie et Géodynamique, NANTES, FRANCE ; (2) Université Paris-Sud XI - Laboratoire IDES, ORSAY, FRANCE ; (3) Open University - Department of Physical Sciences, MILTON KEYNES, UNITED KINGDOM

An increasing number of studies have shown that there is seasonal activity at high and medium latitudes on Mars, which leaves a lasting effect on the surface [e.g. 1-8]. This seasonal activity takes a variety of forms (e.g., dark spots, dark flows, dust devil tracks, perennial rills, etc), and each generally occurs at the same time each martian year [3,5,8].

The focus of our study is one of the largest barchan dunes in the Solar System (~7 km wide, ~300 m high), located on the dune field inside Kaiser crater (46°10'S ; 18°50'E). This barchan contains three groups of gully systems on the lee slope, which differ in morphology, orientation and location on the dune's slipface [3].

We have used data from the High Resolution Imaging Science Experiment camera, onboard Mars Reconnaissance Orbiter, which provides high resolution images (~25 cm/pixel) over several martian years.

We have catalogued the occurrence of the various forms of seasonal activity occurring on the barchan, and focused on one particular type of activity which occurs in local autumn and winter and seems to originate in gullies. We have described in detail its evolution in morphology of this seasonal activity, that appears to involve significant quantities of dune material.

We have also described and characterised a discrete but relatively massive event that occurred in our zone of study.

We will discuss the processes that lead to this seasonal activity, which seem to be linked to the CO<sub>2</sub> seasonal cycle, and their impact on the long-term evolution of Martian dunes.

References : [1] Kieffer *et al.* 2006, *Nature*, 442:793–796. [2] Diniega *et al.* 2010 *Geology*, 38(11):1047–1050. [3] Dundas *et al.* 2010 *Geophys. Res. Letters*, 37:7202. [4] Gardin *et al.* 2010 *JGR (Planets)*, 115:6016. [5] Reiss *et al.* 2010 *Geophys. Res. Letters*, 37:6203. [6] Hansen *et al.* 2011 *Science*, 331:575. [7] Kerezuri *et al.* 2011a, *Planet. & Space Science*, 59:1413–1427. [8] Jouannic *et al.* 2012 *Planet. & Space Science*, submitted.

\*\*\*\*\*

### Mare Basalt thickness Model of Lunar Polar Regions

WANG W., LIU J., ZOU X., LI C.

National Astronomical Observatories, Chinese Academy of Sciences, BEIJING, CHINA

Thickness of Lunar mare basalts which cover most of the lunar craters and basins plays an important part in investigating the thermal history, lithospheric thickness, gravity field, and the effect of vertical impact. Basic approaches for determining mare thicknesses make use of a flooded crater's morphology, the composition of crater ejecta, and subsurface reflections observed in the radar sounding experiment. The interpretation of gravity anomalies can also be used to constrain the thickness of a mare deposit. In the 1970s, Eggleton, DeHon and Waskom produced lunar nearside maps of mare basalts with morphological methods. In 1998 and 2002, Oceanus Procellarum, Mare Humorum and Mare Smythii were studied by the Clementine multispectral data. After 1997, Yingst *et al.* calculated the lava ponds volumes of South Pole Aitken.

However, due to the coverage and resolution limitations of terrain and image data of historical exploration missions, the mare basalts distributions in the lunar polar region are little concerned. In this paper, based on the image and topography data from CE-2 and LRO missions, and gravity data from SELENE mission, the admittance and correlation between topography and gravity can be calculated. With their power spectra curves, the gravity anomalies of different depths can be divided, and the mass anomalies distributions can be inverted, among which the surface mass anomalies reflect the high density mare basalts distributions. Furthermore, it's concluded that mass anomalies of mare basalts and of crust-mantle terrain are of similar magnitudes, and they contribute together to the lunar massons.

Polar images of 7m/pixel obtained from CE-2 and images of 2m/pixel from LRO NAC are merged as the source data, in order to obtain more crater information. The diameters of craters larger than 1km are recorded, and together with the mean density anomaly (e.g.500kg/m<sup>3</sup>) of mare basalts, we get the mare basalt thickness models of main craters of lunar polar region.

### Rates of Dune Migration in a Polar Cavi on Mars

BOURKE M.(1), PARTELI E.(2), BYRNE S.(3), BERMAN D.(4)

(1) Trinity College, DUBLIN, IRELAND ; (2) Universität Erlangen, NURNBERG, GERMANY ; (3) University of Arizona, TUCSON, UNITED STATES ; (4) Planetary Science Institute, TUCSON, UNITED STATES

Sand is mobile under the current Martian climate. Here we present a detailed study of the morphometry and migration of barchan and dome dunes in the North Polar Region of Mars.

The dunes are located at the head of an unnamed Polar Cavi. Dune sediment is locally sourced from the Basal Unit exposed in the adjacent Cavi wall and are enriched with gypsum derived from the Upper Layered Deposits. The dunefield is composed of barchan and barchanoid dunes that traverse a number of topographic steps up and away from the Cavi head wall.

Dune width and length of 34 dunes were measured from 25 cm/pixel resolution HiRISE Images. In order to estimate dune heights, a HiRISE stereo pair were processed to build a high resolution DTM. Change in dune morphology and position was mapped using HiRISE images taken at two time steps extending over two Mars years.

*Dune Morphometry.* Dunes are on average 170 m long and 121 m wide. Mean dune height is 18 m and is positively correlated with dune width ( $R^2 = 0.71$ ). 68% of the sample dunes are asymmetric suggesting that, similar to Earth, barchan asymmetry is a morphological norm.

*Dune Displacement.* Dunes at the Cavi sample site have migrated 5 m on average over 2 Mars Years. The individual dune rates are highly variable, measuring between 0.57 and 17.7 m. Dune displacement distance decrease with increasing dune height, but the relationship is poorly correlated.

Dunes in the North Polar Region are migrating under the current climate regime. Rates are variable and may be influenced by topography, proximity to other dunes but not dune form. The smallest dunes have migrated the greatest distance. These include both dome dunes and dunes that are transitional forms between dome and barchan.

\*\*\*\*\*

### The alluvial fans of northern Chile as a terrestrial analog of the fan systems on Mars

MORGAN A.(1), HOWARD A.(1), HOBLEY D.(1), MATSUBARA Y.(1), MOORE J.(2), PARSONS R.(2), DIETRICH W.(3), BURR D.(4), WILLIAMS R.(5), HAYES A.(6)

(1) University of Virginia, CHARLOTTESVILLE, UNITED STATES ; (2) NASA Ames Research Center, MOFFETT FIELD, UNITED STATES ; (3) University of California, Berkeley, BERKELEY, UNITED STATES ; (4) University of Tennessee, KNOXVILLE, UNITED STATES ; (5) Planetary Science Institute, TUCSON, UNITED STATES ; (6) Cornell University, ITHACA, UNITED STATES

Alluvial fans in the Pampa de Tamarugal region of the Atacama Desert in northern Chile, located along a 180km stretch of the western slope of the Andes constitute an exceptional terrestrial analog for the numerous fans observed on Mars due to 1. similar scale (~30 km length, source basin relief ~2 km), and gradient ( $< 3^\circ$ ), 2. hyperaridity of the environment (Atacama precipitation rate of  $< 2$  mm/yr), 3. low channel branching density, 4. dominance of wind over fluvial erosion of the inactive fan surface, and 5. dominance of mud sedimentation.

Sediment deposited on railroad tracks and roads indicates that flows have occurred within the past few decades. Vegetation is very scarce and localized to recently active flow channels. Avulsions occur frequently. The source region provides sediment of varying composition (fine grained mudstones, sandstones, volcanic ash) from the western edge of the Andes.

The exposed stratigraphy contains cobble-sized alluvium interbedded with fine-grained mudflows. Recently active flows are dominated by fine sediment with fine-grained, sheetflow-like mud deposits extending outward of the active channel for about 150m bilaterally. Well-sorted, rounded, gravel to cobble sized material on the channel floor was probably deposited by less muddy waning-stage flows. Multiple, compositionally distinctive overbank mudflows typically contain 10-25% clay, 10-50% silt, 15-60% sand, and  $< 5\%$  fine granules. Channels on inactive portions near the fan periphery have been partially inverted in relief by wind erosion of interbedded overbank deposits.

We infer the fans have formed through hundreds of separate (temporally widely spaced) flows, with only a small portion of the fan receiving sediment during a single event. We conclude that the processes and formative environment are good analogs for those that occurred on Mars. These lessons will be applied to future quantitative modeling.

### Modeling barchan dune asymmetry

PARTELLI E.(1), DURAN O.(2), BOURKE M.(3), TSOAR H.(4), HERRMANN H.(5)

(1) University of Erlangen-Nuremberg, ERLANGEN, GERMANY ; (2) University of North Carolina-Chapel Hill, CHAPEL HILL, UNITED STATES ; (3) Trinity College Dublin, DUBLIN, IRELAND ; (4) Ben-Gurion University of the Negev, BEER SHEVA, ISRAEL ; (5) ETH Zürich, ZÜRICH, SWITZERLAND

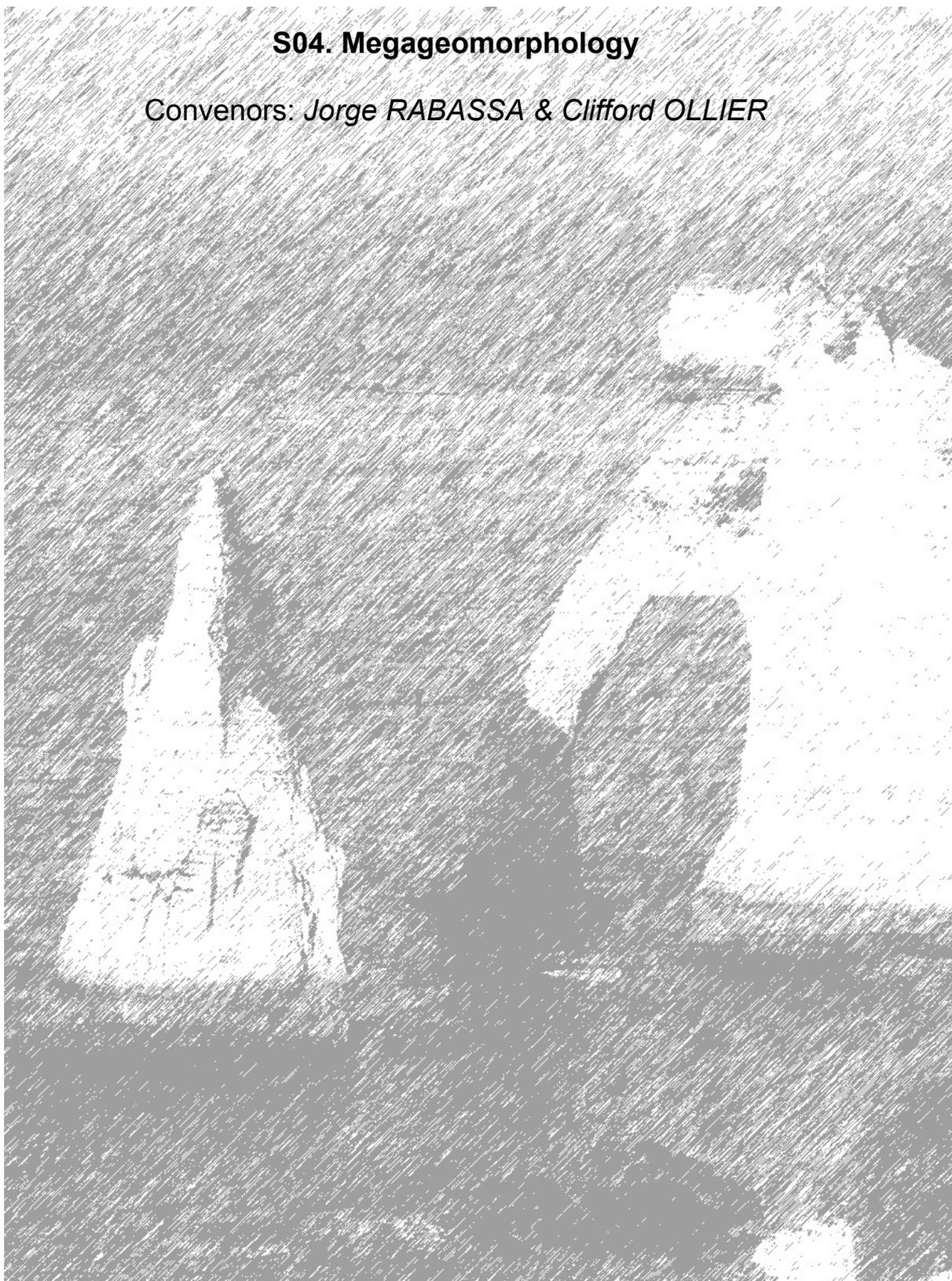
Barchan dunes — crescent-shaped dunes that form in areas of unidirectional winds and low sand availability — commonly display an asymmetric shape, with one limb extended downwind. Several factors have been identified as potential causes for barchan dune asymmetry on Earth and Mars: asymmetric bimodal wind regime, topography, influx asymmetry and dune collision. However, the dynamics and potential range of barchan morphologies emerging under each specific scenario are far from being understood, and if better understood could be used to indicate environmental conditions and dune morphodynamics on Earth and Mars. Here we use numerical modeling to investigate the formation and evolution of asymmetric barchans.

We find that a bimodal wind regime causes limb extension when the divergence angle between primary and secondary winds is larger than  $90^\circ$ ; the extended limb evolves into a seif dune if the ratio between secondary and primary transport rates is larger than 25%. Barchans migrating along an inclined surface also display asymmetry. Such asymmetric barchans move laterally, with transverse migration velocity proportional to the slope of the terrain. Limb elongation induced by topography can occur when a barchan crosses a topographic rise; the limb closest to the topographic rise elongates downwind. Moreover, asymmetric barchan shapes caused by sediment influx asymmetry are transient: the limb subjected to the smaller influx elongates downwind, while the dune migrates laterally towards the region of higher influx. Asymmetry can be also triggered by collisions between two barchans with lateral offset, the colliding limbs of which merge to form a single limb extended downwind. Collisions between multiple barchans give rise to more complex asymmetric patterns. Our findings can be useful for making quantitative inference on local wind regimes or understanding the spatial heterogeneities in transport conditions of planetary dune fields hosting asymmetric barchans.

\*\*\*\*\*

## **S04. Megageomorphology**

Convenors: *Jorge RABASSA & Clifford OLLIER*





## **Oral presentations:**

### **Late-Cenozoic relief evolution under evolving climate: A review of quantitative arguments**

CHAMPAGNAC J.

*ETH, ZURICH, SWITZERLAND*

Relief is defined as an elevation difference between two points. Relief can increase, decrease, or remain constant through time, regardless of the absolute erosion rates. The relief evolution directly reflects the spatial distribution of the equilibrium between the uplift and the erosion of rocks. Understanding how, why, and when relief has changed in the past can help to understand the causal relationship between tectonics, topography and climate and the relation between erosion and the climate. Relief change can be addressed by three different ways, or by combination of them: (1) direct quantification of differential erosion by surface dating, or direct erosion rate quantification with cosmogenic radionuclides inventories, (2) quantification of differential exhumation histories using thermochronology, and (3) numerical modeling of landscape evolution. This study mostly focus on the results from cosmogenic radionuclides dating that has demonstrated the ability to quantify relief change at kyr timescale, and from low-temperature thermochronology, which has been used to constrain relief change at Myr timescale, as well as a critical review of results from landscape evolution modelling. Finally, I review the different views provided by the literature on the potential links between relief and erosion, climate and tectonics, as well as their respective evolution through geological times. Tracking relief evolution is different than tracking changes in erosion rate, because relief evolution depends on the spatial variability of the erosion, not directly on the local or spatially-averaged erosion rates. Hence, tracking relief changes through time may provide insights on the location of the erosion, and therefore can be used to better understand (1) geomorphic/physical rules that govern each individual erosional agent (e.g. fluvial, glacial, etc.), and 2) how the distribution of the different erosional mechanisms are distributed in both space and time.

\*\*\*\*\*

### **Gondwana paleosurfaces: large-scale and long-term landscape evolution in cratonic areas of Argentina**

RABASSA J.

*CADIC-CONICET and Universidad de Tierra del Fuego, USHUAIA, ARGENTINA*

Gondwana paleosurfaces in Argentina were identified by Juan Keidel and Walther Penck at the beginning of the 20th century. However, these concepts gradually disappeared from the Argentine geological scene, dominated instead by the influence of American geomorphologists, and particularly William Thornbury, who doubted about the existence of such ancient landforms, when one of the main paradigms of the time was that "practically there is no landscape older than the Pleistocene". These landforms are the result of deep chemical weathering and/or pedimentation processes, developed in very stable tectonic and climatic environments, mostly under hypertropical climates, either extremely wet, arid or seasonally changing. Remains of the Gondwana paleosurfaces have been recognized in Argentina, from N to S, in the basaltic hills of the province of Misiones, the Sierras Pampeanas of the provinces of Catamarca, La Rioja and San Juan, the Sierras Chicas, Sierras Grandes and Sierra Norte of Córdoba province, the Sierras de San Luis, the Sierra Pintada or San Rafael Block of Mendoza province, the Sierras de Tandil, Sierra de la Ventana and the Pampa Interserrana of Buenos Aires province, the Sierras de Lihuel Calel of the province of La Pampa, the Somuncurá or Northern Patagonian Massif in the provinces of Río Negro and Chubut, and the Deseado Massif of Santa Cruz province. In other cratonic regions of Argentina, these surfaces have been down-warped in tectonic basins and are covered by sedimentary and/or volcanic units of various ages. The age for the Gondwana paleosurfaces has been estimated in between the middle Jurassic and the Paleogene. The Gondwana paleosurfaces were uplifted, fragmented, denudated and isolated during middle to late Tertiary due to the Andean orogeny, and they have remained above extensive pediplains and piedmont deposits, while climate and environments changed to more arid and cooler during the late Cenozoic.

## **Geomorphological characterization of relictic Gondwanic paleosurfaces in the Comechingones range, Central Pampean Mountains, Argentina**

DEGIOVANNI S.

*Universidad Nacional de Rio Cuarto, RIO CUARTO, ARGENTINA*

The genesis and age of remnants of pre-Andean planation surfaces in the Pampean Mountains, described by several authors, are still controversial, but in general are considered as erosional surfaces (etchplains, pediplains) generated in Middle to Late Jurassic – Paleogene period. The surfaces preserved at the summit of Comechingones range (between 32°22'-32°51'S and 64°50'-64°57'W) were developed on Late Proterozoic-Cambrian moderate-high grade metamorphic rocks and Devonian granites. During the Andean movements almost all surfaces were fragmented, elevated and tilted, and consequently exposed to a new erosional cycle. They are partially covered by a Quaternary loessic sequence. Morphologic, genetic and evolutive features from these surfaces are discussed in this work, by using digital elevation models, and metalogenetic, stratigraphic, structural and chronological background information. The surfaces are located between 2150 and 1500 m.a.s.l. and are interpreted as a single level that tilts southwards and eastwards. The planation surfaces on metamorphic rocks show more homogeneity than the granitic surfaces, with a minimal local relief. In contrast, the granitic surfaces present residual landforms, such as bornhardts, tors and corestones, and greater fluvial incision. These paleosurfaces are linked to an etchplanation-pedimentation process associated with: 1- a deep weathering cycle in a tropical humid climate during Jurassic times. In the granitic rocks, in addition to the residual landforms, epithermal fluorite-chalcedony deposits (117±26 Ma) indicate a mixing of hydrothermal fluids with meteoric waters, at successively shallower depths (less than 2 km). 2- a denudation cycle in semiarid-arid climate, evidenced by the sedimentary record in the surrounding Mesozoic rifting basins. The different geomorphological evolution of the analyzed paleosurfaces was conditioned by the lithology and mainly by the degree of fracturing of granitic rocks.

\*\*\*\*\*

## **The Neogene evolution of the Congo and Kalahari basins, with a focus on the Congo-Zambezi watershed**

FLUGEL T.J.(1), ECKARDT F.D.(2), COTTERILL F.P.D.(3)

*(1) Department of Military Geography, Faculty of Military Science, Stellenbosch University, SALDANHA, SOUTH AFRICA ; (2) Department of Environmental & Geographical Science, University of Cape Town, CAPE TOWN, SOUTH AFRICA ; (3) AEON Geoecodynamics Research Hub, c/o Dept Botany & Zoology, University of Stellenbosch, STELLENBOSCH, SOUTH AFRICA*

Two of the most distinctive morphological features of sub-Saharan Africa are the low lying Congo basin (mean elevation ~400 m.a.m.s.l.) that abuts the elevated Kalahari plateau (mean elevation ~1100 m.a.m.s.l.). These basins maintain the world's 2<sup>nd</sup> and 21<sup>st</sup> largest rivers by volume, the Congo and Zambezi respectively. The majority of the Congo-Zambezi watershed that separates these two continental rivers is a topographical smooth tableland, with the Angola highlands in the west and the Western branch of the East African Rift System (EARS) in the east, separated by a flat seasonal wetland. The Congo-Zambezi watershed is, therefore, a transition zone, incorporating three types of landforms: old, macro-landforms of the Kalahari Plateau and Congo Basin; newer, meso-landforms of EARS, horst and graben structures; and newer, process landforms evidenced by headwater capture features along the watershed. Thus, the Congo-Zambezi watershed is uniquely placed to provide insight into the development of the mega-geomorphology of southern and central Africa.

Hydrographically, the watershed separates the northerly flowing rivers of the Congo Basin from the southerly flowing rivers of Kalahari (Zambezi and Okavango) Basin. The evolution of these large river systems and their associated tributaries is of fundamental importance when investigating the ongoing development of the continental watershed. Remote sensing and GIS was used to study the region. Several key events, which are pivotal to understand the geomorphic evolution of bimodal Africa, were identified. Much of the present day Congo system was established by the late Neogene, with the modern form of the Zambezi system being Plio-Pleistocene in age. However, some elements of both systems are substantially older than this. These results are combined with published data from several fields, including phylogeography, to provide an overview of the Neogene evolution of these landscapes.

### **The lateritic materials occurrence in Brazil - geographic distribution and association to the paleosurfaces**

LADEIRA F.S.B.(1), LEONARDI F.(1), SANTOS M.(2)

(1) Unicamp, CAMPINAS, BRAZIL ; (2) Unesp, OURINHOS, BRAZIL

The lateritic materials occurrence in Brazil is very common and widely treated by the literature. These materials correspond to lateritic profiles and deposits derived from reworking of such profiles, which concentrated iron and/or aluminum relative to bedrock.

Although quite common in Brazilian literature there is no systematic mapping and association of these materials to geomorphological surfaces. The main objective of this study consisted in mapping the geographical distribution of these materials, its altitude occurrence and its association to the main Brazilian morphostructural units.

Geological Mapping of Brazil in scale 1:1,000,000 existing in the literature was basic source for this work. The surface covered by Brazilian lateritic materials corresponding to 11.69% of the Brazilian territory (995,372.28 km<sup>2</sup>), 25.4% of the area occurs over 300 meters, 45.3% between 300 and 600 meters, 28.6% between 600 and 1,000 meters and only 0.7% between 1,000 and 1,200 meters of altitude.

The larger occurrence areas of lateritic materials are concentrated in the northern and northwestern Brazil, while less significant areas are in the southeastern and northeastern and nearly nonexistent in the southern Brazil.

It is known that due to the representation scale, multiple occurrences were not mapped, especially those at higher altitude, which have more limited geographical distribution. More detailed mapping, geochemical characterization and association to the surfaces still need to be performed.

ACKNOWLEDGEMENTS: to FAPESP for funding the project Geomorphic Paleosurfaces Correlation of Summit in Brazil, Uruguay and Argentina - dating, morphology, cartography, deposits and associated alteration profiles (2011/23325-7), and PhD scholarship for second author. To CNPq for the first author's productivity scholarship (312583/2009-5).

\*\*\*\*\*

### **Poster presentations:**

#### **Long-term evolution of West African drainage, denudation and paleo-river long profiles using the lateritic record from the Cenozoic**

GRIMAUD J.(1), CHARDON D.(1), ROUBY D.(1), BEAUVAIS A.(2)

(1) GET Toulouse, TOULOUSE, FRANCE ; (2) CEREGE, AIX-MARSEILLE, FRANCE

We characterize and quantify the long-term erosion processes and drainage evolution of the West African craton on the basis of its Cenozoic lateritic paleosurface record. We use stepped, abandoned surfaces of regional extent as markers of former erosion levels. Each abandoned surface has a specific morphology and position within the landscape and is sealed by a type-duricrust. We assume that those surfaces, described all over West Africa and whose age is bracketed by published <sup>39</sup>Ar/<sup>40</sup>Ar dates on lateritic K-Mn oxides of the Tambao Mn deposit in Burkina Faso, formed broadly synchronously on a craton scale. S1, the African bauxitic surface, was abandoned in the Mid-Eocene at ~ 45 Ma, S2, the Intermediate ferruginous surface at the end of the Oligocene (~ 24 Ma), and S3 and S4 the ferruginous pediments at ~ 11 and 6 Ma, respectively.

We produce interpolated surface maps based on remnant surfaces of S1 and S2. This allowed constructing large-scale cratonic relief at ~ 45 and 24 Ma and evaluating the modification of divides for 2 time spans (45-24 and 24-0 Ma). Subtraction of interpolated surface maps allowed evaluation of preliminary sedimentary fluxes exported over the same time intervals by sub-drainage area. Successive Paleo-river long profiles of the main drains were reconstructed by interpolating base levels corresponding to each paleosurface.

We document craton-scale drainage rearrangement and establishment of the modern drains of West Africa back in the Oligocene. Since then, the river long profiles evolved slightly and display stationary features such as knick points. Epeirogeny is suggested by convex patterns of modern and paleo-river long profiles on the slopes of the Hoggar swell, whereas the Guinean & Leo rises could be essentially inherited from the Eocene. Comparisons of denuded volumes with offshore clastic sedimentary record provide first-order preliminary constraints on the West African Cenozoic source-to-sink system.

## The neotectonic period and geomorphology

OLLIER C.

University of Western Australia, PERTH, AUSTRALIA

Most mountain regions are dissected plateaus, formed by uplift of a planation surface. The age of mountains is not the age of the last folding (if any) but the age of vertical uplift.

A compilation of mountain uplift throughout the world shows that a major phase of uplift started about 8Ma, and much uplift occurred in the last 2 Ma. This period is known as the Neotectonic Period. It has several important implications to tectonics and geomorphology. In plate tectonics theory, mountains are explained as resulting from compression at active margins, and mountains in other locations are said to have been caused by the same process but further back in time. This is disproved by the young age of uplift in intercontinental and passive margin positions. Seafloor spreading and alleged subduction have been continuous for hundreds of millions of years, so cannot explain the world-wide uplifts in just a few million years.

Neotectonic uplift often affects broad areas though epeirogenic uplift, but may be more localised, as in the horsts of the Rocky Mountains. Downward movement forming rifts and graben is also associated with the Neotectonic Period, and together with uplift caused many changes of base level.

The Neotectonic Period does not fit into conventional theories of geomorphology. Davisian geomorphology depends on a rapid uplift to initiate a new cycle. The Neotectonic period might initiate several cycles but most planation surfaces are much older. King's pediplanation cycle has the same problem. He also had the formation of new continental margins as a way to initiate new planation surfaces, but this is long before the Neotectonic Period.

The increasing relief associated with Neotectonic uplift would have affected rates of erosion and sedimentation, and late Cenozoic climate.

Geomorphologists should be guided by their own findings, and refrain from theory-driven hypotheses of plate collision.

\*\*\*\*\*

## Bajada del Diablo impact crater-strewn field: the largest crater field in the Southern Hemisphere

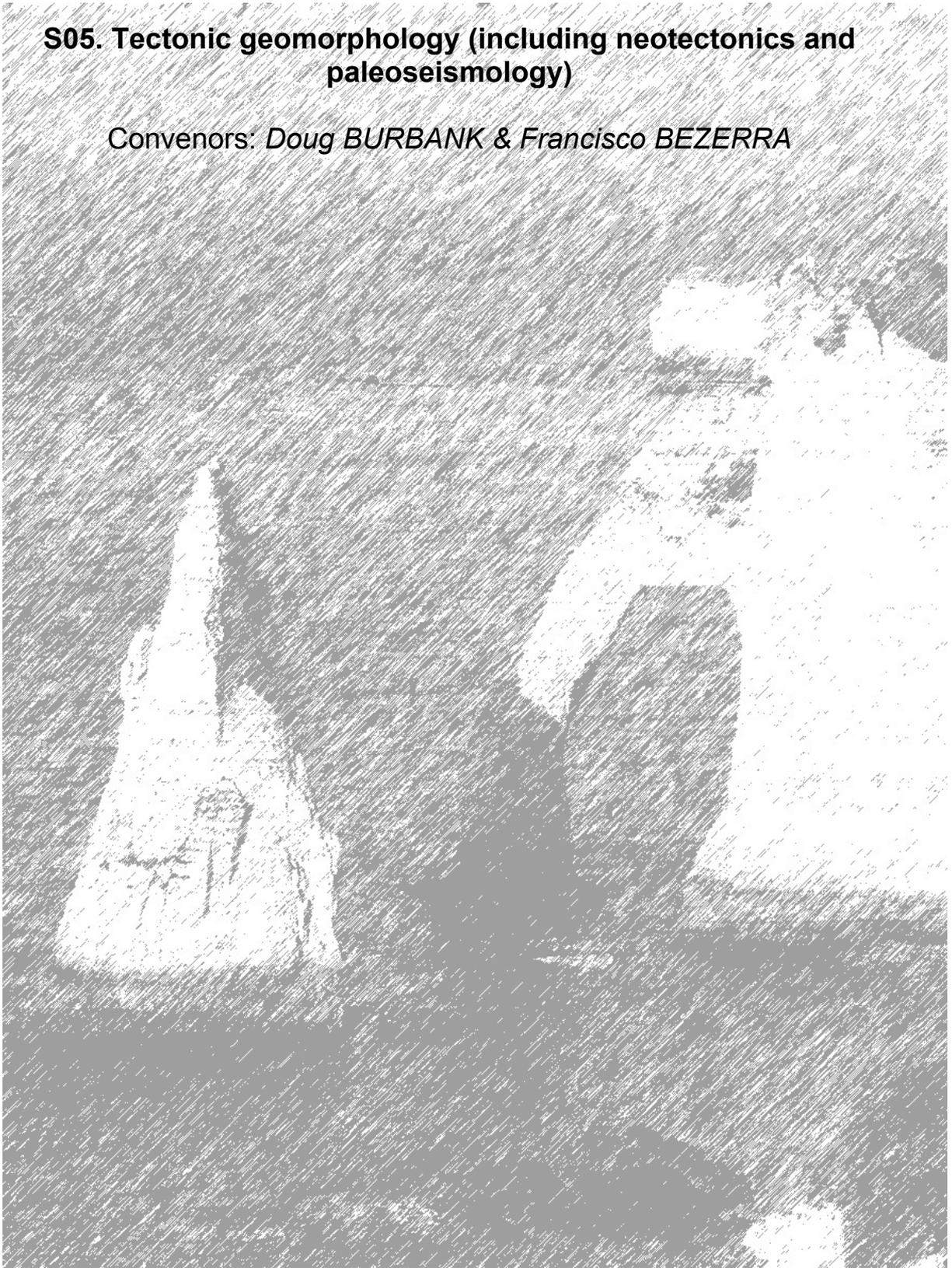
*RABASSA J.(1), ACEVEDO R.D.(1), PONCE J.F.(1), MARTÍNEZ O.A.(2), ORGEIRA M.J.(3), PREZZI C.(3), CORBELLÀ H.(4), GONZÁLEZ-GUILLOT M.(1), ROCCA M.(5), SUBÍAS I.(6), VÁZQUEZ C.(3)*

*(1) CADIC-CONICET and Universidad de Tierra del Fuego, USHUAIA, ARGENTINA ; (2) Universidad Nacional de la Patagonia, ESQUEL, ARGENTINA ; (3) CONICET & Universidad de Buenos Aires, BUENOS AIRES, ARGENTINA ; (4) CONICET & Museo Argentino de Ciencias Naturales, BUENOS AIRES, ARGENTINA ; (5) Mendoza 2779, BUENOS AIRES, ARGENTINA ; (6) Universidad de Zaragoza, ZARAGOZA, SPAIN*

Recent remote sensing analyses and field studies have shown that Bajada del Diablo, in Argentine Patagonia, is a huge, new crater strewn field. The Bajada del Diablo astrobleme-strewn field is a domain of enigmatic circular structures located in central Patagonia. Four different impact areas are herein described, investigated, mapped, and geo-referenced. A single, blurred crater dispersion ellipse has been identified. A total of 185 circular structures (some of which are partially obliterated by erosion or sediment accumulation), were identified by remote sensing techniques, but many have been evaluated in situ and interpreted as impact craters. Moreover, two of the structures have been surveyed in detail in the field using a total station instrument. The crater-type structures have diameters ranging from 100 to 500 m in width and 30 to 50 m in depth. The four impact crater fields were formed simultaneously, impacting upon a Miocene basaltic plateau and Pliocene–Early Pleistocene pediments. The original crater field was later eroded by Late Pleistocene fluvial processes, isolating the different areas. The rocks within the craters have strong and stable magnetic signature. No meteorite fragments or other diagnostic landmarks have been found yet. The origin of these crater fields may be related to multiple fragmentation of one asteroid that broke up before impact, perhaps traveling across the space as a rubble pile. Alternatively, multiple collisions of comet fragments could explain the crater formation. Other preliminary observations on collected samples (glass, breccias, and, most relevant, Fe-Ni-bearing spherules found within the impacted zones) are herein discussed. Based on field geological and geomorphological data, the age of this event is estimated to be bracketed between Early Pleistocene and the beginning of Late Pleistocene (i.e., 0.78–0.13 Ma ago).

**S05. Tectonic geomorphology (including neotectonics and paleoseismology)**

Convenors: *Doug BURBANK & Francisco BEZERRA*





## **Oral presentations:**

### **Tectonic tilting toward the west during the past 7000 years indicated by spatial difference in relative sea-level changes across the Nobi Plain, on the footwall of the Yoro fault system, central Japan**

*NIWA Y.(1), SUGAI T.(1), OGAMI T.(2)*

*(1) The University of Tokyo, KASHIWA, CHIBA, JAPAN ; (2) Chuo University, TOKYO, JAPAN*

This study detected tectonic tilting during the past 7000 years on the basis of spatial difference in relative sea-level (RSL) changes for six core sites on the Nobi Plain, on the footwall of the Yoro fault system, Japan. The cores reveal a typical deltaic succession in which sedimentary facies can be divided into five units; braided river (unit A), fluvial to intertidal (unit B), inner bay (unit C), delta front (unit D), and delta plain (unit E) in ascending order. Electrical conductivity (EC), which primary records salinity, in uppermost unit C is proportional to the thickness of unit D, and provides an indication of the water depth close to the top of unit C. We translated EC in unit C to water depth by applying the proportional relation. We then estimated RSL by adding the EC-derived water depth to the compaction-corrected sea-floor elevation for unit D obtained from sediment accumulation curves derived from over one hundred <sup>14</sup>C ages. RSL at 7000 cal BP is tended to be higher at the core sites farther from the Yoro fault system. RSL at the four core sites nearest the fault system has been rising continuously since 7000 cal yr BP, indicating subsidence in this area. This trend of continuous rise of RSL and the differences in RSL among core sites show that the Nobi Plain has been tilted down to the west in response to Holocene activity on the Yoro fault system. Our study shows that local variance of RSL is resulted from vertical tectonic displacement.

\*\*\*\*\*

### **Geomorphological evidence for a 2000 km long intracontinental fault system in the 'Stable Continental Region' of Western Australia**

*WHITNEY B., HENGESH J.*

*The University of Western Australia, CRAWLEY, AUSTRALIA*

Analysis of tectonic geomorphology within the "Stable Continental Region" (SCR) of Western Australia indicates the presence of an approximately 2000 km long zone of interrelated dextral-transpressive neotectonic features including active faults and folds, herein referred to as the Western Australian Transpressional Belt (WATB). The WATB is coincident with an extended passive margin crustal domain that initially formed during periods of continental-scale rifting during the Paleozoic and Mesozoic Eras along the edge of Archean Pilbara and Yilgarn cratons. Neotectonic deformation is dominated by transpressional reactivation of these much older rift related structures.

Geomorphological features of the WATB are evident both onshore and offshore. The region's arid climate, low gradient rivers, and low relief landscape are highly sensitive to minor perturbations in both climate and tectonically driven land-level changes. Analysis of fluvial systems in the WATB suggests hydrogeomorphic processes are influenced by crustal deformation on individual tectonic structures. Crustal shortening has topographic expression at the Cape and Giralia Ranges and also is expressed at the channel scale such as where the supercedent Minilya and Lyndon Rivers have deflected around the tips of growing anticlines. Bathymetric data from Australia's northwest shelf indicate the presence of numerous transpressional tectonic structures as scarps on the seabed and deformed sea-level low-stand shoreline features.

The recognition of active fault systems within the Western Australian "Stable Continental Region" (SCR) indicates the presence of potentially significant seismic sources and will improve our understanding of seismic hazards in this SCR and other seismically enigmatic regions.

**Passive vs. active control of tectonic structures on the recent sedimentary evolution of a turbidite system: a tectonic geomorphology study from the Po Plain (Northern Italy)**

BARCHI M.(1), POZZOVIVO V.(1), GALBIATI M.(2), ROCCHINI P.(2), CAIRO E.(3)

(1) *Universita' di Perugia, Dipartimento di Scienze della Terra, PERUGIA, ITALY* ; (2) *ENI E&P, S.DONATO MILANESE (MI), ITALY* ; (3) *STOGIT s.p.a., CREMA, ITALY*

Seismic geomorphology may be defined as the application of analytical techniques pertaining to the study of landforms to the analysis of ancient, buried geomorphic surfaces as imaged by 3D seismic data, in a map view.

In this study we reconstruct the evolution of syn-tectonic clastic depositional systems from the late Messinian to the late Pleistocene in the subsurface of the central Po Plain, a structurally complex region, comprised between the opposite-verging South-Alpine and Northern Apennines thrust belts. The Northern Apennines external thrust is still active at very low deformation rate, as indicated by both seismicity and geodetic data.

Our innovative approach is based on image processing techniques and dedicated software, aimed to derive a continuous *Geo-Model* from 3D seismic data, which allows a comprehensive understanding of the geological models and a detailed definition of the sediments architecture; the interpretative workflow comprises a dynamic scanning (slicing) of the stratigraphic surfaces across the *Geo-Model*, computation and analysis of seismic attributes, fault detection, geobodies extraction and calibration to litho-stratigraphic data from wells.

Within our study area, the synsedimentary growth of three anticlines controlled the topography of the basins: the turbidite systems progressively filled a subsiding and tectonically mobile basin floor, forming a set of distinct ponded basins. After the Early Pleistocene, the tectonic activity decreased, but the structural imprint of the thrust still exerted a control on the basin topography, possibly through a combination of isostatic rebound and differential compaction of sediments. During the Late Pleistocene, the basin was filled by the rapid prograding of the Po Plain shelf and deltaic systems: however, even the most recent geomorphic features and the current hydrographic network show the imprint of the underlying structural high.

\*\*\*\*\*

**Seismic and Eustatic cycles in the southern Apennine deformation front (Basilicate -Southern Italy)**

DEFFONTAINES B.(1), FORTUNATO G.(2), MAGALHAES S.(2)

(1) *Universite Marne-La-Vallee, MARNE-LA-VALLEE, FRANCE* ; (2) *ALphaGEOmega, PARIS, FRANCE*

This detailed study re-interpret from a tectonic point of view the new soil datations of the different marine terrassic levels of the Tarento Gulf (Southern Italy) acquired by D.Sauer et al., Int Quaternary, 2009. By combining these observed datation to the known eustatic curve of the mediteranean sea along italian shore, we were able to better understand the landscape evolution of that deformation front and we are able to differentiate both active tectonic and eustatic processes and their related geomorphic features on the Tarento Gulf marine terrasses. Therefore the observed seismic cycle of the Southern Apennine deformation front is revealed and appear to be coherent with both a regular linear creep period (240 kyears) and a rapid uplift (42m) corresponding very probably to numerous major earthquakes events. This give us new major inputs to better understand the deformation front of Southern Apennine.

### **The sedimentary response of mountain environments to large earthquakes: an example from south Westland, New Zealand**

*FITZSIMONS S.(1), HOWARTH J.(1), JACOBSEN G.(2), NORRIS R.(1)*

*(1) University of Otago, DUNEDIN, NEW ZEALAND ; (2) Australian Nuclear Science and Technology Organisation, SYDNEY, AUSTRALIA*

In tectonically active mountain belts large earthquakes trigger pervasive landsliding, which drives landscape evolution and is a source of considerable hazard to infrastructure and society. Despite this, the magnitude and duration of postseismic landscape response remains poorly understood. We use lake sediments to constrain the magnitude and duration of postseismic landscape responses in small range front catchments and large trunk valleys of the Southern Alps to sequential great ( $M_w8$ ) earthquakes on the Alpine Fault. The lake sediments contain a detailed record of co-seismic, post-seismic and aseismic deposits that are correlated to the Alpine Fault seismic cycle using high precision chronologies derived from Bayesian modeling of AMS radiocarbon dates. The landscape response to the last three earthquakes (1717 A.D., ~1570 A.D. and ~1400 A.D.) persisted for several decades after each event in both range front and trunk valley catchments. During this time increased rates of landsliding on catchment hillslopes caused a threefold increase in sediment flux from the mountain belt. Increased postseismic sediment flux suggests that Alpine Fault earthquakes are important drivers of millennial scale denudation rates in the Southern Alps. The greatest impact of these events occurs in small range-front catchments that are situated adjacent to the fault, while larger catchments experience a more subdued sedimentary response that occurs over a longer duration. These data demonstrate that the landscape response to co- and postseismic landsliding in mountains can be protracted and a source of seismic hazard that persists long after the initial earthquake.

\*\*\*\*\*

### **Fossil shorelines at Corfu and surrounding islands deduced from erosion notches**

*PIRAZZOLI P.(1), EVELPIDOU N.(2), KARKANI E.(2)*

*(1) CNRS, PARIS, FRANCE ; (2) National and Kapodistrian University, ATHENS, GREECE*

New geomorphological investigations carried out in 2012 along the coasts of Corfu, Othonoi, Paxoi and Antipaxoi Islands have allowed the identification of recent fossil shorelines. Former sea-level positions were deduced from sea-level indicators, such as emerged and submerged notches. Notch geometries (height, inward depth and vertex depth) were measured. Due to the absence of tidal records at the closest tide-gauge station during the period of fieldwork, an uncertainty of  $\pm 14$  cm in depth measurements was taken into consideration.

A "modern" tidal notch, submerged ca. -20 cm, was observed in all studied islands, at various sites. This notch is regarded to have been submerged by the global sea-level rise that occurred during the 19<sup>th</sup> and 20<sup>th</sup> centuries at a rate exceeding the possibilities of intertidal bioerosion. Its presence provides evidence that no vertical tectonic movements occurred since its formation.

At Paxoi possible marks of erosion by waves, a few decimetres above sea level at two sites, may be interpreted as a still undetermined short-lived period of emergence. Below the "modern" notch, lower shorelines measured at  $-45 \pm 14$  cm and  $-58 \pm 14$  cm may correspond to the same fossil shoreline, apparently submerged by a coseismic vertical movement.

At Antipaxoi, no evidence of emergence were found and Holocene vertical movements seem to have been only of subsidence; two submerged tidal notches have been distinguished at about -70 and -120 cm.

On Corfu island impacts of ancient earthquakes have left some marks of emergence at about +20, +45, +110 and +140 cm, as well as marks of submergence at about -35 -50, -75, -100 and -180 cm.

The emergence of +140 cm, which had been previously dated at or after 790-400 cal. B.C., was detected through erosion notches at various sites of the western part of Corfu and seems to continue even more west, at Othonoi Island.

**Fault activity, basin architecture and structural evolution of extensional tectonic depressions: case studies from central Apennines (Italy), investigated through geological and geophysical surveys**

GORI S., FALCUCCI E., LADINA C., MARZORATI S., VALENSISE G.  
*Istituto Nazionale di Geofisica e Vulcanologia, ROMA, ITALY*

The present tectonic setting of the central Apennines results from the superposition of a Plio-Quaternary NE-SW trending extension onto a preceding co-axial contractional deformation. This determined the formation of structural features during the compressive tectonic phase, some of which were then partly re-activated as extensional structures during the subsequent extensional deformation. Galadini and Messina (2001) and Cavinato et al. (2002) defined that a ENE-WSW trending regional tectonic lineament, known as "Avezzano-Bussi fault system" (Ghisetti and Vezzani, 1997), formed during the compressive tectonic phase, has been locally re-used as extensional feature during the Pliocene-Early Pleistocene, relating to it the early stage of formation of the Fucino Basin, the widest tectonic depression of central Apennines. After the Early Pleistocene, the progressive opening of the Fucino depression was "picked up" by the presently active NW-SE trending normal fault system, that bounds the basin to the NE.

As the "Avezzano-Bussi fault system" also affects the northern sectors of further central Apennine tectonic depressions, i.e. the Subequana Valley and the Sulmona Basin – which are in turn bounded to the NE by active NW-SE trending normal fault systems (e.g. Falcucci et al., 2011) – we aimed at unveiling whether the structural evolution of the Fucino Basin could have also affected these depressions.

At this purpose, we performed geological field studies in the Subequana Valley and the Sulmona Basin, coupled with geophysical investigations (ambient seismic noise and ground motion analyses), aiming at defining the architecture of the tectonic depressions and to relate it to the Quaternary structural evolution of the conterminous fault systems. These investigations allowed us defining a similar Quaternary structural evolution of the Fucino Basin, Subequana Valley and Sulmona Basin.

\*\*\*\*\*

**Dating fault movement in southeastern Australia, using paleomagnetism**

PILLANS B.  
*Australian National University, CANBERRA, AUSTRALIA*

Dating recent fault movement in areas where basement rocks are pre-Cenozoic is challenging. Here I give two examples from the passive continental margin of southeastern Australia, where paleomagnetism provides chronological constraints on the timing of faulting:

1. Lake George, straddles the crest of the Great Dividing Range at an elevation of 670 m, 30-40 km north of Canberra. Basement rocks are Paleozoic. The western margin of the lake is bounded by a prominent fault scarp, with local relief up to 300 m. Up to 165 m of lacustrine and fluvio-lacustrine sediment occurs beneath the lake floor, including quartzose gravels between 100 and 165 m depth, dated by magnetostratigraphy and pollen biostratigraphy to be 3-4 Ma. Correlative quartzose fluvial gravels, 70 m above the lake floor, on the upthrown side of the fault, are remnants of a westward flowing river, prior to uplift on the fault and formation of the lake. It is inferred that 170-235 m of vertical displacement has occurred on the Lake George fault in 3-4 Ma.

2. Australia's only nuclear reactor is a research reactor located at Lucas Heights on the southern outskirts of Sydney. In 2002, work was begun to replace the reactor that had operated on the site since 1958. Small faults, with dip separations up to 1.3 m were exposed in Triassic quartz sandstone bedrock in the excavation for the replacement reactor. Deep oxidative weathering has affected the bedrock, including formation of iron oxide layers, subparallel to bedding. One such layer, post-dating fault movement, has reverse polarity and therefore was deposited prior to the Matuyama/Brunhes reversal at ~0.78 Ma. Thus, fault movement is inferred to have occurred prior to 0.78 Ma. A paleomagnetic pole was determined for the mean remanence direction, and compared with the Australian Apparent Polar Wander Path to yield a minimum age of 5 Ma for the unfaulted iron oxide layer. The fault was deemed 'non-capable' and construction was allowed to continue.

**Evolution of Neotectonic Landforms between Srinagar and Bagwan in Lower Alaknanda Valley, Garhwal Himalaya, India**

DEVI DATT D.

*H.N.B Garhwal Central University, Srinagar, (Garhwal), Uttarakhand, SRINAGAR (GARHWAL), INDIA*

The Himalayan Mountains represent a typical example of continuous upliftment with spells of tectonic restlessness or crustal disturbances. These disturbances indicate accumulation of inner tectonic stress in the crust. Some of the recent Pleistocene and Quaternary features are reactivated in the Himalayas those appear to have significant bearing on the neotectonism. In this paper an attempt has been made to identify the places of recent displacement and upliftment along the North Almora Thrust (NAT) in the Lower Alaknanda Valley of Garhwal Himalaya, India with the help of large scale topographical maps, Remote Sensing & GIS techniques and intensive field study.

Four sites are selected for the identification of neotectonic landforms. The recent neotectonic activities and associated features are reported in the quaternary deposition at the confluence of Dhundsir Gad and Alaknanda River near Kirtinagar and at the confluence of Takoli Gad near Chopriya village.

The study shows that there are significant evidences of neotectonic activities and associated landforms along the NAT in the Lower Alaknanda valley, which was not recorded earlier. This indicates that active movements took place along Thrust plane and transverse tectonic elements in the recent past. The main tectonic features in the Quaternary deposition are folding, faulting, tilting, thrusting and bending along the reverse/strike slip fault. Other tectonic features are upliftment of terraces, uneven level of terraces, triangular facet, and fault gap, drainage anomalies, pale channel, tilting of terraces etc. The neotectonic activities during past can be observed on Quaternary deposition at the junction of NW-SE, N-S and NE-SW trending lineaments and their proximity.

\*\*\*\*\*

**Neo-tectonics in the Genesis of Terraces in the Eastern Himalayan Foothills between River Gish and Jaldhaka, North Bengal, India**

BHATTACHARYA SOMA S.

*Vivekananda College For Women, KOLKATA, INDIA*

In the foot hill section of the Eastern Himalayas between the river Gish in the west and river Jaldhaka in the east the mountain front recedes northward to form a re-entrant which runs for about 20km. Absence of the Sub Himalayan zone here, probably due to relief thrusting, makes the fall from the mountains to the alluvial plains steep and precipitous. Geomorphic surfaces are extensive in the region and spectacular terraces have developed on them. Three distinct terrace levels are found exhibiting almost same height along all the river basins between river Gish and river Jaldhaka. The terraces are extended through the geomorphic surfaces far within hills.

Neo-tectonic activities, which are common in the Himalayas and occur as subsiding remnants of the great tectonic activity of the area and the resultant geomorphic processes, are responsible for the genesis of the geomorphic surfaces and the spectacular terraces built on them with several levels of development. The researcher aims to study the role of Neo-tectonics in the building of the terraces and tries to reveal the characteristic features of the terraces.

Key words: re-entrant, relief thrust, neo-tectonics, terrace levels.

**New techniques within paleoseismological study of mountain terrains based on dendrocronological analysis and statistical approach by the example of SE Altai (Russia)**

*NEPOP R.(1), AGATOVA A.(2), MYGLAN V.(3), BARINOV V.(3)*

*(1) Institute of geology and mineralogy, NOVOSIBIRSK, RUSSIAN FEDERATION ; (2) Institute of geology and mineralogy, NOVOSIBIRSK, RUSSIAN FEDERATION ; (3) Siberian Federal University, KRASNOYARSK, RUSSIAN FEDERATION*

This paper focuses on paleoseismogeological study of the mountainous, seismically active southeastern part of Russian Altai. It presents new dating technique that defines the timing of the seismically induced mass wasting processes and the erosion rate due to earthquake triggered landslides.

This new technique is based on estimating of the absolute age of tree injuries caused by rockfalls. A continuous 2367-years absolute tree-ring chronology "Mongun" developed for the adjacent region has enabled the use of dendrochronological analysis for this purpose. The accuracy of an approach was supported by data obtained from analyzing injuries occurred on trees as a result of rockfalls triggered by the 2003 Chuya earthquake ( $M_s=7.3$ ), with its epicenter located within SE Altai. It allows us to determine the date of previously unknown medieval earthquake (which was also supported by radiocarbon ages of seismically cut fossil soil overlapped by that undistorted), estimate the age of seismically triggered landslides and specify the recurrence interval of strong earthquakes for SE Altai.

Another line of our paleoseismological investigations touch upon the study of seismically induced landslides which are especially important agents of denudation in tectonically active mountain terrains. In spite of diversity in climatic, geological, geomorphological conditions and peculiarities of seismic process for different areas, there is a good correlation between the magnitude of an earthquake and the volume of the largest landslide it causes. This relationship, calculated by us on the basis of data on 17 earthquakes all over the Globe, allows estimating the total volume of earthquake triggered landslides, the contribution of landslides caused by aftershocks and, finally, the Holocene erosion rate due to these landslides. Calculating the volume of all Holocene earthquake triggered landslides within SE Altai using the method of detailed profiling also supports our estimates.

\*\*\*\*\*

**Tectonic Geomorphology of Slow Faults in Northern Mongolia: Implications for Seismic Hazard in Ulaanbaatar**

*FERRY M.(1), SCHLUPP A.(2), MUNKHUU U.(3)*

*(1) UMR 5243, Université Montpellier II, MONTPELLIER, FRANCE ; (2) UMR 7516, Université de Strasbourg, STRASBOURG, FRANCE ; (3) RCAG, Mongolian Academy of Sciences, ULAANBAATAR, MONGOLIA*

Beside the famous series of M 8 earthquakes that struck western Mongolia in the first half of the 20<sup>th</sup> c., the Hustai fault presents a more directly concerning picture. With its northeastern tip located ~10 km from the city of Ulaanbaatar (1 M inhabitants), the 92-km-long fault may produce consequential M 7 earthquakes. It displays continuous microseismicity with five M 4+ since 1974 and a M 5.4 event in that same year. Most events occur in the shallow crust.

We present preliminary results of a multi-disciplinary study of the Hustai Fault, northern Mongolia. By combining high-resolution satellite images, digital elevation models, magnetic mapping, geomorphology and trenching, we provide a detailed morphotectonic map of the fault as well as insight on its recent episodes of surface faulting.

The Hustai Fault is more than 92 km long and divided into three segments. The northern segment is 23 km long and oriented N 68; the central segment is 33 km long and oriented N 55; and the southern segment is at least 36 km long and oriented N23. Overall, the Hustai Fault forms wide W open to the southeast. The active trace appears as a main trace running at the foot of the main topography and outlined by exhumed chert slabs, contrasts in water content, right-laterally offset streams and elongated sag basins. The latter are bounded on their SE edge by antithetic faults. Stream bed profiles show a systematic uplift of the NW block by 20-30 m and high-resolution satellite images document right-lateral offsets in the range of 20-30 m, thus suggesting an oblique regime. Antithetic faults only exhibit dip-slip movement in the order of a few meters (< 10 m).

An exploratory trench dug across the main trace reveals faulted Holocene deposits trapped inside the sag basins. Trench observations reflect the oblique nature of the fault with mixed normal and reverse faulting geometries.

### **Paleoseismicity of the North Zhongtiaoshan Fault zone, Shanxi Graben System, China**

LI Y., LV S.

*College of Urban and Environmental Science, Peking University, BEIJING, CHINA*

The North Zhongtiaoshan fault is located in the east and south margins of the Yuncheng Basin, which is one of a series faulted basins in the Shanxi Graben System, Northeast China. Previous paleoseismological studies indicated that the east and the west segments of the fault have not moved in Holocene. Six trenches excavated across the North Zhongtiaoshan Fault recently, with 34 <sup>14</sup>C ages used to limit the faulting events. The trench I is on the west segment. 3 faulting events are revealed. The event 1 occurred between 2030±40 and 390±40 aBP, with a vertical displacement of 1m; the event 2 occurred between 7300±50 and 5060±35 aBP, with a vertical displacement of 0.95 m; the event 3 occurred between 11070±50 and 7300±50 aBP, with a vertical displacement of 1 m. The Trench II is on the west part of the middle segment. 2 faulting events are revealed. The event 1 occurred after 2680±30aBP, with a vertical displacement of 1.6 m; the event 2 occurred between 5370±40 and 4070±40 aBP, with a vertical displacement of 1 m. The trench III reveal 2 faulting events, the event 1 occurred between 7000±40 and 3730±40aBP, the event 2 occurred between 7700±40 and 7000±40 aBP. The trench IV revealed a faulting event from 6520±40 to 7910±40 aBP. The trench V revealed 8 faulting events since 28800±160 aBP, the youngest faulting event occurred after 3250±40 aBP, and the total vertical displacement is 14 m since 14490±80 aBP. The trench VI revealed 4 faulting events, the event 1 occurred after 720±30 aBP, with a tomb bed of the Dongjin Dynasty was vertically displaced 30 cm. The event 2 occurred between 4140±30 and 720±30 aBP. The event 3 and 4 occurred between 25870±140 and 4140±30 aBP. Trench studies indicate that the North Zhongtiaoshan Fault is a Holocene active fault, at least there were 4 faulting events occurred on it. The youngest faulting events on the fault were possibly the surface ruptures of the two historical earthquakes in the Yuncheng basin.

\*\*\*\*\*

### **How old are the Himalayan river valleys?**

GHOSH P.

*Indian Statistical Institute, Geological Studies Unit, KOLKATA, INDIA*

The first order physiographic features of the Himalayan landscape include high peaks, ridges and plateaus as well as enormous and numerous deep valleys of the trans-Himalayan rivers. These features are the product of tectonic movements driven by continuing collision between the Indian and Tibetan plates as well as the concomitant erosion by surface processes. The dimensions of the features are governed by the feedback relationships between the competing forces and the limits imposed by crustal strength. Therefore, the geomorphic parameters of some of the large-scale landforms could be used to assess the long-term interplay between different land sculpturing processes.

This work studies the modern landscape of the entire Himalayas (as represented by SRTM DEM) through a new terrain analysis technique and reveals the shape and the arrangement of the major Himalayan valleys as well as the erosional relief of the individual valleys. The results show that the erosional relief is highest at the central part of the orogen compared to its western and its eastern flanking regions.

If it is assumed that the modern landscape has attained topographic steady state then the observed variation in erosional relief would primarily indicate along-arc variation in uplift averaged over the temporal range of formation of these valleys. However, in order to put this interpretation in the context of evolution of this mountain belt the temporal range is to be known. For that reason it needs to be determined when the major catchment valleys started to develop and if they are synchronous. We discuss this issue taking into consideration the existing theoretical models and observations as well as our own observations on the shape and spatial arrangement of the valleys and attempt to interpret the along-arc variability of the erosional relief.

**The Pingding segment of the Altyn Tagh Fault (91°E): Holocene slip-rate determination from cosmogenic radionuclide dating of offset fluvial terraces**

MERIAUX A.(1), VAN DER WOERD J.(2), TAPPONNIER P.(3), RYERSON F.(4), FINKEL R.(5), LASSERRE C.(6), XU X.(7)

(1) Newcastle University, NEWCASTLE UPON TYNE, UNITED KINGDOM ; (2) IPGS-EOST, STRASBOURG, FRANCE ; (3) EOS, Nanyang Technological University, SINGAPORE, SINGAPORE ; (4) Lawrence Livermore National Laboratory, LIVERMORE, UNITED STATES ; (5) Earth and Planetary Science Department, University of California, BERKELEY, UNITED STATES ; (6) Maison des Géosciences, ISTERre, GRENOBLE, FRANCE ; (7) Central Earthquake Administration, BEIJING, CHINA

Morphochronologic slip-rates on the Altyn Tagh Fault (ATF) along the southern front of the Pingding Shan at 90.5°E are determined by cosmogenic radionuclide (CRN) dating of seven offset terraces at two sites. The terraces are defined based upon morphology, elevation and dating, together with fieldwork and high-resolution satellite analysis. The majority of the CRN model ages fall within narrow ranges (<2 ka) on the four main terraces (T1, T2, T3 and T3'), and allow a detailed terrace chronology. Bounds on the terrace ages and offsets of 5 independent terraces yield consistent slip-rate estimates. The long-term slip-rate of  $13.9 \pm 1.1$  mm/yr is defined at the 95% confidence level, as the joint rate probability distribution of the rate derived from each independent terrace. It falls within the bounds of all the rates defined on the central Altyn Tagh Fault between the Cherchen He (86.4°E) and Akato Tagh (88°E) sites. This rate is ~10 mm/yr less than the upper rate determined near Tura at 87°E, in keeping with the inference of an eastward decreasing rate due to progressive loss of slip to thrusts branching off the fault southwards but it is greater than the  $9 \pm 4$  mm/yr rate determined at ~90°E by GPS surveys and other geodetic short-term rates defined elsewhere along the ATF. Whether such disparate rates will ultimately be reconciled by a better understanding of fault mechanics, resolved transient deformations during the seismic cycle or by more accurate measurements made with either approach remains an important issue.

\*\*\*\*\*

**Late quaternary landform evolution along the Indus River, Ladakh, NW Himalaya**

KUMAR A., SRIVASTAVA P.

*Wadia Institute of Himalayan Geology, DEHRADUN, INDIA*

The Indus River is one of the largest rivers on Indian continent that originates from Mount Kailas passes through Karakoram zone, Ladakh Batholith and tectonic units of Indus suture zone. Thus the landscape along this river has potential to unravel responses of Indus River to the neotectonic evolution of Indus Suture zone and to arid climate of trans-Himalaya. The synoptic study of Quaternary evolution of the Indus River in these connections has not been done judiciously.

This study focuses this aspect using the remote sensing data ASTER DEM (30m), SRTM (90m) and Toposheets (1:50,000), field geomorphological mapping and Optically Stimulated Luminescence (OSL) Dating technique. The study area includes the stretch of river from village Nyoma to Dah, where the Indus River shows marked change in its channel pattern and geomorphic configuration. There are thick sedimentary fills of wide braided channel from Nyoma to Nimu and several levels bedrock strath terraces are observed from Nimu to Dah, where rivers flows into a thin gorge. The geomorphological and sedimentological studies have been attempted on the quaternary deposits of Indus River and sand ramps in this area. The dating of strath terraces indicated the bedrock uplift rates varying from 2-5 mm/y and that the thrust contact between the Ladakh Batholith and Indus Molasses is neo-tectonically active. These results surprisingly matched with the incision rates (2-12 mm/y) of NW Himalayan syntaxis (Burbank et.al, 1996 and Leland et.al, 1998). Hence this area is equally tectonically active to North western syntaxis of Himalayan (Nanga Parbat). The Indus molasses is highly deformed and thrustured with north dipping sequence of thrusts and high angled reverse faults from chilling to Nimu, where Zanskar River is flowing in the gorge and confluence with Indus River at Nimu. We envisage that the bedrock incision in this zone is in response to the uplift due to the Pleistocene-Holocene crustal shortening in the Indus Molasse.

**Deforming rate and kinematics of a potential part of the Tibetan Plateau on the mid-portion of the Qilian Shan Moutian, China**

*HU X., PAN B., WANG J., LI Q., HU Z., CAO B., JIANG S.*

*Key Laboratory of Western China's Environmental Systems (Ministry of Education), Lanzhou University, LANZHOU, CHINA*

How the Tibetan Plateau is extended is one of the key problems to understand the earth crust evolution in the frame of plate tectonics. A newly uplifting area, the Dahe region, locating between the Yumu Shan Mountain and the Qilian Shan Mountain, in the northeastern Tibetan Plateau, would supply us a fresh sight on the process that how the plateau is extended to a new region. The Dahe region was a relatively depressing or stable area before late Pleistocene, and received deep fluvial sediment derived from the Qilian Shan in the south. In recent 140 ka, the old depositing surface (alluvial fan) was deeply cut by the Dahe River and several fluvial terraces were formed. By the uplifted terrace staircases and warped long profiles of terraces, we can see that the region is not only experiencing uplifting, but also experiencing folding deformation. Below the old depositing surface, four staircases of strath terraces (strath is the old fluvial deposition) are formed by the Dahe River, and each terrace surfaces are buried by aeolian loess. By the OSL dating on overlying loess on the terraces and correlating to climate records, we obtain formation ages (terrace surface abandoning time) of the four terraces (from high to low): 143-125 ka BP, 103-97 ka BP, ~91 ka BP, and 14.5-12.8 ka BP. After the climate influence is subtracted by considering river-long-profile slope changes respect to different climate conditions, average uplift rate of the Dahe region is calculated as 0.53-0.67 mm/a in late Pleistocene. Through analyzing the geometry of the deforming terrace surfaces, we propose that a new blind thrust fault was derived from the main decollement in the upper crust, and thus the growing fault deduced the uplift of the Dahe region and the folding near the fault tip. If we assuming a constant rate of uplift, the Dahe region will uplift to the Plateau level of ~5000 m at 5-8 million years later.

\*\*\*\*\*

**Differentiating between gravitational faults related to evaporite dissolution and tectonic faults by means of geomorphological mapping, trenching and geophysical surveys**

*GUTIERREZ F.(1), CARBONEL D.(1), LINARES R.(2), ROQUE C.(3), ZARROCA M.(4), GUERRERO J.(1), MCCALPIN J.(5)*

*(1) Universidad de Zaragoza, ZARAGOZA, SPAIN ; (2) Univerisdad Autónoma de Barcelona, BARCELONA, SPAIN ; (3) Universidad de Gerona, GERONA, SPAIN ; (4) Universidad Autonoma de Barcelona, BARCELONA, SPAIN ; (5) Geo-Haz Consulting Inc., CRESTONE, CO, UNITED STATES*

Differentiating between gravitational and tectonic faults constitutes a relevant issue for seismic hazard assessment with a poorly developed scientific basis. Gravitational faults may cause surface deformation, but are not capable of producing damaging earthquakes like tectonic faults. Misinterpreting nontectonic faults as seismogenic structures may lead to significant seismic hazard overestimates with relevant implications. Active faults related to interstratal dissolution of evaporites have been investigated in several regions by detailed mapping, geophysics and trenching: (1) Faults controlling the Rio Seco Graben (Iberian Range, Spain), developed in the crest of a monocline caused by dissolution-induced sagging. (2) The Zenzano Fault (Iberian Chain, Spain), formed at the top of an erosional escarpment underlain by an upper brittle unit and a lower tectonically thickened evaporitic formation. (3) The grabens of Peracalç (Eastern Pyrenees, Spain), related to subsidence and lateral spreading of a brittle carbonate plate resulting from dissolution and outward expansion of an underlying evaporitic unit more than 2 km thick. (4) Flexural-slip fault scarps in the Rocky Mountains, Colorado, generated by the unfolding of a monocline due to the loss of basal-lateral support resulting from evaporite dissolution. The geometrical relationships observed in the trenches, together with the numerical dates, indicate that these gravitational faults may have episodic displacement behaviour, tend to reach  $D_{max}/L$  (maximum displacement/length) ratios higher than those reported for tectonic faults, slip rates and displacement per event values are generally higher than in tectonic structures, and the inferred recurrence intervals may be significantly lower.

**Neotectonic deformation of a Late Quaternary glaciofluvial outwash plain in Southern Denmark caused by glacio-isostatic fault reactivation**

*SANDERSEN P.B.E., JØRGENSEN F., MØLLER R.R.*

*Geological Survey of Denmark and Greenland (GEUS), HOEJBJERG, DENMARK*

Unambiguous morphological expressions of Quaternary tectonic events are scarce in Denmark because the landscape has been intensively molded by the ice sheets during the Quaternary glaciations or has been altered by late/postglacial erosional processes. However, the Late Weichselian outwash plains outside the Last Glacial Maximum (LGM) in the western part of Denmark constitute an ideal landform for identifying tectonic events post-dating the glaciation because the gently sloping surface of the outwash plain has remained undisturbed by glacier ice.

Early observations of the irregular topography around the village of Tinglev led to the theory that the outwash plain must have been temporarily covered with ice from an early advance during the LGM that reached beyond the Main Stationary Line (Hansen 1978). According to this theory, this short-lived ice advance left behind thin sheets of dead ice which were subsequently covered by a thin sheet of meltwater sand during the final sedimentation of the outwash plain. When the dead ice melted, the irregular topographical features including lakes, bogs and sinkholes were formed.

This model is now challenged by results from interpretation of LiDAR-data that have enabled us to identify morphological features on the outwash plain indicative of neotectonic movements: Significant level changes along distinct lineaments, frequent slope changes of neighbouring areas, 180 degree changes in dip direction and presence of close lying polygonal areas with marked shifts in terrain level. Using information from boreholes and seismic data we relate these morphological features to movements of the underlying Tønder Graben structure. Dating of soil samples from depressions in the outwash plain constrains the onset of the deformations to around 9.000 years BP. We conclude that the deformation of the outwash plain is related to short-term reactivations of faults related to the Tønder Graben structure during the deglaciation phase.

\*\*\*\*\*

**The topography of the Iberian Chain (Spain): tectonic and surface processes interaction in landscape evolution**

*SCOTTI V.(1), FACCENNA C.(2), MOLIN P.(2), SOLIGO M.(2)*

*(1) Università Roma TRE, ROME, ITALY ; (2) Università Roma TRE, ROME, ITALY*

First-order topographic features, drainage system pattern and spatial variation in surface processes rates in tectonically active areas represent proxies to quantitatively characterize the landscape's response to tectonic forcing.

We investigated the recent landscape evolution of the Iberian Chain (NE Spain), an intraplate thrust-belt formed in Late Cretaceous to Middle Miocene times. In the whole Iberia, the Iberian Chain represents a unique case of dome-shaped topography. Its central sector is dominated by a wide planation surface, developed during Upper Neogene (?), presently lying at an average altitude of 1300 m. In Late Pliocene (?) -Quaternary, the onset of a regional uplift controlled the organization of the present fluvial network and the dissection of the landscape.

Geomorphic responses to tectonic forcing have been analyzed by the calculation of morphometric parameters, focusing on topography (map of local relief, swath profiles) and hydrography (basin hypsometric curve and integral, basin asymmetry factor, river longitudinal profiles and relative indices), using the SRTM DEM as main data source. Morphometric analysis has been also combined with radiometric Uranium-series dating of calcareous tufas lying on fluvial terraces. The results allow the estimation of incision rate along the High Tagus and Martin rivers.

Our results indicate that uplift and rock-type erodibility are the main factors ruling landscape evolution of the study area. The values of incision rate are very similar throughout the central sector of the range, indicating that, despite local small variation, the rivers respond mainly to a homogeneous regional uplift.

In conclusion, the Iberian Chain landscape is in a transient state in response to a recent uplift. Indeed, the fluvial processes that so weakly incised this landscape are still far from counterbalancing the tectonics input.

**Morphotectonic analysis of coastal chalk cliffs in Picardy (NW France): field evidence of neotectonic fault systems occurrence in step-graben structure**

DUPERRET A.(1), VANDYCKE S.(2), COLBEAUX J.P.(3), VAN VLIET-LANOE B.(1), DROMELET E.(4), CANCOUET R.(1)

(1) UMR 6538 CNRS Domaines Oceaniques, PLOUZANE, FRANCE ; (2) FNRS, Université de Mons, MONS, BELGIUM ; (3) Conseil Scientifique de l'Environnement Nord Pas de Calais, LILLE, FRANCE ; (4) Université Libre de Bruxelles, BRUXELLES, BELGIUM

Neotectonic activity is often difficult to evidence in the chalk of the Anglo-Paris basin using only geomorphological analysis. The chalk of a sedimentary basin, located in a context of actual low stress-field favors the formation of smooth landscapes, due to chalk exposure to continental weathering during actual period and Quaternary periglacial conditions.

We study in details a small area along the coastal chalk cliffs of the English Channel located at Bois de Cise in Picardy (NW France). The study site is located between the Variscan front crossing the Dover straits and the Bray fault system. The use of high resolution digital topography with LiDAR data (RGE-Altitude) allow to evidence some particular surficial slope deformation, made of topographic steps aggregated behind the cliff face or along (perched) valleys transverse oriented to the cliff. These organised structures are defined as step-graben. Topographic steps present always a few meters high, a mean slope of 40°, several ten meters length and a linear morphology with slight curvatures at their borders.

At Bois de Cise site, a 3D field description will be presented. A step-graben develops along a transverse perched valley, where normal faults and tectonic faulting graben structure are evidenced on the cliff face. Step-graben structures are also associated with caves development at the base of the cliff, *i.e.* at about 100m below the surface of chalk plateau. Caves and temporary springs of fresh water along faults evidence a karstic behavior in the chalk and allow propose step-graben structures, as geological guides for hydrogeological circulation in the chalk of Picardy.

The observed normal faults cut quaternary deposits accumulated on the chalk at top of the cliff. This is a strong argument to prove the quaternary activity of step-grabens and a neotectonic activity recorded in the chalk of Picardy, mainly guided by the most recent paleostress field recorded in the chalk of NW France, with a NNE-SSW extension.

\*\*\*\*\*

**Remote Sensing and Ground Penetrating Radar in the characterization of Tectonic Geomorphology of South Andaman Islands, India ' A step towards hazard preparedness and mitigation**

SANKARAN B.

PONDICHERRY UNIVERSITY, PORT BLAIR, INDIA

The rapid growth of population and their excessive demand for resources, urbanization, industrialization have affected the coastal environment and its aquifers. Coastal flooding, tsunami and storm surge have inundated the coasts resulting in the contamination of aquifers, shoreline retreat and marginal land loss. The characterization of tectonic geomorphology is important as it throw lights on earthquake, tsunami and landslides. In the characterization of geomorphological landforms and structures, the remote sensing and Ground Penetrating Radar play a pivotal role. The interpretation of Indian Remote Sensing P6 satellite imagery and GPR image of South Andaman islands have brought out horst and graben, escarpment, synclinal and anticlinal valley, offsetting of beds, sinistral and dextral drag of beds. Therefore, the role of tectonically controlled structures and landforms cannot be negated in the wake of coastal faulting, submergence and emergence of shorelines exposed to several hazards.

The Andaman and Nicobar islands are confronted with many hazards such as tsunami, earthquake, landslides, erosion, coastal flooding and storm surge. The landforms and drainages are structurally controlled and are trending in NW-SW, NW-SE, N-S and E-W directions play a vital role in the landscape evolution. The NE-SW trending lineaments show sinistral drag of beds. The parallel faults have caused several horst and graben. The graben and the concave coasts acts as pathways for the inundation and/or coastal flooding causing contamination of fresh water aquifers thus reducing the land areas and recharge. The creeks are mostly fault controlled similarly act as easy channel way for tide propagation towards inland.

Therefore, a clear understanding of the tectonic geomorphology and its analysis is important in the present context of global warming and climate change for the sustainable development of South Andaman islands.

### Prehistoric large earthquakes produced by slip on the Central Iran strike-slip faults

*FOROUTAN M.(1), LE DORTZ K.(1), MEYER B.(1), SÉBRIER M.(1), NAZARI H.(2), FATTAHI M.(3), RASHIDI A.(4), BATEMAN M.D.(5), BRAUCHER R.(6), BOURLÈS D.(6), BENEDETTI L.(6), SIAME L.(6), TALEBIAN M.(2), GHORAISHI M.(2)*

*(1) Université Pierre et Marie Curie, Paris 06, ISTEP UMR 7193, F-75005, PARIS, FRANCE ; (2) Research Institute for Earth Sciences, Geological Survey of Iran, TEHRAN, IRAN ; (3) The Institute of Geophysics of the University of Tehran, TEHRAN, IRAN ; (4) Geological Survey of Iran, KERMAN, IRAN ; (5) Sheffield Centre for International Dryland Research, Department of Geography, University of Sheffield, SHEFFIELD, UNITED KINGDOM ; (6) CEREGE UMR 6635, AIX-EN-PROVENCE, FRANCE*

Central Iran plateau appears aseismic during the period of time of few millenniums covered by the instrumental and historical seismic records. Nevertheless, it is sliced by several strike-slip faults such as the Dehshir and Anar faults that are hundreds kilometres-long. These faults display along-strike, horizontal offsets of intermittent gullies that give evidence for Holocene activity. Both the sharpness of these cumulative offsets and the absence of along fault microseismicity suggest these offsets have occurred through large and infrequent earthquakes. Then, demonstrating the occurrence of earthquakes in the Holocene is crucial for assessing the regional seismic hazard. The paleoseismic studies performed along these faults show that they hosted large ( $M_w \approx 7$ ) earthquakes during the Holocene. Combining paleoearthquake indicators with OSL dating implies that three seismic events have occurred over the last  $20.1 \pm 1.6$  ka on the Dehshir fault and three seismic events over the last 15 ka on the Anar fault, suggesting average recurrences of at most 7 and 5 ka respectively for the Dehshir and Anar faults. The most recent event took place  $2.0 \pm 0.2$  ka ago on the Dehshir fault and between 3.6 and 5.2 ka on the Anar fault. For the later, this suggests the fault is approaching the end of its seismic cycle and the city of Anar could be under the threat of an impending earthquake. Additionally, our results confirm a previous minimum slip rate estimate of  $0.8 \pm 0.1$  mm yr<sup>-1</sup> for the Anar fault, and a slip rate of  $1.2 \pm 0.3$  mm yr<sup>-1</sup> for the Dehshir fault indicating the westernmost prominent right-lateral faults of the Central Iran plateau are characterized by slip rates close to 1 mm yr<sup>-1</sup>. These faults, which have repeatedly produced large earthquakes with long recurrence interval during the Holocene, show that the Central Iran plateau does not behave totally as a rigid block and that its moderate internal deformation is nonetheless responsible for a significant seismic hazard.

\*\*\*\*\*

### Uplift vs. denudation in the southern Apennines (Italy): geomorphologic evidence and constraints from terrestrial cosmogenic nuclides and apatite (U-Th)/He data

*ASCIONE A.(1), CAPALBO A.(2), CAPOLONGO D.(3), MAZZOLI S.(1), PAZZAGLIA F.J.(4), VALENTE E.(1), ZATTIN M.(5)*

*(1) Dipartimento di Scienze della Terra, Università Federico II, NAPOLI, ITALY ; (2) Dipartimento di Scienze geologiche, Tecnologie Chimiche e Ambientali, Università Carlo Bo, URBINO, ITALY ; (3) Dipartimento di Scienze Geologiche e Ambientali, Università Aldo Moro, BARI, ITALY ; (4) Department of Earth and Environmental Science, Lehigh University, BETHLEHEM, PENNSYLVANIA, UNITED STATES ; (5) Dipartimento di Geoscienze, Università di Padova, PADOVA, ITALY*

Over a variety of mountain belts, evidence that erosion rates are comparable with exhumation rates supports the idea that, under steady uplift and over  $10^3$ - $10^6$  yr time scales, mountain chains tend to achieve dynamic equilibrium between uplift and denudation. We investigate the relationships between uplift and denudation in the southern Apennines, a young orogen affected by crustal shortening until c. 0.7 Ma, and subsequently by regional uplift. The study is based on the integration of geomorphologic and morphometric data with constraints to the uplift and erosion rates.

Quaternary marine terraces from the two sides of the mountain belt, and Pliocene-Pleistocene deposits from the chain axis, indicate that uplift coeval with shortening was both spatially and temporally uneven, and was slower than that (of c. 0.8 mm/yr) recorded after the ceasing of shortening.

Constraints to the denudation are provided by (i) cosmogenic nuclides and long-term sedimentary yield, constraining erosion rates, and (ii) low-T thermochronometric data, constraining the unroofing of originally deeply buried tectonic units. Paleoerosion rates range from c. 0.2 to 0.4 mm/yr, and are consistent with the 0.6 to 0.3 mm/yr exhumation rates. Collectively, such values average denudation affecting most of the mountain belt, which includes bedrocks with variable resistance to erosion. Such results, which provide information on different time windows (collectively spanning from the Early Pleistocene to the Present), suggest that denudation averaged over long time spans is insensitive to climatic fluctuations.

The overall data set indicates that the changing style and rate of uplift has not affected the development of denudation in the mountain belt. The imbalance between uplift and denudation, which is mirrored by the large-scale topographic features of the chain, appears as a result of the long response time of hillslope and fluvial systems with respect to the relatively young age of uplift acceleration.

## **Linking topographic indices and rock uplift rates to denudation in a low uplift rate setting: Betic Cordillera, SE Spain**

BELLIN N.(1), VANACKER V.(1), KUBIK P.(2)

(1) *Université Catholique de Louvain. Georges Lemaître Centre for Earth and Climate Research (TECLIM), LOUVAIN-LA-NEUVE, BELGIUM* ; (2) *Paul Scherrer Institute, c/o Institute of Particle Physics, ETH Zürich, ZÜRICH, SWITZERLAND*

During the last decade, relations between catchment morphology, topographic indices, long-term catchment-wide denudation rates and rock uplift rates have been studied for high tectonic uplift rate settings. However, the validity of these relations for low uplift rate settings has received less attention.

Here, we present cosmogenic nuclide-derived denudation rates for 20 small catchments that were selected along a gradient of tectonic uplift within a region with low bedrock uplift rates (Betic Cordillera, SE Spain). Then, topographic indices were derived from high-resolution (10m) Digital Elevation Models to analyse the association between the spatial pattern of denudation rates and the spatial variability in stream-length normalized index (SLk), steepness index ( $k_{sn}$ ), valley-width ratio (Vf), concavity indices (SCI- $\theta$ ), hypsometric index (HI), mean local relief (Lr) and mean catchment slope ( $S_{basin}$ ). Additional information on bulk erosion (minimum) was also derived based on the reconstruction of the theoretical pre-incision surface ( $Bulk_{Er}$ ). This paper aims to unravel the association between the spatial variability in denudation rates, topographic indices and rock uplift rates.

Results indicate low denudation rates (mean = 63 mm kyr<sup>-1</sup>) with high spatial variability between the selected Betic Sierras (13-246 mm kyr<sup>-1</sup>). Spearman correlation coefficients show that SLk (0.8\*\*),  $Bulk_{Er}$  (0.6\*\*), Vf (-0.62\*\*) and Lr (0.52\*) accurately reflect the spatial variability of denudation. The similar magnitude obtained between local rock uplift and denudation rates suggests that the rates at which millennial erosion processes shaped the eastern Betic Sierras was roughly constant through geological timescales. We suggest that eastern Betic Cordillera approached dynamic equilibrium where rock uplift is balanced by denudation (topographic steady-state).

\*\*\*\*\*

## **Long Term Evolution of Active Folding in North Africa: Surface deformation and modeling**

MEGHRAOUI M.

*EOST - Institut de Physique du Globe, STRASBOURG, FRANCE*

The Atlas Mountains of North Africa experienced the largest thrust earthquakes of the western Mediterranean region. We investigate the geomorphologic similarities and differences between different active fault-related folds along the Africa - Eurasia convergent plate boundary. These active structures are seismogenic and the striking case studies are the 1960 Agadir (Mw 5.9), the 1954 Orleansville (Mw 6.7), the 1980 El Asnam (Mw 7.3), the 1992 Gafsa (Mw 5.3), the 1999 Ain Temouchent (Mw 6.0), and the 2003 Zemmouri (Mw 6.8) earthquakes. Using remote sensing images, or measured using space-borne geodesy (GPS or INSAR) combined with paleoseismic investigations the long-term active tectonics appear mainly as a thrust escarpment and fold-related faulting. The late Quaternary active folding is attested by the major uplift of late Pleistocene and Holocene alluvial and marine terraces and folding with steplike morphology. The El Asnam active fold shows the coseismic ruptures and 0.6 to 1.0 mm/yr uplift rate. The 2003 earthquake was responsible of ~ 0.5 m uplift along ~ 55 km shoreline east of Algiers. West of Algiers on the coastal Sahel anticline, the levelling and dating of uplifted successive benches and notches document the incremental folding uplift with 0.84 – 1.2 mm/yr uplift rate in the last 120-140 ka. The timing of successive uplifts related to past coseismic movements on active folds illustrate the episodic activity of thrust ruptures and their relation to past earthquakes. The dislocation modelling of coseismic thrust ruptures document the incremental evolution of active folds and illustrate the surface deformation. The relatively fast folding growth during late Pleistocene and Holocene in the Atlas Mountains attests for the significance of earthquake activity and the importance of convergent movements between Africa and Eurasia in the Western Mediterranean.

### The role of tectonics on the evolution of late Quaternary Amazonian landscape

ROSSETTI D.(1), ROSSETTI D.(1), HYAKAWA E.(2), BERTANI T.(1), ZANI H.(1), CREMON É.(1)  
(1) INPE, SAO JOSE DOS CAMPOS, BRAZIL ; (2) Universidade Federal de Alfenas, ALFENAS, BRAZIL

The Amazonas basin houses the most impressive ecosystem on Earth. This region is of relevance for the reconstruction of Quaternary climate changes due to its role as a global climate regulator. Changes in sedimentation and river dynamics over the Quaternary have been linked to climate. This reasoning could have primacy over other hypotheses if one disregards other influences on landscape evolution, such as tectonics. Considering the latter, a scenario different than currently reconstructed under a paleoclimatic scheme can be depicted. Although the majority of the geological investigations considers this region as a tectonically stable setting in the Cenozoic, several publications suggest that the Amazonian lowlands were undergone to tectonic deformation even in the Holocene. Hence, previously proposed climatic-related hypothesis for landscape dynamics may be an oversimplification of the geological record. This should be revisited in the light of a tectonic hypothesis. Advances in this field are still biased by a high degree of criticism on the tectonic influence over this region. The aim of the present work is to present morphological evidence for relatively recent tectonic activity in the Amazonian lowlands exploring mostly remote sensing products. The results revealed anomalous features, consisting of: lateral displacements of entire depositional systems (i.e., megafans, paleochannels and entire fluvial valleys), localized fluvial terrace downcutting and deposition, straight channels with orthogonal junctions, anomalous meander loops and enlarged river segments, highly asymmetric drainage basins, multibasinal drainage, and orthogonally-shaped lakes. It is unquestionable that geomorphic processes and changes in landscape dynamics over this region was strongly influenced by fault activity. This factor should be better understood prior to issuing climatic inferences when reconstructing the Quaternary history of the Amazonian lowlands.

\*\*\*\*\*

### Uplift history of the coastal Central Andes deduced from morphology

REGARD V.(1), MARTINOD J.(1), CARRETIER S.(1), SAILLARD M.(2), PEDOJA K.(3), RODRÍGUEZ M.P.(4), RIQUELME R.(5), HÉRAIL G.(1), BENECH N.(1), GUILLAUME B.(6), AGUILAR G.(7)  
(1) GET, Université de Toulouse/UPS/CNRS/IRD, TOULOUSE, FRANCE ; (2) Géoazur, Université Nice Sophia-Antipolis/CNRS, VILLEFRANCHE-SUR-MER, FRANCE ; (3) M2C, Université de Caen/CNRS, CAEN, FRANCE ; (4) Dep. Geología, Universidad de Chile, SANTIAGO, CHILE ; (5) Dep. Ciencias Geológicas, Universidad Católica del Norte, ANTOFAGASTA, CHILE ; (6) Geosciences Rennes, universit  de Rennes 1/CNRS, RENNES, FRANCE ; (7) Universidad de Atacama, Dep de Geologia, COPIAPO, CHILE

Most of the Pacific coast of the Central Andes, between 15°S and 30°S, displays a wide (a couple of kilometres) planar feature, gently dipping oceanwards and backed by a cliff. This morphology, usually of marine origin, is called *rasa*. Such feature and marine terraces have been observed without important gap, along the 1,500-km-long study area. This is a clear evidence of uplift, even along the 1,000m-high cliffs in the Atacama area, in northern Chile.

In a previous work (Regard et al. 2010), we observed the main cliff foot at *rasa* summit has similar elevation (~110 m amsl) over most of the study area. Moreover, the compilation of published chronological data and the extrapolation of re-appraised uplift rates provide evidence for a common cliff foot age of around 400 ka (i.e., Marine Isotopic Stage MIS 11). Additional geological constraints show that the area has not undergone significant uplift since the Pliocene. Thus we proposed a renewal of uplift in the Central Andes forearc after a late Pliocene quiescence or subsidence.

Since then, we observed in north-central Chile continental pediments connected to the *rasa* summit, with similar dating constraints. Pediment setup is a long process which needs little base level variation: pediments have probably formed during the same late Pliocene-early Pleistocene quiescence, as proposed for the *rasa* (Rodríguez et al., in press).

We present new <sup>10</sup>Be ages and further field mapping allowing for a finer description of this history.

References: Regard, V., et. al., Renewed uplift of the Central Andes Forearc revealed by coastal evolution during the Quaternary. *Earth and Planetary Science Letters*, 2010. 297: p. 199-210, DOI: 10.1016/j.epsl.2010.06.020.

Rodríguez, M. P., et. al., Geochronology of pediments and marine terraces in north-central Chile and their implications for Quaternary uplift in the Western Andes: *Geomorphology*, in press, doi: 10.1016/j.geomorph.2012.09.003.

### Local tsunamigenic earthquakes off northeastern Venezuela, in the southern Caribbean realm

AUDEMARD F., LEAL A.

*Venezuelan Foundation for Seismological Research -FUNVISIS-, CARACAS, VENEZUELA*

The 1983 National Inventory of Geologic Hazards and the 1999 Catalog of felt/destructive Venezuelan Earthquakes (1530-1998) report reliably the occurrence of tsunami waves on the Caribbean eastern Venezuelan coasts, or phenomena that might be interpreted as substantial sea level modifications in the region, during 5 local earthquakes only. We have confirmed this through the search and evaluation of the accounts by primary sources (eye witnesses) of the tsunami inundation during the 5 events. Such tsunamigenic events are the 1-IX-1530, 15-VII-1853, 29-X-1900, 17-I-1929 and 9-VII-1997 earthquakes. All but the 1900 shock affected the Cumaná city, and the offshore right-lateral strike-slip El Pilar fault has been accounted for. The 1900 AD tsunami waves were reported along most of the Ensenada de Barcelona coast (W of Cumaná) and Los Roques Archipelago, being this quake attributed to the San Sebastián fault segment running offshore Cabo Codera. The 1530 and 1853 quakes were produced by the Cariaco trough segment of the El Pilar fault, within a restricted over-1000-m-deep marine pull-apart basin on the San Sebastián-El Pilar releasing step-over, whereas the 1929 and 1997 events occurred on the Cariaco gulf segment. Several authors have interpreted all four events as the result of major submarine sliding inside the steep-walled trough. First-hand accounts by locals about the abnormal waves during the Cariaco 1997 event, as well as the identification of coastal sliding at the Manzanares river mouth at Cumaná, support this thesis at least for the two latest events, because of the small size of the tsunami-affected area. In addition, recent monitoring (CARIACO Project) has observed turbidite currents in the Cariaco trough and the Manzanares canyon during the Cariaco Mw 6.9 quake and the smaller Mw. 5.2 August 2008 event. However, the 1900 tsunami, and the 1530 and 1853 tsunamis by extension, appears to result from right-lateral tectonic slip along the Cariaco trough walls.

\*\*\*\*\*

### Active deformation of a passive margin: geomorphic evidence for persistent faulting consistent with the 23 August, 2011 Louisa County, VA earthquake

BERTI C., PAZZAGLIA F.J., MELTZER A.S.

*Lehigh University, BETHLEHEM, PA, UNITED STATES*

The recent Virginia seismic sequence, originated by the M 5.8 Louisa County, VA earthquake in August 2011, offers a singular opportunity, to our knowledge, to integrate seismicity with a long term record of deformed geomorphic markers in the intraplate setting of the eastern U.S. passive margin. Over 340 recorded aftershocks define a clear NE-SW striking SE dipping fault plane extending 7-9 km along strike at depths from 1 to 7 km.

Preliminary geomorphic field work along the South Anna River in Louisa County has mapped evidence for repeated faulting and surface deformation surrounding the illuminated fault plane, as warped (middle-late Pleistocene?) straths and terrace deposits. The South Anna River has several large knickpoints in its long profile. We suspect that these have been created by both far-field base level fall and local faulting. In the area affected by the recent earthquake, the top of a large knickpoint at Byrd Mill (VA Rt 649) is accordant with a low-gradient strath terrace that projects downstream across the epicenter of the recent earthquake, in the Yanceyville area. Continuing downstream for several kilometers beyond Yanceyville, the strath terrace and its thin alluvial cover climbs about 6 to 10 m in elevation, ultimately showing a clear downstream divergence from the South Anna channel. This observation is best explained by a history of local uplift of the bedrock consistent with the reverse fault focal mechanism of the recent earthquake. This interpretation is further supported by a higher, older terrace that shows a similar downstream divergence, and by channel form, that changes from low-gradient, low sinuosity in the subsiding footwall to steeper, higher sinuosity in the uplifting hanging wall.

## **Poster presentations:**

### **Quaternary tectonic deformation in the front of the northern Tian Shan, northwestern China revealed by sedimentary and geomorphic evidences of the Urumqi River**

LU H.(1), ZHANG T.(1), LI Y.(2), SI S.(2), ZHENG X.(1)

(1) Department of Geography, East China Normal University, SHANGHAI, CHINA ; (2) Key Laboratory of Earth Surface Processes of Ministry of Education, Peking University, BEIJING, CHINA

Timing of Quaternary deformation in the range front of the Urumqi River is still unclear. Here we chronologically constrain deformation in this region by analyzing the deformed Pliocene and lower Pleistocene strata as well as terraces of the Urumqi River.

The oldest alluvial fan ( $F_1$ ) of the Urumqi River is composed of ~400-m-thick lower Pleistocene conglomeratic strata. Near the fan end, the underlying Pliocene strata were folded and exposed due to basinward thrusting of the range-bounding fault. Wherever the two strata are juxtaposed, the dips of the lower Pleistocene gradually decrease upward from ~90° near the river bed to ~45° at the ditch on the west bank. This change in the dips of the lower Pleistocene is interpreted to indicate the occurrence of growth strata (Burbank et al., 1996), suggesting continuous tectonic deformation when the conglomeratic sediments deposited. An ESR age of 1148 ka for the sample from the top of the fan  $F_1$  (Zhou et al., 2002) shows that aggradation of this fan ended around this age. We thus propose that deformation in the study area continued at least till ~1.2 Ma.

The further deformation is revealed by geomorphic evidences of the Urumqi River. Nine terraces ( $T_1$  to  $T_9$ ) are identified in the range front. The highest terrace  $T_9$  surface is the surface of  $F_1$ .  $T_7$ ,  $T_5$ , and  $T_4$  with relatively planar surface are well displayed on the east bank. The longitudinal profiles of the there terraces obviously display fold deformation just near the fan end of  $F_1$ , decreasing systematically in magnitude of deformation. ESR ages of two samples from terraces  $T_7$  and  $T_5$  are 255±25 and 142±14 ka, respectively. Combining with an ESR age of 114 ka for the sample from the undeformed terrace  $T_3$  (Zhou et al., 2002), we conclude that Quaternary deformation in the range front of the Urumqi River continued till late Middle-Pleistocene.

Burbank, D.W., et al. Basin Res., 1996, 8, 199-223.

Zhou, S.Z., et al. Science in China(Ser. D), 2002, 45(11), 961-968.

\*\*\*\*\*

### **Sequence stratigraphic analysis and hydrocarbon prospects of the late Neogene-Quaternary off shore sediments north west of Sinai, Egypt**

ELHABAB A., EL ADSANI I.

College of Technological Studies, KUWAIT, KUWAIT

Detailed sequence stratigraphic analysis of the Late Neogene-Quaternary offshore subsurface sediments, NW of Sinai has revealed five third-order major depositional sequences. The Late Miocene sequences include two sequences, MSq-1 and MSq-2 whereas the Plio-Pleistocene sediments are represented by the sequences, PSq-1, PSq-2 and P-QSq. The different characteristics of each sequence are discussed in detail including their boundaries, transgressive and maximum flooding surfaces and the characteristic features of the enclosing systems tracts. The sequential evolution of the encountered sediments has revealed four successive depositional cycles mainly related to the sea level oscillations of the paleo-Tethys during the Late Neogene-Quaternary times. Moreover, for further hydrocarbon prospects in the study area and surroundings along the Egyptian offshore, the study recommends that: 1) The efforts should be directed to the stratigraphic traps comprising the sandy levels within the high-stand system tracts (1<sup>st</sup> priority) and the sand levels within the transgressive systems tracts (2<sup>nd</sup> priority). 2) The efforts should be directed to the combination traps consisting of the sediments of Pliocene sequence-2 (PSq-2) when only affected by the rollover anticlinal folds.

Keywords: Neogene – Quaternary — Stratigraphic Sequence – depositional – Tethys – hydrocarbon prospects

**Landscape evolution in a active tectonic context: the case of the Aterno river basin (L'Aquila, Abruzzo, Italy)**

FUBELLI G.(1), FALCUCCI E.(2), GORI S.(2), DELLA SETA M.(3), FREDI P.(3)

(1) Department of Geological Sciences, Roma Tre University, ROME, ITALY ; (2) INGV Istituto Nazionale di Geofisica e Vulcanologia, ROME, ITALY ; (3) Department of Earth Sciences Roma "La Sapienza" University, ROME, ITALY

The intermontane basins of Central Apennines are key areas to comprehend Quaternary morphotectonic evolution of this part of the mountain chain, where active tectonics strongly affected the assessment of previous drainage basins and networks. The present Aterno River catchment – the study area of this work - is located in Abruzzo Region and crosses some of these intermontane basins. Our aim is to reconstruct the shape and location of the paleo-Aterno River catchment before the occurrence of the extensional tectonics that determined its present configuration. The expected results might contribute to the better comprehension of the role played by both the tectonic and geomorphological events in the recent landscape evolution.

To model the Aterno River paleo-drainage basin we used a simple GIS based method. GIS technique allowed outlining and redrawing the shape of the Quaternary alluvial plain and tributary fans. The first step was the sampling of all the remnants of the plain surface and of the lower limit of the Quaternary deposits, from a 20 m resolution DTM. Then, using geospatial analysis, we reconstructed the top and base surfaces of this sedimentary body. The raster difference between the top and base surfaces allowed us estimating also the alluvial deposit thickness, thus confirming the occurrence of Quaternary faults in the study area, whose activity is also testified by paleoseismological data. Extending the investigations to the surrounding divide areas characterized by a gentle landscape (known in the literature as "Paleosuperficie Sommitale"), elevation ranging between 1100 and 1500 a.s.l. and lack of continental deposits, we reconstructed the relict erosional landscape existing before the occurrence of the extensional tectonic that affected this part of Apennines. The correlation between the relict erosional landscape and the Quaternary alluvial plain surface, allowed the localization of the head of the paleo-Aterno River drainage basin.

\*\*\*\*\*

**Application of Geomorphic Indices of Active Tectonics (GAT) in Morphotectonic Analysis of the Par River from Western India**

HIRE P.S.(1), PATIL A.D.(2)

(1) G. E. Society's Arts and Commerce College, JAWHAR, INDIA ; (2) Department of Geography, Tilak Maharashtra Vidyapeeth, Gultekadi, PUNE, INDIA

In order to test the hypothesis of ongoing uplift or neotectonic activity in the Par River Basin from Western India, a part of western Deccan Basalt Province (DBP), geomorphometric analysis was carried out and commonly used geomorphic indices of active tectonics (GAT) such as the hypsometric integral (HI), the basin asymmetry factor (AF), the valley width-height ratio (Vf), the stream gradient-length ratio (SL), and the basin elongation ratio (Re) were derived. ASTER-DEM data and ArcGIS were used to derive the indices. Tectonic geomorphic analysis based on five proxy indicators suggests that the index values are not very far from the GAT values typically associated with drainage basins affected by active tectonics and deformation. Therefore, the presented results indicate that the Par River Basin belongs to the class of relatively high tectonic activity as compared to other river basins of western DBP. The results are consistent with field observations on landforms and geology.

### **Evolution of large-scale gravitational deformations in tectonically-controlled mountain slopes**

BUCCI F., CARDINALI M., FIORUCCI F., GUZZETTI F., SANTANGELO M.  
CNR-IRPI, PERUGIA, ITALY

Evidences of large-scale gravitational movements evolving close to Quaternary faults have been recognized in the north eastern Sicily (south Italy) through the visual inspection of multi-scale and multi-temporal aerial photographs. Geomorphological and photo-geological survey have defined the relationship between the gravitational displacements and the tectonically-controlled landscape modifications conditioned by the presence of fault planes crossing the mountain slopes. In most cases the faults played, or are playing, an active role in increasing the local relief. Furthermore their activity represents the main geomorphic factor conditioning the gravitational movements. These mass movements may have developed in response to the slope weakening subsequent to multiple earthquake events, thus they occurred in the same time period of the Quaternary fault activity. In other cases the faults have also played a passive role by forming the boundary of the sliding masses and coincide with the slip surfaces. In both cases the evolution of the large-scale mass movements is conditioned by the incision of the hydrographic network in response to regional Quaternary uplift. The related erosion causes modifications of the slope morphology and the exhumation of weak discontinuities which may lead to slope instability. The spatial association of Quaternary faulting and large-scale gravitational movements greatly increases the hazard in fault-controlled mountain front landscapes. The evolution of tectonic displacement by coseismic offset may represent a potential cause for the sudden and catastrophic evolution of the gravitational movements. After their emplacement, the large-scale landslide bodies are deeply dismantled by the recent morphogenesis, including recent and present-day landslides that can propagate without any evidence of tectonic displacement and further increase the local landslide hazard.

\*\*\*\*\*

### **Neotectonic structures in the precordillera geological province. Structural setting from geomorphologic, gravity and magnetic data**

PERUCCA L.(1), RUIZ F.(2)  
(1) UNSJ-CONICET, SAN JUAN, ARGENTINA ; (2) UNSJ, SAN JUAN, ARGENTINA

The Central and Eastern Precordillera of San Juan, Argentina, form oppositely verging thrust systems on the western and eastern sides of the Matagusanos-Maradona-Acequi n valley, resembling a thick-skinned triangle zone with significant changes in the axis position along strike, north to south.

Between the Del Agua and the De La Fecha rivers, for example, the axis of this triangular zone is located in the eastern portion of the depression, while to the north, it is placed in the western flank. Changes in the position of the triangle zone axis along strike, alternatively to the east or to the west, would take place during Pliocene-Pleistocene times.

Geophysical, geodetic and geomorphologic data indicate a sub-surface structure striking NE, with dextral displacement and oblique to the general direction of the foreland, shows that the change in the location of the triangular area could be attributed to stress transfer favored by heterogeneities in the basement, provoking its jump through longitude.

By analytic signal analysis of magnetic anomalies, it is possible to assess the regional role of structural control of the coupling between Pie de Palo and Eastern Precordillera. The basement blocks oblique arrangement could explain transversal lineaments and the sigmoidal geometry of the Eastern Precordillera.

Basement structures might have also played a primary role in the localization of quaternary faults trending N-S. A structural cross section shows the same Cenozoic faults with opposing vergence, responding to different controls imposed by those previous basement structures.

**Capturing the timing and rates of valley incision through cave dating in the Eastern Pyrenees: geodynamic implications**

CALVET M.(1), GUNNELL Y.(2), HEZ G.(3), BRAUCHER R.(4), GUILLOU V.(4), BOURLES D.(4), DELMAS M.(1), SORRIAUX P.(5)

(1) *Université de Perpignan-Via Domitia, EA 4605 Médi-Terra., PEPIGNAN, FRANCE* ; (2) *Université Lumière-Lyon 2, UMR 5600 CNRS Environnement, ville, société., LYON, FRANCE* ; (3) *Université de Savoie, UMR 5204 CNRS Edytem, LE BOURGET DU LAC, FRANCE* ; (4) *Aix-Marseille Université, CEREGE CNRS UM 34, AIX-EN-PROVENCE, FRANCE* ; (5) *Total E&P, PAU, FRANCE*

Tectonic uplift in active mountain belts narrowly controls the rate and tempo of valley incision, with additional modulation effected by climatic change. There is no consensus over whether the Pyrenees still is an active orogen, even though surface uplift rates based on modern land levelling techniques register values of up to 1 mm/yr. Clarifying matters for the longer term should rely on opportunities to measure and date the vertical displacement of landforms of known initial geometry. Fluvial terrace systems in the Pyrenees have so far not yielded any dated sequences that reach further back in time than the latest Middle Pleistocene. Subterranean karstic networks, however, provide a fruitful alternative, with potential for obtaining coupled <sup>26</sup>Al and <sup>10</sup>Be burial ages for fluvial sediment which became trapped in limestone cavities while being conveyed through the catchment during valley incision.

Suitable subhorizontal, gravel-filled phreatic cave galleries cross-cut by limestone canyon sidewalls occur in the Têt valley. These can effectively be treated as a bedrock straths correlatable with subaerial terrace treads situated further up- and downstream. Such markers also provide information about karstic base levels, which in this setting connect directly to the regional marine base level.

The Têt valley exhibits a succession of cave levels spanning 300 m of vertical relief, two of which have been dated. Quartz-rich sediment samples were collected from of each system but also replicated among sand-sized and gravel-sized clasts, dated separately. Initial results reveal a continuous process of canyon incision throughout the entire Pliocene and Quaternary, with relatively steady mean incision rates. Nuclide inheritance in the samples provides added information about catchment-wide mean denudation rates. These rates are found to triple after 2 Ma, clearly reflecting a climatic signal linked to the onset of the Pleistocene glacial–deglacial cycles.

\*\*\*\*\*

**Geomorphologic correlation of the reconstructed and contemporary relief in Kolubara - Tamnava Coal Basin**

KEZOVIC M., DRLJEVIC N.

*EPI Serbia, Kolubara-Open Cast Mines, LAZAREVAC, SERBIA*

Based on results of the geophysics exploration and numerous exploration drillings, morphometric-statistic analysis and field research, geomorphologic correlation of the Kolubara-Tamnava coal Basin was reconstructed through time from paleo-relief up to modern relief.

Directions of neo-tectonic movement were defined, structures separated and neo-tectonic zoning performed, and all of that based on connection between relief and neo-tectonic movements.

Keywords: Geomorphologic correlation, Kolubara-Tamnava coal Basin, relief, neo-tectonic movement.

### **Tectonic influence on the geomorphologic evolution of Tocantins river near Marabá, South Amazonia**

MORALES N.(1), FELIPE L.B.(2), SOARES JR. A.V.(3)

(1) Universidade Estadual Paulista - UNESP, RIO CLARO, BRAZIL ; (2) Universidade Federal do Pará - UFPA, MARABÁ, BRAZIL ; (3) Universidade Federal de São Paulo, SÃO PAULO, BRAZIL

Supported by high-resolution remote sensing, digital terrain models and field survey geological and geomorphological studies were carried out in the region of Marabá, Southern Amazonia, northern Brazil. They allowed the recognition of tectonic faults influencing the geomorphological subdivision, the distribution of Cenozoic sediments and fitting the Tocantins River into a structurally controlled basin. Geomorphologic compartments fit around the Archaean basement rocks (Amazonian Craton), Araguaia Belt (Upper Proterozoic low-grade metasedimentary rocks), domains with residual tabular relief sustained by sediments Barreiras Group and downward blocks at the right margin of the Tocantins River. Sets of lineaments denounce the macroscopic structural pattern and they coincide with the principal directions of the mapped fractures. Geomorphologic boundaries between compartments are defined by faults or fault zones. NS normal faults control the Tocantins River downstream and limit the outcrops of Barreiras Group that from these failures towards East occurs as proximal alluvial fans, stating that it was an important geomorphologic boundary at that time of sedimentation. This set of rocks shows well-developed lateritic profile associated with a planing surface also preserved on top of flattened hills. Faults striking WNW-ESE to NW-SE control down compartments, fitting the rivers and docking the Tocantins River into a pull-apart basin controlled by NS and NW-SE normal faults, forming a rhombohedral geometry that controls the quaternary alluvial plain. The arrangement of faults and their kinematic interpretation point to a transtensive segment associated with dextral transcurrent system oriented near the EW direction. This arrangement is interpreted as associated with neotectonic regime in intraplate environment, resulting from the migration to NW of South American Plate and its interaction with the Nazca and the Caribbean Plates.

\*\*\*\*\*

### **Recent tectonics control on the morphological evolution of the eastern sector of the Monti Sabatini Volcanic District (Lazio, Italy)**

CICCACCI S.(1), FALCUCCI E.(2), FREDI P.(1), LUPIA PALMIERI E.(1)

(1) Dipartimento di scienze della terra - sapienza Università di Roma, ROME, ITALY ; (2) Istituto nazionale geofisica e vulcanologia, ROME, ITALY

This work focuses on the role of recent tectonics in the morphological evolution of the eastern sector of the Sabatini Volcanic District (Lazio). The Monti Sabatini volcanism evolved in a NW-SE directed Graben, tied to the tensile tectonics which followed the compressive phases of the Apennine building. The typically areal and mainly explosive volcanism of this District started about 0.6 m.y. B.P. and lasted until 0.05 m.y.B.P.. Volcanic activity affected a total area of about 1600 km<sup>2</sup> to the North of Rome; in the eastern sector, however, the most important emission centres concentrated in the surrounding of the present towns of Sacrofano, Morlupo and Castelnuovo di Porto.

The present morphology of the study area is strongly conditioned by the volcanic events. Actually, volcanism represents one of the main morphogenetic processes although it is efficaciously helped by the more recent processes due to surface running waters. The control exerted by recent tectonics on the evolution of the area is also clearly evident. The study of drainage network pattern shows the existence of many anomalies in the spatial arrangement and in the flow directions of fluvial channels which are often inconsistent with regional slope. The analysis of these morphological anomalies allowed inferring the existence of some tectonic dislocations, besides those leading the same volcanic activity, which are likely to have acted after the volcanic paroxysmal phases. Moreover, the areal distribution of geomorphic parameters allowed the identification of differentially uplifted or downthrown areas.

The study area is not considered as highly seismic; however seismological data about historical and contemporary earthquakes (the most recent occurred close to the Morlupo town on 10 July 2011, with magnitude 3.2) seems to support both the existence and the recent activity of some of the morphologically inferred tectonic lines.

### **Spatial variation in erosion rates and river longitudinal profiles along the Calabrian Arc**

OLIVETTI V.(1), MOLIN P.(1), CYR A.(2), FACCENNA C.(1)

(1) *Università Roma TRE, ROME, ITALY* ; (2) *U.S. Geological Survey, MENLO PARK, CALIFORNIA, UNITED STATES*

Fluvial systems are very sensitive to tectonic and climatic changes. So, deviations from a smooth concave-up river longitudinal profile indicate the landscape is in a transient state of disequilibrium. The relationship between erosion rates and uplift rate provides further evidences of steady state or transient landscape. In this framework, in order to study the different landscape response to tectonic forcing we analyzed two regions in the Calabrian Arc, the Sila Massif and the Messina strait, through the comparison of the river longitudinal profile with the erosion rates calculated by <sup>10</sup>Be content in modern fluvial sediments. The Sila Massif is characterized by uplift rate of 0.8-1 mm/yr and by a low relief upland (mean elevation of 1200 m), interpreted as a relict of an old landscape developed in stable base level conditions. The Messina Strait, one of the most seismically active region in the Mediterranean, is constituted by a narrow and deep NNE striking topographic depression. The elevation of dated marine terrace on both strait margins indicates uplift rates of 0.6-1,6 mm/yr. In the Sila Massif, the shape of river longitudinal profiles as well as the wide range of erosion rate values indicates a landscape in a transient state in response to an uplift not yet counterbalanced by erosion. In the Messina Strait smooth concave up river profiles and high erosion rate comparable with uplift rate indicate a landscape in almost steady state condition.

In conclusion, although the Sila Massif and the Messina Strait region are characterized by similar climate and lithology, their landscapes evolve differently in response to a slightly different rock uplift rates and probably to a different susceptibility to erosion as a consequence of tectonic deformation.

\*\*\*\*\*

### **Quaternary landscape response to neotectonics and fluvial processes: an example from the San Jose del Cabo basin, Baja California, México**

MARTINEZ-GUTIERREZ G.

*Universidad Autonoma de Baja California Sur, LA PAZ, MEXICO*

The San José del Cabo fault is located in the southern tip of Baja California peninsula and extends about 100 km with a NNW-SSE trending. The fault defines the boundary between Mesozoic metamorphic-igneous massif, and Tertiary-Quaternary sedimentary sediments (San José del Cabo basin). The fault represents the major geomorphic structure in the region. East-West elongated-watersheds occur perpendicular to the fault that supplied sediments to the basin. Quaternary alluvial deposits (El Chorro Formation) represent the late sedimentary event within the basin. These sediments are deeply incised by ephemeral streams from the massif's watersheds. Field-work and geomorphological mapping in the San Jose de Cabo basin, using field survey, topographic maps, aerial photographs and SPOT imagery revealed a landscape characterized by a series of dissected alluvial fans and channel pattern changes across the San Jose del Cabo fault. The Quaternary alluvial-fan surfaces were dated using scarp diffusion approach. The oldest geomorphic surface corresponded to the upper section of El Chorro Formation, which exhibits four levels of terraces stages produced by diverting streams and incision processes crossing the fault. These features are unique only in this section of the San Jose del Cabo fault; but field evidence does not show surface ruptures. Dating of the terraces suggests a time-average incision rate of ca. 0.4 m/ka was estimated for the last 2.6 Ma. The incision and later stream capture (present stream) was probably a climatically rather than tectonically driven process, although probably assisted by a long-term base-level changes.

## **Uplifts of the Longmenshan mountain in the eastern margin of Tibetan Plateau constrained by geomorphic evidences**

ZHANG S., DING R., MAO C., LI T., LV Z.

*Institute of Crustal Dynamics, China Earthquake Administration, BEIJING, CHINA*

Longmenshan mountain is a striking Cenozoic orogen as the eastern margin of the Tibetan plateau where Mw 7.9 Wenchuan earthquake occurred in 2008. We have rebuilt the surface deformation history in late Cenozoic there by geomorphologic surveyings.

Peneplain and river terrace are two kinds of ideal datum planes for gauging the tectonic deformation in Cenozoic time there. The relict tertiary peneplains were recovered by DEM analysis and field work. There are two levels of peneplains whose peneplanations may begin in early Cenozoic time and end at late Miocene when the final fluctuations of elevations were possibly less than one kilometers.

Dadu river and Minjiang river, two major streams across the east Tibetan plateau, recorded the Quaternary deformations by river terraces. The two main streams incised into the peneplains and formed a staircase of terraces no less than ten levels. The highest terrace is a strath which joins with the pediplane in the east piedmont of Longmenshan mountain. The longitudinal profiles of the river terraces were surveyed.

Based on the correlations of the peneplains, the southeastern side of Longmenshan mountain shows thrust-faulting with a total vertical slip of ~4500 m against the Sichuan basin since late Miocene, meantime the mountain range has been uplifting with the Longriba fault as the west boundary where vertical thrust slip is insignificant. As a landform barrier between Tibetan plateau and Sichuan basin, the crest lines of the mountain are about 500 to 1000 m higher than the hinterland surface on the west side. In a word, Longmenshan mountain has been formed by the combination of eastern-wing thrusting and west-wing flexing which are attested by the deformation of the Tertiary peneplains, the longitudinal profiles of river terraces and modern geodetic levelling surveys. We suppose that fault-bend folding of the upper crust may be the leading factor for the uplifting of the mountain.

\*\*\*\*\*

## **Morpho-structural features and drainage pattern related to extensional faulting: an example from the Northern Apennines (Italy)**

MIRABELLA F.(1), BUCCI F.(2), CARDINALI M.(2), GUZZETTI F.(2)

*(1) Dip. Scienze della Terra, University of Perugia, PERUGIA, ITALY ; (2) Istituto di Ricerca per la Protezione Idrogeologica, PERUGIA, ITALY*

The combined effect of regional uplift, denudation/deposition processes and active faulting produces characteristic drainage networks and morpho-structural features. In areas undergoing extensional faulting, the investigation of the tectono-sedimentary evolution of fault-controlled basins through the analysis of morpho-structural features and drainage pattern can provide valuable information on the space-time evolution of the active deformation.

We explore this topic on a Quaternary extensional basin located in the upper part of the Puglia and Attone basins (Northern Apennines of Italy) where both GPS and seismological data reveals the recent tectonic activity of the area. The Quaternary extension has been accommodated by NW-SE trending normal faults, which have attained mature morphologic and structural features and, nowadays, separate mountain ranges from intermountain basins.

In order to understand the Quaternary evolution of the study area, we integrate field data with river longitudinal profiles analysis and aerial-photo-geological interpretation. Most of the morpho-structural features were identified through the analysis of multi-scale and multi-temporal aerial photographs, identifying the: (i) attitude of fault and bedding planes, (ii) fault-controlled landslides, (iii) pattern of rivers network and (iv) spatial distribution of river terraces.

Basing on our analysis we show that recent faulting occurs on NE-dipping and SW-dipping structures, which cut the inherited landscape and deform the continental deposits. Recent fault motion has conditioned the rivers pathway and the tectono-sedimentary evolution of their valleys, where fault-controlled subsidence has captured the river courses and produced subsiding plains. The location of landslides close to extensional faulting suggests a structural control also on the morphological instabilities and hence has implications for hazard.

### **Morphological and hydrological response to extensional faulting. An example from the Northern Apennines of Italy**

*MIRABELLA F.(1), PUCCI S.(2), DEMARTINI P.M.(2), CIVICO R.(2), BURATTI N.(1), BAGLIONI S.(1), SMEDILE A.(2)*

*(1) Dip. Scienze della Terra, University of Perugia, PERUGIA, ITALY ; (2) Istituto Nazionale di Geofisica e Vulcanologia, ROMA, ITALY*

Extensional faulting produces areas undergoing anomalous trends of erosion and sedimentation at the faults footwall and hanging walls respectively. The record of the uplift/subsidence history related to faulting can hence be provided by the investigation of the sedimentation record as documented by syn-tectonic basins infill as well as by the incision history as provided by the flights of river terraces and erosional surfaces.

We show evidences of drainage inversion due to faulting in the Northern Apennines of Italy where extensional faulting is active since the lower Pleistocene and documented by seismological and GPS data. This work is in progress, the aim is to show that the investigation of both the morpho-structural features and the rivers incision history provides a key to the understanding of the continuity of the deformation processes through time.

We analyze two intermountain basins (Nese and Pantano) and the main rivers draining them (Nese and Caina). Both basins are associated to the activity of two west-dipping fault segments which acted as barriers to the waters flowing to the east.

At present, the Nese basin is still drained towards the east by the Nese river after the incision of the barrier. On the contrary, the Pantano basin is presently drained in the opposite direction by the Caina river flowing to the west. The analysis of the remnant surfaces hanging above the Pantano basin testify for the paleo eastward-directed drainage which is now inverted towards the west.

We plot the rivers profiles and project onto them the faults location and the terraces and erosional surfaces position. We compare the data with the analyses of the continental basins deposits obtained through a motor hand driller sampling system.

We discuss the drainage inversion and the obtained data in the context of the normal faults activity by focusing on the possible role of footwall uplift and/or of fault segmentation in producing such a configuration.

\*\*\*\*\*

### **Tectonic versus climatic controls on landscape denudation: A test in the central Himalayas**

*GODARD V.(1), SPINABELLA F.(1), BOURLÈS D.(1), BURBANK D.(2), BOOKHAGEN B.(2), FISHER B.(2), MOULIN A.(1)*

*(1) CEREGE - Aix-Marseille University, AIX-EN-PROVENCE, FRANCE ; (2) ERI - UC Santa Barbara, SANTA BARBARA, UNITED STATES*

Landscape denudation in actively deforming mountain ranges is under the dual control of internally driven rock uplift and erosion due to surface processes. The relative contribution of these factors in setting the pace of landscape evolution is key to our understanding of orogenic evolution and lies at the core of an emerging paradigm which proposes that external factors could be the predominant driver of deformation in orogenic systems. The Himalaya are a favorable location to test these propositions due to the intensity of tectonic and geomorphic activities and the host of data available. To study short-term denudation in a ~200-km-wide region of the Lesser Himalayas in central Nepal, we measured  $^{10}\text{Be}$  concentrations in detrital sediments from small basins to infer their denudation rates at millennial time-scales.

Along a northward strike-perpendicular transect, denudation rates start at <0.5 mm/yr in the Lesser Himalayas before sharply rising to 2-3 mm/yr when crossing the Physiographic Transition and reaching the southern flank of the high range in the Higher Himalayas. Despite a more than 5-fold increase in denudation rate between the two extremities of the transect, it is noteworthy that the corresponding areas display similar relief, distribution of hillslope angles, and precipitation rates. The only parameter that presents a significant co-variation with denudation is the long term-rock uplift rate resulting from the flat-ramp transition along the MHT.

We propose that in this rapidly uplifting mountain range, landscapes are rapidly adjusting to changing climatic conditions and that denudation is, therefore, mainly limited by the rate at which material is pushed upward by tectonic processes and made available for removal by surface processes. In this particular context, variations in precipitation appear to have mainly a second-order modulating role on the denudation signal that is primarily set by the background rock-uplift rate.

### **Role of Neogene-Quaternary faults on landform evolution in the continental margin of northeastern Brazil**

BEZERRA F.(1), ROSSETTI D.(2), ANDRADES FILHO C.(3), NOGUEIRA F.(4), GÓES A.M.(5), MEDEIROS W.E.(1), OLIVEIRA R.G.(6), FUCK R.A.(7)

(1) Federal University of Rio G Norte State, NATAL, BRAZIL ; (2) Instituto Nacional de Pesquisas Espaciais, SÃO JOSÉ DOS CAMPOS, BRAZIL ; (3) Universidade Estadual do Rio Grande do Sul, SÃO FRANCISCO DE PAULA, BRAZIL ; (4) Federal University of Campina Grande, CAMPINA GRANDE, BRAZIL ; (5) University of São Paulo, SÃO PAULO, BRAZIL ; (6) Brazilian Geological Survey, RECIFE, BRAZIL ; (7) University of Brasília, BRASÍLIA, BRAZIL

The eastern continental margin of South America comprises a series of rift basins developed during the breakup of Pangea in the Jurassic-Cretaceous. We concentrate our study in the Paraíba Basin, where sediment deposition spans from the late Cretaceous to the Quaternary. The region is one of the most seismically active parts of the South American stable continental margin. We integrated high resolution aeromagnetic data with topographic, structural, and stratigraphic data to evaluate the role of faults in the deposition of Neogene-Quaternary sediments and related landform evolution. Our results indicate that the reactivation of basement faults controlled depocenter location, geometry, and orientation, and coastal morphology in the Neogene-Quaternary. Tablelands along the coast are cut by linear alluvial valleys. These valleys mainly trend NE, are bounded by faults, and exhibit topographic breaks 20-40 m that bound Quaternary alluvial deposits. The throws of these faults are on the order of hundreds to tens of meters in Cretaceous units and tens of meters in Neogene-Quaternary units. The coastal tablelands are slightly tilted seaward, as shown by the gradual decrease of the height from ~200 m to ~50 m. In the littoral zone, these tablelands form sea cliffs 30-50 m high. Faults were reactivated as oblique-normal and oblique-reverse faults. Multiple episodes of faulting are recorded, which are followed by concomitant sedimentation. We conclude that this coastal topography is characterized by tablelands, which correspond to horsts and grabens, with alluvial valleys entrenched in the latter. Degraded fault scarps mark the transition between faulted blocks. In the Neogene-Quaternary, faulting resulted in subsidence-uplift, which was largely responsible for the present-day morphology of the continental margin. Results of this study show that the passive margin of South America has been active long after the breakup.

\*\*\*\*\*

### **Travertines distribution in Southern Italy: tectonic and geochemical implications**

SANTANGELO N.(1), ASCIONE A.(1), IANNACE A.(1), IMBRIALE P.(1), SANTO A.(2)

(1) Department of Earth Sciences, University of Naples Federico, NAPOLI, ITALY ; (2) Department of Hydraulic, Geotechnical and Environmental Engineering, Applied Geology Division, University of Naples Federico, NAPOLI, ITALY

In the present paper we claim that all the geologically significant travertine/tufa bodies of southern Italy due their existence to CO<sub>2</sub>-rich waters feeded by deep-seated faults. Meteoric waters alone can precipitate only limited amount of carbonates. The data presented include: i) a field analysis of the relationships of the main tufa outcrops with active faults, ii) a appraisal of the chemical data on the springs associated to the tufa/travertines, iii) a petrographic and stable isotope investigation of selected tufa outcrops.

The analysis of travertine distribution pointed out that both ancient and recent travertine bodies systematically crop out close to active deep seated faults of regional relevance, which generally bound the main extensional basins of the chain. As regards to karst springs only 18 out of 65 are associate with present or fossil travertine deposition. Even if all the springs show a Ca-Mg-HCO<sub>3</sub> freshwater typical of limestone aquifers, the depositing travertine springs have higher salinity and alkalinity, are slightly warmer and have lower pH. Furthermore, they are always enriched in SO<sub>4</sub> and CO<sub>2</sub>.

We acknowledge that organic activity play an important role in shaping the texture of the deposits through a micro-control on the precipitation environment. However, a supplementary source of CO<sub>2</sub> is a necessary prerequisite for inducing a rise of TDS and alkalinity sufficient to sustain the precipitation of geologically significant carbonate deposits. This is confirmed by d<sup>13</sup>C values of travertine samples which are systematically positive and compatible with a crustal or mantle derived carbon source.

The co-presence of mineral springs and travertine deposits with peculiar karst morphologies (karst collapse sinkholes) already pointed out in literature, seem to confirm the strong interrelations linking dissolution phenomena, and consequent carbonate deposition, to the rising of aggressive fluids along active faults.

### Denudation rate spatial variation across the Eastern Tibetan margin

ANSBERQUE C.(1), GODARD V.(1), BELLIER O.(1), DE SIGOYER J.(2), LI Y.(3), LIU-ZENG J.(4), REN Z.(4), BOURLÈS D.(1)

(1) CEREGE, Aix Marseille University, AIX EN PROVENCE, FRANCE ; (2) Laboratoire de géologie ENS, PARIS, FRANCE ; (3) Chengdu University of Technology, CHENGDU, CHINA ; (4) China Earthquake Administration, BEIJING, CHINA

The Eastern Tibetan margin, delimited by the Longmen Shan range, forms one of the steepest topographic escarpment in the world. Most of the current deformation in Eastern Tibet appears to be accommodated in the Longmen Shan thrust system whose major seismogenic potential is attested by the 2008 Wenchuan earthquake. The velocity gradient across the margin revealed by GPS measurements (e.g. Shen et al., 2009) decreases significantly from west to east. These observations suggest that other tectonic structures might contribute to the global deformation in Eastern Tibet, such as the recently identified Longriba Fault Zone (e.g. Xu et al., 2008).

Understanding the global deformation pattern over this area requires to constrain the parameters of the geomorphic evolution of the margin. Quantifying denudation rates using cosmogenic nuclides is an efficient way to assess spatial variation in denudation, and provide some critical insights on the effective role of various parameters such as tectonic, climate or nature of geological substrate, on surface processes. Apprehending the spatial evolution of geomorphic context through the Eastern Tibetan margin using this method will permit to assess differences in denudation intensity across the Longriba Fault Zone, which appears to present significant thrusting activity on some of its major strands.

Our dataset consists in 20 new denudation rates inferred from <sup>10</sup>Be concentrations in river sediments from small (2nd or 3rd order) catchments at the edge of the Plateau. Starting from high denudation rate at 0.5-0.6 mm/yr at the range crest, we observe a decrease down to <0.1 mm/yr toward the west and the headwaters of the Minjiang basin. This gradient in denudation rate occurs under homogeneous precipitations, suggesting that it is either the consequence of a long-wavelength (~100 km) variation in rock uplift across the topographic step or the expression of progressive propagation of margin dissection toward the Plateau interior.

\*\*\*\*\*

### Channel-profiles metrics in tectonic geomorphology: new insights from a continental piedmont area, a sub-marine canyon system and analogues on Mars

BAIONI D.(1), CAVITOLLO P.(2), DELLA SETA M.(3), FREDI P.(3), GIANGIOLINI F.(2), NESCI O.(2), SAVELLI D.(2), SGAVETTI M.(1), SPIGARELLI A.(4), TRAMONTANA M.(2), TROIANI F.(2)

(1) Department of Physics and Earth Sciences, University of Parma, PARMA, ITALY ; (2) Department of Earth, Life and Environmental Sciences, University of Urbino, URBINO, ITALY ; (3) Department of Earth Sciences, Sapienza University of Rome, ROMA, ITALY ; (4) SAIPEM-Energy Service, ENI Group, FANO, ITALY

Quantitative geomorphic analysis of landforms has developed and validated many indices that identify the fingerprints of active tectonics on the topography. Specifically, the Steepness Index (Ks), the Stream Length-Gradient Index (SL) and the Distance-Slope (DS) log-log plots of longitudinal profiles are particularly useful in tectonic Geomorphology to delineate catchment morphology and channel-profile anomalies. Numerous tests have demonstrated the validity of channel-profile metrics to detect tectonic-generated knickpoints, especially along trunk valleys. In particular, the Ks index demonstrated to be useful in detecting anomalies in catchment morphology and channel-profiles related to active tectonics in both emerged ranges and sub-marine canyons. Recent outcomes from analogous investigations on Martian surface match the findings from catchments on Earth. Further researches, however, are needed to better understand the sensitivity of the single parameters in detecting tectonic-generated knickpoints in different geodynamic and physiographic settings. Additional investigations are also necessary to verify the validity of the channel metrics regardless of specific typology of flows, for example along debris-flow dominated channels, submarine canyons, and drainage systems on Mars that do not belong to the typical fluvial systems. Accordingly, our research focuses on the calculation and evaluation of Ks, DS, and SL indices, derived from Digital Terrain Models (DTMs), within different test areas from emerged and sub-marine zones on Earth and analogues from Mars. Preliminary results obtained within the Adriatic piedmont area of Apennines (Italy) and a sub-marine canyon system at the Makran margin (Iran), as well as findings from Mars, emphasize the capability of channel-profiles metrics to detect the long-wavelength effects of regional tectonic structures regardless of style and rate of deformation, as well as regardless of processes that act along the present channels.

**Relationships between tectonic fractures and cliffs morphologies: examples along chalk coast in France (Normandy, Picardy, Boulonnais)**

VANDYCKE S.(1), DUPERRET A.(2), COLBEAUX J.P.(3)

(1) University of Mons, MONS, BELGIUM ; (2) Institut Universitaire Européen de la Mer, UMR 6538 CNRS, 29 280 PLOUZANÉ, FRANCE ; (3) Conseil scientifique de l'Environnement Nord Pas-de-Calais, BP 216 LILLE, FRANCE

Fractures, in particular master joints and faults, have an active role in the geomorphological development of the chalk cliffs. Master joints are defined as planar structures cutting the total height of a chalk cliff. They are repeating at equal distance with plumose and twist hackle steps. In some particular areas, flint filling is associated to jointing. In clayey chalk, hybride joints can be also very developed. The faults are used to define the tectonic context in relation with the main geological events of the basin environment. But, the number of faults is quite small comparing to the jointing. These tectonic features have a direct impact on the development of the coastline, in terms of trending but also concerning slope development and local cliff morphologies.

Normandy and Picardy chalk districts are located in the most protected sedimentary deposit zones of the Anglo-Paris Basin far from the active crustal zone in Europe. Nevertheless the chalks deposits have recorded tectonic events mainly in relation with inversion tectonics and crustal development of the English Channel. In the Boulonnais, chalks fracturing are mainly influenced by the tectonic evolution of crustal Nord-Artois-Shear Zone.

Faults, joints and fractures have a strong influence on the hydrogeological dynamics in chalk rocks. Along the coastlines, different stages of alteration and excavations along the fractures can be observed with the appearance of major karstic features. The large development of caves at base of the cliffs, like near Etretat, results from initial chalk fracturing and local expulsiing of chalk alterite.

Comparative observations can be done between each chalk district to deduce a correlative analysis between chalk and fractures in view of characterizing the fractures network in terms of reservoirs behavior.

\*\*\*\*\*

**GEONAS GNSS network for geodynamic observations of surface development in Czechia**

BLAHUT J., BALEK J., FUCIK Z., KAPLAN Z., KLIMES J.

*Institute of Rock Structure and Mechanics, ASCR, PRAGUE, CZECH REPUBLIC*

GEodynamic Network of the Academy of Sciences of the Czech Republic is a research infrastructure within the CzechGeo/EPOS project used to observe surface development using geodetic GNSS receivers. It consists of 20 permanent stations and 37 sites for campaign measurements. It was established in 2001 and the stations are placed along major tectonic lineaments in western and northern part of Czechia. Most of the receivers are registering NAVSTAR and GLONASS signals and some sites are already capable to start registering the GALILEO satellites. The processing of the data, together with their quality and reliability is presented. Interpretations of surface movements are shown with respect to other measurements (seismic, gravimetric, tectonic micromovements, etc.).

### **Regional vs. local morphological effects of the late quaternary deformation of ne Sicily**

PAVANO F., CATALANO S., ROMAGNOLI G., TORTORICI G.  
UNIVERSITA' DEGLI STUDI DI CATANIA, CATANIA, ITALY

The available geodetic data on the southern margin of the Calabrian arc, in NE Sicily, evidence that a discrete crustal mobile block (Peloritani Mobile Block; **PMB**), including the Peloritani region, moves towards the NNW, diverging from both the Calabrian sector of the arc, pointing to the NE, and the African domains of Sicily, shifting to the NW. The mobile block is characterized by a spectacular flight of Late Quaternary marine terraces that constrains an uplift rate of about 1.1 mm/a, almost constant since 600 ka B.P. A significant segment of the southwestern margin of the mobile block has been recognized along the Nebrodi-Peloritani boundary, in the region affected by the swarm of low-magnitude seismic events ( $M \leq 4.1$ ) of June-August 2011. This consists of a 10 km wide fault zone, which is composed of several discrete, NW-SE oriented normal faults that have displaced the marine terraces at vertical displacement-rate of about 0.4-0.5 mm/a, also showing rejuvenated fault scarps, which evidence their Holocene activity.

A quantitative morphological analysis of the relief and of the drainage system, based on the calculation and the interpretation of the most relevant morphometric indexes, has been carried out, in order to discriminate the effects due to the regional uplift from those due to the tectonic deformation. The analysis of the relief evidenced an almost uniform behavior in the whole region, revealing rapid adjustments of the river entrenchment with respect to the rate of tectonic uplift. On the contrary, evident anomalous values of morphometric indexes of the drainage system, due to rivers diversions and captures phenomena triggered by the systematic NE-ward tilting of blocks across the active fault belt, have been recognized along the Nebrodi-Peloritani boundary. This evidence could represent a tool for localising the occurrence of low displacement-rate (0.4-0.5 mm/a) active faults within zones affected by more intense regional tectonic processes (1.1 mm/a).

\*\*\*\*\*

### **Morphotectonic analysis of Kozani Basin (Western Macedonia, Greece)**

SIMOUE.(1), KARAGKOUNI V.(2), PAPANTONIOU G.(2), PAPANIKOLAOU D.(2), NOMIKOU P.(2)  
(1) University of Athens, Faculty of Geology and Geoenvironment, ZOGRAFOU, GREECE; (2) University of Athens, Faculty of Geology and Geoenvironment, ZOGRAFOU, GREECE

Kozani Basin is located in northern-central Greece and constitutes the southernmost of the Plio-Pleistocene basins of central Macedonia. Quantitative and qualitative analysis of morphological slope values, as well as the analysis of the drainage pattern in Kozani Basin confirms that the current topographic relief reflects intense neotectonic activity. Synthetic Morphotectonic Map of the under study area was carried out by means of the combined use of: (a) Digital Elevation Model (DEM), (b) Slope distribution Map, (c) Morphological slope Map and (d) Drainage Pattern Map. The composition of the digital modeling in conjunction with the regional geological setting, allows the identification of the main morphological discontinuities and lineaments that result from morphotectonic interpretation. The high morphological slope values indicate well-defined morphotectonic features, which mainly trend northeast - southwest (NE - SW) and, secondarily, northwest - southeast (NW - SE). Distinct tectonic structures are mostly recognized in the southwest (SW) margin of Kozani Basin, which is characterized by intense topographic relief. The main large-scale tectonic structure trends northeast - southwest (NE - SW) and corresponds to the major Aliakmonas marginal fault zone that bounds the Kozani basin to the south. On the other hand, the northwest (NW) margin's features are indiscernible; Thus, the criteria for their recognition are based on the existence of the terraces which reflect the tectonic control. The results of our morphotectonic studies can be proposed following our 3D model of Kozani Basin.

## **Morphotectonics and Cenozoic Sedimentation on Aiuruoca Region - Mantiqueira Range (MG), Brazil**

SANTOS M.

*Unesp - Univ Estadual Paulista, Campus Experimental de Ourinhos, OURINHOS, BRAZIL*

The Aiuruoca region involves part of Mantiqueira Range (1.800 to 2.350 m high) and Alto Rio Grande Plateau (900 to 2.000 m high) presenting a complex morphotectonic framework which resulted from two tectonic events (Paleogene and Neogene-Quaternary). The events were recognized by faults mapping and control on drainage rearrangement, relief anomalies and distribution and deformation of superficial deposits. The first one, extensional, is related to Atlantic opening processes, and the second one, transcurrent, to intraplate neotectonics. This Cenozoic tectonic activity modified the landscape by rearrangements of drainage and relief forms, preferentially along the reactivated dextral ENE-WSW and NE precambrian shear zones. The progressive advance of fragmentation towards the hinterland in the Paleogene implicated truncation, tilting and subsidence of ENE blocks. The extensional event ( $\sigma_3$  NW  $\sigma_2$  NE, both subhorizontal, and  $\sigma_1$  NE subvertical) originated the Aiuruoca Basin (Eocene-Oligocene) and filled up by sediments here defined as Entre-Córregos Formation (lake facies) and Pinheirinho Formation (alluvial fan facies). Since Neogene the area has been submitted to transcurrent tectonics with transpressional component and reactivation of earlier structures, with differential uplift of ENE blocks and increasing tilting towards NNW. This neotectonic activity ( $\sigma_1$  NW and  $\sigma_3$  NE, both subhorizontal, associated to E-W dextral binary), involved inversion of the relief, the Aiuruoca Basin and the pleistocene covers, promoting the drainage network rearrangement by capture, diversion and beheading processes, and progressive migration of regional divide towards the ocean. Two captures was dated by  $C^{14}$  of organic horizons and paleosoils on  $30.070 \pm 370$  and  $7.300 \pm 80$  y.B.P., and the palaeoenvironment was reconstituted by palynologic analysis. The area remains active tectonically as indicated by drainage and relief anomalies, and imminent process of stream piracy by the Aiuruoca river.

\*\*\*\*\*

## **Morphogenesis and Pedogenesis Relationship as Evidence of Neotectonics in Sedimentary Rocks in the Upper Cretaceous - Portion Center-South of the South American Platform - Brazil**

COUTO E.(1), SANTOS L.J.C.(1), GONTIJO A.H.P.(2)

*(1) Federal University Of Parana, CURITIBA, BRAZIL ; (2) Rural Federal University of Rio de Janeiro, RIO DE JANEIRO, BRAZIL*

The differentiated evolution and distribution of Oxisols and Alfisols in sedimentary rocks in the Upper Cretaceous, located in the Southern Brazil, in Paraná State, indicates different degrees of dissection of the relief and leads to the hypothesis that the morphotectonic action is changing the regional relief. For this work, we used remote sensing SRTM, drainage basin Shapefile, and soil and geologic maps of this area. The data were processed in GIS, from where we extracted lineament topographic profiles and anomalies of drainage by using Hack Profile (SL index). The soils are often associated with the degree of indentation in the drainage basin, namely, in the relief of rolling hills, with predominance of Oxisols, the drainage is little indented, while in the south of the Ivai river (left margin) the relief is composed of medium hills, where the Alfisols becomes more predominant, the drainage basin is denser and more indented. These characteristics show that there are different degrees of relief dissection through the action morphotectonic which controls and orientates the organisation and the distribution of drainage basin and, consequently, of the systems Oxisol-Alfisol pedology in the region. From the analysis of the longitudinal profiles it is possible to identify anomalies in the profiles, the indices pointing to several parts and segments of drainage maladjusted by subsidence and raising. The Asymmetry Factor shows moderate rise in the main bays that compose the area. Moreover, larger values of anomalies can be observed by SL index, among them can be noticed abrupt widening of the canals. These can be associated with changes in the course of the rivers, forming orthogonal junctions, alternating between straight canals with narrow meanders and alignment of confluences.

Key Words: Structural Lineaments; Oxisols; Alfisols and drainage basin

### **SL index as indicator of anomalies in the longitudinal profile of the Alonzo River, Southern Brazil**

COUTO E.(1), LUCIANE MARIA V.(2), FORTES E.(3)

(1) Federal University Of Parana, CURITIBA, BRAZIL ; (2) Federal of Paraná Technical Federal University, LONDRINA, BRAZIL ; (3) State of Maringá University, MARINGÁ, BRAZIL

This work principally uses morphometric analysis in the drainage net as indicator of neotectonism in the hydrographic bay of the river Alonzo, in Parana State, Southern Brazil. The applied methodology consisted of the integration of SRTM data, morphometric variables in SIC environment (Geographic Information System). The set of SRTM data (90m) were used for achieving the following aims: a) preparation of Digital Models of Raising (MDEs) to identify and delimit the features of the relief, b) lineaments, c) identification of anomalies in drainage. The identification and vectorization of these features were based on visual interpretation, and comparison of morphometric indices, such as: Factor of Transversal Topography Symmetry, Asymmetry of Drainage Bays and RDE indexes, in order to obtain parameters of analysis of geomorphic anomalies with possible relations with morphotectonic processes. The drainage of the bay is strongly controlled by lineaments. The analysis of the longitudinal profile of the river Alonzo shows that it presents, in its first 20 km, a rise of about 500m above the line of better adjustment. Also in this stretch is located its biggest anomaly of SI index, part whose value is 11,8. In this trajectory is the anomalous transition of the Teresina Formation with the Serra Alta Formation, a place where the drainage indented through a gap line and eroded all the lithology of the Teresina Formation, making the Serra Alta Formation outcrop along the canal. The high values of the indices, which represent morphometric anomalies in the equations adopted in this research, are located on the North and North East portions of the high course of the hydrographic bay of the river Alonzo. It is possible to observe that the hydrographic bay of the river Alonzo is strongly controlled by regional geologic structures.

Key words: morphostructure, morphotectonic, drainage net, river Alonzo

\*\*\*\*\*

### **Evolution of uplifted structural landforms in northeastern Brazil**

GURGEL S.P.D.P.(1), BEZERRA F.H.R.(2), CORRÊA A.C.D.B.(3), MARQUES F.O.(4), MAIA R.P.(5)

(1) Universidade do Estado do Rio Grande do Norte, NATAL, BRAZIL ; (2) Universidade Federal do Rio Grande do Norte- UFRN, NATAL, BRAZIL ; (3) Universidade Federal de Pernambuco, RECIFE, BRAZIL ; (4) Universidade de Lisboa, LISBOA, PORTUGAL ; (5) Universidade Federal do Rio Grande do Norte - UFRN, CAICÓ, BRAZIL

Elevated areas on passive margins are considered to be the weathered remnants of zones uplifted following the breakup of continents. However, an increasing number of studies have contradicted the idea of permanent uplift and elevated remnants. The purpose of this study was to analyze the evolution of elevated areas in the continental margin of northeastern Brazil. We focused on the Pereiro Massif (PM), an 876-m-high plateau composed of Precambrian granites, surrounded by a low-lying surface, 200 m high, composed of Precambrian metamorphic rocks and Cretaceous rift basins. We mapped the area using GIS-assisted geomorphological and geological mapping. In addition we dated Quaternary sediments using optically stimulated luminescence (OSL) and the single-aliquot regenerative-dose (SAR) protocol. The maximum uplift rate of the PM is 34 m/My, as constrained by the age of flat topography capped by Miocene laterite, which represents the previous peneplain subsequently uplifted by ca. 600 m in a nearby area. The minimum uplift rate is 13 m/My, as constrained by fission-track data of differential crustal block movements across a nearby fault. Erosion of the PM occurred mainly by scarp retreat rather than by erosion of the top surfaces. The extreme soil erosion is concentrated mainly along the fault-controlled escarpments. The spasmodic nature of the processes that shaped the landscape ensures that soils and sediments reflect the last erosion and sedimentary cycle. Therefore, the observed colluviation process has been active in the last 46 ka. This process occurred mainly under a semi-arid climate setting similar to the present-day conditions. We conclude that the PM is an ancient horst, which has been repeatedly uplifted and faulted since the breakup of Pangea and especially in Cenozoic times. Our study indicate that the approach of using erosion surfaces as reference levels across fault lines is inadequate, even in seemingly stable continental areas.

## **The neotectonics and its impact on the evolution of the Yellow River at the northeastern margin of the Tibetan Plateau, China**

LIANG H., LI S., ZHANG K.

*Sun Yat-sen University, GUANGZHOU, CHINA*

Northeastern margin of the Tibetan Plateau is a key area to understand the formation and evolution of the plateau. Four arc-form mountain ranges uplifted along the margin and the northernmost one, Niushou Mountains, located at south of the Yinchuan Basin, is cut by the Yellow River, forming the Qingtong Gorge on west side and by Kushui River (much smaller than the Yellow River) on east side, which records the evolution of landform in this area. The Pliocene fluvial and lacustrine deposits can be found both on east side and in half graben controlled by a North-South normal fault on west side of the Niushou Mountains. The deposits in west of the fault, representing lakes and small rivers and much differing from the present ones of the Yellow River, was folded, implying a North-South shortening which is about 10km by balance section measurement. However, the deposits along the Kushui River indicate lakes and larger rivers in the ancient Yinchuan Basin. The rivers on the west side were actually tributaries of the ones on the east side in Pliocene. A North-South thrust fault cut into the Quaternary deposits on southeast part of the research area, shows a East-West shortening afterward, leading to uplift of research area, westward shift of the late Pliocene to early Quaternary deposition and down cutting of the rivers, leaving a series of strait terraces. As a result, the Pliocene rivers on the east side shrank into the small Kushui River while the ones on the west side enlarged into the current Yellow River, which cut down into western part of the Niushou Mountains and formed the Qingtong Gorge. The Pliocene deposition retreated northward into modern Yinchuan Basin.

\*\*\*\*\*

## **Fracture density as a controlling factor of erosion and exhumation over glacial-interglacial cycles: Insights from low-temperature thermochronology (AHe & OSL) and remote sensing, Granite Range, AK**

CHAMPAGNAC J.D.(1), VALLA P.(1), HERMAN F.(2), LOWICK S.(3), GURALNIK B.(1), FELLIN G.(1)

*(1) ETH, ZÜRICH, SWITZERLAND ; (2) UNIL, LAUSANNE, SWITZERLAND ; (3) UNIBE, BERN, SWITZERLAND*

The Granite Range (GR) in Alaska presents an ideal setting to study the climate-tectonics-erosion system: its W-part shows preserved glacial landscape, whereas its E-part presents a strong fluvial / hillslope imprint, and only a few relicts of glacial surfaces. However, low-temperature thermochronometry data (AHe) displays rather homogeneous, yet largely scattered (~15Ma±7Ma AHe ages) throughout the massif. The recent development of luminescence thermochronometry (OSL-T) and its very low closure temperature (0-60°C) opens a new spatial and temporal window for the study of latest stages of rock exhumation and thus to address potential topographic relief changes during the late Quaternary. We sampled 4 elevation profiles over an 80-km E-W transect. The 15 feldspar bedrock separates from surface dated exhibit good internal reproducibility. Apparent ages vary from ~250 ka in the western part of the range, towards younger ages of ~30 ka in the East. On the field, the eastern part appears to be highly fractured, with many, large, penetrative faults, associated with km-thick fault gouges and cataclasites. The westernmost part shows massive bedrock, with minor, localised faults. Remote-sensed fracture mapping confirms this: fracture density is much higher to the east, where hypsometric parameters display anomalies, and where high post-glacial incision (up to 600m) is observed. We provide here an impressive case study for climate-tectonic-erosion interactions through rock crushing effect, and document that half of the sediments coming out of the range come from the ~10% of the most fractured area, all other being equal. Also, we are supporting the notion of high rates of erosion correlated with intense glacial / periglacial activity, confirmed by thermochronological data. We also demonstrate the great potential of OSL-T in resolving topographic evolution and surface processes over 100-kyr timescales and high-frequency climate modulations (glacial-interglacial oscillations).

### Some remarks and additions to legend about neotectonics map

BALYAN H.

Yerevan State University, YEREVAN, ARMENIA

For the preparation of neotectonic map it is necessary to have the precise idea about the using in the legend the map with terms and nomenclatures which are characterized of neotectonical movement. For example: the term of raising. The raising: This term which gets the wide use in literature is imperfect. It includes the different meanings a) just orographic or morphologic, as an existing raise of the land surface, which is fixed by the statistic position of the relief forms of the certain generation. b) neotectonical process of the raising site, its kinematics. In this case not all raisings can be neotectonical raisings. Neotectonical movement gets its reflection in the relief forms e.u. in the statistical raisings with the wholly opposite signs of its kinematics. For example: the deep anticlinal valleys. More precise reflection of the quantitative marks of temp, time and absolute raising we can get in the case of anticlinal and epigenetic valley, where the theme about erosion in cisions precisely conform to the temp of raising. And those are available in Armenia and can serve authentic reference points for reception of an assessment for raising in case of absence of geology-phacial points (marine, lagoon deposits which exist in flora and fauna). In this case the term of raising in the neotectonical map (and in legends for map) should be put on the meaning of neotectonical kinematics of raising area that is an independent from its morphological reflection in relief. Differential isolation of temp of raising blocks, and structure gets its more precise and bright reflection in the process of integration of the map scale 1:20000 and larger. In this case the raising can be reflected with the izogypses in the absolute marks /metres/. It is possible to get the certain corrections in the legend of neotectonical map and the meaning of the morphologic and morphosculpture.

\*\*\*\*\*

### Neotectonics of Jerba (S. Tunisia): A pull-apart on a NW-SE right lateral transtensive fault zone

GHEHOUJI r.(1), DEFFONTAINES B.(2), ZETRINI H.(3), RABIA M.C.(4)

(1) Université paris est marne la vallée, CHAMPS SUR MARNE, FRANCE ; (2) universit? paris est marne la vall?e, CHAMPS SUR MARNE, FRANCE ; (3) CERTE borj cedria, TUNIS, TUNISIA ; (4) Université de la manouba, TUNIS, TUNISIA

What is the neotectonic of the Coastal Jeffara (southern Tunisia)? We herein study the input of numerous seismic profiles at depth, combined with geomorphometric drainage network analysis, photo-interpretations from the Digital Terrain Model (SRTM), detailed optical images (Landsat ETM+) and air photos, all confirmed by field works.

Helped by the results of previous researchers, and new evidences developed in this study, we propose below a new structural geodynamic Jeffara model, due to the continuous post lower cretaceous northward migration of northern African migration toward the Eurasian plates.

Available data were then integrated within a GIS (Geodatabase) where Jerba, Zarzis and Jorf appear to be part of a simple pull-apart model within a NW-SE right lateral transtensive major fault zone.

Our structural geologic and geomorphologic analyses prove the presence of NNW-SSE right lateral en-echelon tension gashes, NW-SE aligned salt diapirs, numerous folds offsets, en-echelon folds, and so-on... that are associated with this major right lateral NW-SE transtensive major coastal Jeffara fault zone that affect the Holocene and Villafranchian deposits.

These evidences confirm the fact that the active NW-SE Jeffara faults correspond to the tectonic accident, located in the south of the Tunisian extrusion, in favour of the eastern migration of the Sahel block toward the free Mediterranean sea boundary. Therefore this geodynamic movement explains the presence, offshore, of small elongated NW-SE, N-S and NE-SW petroleum transtensive basins and grabens.

To conclude, at the regional scale, the structural geomorphologic approach combined with both field work and reflexion seismic profiles analyses appear to be an excellent tool to prove and confirm the NW-SE right lateral transtensive fault zone that is interpreted as the southern branch of the eastward Sahel block extrusion of Central Tunisia due to the northward migration of African plate.

### **Drastic late Pleistocene-Holocene faceting of the continental shelf off Central Venezuela by eustatism and local active tectonics**

COLON S.(1), BECK C.(1), AUDEMARD F.(2), PADRON C.(3), DE BATIST M.(4)

(1) ISTERre UMR CNRS 5275 Grenoble University, LE BOURGET DU LAC, FRANCE ; (2) Venezuelan Foundation for Seismological Research FUNVISIS, CARACAS, VENEZUELA ; (3) Universidad Simon Bolivar, CARACAS, VENEZUELA ; (4) Renard Centre of Marine Geology, University of Gent, GENT, BELGIUM

The continental shelf north off Central Venezuelacomprisesthree physiographic provinces, from west to east: the Golfo Triste Platform, the Choroní Basin and the Guaira Platform. The Choroní Basin is a deep depression incised by submarine canyons prolonging the Mamo and Ocumare rivers mouths, named Mamo and Ocumare canyons, respectively. The Mamo River happens to be the longest and most powerful river in the Cordillera de la Costa, a coast range whose peaks are commonly over 2000 m high, which is bounded by the seismically active San Sebastián fault on its seaside. The Mamo and Ocumare canyons merge into a single north-trending canyon, probably running into the Bonaire basin. Apparently, these canyons seem to be related to turbiditic currents with greater flows during the Pleistocene wetter periods. Several authors have pointed out that these submarine canyons are partially or completely structurally controlled by major structures present in the north-central coastal range of Venezuela (e.g. San Sebastián and Tacagua faults). In particular, we have looked into the past with the help of high resolution seismic profiles acquired in 2007 by an international team (FUNVISIS in scientific collaboration with the Universities of Savoie–France-, Ghent –Belgium- and UDO –Venezuela-). Two regional unconformity-bounded seismic-stratigraphic units related with MIS 2 (Last Glacial Maximum) and MIS 6 have been identified and mapped throughout. The still visible and active Mamo and Ocumare canyons were carved during a sea-level lowstand, most probably during the MIS 2 stage. In addition, using a series of sedimentary features, subsidence model and the relative sea level history, we have reconstructed the shelf paleo-bathymetry for these lowstand stages. However, in the La Guaira platform, a major issue still to be solved is whether this shelf was sub-areal or sub-aquatic during lowstand–glacial- periods.

\*\*\*\*\*

### **The influence of tectonic movements upon river changes on the example of Lower Khazir river**

ELIAS Z.

*Institute of Geography and Spatial Management / Jagielloinan university, KRAKOW, POLAND*

Lower Khazir river sets a good example of river changes connected with tectonic movements. The aim of this paper is to address the three following questions: 1- How big of an impact does the river has in the process of anticline growth? 2-Where are the largest geomorphic changes along Khazir River course and how are they connected to the sinuosity of Maqlub and Ain Al-Safra and Makhmore anticlines?

In order to draw the dry gaps on the anticlines, analyzes of two and three dimensional images are included in this research. Growing anticline exerts an influence upon the latitudinal throw over of the river bed to the east. Soft rocks also play a role in the river morphology. The present gap (water gap) is shaped by the river flow after the drainage of old gap (dry gap) located on the limbs of the anticlines.

Morphology of the river changes along with an increase of sinuosity in the Maqlub and Ain Al-Safra anticlines. The distance of intense morphologic changes of the old gap reaches 2.5 km and 3.5 km in case of the water gap. Morphology of this river is more straightforward in the Makhmore anticline than the Maqlub and Ain Al-Safra anticlines. Considerable changes in the river's morphology continue in the Makhmore anticline through 11.5 km from old gap to the water gap.

Key words: dry gap, water gap, digital elevation model, Lower Khazir River.

### **Geological and geomorphological effects induced by the Emilia seismic swarm of May 2012 (northern Italy)**

CASTALDINI D.(1), DI MANNA P.(2), GUERRIERI L.(2), VITTORI E.(2), PICCARDI L.(3), BERLUSCONI A.(4), LIVIO F.(4), MICHETTI A.M.(4), COMERCI V.(2), TOSATTI G.(5)

(1) Dipartimento di Scienze Chimiche e Geologiche, Universite di Modena e Reggio Emilia, MODENA, ITALY ; (2) Istituto Superiore per la Protezione e la Ricerca Ambientale, ROMA, ITALY ; (3) CNR, Istituto di Geoscienze e Georisorse, FIRENZE, ITALY ; (4) Dipartimento di Scienza e Alta Tecnologia, Università Insubria, COMO, ITALY ; (5) Dipartimento di Scienza Chimiche e Geologiche, Università di Modena e Reggio Emilia, MODENA, ITALY

Since May 16<sup>th</sup> 2012, a seismic swarm has affected the central-southern sector of the Po Plain. A first main shock occurred on May 20 (M = 5.9; focal depth: 6.3 km; epicenter: N of Finale E.) and a second one on May 29 (M= 5.8; focal depth: 10.5 km; epicenter: about 12 km W of the first one). This seismic swarm has consisted of another five M>5 quakes and about 2,500 minor shocks till the end of November 2012. The subsurface is made up of marine and continental deposits overlying compressional northverging faulted folds of the Apennines ("Ferrara Folds") which caused the quakes.

The geomorphological setting is characterized by a complex drainage and ancient drainage pattern of the Rivers Po, Secchia, Panaro and Reno.

The most relevant effect caused by the two stronger earthquakes was the 10-15 cm uplift of the epicentral area detected by InSAR interferometry.

On the whole, more than 500 geological and geomorphological effects were recorded over an area of about 700 km<sup>2</sup>. The effects are mainly due to liquefaction with ejection of sand from ground fractures, sand-boils and wells. In some places the bottom of artificial canals showed uplifting, bulging and cracks and fractures and landslides were mapped on the banks. About 80% of the effects were induced by the May 20 main shock, while 20% of the effects were triggered by the second main quake. Many cases of liquefaction triggered by the first main quake were reactivated by the second one, with jets of water up to 1.50 m high. The material erupted reached in many cases a thickness of more than 30 cm and, inside some buildings, from pavement cracks it uplifted up to 1 m.

Hydrogeological anomalies, such as strong water-table fluctuations, water level variations in some tracts of Po and Secchia rivers, emission of hot water from ground cracks and water wells, were also recorded.

The co-seismic effects appear to be caused not only by the local stratigraphic characteristics but also by the network of abandoned riverbeds.

\*\*\*\*\*

### **Morphotectonic analysis and some geo-environmental implications of the Gai River basin, North-East India**

GOSWAMI U., BEZBARUAH D.  
*Dibrugarh University, DIBRUGARH, INDIA*

The Gai River basin in the North East India, extending from the hilly West Siang district of Arunachal Pradesh to the alluvial plains of Assam, encompasses an area of 863 km<sup>2</sup> out of which about 82% falls within Assam. It is a sixth order stream flowing along the mountainous course through the Siwaliks for 50 km, whereas its total main stream length is 133 km. The hilly catchment of the Gai River basin is confined within the frontal fold thrust belt of Arunachal Himalaya comprised of Siwalik Group of rocks of Mio-Pliocene age which were subsequently uplifted during the last phase of Himalayan orogeny. The Gai river basin has developed as a network of streams for draining the uplifted area. Therefore, morphology of the Gai River basin evolved contemporaneously with the last phase of Himalayan upheaval.

Drainage basin characteristics indicate the form-process relationship of morphological system and also the form-process relationship. Study of the basin characteristics like bifurcation ratio, basin elongation, drainage density, channel slope, relief ratio etc. of the Gai River indicates the influence of active tectonics on the form-process relationship. Furthermore, study of the morphotectonic indices like mountain front sinuosity, drainage basin asymmetry, valley floor width to height ratio, stream length gradient index of the basin indicates the prevalence of neo-tectonic movements. The neo-tectonic activity and the soft and friable nature of the Siwalik Group of rocks make the basin more prone to landslides leading to high sediment yield and aggraded river bed. As a result, carrying capacity of lower reaches of the river has decreased considerably making the channel more vulnerable to frequent channel migration and flood. A number of devastating floods have occurred in recent years, of which the flood of 15 August 2011 was caused by bursting of a landslide dam formed in mountainous part of the Gai River basin.

### **The earthquake of Van on 23 October 2011 and its geomorphological effects**

AKKOPRUE.(1), SENGUL A.(2), GURAY E.(3)

(1) University of Van-Turkey, VAN, TURKEY ; (2) University of Istanbul, ISTANBUL, TURKEY ; (3) Maps Engineer, VAN, TURKEY

In the Van Lake Basin, tectonic activity and the geological structure of region has a direct effect on topography. In this sense, as a result of continent- continent collision that occurred in middle Miocene, Eastern Anatolia region and Lake Van basin have a topographic height above average 2000m. Thickening and shortening of the crust as a consequence of the N-S compression forces, caused re-shaping the entire morphology. In this way, many new structural elements have re-appeared. One of these structural elements is the thrust faults which still maintain their activity. Earthquake, that occurred M=7.1 magnitude in Van at 13.41 local time on October 23, has left many morphological traces in the region. According to geological and seismological data, earthquake which occurred along approximately 40km long thrust fault affected a large area. Aftershocks still continue. The earthquake has an excessive impact on the surface. Displacements have been measured on the main fault up to 10cm on the surface. However, lateral spreading, big mass movements, creeps were marked in many areas. Soil liquefaction has been observed in water saturated lowland areas by effect of earthquake, and the morphological structures were also affected. The majority of these structures are sub-structures changing morphology rather than being surface rupture of earthquake. Approximately 80cm ruptures and splits occurred in vertical directions on surface. This is especially observed in water-saturated areas of Erciş, the biggest town of Van.

Besides, data were obtained with researches in about relationship between lake level changes and tectonic controls are examined comparatively with the data obtained after the earthquake. Morphological studies and DGPS measurements carried out in Van lake Basin and especially old lake terraces in Van and Erciş areas renewed in this study and changes on the vertical direction of region were tried to be determined. In this context, we tried to reveal changes after earthquake on topography.

\*\*\*\*\*

### **The Effect of Tectonics on Geomorphologic Evolution of Kalkım Basin (NW Turkey)**

EFE R., SOYKAN A., CUREBAL I., SONMEZ S.

Balikesir University, BALIKESIR, TURKEY

Geomorphologic indicators present important data in the identification of active tectonic areas. There is a close relationship between the age of geomorphologic units and tectonic movements. Tectonic movements were very effective in Biga Peninsula and generated important landforms in NW Turkey.

The current study investigates the effect of neo-tectonic movements in the geomorphologic formation and development of Kalkım Basin situated in the northwestern part of Turkey. Topography maps of 1/25000 scale were used in the study and digitization was completed with 10 m contour lines in ArcGIS Desktop Program. Contour curves identified in ArcMap program were transformed into a digital elevation model by utilizing 3D Analyst application program. Profiles and geological sections were developed with the help of this model. 3D model, profiles and sections helped in the identification and interpretation of tectonic and morphological units. Geological data was taken into consideration during interpretation and tectonic lines were specifically correlated with geomorphologic data.

The Basin forms a morphological unit along with Kalkım plain, hills, plateaus and the mountains surrounding it. Kalkım Basin was shaped by the tectonic, structural and morpho-climatic processes that started in Upper Oligocene and Lower Miocene and continued. These tectonic movements which were observed as faulting, uplifting and subsidence and fluvial processes shaped the area. Climate changes were effective in the landforms of Pliocene, Pleistocene and Holocene periods.

Tectonic movements effective in the area and N-S and E-W directional faulting have played an important role in the development of the Basin. As a result, depression has started in the basin and a graben was formed. Later, the impact of fluvial processes increased and the basin gained its current form. The graben is a tectonic based pull-apart depression stuck among mountains.

Key words: Turkey, Kalkım basin, tectonics, geomorphology

**Geomorphic development of an actively uplifting footwall: integration of short-term co-seismic deformation (InSAR) and river network evolution. Examples from L'Aquila earthquake (April 2009), Italy**

BERTI C.(1), PAZZAGLIA F.J.(1), RAMAGE J.M.(1), MICCADEI E.(2)

(1) Lehigh University, BETHLEHEM, PA, UNITED STATES ; (2) Università degli Studi "G. d'Annunzio", CHIETI, ITALY

Central Italy is a well known region of frequent extensional earthquakes focused along the topographic axis of the Apennines. The integrated effect of these earthquakes is recognized as an important, although poorly understood process in shaping the long term regional landscape evolution. The M. 6.3 L'Aquila earthquake of 06 April, 2009 ruptured a fault in a region of well-known constraining data including hanging wall continental basin Quaternary deposits, footwall stream networks with distinct knickpoints, a dense GPS network, and InSAR interferometry. Envisat and ALOS derived interferograms generated using ROI PAC show close spatial overlap of the InSAR-determined rupture and the Paganica fault, separating a deeply incised, uplifted carbonate footwall block and an actively subsiding Quaternary continental basin. We note, that the longitudinal profiles of streams in the footwall are marked by distinct knickpoints that do not correspond to known or obvious lithologic or structural controls. Rather, the elevation distribution of knickpoints, their distance from the Paganica Fault, and the magnitude of incision can be explained by a repeated history of deformation consistent with the co-seismic InSAR deformation pattern.

Knickpoints elevation is consistent with detachment-limited stream-power erosional retreat processes instigated by base level fall. The timing of the base level falls can be estimated assuming a model for knickpoint retreat rate and through correlation of knickpoints to lithostratigraphic packages of sediment found in the footwall block. Results of the modeling are consistent with periods of tectonic activity recognized in the area and suggest that the Paganica fault has a characteristic rupture geometry, but an unsteady behavior punctuated by periods of frequent activity interspersed with periods of relative quiescence that persist for several millennia.

\*\*\*\*\*

**The Pliocene basalt and the history of the modern Longchuanjiang River in Tengchong, SW China**

LIU F., ZHAO Y., YANG Z. Y.

*Institute of Geomechanics, Chinese Academy of Geological Sciences, BEIJING, CHINA*

River is a time-integrated product of landscape evolution. Thus its history documents changes of landscape. Geomorphic marker is an important precondition for decoding history of a river. However, significant uncertainties remain an outstanding research challenge for the history of a river, largely due to a lack of the age of a geomorphic marker. In our study area, the basalt in the Longchuanjiang River, as a geomorphic marker, offer an excellent opportunity to constrain the history of the river. The Longchuanjiang River is a tributary of the Irrawaddy River, one of the ten drainage systems originating from the Tibetan Plateau. We focused on the reach of the Longchuanjiang River in Tengchong, SW China. The river enters the late Pliocene basaltic area in its upper reach for tens of kilometers. It has carved its course and cut gorges on the scale of tens of meters through the basalt flow. The present river bed sits on the exposed basalt rock. The height of the basalt flow is almost the same on both sides of the river valley based on the RTK-GPS measurements. In addition, the present river flows through the early Pleistocene basalt in the middle reach of the Longchuanjiang River. From these observations above, we can infer the maximal history of the present Longchuanjiang River is not older than the late Pliocene.

### **Morphotectonic indicators of late Quaternary faulting in the Mercure River basin, southern Italy**

GIOIA D.(1), DANESE M.(1), LAZZARI M.(1), SCHIATTARELLA M.(2)

(1) *Consiglio Nazionale delle Ricerche - Istituto per i Beni Archeologici e Monumentali, TITO SCALO (POTENZA), ITALY*; (2) *Dipartimento di Scienze, Università della Basilicata, POTENZA, ITALY*

Morphometric analyses of both topography and drainage network are valuable tools to investigate the influence of Quaternary tectonics on landscape evolution. A detailed quantitative analysis of topography combined with the study of drainage pattern was performed in the Mercure basin (southern Italy), a mid-Pleistocene tectonic basin located to the north-western sector of the Pollino Ridge, southern Italy, and filled by a fluvio-lacustrine succession. The genesis and evolution of the endorheic depression have been commonly related to the reactivation with normal and oblique kinematics of a pre-existing, N120° trending strike-slip fault system. Basin and ranges have been studied by means of both traditional and innovative methodologies in the field of morphostructural analysis. We calculated statistical properties of landscape and estimated some geomorphic indices that reflect the interaction between erosional and tectonic processes. Studies on topographic attributes and morphometric indices were integrated with classical (*i.e.* field survey and photo-aerial interpretation) morphostructural analysis, focused on both relict and active landforms. Two orders of erosional surfaces, wineglass-shaped valleys, and fluvial knickpoints arrangements permitted us to recognize the amount of the recent uplift of the ridge bordering the basin in its northern sector and the effective response of the hydrographic networks to late Quaternary block-faulting. As a matter of fact, morphometric indices of drainage basins, drainage network pattern, and analysis of longitudinal river profiles suggest a strong influence of tectonics on landscape evolution. Morphotectonic markers such as fluvial elbows, right angle confluences, and anomalous bend of channels are generally investigated just in a qualitative way. We developed a GIS-aided methodological approach aimed to a quantitative approach, tested as a tool to individuate spatial distribution of faulting-related drainage network anomalies.

\*\*\*\*\*

### **Erosion-induced isostatic rebound triggers extension in Pyrenees: insights from numerical modeling**

GENTI M., CHÉRY J., CATTIN R., VERNANT P.

*Geosciences - UM2, MONTPELLIER, FRANCE*

Present day convergence rates across Western Alps and Pyrenees are very low ( $< 0.5$  mm/yr, e.g., Nocquet, 2012), whereas continuous GPS measurements as well as geomorphic observation indicate significant active uplift ( $\geq 1$  mm/yr) in the Alps. Previous studies (Champagnac et al., 2007; 2008) suggest that this uplift likely results from isostatic rebound due to erosion and deglaciation processes. These mountains are also underlined by moderate but frequent instrumental seismicity (0-15km depth). Available focal mechanisms show normal faulting in regions of moderate to high elevations, with an extension direction normal to the main ridge axis of these mountain ranges, and compression in the Western Alpine foreland (Sue et al., 2007, Larroque et al., 2009, Chevrot et al., 2011). This extensional strain pattern, associated to minor horizontal motion, is usually interpreted as the effect of a gravitational collapse (eg. England and Houseman, 1989). Previous studies have shown that there is a trade-off between gravitational collapse, erosion and mountain growth (Avouac and Burov, 1996). However, the impact of erosion on tectonics in low convergence mountain ranges is still poorly studied.

Following Vernant et al., (Geology, in press), we use a 2D finite element thermo-mechanical modeling, to assess the relationship between surface processes and the pattern of both extension and uplift across the Pyrenees. The present-day Pyrenean range has a deep crustal root related to the under-thrust Iberian crust and several large fault zones. The erosion-induced isostatic exhumation of this geological setting crust might have an impact on the regional strain regime. Here we quantify the impact of this structural heritage on the vertical and horizontal displacements associated to the distribution of the erosion rates across the Pyrenees.

### **Geomorphic evidence of active fold growth along the Ainos Thrust Fault (Cephalonia Island, Greece)**

TSODOULOS I.(1), GALLOUSI C.(2), KOUKOUVELAS I.(2)

(1) Department of Physics, University of Ioannina, IOANNINA, GREECE ; (2) Department of Geology, University of Patras, PATRAS, GREECE

We document the active fold growth of the southern segment of the Ainos Thrust Fault (ATF), in the Cephalonia Island, Greece, based on tectonic geomorphic analysis using several indices of active tectonics along with geomorphic criteria. The Cephalonia Island is located at the external edge of the Hellenic fold-and-thrust system, one of the most active seismic regions worldwide, characterized by the frequent occurrence of large magnitude earthquakes. The approximately NW-SE-trending ATF is one of the most prominent tectonic features of the island. The southernmost ~20 km of the fault, which is the focus of this work, exhibits up to ~1600 m of topographic relief.

Quantitative measurement of geomorphic indices such as the stream length-gradient index ( $S_L$ ), the mountain-front sinuosity ( $S_{mf}$ ), the valley floor width to valley height ratio ( $V_f$ ) and the hypsometric integral ( $H_i$ ), extracted from the DEM using standard GIS methods, were analyzed in order to identify the level of tectonic activity.

Several geomorphic criteria were employed in order to demonstrate the lateral propagation of the fault related fold. Drainage patterns of fold fore-limb, back-limb and of the nose ramp were analyzed in order to evaluate the drainage density and the degree of dissection of the surface. Two wind gaps of varying depth are preserved across the southeastern part of the fold. Topographic profiles along the crest of the fold indicate the decrease in elevation of the wind gaps as well as the elevation of the crest of the ridge. Back limb rotation measured by the dip of strata along the southernmost ~5 km of the fold, decreases from NW to SE, from ~38° to ~15°.

The combined geomorphic indices and geomorphic criteria suggest that the analyzed fault-related-fold is active and propagating laterally to a southeastern direction. Evaluation of the rate of lateral propagation needs to be established through chronology of the deposits or landforms being folded.

\*\*\*\*\*

### **Tectonic evolution of the Paleogene to Quaternary Rio Santana Graben in the Ribeira Belt, continental margin of Brazil**

GONTIJO-PASCUTTI A.(1), BEZERRA F.H.R.(2)

(1) UFRRJ UNIVERSIDADE FEDERAL RURAL DO RIO DE JANEIRO, RIO DE JANEIRO, BRAZIL ; (2) UFRN UNIVERSIDADE FEDERAL DO RIO GRANDE DO NORTE, NATAL, BRAZIL

Paleogene to Quaternary reactivation of basement shear zones led to the development of several grabens in the Ribeira Belt, continental margin of southeastern Brazil, along a 900 km long and 1,000 km wide area. We investigated one of these grabens, the Rio Santana Graben, which is located along the Arcadia – Areal shear zone in the State of Rio de Janeiro. This shear zone separates different Precambrian terrains and forms the largest Moho gradient in the region. We carried out a multidisciplinary investigation that included geological–geomorphological mapping, controlled-source audiofrequency magnetotelluric and resistivity surveys, and luminescence chronology. Our study indicates that the graben is limited on both sides by NE-trending subvertical normal faults, which are related to the reactivation of the Arcadia-Areal shear zone. This graben is 15 km long and 2 km wide and consists of two main depocenters. The depocenters are linked by a relay ramp and have a left-bend, en echelon geometry. A layer of Quaternary sediments occurs at depths of 1–30 m and several layers of Paleogene–Neogene sediments occur at depths of 30 to 300 m. These sediments consist of Paleogene alluvial deposits, Quaternary alluvial deposits, and Quaternary colluvial deposits. The Quaternary sediments yielded luminescence ages at 49,200 ± 6200 yr, 17,500 ± 2100 yr, and 13,000 ± 1600 yr. The age of first sediments is constrained by bauxite weathering profiles, which has an estimated Paleogene age according to stratigraphic correlations. The Rio Santana Graben presents evidence of Cenozoic faulting. The present-day offset between the central plain in the graben and the adjacent blocks in the lateral horsts is roughly 500 m. NE-trending faults control river incision and triangular facets occur at the border of the graben. Small and narrow waterheads are offset by the facets. These river incision and fault scarps are consistent with Quaternary faulting events in the graben.

**Neotectonic activity hypothesis in the SE Brazilian highlands supported by morphometric and statistical analysis: an initial approach**

*LAVARINI C., MAGALHÃES JR A.P., OLIVEIRA F.S.*

*Universidade Federal de Minas Gerais, BELO HORIZONTE, BRAZIL*

Several researchers have pointed out that the Quadrilátero Ferrífero region, in the SE Brazilian Highlands, has had a Cenozoic morphogenesis controlled by uplift of regional scale with interference of faults located at the contacts of morphostructural and lithological compartments. These compartments are strongly adapted to the Precambrian lithostructural domains which have controlled the geomorphological evolution of different parts of the valleys. In order to evaluate and testing the neotectonic activity hypothesis we carried out an initial approach research based on the Stream-Gradient Index associated to Transverse Topographic Symmetry Factor, Basin Asymmetric Factor and statistical analysis in the Ribeirão Mata Porcos Watershed. This watershed might be considered as a representative study area of Quadrilátero Ferrífero's geomorphological complexity, comprising the main regional lithologies and a typical geosyncline structure. The results indicated that the neotectonic activity hypothesis cannot be rejected as well as supported the existence of many drainage patterns probably associated to different lithostructural compartments. Thus, the Stream-Gradient Index exhibited second and third order anomalies in 72% and 11% of fluvial reaches, respectively, while only 16% did not achieved the threshold value to be considered an anomaly. The Transverse Topographic Symmetry Factor evidenced that the tectonic tilting was not equal in the whole watershed but much more effective in the Lower and Middle-Lower Course of Ribeirão Mata Porcos, according to the significance levels of statistical analysis. Summarizing, although we are not able to exclude other external influences such as the lithology, the location, values and statistical significance levels of morphometric patterns and their relation to Precambrian faults are strong evidences for supporting the regional neotectonic activity hypothesis.

\*\*\*\*\*

**Neo-Tectonics and Landform Assemblage in the Middle Valley of Ramganga River (W), Kumaun Lesser Himalaya, India**

*TRIPATHI M.*

*KUMAUN UNIVERSITY, NAINITAL, NAINITAL, INDIA*

The Quaternary geomorphological study has been undertaken in the middle part of Ramganga (W) valley covering an area of ~200 Km<sup>2</sup> (study area 94.8 Km<sup>2</sup>) from Chaukhutia to Bhikiyasain in the Kumaun Lesser Himalayan terrain of Almora district, Uttarakhand to study how the structure controls the landforms and to understand the various geomorphic features of the study area where the fluvial erosion is dominant, as this region offers a variety of structural landforms modified by fluvial action. Knowledge based semi-automated method has been carried out to define geomorphological units and mapping of major geomorphic features in the form of landforms and their analysis in conjunction with structures. The study is intended to mainly understand the role of tectonic movements on morphological variations and landscape development along the middle Ramganga (W) valley. The neo-tectonic movements have affected various Quaternary landforms in the Ramganga river basin. Signatures of neo-tectonic movements in the area are documented in the form of; sharp bends, elbow turning, narrow and straight course of the Ramganga (W) River etc. Indirect evidence of recent epirogenic movements is available in the area. The presence of different levels of river terraces and break in slopes along the Ramganga valley is indicative of lowering of base level of erosion. The basal thrusts of Crystalline Nappes as well as Transverse Faults of the region are neo-tectonically active.

Considering the geomorphology, constituent materials, movements (neo-tectonic) and morphometric analysis it has been inferred that the landscape of middle Ramganga valley is dynamic and complex with geomorphic thresholds resulting from the progressive change of landscape component as well as complex response of drainage systems.

Keywords: Himalaya, Geomorphology, Neo-tectonics, Structural control, Landforms.

### Using detrital thermochronologic and cosmogenic data to understand the evolution of modern Himalayan megafans

ABRAHAMI R.(1), HUYGHE P.(1), VAN DER BEEK P.(1), CARCAILLET J.(1), CHAKRABORTY T.(2)

(1) Institut des sciences de la Terre, Université Joseph Fourier - CNRS, SAINT-MARTIN D'HÈRES, FRANCE ;

(2) Geological Studies Unit, Indian Statistical Institute, KOLKATA, INDIA

Megafans are very large (10's to 100's of km<sup>2</sup>) alluvial accumulations deposited by laterally mobile river systems and are common in several foreland basins across the globe. They are located at the topographic front of large mountain belts and are postulated to be common in areas subjected to marked seasonal rainfall such as the Himalaya. Thus their recognition in the ancient rock record could denote a drainage system emanating from a high mountain belt and monsoonal climate in the area (Horton and Decelles 2001, Leier et al. 2005). Several megafans are present in the Ganga plain, associated with rivers draining vast catchments of the central Himalaya. Of these, the two easternmost ones are the Kosi and the Tista megafans. While the Kosi megafan is currently still aggrading (Chakraborty, 2010), the Tista megafan located 150 km further east is presently incised about 30 meters (Chakraborty & Ghosh, 2010). Many questions arise from the comparison of their catchment area (size and elevation), their sedimentary characteristics (mean grain size) and their recent evolution. We combine several methods to answer these questions and to understand the tectonic and climatic parameters that impose the major controls on the development of modern Himalayan megafans. Cosmogenic isotopes (<sup>10</sup>Be, <sup>26</sup>Al) are used to date the abandonment of the three different lobes of the Tista megafan and determine both present-day and paleo-erosion rates averaged over the source area. These data are combined with existing and new <sup>14</sup>C and OSL ages of the deposits in order to compare erosional and depositional fluxes through time. To constrain long-term exhumation and erosion rates in the source area, detrital and in-situ thermochronological studies (using the Apatite Fission-Track system) are used. In addition, isotope geochemistry ( $\epsilon_{Nd}$  and <sup>87</sup>Sr/<sup>86</sup>Sr) from the Tista megafan deposits provides information about sediment provenance through time and its variation in response to climatic conditions.

\*\*\*\*\*

### The application of the slope x length index at the riacho grande watershed, northeast of Brazil

BARROS A.C.M., TAVARES B.A.C., MONTEIRO K.A., CORRÊA A.C.B.

Universidade Federal de Pernambuco, RECIFE, BRAZIL

The geomorphological analysis based on the study of watersheds can reveal physical indicators which organise the landscape caused by the watercourse's capacity of adjustment, registering geomorphological phenomena. The analyses of Slope x Length Index provide data that allow the identification of knickpoints along the longitudinal profiles, due to its sensitivity towards slope changes, which might be related to possible recent crustal deformations. Its contribution lies in the identification of areas with abnormal features in the longitudinal profile of the river, permitting to identify and normalise these amounts in the gradient of the longitudinal profile. The Riacho Grande's watershed is located in the province of Borborema, in a relief classically designated a platform one. The structural context is associated to the "median shear corridor", featured by faulting and shear zones from the Meso and Neoproterozoic. Anomalies of first order with 13,9 and 11,9 were found, as well as anomalies of second order, standing out the ones with 9,8 and 9,3 in the lower third of Riacho Grande. The SL analysis together with the structural map data and *in loco* observations enabled to observe knickpoints marked by lithological discontinuities, these ones producing a level difference less steep. Also it was possible to find linear segments with rocks of the substrate, with striae filled with supergene material (oxy-hydroxides of Fe and Mg). The greatest index is found in a Contractual Shear Zones context, where it was observed the presence of faulted quartz veins and scaling of the substrate with the occurrence of striae along some likely fault planes, which implies the reactivation of these ancient shear zones, indicating a brittle tectonism of the ductile shear zones. Therefore, these structural controls have been acting as the main engine in the morphotectonic dynamic of the area.

### **Drainage rearrangement and sediment production in response to uplift of the Andean Eastern Cordillera, NW Argentina**

HARBOR D.(1), RAHL J.(1), BOVAY A.C.(1), GALLI C.(2), SBERNA D.(1), HARTMAN R.(1)

(1) Washington & Lee University, LEXINGTON, VIRGINIA, UNITED STATES ; (2) Universidad Nacional de Jujuy, SAN SALVADOR DE JUJUY, ARGENTINA

Dynamic erosion of the Eastern Cordillera (EC) in Northwest Argentina supplies a rapidly growing sediment load to the foreland. Divide migration, knickpoint retreat, capture, and drainage reversal undercut a low-slope, high elevation Puna-level surface to create valleys with up to 2.5 km relief. The foreland basin sedimentary record suggests that vigorous erosion of the EC basement began ~ 4 Ma with the arrival of cobble conglomerates, whereas a cosmogenic burial date from the base of a valley fill implies that the deeply incised, reversed drainage in the headwaters of the Río Iruya was already established by 1.3 Ma. Sediment from the deep incision, headward erosion and capture caused a complex response leading to a valley filling episode lasting until 200 ka. Removal of the valley fill and subsequent bedrock incision occurs today at rates exceeding 1 mm/a. Modern cut/fill cycles reflect the removal of the valley fill and deepening of the valleys. Cutting of epigenetic gorges and bedrock reaches demonstrates that the stream power is sufficient to promote valley deepening, but is locally insufficient to remove the sediment supplied by oversteepened tributaries. Likewise, propagation of > 500 m knickpoints into the headwaters of the Río Nazareno induces valley aggradation downstream of gorges cut into low-relief uplands. Current and former fluvial systems parallel to the strike of the Eastern Cordillera are cut by deep, modern transverse drainage as the basin propagates headward toward the Puna. The modern Río Iruya transports the highest sediment load in the region, which is even greater than geologic rates determined from the valley filling and cutting episode. The response in this basin illustrates the positive feedback in response to Neogene uplift that is capable of producing increasingly coarse and voluminous sediment for piggyback basins and megafans of the foreland to the east.

\*\*\*\*\*

### **Strutural controls landscape in the south of Rio de Janeiro (Brazil): Morphotectonics evidences**

SILVA S.L.S., SILVA T.M.

UFRJ, RIO DE JANEIRO, BRAZIL

The southern state of Rio de Janeiro characterized by steep features arranged parallel to general direction of the shoreline (generally oriented to E-W), corresponds to stretch where the Serra do Mar is closest to the coast, resulting in an abrupt transitional forms between lowered and very soft sedimentary coastal and/or river plains, with extremely high slopes, this fact associated with high rainfall sets a high energy environment, emphasizing the conditions of environmental fragility and occurrence of dense drainage network characterized by numerous basins that strongly dissect the escarpment mountainous and favor the triggering of various erosive processes. Retaking its geological and geomorphological evolution (GONTIJO, 1999, SANTOS 1999; HIRUMA *et al.* 2001) we can note that orientation, clearly marked topography, is directly associated with controlling geological structures, and its evolutionary history associated with the formation of a System of Rifts the Serra do Mar, described as a compensation model isostatic between the continental and oceanic (SILVA, 2012). Considering the strong geological substrate influence on water flows orientation, the identification of lineaments drainage is essential to understanding structural control on drainage systems and on relief morphology. Thus, we propose further discussion about relief structural orientation, extracted from drainage segments, and morphotectonics features, identified from satellite imagery (Geo Eye 2011) interpreted at GIS - System Geographic Information (ArcView 9.0), these morphotectonics features have been identified as: ridge alignments, spurs ridges, triangular facets or shutter ridges. It is expected indicating possible areas fault reactivation, considered potentially more unstable, however, such information should be evaluated in combination with data about seismicity of southeastern Brazil, where great magnitude events are commonly associated with reactivation of old zones of weakness.

## Geomorphometric Insights into Tectonically Active Intraplate Gavilgarh Fault Zone, Central India

GHATAK S.(1), GHATAK M.(2)

(1) Geological Survey of India, NEW DELHI, INDIA ; (2) Saarc Disaster Management Centre, NEW DELHI, INDIA

The crescent shaped Purna basin located to the south of Satpura foothills in Central Indian Tectonic Zone (CITZ) is a tectonic half graben, bound to its northern margin by regional scale ENE-WSW trending Gavilgarh Fault Zone (GFZ) and by Ajanta-Buldana plateau to its south. In order to assess the tectonic geomorphology, tectonic activity and consequent sedimentation in this basin along the 230km stretch of GFZ, morphometric analysis and data integration in GIS have been carried out and validated with field data. Digital terrain model (SRTM, 90m) was processed to analyze the elevation, slope and aspect data for characterization of morphotectonic features and alluvial fans of Purna basin. Mountain Front Sinuosity (Smf) of 165 mountain front segments and Stream Length Gradient (SL) index of Purna River and its transverse tributaries derived from topobase data of 1:50K scale were analyzed to identify the relative rates of uplift along the fault zone. The elevation pixel distribution shows GFZ is marked by a salient mountain front. Surface breaking fault segments are aligned at higher elevations in the east and the blind faults are disposed at lower elevations in the west. Slope of 4° in the east and 2° in the west with uniform southerly aspect define this fault zone. Smf values range between 1.0 and 3.5 while SL index varies between 0 & 950. The activity classes defined by Smf and SL values match well with each other to underline the stretches of this fault zone that have experienced relatively higher rates of uplift in Quaternary times. The study helps in characterizing the nature and pattern of sediment flux controlled by foothill Gavilgarh fault, Purna North Fault (PNF) and younger transverse faults to the south of intraplate GFZ. Corroborating uplift rates with sediment architecture and depth distribution of the alluvium along the fault zone, an overall low tectonic subsidence and creation of maximum accommodation space at the central part of PNF are conceived.

\*\*\*\*\*

## Tracking tectonics in relief in selected model areas in the Bükk Mountains, NE Hungary

MCINTOSH R., KOZÁK M.

Department of Mineralogy and Geology, University of Debrecen, DEBRECEN, HUNGARY

Who would be not interested in how the landscape we see in a mountain was formed? Why the peaks are there where they are, why ridges have the form we see and what made the valleys run in the (sometimes curious) direction they do?

The authors carried out structural geological analyses in an area composed of a relatively diverse geology with Triassic carbonates, Triassic and Jurassic siliciclastic sediments and Triassic igneous rocks. Structural elements of both brittle and ductile deformations have been identified and measured in the form of frontal thrusts, transverse (tension) joints, conjugated lithoclasts, cleavage planes, fold limbs and fold axes. Based on the results, the orientation of two major stress fields acting in several phases (mostly in the Cretaceous) have been identified as responsible for the production of the major structural elements.

Observing the interesting orientation of valleys and the appearance of peculiar landforms both in field and on topographic maps / satellite images made the authors curious to find their explanation.

The orientation of valleys was correlated to the orientation of the prevailing brittle structural elements in selected areas in the Bükk Mountains. Even smaller valley sections were correlated to joint directions. Correlation between the directions of ridges and structural elements was also found. Strong correlation between the morphological and structural features was detected even underground as the direction of the passages of caves also matched the direction of brittle structural elements.

Appearance of unusual relief forms could be explained by the occurrence of special structural features produced by the interaction of the two dominant stress fields, i.e. by special superposed structural elements.

Based on the results, morphology may prove to be a useful tool in detailed structural analyses in certain areas.

**Geomorphologic analyses of coastal Uplift coupling the marine terraces and the drainage pattern : the case of the Sahel ridge, Algeria**

AUTHEMAYOU C.(1), PEDOJA K.(2), HEDDAR A.(3), YELLES K.(3), DJELLIT H.(3), DEVERCHERE J.(4), BOUDIAF A.(3)

(1) LDO UMR 6538 IUEM Universit\_ Brest, PLOUZANE, FRANCE ; (2) MC2 Université Caen, CAEN, FRANCE ; (3) CRAAG, ALGER, ALGERIA ; (4) LDO UMR 6538 IUEM Universit? Brest, PLOUZANE, FRANCE

The Algerian Cenozoic passive margin is presently reactivated in compression along the plate boundary between Africa and Europe producing the uplift of the coast. The uplift rate is moderate that implies to use several methods to document the coastal landscape evolution. We chose to couple quantitative geomorphologic analyses of the drainage pattern with the analysis of marine terraces. The coast selected for the study runs along the NE-trending Sahel ridge whose emersion is associated with fault-related folding. We proceeded to a detailed mapping of Quaternary marine terraces using field data and DEM analyses. The lower terraces were dated to estimate uplift rate. Then, we sampled 148 alluvial basins to calculate geomorphic parameters used as indicators of stages in landscape evolution. The results of the two methods are in agreement showing a spatial gradient of deformation inversely correlated with the gradient of basin maturity.

\*\*\*\*\*

**Miocene Tectono-geomorphic evolution of the eastern Tibetan plateau and the course change of the Yangtze River**

YANG Z.(1), LIN A.(2)

(1) Institute of Geomechanics, Chinese Academy of Geological Sciences, BEIJING, CHINA ; (2) Division of Earth and Planetary Sciences, Kyoto University, KYOTO, JAPAN

The major rivers of the eastern Tibetan Plateau have attracted considerable attention due to the topographic and morphologic features of peculiar drainage systems. The major river courses, including the Yangtze River, the Lanchangjiang and Nujiang, developed in the southeastern margin of the Tibetan Plateau provide an interesting place to test the link between the geometric and fluvial patterns of drainage system and the uplift of the Tibetan Plateau.

The erosion sedimentary facies (e.g. alluvial, fluvio-lacustrine sedimentation) and regional tectonics in the large-scale drainage basins of southwest China are analyzed, which provide some key evidences to demonstrate why the Lanchangjiang and Nujiang flow southward into the Indian Ocean along the eastern margin of the Tibetan Plateau, however, the Yangtze river flows south-southeastward to northeast-eastward with a sharp right-angular bend in the Jianchuan-Dali area of Yunnan province.

### **Morphotectonic study of the north Evia Island, Central Greece**

VALKANOY K.(1), KARYMBALIS E.(1), PAPANASTASSIOU D.(2), CHALKIAS C.(1), GAKI PAPANASTASSIOU K.(3)

(1) *Department of Geography, Harokopio University, ATHENS, GREECE* ; (2) *Institute of Geodynamics, National Observatory of Athens, ATHENS, GREECE* ; (3) *Department of Geography-Climatology, Faculty of Geology & Geoenvironment, National Kapodistrian University of Athens, ATHENS, GREECE*

In tectonically active areas drainage systems are often controlled by the type, geometry, and recent activity of regional and local faults.

The aim of this study is to investigate the contribution of neotectonic processes in the development of the fluvial landscape in North Evia Island, in Central Greece. For this purpose various quantitative geomorphological indices of the drainage networks and associated basins like bifurcation ratio, basin area, hypsometric curve, basin slope, Melton's ruggedness number, basin circularity, asymmetry factor were estimated using a DEM derived from topographic maps at 1:50,000 scale with 20m contours. Furthermore, the longitudinal profiles of the drainage networks' main channels were drawn and analyzed while field qualitative observations and geomorphological mapping were also performed.

Quantitative analysis and field observations showed that the development of the present drainage systems of the study area has been influenced by the fault tectonism of the two NW-SE trending offshore active normal fault systems of the North Evoikos Gulf (Kandili fault) and the Aegean Sea (Dirfys fault) respectively.

The north part of the Evia island demonstrates a contrast between footwall- and hangingwall- sourced drainage. In the northwest part of the island the steep, short and small drainage basins of the footwall of the North Evoikos Gulf coastal fault flow southwest, whilst a large drainage basin eroded into Neogene sediments dominates the NE-facing backtilted dip slopes. A 20km wide zone in the central part of the island where fault polarity reverses also shows a complete reversal of drainage basin type, with the footwall drainage of the Aegean fault flowing towards the north or northeast, and the large dip slope drainages flowing towards the SW.

\*\*\*\*\*

### **Proposition of a morphotectonic subdivision of Sepetiba's Bay (Guanabara Graben, Rio de Janeiro, Brazil) based upon MDT of nautical charts and high resolution seismic profiles**

SAMPAIO A.(1), GONTIJO-PASCUTTI A.(1), MOURA J.R.(2)

(1) *UFRRJ - Universidade Federal Rural do Rio de Janeiro, RIO DE JANEIRO, BRAZIL* ; (2) *UFRJ - Universidade Federal do Rio de Janeiro, RIO DE JANEIRO, BRAZIL*

The combined use of nautical charts as a historical series projected in MDT and the interpretation of high resolution seismic profiles allowed the understanding of the recent evolution of Sepetiba's Bay, revealing structural lineaments that conditioned the bottom shape and the contour of the bay, evidencing the control of ancient axis over present sedimentary processes and suggesting morphotectonic compartments.

The charts highlighted the main morphosculptural lineaments and the evolution of the erosive processes at the Marambaia's barrier island (an east-west feature at south border which is an extension E-W lineament that defines the center and south sector of Rio de Janeiro coast). These lineaments matched with deep structures revealed by the seismic profiles.

At the north border (continental face), the silting up processes are related to the increased flow of sediments. Nevertheless, the NW-SE coastal line direction is related to a significant subsurface shift with the same axis suggesting features of Quaternary period activity.

The Sepetiba Bay is part of the western sector of the Guanabara Graben (a Mesozoic-Cenozoic structure), named Sub-Graben Guandu-Sepetiba, characterizing its submerged segment. In the regional geology predominate Migmatites truncated by shear zones (NE and ENE), dikes and tertiary alkaline. Neotectonics reactivations are identified in faults with NE, NE, NW, SW and EW directions, normal character, oblique and directional, high and medium deep, controlling the relief forms, drainage and erosional and sedimentation areas. There are also identified deformations into Cenozoic deposits.

Although the seismic studies didn't allow the crystalline basement rock complete visualization in the majority of the profiles, the pre-holocene subsurface stratum drainage axis exerts a clear control on the outline and bottom morphology with many recent features suggesting related tectonic period activity.

### Neotectonic control on evolution of quaternary lake systems in southeastern Brazil

MELLO C.(1), SILVA C.G.(2), METELO C.M.S.(3), HATUSHIKA R.S.(3), SUGUIO K.(4)

(1) UNIVERSIDADE FEDERAL DO RIO DE JANEIRO, RIO DE JANEIRO, BRAZIL ; (2) UNIVERSIDADE FEDERAL FLUMINENSE, NITEROI, RJ, BRAZIL ; (3) PETROBRAS, RIO DE JANEIRO, BRAZIL ; (4) UNIVERSIDADE DE SÃO PAULO, SÃO PAULO, BRAZIL

The present study includes geomorphologic, structural and seismic stratigraphic analysis in order to discuss neotectonic influences on evolution of two barred lake systems in the Doce River Basin, one of the most important fluvial basins at Southeastern Brazil Atlantic margin. One of the studied lake systems is located at the Middle Doce River valley and the other is located very near the river mouth. Previous studies of these lake systems have respectively considered paleoclimatic controls and Quaternary relative sea level changes to explain their evolutions. Stratigraphic analysis confirm the beginning of the lacustrine sedimentation in early Holocene, simultaneously with a very important regional alluvial sedimentation that influenced the damming of the lakes. The lake morphology is controlled by a NW-oriented structural trend. A NE-oriented trend controls the alignment of the lake mouths. Two sets of brittle tectonic structures (joints and faults) affect the Cenozoic deposits in the two studied areas: 1) NW-SE normal faults and WNW-ESE to ENE-WSW transtensive faults are related to a regional Pleistocene-Holocene E-W dextral transcurrent regime; 2) NE-SW to ENE-WSW normal faults are related to a regional Holocene NW-SE distensive regime. The first set of neotectonic structures controls the orientation of the lakes. The second set has a strong correlation to the alignment of the lacustrine mouths and is related to expressive disruptions in lake bottoms. As seismic profiles show, NE-SW to ENE-WSW normal faults also affect Holocene alluvial deposits located at the lake dams and, thus, is supposed that the Holocene NW-SE distensive regime controls the evolution of the Doce River Basin lake systems.

\*\*\*\*\*

### Late Quaternary faulting on the Sudetic Marginal Fault in intraplate Bohemian Massif (Central Europe)

STEPANCIKOVA P.(1), NYVLT D.(2), ROCKWELL T.(3), HARTVICH F.(1), HOK J.(4), TABORIK P.(5)

(1) Institute of Rock Structure and Mechanics, Czech Academy of Sciences, PRAGUE 8, CZECH REPUBLIC ; (2) Czech Geological Survey, Brno branch, BRNO, CZECH REPUBLIC ; (3) Geological Sciences, San Diego State University, SAN DIEGO, UNITED STATES ; (4) Faculty of Natural Sciences, Comenius University in Bratislava, BRATISLAVA, SLOVAKIA ; (5) Faculty of Science, Charles University on Prague, PRAGUE 2, CZECH REPUBLIC

The Sudetic Marginal Fault (SMF) forms a part of the north-eastern limit of the Bohemian Massif (central Europe) and controls the pronounced mountain front of the Sudetic Mountains for a length of 130 km. As the SMF does not show present-day seismicity and only small to moderate historic earthquakes (I=4-7 MSK), paleoseismic search for larger prehistoric earthquakes responsible for the origin of the mountain front was initiated.

Ten fault-crossing trenches were excavated at the SMF at Bila Voda (Czech Republic) to study the fault activity. The trenches revealed a subvertical fault zone (striking 135-150°/75°NE) with a flower structure, suggesting strike-slip motion. The SMF juxtaposed deposits overlying warped Miocene sediments on the downthrown hanging-wall. The colluvial deposits near the fault show characteristics of fault-derived colluvial wedges. The alluvial deposits show a fan-like geometry. Six fault-parallel trenches were excavated to find a source and piercing points of the alluvial fan deposits, and to specify the geometry of the fan cut by the fault. Trenching was accompanied by geophysical survey (electrical resistivity tomography, GPR) to catch continuation of the fault trace and sedimentary bodies. The fan apex appeared to be offset about 60 m left laterally from the only source drainage.

The results completed by OSL and radiocarbon dating show that during Late Pleistocene, at least 4 to 5 large morphogenic earthquakes occurred at the SMF, along with at least one during Holocene (?). Left lateral horizontal motion with 60 m offset of displacement in as little as the past 25 ka yields an average slip rate of 2.4 mm-yr. However, with little or no Holocene displacement, this may imply that most of this displacement occurred at higher rate in the late Pleistocene. This suggests that ice loading may have been a factor in accelerating the slip rate, as our trench site lies less than 100 km from the ice front during the last Weichselian glaciation.

### **Geomorphology along Major Continental Faults: Slip rate constraint from climatic fluctuations**

FERRY M.(1), AKSOY E.(2), MEGHRAOUI M.(3)

(1) Equipe Risques, Geosciences Montpellier, MONTPELLIER,, FRANCE ; (2) Dept of Engineering, University of Mugla, MUGLA, TURKEY ; (3) EOST - Institut de Physique du Globe, STRASBOURG, FRANCE

We construct the slip history for the DSF and NAF based on the interaction between stream offsets along faults and alluvial and lacustrine deposits. Our analysis focuses on the geomorphology of active faults and paleoclimate history of the Eastern Mediterranean for the last 140 kyr with an emphasis on Intense Precipitation Episodes (IPEs) likely to have triggered systematic stream gully erosion and alluvial fan aggradation. IPEs are documented by the occurrence of sapropel layers, high lake stands and significant changes in vegetation and dated by multiproxy approaches. The 45-km-long co-seismic 1912 surface ruptures and related slip along the Ganos segment of NAF have been investigated to document cumulative right-lateral displacements. The classification of stream offsets at 69 localities and correlations with climatic events deduced from Black Sea sea level curves reveal the correlation between consecutive 5 cumulative slip groups (from 70 to 300 m) and subsequent sea level rise periods at 4 ka, 10.2 ka, 12.5 ka, 14.5 ka and 17.5 ka BP. Slip rate estimations yield a constant slip rate of 17.9 mm/a for the last 20.000 years. Along and 120-km-long Jordan Valley segment of the DSF the isotopic dating of six paleoclimatic events yields a precise chronology for the onset of six generations of gully incisions at 47.5 ka, 37.5 ka, 13 ka, 9 ka, 7 ka, and 5 ka BP. The cumulative slip of 20 dated incisions along the DSF consistently fall into six distinct classes yielding an average constant slip rate of 4.7 to 5.1 mm/a for the last 47.5 ka. These estimates of long-term fault slip rate are consistent with the 16 – 18 mm/a and 4.5 – 5.5 mm/a from paleoseismology and with the 22 – 26 mm/a and 4 – 5 mm/a from GPS velocities, for the NAF and DSF, respectively. The timing of cumulative offsets also reveals slip rate variations critical to our understanding of the slip deficit and seismic cycle along major continental faults.

\*\*\*\*\*

### **Morphostructural analysis of a subarea of Haiti, struck by the 2010 Earthquake, seated along the the Enriquillo-Plantain Garden Fault**

KANAKAKI S.(1), CAMIZ S.(2), POSCOLIERI M.(3), PARCHARIDS I.(1)

(1) Dept. of Geography, Harokopio University of Athens, ATHENS, GREECE ; (2) Dept. of Mathematics, Sapienza University of Rome, ROME, ITALY ; (3) CNR - Institute of Acoustics and Sensor O.M. Corbino, Rome, ROME, ITALY

A landscape may be characterized by the relief representing its major component, while significant changes on its shape are often determined by the tectonic activity.

The main purpose of this study is to define possible relationships between morphological information, collected by analyzing satellite data and classifying terrain units on the basis of a DEM, and structural features gathered considering the geological and structural setting of the study area.

As test site was chosen the Haiti area struck by the strong earthquake occurred on January 12th 2010. The epicenter was located few kilometers away, in SSW direction, from the capital Port-au-Prince that is crossed by the major Enriquillo-Plantain Garden Fault. The earthquake caused considerable damages in buildings and many casualties.

In this study, ASTER multispectral images covering the broader area as well a subset of a ASTER GDEM tile were used to investigate the morphostructural pattern along the segment of Enriquillo-Plantain Garden Fault, where the Earthquake epicenter was located. The area is characterized by a system of two rivers Froide and Momanche whose flows are split up by sectors of the Enriquillo-Plantain Garden Fault.

The methodological approach for the morphometric classification is based on statistical multidimensional analysis of local elevation gradients, extracted considering each pixel of the DEM and its nearest neighbours.

The spectral data are, instead, represented by an ASTER scene, acquired on January 21th 2010, which exhibits visible, near-infrared (VNIR) and thermal bands (TIR), and is cloud free. The VNIR bands were transformed by applying the Principal Components Analysis (PCA); then, the first component, where the morphology is well displayed, was filtered using a high pass kernel in order to enhance the high frequency information.

**Cosmogenic CL-36 dating of alluvial fans: implications for the late quaternary slip rates of the Ecemiş fault in Turkey**

SARIKAYA M.(1), YILDIRIM C.(2), CİNER A.(3)

*(1) Fatih University, Department of Geography, BUYUKCEKMECE-ISTANBUL, TURKEY ; (2) Istanbul Technical University, Eurasia Institute of Earth Sciences, MASLAK-ISTANBUL, TURKEY ; (3) Hacettepe University, Geological Engineering Department, BEYTEPE-ANKARA, TURKEY*

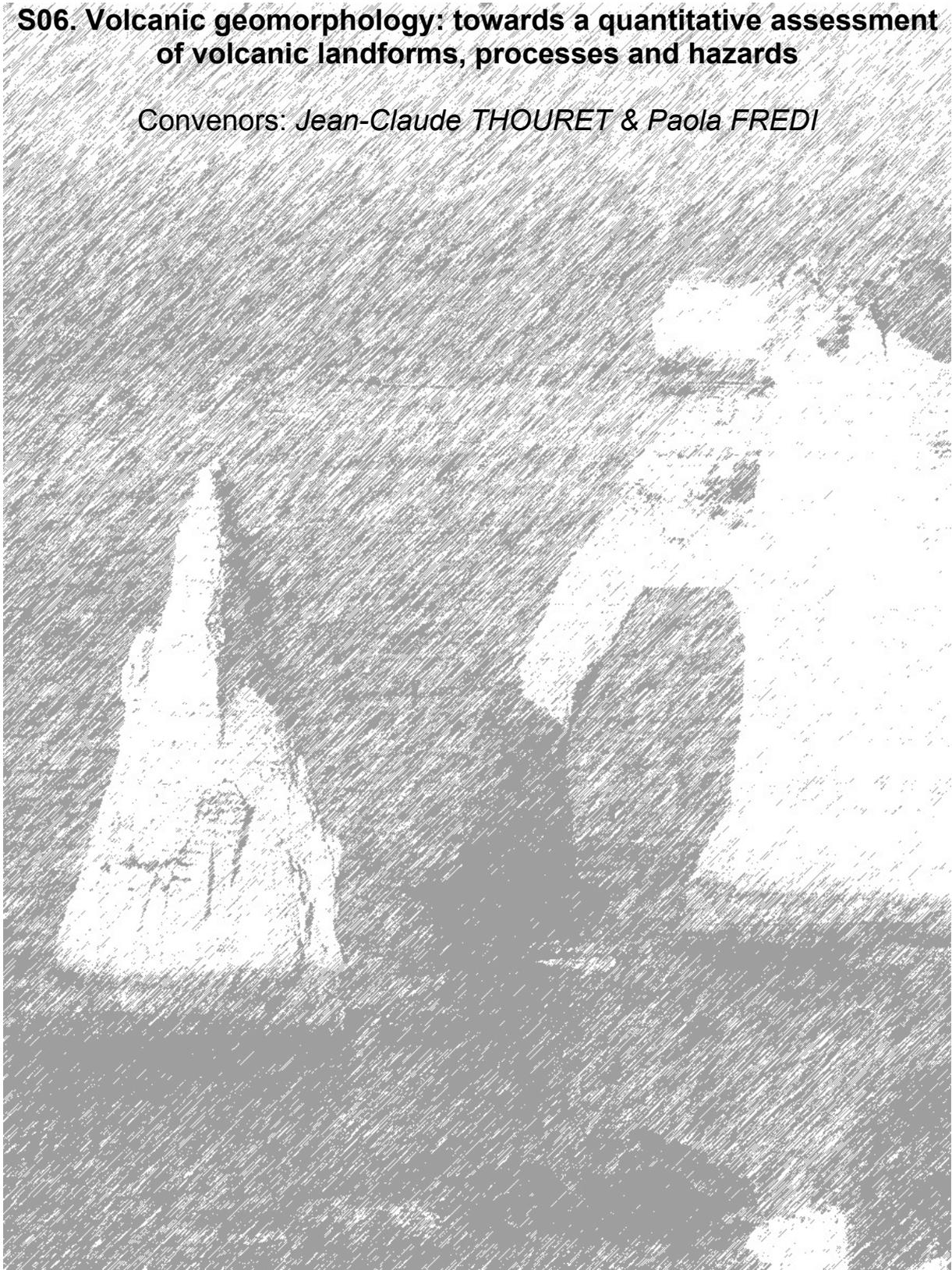
Alluvial fans are very useful geomorphic markers to date and estimate the timing and rate of active tectonic deformations. In the central Taurus Mountains of Turkey, we used excellent exposures of alluvial fans along a ~15 km long, NNE trending linear valley to understand the Late Quaternary tectonic activity of the left-lateral oblique slip Ecemiş Fault. Although the geomorphic expression of the fault is very distinct, the rate of active slip is not well-known due to the constraints of explicitly dating offset markers along the fault line. In this study, we have determined the slip of the Ecemiş Fault by remote sensing and in-situ measurements and the alluvial fan ages associated with the Ecemiş Fault by cosmogenic Cl-36 dating. Finally, we calculated the Late Quaternary slip rates of the fault based on the cosmogenic age results. According to the digital terrain model obtained from high-resolution airborne survey, we determined the horizontal slip amount to be in between 20 to 40 m, and the vertical slip to be 15-20 m. Our cosmogenic Cl-36 geochronology analysis revealed that the surface age of the alluvial fans cut by the Ecemiş Fault is  $84.3 \pm 7.4$  kyr (kilo years). Depending on our preliminary slip measurements, we propose horizontal and vertical mean slip rates in between 0.24 and 0.47 mm/year and 0.18 and 0.24 mm/year, respectively.

Keywords: Ecemiş Fault, slip rate, alluvial fan, cosmogenic chlorine-36 surface exposure dating, Turkey

\*\*\*\*\*

**S06. Volcanic geomorphology: towards a quantitative assessment of volcanic landforms, processes and hazards**

Convenors: *Jean-Claude THOURET & Paola FREDI*





## **Oral presentations:**

### **Geomorphic analysis of eruptive vents, landslide and debris flows of the 2012 Te Maari eruption from Mt. Tongariro, New Zealand**

*PROCTER J.(1), ZERNACK A.(1), CRONIN S.(1), PATRA A.(2), SHERIDAN (2), LEONARD G.(3), JOLLY G.(3), KEYS H.(4)*

*(1) Massey University, PALMERSTON NORTH, NEW ZEALAND ; (2) SUNY, BUFFALO, UNITED STATES ; (3) GNS, WAIRAKEI, NEW ZEALAND ; (4) Department of Conservation, TAUPO, NEW ZEALAND*

The 6 August 2012 Te Maari eruption from Mt. Tongariro was an event that had not been considered in recent hazard analysis of the Tongariro Volcanic Centre. While scarce historic reports describe similar events occurring during the last eruptive episode at Te Maari craters from 1869-1896, they lack any information on geomorphic changes to the crater configuration. Similarly the products of these historic eruptions, such as debris flows or pyroclastic flows, are not preserved in the geologic record. In response to seismic activity in July 2012 and a possible eruption threat from Mt. Tongariro, there was need to develop likely scenarios of mass flows prior to the event. However, due to the lack of accurate historic information the location of possible vents, volumes and flow rheologies were complete unknowns. With no validation available from past events, the Titan2D computation flow model was applied to scenarios developed around historic eruptive centres to create a mass flow hazard zone for public hazard maps. The subsequent 6<sup>th</sup> August phreatic to phreatomagmatic explosions altered the landscape with newly established volcanic vents and potentially unstable craters. The eruption also displaced 320,000 m<sup>3</sup> of material from the flanks of the vent area in the form of a landslide, generating a small debris flow that flowed 2.5 km from source and blocked a valley system. These geomorphic changes were characterised by RTK-GPS surveys and LiDAR. A combined analysis of the newly acquired high-resolution surface data with sedimentological data provided insights into how this mass of material was emplaced. The damming of the valley and the formation of a lake behind the dam presented a changing hazardscape. The dam collapsed on 14 October remobilising material. This rapidly evolving landscape and the ever-changing geomorphic conditions continually alters the hazardscape requiring careful monitoring and providing challenges for hazard simulation analysis.

\*\*\*\*\*

### **The geomorphology of the Rinjani volcanic complex, Lombok Island, Indonesia: a result of a major historic eruption**

*LAVIGNE F.(1), DEGEAI J.P.(2), LAHITTE P.(3), ROBERT V.(1), KOMOROWSKI J.C.(4), VIDAL C.M.(4), METRICH N.(4), SRI HADMOKO D.(5), ARYA DIPAYANA G.(5), PRATOMO I.(6), WASSMER P.(7), DE BÉLIZAL E.(1)*

*(1) Université Paris 1 Panthéon-Sorbonne, Laboratoire de Géographie Physique, UMR 8591 CNRS, MEUDON, FRANCE ; (2) CNRS, UMR5140 Archéologie des sociétés méditerranéennes, LATTES, FRANCE ; (3) Université Paris-Sud, Département des Sciences de la Terre (IDES), ORSAY, FRANCE ; (4) Institut de Physique du Globe de Paris (IPGP), CNRS UMR7154, PARIS, FRANCE ; (5) Gadjah Mada University, Faculty of Geography, YOGYAKARTA, INDONESIA ; (6) Geological Museum, Center for Geological Survey, BANDUNG, INDONESIA ; (7) Université de Strasbourg, Laboratoire de Géographie Physique, UMR 8591 CNRS, MEUDON, FRANCE*

Rinjani volcanic complex is located in Lombok Island, east of Bali, Indonesia. Rinjani volcano (3,726 m above sea level a.s.l.) towers ca. 1,700 m above a 6×8.5 km caldera. This caldera hosts a 11 km<sup>2</sup> crater lake (2000 m elevation) called Segara Anak (Child of the Sea in local language), enclosed by 500-800 m high walls. The lake is about 200 m deep and its water volume is estimated at 1 billion cubic meters. Lava flows and scoriaceous tephra from recent post-caldera eruptions of Gunung Baru (New Mountain) have formed an intracaldera cone.

The caldera rim is comprised of lava domes and their residual structures as well as proximal pyroclastic deposits from past eruptions. The eastern flank of the Rinjani volcano descends abruptly to the Sembalun plain, a remnant of an older caldera. The Holocene caldera-forming explosive eruption produced extensive and voluminous Plinian pumice fallout deposits and multiple units of massive unwelded pumiceous pyroclastic density current (PDC) deposits that reach up to 35-40 m in thickness. North and south of the Segara Anak caldera, these deposits form a pyroclastic apron that descends gradually from the caldera rim and terminates in the sea up to 35 km from source. Emplacement of the PDCs entirely modified the pre-caldera topography. Post-eruptive dissection of the 35-40 m thick PDC deposits has resulted in the formation of the northern valleys of Lombok Island and relief inversion. The minimum bulk volume of the on-land mapped PDC deposits is 14.5 ±0.7 km<sup>3</sup>, corresponding to 8.0 ±0.4 km<sup>3</sup> of magma DRE (dense rock equivalent). Our study aims to reconstruct the very large recent eruption at the origin of one of the most beautiful volcanic landscape of the world.

**Using volcanic landforms, their ages, bedrock and tectonic setting across the very large monogenetic field of the Newer Volcanic Province of southeastern Australia to assess future eruptions**

JOYCE E.B.

*Earth Sciences, The University of Melbourne, PARKVILLE, AUSTRALIA*

Young monogenetic volcanoes of the Newer Volcanic Province (NVP) of central and western Victoria and adjacent southeastern South Australia provide a detailed story of activity over the last 5 Ma which continues up to just a few thousand years ago. Some 400 large and small scoria cones, lava shields and maar craters have been catalogued and the distribution of lava flows and ash deposits mapped. Many volcanoes are on the western plains, but the greatest concentration of some 100 scoria volcanoes, often as little as 2 km apart, are clustered in an upland area, with similarities to parts of the Auvergne region of France. K/Ar dating and newer techniques including cosmogenic exposure dating have provided a detailed story of the youngest activity, and geomorphic and regolith mapping have been used to fill gaps. Geostatistical modelling has allowed an analysis of activity over time, identifying cycles of activity and periods of little or no activity. In a period of greater activity over the last 20,000 to 30,000 years on the plains in the far west of the NVP, perhaps a dozen volcanoes may have erupted – and if not clustered these indicate a repose interval or recurrence rate (i.e. eruption frequency) of some 2,000 years. The recent redating of the Mt Gambier volcanic complex at ~5,500 years BP demonstrates the need to consider long term volcanic risk and hazard. Among the hazards which may need to be dealt with in any future eruption in this closely-settled region are local effects of scoria cone eruption or lava shield construction, maar eruptions and local (but possibly extensive) ashfall and base surge ash flows, and the longer term and more broadly distributed problems of lava flows, which can be seen to have followed valleys in the past for tens of kilometers and so are potentially a hazard to modern infrastructure such as bridges, road and railways, and a major fire hazard on the dry grassland plains of Western Victoria in summer.

\*\*\*\*\*

**Lahars at Merapi Volcano following 2010 eruption: geomorphic impacts and hazards assessment**

HADMOKO D.S.(1), DIPAYANA G.A.(1), SARTOHADI J.(1), LAVIGNE F.(2), MARFAI M.A.(1), SURATMAN S.(1)

*(1) Faculty of Geography, Universitas Gadjah Mada, YOGYAKARTA, INDONESIA ; (2) Institut de Géographie. Université Paris 1 Panthéon-Sorbonne, 191, rue Saint-Jacques 75005 Paris, France, PARIS, FRANCE*

Lahars are the most frequent hazardous events on Merapi Volcano since 2010 centennial eruption. Over 290 lahars have been documented at 13 rivers coming from Merapi and 20 % of them have been observed at Kali Putih. The devastating lahars at Kali Putih in January 9<sup>th</sup>, 2011 caused the extensive damaged on infrastructures, agricultural lands and abrupt channel evolution at the downstream areas. The aims of this research are twofold: (1) understanding the lahars dynamics and its geomorphic impact on channel and (2) assessing the spatial extension of the hazardous area at the downstream of Kali Putih. A threefold of methodological approach has been applied in this research namely: (1) remote sensing approach has been used in order to understand the river dynamic before and after lahars through visual interpretation. Three different kinds of very high resolution images have been used in order to identify the evolution of river morphology. We identify the pre-event morphology through Quickbird Images taken at April 22, 2010 while the post-event morphology has been studied from GeoEye Image taken at June 11, 2011 and orthophoto images recorded at January 22<sup>th</sup>, 2012; (2) numerical simulation of lahars extension has been done through Titan2D model. High resolution DEM of Airborne Lidar has been used to simulate the spatial extension of lahars with several scenarios of volumes, (3) field measurement coupled with real-time video recording of lahars allow us to understand the dynamic and mechanism of erosion and depositional process of lahars along the channel. The hazard map is useful for developing the lahar risk micro-zonation for anticipating the potential damage and loss caused by the future lahars.

Keywords: lahars, geomorphic impacts, hazards, DEMs, dynamic.

### **Intrusion generated topography in monogenetic volcanoes**

VAN WYK DE VRIES B.(1), MARQUEZ A.(2), PETRONIS M.(3), DELCAMP A.(4), KERVYN M.(4), PABLO G.(5)  
(1) *Laboratoire Magmas et Volcans, CLERMONT-FERRAND, FRANCE* ; (2) *Universidad Juan Carlos, MADRID, SPAIN* ; (3) *New Mexico Highlands University, LAS VEGAS, NM, UNITED STATES* ; (4) *Vrije Universiteit Brussel, BRUSSELS, BELGIUM* ; (5) *CONICET & Fundación Miguel Lillo, TUCUMAN, ARGENTINA*

Monogenetic volcanoes are produced by short (< decades) and low volumes (<1 km<sup>3</sup>) eruptions of usually one magmatic event. They are usually described by their lavas and eruptive products, but in certain eroded or quarried cases, it has become clear that intrusions can play a major role in their evolution. In other cases it has become clear that the surface morphology has been extensively controlled by late stage intrusions. This presentation describes intrusions seen in several volcanoes, in the Chaine des Puys, Central France, either in exposures in quarries, or interpreted after an analysis of the surface morphology and structure. We show that large-scale surface modification can occur at any time before, or during, an eruption and that subsequent intrusion into a previous edifice can also cause large scale-topographic changes. In particular we show: 1) the internal structure of intrusions exposed in the Lemptégy Scoria cone, 2) the large scale topographic remodelling of the Petit Puy de Dôme scoria cone during a latter trachytic intrusion phase, 3) the formation of a lacolith-related bulge before the Killian Plinian eruption, and the collapse of the Puy de Gouttes cone related to a shallow intrusion that formed the Puy Chopine Trachytic eruption. While we concentrate on small-scale monogenetic events, we will compare these with cases from larger stratovolcanoes, such as Teide, Tenerife, and Momotombo, Nicaragua which indicate that such large scale topographic changes can occur at all scales and can significantly alter the shape of a volcano.

\*\*\*\*\*

### **Morphological changes associated with the emplacement of lava flows in coastal environments on the island of El Hierro (Canary Islands)**

GUILLÉN-MARTÍN C.(1), ROMERO-RUIZ C.(2), ROBERT A.(3), DÓNIZ-PÁEZ J.(2)  
(1) *Instituto Volcanológico de Canarias (INVOLCAN), GRANADILLA DE ABONA, TENERIFE, SPAIN* ; (2) *Department of Geography, University of La Laguna. Tenerife/Spain., LA LAGUNA TENERIFE, SPAIN* ; (3) *Département de Sciences Humaines et Sociales, Université de La Rochelle, LA ROCHELLE, FRANCE*

In the Canary Islands, the existence of specific lava forms generated as a result of the emplacement of lava flows into the sea, with the development of hydrovolcanic explosions within it, has been highlighted by authors such as Bravo (1964), De la Nuez et al (1997) and Romero (2003). Most of these authors deduce the existence of hydrovolcanic explosions from the presence of small scoriaceous mounds on the surface of the lava flows; these morphologies have been described in lava flows of the islands of Lanzarote, Fuerteventura, La Graciosa and Alegranza. Despite its importance for the establishment of the potential risks associated with the emplacement of lava flows, detailed studies or research analyzing the morphology or traits lava deposits associated with these forms do not exist yet. On the other hand, mention of surface morphologies of this same type has not been carried out on the island of El Hierro yet. In oceanic volcanic islands, the possibility of lava flows reaching the sea is relatively high. In the Canary Islands this has happened at least nine times during the past 600 years, confirming the arrival of lava flows to the sea during the Timanfaya eruption in 1730/36 and the New Volcano of Fire in 1824 in Lanzarote; in 1706, in Tenerife, and during the 1585, 1646, 1677-1678, 1712, 1949 and 1971 eruptions in La Palma. This means that lava has entered the ocean at more than 60% of developed eruptions at historical times, although there is no evidence of the development of significant explosions in the lava fronting during lava emplacement in shallow marine environments. This work carries out the study of the flows belonging to the eruptive zone of Punta de la Dehesa, in the northern area of the lava platform of El Verodal. The establishment of forming sequences of the lava flows in the platform of El Verodal has been carried out from the stratigraphic analysis of individual lava flow units present in natural breaks in the cliffs around this sector.

### **Evaluation of mechanical erosion and volcanic construction rates in the Basse-Terre Island (Guadeloupe, Lesser Antilles)**

*RICCI J., LAHITTE P., QUIDELLEUR X.*  
*UMR 8148 CNRS, IDES, ORSAY, FRANCE*

The current topography of the volcanic island of Basse-Terre highlights the complex interaction between construction and dismantling processes having marked its history. Even if this island may have sometimes been affected by flank collapses event, the geomorphologic evolution of massive volcanic remains dominated by the important erosion resulting of the tropical climate. To better constrain its origin, evolution and influence, it is necessary to characterize and quantify the dynamics of both construction and destruction of each volcanic edifice.

In this study, we combine a wide K/Ar geochronological coverage obtained by the Cassinot-Gillot technique with DEM geomorphological analyses that allow us to numerically model the evolution of paleo-surfaces in order to quantify the successive eroded volumes. For this purpose, we extract from the present-day numerical topography the key-points whose current altitudes constrain the upper surface of the different edifices at the end of their volcanic activity. The complete paleo-surface obtained by interpolation of these key-points is then subtracted to the current DEM to deduce the altitude lost at each location of the grid. The integration of these differences over the whole surface quantifies the total erosion affecting each edifice since its activity ended. Erosion rate deduced are then compared between different geographic sectors with contrasting climates. Moreover, the obtained erosion rates will allow us to propose new constraints on the mechanical versus chemical erosion rates budget having affected the Basse-Terre volcanic island for the last million years.

\*\*\*\*\*

### **Comparison of Andean Volcanoes landforms through geomorphometric analysis**

*CAMIZ S.(1), POSCOLIERI M.(2), ROVERATO M.(3)*

*(1) Sapienza Università di Roma, ROMA, ITALY ; (2) CNR - Istituto di Acustica e Sensoristica, ROMA, ITALY ; (3) UNAM - Centro de Geociencias, QUERETARO, MEXICO*

The comparative studies of volcanoes structure can highly benefit from the increasing availability of DEM models, since most morphometric characters may be extracted by the analysis of the data they produce. Studies in this sense have been performed on the Andean volcanoes by Grosse et al. (2012) that developed a data base of volcano edifices morphometry, describing their most relevant landforms.

In Camiz and Poscolieri (2010) a new geomorphometric analysis method has been introduced, able to classify ground pixels according to their local relation with the neighboring ones. This way, two main targets may be reached: a fine tuned description of the morphological features and the possibility of their direct comparison among volcanoes. In addition, the associated coloring technique gets possible a direct visual comparison.

The technique is based on the so-called Tandem Analysis, composed by the pairing of a Principal Components Analysis, and a mixed classification that alternates K-means and Hierarchical clustering (Lebart et al., 1995), applied on the eight gradients of each DEM pixel, computed as the difference between the pixel's altitude and that of the eight surrounding ones.

In this paper we apply this technique to a sample of Andean and other American volcanoes, in order to ascertain to what extent some similarities in the slopes orientation, already observed in some of these apparatuses, may be generalized to a larger sample.

#### References

- Camiz S. et al. (2011). Actas E-ICES 6, ISBN 978-987-1323-21-0: 19-29  
Grosse P. et al. (2012), Geomorphology, 136: 114-131  
Lebart L. et al. (2006), Statistique Exploratoire Multidimensionnelle, Paris, Dunod.

## Quantitative assessment of external environmental controls on the style of monogenetic volcanic eruptions

NEMETH K., KERESZTURI G., AGUSTÍN-FLORES J., CRONIN S.  
Massey University, CS-INR, PALMERSTON NORTH, NEW ZEALAND

The external environment, where volcanic field-forming magmas intrude plays an important role to control the style of monogenetic volcanism. The external environment could be the source of the amount and type of ground or surface water that determines the style and length of magma-water interactions. Due to its hazardous nature, the phreatomagmatic volcanism in the Quaternary Auckland volcanic field (AVF) is the most dangerous volcanic hazard we need to deal with. In order to assess the susceptibility of a phreatomagmatic eruption in the future, the external-forcing factors should quantitatively be determined using the best possible geological data set on the volcanoes erupted in the past and their eruptive environment. A combination of Dense Rock Equivalent (DRE) eruptive volumes with stratigraphic-positions were used to discriminate the total amount of magma fragmented in a phreatomagmatic way in the AVF. Out of the total DRE eruptive volume of the field (1.5 km<sup>3</sup>), only small fraction were emplaced by phreatomagmatic eruption forming tuff rings (0.1 km<sup>3</sup>). The rest of the magma output (1.4 km<sup>3</sup>) was emplaced as spatter/scoria cones and lava flows, controlled mostly by the magma "internal" physical-chemical parameters. Important external factor were found to be the hydrogeologic condition of encountered country rocks, which is in functions of thickness, porosity and permeability of alluvium deposited upon differentially subsided blocks of the Miocene, variously fractured hard rocks (Waitemata Group), the fracture pattern of the deep hard rock aquifers, the fluctuation of sea level and the changes of fluvial network over the evolution of the field. Due to the young age of the AVF (<250 ka), the eruption history of each volcano and the way of interaction between the magma and the external environment can be used as an input data to develop "scaled" and quantitative volcanic hazard scenarios for future eruptions.

\*\*\*\*\*

## Towards a comprehensive morphometric classification of composite volcanoes

GROSSE P.(1), KERVYN M.(2), VAN WYK DE VRIES B.(3)  
(1) CONICET & Fundación Miguel Lillo, TUCUMÁN, ARGENTINA ; (2) Department of Geography, Vrije Universiteit Brussel, BRUSSELS, BELGIUM ; (3) Laboratoire Magmas et Volcans, Université Blaise Pascal, CLERMONT-FERRAND, FRANCE

Shape and size are fundamental properties of a volcano. This is reflected in the fact that most volcano classifications are based entirely or partially on morphology. However, most existing classifications are qualitative and unsystematic, based on vague morphological characteristics and sometimes also using other data (e.g. composition). This has led to classification schemes that are ambiguous or inconsistent, containing different and in some cases overlapping terminology such as simple, composite, compound, complex, cluster, multiple, twin, shield, shield-like, somma, collapse-scarred, etc. In order to obtain a comprehensive classification, quantitative and comparable morphometric data for all volcanoes at a global scale should be analyzed. To this end, we have used the near-global SRTM DEM to compile a database of morphometric parameters of approximately 800 composite volcanoes that are listed in the Smithsonian Institution Global Volcanism Program database. The parameters were obtained using a specifically developed code (MORVOLC) which computes several parameters that thoroughly and quantitatively describe the morphology of volcano edifices. Analysis of the database indicates that edifice shape can be reasonably summarized by a number of independent parameters: height / basal width ratio, summit width / basal width ratio, ellipticity index (*ei*), irregularity index (*ii*), average slope, number of main vents and presence of large summit crater or caldera. More detailed characterization can be obtained considering the variation with height of *ei*, *ii* and slope. Edifice size can be summarized with height, basal width and volume. Statistical cluster analysis of these parameters via different algorithms results in a set of possible classification schemes. The usefulness and validity of the obtained categorizations are discussed in terms of their links with the dominant constructive and destructive processes controlling edifice morphologies.

### **Mapping and quantifying the morphometry of volcanic features using high resolution Tandem-X DEM: the Virunga Volcanic Field, DR. Congo**

*KERVYN M.(1), POPPE S.(1), ALBINO F.(2), SMETS B.(3), KERVYN F.(2)*

*(1) Vrije Universiteit Brussel, BRUSSELS, BELGIUM ; (2) Royal Museum for Central Africa, TERVUREN, BELGIUM ; (3) European Center for Geodynamics and Seismology, WALFERDANGE, LUXEMBOURG*

Detailed morpho-structural mapping of volcanoes is essential to understand the structure of a volcanic system and the spatial distribution of eruption probability. Quantifying the volume of pyroclasts and lava emitted by a given eruption further enable to constrain the eruption dynamics, the volcano long term magma production rate and to constrain hazard models. Here we present a new volcano-structural map of the Virunga Volcanic Province (VVP) based on high-resolution topographic and multispectral remote sensing data. The VVP located within the Western branch of the East African Rift system at the boundary of D.R.Congo, Rwanda and Uganda, hosts 8 volcanoes, including two active ones, Nyiragongo and Nyamulagira. The latter one, with one eruption every 1-4 year requires frequent update of the geological map. Panchromatic and multispectral images from sensors of SPOT and Pléiade constellations were used to systematically map the hundreds of volcanic spatter-and-scoria cones, lava flows, eruptive fissures and other lineaments in the VVP. Using bistatic images from the Tandem-X mission, a high-resolution DEM at 5 m resolution was produced by radar interferometry. This DEM, which is 6 times more accurate than the so-far available DEM of the area, enables us to systematically quantify the morphometry of volcanic cones and to constrain the volume of lava flow lobes. From difference between two Tandem DEM's taken before and after the last eruption at Nyamuragira, the extension and volume of the lava flows have been estimated with a higher accuracy than preliminary field estimation. The new map and GIS database will serve as a basis for modelling the spatial distribution of volcanic hazard in the VVP. This research highlights the added value of newly available remote sensing data to study hazardous or inaccessible volcanic regions.

\*\*\*\*\*

### **Morpho-structural evolution of a volcanic island developed inside an active oceanic rift: São Miguel Island (Terceira Rift, Azores)**

*SIBRANT A.L.R.(1), HILDENBRAND A.(1), MARQUES F.O.(2), BOULESTEIX T.(1), COSTA A.C.G.(2)*

*(1) Univ. Paris Sud, laboratoire IDES, UMR8148, 91405 ORSAY, FRANCE ; (2) Universidade Lisboa, LISBOA, PORTUGAL*

The evolution of volcanic islands is generally marked by fast construction phases alternating with destruction by a variety of mass-wasting processes, such as giant landslides, caldera collapse events, or graben development. More specifically, volcanic islands located in areas of intense regional deformation represent rapidly evolving and unstable reliefs, particularly prone to gravitational destabilization.

The island of São Miguel (Azores) has developed during the last 1 Myr inside the active Terceira Rift (TR), a major slow-spreading extensional structure materializing the present boundary between the Eurasian and Nubian lithospheric plates. The island is composed of a few main edifices affected by several volcano-tectonic structures. In this work, we depict the morpho-structural evolution of the island, based on high-resolution DEM data, fieldwork and structural investigations, and high-precision K/Ar dating on separated mineral phases.

The new results indicate that: (1) the primitive volcanic complex composing the eastern half of the island was active until ca. 800 ka, and experienced a major southward lateral flank collapse; (2) the resulting depression was extensively filled by basic volcanic activity; (3) tectonic deformation yielded the development of graben-like tectonic depressions oriented N150 and N110 close to the collapse rims, whereas a new volcano grew in the western part; (4) this volcano was affected by caldera collapse episodes, and associated ignimbrites filled the graben and erosional depressions; (5) recent volcanism and tectonics controlled the construction/destruction on the central and western parts of the island, including the development of N150 and N110 linear chains of strombolian cones and caldera forming eruptions.

Persistent magma focusing and faulting along the N110 and N150 main structural directions at different epochs suggest a great influence of regional tectonics, in close relationship with the evolution of the TR.

### **The volcanic morphology of the intra-caldera Kameni islands, Santorini, based on high resolution bathymetry and LiDAR data**

NOMIKOU P.(1), CAREY S.(2), PAPANIKOLAOU D.(1), PYLE D.(3), PARKS M.(3), BELL K.(2), MATHER T.(3), LIVANOS I.(1), BEJELOU K.(1), PERROS I.(1)

(1) University of Athens, ZOGRAPHOU, GREECE ; (2) Graduate School of Oceanography, University of Rhode Island, NARRAGANSETT,, UNITED STATES ; (3) Department of Earth Sciences, University of Oxford, OXFORD, UNITED KINGDOM

The present day landscape of Santorini caldera is the product of a series of major caldera forming eruptions (including the Minoan eruption ~1600 B.C.) and post-Minoan dome-building eruptions, which have gradually built up the intra-caldera Kameni islands. These islands (Nea Kameni and Palea Kameni) represent emerged portions of extended submarine volcanic complexes that rise from 380m b.s.l. In contrast to the well-known geological, petrological and geomorphological evolution of the subaerial portions of the volcanic edifices, the submarine portions of them are surprisingly poorly identified. We present a new high-resolution, digital elevation model (DEM) for the volcanic edifices that form the Kameni Islands based on LiDAR data from the airborne survey carried out in April 2004 and multibeam data with 5m resolution.

The new DEM has enabled us to compile a revised geomorphological map of the Kameni islands, based on the identification and mapping of the main volcanic deposits (both onshore and offshore). This map allow us to: (1) characterize the morphology of submarine volcanic structures and deposits; (2) define the main submarine tectonic structures and relate them to those on land; (3) analyze the relationships between tectonics and volcanism in the Kameni Islands; (4) define the submarine continuation of the historic onshore lava flows.

The merged dataset reveal details of the total surface morphology (from -390m up to +127m) of young dacite lava flows, craters and domes, which in combination with historical accounts and information from previous studies, has enabled the compilation of a new geological map of Kameni islands. The revised map provides insight into the volcanological evolution of the islands, their tectonic features and new estimates for the volumes of extruded material during each of the historic dome building eruptions. Finally, the collected data allow us to put constraints on the evaluation of the volcanic hazard inside Santorini caldera.

\*\*\*\*\*

### **Multi scale patterns of aggradation and degradation on persistently active composite cones: the case study of Semeru, Indonesia, mapped and measured from satellite imagery, aerial photographs, and DEMs**

THOURET J.C.(1), OEHLER J.F.(2), SOLIKHIN A.(3), GUPTA A.(4), LIEW S.C.(5)

(1) University Blaise Pascal, Laboratoire Magmas et Volcans, CLERMONT-FERRAND, FRANCE ; (2) ALTRAN OUEST Atlantide, BREST, FRANCE ; (3) Center of Volcanology and Geologic Hazard Mitigation, BANDUNG, INDONESIA ; (4) University of Wallongong and CRISP, WALLONGONG, AUSTRALIA ; (5) CRISP National University of Singapore, SINGAPORE, SINGAPORE

Very high sediment yields in the world are derived from erosion on persistently active volcanoes in humid climate. Sediment yields have been evaluated after large eruptions, but not long-term geomorphic response of rivers to disturbances on such volcanoes. We have used high-spatial resolution satellite imagery and DEMs, combined with field-based mapping, to determine sediment budgets for one catchment on the active volcano of Semeru, Indonesia. The measured annual (2007-2011) sediment yield from the Kobokan catchment (109 km<sup>2</sup>) is 10<sup>4</sup>-10<sup>5</sup>m<sup>3</sup>/km<sup>2</sup>, and that from one of its sub-catchment (Lengkong: 8.25 km<sup>2</sup>) is 10<sup>4</sup>-10<sup>2</sup> m<sup>3</sup>/km<sup>2</sup>. Patterns of aggradation and degradation on the Semeru differ from examples for other active volcanoes due to three factors. 1. Pyroclastic flows generate episodic pulses of sediment along with the continuous supply of tephra. 2. Rain-triggered lahars remove huge volumes of material during intense rainfall events and at much higher rates than by fluvial transport. 3. Storage and transfer of sediment develop a cycle of aggradation and degradation that lasts >15 years in river channels after each pyroclastic-flow eruption. Rivers respond to such cycles by creating two different channel forms. Large catchments show voluminous sediment choking long, multi-thread and meandering channels as a long-term characteristic (>10 years). Single-thread, shorter and narrower channels of sub-catchments show faster (<10 years) response with a set of terraces cut into infilling sediment. Sediment yields are two to three orders of magnitude less than those calculated for large eruptions and short-term periods at Pinatubo and Mt. St. Helens. However, persistently active volcanoes in a wet environment are characterized by average sediment yields that remain about ten times (10<sup>3</sup> t/km<sup>2</sup>/yr) above the ambient values between eruptions. Over a long-term period (≥30 years), persistently active volcanoes supply more sediment than derived from large but infrequent eruptions.

**Morpho-structural evolution of an active large-scale slump on the flank of an unstable volcanic island (Pico, Azores)**

*COSTA A.(1), HILDENBRAND A.(2), MARQUES F.(1), SIBRANT A.(2), CATALÃO J.(1), CATITA C.(1)*  
(1) University of Lisbon, LISBOA, PORTUGAL ; (2) Université Paris-Sud, ORSAY, FRANCE

The evolution of large-scale slumps on active volcanic islands is marked by a gradual development of normal faults and episodes of volcanism partly filling the resulting depression(s). Here we present the case of an active slump on the SE of Pico Island, Azores. This slump is located on the S flank of an active WNW-ESE volcanic ridge, and is characterized by, at least, three concentric arcuate faults concave towards the sea. These structures propagated progressively towards the SE, and were intercalated in time with several phases of volcanic filling, erupted from vents located in and along the borders of the depressed area.

In this work we investigate the interactions between slump development and volcanic activity, based on high resolution DEM, structural analyses, and high-precision K-Ar dating.

The new data suggest that: (1) the slump activity initiated with the largest fault, first displacing several km<sup>3</sup> of the volcano flank; (2) the slump structure was then filled by volcanic deposits, which fossilized a talus deposit at the base of the scarp; (3) concentric failure occurred along new faults inside the slump area, and towards the sea; (4) the new depression was again filled by lava flows that fossilized the new talus deposit at the base of the main scarp, and cascaded over the scarp newly created.

Four GPS campaigns were conducted between 1999 and 2006, and InSAR data were obtained between 2006 and 2009. The InSAR and GPS data show that the subsidence is faster in the central part of the slump (7-12mm/yr) relatively to the outer part (5-8mm/yr), suggesting the individualization of one of the slump structures, whose sudden collapse could be potentially tsunamigenic.

In order to monitor the activity along the structures of the slump, GPS and microseismic networks were installed, as well as an inclinometer.

\*\*\*\*\*

**Poster presentations:**

**Landslides in the Western Highlands of Cameroon: environmental impact.**

*NKOUATHIO D.G.(1), KAGOU DONGMO A.(1), ZANGMO TEFOGOM G.(2), MEWOULOU NDI Y.(1), ABOUBAKAR B.(1), GUEDJO SUH C.(1)*  
(1) University of Dschang, DSCHANG, CAMEROON ; (2) University of Maroua, MAROUA, CAMEROON

The Western Highlands of Cameroon (WHC) formed a well individualized geographical entity. It lies between 4°5' and 6°5'N, and 9°25' and 11°40'E. This region is intensely fractured, cut in plateaus (1100-1600m), surmounted of volcanoes (Manengouba, 2411m; Bambouto, 2740m; Oku, 3011m) and pierced by collapsed basins (Mbo, 700m; Ndop, 900m). These structures predispose the WHC to mass movement's hazards.

The main characteristic of WHC is the compartments of the relief, often reorganised by erosion. The Mount Bambouto subdivides the highlands into two parts: the highlands of Bamenda-Nkambé and of Bamiléké-Bamoun consisting in plateaus separated by escarpments.

The WHC were a seat of an intense volcanic activity which generated lavic formations and pyroclastic rocks. These volcanic formations induce fertility that becomes an appeal for populations who moreover benefit of the cool and humid climate. The consequence is that the WHC are densely populated (< 200 habitants/km<sup>2</sup>) and colonized by man for agricultural and pastoral practices.

This anarchical implantation associated to other factors (relief, hydrography, rainfall (> 1700mm) and anthropic factors) are creative of mass movements. A trigger factor is sufficient to provoke the avalanche. This factor can be an upsurge of rains, inadequate shearing of banks or flanks of hills or a light earthquake. The most recurrent mass movements in WHC are landslides. When it occurs the damages recorded are mainly:

- Losses of human lives and livestock,
- Destruction of plantations and communication way,
- Reduction of cultivated surface and destruction of pasture and vegetation.

Identification and analysis of the risk factors are of paramount importance to any planning project in these regions in order to reduce the effects of landslides. We propose zonation hazards maps in some exposed regions in order to circumscribe the dangerous areas. This study can stand as model for African highlands submitted to subequatorial monsoon climate.



## **Pyroclastic density current and lahar deposits at Merapi, Indonesia, identified and measured with GeoEye and Pléiades imagery**

THOURET J.(1), GUPTA A.(2), LIEW S.C.(3), KASSOUK Z.(1), OEHLER J.F.(4), SOLIKHIN A.(5)

(1) University Blaise Pascal, Laboratoire Magmas et Volcans, CLERMONT-FERRAND, FRANCE ; (2) University of Wallongong and CRISP, WALLONGONG, AUSTRALIA ; (3) CRISP National University of Singapore, SINGAPORE, SINGAPORE ; (4) ALTRAN OUEST Atlantide, BREST, FRANCE ; (5) Center of Volcanology and Geologic Hazard Mitigation, BANDUNG, INDONESIA

Very high-spatial resolution imagery enable us to identify pyroclastic and lahar deposits around erupting volcanoes. We have identified and mapped the extent and effects of the pyroclastic density current (PDC) and lahar deposits at the end of the 2010 eruption of Merapi volcano, its largest (VEI4) over the past 140 years, using two 50 cm GeoEye and Pléiades images. We determined remotely sensed textural indices and automatic classifications with DEMs, field-based D-GPS and thicknesses of the deposits, all embedded in a GIS. Detailed geologic map of the Gendol and Opak River catchment on the south flank of Merapi shows the effects of PDCs, including the longest (17 km) block-and-ash flow and widespread (20 x 4 km) pyroclastic-surge deposits and subsequent lahar activity. The erupted deposits cover an area of about 50 km<sup>2</sup> on the south flank. The volume of PDC deposits ranges between 40 and 50 million m<sup>3</sup>, 35 to 40% of the volume of 2010 Merapi PDCs and tephra deposits. The GeoEye image enables us to identify: (1) several channel-confined and unconfined pyroclastic-flow deposits on the basis of textures and origins and large-scale surges that devastated the upper catchment, separated from ash-cloud surges that singed the forest along the valley edges; (2) Over-bank pyroclastic flows caused by anthropogenic structures and the sinuous, former valley channel, and lahars due to the mixture of pyroclastic material with water and paddy field sediment; (3) Lobes and tree logs on top of the pyroclastic flows and damaged houses in the over-bank lobes and in surge-hit edges of the valley. Geomorphic changes to the Merapi summit and vent area following the eruption were reviewed with a 2011 GeoEye image. The summit vent area was reduced by about 0.1 km<sup>3</sup> and stubby dome lava flows were isolated by a rectangular-shaped vent 400x300x75 m. A 1.2 km long and 200 m-wide scar was re-excavated and PDCs have scoured furrows on summit lava flows and gullies in thick tephra deposits.

\*\*\*\*\*

## **Mud volcanoes of Azerbaijan as the relief unite: natural phenomenon and hazard**

RASHIDOV T.

*Geology Institute of Azerbaijan National Academy of Sciences, BAKU, AZERBAIJAN*

Mud volcanoes are the unique natural phenomenon representing more or less large elevations, often of plane-conical shape, rising for 400 m and more over the country. The base diameter is from 100 m to 3-4 km and more. Like the magmatic ones, the mud volcanoes are crowned with crater of convex-plane or deeply-seated shape. In comparison with magmatic volcanoes this type has restricted distribution in global scale; they basically locate within the Alpine-Himalayan, Pacific, Central Asian mobile belts.

Azerbaijan is the classic region of mud volcanoes development. From over 800 world mud volcanoes there are about 400 onshore and within the South-Caspian basin. There are all types of mud volcanic manifestations: active, extinct, buried, submarine, island, abundantly oil seeping. According to their morphology there are cone-shaped, dome-shaped, ridge-shaped, plateau-shaped. The crater shapes are also various: conical, convex-plane, shield-shaped, deeply-seated, caldera-like. The most complete morphological classification was given in "Atlas of mud volcanoes of Azerbaijan" (Yakubov et al., 1971). Recently (Aliyev Ad. et al., 2003) it was proposed a quite new morphological classification of mud volcanoes of Azerbaijan. For the first time the mud volcanic manifestations had been defined. Volcanoes are ranged according to morphological signs, crater shape and type of activity.

At the same time mud volcanoes represent a specific hazard. In Azerbaijan the majority locates far from the localities. But those locating close by the settlements bear the hazard during the eruption: gas burning, outburst of mud volcanic breccia, i.e. the hard fragments of rocks that can damage the nearby buildings, great volume of mud that cover the adjacent territory with thick mud layer. There are historical records when mud volcano eruption caused the human victims. At the same time the submarine volcanoes also represent hazard for drilling wells, rigs and other offshore infrastructure.

**Long-runout volcanoclastic sediments from Asama volcano due to the catastrophic sector-collapse in the Pleistocene, Japan**

YOSHIDA H.

*Meiji University, TOKYO, JAPAN*

This paper introduces the long-runout debris observed in the northwestern Kanto Plain from Asama volcano, Japan. The stratum observable there, with a thickness of 10-20 m, is named as the "Maebashi Mudflow deposits" conventionally. The most conspicuous characteristic of the mass transport is that their runout distance is ca. 100 km along the drainage system. Therefore, it is worth of attention from the viewpoint of catastrophic natural hazard. However, there is no consistent view about the transport mechanism of the "Maebashi Mudflow", although the author has once investigated the deposits as a debris avalanche. Thick deposits with non-bedded and non-sorted facies are exposed. Additionally, the deposits consist of block boulders and gravels with muddy matrix. The deposit is divided into block facies (unmixed) and matrix facies (mixed). Such blocks consist of a single rock type of layers of airfall tephra, pyroclastic flows, lahars, and the others. Among these blocks, some seem to have formed part of the former volcanic cone. They are small, but were possibly transported gently in the debris avalanche mode and deposited relatively intact. Such facies and distribution show that the "Maebashi Mudflow" were partly debris avalanche even though its runout distance was surprisingly large. More detailed analysis of sedimentary facies will make out its true image.

\*\*\*\*\*

**The Degradation Of Recent Volcanic Landscapes Associated To The passage Of People. The Example Of Canary Islands, Spain**

ROMERO RUIZ C.(1), GUILLÉN-MARTÍN C.(2), DÓNIZ-PÁEZ J.(1), SÁNCHEZ-JIMÉNEZ N.(3), ROBERT A.(4)  
(1) *Universidad de La Laguna, LA LAGUNA - TENERIFE, SPAIN* ; (2) *Instituto Volcanológico de Canarias (INVOLCAN), PUERTO DE LA CRUZ - TENERIFE, SPAIN* ; (3) *Spanish Geological Survey (IGME), LAS PALMAS DE GRAN CANARIA, SPAIN* ; (4) *Département de Sciences Humaines et Sociales, Université de La Rochelle, LA ROCHELLE, FRANCE*

The Canary Islands constitutes a natural space of great geological and geomorphological complexity due to several factors as the wide variety of eruptive processes associated to the basaltic volcanism and to the emitted products. The very recent volcanic areas without dense vegetation cover are extremely fragile territories.

This research has as a main goal the establishment and analysis of the landscape impact due to the uncontrolled ongoing massive influx of visitors to the recent volcanic landscapes. To do so, different degrees of fragility have been investigated taking into account the main characteristics of land elements at these spaces.

The assessment of the impact level of hikers activity has been established as a function of several factors: 1) fragility of the element exposed depending on the type of volcanic material affected (pyroclastics and lavas), specific features of these materials, morphology and age of formations, 2) degree of geodiversity, 3) slope, 4) frequency of use, 5) visual impact, 6) lost of outstanding geomorphological or geological elements, 7) irreversibility of alterations and 8) bioindicators of the degradation process (e.g. lichen coating).

## **Geomorphic Degradation of Volcanic Cinder Cones in Different Climatic Zones**

INBAR M.

*Department of Geography, University of Haifa, HAIFA, ISRAEL*

The evolution of landscape over time is a central aspect of geological, paleogeographical and geomorphological studies. Cinder cones are the simplest and most common volcanic landforms in existence. It is probably the only landform on the globe with a distinct and defined initial date of formation, and lasting no more than a few million years. The progressive decrease of morphometric parameters with increasing of age is the basis for relative dating of cinder cones. Morphometric and morphological studies are efficient tools for determining ages of cinder cones and their morphological evolution.

There is no comprehensive inventory of the cones in the globe, but my estimation is about fifty thousand, around four thousand in Mexico, and five thousand in Kamchatka. The aim of this study is to analyze erosional processes affecting the degradation of the cinder cones under different climatic conditions.

Global examples: Degradation values for the Kamchatka peninsula are higher than for semiarid areas in the Southern Andes or the Golan Heights. Peaks of erosion occurred probably in the first stage of one or two years after the eruption, with the stripping of the fine ash material. The study on about 800 cones of the Payun Matru Volcanic Field in the Southern Andes (Mendoza, Argentina) showed a good correlation between the old cones with a low ratio of height/diameter of cone and the more recent of Holocene times with a high ratio. Morphometric values of the 1988 erupted Navidad cone, close to the Lonquimay volcano in Chile, are similar to those of recent erupted cones. Erosional processes on monogenetic volcanism determine their morphometric characteristics according to their climatic environment.

\*\*\*\*\*

## **Quaternary evolution of the waste mantle of the central volcanic Armenian highland**

BALYAN H.

*Yerevan State University, YEREVAN, ARMENIA*

Post-Pliocene period is characterized by often changes of the geomorphologic and landscape climate conditions of the Armenian highland. Thus, because of that development, strong miopliocenic hypergenic waste mantle on effusive was denudated and formed into different types of plain formations. Space development and genetic ties of ancient waste mantle is highly revealed in different aged moraines of quaternary glaciations of the alpine and subalpine zones of the volcanic massive of Aragats, Gegham highland, etc. Along with the young orthoeluvium formed in the alpine climate conditions, there are also spots of clay metasomatists survived the exaration which consist of hydromicas, baidelite, koalinite and partially geolite. These are fragments of the Pliocene waste mantle on acid effusive, formed in conditions of mild and moisture climate. The main mass of ancient waste mantle is caught by moraine of mountain cover glaciations, occupying top plateaus. Moraines are complicated by weathering fragments of acid effusive, full of ferrum hydroxide. There are kaolin lenses in loam filling of moraine. Compared to above-mentioned, wurm moraines are to trough only which are cut into andesite-basalts. They have fresh look and have relatively monogenetic content. On thee slopes and pre-mountain of massive there are correlative ties of different aged moraines with lake-fluvial facies. This gives a chance for more careful palaeogeographical study of the issues of the post-pliocene history of the relief and landscape of volcanic highland.

### **Geomorphic impacts and socioeconomic consequences of rain-triggered lahars at Merapi volcano (Java, Indonesia) following the 2010 eruption**

DE BELIZAL E.(1), LAVIGNE F.(2)

(1) *Université Paris Est Creteil - CNRS UMR 8591 Laboratoire de Géographie Physique, MEUDON, FRANCE ;*  
(2) *Paris 1 Panthéon-Sorbonne - CNRS UMR 8591 Laboratoire de Géographie Physique, PARIS, FRANCE*

Lahars on Merapi volcano are a common phenomenon, as they remobilize the pyroclastic deposits of the frequent eruptions of the volcano. The 2010 VEI 4 eruption of Merapi volcano deposited about ten times the volume of pyroclastic materials of 1994 and 2006 dome-collapse eruptions. Although the eruptive phase is over, another threat endangers local communities: rain-triggered lahars. The aims of this communication are to study the post-eruptive lahar-related impacts at Merapi after a major eruption. The results were acquired through a methodology mixing field measures, remote sensing, laboratory analyses, and secondary data obtained from local administrations.

First, the high frequency of lahars and the broad distribution of affected drainages will be exposed: 240 events have been reported from October 2010 to May 2011 on 17 rivers, with runout distance exceeding 20 km. Second, the geomorphic impacts of the lahars (avulsions, river bank erosion, channel widening, riverbed downcutting, volume and sedimentological characteristics of the deposits) will be explained, with emphasis on the distal slope of the volcano which has been spared by large-scale lahars for about 40 years. Those geomorphic processes cause important damages which will be presented; the socioeconomic losses (more than 3000 affected people, 860 destroyed houses...) will also be detailed. Eventually, the risk management strategies developed by the NGOs, the local stakeholders and the communities living near the rivers on hazard-prone areas will be discussed.

\*\*\*\*\*

### **Construction and destruction rates of volcanoes constrained from a DEM-based geomorphological reconstruction**

LAHITTE P.(1), GERMA CHARBONNIER A.(2), LAVIGNE F.(3)

(1) *Univ. Paris-Sud, Laboratoire IDES, UMR 8148, ORSAY, FRANCE ;* (2) *Univ. Of South Florida, Department of Geology, TAMPA, FLORIDA, UNITED STATES ;* (3) *Univ. Paris 1 Sorbonne, Campus Bellevue, MEUDON, FRANCE*

Determining growth and dismantling rates of a given volcano is critical to understand timing of its eruptive processes, to identify any possible periodicity of volcanic episodes, and, to a broader extent, define global impact of some major eruptions. Our DEM-based numerical reconstructions intend to model quantitative paleo-topography of landforms showing the geomorphological evolution of volcanoes. Based on the analysis of DEM cells dataset, each key-stage reconstruction allows us to define either a volcanic constructional event or a destructive one by caldera and/or flank collapses and long-term erosion and the correlated geochronological map. Primary volcanic landforms are modelled from the current DEM cells extracted as representative of the resultant remnant surfaces of each evolution stages. Because primary volcanic surfaces resulted from different settings and periods of construction and/or denudation, we define for each of them the optimal set of parameters that best model these surfaces by a specific least square method. We then correlate the modelled surfaces with the entire massif history by taking into account the evolution of the previous stages by erosion, caldera and flank collapse processes. Finally calculation of volumes involved in both volcanic construction stages and erosion/dismantling ones allows us to assess relief evolution rates. Such morphometric investigation is here applied to preserved enough edifices: Conil–Pelée volcano, the youngest volcanic complex (< 0.5 Ma) of Martinique Island, and to the Holocene Rinjani Volcanic Complex (Indonesia) that experienced a global climate impacting eruption with caldera collapse during historic period. The rather good preservation of remnant landforms and the high temporal resolution available allow us to discriminate from their volcanic history up to ten evolution stages though time, and to accurately quantify the volume variations involved by the main constructive or destructive events.

### **Lahar characteristics and erosion in the Gendol catchment after the centennial 2010 Merapi eruption**

HADMOKO D.S.(1), THOURET J.C.(2), SOLIKHIN A.(2), WIBOWO S.B.(3), WACANO D.(1), KIKY P.(1)

(1) Faculty of Geography, Universitas Gadjah Mada, YOGYAKARTA, INDONESIA ; (2) PRES Clermont, Université Blaise Pascal, Laboratoire Magmas et Volcans et ClerVolc, 5 rue Kessler, 63038 Clermont-Ferrand, France \*\* ANR Laharisk project, CLERMONT FERRAND, FRANCE ; (3) Institut de Géographie. Université Paris 1 Panthéon-Sorbonne, 191, rue Saint-Jacques 75005 Paris, France, PARIS, FRANCE

Lahars are the most destructive volcanic phenomena with pyroclastic density currents but they can propagate much farther. Lahars are complex flows that can be triggered during and after, or without eruptions. Our experimental method aims to measure hydraulic and physical characteristics of lahars in river channels on active volcanoes. The method encompasses: (1) hydraulic and geophysical in situ measurements of flows with sensors located at the valley bottom and on the edges, (2) high-resolution DEMs of the valley channel before and after a lahar, aiming at measuring the processes of aggradation and degradation in a catchment and bulking/debulking in flows, (3) remote sensing analysis of erosion processes on aprons of pyroclastic deposits and remobilization by lahars and fluvial transport.

We use two experimental stations located on 2 check dams c.250 m apart for in situ measurements along the middle course of the Gendol River on the south flank of Merapi. This valley was heavily impacted by PDCs during the 2010 eruption. The stations include 2 seismometers, 2 geophones, 2 load cells, 2 pore pressure sensors, 1 radar gauge, 2 rain gauges, 1 barometer and 4 cameras. We measure discharge, sediment concentration, arrival and surface velocities, and dynamics features at the flow surface. The sediment concentration is measured using direct buckets in the lower station every 5 minutes during the flow. The data analysis helps to compute the volumes of transported sediment, understand the flow dynamics, the processes of entrainment, and the rheology of the lahar material. From the stations we measure the time-related propagation of the flows down valley and the process of erosion / sedimentation through the DEM of the channel before and after lahars. The final goal is to calibrate the input parameters of two numerical models (Titan2D, VolcFlow) used in volcanic hazard studies.

**Keywords:** lahar, hydraulic characteristics, experimental measurements, flow dynamics, bulking, DEM.

\*\*\*\*\*

### **Lahar flow characteristics on Putih River during 2012-2013 rainy season after centennial eruption of Merapi**

WIBOWO S.B.(1), MOUROT P.(2), LAVIGNE F.(3), HADMOKO D.S.(4)

(1) Université Paris 1 Panthéon-Sorbonne, PARIS, FRANCE ; (2) Myotis S.A.S, ECHIROLLES, FRANCE ; (3) Laboratoire de Géographie Physique, MEUDON, FRANCE ; (4) Research Center for Disaster, YOGYAKARTA, INDONESIA

Three years after centennial eruption of Merapi volcano, rainfall-induced lahars still flow on Putih River. The first lahar flow in 2012-2013 rainy season occurred on 25 December 2012. The objectives of this study are to (1) compare lahar characteristics (arrival times, magnitude, flow turbulence) on upstream and downstream; and (2) to analyse lahar composition and material size distribution. We installed two stations consisted of 2 seismometers and 2 videos. Each seismometer are connected to 2 geophones 70 m apart. The upstream station is installed beside the new constructed check dam PU-D5 in Jurang Jero area (888 m asl; 7,1 km as the crow flies from summit) and the downstream station is located nearby check dam in Plosogede village (248 m asl). River length between these two stations is 16.51 km. Daily fieldwork is also conducted to measure water content in upstream channel bottom before event, take direct bucket sampling during the lahars and fresh deposit samples after its occurrence. We use handy talky communication to update very recent lahar flow information from local communities including occurrence, approximate velocity, as well as stage and width fluctuation between these two stations. Until 2 January 2013, 4 rainfall-triggered lahars have been recorded with 3 m maximum height, 30 m maximum width, 1 hour duration and velocities of 3-4 m/s (upstream) and 2.5-3 m/s (downstream). There was only one lahar which could reach downstream station. Lahar behaviors were different within each occurrence due to its magnitude, infiltration rate and previous water content of river bed, morphology of the channel as well as lahar materials.

**Keywords:** lahars, putih river, seismometer, video, infiltration.

### **The morphology of the Chaîne des Puys and Limagne Fault: a Linked Volcanic and Tectonic landscape**

VAN WYK DE VRIES B.(1), KERVYN M.(2), DELCAMP A.(2), MOSSOUX S.(2), LAGMAY M.(3), GROSSE P.(4)  
(1) *Laboratoire Magmas et Volcans, CLERMONT-FERRAND, FRANCE* ; (2) *Vrije Universiteit Brussel, BRUSSELS, BELGIUM* ; (3) *NIGS University of the Philippines, QUEZON CITY, PHILIPPINES* ; (4) *CONICET & Fundación Miguel Lillo, TUCUMAN, ARGENTINA*

The Chaîne de Puys stands as an 80 monogenetic volcano-long alignment, parallel to the Limagne Fault in Central France. The volcanoes stand on the elevated footwall of the fault. While both the Fault and Volcanoes have a general North-South orientation, smaller segments of fault and volcano alignments have a distinct NNE-SSW trend. The Limagne Rift initiated in the Eocene, but the structure may be a reactivated Hercynian structure related to large-scale strike-slip movements at the end of that orogeny. Some of the older lavas originating from the Tertiary volcanoes that erupted from the Chaîne de Puys site, have clearly been cut by the Limagne faults, while the more recent ones show little, if any tectonic effect. In addition, erosion along the fault scarp during the Quaternary uplift has resulted in relief inversion, with older lavas forming the plateaux and younger ones the valley bases. The southern part of the Fault and Chaîne are the least eroded, and the fault is less clearly expressed in this area over a wide set of down faulted blocks. Further north, the fault escarpment narrows, erosion increases and the Rift margin becomes far more pronounced. In this area NNE-SSW deep valleys are associated with fractures and mylonite zones, and the streams show increased nickpoints that may indicate more recent structural movement. It is in this area, that the volcanoes are most clearly aligned with basement structures, and that structures are preserved in the volcanoes to suggest contemporaneous tectonic activity. Thus, it appears that tectonics and magmatic activity are strongly linked and that both are guided by a Hercynian tectonic inheritance. Any renewal of tectonic activity in the area may link to a resumption of magmatic activity, and lava flows, will probably be channelled down the deep fault-scarp valleys to the populated urban areas at the fault scarp foot.

\*\*\*\*\*

### **Volcanic features of the central part of the Chaîne des Puys (Massif Central, France) revealed from the morphoquantitative analysis of a high resolution LiDAR-derived Digital Terrain Model**

LABAZUY P.(1), VAN WYK DE VRIES B.(1), BOIVIN P.(1), MIALLIER D.(2)  
(1) *Laboratoire Magmas et Volcans, Université Blaise Pascal-CNRS-IRD, CLERMONT-FERRAND, FRANCE* ;  
(2) *Laboratoire de Physique Corpusculaire, Université Blaise Pascal-CNRS-IN2P3, CLERMONT-FERRAND, FRANCE*

High resolution LIDAR-derived digital terrain models (DTMs) of volcanic areas permit to highlight subtle topographic features that can significantly improve the understanding of the morphology, the structure and the behavior of volcanoes during and after their formation. Here, we present an application focused on the central part of the Chaîne des Puys (Massif Central, France), a classic volcanic alignment of monogenetic volcanoes. The volcanic chain is located on the uplifted footwall block of the Limagne fault, near Clermont-Ferrand. This study has been done in the framework of a UNESCO world heritage proposal and it aimed at revealing the main topographic features of the studied area to understand the link between volcanism, faulting and tectonics. The main topographic dataset used is a 0.5-m resolution DTM with an average altimetric and planimetric precision better than 10cm, obtained from airborne LiDAR survey made in March 2011.

The monogenetic volcanoes of the Chaîne des Puys form an overall NS trend, showing distinct NE-SW elongations, and local NNE-SSW alignments. Basement fractures are predominantly NE and NNE-SSW orientated with minor EW and NS components. Using the high-resolution topographic data set we investigated the complex relationships between the construction processes of the volcanoes and the structure of the basement of the central part of the Chaîne des Puys. Therefore, the quantitative morphometric analysis of the LiDAR-derived DTM makes it possible constrain the evolution of the Puy de Dôme volcano, a large trachytic dome of kilometeric size and its relationships with surrounding small scoria cones and domes and inferred hidden intrusive features.

**The SEDIMER Project: Sediment-related Risks and Disasters following the 2010 eruption of Merapi Volcano, Indonesia**

LAVIGNE F.

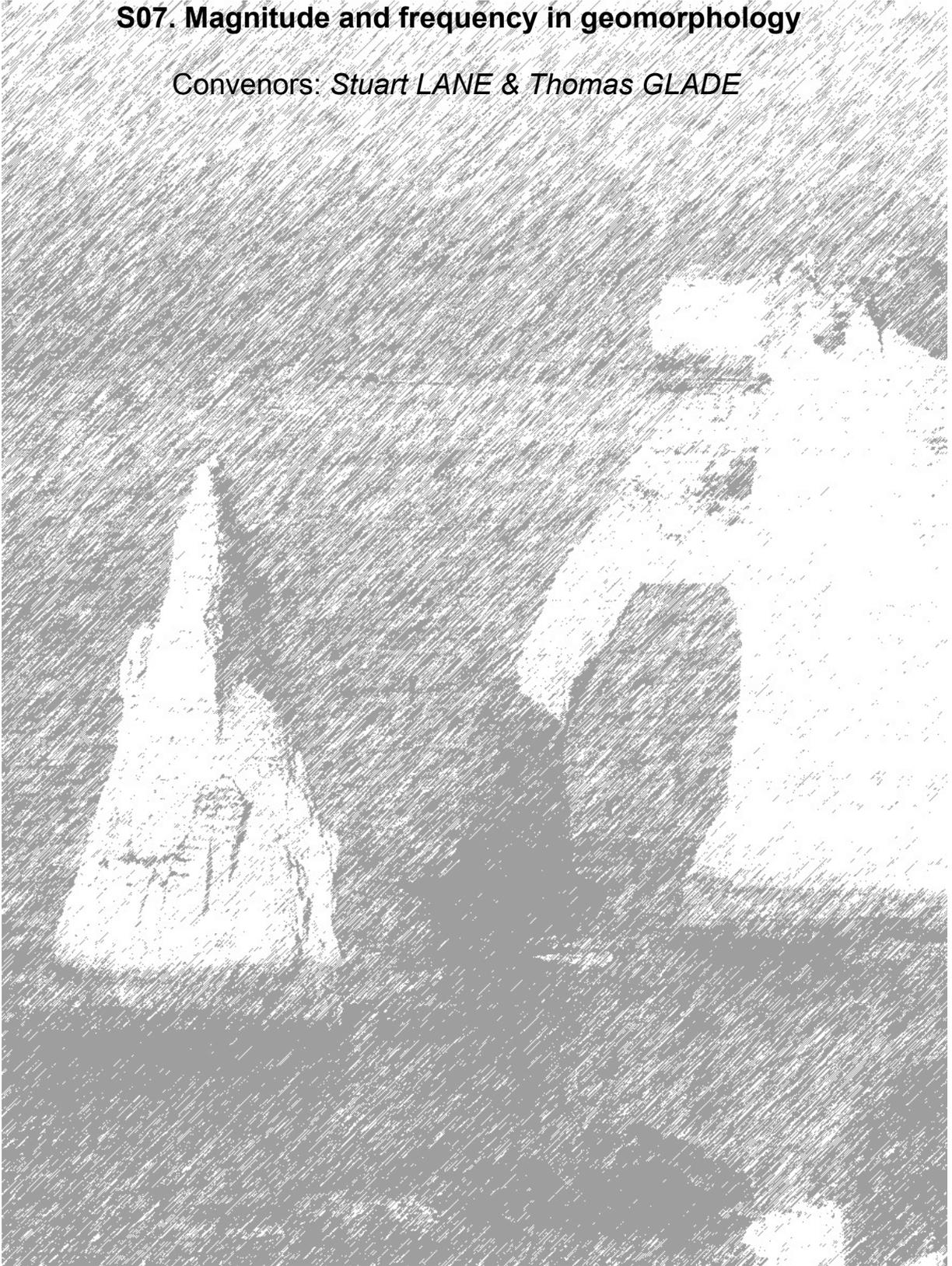
*Panthéon-Sorbonne University, Laboratory of Physical Geography, MEUDON, FRANCE*

The 2010 Merapi eruption has demonstrated that downstream areas can be impacted quickly and with economically devastating consequences by lahars and flooding in response to extreme sediment loading of watersheds by ashfall and pyroclastic flows. Funded by the AXA Research Fund, the SEDIMER Project (2012-2015) proposes a collaborative study gathering experienced international experts and young scientists from seven countries including Indonesia to determine what happened in 2010 and what is likely to happen in the next three years in the valleys downstream of Mt Merapi. We plan to complete a database on lahar occurrence and related disasters, to identify the sediment sources, to study the lahar dynamics and geomorphic impacts with implications for risk prevention. We will calculate the economic impacts caused by lahars and assess risk perception among local residents. This multi-disciplinary study will rely on a combination of innovative methods using high-tech instrumentation: optical and high-resolution radar remote sensing; hydrological monitoring based on various seismic and acoustic sensors, video footage of lahars in motion including nocturnal recording by infrared cameras; up-to-date modeling techniques; an innovative protocol for studying lahar depositional processes; and widespread surveys among risk managers and residents. In the shorter term, a better understanding of what is currently happening in the rivers downstream of the Merapi volcano can inform public policy with respect to rebuilding or relocating some villages and other facilities. In the longer term, the evidence gained can guide land-use and emergency-response planning in the vicinity of this volcano but also in other similar settings where sedimentation hazards during and following future eruptions are significant. The SEDIMER Interdisciplinary project will contribute to strengthening links between international networks working on lahars, regional networks of scientists from various institutions, field operatives, and populations at risk.

\*\*\*\*\*

**S07. Magnitude and frequency in geomorphology**

Convenors: *Stuart LANE & Thomas GLADE*





## **Oral presentations:**

### **Magnitude and frequency in geomorphology on changes and choices**

KORUP O.

*University of Potsdam, POTSDAM, GERMANY*

The steadily growing number of field and remote sensing data continues to underscore systematic inverse relationships between the magnitude and frequency of Earth surface processes, based on metrics such as mass-wasting volume, flood discharge, wildfire size, turbidite thickness, or sediment yield. Such frequency-magnitude relationships have turned out to be a useful tool, if not paradigm, for assessing the geomorphic efficacy of a given process, while serving as a quantitative basis for assessing concomitant natural hazards.

In the light of contemporary global warming and environmental change, however, current research interest has shifted towards quantifying potential changes to frequency-magnitude relationships in order to predict future consequences and regime shifts in Earth surface processes. This research focus raises a number of issues that have been partly disregarded in previous work mostly for reasons of mathematical convenience. Here I encapsulate and discuss some of these issues and highlight potential avenues of future research.

The most pertinent issues include (1) statistical means to distinguish reliably different frequency-magnitude relationships with a view towards the question of their particularity vs. universality; (2) the pitfall of confusing frequency with abundance; and (3) adequate choice of model fit, which eventually dictates our capability of meaningfully detecting changes to frequency-magnitude curves brought about by external changes. I outline possible solution pathways to resolving these issues by presenting several current examples from natural hazards research.

\*\*\*\*\*

### **Human-induced changes in geomorphic process rates: Can we gain new insights when analysing magnitude-frequency distributions?**

VANACKER V.(1), BELLIN N.(1), KUBIK P.W.(2)

*(1) University of Louvain, LOUVAIN-LA-NEUVE, BELGIUM ; (2) Lab for Ion Beam Physics, ETH Zurich, ZURICH, SWITZERLAND*

Very few, if any, geomorphic systems remain unaffected by human disturbances. An increasing number of quantitative studies are now available that show clear evidence of rapid acceleration of erosion as a response to human impact. While looking at overall changes in geomorphic process rates, most studies make abstraction of complex response and thresholds that may exist in geomorphic systems. Can we gain new insights on human-induced changes in geomorphic processes by analyzing magnitude-frequency distributions of geomorphic process rates ?

In this paper, we explore this idea by analyzing temporal changes in erosion rate-frequency distributions for two mountainous sites with very different human history: (1) the tropical Andes with a rapid conversion of native forests and grasslands to agriculture, and (2) the Spanish Betic Cordillera characterized by a long human occupation and recent abandonment of traditional mountain agriculture. Pre-disturbance erosion rates are derived from in-situ produced <sup>10</sup>Be concentrations in river sediment, and post-disturbance erosion rates are estimated from checkdam infillings. The erosion rate-frequency distribution then captures the spatial variation of erosion rates for a given location and disturbance level.

Our data show that overall shifts in erosion rates are largely controlled by the intensity of human disturbances. Furthermore, they also indicate that the local context matters as geomorphic response to human impact depends on the history and location of human disturbances. When including information on shifts in erosion rate-frequency distributions as a response to human disturbance, we can better grip the variety of potential response trajectories of geomorphic systems.

### **Event based magnitude/frequency analysis in geomorphology**

GARES P.(1), SWANN C.(2), HILL S.(3)

(1) East Carolina University, GREENVILLE, NC, UNITED STATES ; (2) Texas A & M University, COLLEGE STATION TX, UNITED STATES ; (3) National Atmospheric and Oceanic Administration, NEW ORLEANS, UNITED STATES

Understanding landscape evolution has been a traditional goal of geomorphology. At the same time, process geomorphologists have focused on establishing a scientific approach to understanding landscape change that often relies on reductionist analyses of geomorphic dynamics. Although these efforts have produced significant advances in earth system dynamics, it has been difficult to establish connections between micro-scale process studies and meso/macro-scale landscape changes. Geomorphologists often return to a field site to discover major changes in an intervening time period. Explanations for the changes often focus on large events that can be identified in the scientific record. Recognizing that events differ in size and frequency, Wolman and Miller became proponents of magnitude/frequency analysis that is widely used in fluvial geomorphology where extreme discharges are used to determine flooding probabilities. Using the single measure of peak annual discharge may not accurately represent the amount of work that the river system does. Geomorphologists are interested in all events capable of producing landform changes. Time is an essential component of geomorphologic magnitude/frequency analysis because, for events of equal magnitude, longer lasting events should produce more change than shorter ones. Although Wolman and Miller consider the overall geomorphic work done by events of different magnitude, event duration is not included in their analysis. To examine the combined effects of magnitude and duration, we examine aeolian and coastal storm events. We provide details about the methodologies used to determine event energies and the magnitude/frequency analysis employed to classify the events. Whereas there are sufficient data to facilitate the analysis of event energy, data about landform response to the events are limited. We illustrate how the response could be related to the process data and discuss potential problems associated with this analysis.

\*\*\*\*\*

### **The concept of frequency-magnitude relationship versus system dynamics in mountain catchments**

KEILER M.(1), FUCHS S.(2)

(1) Institute of Geography, University of Bern, BERN, SWITZERLAND ; (2) University of Natural Resources and Life Sciences, VIENNA, AUSTRIA

Torrent processes pose a threat to elements at risk exposed. In order to assess the hazardousness of such phenomena, firstly information on the probability of occurrence of the process is necessary, usually with respect to a defined design event. Secondly, this design event is characterised by a certain process magnitude. As a consequence, frequency-magnitude relationships are developed and used for hazard assessment and the subsequent management options considering natural hazard risk.

Traditional approaches are based on discrete hydrological events and a magnitude by measures of volume or mass of water and sediment associated with those events. They assume a direct relationship between the hydrological processes and the geomorphic response, such as the capacity of the water body to entrain and transport a certain amount of sediment in dependence of the shear stress and the grain size. However, such an assumption cannot be made considering torrent processes as once a major event has occurred in a catchment; time is required before sufficient material available for further events can accumulate. With respect to torrent events, internal system dynamics are responsible for a major limitation of frequency-magnitude relationships. Moreover, the relation between the trigger of torrent processes (e.g., precipitation intensity) and the system response of the catchment is nonlinear, therefore, even if empirical relationships propose a certain statistic relation they do not mirror the different system behaviour accordingly.

By analysing system loading and response scenarios, the challenge of system dynamics is treated in this paper and alternative concepts to express the frequency and magnitude of torrent processes are discussed. It is argued that such an approach can contribute to the discussion on an enhanced hazard assessment procedure which is targeted under the umbrella of the risk concept at a sustainable use of mountain environments for human settlement.

## **Magnitude and frequency scenarios for a changing alpine environment**

MANI P.(1), LIENER S.(1), TOBLER D.(2), HAEHLEN N.(3)

(1) *geo7 AG, geoscientists, BERN, SWITZERLAND* ; (2) *GEOTEST AG, ZOLLIKOFEN, SWITZERLAND* ; (3) *Civil Engineering Office Canton of Bern, THUN, SWITZERLAND*

In recent decades, large natural disasters have become more frequent in the Swiss Alps. Landforms such as debris flow cones and alluvial fans indicate that comparable events occurred in the past, however, for many areas, there are no historical records of such events available. It is likely that the higher temperatures and more intense rainfall associated with climate change contribute to this amplification.

For predictive natural hazard assessment and protective measure planning, effects due to climate change must be taken into account. In this regard, we present a new periglacial hazard index map for the Bernese Oberland based on hydro-meteorological scenarios. The used scenarios are derived from the new climate change scenarios for Switzerland (CH2011 (2011)). To evaluate changes in magnitude and frequency of natural disasters, we analyse the influence of these scenarios on various process chains. Changes in process chains are mainly due to glacier retreat, permafrost degradation, rise in snowline altitude, and increased duration and intensity of rainfall. The scenarios cover both mean and extreme values, which is particularly important for precipitation. Our scenarios also cover expected changes in variability. In this paper, we present our methods to derive the scenarios as well as first results.

CH2011 (2011), Swiss Climate Change Scenarios CH2011. C2SM, MeteoSwiss, ETH, NCCR Climate and OcCC, Zurich

\*\*\*\*\*

## **Flood Reconstruction and Implications for Magnitude-Frequency**

CROKE J.(1), THOMPSON C.(1), PIETSCH T.(1), SHARMA A.(2)

(1) *Australian Rivers Institute, BRISBANE, AUSTRALIA* ; (2) *DISiTA, BRISBANE, AUSTRALIA*

Twenty-two lives were lost in the Lockyer Creek floods in southeast Queensland (SEQ), Australia in the summer of 2011. The predicted recurrence interval for this event in the upper catchment was 1 in 1000 yrs. Flood predictions in these systems are, however, based on relatively short river discharge records (median 38). Given Australia's hydrologically-variable climate, understanding the frequency and magnitude of extreme events is important for regional planning. Immediately following the Lockyer event in January 2011, detailed stratigraphic and sampling for optically stimulated luminescence (OSL) dating sampling was undertaken in order to investigate magnitude-frequency relationships for extreme events in the catchment. Lockyer Creek is a laterally stable, non-migrating channel with well developed floodplains and levees. Samples were taken from both bedrock and alluvial reaches and from within the main channel in within-channel benches. This talk explores the process of statistically representing over 100 OSL dates from the catchment. Two methods were trialled, including Bayesian modelling, to extrapolate the timing of flood events to infer some evidence of changing magnitude. The results highlight the complexity of the task and the importance of emerging concepts such as nonlinearity in fluvial systems.

## **Landslide frequency-area distribution in the region north of Lisbon (Portugal)**

GARCIA R.A.C., OLIVEIRA S.C., ZEZERE J.L.

*Centre for Geographical Studies, University of Lisbon (CEG-UL), LISBOA, PORTUGAL*

This work is focused in the assessment of landslide magnitude and has two main objectives: (i) to compare and adjust the frequency-density distribution to a three parameters inverse gamma function; (ii) to establish a probability-magnitude curve for the north of Lisbon region to be used in landslide hazard analysis.

Field work and aerial photo interpretation allow identifying 2.104 landslides in an area of 319 square kilometers. The same methodological approach is applied to 3 different landslide data sets: (i) total landslides; (ii) shallow landslides (#1178); and deep landslides (#926).

Assuming that landslide area can be used as proxy of landslide magnitude, the probability-density function can be used to support the achievement of the probability of occurrence of landslides with a given magnitude. Additionally, it is possible to adjust this distribution to a three parameter inverse gamma distribution, as proposed for Malamud *et al.* (2004), as the best for characterizing general landslide distributions.

Previous results reveal that frequency-density curves applied to total landslides in the north of Lisbon region show a similar distribution to general curves obtained by Malamud *et al.* (2004). These distributions were marked by a power-law decay for medium and large landslides and an inflection of this tendency (rollover) on small landslides. The inflection location indicates the maximum probability distribution.

However, despite the similarity of the distribution pattern, the location of the inflection seems to be shifted to landslides with lower magnitude (area) when compared with the abovementioned general curves. Furthermore, the exponential decay of smaller landslides is not as significant as the reference distributions. These differences are probably due to the importance of shallow landslides in the total inventory (67%) that is associated with the field work inventory, which allowed to identify small landslides that cannot be identified using aerial photo interpretation.

\*\*\*\*\*

## **Poster presentations:**

### **Clusters of heavy rains at orographic barriers-geomorphic effects**

STARKEL L.

*Institute of Geography PAS, KRAKOW, POLAND*

Edges of mountains form the barriers for invading air masses or only provoke the formation of convective clouds. From a hydrogeomorphic point of view, very important is not only total rainfall and its intensity but also clusterings in several months or years. The particular forms or their complexes may proceed total transformation, change a trend of evolution or opposite, restore its previous shape. As examples may serve barriers of various height in different climatic zones. The southern edge of the Meghalaya Plateau, rising nearly to 2000 m, is getting 10-15 000 mm rain yearly and notes every summer about 37 days with above 1000 mm and 6-7 days with 300-800 mm. There are clusters above 2000 mm in one week. Intensities reaching several mm/min are restricted to small areas. These flash floods are connected with convective clouds and are responsible for washing up to bare rock. The highest global barrier of the Himalaya is blocking air masses. Every year are registered downpours at the very edge of mountains 1500-2000 m high. Those downpours up to 400-500 mm cause flash floods in small catchments, debris flows and upbuilding of torrential fans. In 1990-ties were recorded several clusters of continuous rains of cyclonic origin (2-4 days long with total rain up to 1000 mm). The cyclones enter deeper in the mountains very rarely. On the northern slope of the Carpathians with prevailing western winds there are two scarps exposed to N-NW. Therefore the role of barriers is restricted. The higher one (300-800 mm) at the margin of higher ridges blocked air masses four times in summer 2010, causing heavy floods and clustering of rainfall (totally 600-800 mm) is leading to deep infiltration and formation of landslides. The scarp of the Carpathian Foothills 100-200 m high can not be an important barrier for invading air masses. But it is sufficient to form convective clouds. Especially in some summers like 1995 or 2009 many downpours were recorded causing slope wash, earth flows and floods.

### Frequency of rockfalls in the permafrost-affected rock walls of the Mont Blanc massif in relation with post-glacial warm periods

RAVANEL L.(1), EGLI M.(2), BRANDOVA D.(2), KUBIK P.(3), DELINE P.(1), GRUBER S.(2)

(1) EDYTEM, LE BOURGET DU LAC, FRANCE ; (2) Department of Geography - University of Zurich, ZURICH, SWITZERLAND ; (3) Ion Beam Physics - ETH Zürich, ZURICH, SWITZERLAND

The characterization of the evolution of rockfall ( $> 100 \text{ m}^3$ ) in high mountain areas is a prerequisite to any risk management. This study aimed to collect and analyse data on past rockfall in the Mont Blanc massif in order to investigate the possible correlation between periods of warming and rockfall and, beyond, between permafrost degradation and rockfall. This required to compile exhaustive inventories and to compare them with climatic data.

We first documented the occurrence of the 58 rockfalls at the Drus and the Aiguilles de Chamonix, documented by photo-comparison since the end of the Little Ice Age (LIA) and direct observation in the recent period. We then crossed these rockfall data with available climate data. In the West face of the Drus, air temperature seems to control the triggering of the 12 documented rockfalls, as suggests by their concomitance with the hottest periods. The main one (2005,  $265\,000 \text{ m}^3$ ) seems to have been promoted by the combination of heat and heavy rainfalls, resulting in high fluid pressure in the rock fractures. Surface runoff has been observed in the scar of this event and massive ice was also observed after the rockfall of October 2011. The role of climate is also demonstrated by the analysis of the 46 rockfalls documented on the North side of the Aiguilles de Chamonix after the LIA, with a very strong correlation between these and the hottest periods: 70 % of the rockfalls occurred during the past two decades, characterized by the increasing global warming. Heat waves are particularly prone to rockfall: the maximum rockfall frequency occurred during the 2003 Summer heat wave.

To investigate beyond the last century and a half, we carried out surface exposure dating on 20 samples of granite from 6 rockwalls of the massif by the determination of  $^{10}\text{Be}$ -concentrations in their surface. The surface ages found vary from less than a few hundred years to tens of thousands years. These dates are generally corresponding to warm periods.

\*\*\*\*\*

### Linking events to landscape evolution - comparing two models

BAARTMAN J.(1), TEMME A.(1), VELDKAMP T.(2), JETTEN V.(2), SCHOORL J.(1)

(1) Wageningen University, WAGENINGEN, NETHERLANDS ; (2) ITC Faculty of Geo-Information, Science and Earth Observation, University of Twente, ENSCHEDE, NETHERLANDS

An obvious timescale gap exists between a single storm event and long term landscape development. In this study the event- and physically based OpenLISEM soil erosion model was compared to the landscape evolution model LAPSUS, deliberately extending and shortening the timescales for which each model was developed. Calibration of OpenLISEM using average erosion rates derived from long-term simulations with LAPSUS and, vice versa, calibration of LAPSUS on event-scale did not give satisfactory results, suggesting that the gap between the different timescales of both models is too large to be bridged directly. However, calibration of LAPSUS on annual basis using the summed OpenLISEM erosion and deposition values for each year resulted in a good reproduction of these values by LAPSUS. Thus, when keeping to the timescale that the model was originally intended for, but calibrating the model using simulation results from the event-based model, short-term variability could successfully be introduced in longer-term modelling of landscape development. Subsequently, the erosion effects of rainfall variability, climate and land use change were explored on a centennial timescale. Results show non-linear behaviour between rainfall input and simulated net erosion. Simulated net erosion for increased rainfall erosivity was compared to rainfall variability, showing that mean annual net erosion of up to 15% increased erosivity is not significantly different from annual mean net erosion of the original simulations. Single events must be very high and/or frequent to leave a signal in the landscape that is beyond the scope of natural rainfall variability. Scenarios of human impact show that land use changes can have a potentially larger effect on erosion dynamics than climate variability and change. This is the first time that an event-based erosion model and a landscape evolution model were calibrated for the same area and compared in terms of erosion and deposition dynamics.

### **Green alder encroachment on alpine pastures: potential for changing type, magnitude and frequency of erosion processes**

CAVIEZEL C., HUNZIKER M., KUHN N.J.

*Department of Environmental Sciences University of Basel, BASEL, SWITZERLAND*

In the European Alps economic and structural changes in agriculture lead both to a cessation of traditional pasture use causing reforestation of open landscape as well as use intensification of favourable areas. As one consequence, the Swiss national forest inventory noted an increase of shrub woodland in the period between 1983/85 and 1993/95 of 17.9%. Land use intensification often increases landscape susceptibility to erosion as shown in the greater frequency of shallow landslides under intensive pasture use in the main Ursern-valley in central Switzerland. On the other hand, the effect of land abandonment on erodibility is discussed controversially in literature.

Generally, vegetation improves the mechanical anchoring of the soil and the regulation of the soil water budget including the control over the generation of runoff. Green alder (*Alnus viridis*) for example, is used in bioengineering to mechanically stabilize slopes with its roots. Stabilizing effect of green alder stands on water budget has been reported. However, we found decreasing shear strength along a chronosequence stands of green alder encroaching on abandoned pasture areas in the Unteralp, a sidevalley of the Ursern-valley in the central Swiss Alps. This apparent reduction in internal friction of the surface regolith layer infers that the encroachment of green alder on former pastures may shift the type, frequency and magnitude of erosion events from individual shallow landslides on pastures towards a continuous creep of the soil not fixed to bedrock by the deep roots of the shrubs. The results also indicate that the effects of shrub encroachment on slopes steeper than the angle of repose must consider the effects on all potential erosion processes and not limit the interpretation of the results to the process dominating erosion under pasture.

\*\*\*\*\*

### **Restoring the geomorphology to magnitude-frequency analyses**

RICHARDS K.

*University of Cambridge, CAMBRIDGE, UNITED KINGDOM*

In some river basins the flood record clearly cannot be represented as a random sample from a single probability distribution; this may be more widespread. In many areas of risk assessment (chemical standards, volcanic hazards), a process-based methodology is preferred to the traditional reliance on arbitrary curve-fitting, which are inadequate when processes are non-stationary.

In flood hydrology, a (neglected) source of structured variability in probabilities is the basin geomorphology and network structure, especially in its interaction with the distribution and extent of runoff-generating processes. Kirkby (1976) showed, in convolution of the hillslope hydrograph with the network width distribution, that for large catchments the hydrograph shape mimics the width distribution. This assumed uniform runoff, when in reality, this is decreasingly likely as catchment area increases. There may be multiple process regimes of extreme events; in small drainage areas (< 10km<sup>2</sup>) the hydrograph mimics the input hillslope hydrograph; in intermediate basin areas (<1000km<sup>2</sup>) it may reflect the rainfall intensity coupled to a consistent flow routing pattern; and in large basin areas it reflects network structure, routing, and the specific locations where runoff is generated.

Because process controls vary between regimes, it is preferable to fit functions within regimes, but sparse data require simple parsimonious functions with few parameters (eg power functions). This paper uses examples to illustrate this regime behaviour. Peak flow magnitudes and frequencies reflect the probability of a rainfall-runoff event being routed from different contributing sub-catchments. This form of analysis lends itself to event-tree structures, involving chains of discrete probabilities (which can accommodate local non-stationarity), and is consistent with general approaches to risk management based on process-level understanding.

### Has sediment transport regime been changed by climate change and human activities?-An analysis of a large semi-arid river basin

MA Y.(1), HUANG H.Q.(1), NANSON G.C.(2)

(1) Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, BEIJING, CHINA ; (2) School of Earth & Environmental Sciences, University of Wollongong, WOLLONGONG, AUSTRALIA

The annual runoff and suspended sediment load in the Wuding River basin has decreased significantly since 1970s due to climate change and human activities (check dams, reforestation and plantation). However, it has not been clear whether the flow-sediment regime has been changed in the wake of decrease in runoff and sediment load. Here, a total of 11 sites with more than 30 years (1956-1989) of measurements were chosen to be representative of all type of rivers in three different geomorphologic regions. We analyzed the magnitude and frequency of sediment transport discharge (effective discharge) between the two periods (before 1970 and after 1970), using the methods proposed by Ma *et al.* (2010). The results show that the effective discharge has not been changed significantly. For the whole river basin, the effective discharge is generally smaller than the flows with exceedance probabilities of less than 2%, and the flows with exceedance probabilities of less than 1% transport more than 50% of the total sediment load. In the loess gully region, the effective discharge is the largest floods with exceedance probabilities of less than 0.1% and the flows with exceedance probabilities of less than 1% transport more than 50% of the total sediment load. The large floods in this region have high transport ability despite of low frequency. In aeolian sand region, the effective discharge is the median flows with exceedance probabilities of 30%-50%, and the flows with exceedance probabilities of less than 30% transport more than 50% of the total sediment load. In aeolian sand region low and/or median flows with high frequency are dominant. Consequently, we can draw a conclusion that climate change and human activities did not essentially alter the flow-sediment transport regime. The high variability of flow events and hyperconcentrated flows in the gully loess region, and the low variability of flow events and transport-limited flows are intrinsic and difficult to be altered.

\*\*\*\*\*

### The Spatial Magnitude-frequency Analysis Applied to Holocene Mass Movements in an Humid Tropical Brazilian Plateau

COLANGELO A.

Sao Paulo University, SAO PAULO-SP, BRAZIL

The Ahnert's (1987) semi-logarithmic magnitude-frequency model was adapted and applied in Holocene slump units, that had their deposits and scars mapped with airphotos. In this case, the magnitude-frequency index refers to the "Spatial Frequency" (Events/Km<sup>2</sup>) and "Spatial Recurrence Interval" (Km<sup>2</sup>) of mapped deposits and scars (Colangelo & Cruz, 1997, 2000 and Crozier & Glade, 1997). The work was performed in three near sample areas, São Carlos, Borba and São José basins, with respectively, Mica-schist, Migmatite and Granite Pre-Cambrian parent materials. The highest frequency of landslides was found at São Carlos area, with 331.210 m<sup>2</sup>/Km<sup>2</sup> of sliding area, represents 33,1% of total basin. For this area, the dominant event has 12.022 m<sup>2</sup> of extent, with spatial frequency of 5,2 events/Km<sup>2</sup>, performing 62.931 m<sup>2</sup>/Km<sup>2</sup>. Here, the event with 31.922 m<sup>2</sup> has the 1Km<sup>2</sup> spatial return interval. In the Borba area, with Migmatite, 191.766 m<sup>2</sup>/Km<sup>2</sup> corresponds to the sliding area, or 19,2 %. In this case, the dominant event has 4.563 m<sup>2</sup> of extent, with spatial frequency of 3,5 events/Km<sup>2</sup>, performing 16.092 m<sup>2</sup>/Km<sup>2</sup>, and the event with 10.314 m<sup>2</sup> has the 1Km<sup>2</sup> spatial return interval. For São José sample area, with Granite basement, 127.964 m<sup>2</sup>/Km<sup>2</sup> is the sliding area, or 12,8 %. Here, the dominant event has 7.467 m<sup>2</sup>, with spatial frequency of 1,39 events/Km<sup>2</sup>, that contributing with 10.382 m<sup>2</sup>/Km<sup>2</sup>, and the event with 9,928 m<sup>2</sup> has the 1Km<sup>2</sup> spatial return interval. These results show us that have a correspondence of the spatial magnitude-frequency distribution of landslides and basement, with its tectonic associated systems. The mass movements in the São Carlos area have the highest magnitude and frequency of all, contrasting with the lowest spatial magnitude-frequency distribution presented by São José area. This may be explained by elevated isotropy associated with granites, that confers a height porosity to the resulting gross material.

### **Extracting quantitative palaeoflood data from lake sediments: a case-study from Brotherswater**

SCHILLEREFF D., CHIVERRELL R., MACDONALD N., HOOKE J.

*University of Liverpool, LIVERPOOL, UNITED KINGDOM*

Assessing the importance of low-frequency, high-magnitude catchment processes, such as flood events, over long time-scales is a key goal in geomorphological research. The geomorphic effects of extreme hydrological events are effectively recorded by upland lake basins as efficient sediment trapping renders flow-related proxy indicators (e.g., particle size) reflective of changes in river discharge. We demonstrate that, with suitable chronological control and spatial replication, lake sediment sequences from Brotherswater, English Lake District, offer a valuable natural archive for addressing magnitude-frequency relationships of hydrological extremes over extended time periods.

A series of sediment cores (3 – 5m length) contain numerous coarse-grained laminations, discerned by applying high-resolution (0.5 cm) laser granulometry, and interpreted to reflect a palaeoflood record extending to ~2000 yr. BP. The chronology is well-constrained through integrating radionuclide (<sup>210</sup>Pb, <sup>137</sup>Cs and <sup>14</sup>C) dating with geochemical markers which reflect phases of local lead (Pb) mining. Geochemical and magnetic profiles have enabled precise core correlation and the repeatability of the flood stratigraphy to be verified.

Phases of increased catchment erosion are evident from down-core profiles of terrigenous elements (e.g., K, Ti, Zr), most likely due to changing land-use practices, resulting in fluctuating sediment supply through time. We also observe a threshold shift as progressively greater background Pb concentrations are recorded in the system in response to short-term pulses of mining pollutants. This non-stationary catchment conditioning may distinctly modify how magnitude and frequency of discrete flood events are reflected in their sedimentary signatures. We combine a multi-proxy palaeoenvironmental reconstruction with a grain-size standardization approach to assess the extent to which the lake sediment palaeoflood record can contribute to the magnitude-frequency debate.

\*\*\*\*\*

### **Late Quaternary extreme floods in the junction between the Alps and the Balkans**

FERK M., KOMAC B., ZORN M., ERHARTIC B.

*Research Centre of the Slovenian Academy of Sciences and Arts, Anton Melik Geographical Institute, LJUBLJANA, SLOVENIA*

The Classical Karst region in southwestern Slovenia is the northern part of the Dinaric Karst. It has been studied from several aspects for centuries, but what is known and understood about this complex karst system is still lacking in chronological data from the Pleistocene. Modern investigations have focused on analysing various sediment sequences in order to acquire a more complete interpretation of palaeoenvironmental conditions in the area affected by both Alpine and Mediterranean glaciation types. Caves turned out to be the most valuable and as-yet underutilized source of information about hydrological and climatological processes here, and consequently about the palaeoenvironment. The origin of sediments and sedimentation conditions were obtained through X-ray and granulometric analyses. The results show that the water-flow directions have not changed much since then. On the other hand, their extent was greater and the elevation of floods was significantly higher than in present hydrological conditions (i.e. during floods on karst poljes in present conditions the water table rises by about 10 m; however, in the past the floods were up to five times higher). Therefore, the floods were extreme from today's perspective. To establish the timeframe of the palaeofloods, flowstone from caves has been dated using radiocarbon <sup>14</sup>C and U-Th dating methods. The dating results place the palaeofloods to the late Pleistocene and early Holocene. These extreme hydrological processes, confirmed by morphological and stratigraphic evidence as well as by dating, could be related to different climate conditions. In the future we intend to compare and combine these results with similar data in the region with the purpose of improving the understanding of palaeoclimatic signals in the junction between the southeastern Alps and the northwestern Balkans.

### **A slope evolution index to estimate adjustments of hillslope morphology in relation to landslide processes**

DONNARUMMA A., REVELLINO P., GUERRIERO L., GRELE G., GUADAGNO F.M.

*University of Sannio, Department of Biological, Geological And Environmental Sciences, BENEVENTO, ITALY*

The morphological configuration of large areas is continually modified by gravitative processes. Among these, landslide phenomena have, as a consequence, the reduction of slope angles on reliefs at values which give a long-term stability.

In particular, in mountain landscapes, high landsliding frequency has a significant control on their morphology and landform. Slope angle is therefore a key parameter in evaluating the likely future evolutive trend of slopes by landslide processes.

Based on the assumption that the frequency distribution of the slope angle can be modeled by the 3-parameter Weibull probability density function (PDF), this study develops a synthetic index for the physical estimation of the morpho-evolution stage of slopes.

The index ( $I_{SE}$ , Slope Evolution Index), using the distinctive parameters ( $\beta, \eta, \gamma$ ) of the Weibull PDF, mathematically describes the shifting between the landslide area and stable area PDFs. Theoretically,  $I_{SE}$  may range from 0 to 1.  $I_{SE} = 0$  means there is no match between the PDFs of the landslide area and the stable area, resulting in areas where slope evolution through landslide processes should still start. On the other hand, when  $I_{SE} = 1$ , this corresponds to areas where mass movements are already totally exhausted and the PDFs of the landslide area and the stable area are completely matching.

The resultant  $I_{SE}$  may then be contextualized in a comprehensive model of slope evolution based on modifications in slopes geometry. The steepness is reduced by mass movements via the removal of unstable materials from the landslide source areas and adding them to the toe.

Several  $I_{SE}$  indices has been calculated for a geologically complex pilot area of the Samnite Apennines (Southern Italy), showing significant differences in relation to lithological shapes of some typical flyschoid formations.

\*\*\*\*\*

### **Modelling differences in catchment-scale sensitivity in neighbouring sub-catchments to the River South Tyne, UK**

MILAN D.

*University of Hull, HULL, UNITED KINGDOM*

Localised intense rainfall fell on three neighbouring tributaries (Knar, Thinhope and Glendue Burns) to the River South Tyne catchment on 17<sup>th</sup> July 2007. Thinhope Burn appeared to show responsive behaviour to the event with 2125 m<sup>3</sup> and 5202 m<sup>3</sup> of erosion and deposition occurring respectively within a 500 m reach (Milan, 2012), and full activation of the sediment system, including slope failures and peat slides. In contrast, the neighbouring catchments of the Knar and Glendue Burns showed limited reworking of the valley floor (robust behavior), despite receiving similar rainfall intensities in their headwaters. This paper uses a cellular landscape evolution model (CAESAR) to simulate the geomorphic response to varying magnitude flood events for the three neighbouring sub-catchments. Morphometric factors such as catchment area and valley slope are thought to be key agents in conditioning geomorphic response to flood events. Specific discharges for the Knar and Glendue Burns (1.1 and 1.3 m<sup>3</sup> s<sup>-1</sup> km<sup>2</sup> respectively), were most likely too small for threshold exceedance, compared with the 5.5 m<sup>3</sup> s<sup>-1</sup> km<sup>2</sup> estimated for Thinhope.

Reference: Milan, D.J. 2012. Geomorphic impact and system recovery following an extreme flood in an upland stream: Thinhope Burn, northern England, UK. *Geomorphology*, 138(1), 319-328.



**S7A - Extreme events in geomorphology (IAG-WG)**

Convenors: *Samuel ETIENNE & James P. TERRY*





## **Oral presentations:**

### **How does 'reshaping' Darwin's 'Subsidence Theory of Atoll Formation' broaden the scope of tsunami hazard assessment for the Pacific Islands?**

TERRY J.

*National University of Singapore, SINGAPORE, SINGAPORE*

Charles Darwin's subsidence theory of atoll formation, conceived during the voyage of the *Beagle* through the Pacific in 1836, has endured the test of time and thus commands a remarkable longevity amongst geomorphic paradigms. Darwin's theory conceptualized a subsiding volcano and the corresponding upward growth of its surrounding coral reefs - an outstanding contribution in the mid-19<sup>th</sup> century considering that plate tectonics had yet to make an appearance in Earth Science.

Darwin's hypothesis emphasised the general circularity of atoll shape. Perhaps surprisingly, this simple premise has rarely been questioned. However, few atolls in the Pacific Ocean actually exhibit such morphology, with most atolls possessing single or multiple arcuate 'bight-like' structures (ABLSs) along their reef rims. These departures from the circular form complicate the simplistic model of atoll formation and signal geomorphological processes which require further examination. ABLs are important since they are the surface expression of large-scale flank failures on the undersea volcanic foundations. Collapse features can occur during any stage of atoll formation and are a valuable addition to Darwin's theory because they indicate the instability of volcanic edifices. Crucially, the research community has recognized that sector collapses of island edifices are invariably tsunamigenic, although we have no clear understanding of how significant such events are on the broader canvas of tsunami sources.

Our inclusion of ABLs into Darwin's iconic theory should reinvigorate assessment of tsunamigenesis across the vast expanse of the Pacific Islands. The presentation is illustrated with examples of ABLs and associated tsunamis in atoll and atoll-like environments. Implications for our present understanding of tsunami hazards are profound, since in essence the significance of locally and regionally generated tsunamis throughout the entire Pacific Ocean is seriously underestimated.

\*\*\*\*\*

### **Large boulders accumulation along the NE Maltese coast: stormwaves or tsunami event?**

BIOLCHI S.(1), FURLANI S.(1), ANTONIOLI F.(2), SCICCHITANO G.(3), CUCCHI F.(1), DRAP P.(4), GAMBIN T.(5), DEVOTO S.(1), SALIBA D.(6)

*(1) University of Trieste, TRIESTE, ITALY ; (2) ENEA, ROMA, ITALY ; (3) Studio geologi associati T.S.T., CATANIA, ITALY ; (4) LSIS Laboratoire des Sciences de l'Information et des Systèmes UMR CNRS, MARSEILLE, FRANCE ; (5) University of Malta, VALLETTA, MALTA ; (6) Il-Majjistral Park, VALLETTA, MALTA*

The accumulation of large boulders related to waves generated by tsunami and extreme storm events have been observed in different areas of the Mediterranean such as the Ionian coasts of NE Sicily, the Apulian coasts, the Algerian coasts and Cyprus. It is known through historical records that very few large earthquakes occurred close to the Maltese Islands. The local seismicity is mainly related to the Malta Escarpment, the Sicily Channel Rift Zone and the Hellenic Arc.

At Armier Bay (NE Malta), large limestone boulders were found at an altitude ranging between 0 and 5 m a.s.l. The deposit is about 100 wide and the blocks are scattered on a gently sloping coast. The boulders, metric in size, belong to the Upper Coralline Limestone Formation and are Miocene in age. They are very similar in lithology and age to those studied along the Ionian Sicilian coasts.

The occurrence of marine encrustations (Serpulids) and the lacking of a calcareous cliff behind the blocks as a feeding zone, attest their marine provenance.

<sup>14</sup>C datings were made on three samples collected on different blocks in order to verify if their ages were comparable with historic tsunami events. A digital photogrammetric analysis was carried out in order to provide a precise measurements of the axes required by the Nott equation. This equation allowed to estimate the minimum wave height required for the detachment and the transport of the blocks: 15-16 m for storm waves and 3.80-4.10 m for tsunami waves. The first option seems too exaggerated compared to local wave heights, while the second one seems more realistic. Regarding <sup>14</sup>C datings, the first boulder is probably related to a storm wave event, both for its age (post 1950 AD) and small size. The second one could be related to the 1693 tsunami event (558-639 years BP), while the third to the 1169 tsunami event (1083-1205 years BP). In any case, tsunami events were originated by strong earthquakes occurred in correspondence to the Malta Escarpment.

**Dating tsunami deposits triggered by the catastrophic flank collapse of Fogo Island, Cape Verde Islands: insights from ESR, U/Th and <sup>36</sup>Cl ages**

*RIXHON G.(1), PARIS R.(2), MAY S.M.(1), ENGEL M.(1), BRÜCKNER H.(1)*

*(1) Institute of Geography, COLOGNE, GERMANY ; (2) Laboratoire Magmas et Volcans, CLERMONT-FERRAND, FRANCE*

Unstable volcanic islands may undergo massive flank failures triggering giant tsunami waves. Given the scarcity of observations, however, such high magnitude but low-frequency phenomena are still poorly investigated. In the Cape Verde archipelago, the steep shield volcanic edifice of Fogo Island displays such kind of an evidence, expressed by a massive failure scar opened to the east. The resulting mega-tsunami stroke the western coastline of Santiago Island, located ~60 km to the east of Fogo. The age of this twofold event (collapse and tsunami), and whether it happened during a sea level highstand or a lowstand are as yet open questions.

A cliff-top tsunami deposit was identified at elevations between ~6.5 and ~12 m a.s.l. in Tarrafal Bay, NW Santiago. The deposit (i) mainly consists of volcanic rocks (basalt, phonolite), (ii) is rich in marine macrofauna (bivalves, gastropods), and (iii) is partly composed of CaCO<sub>3</sub> cemented elements. It has a remarkable thickness of up to 5 m and contains rip-up clasts of a reddish palaeosol in its lower part. Given these morpho-sedimentary architecture, we adopted a multi-dating approach in order to yield a reliable age for the event and to crosscheck the results of the different dating techniques:

(1) ESR dating of bivalve mollusk shells (well-preserved Glycymerididae and Venusidae);

(2) U/Th dating of different kinds of marine fossils, such as (i) bivalve mollusks, (ii) branching forms of corals (Hydrozoan) and (iii) marine gastropods (Conidae, Strombidae);

(3) cosmogenic nuclide dating (<sup>36</sup>Cl) on basaltic elements of the deposit. Two sampling strategies were implemented: a surface exposure sampling on the largest boulders lying at the sediments surface, and a depth profile from the subsurface down to ~5 m, taking advantage of the unusual thickness for this tsunami deposit.

\*\*\*\*\*

**Effects of the 1755 tsunami on the southern coast of the city of Cadiz (Spain)**

*GRACIA PRIETO F.(1), ALONSO VILLALOBOS C.(2), MENANTEAU L.(3), BENAVENTE J.(1), DEL RIO RODRÍGUEZ L.(1), MÁRQUEZ CARMONA L.(2)*

*(1) Universidad de Cádiz, Facultad de Ciencias del Mar y Ambientales, Departamento de Ciencias de la Tierra, PUERTO REAL, SPAIN ; (2) Instituto Andaluz del Patrimonio Histórico, Centro de Arqueología Subacuática, CADIZ, SPAIN ; (3) LETG-Nantes Géolittomer UMR 6554 CNRS et université de Nantes, NANTES, FRANCE*

The historical tsunami generated by the Lisbon Earthquake (1<sup>st</sup> November 1755) had a considerable impact on the coasts of Portugal, southern Spain and Morocco. Geo-archaeological and geomorphological analysis of the shore of the Gulf of Cadiz provides insight into the erosive and depositional effects of the tsunami event, as well as the extent of flooding at various points along the coast. The data can be very useful for defining the areas that would be at risk in the event of a similar phenomenon in the future.

The city of Cadiz was hard-hit by the tsunami. Most of the southern part outside the walls was washed away by waves. This resulted in many casualties and the destruction of most of the infrastructures, including the only road linking Cadiz to the mainland across the tombolo and the Isla de León (San Fernando). Drillings and archaeological excavations have revealed gravel and sand deposits in different parts of the city, which help to define the extent of the affected area. These data together with those obtained from archives, eye witness accounts and early maps as well as geomorphologic analysis and mapping of the area allow us to determine the consequences of the tsunami and its influence on shoreline evolution in this sector of the Gulf of Cadiz over the last 250 years.

**The application of Ground Penetrating Radar analysis to investigate the impact and recovery of a coastal dunes and the recurrence interval of palaeotsunami events on the coast of Phra Thong Island, Thailand**

SWITZER A.(1), GOURAMANIS C.(1), LEE Y.S.(1), RUBIN C.M.(2), BRISTOW C.B.(3), JANKAEW K.(4), PILE J.(1), PHAM D.T.(1)

(1) Earth Observatory of Singapore, SINGAPORE, SINGAPORE ; (2) Division of Earth Sciences, Nanyang Technological University, SINGAPORE, SINGAPORE ; (3) Dept Of Earth Sciences, Birkbeck University College London, LONDON, UNITED KINGDOM ; (4) Dept of Earth Sciences, Chulalongkorn University, BANGKOK, THAILAND

This presentation discusses the application of Ground Penetrating Radar (GPR) and complimentary techniques to reconstruct the tsunami history of Phra Thong Island. The common techniques for investigating the impact, recovery and recurrence interval (palaeoevent history) in coastal systems are point source augering or pitting and/or trenching. These techniques are time and cost intensive. GPR presents a rapid, non-invasive, spatially-continuous technique for identifying subsurface stratigraphy. Although GPR facies are not diagnostic of a particular sedimentary characteristic, when combined with satellite imagery they do provide an avenue for reconstructing a tsunami impact and the post event recovery, or to help constrain the spatial extent of sandy deposits in the subsurface. Here we present results from two GPR survey campaigns at Phra Thong Island. The first aimed at investigating the large scale recovery of the coast using (100 MHz antennae) and the second a thin-bed approach aimed at imaging thin (<15 cm) sandy tsunami deposits and their associated structures using high-frequency (500 and 1000 MHz) GPR antennae complemented by auger cores. The tsunami impact and recovery was reconciled by two 100 MHz GPR profiles and quasi-yearly satellite imagery. The GPR revealed the depth and extent of tsunami scour along with the sedimentary history of post tsunami coastal aggradation (recovery). For the second program two swales with three distinct palaeotsunamis deposits recognised as discreet thin sand layers were examined. The bases of the swales are clearly evident as are the contacts between sandy and muddy layers, although these reflectors are less consistent across the profile, suggesting that the contacts between thin sand and mud units can be accurately imaged provided the units are thicker than ca. 10cm. Our investigations show that GPR can be used to rapidly and non-invasively assess tsunami post event recovery and to image sandy washover events in muddy swales.

\*\*\*\*\*

**Constraining bedrock erosion rates and processes during extreme flood events: case study in Iceland**

BAYNES E.R.C.(1), ATTAL M.(1), DUGMORE A.J.(1), KIRSTEIN L.A.(1), NIEDERMANN S.(2), CODILEAN A.T.(2)

(1) University of Edinburgh, EDINBURGH, UNITED KINGDOM ; (2) GeoForschungsZentrum, POTSDAM, GERMANY

Extreme flood events can be triggered by subglacial volcanic eruptions or dam failures and they are characterised by the release of vast quantities of water in a short period of time, with discharges potentially exceeding  $10^6 \text{ m}^3/\text{s}$ . During such events, the energy transferred to the Earth's surface can be considerable. Such energy transfer has the potential to significantly alter the landscape. This study examines the impact of extreme flood events (jökulhlaups) triggered by subglacial eruptions along the Jökulsá á Fjöllum River, North-East Iceland. In particular, the study analyses the bedrock erosion processes at work during the formation of both the Jökulsárgljúfur gorge system and Asbyrgi, a large canyon (3 km long, ~0.5 km wide, up to 90 m deep) that is now disconnected from the course of the current river. Terrestrial cosmogenic nuclide exposure ages ( $^3\text{He}$ ,  $^{21}\text{Ne}$ ) of abandoned strath terraces combined with detailed geomorphological mapping of landforms and an assessment of bedrock jointing demonstrate the mechanisms and magnitude of waterfall retreat within the Jökulsárgljúfur gorge system during the jökulhlaups that have occurred over the last 8 ka. The exposure ages also provide constraints on the exact timing of the flood events, allowing a detailed reconstruction of the evolution of the landscape following the flow events. Ongoing research is being undertaken to develop a numerical model that accurately replicates bedrock erosion processes and rates during jökulhlaups.

**Geomorphic implications of differential changes in the frequency of large rainstorms of varying return period: evidence from tropical and temperate environments, Borneo and South Wales 1906-2012**

*WALSH R.(1), ELLISON S.(1), JENKINS M.(1), BIDIN K.(2)*

*(1) Department of Geography, Swansea University, SWANSEA, UNITED KINGDOM ; (2) Scholl of Science and Technology, Universiti Malaysia Sabah, KOTA KINABALU, MALAYSIA*

Different landforms and rates of action of different geomorphological processes are influenced by rainfall events of often very different return period. Although increases in the magnitude and frequency of extreme rainstorms are confidently predicted by IPCC 2007 with continuing global warming in the 21<sup>st</sup> Century, predictions are vague as to the scale of changes and the return periods involved. Also most studies of change to date have tended to use relatively short periods of record rarely extending back beyond 1960, thus raising questions as to the longer-term context and meaning of any increases found. Using daily rainfall series extending back over a hundred years for three stations (Sandakan, Kota Kinabalu and Tawau) in the humid tropical environment of Sabah (Malaysian Borneo) and upland (Treherbert) and coastal (Swansea) stations in the humid temperate environment of South Wales, this paper presents evidence in both locations of major recent changes in rainstorm magnitude-frequency that, however, vary with the return period of the rainstorms involved. In both regions significant increases in the frequencies of rainstorms > 50 mm per day (events that produce major runoff events and sediment transport) have occurred since 1980, with an intensification of this trend since 1999 in the case of Sabah. Extreme value analysis, however, demonstrates that the rises only apply to return periods of 5 years and less and that to date daily rainfalls of >10 years return period have actually reduced in size. Impacts of these findings for a range of geomorphological processes and features in the two areas are considered. In South Wales, analysis of river flow records for the Taff catchment since 1958 shows a parallel rise in magnitude of flows of < 5 years return period and fall in the size of events of higher return period. The effects of recent changes on monitored slope wash rates, pipe erosion, landslide activity and sediment transport are presented and discussed.

\*\*\*\*\*

**Poster presentations:**

**3D modelling of boulder shape and volume using digital photogrammetric techniques. Applications in coastal geomorphology**

*GIENKO G.(1), TERRY J.(2)*

*(1) University of Alaska Anchorage, ANCHORAGE, UNITED STATES ; (2) National University of Singapore, SINGAPORE, SINGAPORE*

Until now, the size and volume of large boulders transported or emplaced on coasts, for example by storm and tsunami waves, can be assessed only inaccurately using traditional measurement techniques. A new methodology is being developed for improving the accuracy of boulder measurement using 3D-image processing techniques. In favourable circumstances, such data will enable better calibration of the power of pre-historical and recent high-energy coastal inundation events.

The research concentrates on creating precise, measurable and textured 3D models of coastal boulders without physical contact with the object. Active measurement techniques such as terrestrial laser scanning are less feasible due to complexities associated with setting up equipment in tidal areas (rough sea floor surface), exposure to harsh tropical environments (direct sunlight, high temperature and humidity), and low mobility of equipment (multiple parts, heavy weight, large batteries, and bulky packaging). Furthermore, raw data acquired in the field require significant post-processing in office.

Our alternative solution is based on close-range photogrammetric techniques. Low-cost equipment (waterproof digital cameras) can be used in various environments to acquire quickly dozens of images of the object of interest. Immediate quality control of the images is possible in the field. The 3D models, built from multi-view digital photographs, allow for reconstruction of precise, quantifiable and realistic-looking textured models of complex-shape objects, such as coral reef or volcanic boulders. Resulting 3D models can be measured in any dimension, including calculation of surface area and volume. Viewing is possible in 2.5D on a regular screen, or in full 3D using stereoscopic monitors and glasses. Preliminary results of boulder measurements from a coastal field site on the Island of Viti Levu in Fiji are presented.

**Identification of liquefied layers in a liquefaction induced by The 2011 Off the Pacific Coast of Tohoku earthquake in central Japan**

SETO M.(1), ASAI T.(2), KITAZAWA T.(3), NAKAMURA Y.(4), OGUCHI T. C.(1), TAMURA T.(3)

(1) *Saitama University, SAITAMA, JAPAN* ; (2) *Undergraduate student of Rissho University, KUMAGAYA, JAPAN* ; (3) *Rissho University, KUMAGAYA, JAPAN* ; (4) *Fukushima University, FUKUSHIMA, JAPAN*

The 2011 Off the Pacific Coast of Tohoku earthquake of  $M_w9$  induced liquefaction in various coastal and fluvial lowlands in northeastern and north-central Japan. At the playgrounds constructed in former back swamp of the Watarase floodplain, central Kanto, where seismic intensity of JMA scale seemed to be 6, several cracks were made around which water and sand gushed out. Although various liquefaction models have been presented based on a profile observation about the old liquefaction and laboratory experiment, few reports have identified liquefied layers on the site of liquefaction occurrence. We collected boiled sand and carried out boring investigations to loosely-deposited sand and mud alternation at four sites (sites A-D) to identify the layers which were liquefied after this mega earthquake. At site D, we had a 500cm deep core sample. We observed some layers; 0-30cm: artificial ground, 30-70cm: silt, 70-250cm: medium or fine sand, 250-400cm: clay, 400-500cm: medium sand. Ground water level was 200cm deep. Boring sites A, B and C were almost similar to site D. In comparison of granulometry and mineral composition of boiled sand with those of borehole-core samples below the watertable, we identified the liquefied layers, which were the medium and fine sand deposits around 200cm deep. All the liquefied sandy layers are correlated to the uppermost members of the Holocene deposits which were interpreted to have been formed during recent 2000years.

\*\*\*\*\*

**Some geomorphological remarks on the 2011 mega-earthquake in Northeast Japan**

TAMURA T.

*Rissho University, KUMAGAYA, JAPAN*

The mega-earthquake of  $M_w9$  broke out on 11 March 2011 off the Pacific coast of Northeast Japan. The thrust movements amounting to 50m occurred on very gently (10 to 15 degrees) westward-dipping plane extending to 500km long and 200km wide. The big eastward slippage of the overriding block resulted in an extensive subsidence zone in its western part, where not reverse but normal faultings occurred afterward. The phenomena show notable plate behavior in the passive margin. Two types of tsunami occurred successively within several minutes. The first relatively low surges invaded deeply into the coastal lowlands and deposited sand and mud in similar extent to that the 869AD tsunami deposits indicated. The second higher ones eroded sandbars and sea cliffs and destroyed constructions. Umitsu et al. and Iwafune present geomorphological analyses of tsunami flow in this conference. On liquefaction, Seto et al. report in this conference the detection of source subsurface deposits by granulometric and mineralogic analyses. Many landslides were induced on natural hillslopes in the zone of 250km from the axis of the hypocentral region. Much more number of small landslides occurred on both filled ground and cut/fill boundary in residential areas transformed artificially from undulating hill-landforms. Characteristic features of the slides are reported by Doshida et al. in this conference. The main facilities of Fukushima Daiichi Nuclear Power Plant, which were located on the ground cut down artificially from the flat marine terrace of 35m above the sea-level, correlated to MIS 5e, to 10m high, were destroyed by tsunami 15m high. Radiological dosage spread from the plant provides a record of combined processes from simple aeolian diffusion to very local overland- and stream-flow, and limited percolation, as some hydrogeomorphologists have traced. Geomorphologists' works as above must contribute to rehabilitation and hazard mitigation too.

### **Extreme Environment and Geomorphological Crisis : the case of the Messinian Crisis**

GARGANI J.

*Univ. Paris-Sud, ORSAY, FRANCE*

There are some times and places that are the centre of numerous catastrophic events. The Mediterranean area was certainly such a place during a brief period of time 6 million years ago. It was yet known that more than 2 km of evaporites were accumulated into the basin and deep canyons were incised when a sea-level drawdown of ~1.5km affected the Mediterranean Sea. This was the consequence of a complex influence of tectonic movement and global sea-level variation associated with climatic evolution. This dramatic event finished with the reflooding of the Mediterranean area. Here we show that during this catastrophic event, a landslide crisis also happened. We observe several landslides of Messinian age in various part of the Mediterranean Basin. These landslides could be due (i) to the relief created by the deep erosion and the bulge of the shoreline, (ii) to the reflooding that produced a pore pressure increase at the end of the Messinian Salinity Crisis. The Mediterranean was affected by a geomorphological crisis during the Messinian. This unique event triggered intense debates in the scientific community but also several reinterpretations outside of the scientific community.

\*\*\*\*\*

### **Extreme events and geomorphic crises: are they a kind of environmental crisis?**

ETIENNE S.

*Ecole Pratique des Hautes Etudes, DINARD, FRANCE*

The concept of 'environmental crises' and the use of the expression 'extreme event' appear more and more popular in the geomorphology literature. Eventually, they are used as synonyms, but sometimes replaced by the term 'geomorphic crises'. This talk will explore the history of these expressions and assess their semantic values. It appears that 'environmental crisis' is a concept with a triple dimension: scientific, ethical and political. The expression 'geomorphic crises' appeared in the 1960's, especially in the French-speaking research community, and was strongly linked to the paradigms of climatic geomorphology, meanwhile extreme events have been removed from researchers' considerations. The reason lies in that catastrophism has discredited for a long time any scientific acceptance of abnormal events (unpredictable and mostly unknown in historical times) so that they cannot enter any explanatory diagram of terrestrial landforms. Progress in the recognition of the importance of nonlinear dynamics and the application of the theory of deterministic chaos led the comeback of a reasoned catastrophism in Earth Sciences. The study of extreme events then appeared as a necessary branch of geomorphology more engaged with the concerns of modern societies (natural hazards).

## Historical embayed coastal evolution under a high energetic hydrodynamic event

RAMOS-PEREIRA A.(1), TRINDADE J.(1), COSTA A.(2), MARTINS J.(3)

(1) Centre Geographical Studies, Inst. Geography and Spatial Planning, University of Lisbon, LISBON, PORTUGAL ; (2) Associação para o Desenvolvimento da Univ. Porto, BRAGA, PORTUGAL ; (3) Laboratório Radiocarbono, IST/ITN, Univ. Técnica Lisboa; Univ. Algarve, LISBOA, PORTUGAL

The Estremadura Portuguese coast (NW of Lisbon) is a present day cliff coast with narrow embayed beaches, most of them with estuaries of small catchment rivers. The case study covers 2100m of coastline and an indentation ca 200-300m.

The research deals with the evaluation of the balance between fluvial and marine influences on sedimentary record, as well as the impact of extreme events.

The methodological approach is based on the bay morphometry, detailed 1cm sedimentologic analysis of core samples and sediment statistical determination, geochemical methods and radiocarbon dating, complemented by historical documents.

The results show an open sheltered lagoon until 1710-1830calBP, followed by a period of progressive infilling and the settlement of the current conditions (beach-dune system), during XIX century. Documents from XII century mentioned a relative large lagoon enough to feed the monks of an ancient monastery that was abandoned during the 17th century.

A question arises: the lagoon infilling would be the result of natural resilience related to previous sea level stabilization or/and the result of an extreme coastal phenomenon?

Some layers of sediments of the infilling period show a high energetic hydrodynamic event after 250±30BP and are probably the result of the tsunami that followed the Lisbon earthquake (1755).

The infilling episode that started post 1830calBP is considered to be the combined result of the system natural resilience after sea level stabilization, the anthropogenic intervention and the extreme hydrodynamic event. A paleolandscape coastal evolution model is presented and discussed.

### Acknowledgements

This research was funded by Project PCDT/CTE-GIX/104035/2008–FMI 5000-Environmental changes: Fluvio-marine interactions over the last 5000 yrs, from Portuguese Science and Technology Foundation (FCT-MCTES). Martins acknowledges the PhD grant SFRH/BD/45528/2008 and Costa projectscholarship CGUP-FMI500-BIM 2010, from the same institution.

\*\*\*\*\*

## Dating tsunami-induced transport of coral reef megaclasts on Bonaire (Leeward Antilles): a cosmogenic nuclide dating approach (<sup>36</sup>Cl)

RIXHON G.(1), BRÜCKNER H.(1), ENGEL M.(1), MAY S.M.(1), BINNIE S.(2), DUNAI T.(2)

(1) Institute of Geography, COLOGNE, GERMANY ; (2) Institute of Geology, COLOGNE, GERMANY

Onshore sedimentary records represent a valuable geo-archive to investigate Holocene high-energy wave events (tsunamis, storms). In contrast to fine sediments which have been subject of detailed sedimentological studies in the recent past, megaclasts in supralittoral position are less investigated. In particular, dating the time of their dislocation is still a major challenge in the research on extreme wave events. On Bonaire (Leeward Antilles), the transport of the largest coral reef boulders is attributed to Holocene tsunami event(s). Despite a large dataset of <sup>14</sup>C and ESR ages, it remains unclear whether these age estimates reflect the time of the initial dislocation.

We applied terrestrial cosmogenic nuclides (TCN, in particular <sup>36</sup>Cl) in order to date the transport event(s), *i.e.* the inferred tsunami(s). This dating method was hitherto disregarded in the coastal environment, particularly in the context of supralittoral megaclasts. Along the eastern coast of Bonaire, megaclast deposits were torn from the cliff edge of the MIS 5.5 coral reef platform and transported further inland by high-energy waves. The following characteristics of the megaclasts are fundamental for the success of the presented dating approach:

- (1) due to the lithology (aragonite, calcite), concentration measurements of <sup>36</sup>Cl were performed;
- (2) only large and thick megaboulders (>50 t, >2 m thickness) for which tsunami transport was inferred were sampled (five samples);
- (3) since the boulders stem from the edge of the coral reef platform, they had been exposed to cosmic radiation prior to the transport event(s) and had already accumulated a certain amount of TCN. To avoid this problem of inheritance, we only sampled (i) the thickest boulders, and (ii) boulders that had experienced a 180° overturn during transport; thus having exposed a “blank” side to cosmic ray only since the event. The complete overturn is attested by former rock pools and bioerosive notches in upside-down position.

### **Response of different land covers to an extreme event in the Spanish Pyrenees**

*LANA-RENAULT N.(1), NADAL-ROMERO E.(2), SERRANO-MUELA M.P.(3), GONZÁLEZ HIDALGO J.C.(2), ALVERA B.(3), SANJUAN Y.(3), GARCÍA-RUIZ J.M.(3)*

*(1) La Rioja University, LOGRONO, SPAIN ; (2) Zaragoza Univeristy, ZARAGOZA, SPAIN ; (3) Instituto Pirenaico de Ecología (CSIC), ZARAGOZA, SPAIN*

An extreme rainfall event occurred on 19-21 October 2012 in the central Spanish Pyrenees, as a consequence of the development of a large cutoff low system. Total rainfall values of approximately 200-300mm in two consecutive rain-showers of different intensity, triggered an extreme hydrological event in the Aragón River basin, with a flood of more than 1300 m<sup>3</sup> s<sup>-1</sup> at the tail of the Yesa reservoir, corresponding to a 100-200 years return period. The flood caused the occurrence of landslides and changes in the fluvial channel morphology, which affected roads and buildings. Since 1996 the Pyrenean Institute of Ecology (CSIC) monitors five experimental catchments in the area most affected by the rainstorm, allowing the record of discharges and suspended sediment concentration during the flood under different plant covers. This paper studies the response of such land covers to the extreme event, including the following scenarios: (i) a densely forest-covered catchment, (ii) a farmland abandoned catchment, actually covered with dense shrubs and small forest patches, (iii) an intensively eroded catchment, with the presence of active badlands, (iv) a catchment afforested with pines in the 1960s, and (v) a sub-Alpine catchment, dominated by grasslands with some eroded areas in the headwater. The authors discuss the role of forests and shrubs in controlling extreme hydrological events.

\*\*\*\*\*

### **Use of repeat aerial LiDAR to assess geomorphic impacts of the January 2012 Cyclone Dando floods on the Sabie River, South Africa**

*MILAN D.(1), HERITAGE G.(2), TOOTH S.(3)*

*(1) University of Hull, HULL, UNITED KINGDOM ; (2) JBA Consulting, WARRINGTON, UNITED KINGDOM ; (3) Aberystwyth University, ABERYSTWYTH, UNITED KINGDOM*

High quality topographic data enabling geomorphic change detection in dryland river systems is difficult to collect and is therefore rare. Aerial LiDAR now permits large complex river systems to be surveyed with great detail. This paper presents some initial findings of the geomorphic response along a 50 km reach of the Sabie River, Kruger National Park, South Africa, to a major flood ( $\sim 3000 \text{ m}^3 \text{ s}^{-1}$ ) during January 2012. Geomorphic changes resulting from this event were quantified through the use of repeat aerial LiDAR survey, specifically by comparing 2005 data with a new survey flown in May 2012. Change detection was assessed through DEM subtraction, whereby spatially distributed error within each surface is assessed through an assessment of the relation between local surface roughness and vertical error. The results reveal widespread sediment redistribution, with net sediment loss from the system, and with both alluvial and bedrock dominated channel types affected. Channel response by channel type was inconsistent, and was thought to be related to remnant fragments of cohesive anastomosed channel that survived a larger ( $\sim 7500 \text{ m}^3 \text{ s}^{-1}$ ) event in 2000. Isolated sediment accumulation was also found to be associated with less active tributary junctions. The overall system response appears to one of partial stripping to both the 2000 and 2012 events, with the removal of large bar units in the alluvial sections of the river, but with no evidence of total stripping. The findings of this investigation allow for the development of a revised model of dryland river system response to large flood events that will be applicable both regionally and possibly to similar mixed bedrock-alluvial, vegetation-influenced, dryland rivers.

## Reconstruct the spatio-temporal distribution of Xiakou landslide using Dendrogeomorphological method

HONG T., BAI S., WANG J.

*Nanjing Normal University, NANJING, CHINA*

The research of landslide magnitude–frequency is necessary for landslide hazard assessment. Dendrogeomorphological techniques allow us to determine the frequency of events, also it is available to use the distribution of disturbed trees to reconstruct the magnitude and spatial distribution of landslide. The main goal of this research is to reconstruct the magnitude and frequency of the landslide using tree-ring analysis.

The study area is located in the middle of Sichuan Province in China. This landslide is a thrust load caused soil landslide located in the left side of Longxi River. The large landslide has a length of 650 m and a width of 470 m. The landslide area is about 0.31km<sup>2</sup>, the average depth is 28.7m, the mean slope angle is 32°. In the field, a standard borer was used to drill fir trees on the landslide body and to extract samples. In total, 75 fir trees were sampled in the landslide area, while 16 fir trees were taken in a stable slope as reference trees. The stable slope is about 2 km east of the landslide. Four cores were taken each tree at the breast height (about 130cm). 222 core samples were taken to the laboratory in total and tree-rings were measured by microscope analysis.

We found ten re-activities (1987,1988,1989,1992,1993,1995,1997,2004,2006,2007) using dendrogeomorphological method, three times of them (1987,1995,2006) consistent with the local archive records, and calculated the return period and frequency of the landslide. The highest probability of reactivation is in the south part of the landslide.

\*\*\*\*\*

## Geomorphological effects of extreme precipitation in 2010 in selected parts of the Polish Carpathians

BOCHENEK W.(1), GIL E.(1), KIJOWSKA-STRUGAŁA M.(1), KISZKA K.(1), WIEJACZKA Ł.(2), RĄCZKOWSKA Z.(2)

(1) *Institute of Geography and Spatial Organisation, PAS, Research Station in Szymbark, SZYMBARK, POLAND* ; (2) *Institute of Geography and Spatial Organisation, Polish Academy of Sciences, Department of Geoenvironmental Research, KRAKOW, POLAND*

Extreme rainfall occurred in the Polish Carpathians in May and June 2010. At the Research Station in Szymbark total rainfall in May constituted 224% of long-term average total monthly rainfall for May, and 25% of average total annual rainfall. Rainfall total for period 1 of May – 4 June was 375.5 mm, with daily maximum total 107.0 mm, and maximum intensity = 28 mm/h and 7.2 mm/10 min.

Differentiated spatially, geomorphological changes was observed both on slopes and in river channel. On slopes there was intense runoff, measured on experimental plots in Szymbark. Overland flow and throughflow showed, however, important differences, particularly in relation to drainage outflow, which affect dynamics of geomorphological processes. During heavy rainfall water flowing on surface of the plot was a 123% of drain flow, but during continuous rainfall this share was about 11%. Many landslides were triggered or rejuvenated. Besides shallow landslides, especially in the Beskids, have started deep, rotational landslides. At the Carpathian Foothills, on the area with dust rill erosion produced, at area of 0.25 ha, 53 shallow fills, which carried out 103 tons of soil and two deep gullies, reaching of 270 cm depth, which carried out 640 tons of material.

In the Ropa river channel, above the Klimkówka reservoir, accumulation and channel widening up to 7-8m dominated, while below it erosion and deepening of river bed up to 40cm. Effects in small stream channel belongs of valley bottom character. In the Bystrzanka channel numerous erosive cuts of banks, up to 2 m high, bank retreat up to 10 m, point and central bars of various size and shape were observed along whole length of channel. The Bielanka channel also experienced transformation by erosion. It was estimated that up to 500m<sup>3</sup> of material in cross section, in its mouth part was eroded.

**Extreme or ordinary processes? Facts and thoughts on geomorphic scales in the Himalayan Mountains**

FORT M.

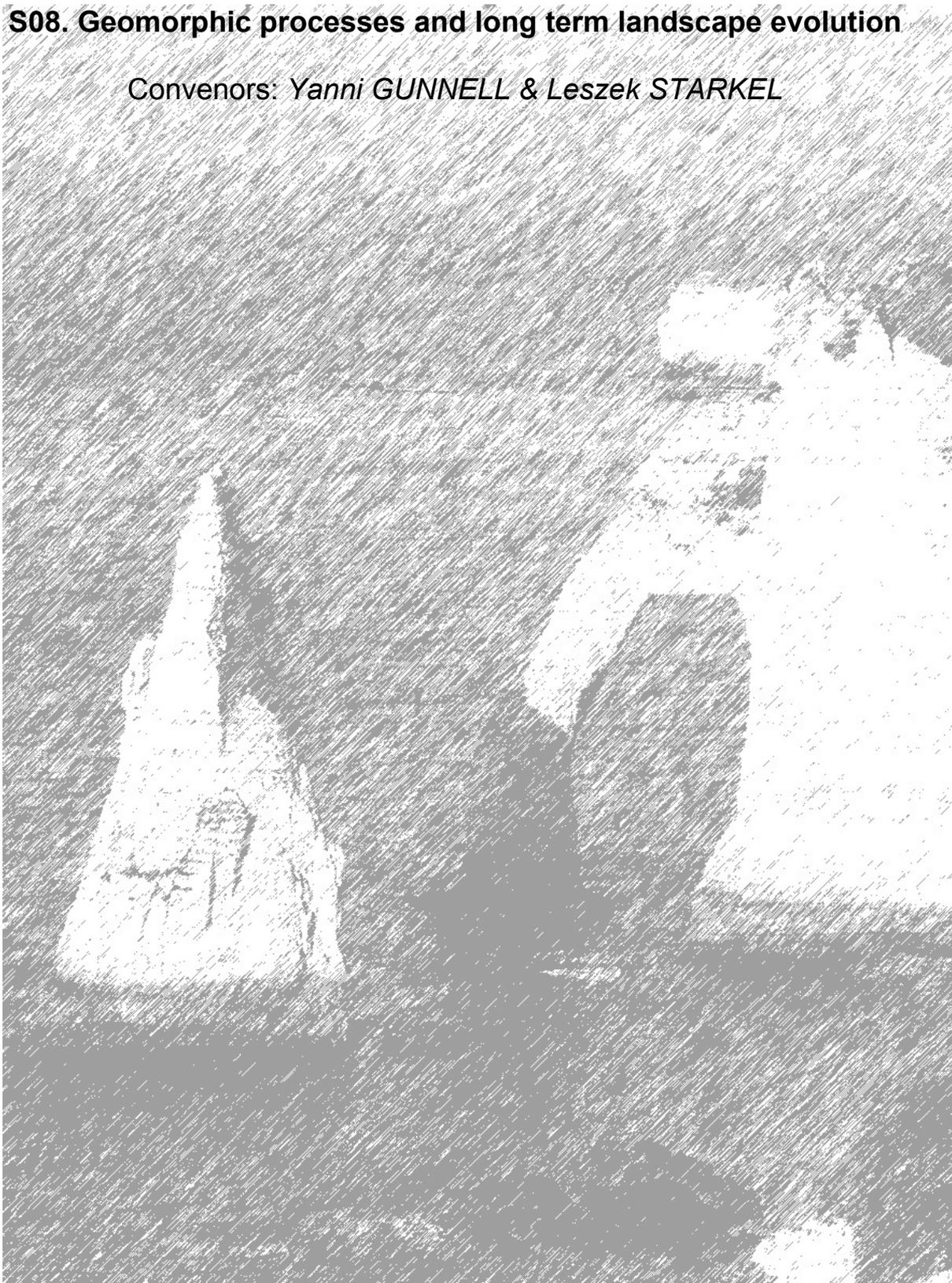
*Université Paris Diderot, Sorbonne-Paris-Cité, CNRS-UMR 8586 PRODIG , PARIS, FRANCE*

The Himalayas are the highest mountains in the world. The erosion work, as expressed by several km deep fluvial valleys and giant (more than 1km<sup>3</sup>) landslides, relies on tectonic and climate forcing. It supplies the largest sediment fluxes on earth, trapped in piedmont megafans (such as Kosi) or in submarine Bengal and Indus fans. The contrasted monsoon climate exerts a strong control on environmental characteristics (river discharge, pore pressure in soil, vegetal cover) hence in geomorphic processes acting seasonally at all spatial scales. We document a few geomorphic features (landslides, debris flow, floods) that may be considered as “extreme” according to alpine standard yet that are “ordinary” features, fairly common in the Himalayan Mountains. Whatever the time and spatial scales considered, it appears that despite regional differences, most of Himalayan landforms are shaped by, processes that are persistent in time. Yet, nowadays their impacts represent a major threat for Himalayan populations, whose increasing density make them more vulnerable to geomorphic hazards, as exemplified by the Higher Himalaya in Central Nepal, characterized by the highest gradients (elevation, slope, rainfall) and rates (uplift, fluvial incision, denudation) ever recorded along this mountain range.

\*\*\*\*\*

**S08. Geomorphic processes and long term landscape evolution**

Convenors: *Yanni GUNNELL & Leszek STARKEL*





## **Oral presentations:**

### **The Quaternary transformation of inherited older mountain landscapes**

STARKE L.

*Institute of Geography PAS, KRAKOW, POLAND*

The transformation of inherited relief during Quaternary is controlled in the mountains by three factors: climatic changes, resistance of substratum and neo-tectonic uplift. The climatic cyclic fluctuations in the lower elevations of Eurasian mountains are reflected in the alternation of interglacial stages with forests, subsurface runoff, chemical weathering and of cold stages with treeless vegetation, permafrost, prevailing overland flow, solifluction, wind activity and at higher elevations in advances of glaciers. In this progressing degradation an important role play the transitional phases of rebuilding of water circulation, which transfer the regolith and deposition from a previous phase. It is related both to early glacial removal of interglacial soils and to lateglacial replacement of periglacial deposits. The rate of degradation of inherited Tertiary planation surfaces and slopes depend on resistance of bedrocks. In case of flysch deposits the degradation during one (last) cold stage fluctuate from centimeters to 10 meters. Therefore the higher planated levels are better preserved on the beds of higher resistance reflecting structure – controlled features. Frequently the lowest piedmont along rivers on less resistant beds was lowered to 50 m and more. In the young mountains the Quaternary uplift may play an additional role. The incision is progressing upstream. Therefore especially in headwaters older surfaces are much better preserved and former pediments under permafrost regime may be transformed into cryopediments. In case of higher rate of Quaternary uplift reaching 2 km in the Himalaya or Pamir the whole fluvial forms were shifted to cryonival or even nival (glacial) vertical zone. The former V- shape valleys undergo extension to wide and deep troughs and on narrow ridges appear cryoplanation terraces. The glacial overdeepenings and thresholds may be initiated on the pre-Quaternary steps limiting younger incision from hanging headwaters.

\*\*\*\*\*

### **Impact of late-Cainozoic climate change on orogenic relief development**

VAN DER BEEK P.

*Institut des Sciences de la Terre, Universit\_ Joseph Fourier, GRENOBLE, FRANCE*

Over the last two decades, multiple feedbacks between tectonics, climate and erosion have been identified. In particular, late-Cainozoic climate change, characterized by overall cooling and increased climatic variability, has been suggested to be responsible for increased erosion rates as well as uplift of mountain peaks through the isostatic response to erosion. Pliocene-Pleistocene increases in sediment flux have been reported from many major mountain belts. It has been suggested this is a global signal in response to increased climatic instability, although recent work suggests that at least part of the signal may be intrinsic to the nature of the sedimentary record. An initial analysis of thermochronology data from the European Alps appeared to support the Pliocene increase in erosion rates. However, recent more detailed work, based on numerical inverse modelling and the use of new high-resolution thermochronometers, suggests locally decreasing erosion rates during that time. In contrast, the new data imply a significant increase in relief through focussed valley incision since mid-Pleistocene times (~1 Ma), which can be related to efficient but highly localised glacial erosion due to extensive glaciation of the Alps triggered by the mid-Pleistocene climate transition. The isostatic response to glacial valley carving may explain part of the surprisingly high measured geodetic uplift rates in the western Alps and may also contribute to the current extensional deformation observed within the core of the mountain belt. Thus, it appears that this recent climatic change had a significant impact on the mountain belt by enabling more focussed and efficient glacial erosion of topography. Confirmation of this hypothesis awaits more detailed analyses of the recent erosional, relief and tectonic history of glaciated mountain belts worldwide.

### **Factors determining the impact of glacial erosion on shield surfaces**

EBERT K.(1), HALL A.(2), KLEMAN J.(1)

(1) Stockholm university, STOCKHOLM, SWEDEN ; (2) University of StAndrews, STANDREWS, SCOTLAND, UNITED KINGDOM

The erosional effect of ice sheets on shield bedrock surfaces has been debated for many decades. Whilst there seems to be agreement that ice sheet erosion of the bedrock landforms was generally modest, and that many preglacial landscape elements remain, we need to know which factors influence ice sheet dynamics and erosional impact on the shield. Using GIS-analysis and field observations, combined with cosmogenic exposure ages, we investigate areas with a similar ice cover history but with greatly different degrees of glacial erosional impact. On two transects with an area of ~35 000km<sup>2</sup> each across the shield, we examine why glacially eroded areas exist adjacent to areas of negligible glacial erosion. Firstly, a E-W transect, identifies two areas of exceptional glacial preservation, the Parkajoki area in Sweden and the so-called ice shed zone in Finland, each with large tors and deep saprolite covers. Secondly a NW-SE transect, overlapping in the northern part with the first transect, includes areas of intense glacial streamlining, with bedrock areas stripped of loose material and barely any weathering remnants. For areas of negligible and advanced glacial erosion, we investigate geology, elevation, topography, hydrology and duration of ice cover in an attempt to identify factors leading to ice sheet erosion/preservation of the underlying shield landscape. We estimate the duration of ice cover from the known ice cover history. We use a single flow path and thereby use steady glaciological parameters. Our results point to glacial bedrock erosion of flat shield surfaces in the range of tens of meters. Erosion only happens in areas where the ice is forced to flow around obstacles or into basins. These preglacial landscape properties are in turn determined by bedrock geology and long-term geomorphic and tectonic evolution. Consequently, a combination of bedrock type and topography determines ice sheet properties and thereby effects of ice erosion on shield surfaces.

\*\*\*\*\*

### **Duricrusts in the Borborema highlands, northeastern Brazil: a climatic and structural approach**

TAVARES B.A.C., BARROS A.C.M., CORRÊA A.C.B.

Universidade Federal de Pernambuco, RECIFE, BRAZIL

The genesis of the duricrusts is closely related to the landscape evolution in tropical environments. The highly evolved lateritic crust has a strong influence in the local features placemen, although the most important is the vital connection between the surface materials and the total landscape building. In order to support these premises, the origin of the laterites and its relation to the summit surfaces evolution in the Borborema Highland turns out to be significant, once these highlands sectors is interpreted as residual massifs from the classical models of landscape evolution, without add a structural component to the morphogenesis analysis. Therefore, this research was conducted in the summit surfaces of the Borborema Highlands, northeastern of Brazil. The study area is characterized as one of the highest surfaces of Borborema, with summits reaching 1.200 meters and three defined intramontane plains. There are lateritic crusts widespread along the flat summits and occur as pisoliths in colluvium and soils found in the steepest slopes of the massif. From the evidences of laterites along the summits surfaces, it was produced a structural mapping with the crusts location, presenting the relation of the duricrusts position and its possible connection to the highland genesis. The data, enable inferred that the evolution of the highest levels of the massif is consistent with the intramontane plain evolution models, where these sectors evolve through tectonics controls and development of lowered areas followed by a tectonic inactivated sequence enabling lateritic crusts build in the summit surfaces. The formation of these duricrusts is linked to the tectonic stability of an area, however tectonics controls in the studied place is keeping those elevated areas with high altimetry differences between the summits surfaces and the lowered areas being this scenario only possible with the reactivation of old shear zones in the Borborema Highlands.

**Geomorphological evolution of the Armorican massif (Western France): a base Upper Cretaceous wave-cut platform degraded in a tropical setting until Late Miocene**

BESSIN P.(1), GUILLOCHEAU F.(1), ROBIN C.(1), BAUER H.(2), SCHROËTTER J.M.(3)

(1) Géosciences Rennes, RENNES, FRANCE ; (2) BRGM, ORLÉANS, FRANCE ; (3) BRGM, SGR Bretagne, RENNES, FRANCE

The Armorican massif is one of the four main variscan basements outcropping in France. Its geomorphological study has been performed since at least one century with the classical works of E. de Martonne, R. Musset, A. Guilcher, A. Meynier among the other ones.

This relief is characterized by numerous planation surfaces, sometimes associated with different types of weathering as laterites, silcretes, calcretes or clays with flints. Surimposed on these surfaces, thin sediments deposits of four different ranges of ages are preserved: Ypresian to Lutetian marine deposits, Bartonian to Rupelian marine to continental sediments preserved in several grabens, Langhian to Serravalian marine deposits and Tortonian to Gelasian marine to continental sediments. These last ones are contemporaneous of a major change of climate, from tropical to temperate, during Late Miocene to Early Pliocene period.

We performed a geomorphological study of those surfaces and associated pediments, weatherings and sedimentary deposits.

DEM (SRTM, 3 arc-seconds resolution) analysis and field controls were used to produce a macro-geomorphological features map.

At least, three types of planation surfaces were defined prior the Late Miocene climate change. They record an overall base level change, which could be due to both tectonic uplift in response to Africa-Iberia-Eurasia convergence and eustasy, and are thereafter listed from high to low levels:

- i) The Cenomanian high surface, a wave-cut platform surimposed on Lower Cretaceous alterites;
- ii) The Paleogene pediplains, composed of pediments with some preserved laterites, silcretes and calcretes, which is sealed by Bartonian deposits;
- iii) The Neogene pediplains and pediments, less weathered and sealed by Langhian to Serravalian deposits.

These planation surfaces and pediments are later incised, first by the "Red sands" system of Tortonian to Gelasian age, and second by the present-day river system since its incision at the end of the Early Pleistocene.

\*\*\*\*\*

**Paradoxical topographies: the example of Betic chains**

FARINES B., CALVET M.

Laboratoire Medi-Terra EA 4605 Université de Perpignan Via Domitia, PERPIGNAN, FRANCE

The chains crowned by post-orogenic planation surfaces are a singular but usual case. They raise the problem of the genesis and the lifetime of transient landscape in total disequilibrium with the internal and external forcing. We present here the example of the Betic Chains, where these planation forms were ignored by the geodynamic works of the last decades. Two generations of forms, in two spatio-temporal scales, recover from geomorphologic singularity. Extended culminating (1200 – 1900 m) surfaces exist on the eastern internal ranges (Sierra de los Filabres, Sierra Nevada, Sierra de Gádor and Sierra Alhamilla) but also on the whole chain. The mapping on DTM confirm their extension; the chronology and the facies of neogene sediments basins, crossed with available thermochronologic datas, demonstrate a very late completion of these forms, in pre-evaporitic Messinian. The gravitational collapse and the post-orogenic neogene extension, now revealed in the Betic chains, provide the favorable structural context to their realization. The second generation of forms is inscribed in the first half of the Quaternary: it's about partial erosional plans, pediments, rocky fans, very flared paleo-valley, karstic poljés. These evolved landscapes, actually very perched at 400 to 900 meters of height, precede a major phase of dissection, particularly intense and extended until the current, the tectonic driving of which seems obviously attributable to the lithospheric detachment of slab. The image that results from it, when these peculiarities are taken that are local and regional planation forms, is thus the one of recent, fast and jerky surrection of Betic chains and not of a continuous movement of emersion since the seas of the Miocene, such as up to here postulated from these only sedimentary markers.

### Numerical simulations of Plio-Quaternary landscape evolution of the Iberian Chain (Spain)

GIACHETTA E., SCOTTI V.N., FACCEENNA C., MOLIN P.  
Roma TRE University, ROME, ITALY

The Iberian Chain is an intraplate range located in the central-eastern Iberian Peninsula, showing a dome-shaped topography characterized by a low relief landscape located at a mean elevation of 1300 m. The mountain range results from the late Cretaceous-middle Miocene compression. During the Upper Neogene, compressive structures experienced planation processes presently recorded by wide erosion surfaces. Since about 2.5 Myr (?), a regional tectonic uplift occurred guiding the organization of the present fluvial network. We performed numerical experiments to simulate landscape evolution characterized by the same tectonic and erosion inputs of the Iberian Chain area, using a range of physical parameters calibrated on field, radiometric and morphometric data. To test the evolution of different initial topographies, we used SIGNUM, a Matlab, TIN-based landscape numerical model. The results show that the initial topography that better matches the geomorphological features encountered in the present-day landscape consists of a wide plain with a slightly higher relief to the NE. This plain was surrounded by endorehic areas. After running the SIGNUM, this initial synthetic landscape evolves into a topography that reaches a mean elevation quite similar to the Iberian Chain high-standing plain, preserves small internally drained areas in its interior and is poorly incised by hydrography. Our results, coupled with geological and geomorphological data, allowed us to conclude that:

- 1) in Miocene-Middle Pliocene a relief of few hundred meters was located in the NE sector of the Iberian Chain; lakes occupied the rest of the present range;
- 2) in Late Pliocene-Quaternary a regional uplift occurred, causing the progressive capture of endorheic lakes;
- 3) the time span necessary to obtain a synthetic topography morphologically similar to the Iberian Chain is almost 3 My. This indicates that the uplift onset could be Late Pliocene-Early Pleistocene in age.

\*\*\*\*\*

### Geochronological constraints on the weathering, exposure, and erosional histories of the Second Paraná Plateau, Southern Brazil

RIFFEL S.B.(1), VASCONCELOS P.M.(1), CARMO I.O.(2), FARLEY K.A.(3)

(1) The University of Queensland, BRISBANE, AUSTRALIA ; (2) PETROBRAS/CENPES/PDGeo/GEOTEC, RIO DE JANEIRO, BRAZIL ; (3) California Institute of Technology, PASADENA, UNITED STATES

The Second Paraná Plateau (2PP), southern Brazil, is a high elevation (ca. 800 m) landscape characterized by widely distributed deep saprolites and scattered lateritic profiles. These lateritic profiles are possible remnants of a more extensive weathering cover now poorly represented in southern Brazil. We dated homogeneous, well-crystallized, and dense grains of Mn and Fe oxyhydroxides to constrain the ages of weathering profiles at two sites: *in situ* ferricretes and mottled zones at Serra das Almas; and a leached and ferruginized sandstone associated with the ruiniform landscape at Vila Velha. Twenty-two grains of Mn oxyhydroxides were dated by  $^{40}\text{Ar}/^{39}\text{Ar}$  geochronology using the incremental heating method, and 28 grains of goethite were analysed by the (U-Th)/He method. Both methods, at both sites, yielded compatible ages ranging from  $36.4 \pm 3.6$  to  $1.0 \pm 0.1$  Ma. The oldest results, ca. 35 Ma, were recorded by (U-Th)/He ages on goethites from Serra das Almas and Vila Velha, and they represent a minimum age for the stratified lateritic weathering profiles preserved in the 2PP. They also record a minimum exposure age for the 2PP. Our results, when combined to other regional geological and geochronological constraints, suggest that the 2PP was carved by erosion of a minimum of ca. 700 m to a maximum of ca. 2100 m of overlying lithologies. Erosion of this cover between ~135 (constrained by the Paraná basalt age) and 35 Ma implies denudation rates ranging from 7 to 21  $\text{m}\cdot\text{Ma}^{-1}$ . Since ca. 35 Ma, the 2PP surface has been continuously exposed to weathering and localized erosion driven by localized river incision, where incision rates range from ca. 1 to 9  $\text{m}\cdot\text{Ma}^{-1}$ .

**Basin inversion, scarp retreat and soil distribution in the Araripe basin (northeast Brazil): implications for denudation history**

PEULVAST J.(1), BETARD F.(2)

(1) *Université Paris-Sorbonne, PARIS, FRANCE* ; (2) *Université Denis-Diderot, PARIS, FRANCE*

At the border between the Ceará, Piauí, and Pernambuco states (northeast Brazil), the high sandstone table called Chapada do Araripe overlooks lower and drier plateaus and depressions shaped into underlying post-rift and rift layers, in the east, or in the basement, to the west and south. The modes and rates of relief inversion that lead the upper layers of the Araripe basin to their culminating position are examined in relation with geological structure and regional uplift, through the presentation and discussion of morphostructural patterns and types of escarpments, differential erosion landforms, soil sequences, modalities of scarp retreat, and possible differential vertical movements (tectonic inversion). The geomorphic and pedological contrast between the plateau (a near-structural surface covered by Ferralsols) and its lower surroundings (either an exhumed Pre-Cenomanian paleosurface covered by Plinthosols, or lower surfaces with relatively immature soils of Luvisol type, often associated with Leptosols) is explained through a study of the evolution of the cuesta-like scarps or glints and outliers that fringe the chapada above sedimentary depressions and basement surfaces. A reconstruction of the conditions and chronology of relief inversion and corresponding area reduction is proposed, according to principles and methods of morphostratigraphy and morphopedology. It brings elements for discussing recently published models of episodic burial and exhumation history, based upon interpretations of thermochronological data obtained in nearby regions. This discussion also bears strong implications about long-term landform evolution in northeast Brazil and other passive margin areas. From a more general point of view, the present work is considered as a case study for analysing processes and rates of vertical erosion and scarp retreat in tropical tabular structures and sandstone plateaus.

\*\*\*\*\*

**Structural and Lithologic Control on Topography in a Post-Orogenic Landscape: East-central Appalachians, Pennsylvania**

GERMANOSKI D.

*Lafayette College, EASTON, UNITED STATES*

During orogenesis and the early history of a mountain system, topography is determined primarily by tectonic processes and processes operating to sculpt the landscape (mass-wasting, glacial, periglacial, and fluvial erosion). Active uplift influences climate and dictates process dominance by generating orographic precipitation and thermal regimes that promote glaciation and periglacial activity. Although lithology and structure affect erosive effectiveness, the landscape is dominated by tectonic, glacial, periglacial, fluvial, and mass wasting processes. Post-orogenic landscapes experience a diminishing influence on climate, and a decrease in potential energy differential that reduces the vigor of fluvial incision, and mass wasting, and eventually eliminates altitude-driven periglacial and glacial activity.

We used DEMs and GIS to quantify the average elevation of segments of a post-orogenic landscape underlain by different lithotypes in two areas of the Ridge and Valley of the central Appalachians in Pennsylvania. The results show that the topography in this region reflects the influence of lithology on the relative effectiveness of chemical and physical weathering to erode the landscape regionally.

Regional scale erosion surfaces correlate with lithology in both regions. The highest topography consists of elongate ridges underlain by resistant sandstones, followed in descending elevation by high-grade metamorphic gneiss and intrusive igneous rocks, slate, shale, and soluble carbonates. Variability in elevation among fault-bounded basement blocks of crystalline rock relates to the size of the areal outcrop of each terrane.

These observations suggest that the relative rates of chemical and physical weathering of different lithotypes exert the primary control on landscape morphology in post-orogenic mountain systems. Therefore, landscape form transitions from a tectonic, mass wasting, and glacial/fluvial dominance to a weathering dominated landscape.

## **Cosmogenic evidence for profound landscape disequilibrium and pre-Pleistocene landscapes in South Africa**

BIERMAN P.(1), ROOD D.(2)

(1) University of Vermont, BURLINGTON, UNITED STATES ; (2) Scottish Universities Environmental Research Centre, EAST KILBRIDE, UNITED KINGDOM

Southernmost Africa is characterized extensive, gently-sloping uplands dissected by drainage systems flowing through deeply incised valleys. These uplands have been interpreted as ancient land surfaces and used in establishing denudation chronologies even though there are few geochronologic constraints on their age or the rate at which they are modified by surface processes.

Measurements of *in situ*-produced, cosmogenic  $^{10}\text{Be}$  and  $^{26}\text{Al}$  place quantitative, geochronologic constraints on the minimum surface exposure age and maximum erosion rate of land surfaces in south-central South Africa. Upland surfaces are little changed since the Pliocene; cobbles and outcrop samples collected from 5 silcrete-mantled surfaces have minimum limiting surface exposure ages of 0.2 to 2.7 My (median = 0.93 My) and maximum limiting erosion rates of 0.11 to 3.2 m/My (median = 0.54 m/My). Considering  $^{26}\text{Al}$  analyses suggests that most samples have experienced only short periods of burial since initial exposure; two-isotope exposure/burial solutions extend minimum total histories of samples back to between 1.0 and 3.7 My and suggest that some of these surfaces have been stable near Earth's surface since at least the Pliocene.

The  $^{10}\text{Be}$  content of 8 sand samples collected from rivers draining to the Southern Ocean indicates that the landscape as a whole is eroding much more quickly (about 5.4 m/My, area-weighted average) than the upland surfaces; thus, relief is increasing over time. Basin-scale erosion rates increase from west to east across southern Africa, suggesting the influence of the East African Rift and/or the African super swell on rates of surface processes.

Together, these data indicate a landscape of profound disequilibrium where ancient, gently-sloping land surfaces, their form inherited from millions of years ago, stand above incised channel networks which are eroding the overall landscape 10 to 25 times more quickly than erosion proceeds on the uplands.

\*\*\*\*\*

## **Robust lithologies preserve ancient alpine-like topography in southern Africa**

SCHARF T.(1), CODILEAN A.(2), DE WIT M.(1), JANSEN J.(3), KUBIK P.(4)

(1) AFRICA EARTH OBSERVATORY NETWORK, NELSON MANDELA METROPOLITAN UNIVERSITY, PORT ELIZABETH, SOUTH AFRICA ; (2) EARTH SURFACE GEOCHEMISTRY, GFZ GERMAN RESEARCH CENTRE FOR GEOSCIENCES, POTSDAM, GERMANY ; (3) DEPARTMENT OF PHYSICAL GEOGRAPHY AND QUATERNARY GEOLOGY, STOCKHOLM UNIVERSITY, STOCKHOLM, SWEDEN ; (4) LABORATORY OF ION BEAM PHYSICS, ETH ZURICH, ZURICH, SWITZERLAND

The Cape Mountains of southern Africa present an exception to the much-cited coupling of topography and tectonics. This relict postorogenic terrain is comparable to present-day active orogens in terms of hillslope and relief, yet returns some of the lowest  $^{10}\text{Be}$ -based denudation rates in the world. Consequently, the Cape Mountains provide an outstanding demonstration that rugged topography alone is not sufficient to incite high denudation rates, and active tectonics need not be responsible for the maintenance of alpine-like topography. We attribute the suppression of denudation rates and maintenance of rugged topography within these mountains to the physically robust and chemically inert quartzites and metasediments that comprise the backbone of these mountains. The Cape Mountains thus provide a striking example of the strong role that lithology may play in long-term landscape evolution.

### **Are flat-topped orogens robust indicators of non-equilibrium mountain topography?**

CALVET M.(1), GUNNELL Y.(2), FARINES B.(1)

(1) *Université de Perpignan-Via Domitia, EA 4605 Médi-Terra, PERPIGNAN, FRANCE* ; (2) *Université Lumière-Lyon 2, UMR 5600 CNRS Environnement, ville, société, LYON, FRANCE*

The skyline of non-equilibrium mountain topography commonly exhibits elevated erosion surfaces, here termed Paleic surfaces, thus forming flat-topped rather than peak-topped mountain ranges. Such enigmatic features go against the common perception of alpine scenery, are still rarely accounted for in geodynamic models, and raise the questions of how and when these landforms were generated and why they have been preserved. Here we review a collection of examples around the complex plate convergence zone of the Mediterranean, some of them underpinned by new morphotectonic field evidence or low temperature thermochronological data (Betics, Bulgaria, Carpathians). We subsequently examine existing answers to this ancient geomorphological problem of transience in landscape development. We show that alternatives to recent vertical uplift, such as 'altiplanation', are difficult to generalise even though the inventory of plausible lithospheric mechanisms responsible for recent and rapid uplift needs further investigation. A key issue also concerns the palaeoelevation at which the Paleic surfaces formed before uplift, and the methods by which to establish it.

Key words: erosion surface, mountain, Cenozoic, denudation, altiplanation, palaeoaltimetry.

\*\*\*\*\*

### **Using landscape evolution models to interpret climatic drivers of cyclic aggradation and incision along the fringes of a decaying mountain range**

LANGSTON A.(1), TUCKER G.(1), ANDERSON R.(2)

(1) *University of Colorado, BOULDER, UNITED STATES*; (2) *Institute of Arctic and Alpine Research, BOULDER, UNITED STATES*

Flights of terraces that flank range fronts throughout the Rocky Mountains record episodic stream incision over at least the past 1.5 Ma. Recent work dating terraces in the Denver Basin along the Colorado Front Range suggests that these high surfaces were formed during glacial intervals and rapidly incised during interglacials. Climate change related to glacial-interglacial cycles has been suggested as a possible driver for the repeated aggradation and incision of these high surfaces. Potential mechanisms for increasing sediment supply and transport in rivers include variations over time in (1) periglacial weathering and hillslope transport, (2) the magnitude and timing of runoff and stream flow, and (3) sediment flux from intermittently glaciated major valleys. These three mechanisms raise the question which of them (if any) is primarily responsible for the cycles of aggradation and incision that appear to have created the staircase-like terrace surfaces along the range front. In this study, we use a landscape evolution model to determine whether the first of these mechanisms, in isolation, is sufficient to explain the observed rates and patterns of terrace formation and abandonment along the Colorado piedmont. We study an idealized catchment in which the upper half lies on resistant rock that detaches into cobble-sized regolith (representing the crystalline mountain range) and the lower half lies on soft rock that detaches into sand-sized regolith (representing the adjacent sedimentary basin). By increasing hillslope diffusivity by a factor of 4, we observe sediment aggradation in valleys within both the mountains and the basin. These results suggest that temporal changes in hillslope diffusivity alone play an important role in sedimentation and incision in mountain-bounded basins.

**The post-orogenic Rocky Mountain Surface on the front ranges of Colorado, USA - its character and possible causes of its deformation**

LEONARD E.(1), MCMILLAN M.(2), OUIMET W.(3)

(1) COLORADO COLLEGE, COLORADO SPRINGS, CO, UNITED STATES ; (2) UNIVERSITY OF ARKANSAS AT LITTLE ROCK, LITTLE ROCK, AR, UNITED STATES ; (3) UNIVERSITY OF CONNECTICUT, STORRS, CT, UNITED STATES

The low-relief Rocky Mountain Surface, which formed on the Colorado Front Range and adjacent ranges during and following the Cretaceous-to-Eocene Laramide Orogeny, has long been used as a marker of Cenozoic deformation. This study employs geomorphic and stratigraphic analysis to investigate original character of the surface, its subsequent erosion, and the location, character, and magnitude of its Neogene/Quaternary deformation. Much of the surface has experienced less than 50 m of erosion since its formation, although local incision along drainages approaches 1 km. This focused incision is greater in the south than in the north, consistent with erosion patterns on the piedmont to the east.

In the north the Rocky Mountain Surface has a consistent eastward dip, presumably reflecting its formational slope. To the south, its geometry is more complex. The southern portion of the surface generally dips eastward or southeastward, but its eastern edge is elevated several hundred meters above its central portions. Deformation of the southern portion of the surface has long been attributed to Rio Grande Rift-related stresses. Additionally, some of the complexity of this part of the surface may reflect its original geometry. Another possibility is that relative uplift of the eastern portion of the surface occurred as an isostatic response to differential Neogene/Quaternary erosion. Long-wavelength, km-scale erosion of the piedmont to the east of the mountain front contrasts with areally much more limited, short-wavelength erosion by mountain streams to the west. Initial modeling suggests that flexural isostatic response to this differential erosion would produce a westward tilt of the eastern portion of the Rocky Mountain Surface consistent with the observed *pattern* of relative uplift. However, the observed *magnitude* of relative uplift is several times that predicted as a flexural response to differential erosion.

\*\*\*\*\*

**The Colorado Plateau of the American Southwest where patterns of river incision are decoupled from topography and proposed mantle sources of uplift**

PEDERSON J.

Utah State University, LOGAN, UTAH, UNITED STATES

The active orogenic plateaus of the world have revealed the linkages between erosion, steep topography, uplift, and climate feedbacks in landscape evolution. Yet none of these linkages is apparent in the Colorado Plateau. Here I present calculations of river energy and steepness as well as new incision-rate data and then relate these patterns to proposed mantle sources of uplift.

Calculations of unit stream power and discharge-adjusted steepness index ( $k_{qsn}$ ) in the upper Colorado drainage highlight four canyon knickzones. The strong coincidence of knickzones with changes in bedrock and mass-movement inputs suggests they are mostly pinned, equilibrium adjustments to greater bed resistance. Similarly, new late-Pleistocene incision rate data exist for locations spanning the trunk drainage, constrained by multiple OSL, CRN, and U-series ages. These results reveal a distinct central-Colorado Plateau bulls-eye of faster river incision. This contrasts sharply with expectations based upon the patterns of energy expenditure and topography, but it matches modeled isostatic rebound from the broad late Cenozoic exhumation of the central plateau. Finally, neither patterns of steepness nor incision rate match recently proposed uplift patterns from mantle sources. For example, the highly incised and steep Grand Canyon region has proposed dynamic-mantle sources of uplift yet contrastingly low rates of incision, while the broadly exhumed central plateau Canyonlands features much more rapid incision yet no mantle sources of uplift.

The latest information from this famous region reveals that, rather than the expected situation of active uplift inspiring steep topography and fast incision rates, the Colorado Plateau is a decaying and transient landscape ruled by bedrock controls and passive isostatic rebound.

### Late Cenozoic River Incision in the Rocky Mountain region and implications for Neogene uplift in the western U.S.

ASLAN A.(1), KARLSTROM K.(2), KIRBY E.(3), HEIZLER M.(4), LAZEAR G.(5), ROSENBERG R.(3)

(1) Dept of Physical and Environmental Sciences, Colorado Mesa University, GRAND JUNCTION, COLORADO, UNITED STATES ; (2) Dept. of Earth and Planetary Sciences, University of New Mexico, ALBUQUERQUE, NEW MEXICO, UNITED STATES ; (3) Dept. of Geosciences, Penn State University, UNIVERSITY PARK, PA, UNITED STATES ; (4) New Mexico Bureau of Geology and Mineral Resources, SOCORRO, NEW MEXICO, UNITED STATES ; (5) Consulting Geologist, CEDAREEDGE, COLORADO, UNITED STATES

The Rocky Mountain province experienced multiple phases of uplift since retreat of the Cretaceous Seaway ca. 80 Ma. To evaluate late phases of uplift, we present data on the incision histories of the Colorado, Green and Yampa Rivers over the past 10 Ma. We also draw connections between patterns of river incision and mantle processes to explain landscape changes during the Neogene.

Provenance of river gravels and ages of Miocene basalt flows show that upper Colorado integration occurred ca. 16-11 Ma, prior to integration through Grand Canyon ca. 6-5 Ma. Colorado River incision began 9.5-7.8 Ma and resulted in 750 to 1500 m of incision at rates of 96 to 155 m/Ma since 10 Ma. Largest magnitudes of incision and fastest incision rates are associated with areas of Miocene basaltic magmatism. In the Yampa River, incision began later than 6.1 Ma, and the river has incised 800 to 850 m at rates of 90 to 115 m/Ma. Integration of the upper Green River is poorly constrained between 8 and 2 Ma, and probably post-dates the advent of the ancestral Yampa River ca. 6 Ma. Using Oligocene river gravels as a datum, the Green River has incised <400 m at rates of <20 m/Ma over the past ca. 30 Ma. In the Colorado River basin where more than one datum is available to calculate long-term rates, incision has remained semi-steady over the past ca. 10 Ma.

Comparison of river incision patterns with P-wave tomography suggests possible connections between mantle processes and landscape evolution. Upper Colorado regions have the fastest incision rates and slowest P-wave velocities. In contrast, the upper Green River basin has the slowest incision rates and fastest P-wave velocities. Post-10 Ma differential bedrock incision could be explained by differences in mantle flow or buoyancy between the upper Colorado and Green River basins.

\*\*\*\*\*

### Role of climate and tectonics in the geomorphologic evolution of the Semiarid Chilean Andes between 27-32°S

AGUILAR G.(1), RIQUELME R.(2), MARTINOD J.(3), CARRETIER S.(3), DARROZES J.(3), REGARD V.(3)

(1) Departamento de Geología, Universidad de Atacama, COPIAPÓ, CHILE ; (2) Departamento de Ciencias Geológicas, Universidad Católica del Norte, ANTOFAGASTA, CHILE ; (3) Geoscience Environnement Toulouse, CNRS, IRD, Université de Toulouse,, TOULOUSE, FRANCE

A morphometric analysis that considers hypsometry and topographic slope reveals longitudinal and latitudinal differences in the degree of maturity of the relief of the Andes between 27-32 ° S. Whereas landscape rejuvenation of the Coastal Cordillera takes place to the south of 29.5°S, in the Main Cordillera it happens south of 28.5°S. The combination of a wetter climate towards the south and the presence of segments with different tectonic features explain these variations. Longitudinally, the geomorphological features indicate the presence of a mountain front that separates the Coastal Cordillera from the Main Cordillera. Between 28.5 and 30.5°S this front can be attributed to the activity of the Vicuña-San Félix Fault System, which during the Oligocene - Early Miocene accommodated the relative uplift of the Main Cordillera. In response to this tectonic activity, successive levels of cut-and-fill pediments formed. During the Middle Miocene, there was a new episode of uplift affecting the entire fore-arc. In response to this uplift, the valleys that cross this region were excavated. Calculated velocities of knickpoints retreat for each period are 7 km/Ma for the early and 10 km/Ma for the later. Knickpoints reached the high Main Cordillera at 17 Ma and 8 Ma respectively. Long-term erosion rates show also these two different periods in the high Main Cordillera. Cut-and-fill pediments from 17 to 8 My show erosion rates between 5 and 30 m/My and valley incision during the last 8 My yields larger erosion rates, between 45 and 75 m/My. This geomorphologic approach shows that the uplift of the Semiarid Chilean Andes occurred in two different episodes with different geomorphological signals. We correlate these episodes with changes in the geodynamics of subduction during Oligocene-Neogene.

### **Erosion rates and their controlling factors along the eastern Qilian Shan Mountain, China**

PAN B., HU X., GENG H., LI Q., GAO H.

Key Laboratory of Western China's Environmental Systems (Ministry of Education), Lanzhou University, LANZHOU, CHINA

The interaction among earth-surface erosion, tectonic uplift and the climate is a key issue to understand the earth surface evolution. In recent two decades, a number of studies are carried out in orogens, especially in the Himalaya area, trying to solve the erosion problem, and also arouse big controversy on which factor is in controlling the erosion rate. One of the uplifting mountain belts along the northeastern Tibetan Plateau, the Qilian Shan Mountain, has been experiencing intense deformation in late Cenozoic. Varied erosion rates in different mountain zones supply an ideally natural lab of the Qilian Shan to study the surface erosion and its controlling factors. With different methods, we obtained erosion rates in different time scales along the eastern Qilian Shan. Apatite fission track and apatite (U-Th)/He studies in the Xiyang River basin give cooling ages of 56~80 Ma and of 22-45 Ma, respectively. Thermo-history modeling results show that: From ~ 70 to 10-8 Ma, the rock was cooling in a relatively low rate; from 10-8 Ma to present, the rock was cooling in a relatively high rate of  $7.5 \pm 1.8$  °C/Ma. Estimated average rate of rock erosion since 10-8 Ma is ~ 0.23 mm/a, and the results illustrate a higher erosion rate in the south (hanging wall) of the Huangchen-Taierzhuang thrust fault (the H-T fault). In the late Quaternary, river terraces are mainly formed in five periods: 10 ka, 20-25 ka, 30-37 ka, 51-56 ka and 67-71 ka. Based on the terrace heights and ages, calculated river incision rates are between 0.3 and 2.5 mm/a. Spatial pattern of river incision rates shows the higher rates are also located in the south of the H-T fault. Cs<sup>137</sup> contents give modern erosion rates of 0.1~0.4 mm/a, and show a good correlation with slope gradient. After we correlate the different erosion rates of different time scales with the tectonic uplift and precipitation, we find out that the erosion rate is mainly controlled by tectonic uplift.

\*\*\*\*\*

### **Rain, water, and ice: driving forces behind rapid erosion in western Bhutan**

PORTENGA E.(1), BIERMAN P.(2), DUNCAN C.(3)

(1) University of Glasgow & Macquarie University, GLASGOW, UNITED KINGDOM ; (2) University of Vermont, BURLINGTON, VT, UNITED STATES ; (3) GISmatters, AMHERST, MA, UNITED STATES

We employ the cosmogenic nuclide, <sup>10</sup>Be, to quantify basin-averaged erosion rates on millennial timescales and analyze spatial patterns of erosion in western Bhutan where knickpoint retreat, tectonic uplift, monsoonal precipitation, and glacial erosion actively shape the landscape. Measurements of <sup>10</sup>Be in quartz purified from modern stream sediment in 47 drainage basins (4-8,000 km<sup>2</sup>) span almost three orders of magnitude, from  $560 \pm 290$  atoms/g to  $3.8 \times 10^5 \pm 7 \times 10^3$  atoms/g, yielding erosion rates ranging from ~98-21,000 m/My; the median erosion rate is 880 m/My. Erosion rates are not correlated with topographic metrics such as elevation, relief, mean annual precipitation, or ice cover. Erosion rates, however, reach a maximum in basins where the average basin slope exceeds 25°. These steep basins are geographically grouped into two regions: one region is south of an uplifted and preserved low-relief step associated with the Greater Himalayan Sequence (27.0-27.4°N) and the other is north of this same preserved land surface (27.6-28.4°N). Monsoonal rains drive erosion along the range front where average basin slope angles are steepest. Headwater streams are likely oversteepened, adjusting to the passing of a knickpoint which is propagating through the Greater Himalayan Sequence, exposing the underlying Lesser Himalayan Sequence. A declining precipitation gradient with increasing latitude ( $R^2 = 0.74$ ) suggests that other factors dominate erosion north of the preserved low-relief step. The percentage of basins covered with ice and glaciers increases abruptly north of the raised step and includes the majority of basins exhibiting high erosion rates. Rates from these northernmost basins are likely the combined result of intense glacial erosion and steepened valleys nearing threshold slope angles. The calculated erosion rates are similar to fission track exhumation rates for western Bhutan but are twice as fast as basin-average erosion rates from eastern Bhutan.

### **Spatial distribution and residence time of large valley-fills along the Himalayan arc**

BLÖTHE J., MUNACK H., KORUP O.

*University of Potsdam, POTSDAM, GERMANY*

Our understanding of sediment routing through mountain belts and their forelands, and their final deposition in large submarine fans remains incomplete with lacking estimates of intermediate storage, which is the crucial link between erosion rates and sediment yields. Sediment storage can have a profound influence on material fluxes through attenuating water and sediment flows; decoupling hillslope from river-channel processes; sequestering biogeochemical constituents; and providing intermontane sedimentary archives of environmental change. Besides this, sediment storage frequently offers flat ground for settlements and land use, but also acts as a source for sediment related hazards. Here we quantify the sediment stored in >38,000 Himalayan mainly postglacial valley fills, based on unsupervised extraction and geometric scaling of digital topographic data. We find large differences between the Western, Eastern, and Central Himalayas. While most of the total volume of ~650 +/- 200 km<sup>3</sup> focuses around the Himalayan syntaxes, where erosion rates are high, and glacially conditioned valley trains provide sufficient accommodation space, the Central Himalaya only hosts very few large valley fills (> 1 km<sup>3</sup>). We compare the spatial distribution of valley fills along the Himalayan arc to different influencing factors, i.e. precipitation pattern, distribution of glaciers, mean local relief, tectonic structures, and long-wavelength topographic gradient. We speculate that the step-like long-wave topography in the central Himalaya limits glacier extent, and thus any significant sediment storage. Our morphometrically based estimates of volume and residence time are in good agreement with published data. The estimated volume stored in Himalayan valley fills could potentially feed contemporary denudation rates for >10<sup>3</sup> yrs, and signifies the elevated residence times of eroded material of up to 10<sup>5</sup> yrs at the mountain-belt scale.

\*\*\*\*\*

### **Poster presentations:**

#### **Significance and age of "megakarrens" in Sardinia (Italy)**

GINESU S.(1), DUNCAN R.(2)

*(1) University, SASSARI, ITALY ; (2) College of Earth, Oceanic and Atmospheric Science, CORNVALLIS OREGON, UNITED STATES*

In the central part of Sardinia, a series of parallel cavities along an erosional surface outcropped in the limestones and marbles of the Miocene that characterize the study area. The survey of the area around the micenic rocks allowed to assign these open cavities to the fractures of the Miocene rocks undergo a slow process of karstification. The fractures show distances between the walls from 0:50 to 2:00 ms, while it was not possible to observe the closure in the bottom. All fractures were filled with residual clay sandly (like "Terra Rossa") with missing components. The distance between the individual fractures is varied but the direction is always parallel, while in the area the fractures sequence has directions concordant with the recent tectonic and different. However, fractures outside the studied area rarely show the fill clay; fact due to the remarkable quantità of water moved into and out for a long time in these morphologies exposed to surface water circulation. The spread of the phenomenon and the morphology of the territory is rather difficult to define, it is a series of "megakarren" whose size suggests a landscape like "forest stones" whose forming time could have been very long. Recently, in a cave not far from the studied site, the exploitation activity revealed a contact between an outcrop of these fractures with an overlying volcanic episode. The sampling has identified a basalt rock of the Plio-Pleistocenic volcanic cycle that affected the whole island through numerous episodes effusive. The dating of this basalt by Ar/Ar method gave an age of 2.2 M.y.b.p. placing it at the end of the Pliocene. This information provides an important element to dating this phenomenon in a sub-tropical environment, under hot and humid climate. The age of this rock let to date the long period of leaching and the important rule of areal erosion consequent to cold phases after the Pliocene.

**Valley slope evolution in a southern thyrrenian coastal area (Calabria, Southern Italy) as a coupled effect of quaternary sea-level changes and river erosion**

*BOZZANO F., CIPRIANI I., DELLA SETA M., MARTINO S.*

*Dipartimento di Scienze della Terra - Sapienza Università di Roma, ROME, ITALY*

The Thyrrenian coastal area between the villages of Scilla and Bagnara Calabria (Calabria, Southern Italy) is the result of polycyclic geomorphological processes influenced by the coupling of high-rate Quaternary regional uplift, eustatic oscillations and intense river erosion. Within this area, the Favazzina and Sfalassà creek valleys represent the main geomorphological evidences of the river erosion, since they consist on deep cuts involving the geological bedrock of Ercinic metamorphic rocks as well as the Pliocene to Holocene terrigenous deposits. Geomorphological evidences, such as remnants of marine terraces and river strath terraces, testify for the polycyclic morphoevolution. Numerous landslides affecting the valley slopes generally do not reach the valley floor as an effect of the aforementioned evolution.

A detailed geological survey, supported by terrain analysis on a high resolution DTM, made it possible to recognize several river deepening phases along the Favazzina and Sfalassà creek valleys, and to associate the observed distribution of the largest landslides to the two main stationary phases, which correspond to an equal number of relict strath terrace surfaces.

A sequential evolutionary model of the Favazzina and Sfalassà creek valleys is here proposed, alternating different steps of river deepening and valley widening. Based on this model, a slope stability analysis was also approached by a finite difference modeling; to this aim, an engineering geological model of the valley slopes was reconstructed along representative geological sections and the geomechanical properties were attributed to the rock masses according to an equivalent continuum rheological behavior.

The numerical modeling was performed under a time dependent creep configuration and it was calibrated by taking into account the available geomorphological constraints. The modelling output the significance of the step-like valley evolution in the triggering of the main existing landslides.

\*\*\*\*\*

**Mechanism and structure of denudation in Island Steppes of Siberia**

*BAZHENOVA O.*

*V.B. Sochava Institute of Geography SB RAS, IRKUTSK, RUSSIAN FEDERATION*

A special regional trigger mechanism of denudation, realizing an intensive transport of matter is established for the sub-arid foothills of the northern periphery of the South Siberian mountain belt. Its essence lies in the progressive removal of the weathering products from the mountain country alternately by wind and water currents. Switch rearrangement process is realized by are the climatic variations. The mechanism is stable; as it is set not only in the course of the modern long-term supervision, but it is found in the structure of the reference sections of Quaternary sediments.

A climate-caused cycle manifests itself in the functioning of denudation systems of various levels. It is expressed in an active interchange of periods of matter drifting, when the relief is being rebuilt, and periods of relative stability. The parts of the cycle are the dynamic phase of denudation, which follow each other in a certain order. The structure of the dynamic phase gives an idea of time invariant of denudation systems, characteristic for a particular morphoclimatic area, as it is stored in the rings of different hierarchical levels (ranging from 11-year-olds and 30-35 thousand years old). The leading role in the reconstruction of the relief does not belong to a long zonal phase of denudation with slow and moderate speed processes, but to occasional extreme impulsive phase with rapid demolition of large volume of material. Summing up in the geological time scale, such a "salvo" matter drifting creates a corresponding geomorphological effect. While in some cases the relief is broken (the middle Siberian denudation type), in other it is aligned (the Minusinsk type), and in others the denudation is accompanied by preservation of the morphological appearance of the relief (the Central Asian type of denudation).

### Differential weathering in the Turvo River Basin

*RICCIONI DE MELOS A., FERREIRA BESERRA S., MENDES J.C., COELHO NETTO A.L.*  
*Universidade Federal do Rio de Janeiro, RIO DE JANEIRO, BRAZIL*

Denudation is caused by a combination of weathering and erosion processes which model the earth's surface, resulting in changes in the landscape. Basins following different evolutionary and functional models can be found in the middle of the Paraíba do Sul River Valley. The Bananal, São José do Barreiro and Sesmarias river basins show erosion features, indicating the great effectiveness of mechanical processes. In addition to operational variations observed between the Bananal and Turvo river basins, the Turvo basin has internal variations in magnitude of the mechanical and chemical denudation processes. This paper attempts to understand the spatial distribution of different weathering degrees in the Turvo River Basin, and to comprehend and explain the geomorphological differences between them. In areas representative of these two denudation types, chemical and textural analyses were performed on weathering profiles with the same lithology and on those with different lithologies. Surface water chemical analyses were made. The results indicated highly weathered profiles across the basin. However, the silt / clay ratio indicated more weathered profiles in the Turvo sub-basin. WIP and CIA chemical indices pointed towards totally weathered profiles in the Turvo sub-basin, with little variation across the depth evaluated. However, in the Pedras sub-basin, a great decrease in weathering occurs from third meters in depth. In this sub-basin, surface water chemical results showed higher concentrations in all elements, indicating that mobile elements are available in weathering profiles, which are thinner, and that water can percolate up to the weathering front. Given the overall data, it is reasonable to conclude that mechanical denudation processes are more active in the Pedras sub-basin, whereas chemical processes dominate the Turvo sub-basin evolution.

\*\*\*\*\*

### Chemical dynamics, weathering rate and atmospheric/soil CO<sub>2</sub> uptake of basalts at São Paulo State, Brazil

*CONCEICAO F., DIEGO S., MATHIAS C., LETÍCIA G.*  
*UNESP, RIO CLARO, BRAZIL*

The balance between the processes of weathering contributes to the geomorphologic modeling the Earth's surface. Weathering rates are therefore an important role in the rate of consumption of CO<sub>2</sub> and moderation of the climate. The chemical dynamics, weathering rate and atmospheric/soil CO<sub>2</sub> uptake of basalts from Serra Geral Formation (917,000 km<sup>2</sup> of area) in the Preto Stream basin, São Paulo State, Brazil, were evaluated using major elements as natural tracers. This basin has serious environmental problems in terms of quality of surface and rainwater, which affect the determination of weathering rate and atmospheric/soil CO<sub>2</sub> uptake. The Preto Stream, downstream from Ribeirão Preto city, receives several elements/compounds through anthropogenic activities, with only sulfate yielding negative flux values. The negative flux of SO<sub>4</sub><sup>2-</sup> can be attributed to atmospheric loading mainly related to anthropogenic inputs. After corrections for anthropogenic and atmospheric inputs in the Preto Stream basin, the transport of dissolved material derived and weathering rate were 30 ton/km<sup>2</sup>/yr and ~7 m/Ma. The weathering rate value is lower than the Amazon basin or other estimations made for equatorial environments. This is equivalent to 10.4 x 10<sup>6</sup> kg of rock being removed each year by the Preto Stream. The instantaneous flux was found to be a function of discharge, with the majority of dry residue (dissolved load) being transported during the summer (wet) months. The Preto Stream basin is in a region where the climate causes moderate chemical weathering, with the predominance of monosiallitization, with partial hydrolysis of minerals from bedrock, with some of the Si remaining in the profile and Na, Ca, K and Mg being removed. The atmospheric/soil CO<sub>2</sub> uptake related to basalts weathering processes corresponded to 375x10<sup>3</sup> mol/km<sup>2</sup>/yr, being this values higher than when compared to world continental averages (161x10<sup>3</sup> mol/km<sup>2</sup>/yr) or Amazon basin (331x10<sup>3</sup> mol/km<sup>2</sup>/yr).

### **The resilience of a badlands area to climate change**

YAIR A.

*Hebrew University of Jerusalem, Department of Geography, JERUSALEM, ISRAEL*

Badlands represent an intensely dissected barren landscape; devoid of soil cover, with a sparse or absent vegetation cover. The very high drainage densities, V shaped valleys and steep slopes have often led to believe that badlands represent a landscape where the frequency and magnitude of runoff, and erosion processes are high; resulting in rapid landscape evolution. This is why badlands have been regarded as 'ideal field laboratories'. Such a landscape may therefore be regarded as highly responsive to climate change. However, hydrological and erosional data collected in the Zin valley badlands (Northern Negev desert, Israel), carved in a uniform lithology of shales, do not support the views listed above. They point to a very low frequency and magnitude of runoff generation; and low hydrological connectivity within very small watersheds. Erosion rates are extremely low. Geomorphological features and prehistoric dated sites point to a very low sensitivity to of the Zin badlands to climate change during the upper Pleistocene. The Zin badlands offer a good opportunity to address the complex issue of geomorphic processes over short distances; while dealing with the question of their sensitivity to climate change.

\*\*\*\*\*

### **Characteristics of hypsometry and valley geometry of the Suoshui basin in Zhangjiajie and their implications in landform evolution**

SHI C., SHAO W., QI D.

*Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, BEIJING, CHINA*

Using data of DEM, landform and geologic maps and surveys in fields, this study investigated the characteristics of valley geometry, the knickpoints along the main stream and first-order tributaries, hypsometry and the stage of landform evolution of the Suoshui River basin, in which most of the sandstone forests or pillars, the typical Zhangjiajie landform, are located. Results show that the Suoshui River has a concave longitudinal profile with a slope declining downstream and a concavity value of 0.70. Over ten knickpoints or knickpoint zones are identified on the trunk stream and first-order tributaries of the river. The total fall of the knickpoints from KP1 to KP10 is about 149 m, which seems to be the result of base level lowering in the past about 0.93 million years. Comparing the downcutting rate of the Suoshui River with the height of sandstone pillars, formation of the sandstone pillars or forests should start before Quaternary. The cross-sectional concavities of both the Suoshui valley and its first-order tributaries are higher than 0.5 on average, suggesting the formation of strips of floodplains along the valleys by lateral erosion, which are the characteristics of landforms in the middle and late mature stage. The lateral erosion and a higher value of cross sectional concavity of valleys should be a favorable condition for the formation of the isolated sandstone pillars in Zhangjiajie. The impacts of relief and rock property are not detectable on the hypsometric integral in the basin. The sandstone forests and pillars in Zhangjiajie concentrate in the areas with Devonian sandstone as the bedrock in the lower section of the upper reaches and upper section of the middle reaches, where the fluvial-erosional landforms are in their mature stage indicated by a mean hypsometric integral of 0.46.

Keywords: Zhangjiajie landform; Suoshui River; Valley geometry; Hypsometric integral; Landform evolution.

### Are cirques exclusively cold-climate landforms? Allometric growth revisited in the Eastern Pyrenees

DELMAS M.(1), GUNNELL Y.(2), CALVET M.(1)

(1) *Université de Perpignan-Via Domitia, EA 4605 Médi-Terra, PERPIGNAN, FRANCE* ; (2) *Université Lumière-Lyon 2, UMR 5600 CNRS Environnement, Ville, Société, LYON, FRANCE*

Cirques have long been the focus of morphometric analysis. Allometric relations underpinned by the ergodic hypothesis have been used as proxies to speculate about the dominant processes responsible for cirque growth patterns, typically making these a combination of floor lowering by subglacial processes (abrasion, quarrying) and headwall recession by periglacial processes. Faith in this direct link between form and process is based on the widely accepted view that cirques are exclusively ascribable to cold-climate processes (they are hence prescribed as 'glacial'), thus dismissing the possibility that cirque volume may include a proportion of pre- and/or interglacial inheritance. A quantified sediment budget of Würmian cirque erosion in the Carlit massif, Eastern Pyrenees, has yielded a maximum bedrock denudation depth of 18.4 m. This result is used here as a benchmark to assess which among a population of 1071 first-order cirques in the Eastern Pyrenees could be of a composite nature, i.e. not exclusively produced in cold-climate conditions. Morphometric results do show that cirque location and size are strongly constrained by solar radiation, the morning-afternoon effect and wind-blown snow accumulation in the lee of ridgetops. However, allometric indices also reveal stronger correlation with bedrock lithology and with characteristics of the pre-glacial topography than with climatic parameters, suggesting that cirque allometry is an imperfect predictor of process and hence a spurious metric. Extrapolation to the entire Pleistocene of Würmian denudation depths in the lightly glaciated Carlit massif show that ~40 % of the cirque basins cannot exclusively be cold-climate landforms, implying that they were partly formed by other processes during pre- and/or interglacial intervals. Likewise, the proportion of composite cirques in massifs on the more intensely glaciated north side of the East-Pyrenean range is ~20%.

\*\*\*\*\*

### GIS-based morphometric analysis of the Blue Nile and Tekeze watersheds (Ethiopia)

SEMBRONI A., GIACHETTA E., MOLIN P., FACCECCA C.

*Roma Tre University, ROME, ITALY*

The Ethiopian plateau is a wide high-plain (mean elev. 2500 m) underlain by ~1000 m of flood basalts (30-29 My) generated by the Afar plume. The basalts overlie Pre-Cambrian basement and Mesozoic sediments. During late Oligocene-Pliocene shield volcanoes formed rising hundreds of meters above the plateau. We examined the topography of the NW Ethiopian plateau focusing on the metrics of the Blue Nile and Tekeze rivers basins. Our main data source is the SRTM DEM coupled with geological maps. We extracted 173 longitudinal river profiles, identified knickpoints and computed concavity and steepness indices. We analyzed the hypsometric curve and integral (HI) of basins to discern the relative dominance of fluvial incision or hillslope processes. Reconstructing the plateau surface, we calculated the minimum and maximum eroded volumes in the two main basins. Our results show the Tekeze R. basin is characterized by wide valley-bottoms and gentle slopes; its smooth concave longitudinal profile indicates this river is close to equilibrium; most of knickpoints of its tributaries are related to rock-types changes; the hypsometric curve shape (HI=0.31) indicates a strongly incised landscape, where the high plain is poorly preserved. The Blue Nile R. basin presents gorges and tectonic-controlled valleys; the longitudinal profiles of the Nile and its tributaries are disturbed by knickpoints: downstream they correspond with tectonic lineaments; upstream they probably record base level changes; the hypsometric curve (HI=0.41) indicates a poorly incised landscape (apart of the valley of the Blue Nile R.) that still preserves the plateau. We conclude that, although both main basins experienced a regional uplift, their evolution was affected by local volcanism and tectonics. The Tekeze R. basin hydrography is more close to steady-state, whereas the Blue Nile R. basin was affected upstream by the formation of large shield volcanoes and downstream by tectonics.

## **Processes and rates of bedrock erosion in Welsh rivers, and the implications for long term landscape development**

RICHARDSON J., TOOTH S., GRIFFITHS H.

*Aberystwyth University, ABERYSTWYTH, UNITED KINGDOM*

Many studies of Welsh rivers have examined contemporary processes and late Quaternary histories in alluvial reaches but the development of shorter, steeper bedrock reaches remains poorly understood. It is unclear whether the characteristic gorges, rapids and waterfalls have developed since the last glacial or are older, inherited features that have been exhumed from beneath glaciofluvial outwash and little modified since. On the River Rheidol, west Wales, we investigated four bedrock reaches up to 524 m long (8% of total river length). The reaches have developed in interbedded, moderately resistant, shales and sandstones with varying degrees of jointing, folding and small-scale faulting. Bedrock erosion during floods is by plucking and abrasion. Seeding experiments in well-developed potholes indicate active gravel exchange during floods, although gravel volumes vary with pothole size, location relative to bedrock outcrop, and inundation frequency. Pothole morphometries suggest that they deepen faster than they widen but deviations from idealised growth trajectories result from preferential widening along bedding planes or from block plucking around pothole rims. Contemporary erosion rates are poorly constrained but some rock engravings near water level have survived for decades and minimal bedrock erosion occurred during extensive flooding ( $Q > 100 \text{ m}^3/\text{s}$ ) in June 2012. Coupled with estimations of reach antiquity derived using a published equation for waterfall retreat rate, the Rheidol bedrock reaches have probably developed intermittently during part of the Quaternary, having been buried by sediment and/or ice during glacial advances and exhumed by river activity during glacial retreat. By influencing upvalley transmission of baselevel changes, the relative stability of bedrock reaches in the Rheidol and possibly other Welsh rivers has implications for wider landscape dynamics, including patterns and rates of alluvial terrace, river profile and hillslope development.

\*\*\*\*\*

## **Mudflow morpholito genesis((MMLG) on the Greater Caucasus**

YURY E.

*Kuban State University, KRASNODAR, RUSSIAN FEDERATION*

Studying of mudflows was spent by a of geology and geomorphology of the Kuban State University within last ten years with use a conceptual model of mudflow morpholito genesis (Efremov,2010). To date experience material makes it possible to imagine the development MMLG ,as follows: conditions - factors - processes - mechanisms of mudflows - a genetic type of mudflow. Developed MMLG theory opens the basic stages, their further change, accumulation of mineral and organic substance within their baths, and also allows revealing various types MMLG.

Mudflow morpholito genesis is total combination of processes and the phenomena with the assistance of which mudflows are formed. Their formation occurs with direct participation of friable deposits in the conditions of the dynamic environment and high energy of endogenetic and exogenous processes. It is supposed that formation of mudflow occurs under the influence of other factors in rather stable environment of the considered territory.

Morpholito logical, climatic and morfolitodinamical objective laws of formation of mudflows processes are considered. Morfolito logical conditions reflect interrelation of a geological structure of the territory with formation of a friable substratum – a material for origin of the mudflows which are forming at strong heavy rain or thawing of snow cover.

Morpholito dinamical conditions are total combination of natural processes to unit tectonic movements, the seismic phenomena, a volcanism and forces of gravitation. Neotectonic and modern movements together with climatic conditions created basis for development of exogenous processes.

Climatic factors created basis for development of exogenous processes. Most significant factors for of mudflow process are air temperature and an atmospheric precipitation.

**The very long wavelength (x1000 km) relief of the Congo Cuvette: a local base level controlled by upstream (EAR) and downstream (Atlantic bulge) uplifts during Miocene times**

GUILLOCHEAU F.

*Geosciences Rennes, RENNES, FRANCE*

The Congo Cuvette is one of the most famous very long wavelength (multiple of one thousand kilometres) relief in the world. Because of its size, it can be related to mantle dynamic and convection and sit is a case example for several models of dynamic topography. Those models imply contradictory recent vertical movements, from a subsiding to an uplifting domain. In order to better constrain its recent evolution we performed a geomorphological study of the Cuvette and surrounding highs (from the Cameroon Volcanic line to Central Africa and Uganda in the north, from the western branch of the East African rift to the Kalahari Plateau eastward and southward), in the frame of the ANR project TopoAfrica.

This study is based on the mapping and relative chronology of three types of forms: the planation surfaces (weathered, pediplains..), the pediments and the incised valleys. Those forms are dated by intersection with sedimentary deposits and magmatism. A synthesis of the magmatism of both the Cameroon Volcanic Line and the Virunga-Kivu domains was compiled and the relationships with the weathering surfaces and pediplains/pediments was studied.

1. No relief, even in the Cameroon Volcanic Line, is older than Eocene (middle?). The oldest one is a weathering surface bearing in some places bauxites.
2. A first regional uplift occurred at the Eocene – Oligocene boundary.
3. Late Oligocene is a period of fluvial sand deposition (“Sables ocres”), followed by a second period of weathering.
4. An Early Miocene uplift occurred along the Atlantic bulge from Cameroon to Gabon, Congo and northern Angola and at the southern edge of the present-day Cuvette (Kalahari Plateau uplift).
5. The East African Rift dome (and its western limit along the western branch) has been uplifted since at least Late Miocene.

The Congo Cuvette is mainly a by-pass to low incision domain bounded by uplifted bulge, dome and plateau during Late and Early Miocene and may be Early Pliocene.

\*\*\*\*\*

**Evolution of catchment basins in the Himalayas: New observations**

GHOSH P., MISRA A., SINHA S., SENGUPTA I., HATUI K.

*Indian Statistical Institute, Geological Studies Unit, KOLKATA, INDIA*

Evolution of drainage basins on a linear mountain belt initiates as small regularly spaced gullies at the contact between the orogen and the base level. With time, due to upstream growth, widening and coalescence, these gullies develop into catchment basins. It has been noted that the outlets of the basins are spaced regularly irrespective of scale, slope, lithology, climate and tectonic setting. However, the spacing (s) is related to the width of the orogen (w). For many orogens the spacing ratio (w/s) takes a value between 1.91 and 2.23. However, in the Himalayas, due to drainage reorganization, the outlet spacing is increased and that leads to a lower spacing ratio of 1.7.

We observe that the cross-sections of these Himalayan catchments does not show a valley-like profile due to the occurrences of orogen transverse ridges that are in many cases higher than the drainage divide. It confirms that these catchments are composite features made-up of lateral juxtaposition of a number of smaller valleys. The transverse streams draining smaller valleys abruptly turn and become orogen parallel in a narrow zone close to the mountain front and immediately north of the Siwalik range. They meet other streams and form a higher order outlet stream.

This work studies the shape and disposition of watersheds of the streams that are one order lower than the outlet stream. The results show a series elongated transverse valleys (some deformed) of similar size. We propose that the disposition of these lower order watersheds provide a crude approximation of the drainage configuration prior to their re-organization. Each of the catchments of Girwa, Gandak, Kosi and Manas comprises three sub-valleys indicating that the original spacing ratio was much higher. These sub-valleys terminate north of the Siwalik range suggesting that they existed prior to the deformation of the Siwalik strata. Thus, they could have served as the conduits for the sediment supplied to the Siwalik foreland basin.

### The Yangben inselberg and planation surface

MBEUGANG TCHEUBONSOU E.M., TCHINDJANG M.

*University of Yaoundé I, YAOUNDE, CAMEROON*

Palaeo landforms remain a concern, which, through morphogenic process that is constantly changing, drive to the understanding of the evolution of the world landforms. The palaeo geomorphological studies in Cameroon remain insufficient. There is the need to move beyond general studies to perform detailed studies at any scale to identify inherited forms. Given the original landscape of Yangben, the present study is seeking to specifically understand the main shapes and explore their implementation.

Yangben relief appears to be a very flat and amazing landscape marked by layering glazes (Northwest, Southeast) and dominated south East and North west by Hills surrounding residual massive (inselberg). Adding to this, one can observe that soil formations varied from gravel, sandy silt and ferrallitic facies. All of these are indicators of a changing landscape contrasting with the reconstruction problem due to the characteristics of current erosion. This observation leads us to study the Yangben inselberg and its planation surface.

In fact, located in the savanna of the Mbam pediplain region, this paper proceeds by collecting Yangben soil sample data, observing soil horizons and collected some for morphoscopic analysis. Also, two main types of inselbergs have been identified: the inselberg of lithological resistance and the inselberg of position. We succeed in describing the genesis process leading to their implementation in this subdry and dissected environment developed on basement structures. Finally the Yangben the pediplain is bristling with massive inselbergs and convex hills arranged in the Precambrian lineaments. This landscape originates from differential erosion during the geological history of Cameroon and shapes in a tropical climate contrasts.

\*\*\*\*\*

### Long-term evolution of Southwest Indian landscapes by $^{40}\text{Ar}$ - $^{39}\text{Ar}$ dating of K-Mn oxides in supergene Mn-ore deposits

BONNET N.

*CEREGE, AIX-EN-PROVENCE CDX 04, FRANCE*

The high-elevation passive margin of Southwest India is marked by the Western Ghats escarpment, which separates the coastal domain from the low-relief East-dipping Mysore plateau. The escarpment has evolved from the Seychelles rifting at ~ 63 Ma which followed the Deccan traps volcanic event at ~ 65-63 Ma.

We investigate and quantify the post-rift evolution of the South Indian passive margin through the characterisation of stepped relicts of lateritic paleosurfaces across the escarpment, and notably by  $^{40}\text{Ar}$ - $^{39}\text{Ar}$  dating of in-situ formed K-Mn oxides in supergene Mn-ore deposits carried by these paleosurfaces. Elevation differences between lateritic paleosurfaces of different ages provide denudation rates for the considered time spans. On the basis of previous work (e.g., [1]) and our own investigations, three main lateritic paleosurfaces were identified on the plateau at altitude ranges of 1000-900 m (S2), 900-800 m (S3) and 800-700 m (S3d), and a last one in the coastal domain at 150-50 m (S4). These lateritic paleosurfaces can bear bauxite (e.g., S2) and/or ferricretes (e.g., S3). Bauxitic weathering also developed under glacia/pediment of paleosurface S4 in the coastal domain.

K-Mn oxides (cryptomelane) were sampled from Mn ore deposits underlying each paleosurfaces. The first  $^{40}\text{Ar}$ - $^{39}\text{Ar}$  ages ( $28.6 \pm 0.5$  to  $36.25 \pm 0.95$  Ma) obtained from carefully characterised assemblages from the Sandur Mn-ore deposit indicate intense lateritic weathering processes at the transition Eocene-Oligocene underneath the paleosurface S2.

Assuming that the genesis and maturation of Mn-ore deposits are linked to progressive weathering of the paleosurfaces that carry them, further dating K-Mn oxides formed in these Mn-ore deposits will thus provide important time constraints on the setting and evolution of successive paleosurfaces and the correlative post-rift denudation chronology of the Southwest India passive margin.

[1]Gunnell, Y. (1998). *Basin Research*10, 281-310.

### **Long-term landscape evolution of the southeast Brazilian highlands: analysis of Poços de Caldas Alkaline Massif region**

*DORANTI-TIRITAN C.(1), HACKSPACHER P.C.(1), GLASMACHER U.A.(2), POÇAY M.A.H.(1)*

*(1) UNESP, RIO CLARO, BRAZIL ; (2) Ruprecht-Karls-Universität Heidelberg, HEIDELBERG, GERMANY*

The aim of this paper is to study the configuration of the long-term landscape evolution of a specific region of southeast Brazilian highland. Poços de Caldas Alkaline Massif (PCAM) was formed during alkaline volcanism event from the Late Cretaceous. It is located on the west side of the Mantiqueira Mountain Range, characterized by alkaline rocks and topography reaches over 1700m high. The topography of the crystalline basement, so called North Crystalline Zone (NCZ), is a dissected plateau with irregular topographic ridges reaching 1200m in elevation. The PCAM and NCZ areas together form the Poços de Caldas Plateau that is characterized as a remnant of the South American Planation Surface resulted from erosional events from Late Cretaceous–Paleogene transition. The present-day relief has resembled over many millions of years, a major feature of denudation is the development of the "circular drainage", a particular feature of some caldera and other circular or concentric structural features. Recent tectonic movements may critically affect regional geomorphology by influencing river patterns and orientations. Apatite Fission-Track (AFT) thermochronology and morphometric analysis on drainage basins and river morphology were used on the tentative of understanding the landscape evolution of this region. AFT ages range from and  $333.3 \pm 27.6$  to  $48.7 \pm 10.7$  Ma and the age-elevation relationship shows that the ages decrease systematically with increasing elevation with a break-in-slope near the 150Ma and another in 80Ma. The morphometric analysis shows some rivers are controlled by reactivated faults, and in the other hand the correlation between the techniques shows that some of the faults that control the river morphology were not reactivated with events displayed by the AFT thermochronology.

\*\*\*\*\*

### **Toward a quantification of long-term evolution of coastal landscapes? Drainage developed on marine terraces sequences on the North Cotentin peninsula (France)**

*NEXER M.(1), AUTHEMAYOU C.(2), PEDOJA K.(1), DELCAILLAU B.(1)*

*(1) Laboratoire M2C - UMR CNRS 6143, CAEN, FRANCE ; (2) Laboratoire CNRS Domaines océaniques, UMR 6538-IUEM, BREST, FRANCE*

Sequences of Plio-Quaternary shorelines generated by sea-level fluctuation and tectonics massively shape the coasts worldwide. Except in arid zones, they are covered by aerial drainage pattern. Surprisingly, few studies deal with both geomorphic features, although such cross-study could lead to the quantification of the coastal drainage evolution.

North Cotentin peninsula is a key site for such studies of coastal landscape evolution. This peninsula was shaped during the Plio-Pleistocene by the alternation of glacial and interglacial stages. The latter, associated with highstand of the sea, result in the carving of marine terraces on Paleozoic and Precambrian rocks. During glacial stages, periglacial climate lead to the deposition of head (solifluction cast) and loess sequences, overlapping marine terraces. Furthermore, glacial periods are marked by important incision due to the base-level retreat.

Our methods include field-work (geophysics, dGPS), analyses of satellite images and DEM (10m, 30m), and morphometry: drainage area, length profile, the stream length-gradient index (SLi), Ks, drainage basin asymmetry, hypsometric integral and curves, sinuosity and incision rate.

We significantly bettered the knowledge on the sequence in this area. As previous authors, we recognized a "low" sequence of four marine terraces (correlated to the MIS 5e, 7, 9 & 11). But we found that this low coastal sequence is overlooked by an upper sequence of three terraces. The paleo-shorelines of the terrace delimit a paleo-island with islets. Longitudinal profiles of 10 rivers developed on coastal terrace (marine terrace and terraces) exhibit numerous knickpoints. We tentatively interpret them as related to the base level migration.

At this stage, our work is still exploratory but such cross studies could be applied to any coast where Plio-Quaternary sequences and aerial drainage are both present.

### **Piedmonts of the Transdanubian Range, Hungary: Limited slope retreat of the pediments?**

CSILLAG G.(1), SEBE K.(2), FODOR L.I.(3)

(1) Geological and Geophysical Institute of Hungary, BUDAPEST, HUNGARY ; (2) University of Pécs, PÉCS, HUNGARY ; (3) Geological, Geophysical and Space Sciences Research Group of Hungarian Academy of Sciences at Eötvös University, BUDAPEST, HUNGARY

The SE side of the Transdanubian Range in the middle of the western Pannonian Basin is accompanied by an approx. 150 km long and max. 10-15 km wide piedmont zone with numerous planation surfaces. Their study indicates that landscape evolution around mountain ranges emerging from soft basin sediments may differ both from the classic pedimentation process and from the accumulation of alluvial (depositional) piedmonts.

The Palaeozoic–Palaeogene rocks of the Transdanubian Range are surrounded by Upper Miocene molasse sediments from the Alp-Carpathian ranges. These deposits used to cover most of the Transdanubian Range; its exhumation started in the Late Miocene, when the beginning of uplift overlapped with the final period of sediment accumulation. The denudation of 200-300 m of Upper Miocene sediments uncovered the mountain front fault scarps. Flights of up to 8, Pliocene–Pleistocene planation surfaces in the piedmont zone lap onto this scarp. These flat surfaces were carved into the weakly consolidated molasse sediments and have slopes  $<1^\circ$ ; in front of valleys 5-10 m thick alluvial fans accumulated.

The described landforms are

- no pediments *s. str.*, because slope retreat is restricted, the ultimate knickpoint is at the scarp, even though they were formed by pedimentation;
- no depositional piedmonts ('bajadas') in front of an active mountain front, because no modern tectonic activity can be detected along the frontal fault, and alluvial fans originating from the mountains cover only a minor portion of the dominantly erosion- or transport-dominated slopes.

Retreat of the piedmont zone is limited by selective denudation at the mountain front scarp undergoing exhumation, since pedimentation can only occur on the soft foreland sediments. Consequently, landscape evolution cannot proceed to produce a pediplain (*sensu* King).

\*\*\*\*\*

### **The spatial distribution of knickpoints in south-central Africa: implications for longterm landscape evolution**

FLUGEL T.J.(1), ECKARDT F.D.(2), COTTERILL F.P.D.(3)

(1) Department of Military Geography, Faculty of Military Science, Stellenbosch University, SALDANHA, SOUTH AFRICA ; (2) Department of Environmental & Geographical Science, University of Cape Town, CAPE TOWN, SOUTH AFRICA ; (3) AEON Geoecodynamics Research Hub, c/o Dept Botany and Zoology, University of Stellenbosch, STELLENBOSCH, SOUTH AFRICA

The spatial distribution of knickpoints (the break in river slope gradient) may provide insights into the evolution of a river. As rivers may be seen as the summation of process occurring across its basin, river evolution reflects the broader landscape processes. As knickpoints may have several origins, it is important for these knickpoints to be characterised. This poster illustrates the distribution of 15 such points that share the Congo-Zambezi watershed. A geospatial information system was created recording the characteristics of these knickpoints as determined from a variety of spatial data sources.

The lithology of each knickpoint has been categorised and is shown in context of the simplified geology. This combined with the knickpoint heights, as determined from Shuttle Radar Topography Mission data, allowed several conclusion may be drawn. The development and evolution of knickpoints are likely to be strongly influenced by underlying geology, where they occur on stable cratonic regions of the regions; whereas those found on shield margins and within the Neoproterozoic mobile belts are predominantly influenced by both localised and regional tectonics.

### **Constraining Cenozoic uplift of the central Appalachians using river profiles and relict surfaces**

HARBOR D.(1), MEYER R.(2), CONNORS C.(1)

(1) Washington & Lee University, LEXINGTON, VA, UNITED STATES ; (2) University of Bergen, BERGEN, NORWAY

Much recent research points to Cenozoic uplift of the Appalachians. Profiles of streams in the James River reveal incision by knickpoint retreat into a relict upland of western Virginia. This inherited landscape occurs at the remote ends of some Blue Ridge or Valley and Ridge tributaries. The landform geometry, regolith weathering, and Eocene extrusive rocks of these pre-Quaternary landscapes describe a low erosion rate currently beyond the reach of more rapid erosion by larger streams. James River basin channel profiles are modeled to estimate deviation from a graded or expected profile for the rock type and regional geomorphic setting. The greatest deviation and profile relief results from progressive landward regression of the drainage divide, and ensuing capture of the James River headwaters. However, the capture-generated deviation decreases from east to west in the basin, implying that capture alone is insufficient explanation for the total relief of the basin and shape of the profile. Restoring the relict landscape as a low-relief surface with a graded profile yields at least 500 m of Cenozoic uplift west of the Blue Ridge and increasing channel slope. In the neighboring Potomac River Basin, tributaries sharing western headwaters with the James River have more than 400 m profile deviation. Capture and uplift produce rates of incision rising to 150 m/m.y. in modern channel of the James River, an order of magnitude higher than extremely low upland denudation rates observed by others throughout the central and southern Appalachians. In the steep modern profile, erosion by knickpoint retreat seems to dominate the response of the James River from mouth to headwaters, similar to the response in other Southern Appalachian basins. Both channel and upland relief in the central Appalachians is growing in response to the difference between headwater and mainstream erosion rates.

\*\*\*\*\*

### **Correlations between geology and erosion surfaces in the central eastern sector of Paracatu river catchment, State of Minas Gerais, Brazil**

BRAGANÇA M.T.R., OLIVEIRA D.D.

University of Sao Paulo, SAO PAULO/SP, BRAZIL

The regularity of the relief of Paracatu river catchment inserted into Atlantic Shield is preserved in weathering and erosion resistant rocky layers. The landscape is organized over a stratigraphic column which keeps its original conditions of deposition with record of small crustal movements, allowing the ideal theoretical conditions for the study of erosion surfaces. The Pediplanation Theory (King, 1953) and the geomorphological method of Ab'Saber (1969) are the theoretical research basics. The work aims is to correlate the Paracatu river catchment geomorphology to material and structure, looking for explanations to the preservation of erosion surfaces in the arrangement of sedimentary successions, unconformities and erosive plateaus. A broad fieldwork through a general and regional approach, followed by an intense bibliographic review and manipulation of topographic and geologic maps, at scale 1:100,000, and its manipulation in GIS, through a development of a Digital Terrain Model and many topographic profiles, allowed to describe the relief in suggesting the reconstitution of the geomorphological history of the study area, resulting in an erosion surfaces map. There were the conditions to identify and describe four surfaces which record the regional morphological evolution: Tabular Plateau Surface, Tabular Plateau Surface with Dissected Valleys, Low Tableland with Ravined Pedments and Dissected Valleys Surface, and Paracatu River Fluvial Plain Depression Surface. The erosion surfaces can be correlated to four tectonic cycles that elevated the Brazilian Platform since Cretaceous until Pleistocene, and drainage incision and dissection of the landscape as a consequence of wet climates installed after Atlantic rift open.

**Relief evolution of the eastern part of the Bierzo Basin (NW Spain): Response of erosion surfaces and fluvial network to Cenozoic Tectonic Activity**

RODRIGUEZ GARCIA A.(1), GARCIA-MELENDZ E.(1), MARTIN-SERRANO A.(2), SUAREZ RODRIGUEZ A.(3), MINGUEZ A.(3)

(1) Universidad de León, LEÓN, SPAIN ; (2) Instituto Geológico y Minero de España, TRES CANTOS, MADRID, SPAIN ; (3) Instituto Geológico y Minero de España, Oficina de Proyectos de León, LEÓN, SPAIN

The eastern part of the Bierzo basin (NW Spain) and its boundary with the Duero basin shows Cenozoic tectonic structures that control the present-day topography. In this work, Homogeneous Geomorphological Units (HGUs) have been used in order to study the relief of this area. The interpretation of aerospace imagery (ASTER and aerial photographs), Digital Elevation Models (DEMs) and derived information (fluvial network, drainage basins, slope, curvature and aspect maps) and fieldwork allowed to delimit a HGUs map to scale 1:100.000. This map compiles geomorphological units (structural, fluvial, glacial and planation units) with homogeneous substrate geology, morphometry and origin. As a result, the morphometry and the spatial relationships among the HGUs show some characteristics of the relief evolution. The planations (erosion surfaces) are characterized by abrupt changes in slope at their limits related to the presence of Cenozoic thrusts (mainly E-W direction) present in the area. In addition, these surfaces show differences in height among them associated with vertical displacements and the two main vergences (S and N) of the mentioned thrusts. The fluvial network has three main patterns grouped in two time slices: a) the older one (Pre-Cenozoic) is determined by the strength of the Pre-Cenozoic substrate units (mainly E-W direction); b) later, the activity of Cenozoic thrusts (mainly E-W direction) forced some fluvial channels (Cenozoic) to follow two main paths, being the first one perpendicular (mainly N-S direction) and the second one parallel (mainly E-W direction) to the main thrusts. Some N-S fluvial channels connect upstream with E-W less steep channels, being interpreted as fluvial captures as a consequence of the Cenozoic fluvial network reorganisation.

Keywords: landscape evolution, landform units, paleoreliefs, drainage patterns

Acknowledgements: work supported by the "Junta de Castilla y León" Spanish project LE311A12-2

\*\*\*\*\*

**Applying hack index in drainages to define slope levels: a case study of the Eastern Borborema plateau Rivers**

MONTEIRO K.(1), CORREA A.C.B.(2)

(1) Universidade Federal de Pernambuco, PAULISTA, BRAZIL ; (2) Universidade Federal de Pernambuco, RECIFE, BRAZIL

How the landscape evolved and how the landforms evolution define it is one of the most important themes in geomorphology. With understanding of the drainages it is possible to think about the evolution of landforms, and comprehending the structures that control the drainages it is plausible to relate the drainage, the structure and the landform dynamic. Hack elaborated an index to define anomalous sections on drainages relating the slope and the length of the drainages. The index consist in the relation between the  $\Delta h$  (difference of altitude of the section) and the  $\Delta l$  (difference of length of the section) multiplied for the distance of the section until the begin of the drainage (L). So, the index is showed as  $\Delta h/\Delta l * L$ . Previous research applied in drainages which drain the east side of the Borborema Plateau, Northeast of Brazil, showed that this index is satisfactory to identify anomalous sections in the drainages and it could be used to define slope levels if used in a set of neighbor rivers. The rivers studied were the Paraíba river, Goiana river, Capibaribe river, Sirinhaem river, Una River and Mundau river. However, Paraíba river, Goiana river and Capibaribe river are in a different structure of the other rivers, more resistant called "median shear corridor", and they present less levels compared with the region that Sirinhaem river, Una river and Mundau river. It is known that rivers are, in many cases, controlled for the structure, so we can deduce that anomalous sections are related with resistant structures or tectonic levels. So, once defined the levels, from the use of the Slope-Length Index, the next step is understand what is making these levels, erosion cycle, tectonic movements, or both actions.

### Denudation rates of the Southern Espinhaço Range, Minas Gerais, Brazil, determined by in situ-produced cosmogenic beryllium-10

*N. BARRETO H.(1), A. C. VARAJÃO C.(2), BRAUCHER R.(3), BOURLÈS D.L.(3), A.R. SALGADO A.(4), F.D.C. VARAJÃO A.(2)*

*(1) Universidade Federal do Maranhao, SAO LUIS, BRAZIL ; (2) Universidade Federal de Ouro Preto, OURO PRETO, BRAZIL ; (3) Université Aix-Marseille, AIX-EN-PROVENCE, FRANCE ; (4) Universidade Federal de Minas Gerais, BELO HORIZONTE, BRAZIL*

To investigate denudation rates in the southern part of the Espinhaço Range (central-eastern Brazil) and to understand how this important resistant and residual relief has evolved in the past 1.38 My, cosmogenic  $^{10}\text{Be}$  concentrations produced in situ were measured in alluvial sediments from the three main regional basins, whose substratum is composed primarily of quartzites. The long-term denudation rates estimated from these measurements were compared with those that affect the western (São Francisco River) and eastern (Doce and Jequitinhonha Rivers) basins, which face the West San Francisco craton and the Atlantic, respectively. Denudation rates were measured in twenty-seven samples collected in catchments of different sizes (6–970 km<sup>2</sup>) and were compared with geomorphic parameters. The mean denudation rates determined in the northern part are low and similar to those determined in the southern part, despite slightly different geomorphic parameters (catchment relief and mean slope). For the southern catchments, the values are  $4.91 \pm 1.01 \text{ m My}^{-1}$  and  $3.65 \pm 1.26 \text{ m My}^{-1}$  for the Doce and São Francisco River basins, respectively; for the northern catchments, they are  $4.40 \pm 1.06 \text{ m My}^{-1}$  and  $3.96 \pm 0.91 \text{ m My}^{-1}$  for the Jequitinhonha and São Francisco River basins, respectively. These low values of denudation rates suggest no direct correlation if plotted against geomorphic parameters such as the catchment area, maximum elevation, catchment relief, average relief and mean slope gradients. These values show that the regional landscape evolves slowly and is strongly controlled by resistant lithology, with similar erosional rates in the three studied basins.

Keywords: The Southern Espinhaço Range;  $^{10}\text{Be}$ ; Cosmogenic Nuclide; Denudation Rates; Brazil

\*\*\*\*\*

### Reconstruction of long-term (last 35 Ma) pediment evolution in the Atacama Desert using a multidisciplinary approach

*SANCHEZ C.(1), TAPIA M.(2), RIQUELME R.(2), CARRETIER S.(3), BRICHAU S.(3), MARQUARDT C.(4)*

*(1) Universidad Catolica del Norte / Géosciences Environnement Toulouse, ANTOFAGASTA, CHILE ; (2) Universidad Catolica del Norte, ANTOFAGASTA, CHILE ; (3) Géosciences Environnement Toulouse-IRD, TOULOUSE, FRANCE ; (4) Antofagasta Minerals., ANTOFAGASTA, CHILE*

Pediment evolution processes have been discussed for over a century by geomorphologists worldwide. Understanding these processes is tackled using both numerical modeling and field observations. However there is generally little agreement between the two, mainly due to lack of observable geomorphological features and the difficulties to date them over such a long term period. Nevertheless, the Atacama Desert represents a promising field study area to understand pediment evolution:

(1) A first estimation of pediment backscarp positions in each stage of landscape evolution can be inferred by contrasting stratigraphic gravel lithofacies distributions and upslope pediment bedrock distribution. In fact, the composition of clasts and exotic mineralization (from nearby porphyry copper deposits) in the gravel exposed due to erosion can reveal the amount of vertical incision related to backscarp pediment retreat.

(2) Ages of gravel deposition can be determined by Ar-Ar dating of inter-bedded ignimbrite layers or syn-sedimentary Mn-oxides, and U-Pb detritical zircon dating.

(3) Although the timing of late Cenozoic (5-30 Ma) climate change in the Atacama Desert is debated, most authors agree that this period is characterized by progressive climate desiccation. Field data indicate that pediplenation began after the Incaic orogen (~38 Ma) with the exhumation of intrusive rocks emplaced at ~2-km-depth before the Oligocene. Subsequent backscarp retreat occurred extremely slowly (<20 km for ~30 Ma) as climate conditions changed from arid to hyper-arid. Since middle Miocene the pediment has not been modified related to the hyperaridity. Ongoing research are refining and quantifying our models by reconstructing the denudation history using high to low temperature thermochronology data, and integrate them into Landscape Evolution Modelling (CIDRE software) under different scenarios.

## **The main elevation levels of the northeastern quadrilatero ferrifero region, Minas Gerais, Brazil and their relation with the different parent materials**

LADEIRA F.S.B., LEONARDI F.  
Unicamp, CAMPINAS, BRAZIL

Works associating elevation levels with the different parent materials have been gaining strength in the world geomorphology for the interpretation of paleosurfaces. Then, this work has had the objective of associating the terrain morphology and elevation with the Iron Laterite Surface present in the northeastern Quadrilátero Ferrífero. Iron Laterite Surfaces are regionally called *Chapadas de Canga* and they result from residual accumulation of iron in humid tropical regions. Iron Laterite Profiles are present in a great part of this area, making it have much interest by the mineral extraction industries. In this work two main procedures have been performed, the production of the Elevation Digital Model through topographic radar image SRTM and field mapping of the lithology and laterite materials. Associating elevation, terrain morphology and iron laterite profiles, there are three well demarcated levels: 1 – above 1500m of altitude, where it is located Serra do Caraça, sustained by quartzite; 2 – from 1000m to 1200m of altitude there are iron mines of Alegria Complex, which exploit Itabirito (corresponding to BIFs); 3 – from 600m to 1000m Ferricrete Continuous Surface appears, that exceeds 8km in extension, exposing a profile with more than 40 meters of thickness. This exposed laterite profile is an old alluvial fan, associated with the Serra do Caraça threshold. In this point the laterite profile evolved over fan deposits, very poorly sorted, composed only by itabirite clasts cemented by iron and not quartzite clasts, though quartzite outcrops be in higher levels, very near this area. Thus, the Laterite Continuous Surface covers a great area between the levels 850-950m of altitude and it functions as a stratigraphic mark, representing the end of the South American erosion cycle.

Aknowledgements: to FAPESP for funding the Project-2011/23325-7 and PhD scholarship for first author. CNPq for the second author's productivity scholarship (312583/2009-5).

\*\*\*\*\*

## **Self-organisation of geomorphological evolution in the brazilian Central Plateau**

DE SOUZA MARTINS E.(1), VASCONCELOS V.(1), CARVALHO JÚNIOR O.A.(2), REATTO A.(1), COUTO JÚNIOR A.F.(2)  
(1) Embrapa, BRASÍLIA, BRAZIL ; (2) Universidade de Brasília, BRASÍLIA, BRAZIL

In the Brazilian Central Plateau are recognized South American (Paleogene) and Velhas (Neogene) geomorphologic cycles. These geomorphologic cycles are preserved in the form of planed surfaces with varying degrees of dissection. The interfaces between these surfaces generally occur through scarps. These interfaces are strongly controlled by litho-structural factors. The processes of laminar erosion and chemical weathering are very slow and tend to preserve the soil and geomorphological characteristics of the formation processes of planing surfaces. Moreover, the iron has a seasonal pattern, especially between the ferruginous horizon and saprolite. In this transition, the iron tends to be dissolved at the season of water saturation for the formation of water-soluble iron in oxidation state II. In dry season ground water tends to be lowering and the iron goes to the oxidation state III, the very low solubility form and precipitates as oxi-hydroxides. Inside the residual surfaces of the Central Plateau ferruginous horizon tends to be very thin or even non-existent by dissolution generated by the continuous reduction and dissolution process of iron oxi-hydroxides. Moreover, the edges of these surfaces occurs a progressive thickening of the ferruginous horizon formed by the process of oxidation of iron from the solutions of the innermost portions sources. At the edges of the planing surfaces occurs iron oxi-hydroxides hardening and the formation of ferruginous lateritic cuirasses. The hardening is caused by the irreversible drying of iron oxi-hydroxides on the edges of planing surfaces, which occurs cyclically in the dry season. This continuous geochemical process generates planing surfaces edges more resistant to chemical and physical weathering, increasing the resilience of their own planing surfaces. This process of self-organized evolution is responsible for preserving of planing surfaces of the Brazilian Central Plateau in the scale of millions of years.

### **Correlation between iron and laterite layers paleosurfaces Minas Gerais, Brazil**

*RODRIGUES DE MORAES G., SÉRGIO BERNARDES LADEIRA F.  
UNICAMP, CAMPINAS, BRAZIL*

The Brazilian relief presents salient features of development in tropical environment for a long duration. Some forms produced during Paleogene remain on the landscape in the form of residual deposits, especially iron and aluminum, the former associated with these surfaces.

In Brazil the Cretaceous was marked by intense mechanical erosion, reflecting the hot and dry weather, a semi-arid climate to arid. Vast planing surfaces were formed. Already in the Paleogene occurred moments of intense chemical alteration, generating thick lateritic profiles, which focused, in southeastern Brazil, especially iron.

The objective of this work is the analysis of lateritic profiles, which present ferricrete, which allowed preservation of old planing surface in the western state of Minas Gerais, Brazil.

The profile has approximately analyzed twenty-nine meters thick, with a ferricrete on top of about 8 meters and the remainder correspond to speckles and kaolinitic horizons. This change affects profile at the base of the Cretaceous deposits Marília Formation, consisting primarily of calcretes. At the base of the profiles occurring silica concentration levels constituting silcretes.

These profiles claim slopes pronounced that enable easy identification of the surface, which has slopes of less than 2%. Under these conditions the surface Oxisols develop thick and high in iron and aluminum.

ACKNOWLEDGEMENTS: to FAPESP for funding the project Geomorphic Paleosurfaces Correlation of Summit in Brazil, Uruguay and Argentina - dating, morphology, cartography, deposits and associated alteration profiles (2011/23325-7), and the scholarship for first author. To CNPq for the second author's productivity scholarship (312583/2009-5).

\*\*\*\*\*

### **Use of detrital cosmogenic $^{10}\text{Be}$ and LIDAR DEM to evidence and quantify the propagation an erosion wave in steep tropical watersheds, Luquillo Critical Zone Observatory, Puerto Rico**

*BROCARD G., WILLENBRING J.K., SCATENA F.*

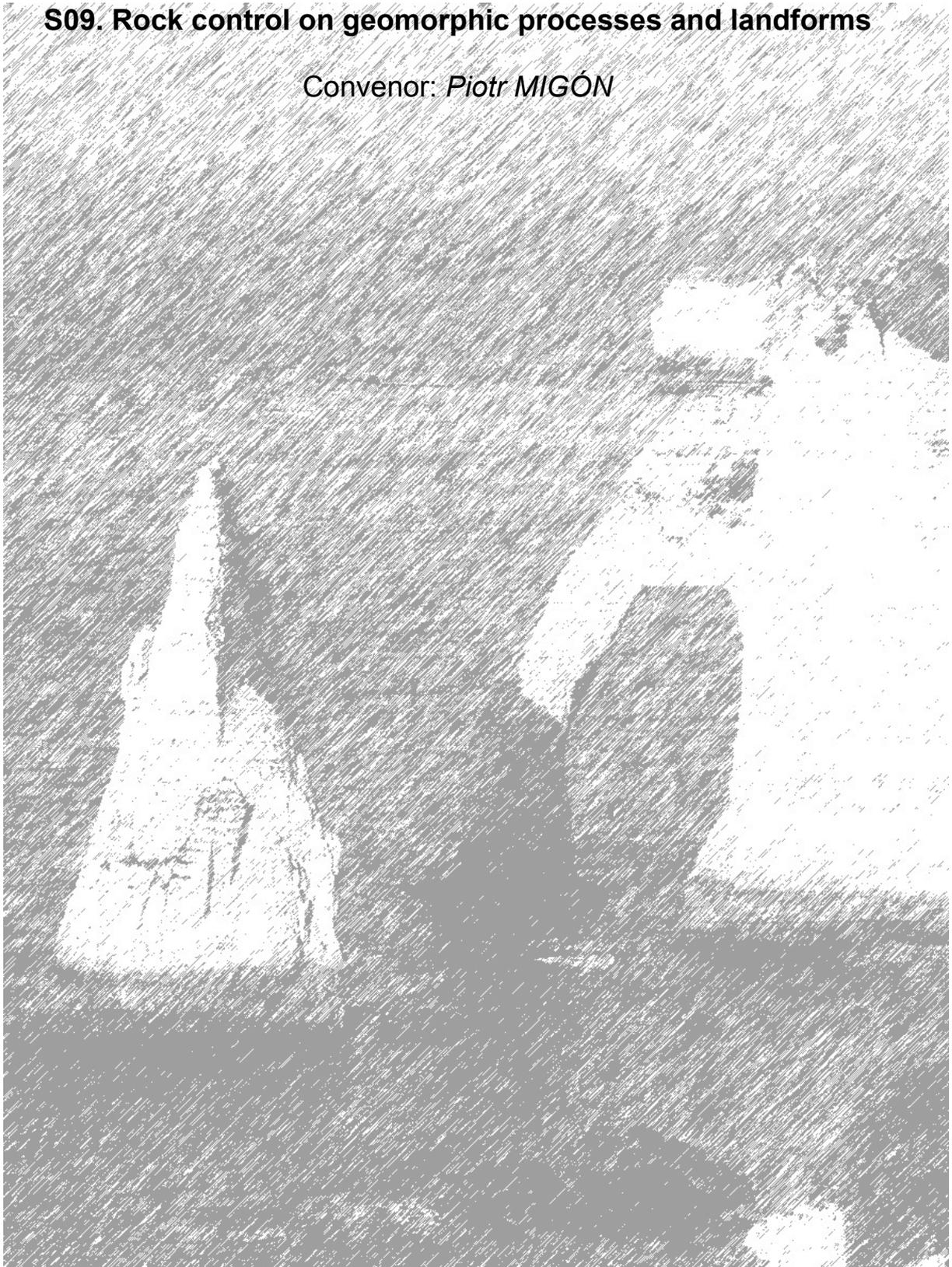
*Department of Earth and Environmental Sciences, University of Pennsylvania, PHILADELPHIA, UNITED STATES*

The modern island of Puerto Rico emerged from the sea some 5 Ma ago. Pervasive planation surfaces in its mountainous highlands have been interpreted as ancient wave-cut platforms. The El Yunque National Forest at the eastern tip of the island is an unscathed primary forest that clads very steep mountains. These mountains receive up to 5 000 mm of annual precipitations. The rivers draining these mountains exhibit dramatic knickpoints. Because these knickpoint lips lie at the elevation of an uplifted regional wave-cut platform (~600m), we interpret these knickpoints as headward migrating erosion waves that nucleated at the coast when tectonic uplift of the mountain resumed. The knickpoints separate a slowly-eroding relict upland region, from faster eroding lower slopes. We use  $^{10}\text{Be}$  concentration of river-borne quartz to compare erosion rates above and below the knickpoints. We find a threefold increase in catchment-scale soil erosion rates below the knickpoints, over timescales of  $10^4$ - $10^5$  years. The change in erosion rate is associated with a change in the dominant erosional processes, as reflected by the grain-size dependency of  $^{10}\text{Be}$  concentration in quartz sediments and the hillslope morphology revealed by a newly acquired LIDAR DEM. The uplands exhibit a strong variation in the  $^{10}\text{Be}$  concentration as a function of sediment grain size, interpreted as the effect of a strong decoupling between the erosion of slopes and ridge tops. This decoupling is evidenced in the DEM by the presence of deep seepage coves propagating into a deep saprolite, dissecting pre-existing broad ridges. Downstream of the knickpoint lips, such coves are absent, hillslopes are straight, ridge crests are narrow and the  $^{10}\text{Be}$  dependency with grain size is less pronounced, indicating a shift from chemical weathering dominated erosion upstream of the knickpoints to mechanical weathering dominated landscape below the knickpoints.



**S09. Rock control on geomorphic processes and landforms**

Convenor: *Piotr MIGÓN*





## **Oral presentations:**

### **Lithological controls on patterns of landsliding in northwest Malta**

*DYKES A.(1), DEVOTO S.(2), SOLDATI M.(2)*

*(1) Kingston University, KINGSTON UPON THAMES, UNITED KINGDOM ; (2) Università di Modena e Reggio Emilia, MODENA, ITALY*

The geomorphology of Malta is strongly determined by a relatively simple pattern of underlying geological structures. Northwest of the Victoria Lines Fault, the altitudes of the stratigraphic layers are lower, bringing a thick calcareous marl known as the Blue Clay Formation down to around sea level. The coastal landforms around the northern 25% of the island, dominated by mass movements, appear to be primarily controlled by the juxtapositions of the Blue Clay and its adjacent lithologies with respect to sea level. Initial field inspections of the entire northwestern coast highlighted an apparently controlling influence of the Upper Corraline limestone that overlies the Blue Clay. The contrasting properties and thicknesses of the two members of the limestone formation appear to be directly associated with both the types and characteristics of the mass movements. Furthermore, the thickness of the upper member of the limestone determines the degree of natural protection from marine erosion, with a very thin limestone cap generally being associated with relatively debris-free clay slopes at the inland sides of bays such as Ghajn Tuffieha Bay. There is thus an apparently counter-intuitive geomorphological situation with the most unstable coastal slopes, having the highest cliffs and exerting the greatest loads on the underlying clay, being the most protected from ongoing marine erosion and generally forming the local-scale headlands. This paper will use these geological and morphological observations, with some geotechnical stability modelling, to derive the most likely explanations for the different types of landslides.

\*\*\*\*\*

### **Factors that Affect the Formation and Development of Gölcük Uvala in Western Turkey**

*CUREBAL I., EFE R., SOYKAN A., SONMEZ S.*

*Balıkesir University, BALIKESIR, TURKEY*

Although Karst topography and terrain is common in Turkey, it is observed in more limited locations in Western Turkey. The development of karst terrain depends on the interplay of several factors in varying degrees. Gölcük Uvala is situated in the south of Balıkesir province and is close to Sındırgı. Uvala was formed on limestone bedrock of Upper Miocene-Lower Pliocene periods.

The current study investigates the karstification conditions of Gölcük Uvala in the past and at present and the factors that have affected its formation.

Lithostratigraphic properties of the rocks in the study area and other geological and geographical elements that control karstification were studied with this purpose. Also, morphological properties, formations and development of the karstic forms in the area were examined by associating them with regional karst elements.

Uvala, developed on the surface of the plateau whose altitude changes between 430-440 m. In terms of shape, the uvala resembles a crescent that faces the southeast. The uvala has a length of 1250 m in the north-south direction and 1000 m in the east-west direction.

The uvala was developed under karst topography formation conditions. However, tectonic activities played a role in its development as well. Faults and lineament in the study area show that the field is tectonically active. Kazan Creek is situated in the west of Gölcük uvala on a tectonic line with north-south direction. There is 100 m difference of altitude between Kazan Creek valley floor and uvala floor. The altitude difference between Kocaova and Gölcük Uvala is 200 m. This difference in altitude was caused by the vertical movements of the active faults in the area. This fact shows that uvala was formed by tectono-karstic processes. A karstification process that can be identified as simple is dominant in the study area and formation and development are still ongoing.

Keywords: Gölcük uvala, karst topography, karstification, tectonics

**A new paradigm in geomorphology and geology of reservoirs: The deep alteration of rocks by « ghost-rock » process**

*MAIRE R.(1), BINI A.(2), BRUXELLES L.(3), CAMUS H.(4), DANDURAND G.(5), DEVES G.(6), DUBOIS C.(7), LANS B.(5), ORTEGA R.(6), ROUDEAU S.(6), QUINIF Y.(7)*

*(1) CNRS, PESSAC, FRANCE ; (2) University of Milano, MILANO, ITALY ; (3) INRAP, MONTPELLIER, FRANCE ; (4) CENOTE, MONTPELLIER, FRANCE ; (5) CNRS-University Bordeaux 3, PESSAC, FRANCE ; (6) CNRS-CENBG, BORDEAUX-GRADIGNAN, FRANCE ; (7) University of Mons, MONS, BELGIUM*

The alteration of rocks was described since a long time in pedology, geomorphology and geology. However, recent discoveries in quarries of Belgium allow to revisit this problematic. A first stage is constituted by an isovolumic weathering of the bed-rock. In conditions of low hydraulic potential, the phreatic water carries the soluble part outside the system. The insoluble or minus soluble part of the rock remains in place and forms the residual alterite. Due to the lowering of the piezometric level, the water flows out of the limestones, forming caves in 1-2 years by evacuating the alterite according to the headward process. This experimental verification revolutionize the classical theory of karst voids genesis. A period of deep alteration need peculiar paleogeographic conditions: long time ( $10^6$ - $10^8$  years), biostasy and tectonic quiescence with a low relief and a close water level allowing the genesis of long alteration roots. This process create a strong porosity (10-50 %), keeps the original rocky volume and prefigures areas of weakness for a future differential erosion. It has been verified in many carbonated areas (Europe, Siberia, South Africa), in the sandstones and quartzites (Venezuela, Australia), in granites (Sidobre). In New Caledonia, the nickel ore is trapped in the altered peridotite showing a typical karst morphology. In the different examples, the petrographic analyses and the chemical imaging by X-Ray Fluorescence shows the pores organization and the distribution of chemical elements. This alteration in a very low oxygen context mobilizes probably a considerable microbial mass and a slow energy dissipation with convection loops to evacuate the dissolved elements (Ca, Mg, C, O, K, Si...). The consequences are very important for understanding the genesis of aquifers (Touvre, Fr.), some oil reservoirs (Rospo Mare-Adriatic) and metalliferous sites (with hydrothermalism), and also the collapse process after lowering of the water table.

\*\*\*\*\*

**Twidale's Rock: a granite block showing linked rock basins, channels and relief inversion**

*ALVAREZ DE BUERGO M.(1), GARCIA RODRIGUEZ M.(2), FORT GONZALEZ R.(3), CENTENO J.D.(4), GOMEZ-HERAS M.(5), SANZ M.A.(4)*

*(1) INSTITUTO DE GEOCIENCIAS (CSIC,UCM), MADRID, SPAIN ; (2) UNIVERSIDAD NACIONAL DE EDUCACIÓN A DISTANCIA UNED, MADRID, SPAIN ; (3) CEI Campus Moncloa, UCM-UPM and CSIC, Madrid, Spain, Instituto de Geociencias, IGEO, (CSIC-UCM), MADRID, SPAIN ; (4) FACULTAD DE GEOLOGIA, UNIVERSIDAD COMPLUTENSE DE MADRID, MADRID, SPAIN ; (5) CEI Campus Moncloa, UPM -UCM and CSIC, Madrid, Spain, ETS Arquitectura (UPM) and Instituto de Geociencias, IGEO (CSIC-UCM), MADRID, SPAIN*

This work shows the results of the study of a granite block, which will be named Twidale's Rock (TR) to pay tribute to the Geomorphologist C.R. Twidale. TR is located in the southern margin of the Amblés basin (Ávila-Spain). Several weathering microforms will be studied to get conclusions on their origin, the exposure processes and the relations between petrophysical properties and the weathering progression.

The Amblés basin is an ENE to WSW elongated tectonic basin (general direction N76°E), between the sierra de Ávila in the North and the sierra de la Paramera in the South. Several families of faults and escarpments with directions 20°, 30°, 63°, 95°, 107°, 120° and 136°, define the southern limit of the basin. During the Tertiary, the depression filled with detritic sediments, and during the Quaternary the basin underwent erosion and entrenchment. In the border of the basin the erosion dismantled previous regolith and weathering mantles, exposing granite bornhardts and minor landforms, like blocks and boulders with abundant weathering microforms.

TR is part of a group of erosion-exposed blocks; it is 12m wide, 21m long and 5m high. The upper part of the block shows interconnected rock basins covering more than 50% of the surface, with most of the outlets pointing towards the NE side, facing the valley. In this NE face, almost vertical, the outlets form channels and several taffoni, between the channels, leave the channels in prominence.

Some geomorphological elements in the NE face of TR (channels, taffoni, duricrust, pitting, etc.), were mapped, and some petrographical characteristics, petrophysical properties were measured and microenvironmental variables (temperature and relative humidity) were recorded. The study of the NE face of TR shows some correlation between petrophysical variables and the outlet-channels and taffoni, giving useful information to understand deterioration processes both in natural and built environments.

## **Poster presentations:**

### **The use of the Schmidt hammer as a complementary tool for cosmogenic dating in Sierra Nevada (Southern Spain)**

OLIVA M.(1), GÓMEZ ORTIZ A.(2), SALVADOR FRANCH F.(2), SALVÀ CATARINEU M.(2), VIDAL MACUA J.J.(2)

(1) *Institute of Geography and Spatial Planning, Universidade de Lisboa, LISBOA, PORTUGAL* ; (2) *Department for Physical and Regional Geography, University of Barcelona, BARCELONA, SPAIN*

The development of cosmogenic dating has substantially improved our knowledge on the timing of the maximum extent and subsequent deglaciation in Sierra Nevada, a high semiarid Mediterranean massif (Gómez Ortiz et al., 2012). However, there are still some uncertainties regarding the Late Pleistocene and Holocene environmental evolution in Sierra Nevada that need to be unveiled.

Several moraines are distributed in the highest northern cirques of the massif, at the foot of the Veleta (3398 m) and Mulhacén peaks (3478 m). Although topography is rather similar in both cirques, the number of moraines in each is substantially different. Former studies have described them as being originated during different time periods: while the two overlapping moraine arches in the Veleta cirque may have developed during the Late Glacial and the Little Ice Age (Gómez Ortiz, 2002), most of the seven generations of moraines in the Mulhacén cirque may have formed during the Holocene (Oliva & Gómez Ortiz, 2012).

The Schmidt hammer technique has been applied in all these moraines in order to find out if differences can be identified among them that can be related to different time phases. Up to 50 measurements were performed on stable boulders from the upper ridge of each moraine. The different rebound values may reveal differences in the exposure time of the boulders, therefore pointing to significant differences in the timing of deposition and stabilization of these boulders.

This method shows very similar values for the two moraines in the Veleta cirque (43-47), which may suggest a close timing for their formation instead of the former very different chronology. In contrast, data reveal notable differences among the moraines of the Mulhacén cirque (44-54), which may be interpreted as significantly different ages of formation of the moraines there located.

Based on these data, on the following campaign we will collect samples from these moraines for cosmogenic dating procedures.

\*\*\*\*\*

### **Subsurface erosion in a badlands area in Southern Italy: controlling factors analysis, types and frequency of pipes**

CAPPADONIA C.(1), ANGILERI S.E.(1), ROTIGLIANO E.(1), BUCCOLINI M.(2), COCO L.(2)  
(1) *Universita di Palermo, PALERMO, ITALY* ; (2) *Universita di Chieti - Pescara, CHIETI, ITALY*

Several of those Italian badlands areas, which are termed in the Apennines as “calanchi”, are affected by tunnelling erosion, due to piping process, which can involve the superficial portion of outcropping terrains, as well as up to some meters deep volumes. Erosion tunnels develop in form of simple or complex networks, having different length and diameter, varying from just a few centimetres up to some metres. The development and density of pipes are generally connected to a large fan of controlling factors referring to topography, climate, lithology, biological activity, coupled morphodynamic. Two different but nearby calanchi fronts located in Sicily (Southern Italy), where silty-clay deposits outcrops, have been studied. The calanchi fronts, were previously subdivided in hydrologic units by integrating GIS analysis and field surveys. Each unit was partitioned in a 4m side square grid and the density of pipes measured. For each survey grid field sheets, containing data on presence of resistant levels of outcropping rocks, vegetation cover, diameters of pipes and their spatial location, were filled out. A set of local topographic attributes (aspect, steepness, curvatures, roughness, topographic wetness index) was derived by processing a 2m resolution dem. A detailed lithological map was also prepared, reporting some litho-structural factors influencing calanchi and pipes evolution: specifically, number, thickness and relative distance of arenaceous levels (more resistant materials). At the same time, by using digital aerial images vegetation cover types were recognized and mapped. Finally, soil sampling and laboratory allowed us to characterize the outcropping soil (texture, grain size and plasticity indexes). By applying multivariate regression technics, correlation between controlling factors (topography, lithology, mineralogy, sedimentology and geotechnical properties) and types and frequency of pipes are investigated and interpreted.

**Bedrock Strength and River Metrics: Spatial and Statistical Correlations on the Incision of the Colorado Plateau, Southwest USA**

BURSZTYN N., PEDERSON J.

*Utah State University - Geology Department, LOGAN, UNITED STATES*

There has been renewed debate over the mechanisms and timing of both uplift and erosion in the Colorado Plateau. Yet, in order to understand the patterns of topography and surficial processes in this landscape a third factor of bedrock properties must be considered. We are building a dataset of bedrock strength and exploring it in the context of topographic metrics. Included are rock-strength measures such as Schmidt-hammer compressive strength, Selby rock-mass strength, and laboratory tensile strength measures. To estimate the strength of units too incompetent to test directly, such as the shales prevalent in the region, we utilize functional relations between reach-scale rock strength and valley-bottom width, gradient, and unit stream power.

The Colorado River drainage across the Colorado Plateau can be broken up into bedrock reaches underlain by a variety of rock types including quartzite, sandstone, shale, limestone, and crystalline basement. Initial results indicate significant correlations between rock strength and channel and valley-bottom width, as well as gradient and unit stream power. High rock strength coincides strongly with narrow and steep canyon reaches in this landscape, but the most rapid incision coincides instead with reaches of low rock strength and stream power. This implies bedrock is a first order control on topography and process rates here, which is intuitive yet often overlooked.

\*\*\*\*\*

**Impact of rock structure on drainage development: a case study from south-western pedimental region of West Bengal, India**

BANERJEE A., BANERJEE A.

*PANDIT RAVI SHANKAR SHUKLA UNIVERSITY, RAIPUR, CHHATTISGARH, BANKURA, INDIA*

Rock structure generally indicate geological set up, presence of fracture, rock composition, hardness and other physical properties. Different geographical regions have different set up and related characteristics because of variation in rock structure. The genesis and pattern of drainage system depends upon the rock structure of a region. It is utmost important factor for fashion that a fluvial system has developed. The present study mainly deals with such types of problems. The study area being a part of easterly extension of Chotanagpur peninsular complex and in periphery plain with Pleistocene formation, hard rock basement complex and previous volcanic lava flows left some imprints in the study region. Geological, geomorphological and hydro chemical analysis has been carried out to understand the correlation between rock structure and drainage evolution in this undulating country. 12 sample sites have been selected in different part of Bankura and Purulia district in different litho geomorphic domain (Pedimental zone of Shallow, Moderate and Deep). A lithomorphic model has generated from sample studies to understand the variability of factors in drainage development. Based on this integrated studies, it has been noted that the lithology of the area mainly represented by amphibolites schist, hornblende-biotite gneiss, quartzite and granite belonging to Archaean and Lower Proterozoic Pleistocene and recent alluvial deposits mainly occur in eastern and northern part of the district. Therefore, in the present study, an attempt has been made to integrate the drainage pattern and evolution in different lithostratigraphic domains.

### Temporal and Spatial Characteristics of Different Sandstone Geomorphology Types: from Zhangjiajie to China

QI D.(1), HUANG H.(1), CHEN A.(2), CUI Z.(3), ZHAI F.(4), CHEN D.(5)

(1) Institute of Geographic Sciences and Natural Resources of Research, CAS, BEIJING 100101, CHINA ; (2) Chinese Academy of Geological Sciences, BEIJING 100037, CHINA ; (3) College of Environmental Sciences, Peking University, BEIJING 100871, CHINA ; (4) Tourism College of Hunan Normal University, CHANGSHA 410081, CHINA ; (5) The Administrative Committee of Zhangjiajie Sandstone Peak Forest Geopark, ZHANGJIAJIE 427000, CHINA

China's sandstone landscapes is concentrated distribution in the southeast, southwest, northwest three large areas. It found in all climates and spaned from Paleozoic to Mesozoic Cenozoic, particularly in the Mesozoic. Sandstone is main material basic for shaping the well-known attractions. Under different climate background and geological condition, different types of sandstone geomorphology were named and classified by Chinese in a specific time and place, and it is important to classify them for the science and the application. These names often appear in articles and sightseeing explanation, such as Danxia landform, Zhangjiajie landform, Zhangshiyuan landform, Yeliu landform, Yuanmou landform, Daigu landform, Yardang landform and so on. It is an innovative named method for rock geomorphology research, but there is some confusion in classifying and naming the rock landform. It is necessary to make a principal to systematize and standardize the classification and the naming for the development of the petrographic geomorphology. The authors considers the "double name", means using both the place name and the landform name, and the "multi-name" can solve this problem.

Zhangjiajie sandstone peak forest landform is one of more ideal geomorphology research nomenclature. The thickness, age and uniformity of Devonian sandstone beds, along with the density, angularity and depth of the joint pattern, have been key determinants of the morphology and stability of more than 3000 thin and very high vertical sandstone pillars and peaks that cover an area of 80 km<sup>2</sup> within the core of the Geopark.; Zhangjiajie and its unique sandstone landscape must step from China to the World. Then it can be assigned in a manner that conveys their true place amongst world landforms and world heritage.

Keywords: Sandstone landform; Temporal and Spatial Characteristics; classify; name; Zhangjiajie Geopark; China.

\*\*\*\*\*

### Thermal and structural controls on polygonal cracking in granite of La Pedriza de Manzanares (Spain)

GARCIA RODRIGUEZ M.(1), CENTENO J.D.(2), GOMEZ-HERAS M.(3), FORT GONZALEZ R.(4), ALVAREZ DE BUERGO M.(5)

(1) UNIVERSIDAD NACIONAL DE EDUCACIÓN A DISTANCIA UNED, MADRID, SPAIN ; (2) FACULTAD DE GEOLOGIA, UNIVERSIDAD COMPLUTENSE DE MADRID, MADRID, SPAIN ; (3) CEI Campus Moncloa, UPM -UCM and CSIC, Madrid, Spain, ETS Arquitectura (UPM) and Instituto de Geociencias, IGEO (CSIC-UCM), MADRID, SPAIN ; (4) CEI Campus Moncloa, UCM-UPM and CSIC, Madrid, Spain, Instituto de Geociencias, IGEO, (CSIC-UCM), MADRID, SPAIN ; (5) INSTITUTO DE GEOCIENCIAS (CSIC,UCM), MADRID, SPAIN

Previous works on polygonal cracking in granite give some explanations on its formation. Some authors propose internal geodynamical factors as main controls, as it could be processes related to final stages of the magmatic consolidation or differential movement in fault planes because of their structural position. Some other authors prefer external factors related to climatic regimes, specifically, insolation rates and thermal differences to explain preferential orientations of this kind of pattern. However, to date is still not clear the extent of the relative influence of both internal and external geodynamical factors to explain this weathering pattern.

La Pedriza de Manzanares is part of a National Park in Madrid. This area includes part of the Late Variscan granites of the Spanish Central Range, eroded and uplifted to its present position during Alpine orogeny. This granite shows a complex fracture pattern (related to Variscan and Alpine processes) visible in a landscape alternating boulders and rock walls ranging from one to one hundred meters with abundant polygonal cracking patterns.

We analyze the relation between thermal and structural controls on the polygonal cracking found in La Pedriza's granite through measuring a series of parameters, including strike and dip of fractures, height from the ground, and shape of polygonal cracks and environmental temperature and relative humidity (by means of i-button sensors)

Polygonal cracking in this area appears always facing S, E or W in fracture planes with directions W-E and N-S. The most developed cracking appears at heights over 30 meters from the ground and in curved fracture planes, as described previously in other regions by other authors because of compressive stresses.

**Genesis of incipient karst systems in saturated/semi-saturated and altered context: the example of « Graves » area (Gironde, France)**

LANS B., MAIRE R.

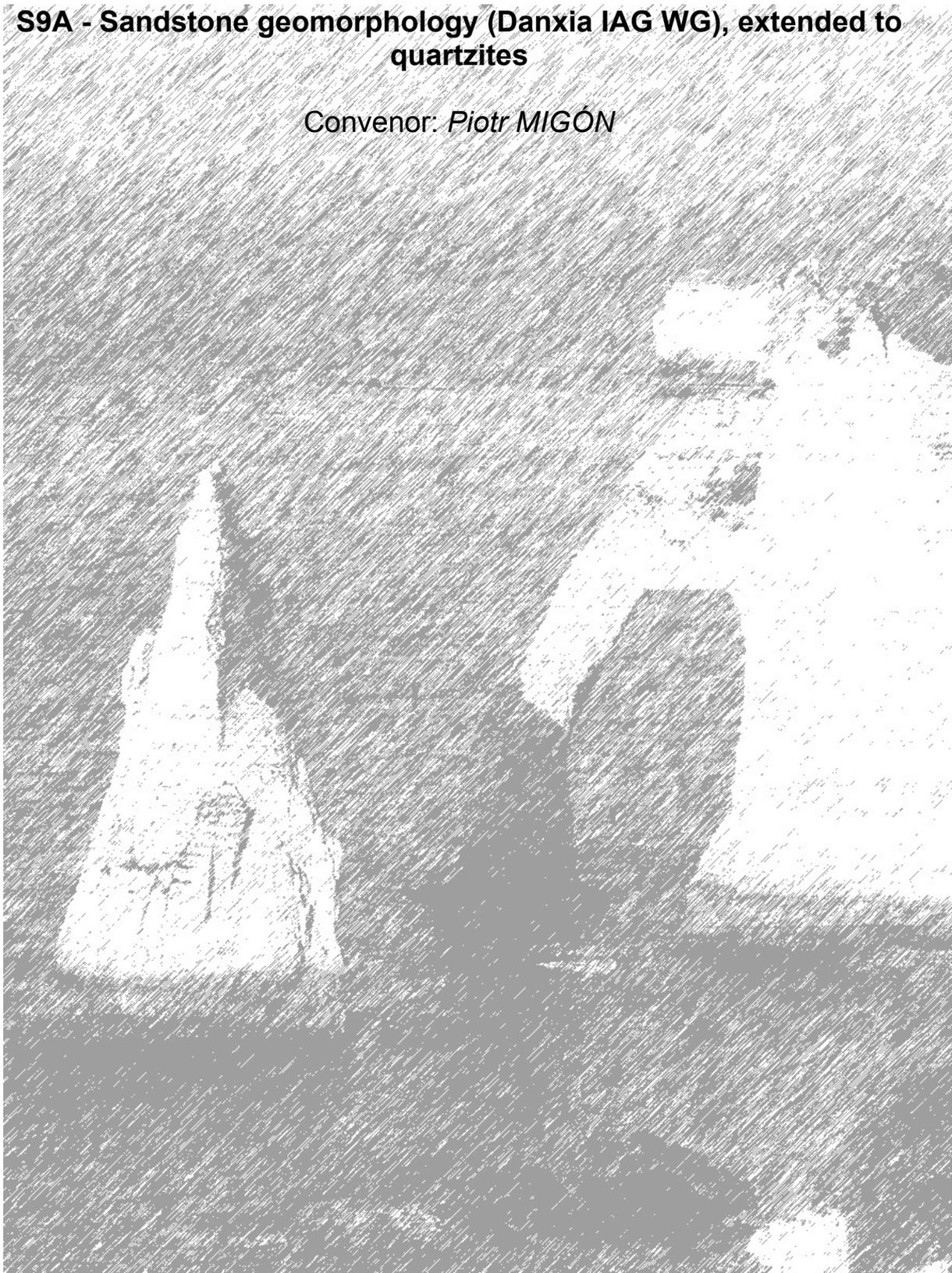
*CNRS-University Bordeaux 3, PESSAC, FRANCE*

The beginning of the karstification process is capital in paleogeography (indicator of emersion) and karstology. The studied examples are situated at low altitude (5-25 m) in the Oligocene limestone on the left side of Garonne (Graves Vineyards). The observations made in the quarries of the Entre-Deux-Mers plateau, on the right bank (50-100 m), have shown the existence of isovolume alteration into the limestone. The same observations and petrographic analyses were performed in the Graves. The interest of this low area, covered by the Quaternary terraces of Garonne, is to have recent sinkholes and collapses. We are in the presence of small systems whose springs are located along the Garonne: Portets, Castres, Virelade, Podensac, Cerons. The flow regime shows slight variations and suggests a non karstic functioning as for alluvial aquifers. The example of Virelade system shows a big collapse of 30 m diameter and 17 m deep, formed in 1983. It indicates the existence of an ancient karstic void 10-20 m below the surface. The water table is visible at + 4 m in limestone covered by 8 m of alluvium. A line of ancient collapses is in connection with several losses located in the Barboue River. Similar observations were made in the near Gargale outlet. We are in presence of young karst systems with incipient drains related to compaction and partial evacuation of the ghost-rock by the water table fluctuations and the water transit towards the springs. These incipient caves probably date from the Middle-Upper Pleistocene. They were introduced by the existence of a hydraulic potential appeared during the last glaciations when the Garonne river dug directly the limestone. The grottoes developed into the Entre-Deux-Mers plateau benefited of a higher hydraulic gradient with a non-saturated flow. Virelade model approximates the model of the Fuie Cave in Charente, but the water pumping since the 1970' have promoted some collapses and the dewatering of some small springs.

\*\*\*\*\*

**S9A - Sandstone geomorphology (Danxia IAG WG), extended to quartzites**

Convenor: *Piotr MIGÓN*





## **Oral presentations:**

### **Primary study on the global distribution and geomorphic development of red beds**

PAN Z., PENG H., SIMONSON S., YAN L.  
Sun Yat-sen University, GUANGZHOU, CHINA

In geology and geomorphology, red beds commonly refer to sedimentary rock series with the color of red as the dominant hue. They are the material foundation of Danxia landform, which is an original Chinese name used to describe erosional landscapes developed on red beds. Danxia landform in China has been studied for more than 80 years, but as a new branch subject in geomorphology, it is still insufficiently known outside China. The literature shows that red beds and Danxia landform are widely distributed in the world, but most studies were limited in the field of geology, relevant studies on red bed landform or Danxia landform were conducted based on sandstone landform, and thus, when compared with other rock geomorphology, this type of rock geomorphology is poorly understood, and there is no specific international research on Danxia landform at present. In July, 2009, the establishment of Danxia Working Group was approved by IAG Council, and global comparative study of Danxia-type geomorphology was included as a main work objective. In this paper, we will provide a review of existing research on red beds, Danxia landform and other similar studies. We will describe the distribution, ages, sedimentary environment, geological structure background, and geomorphic features of red beds in the world. Besides, some comparative analysis will also be included. We expect this review research on red beds throughout the world to make a clear reference, and draw attention from international colleagues to the global research of Danxia landform.

\*\*\*\*\*

### **Preliminary Study on Danxia Landform in China**

HUANG J.(1), CHEN Z.(2), ZHANG R.(3), PENG H.(1), QI D.(4)  
(1) School of Geography and Planning, Sun Yat-sen University, GUANGZHOU 510275, CHINA ; (2) Department of geology Science, Lanzhou University, LANZHOU 730000, CHINA ; (3) School of Geographical Science, Nanjing Normal University, NANJING 210097, CHINA ; (4) Institute of Geographic Sciences and Natural Resources of Research, CAS, BEIJING 100101, CHINA

Danxia landform is a special continental red beds landform which is characterized by red scarp slope. A great amount of work has already been done by Chinese scholars on Danxia geomorphology more than 80 years of history. In this paper, we make a brief overview on the field of China Danxia geomorphological study, including the definition of Danxia landform, types and distribution of Danxia landform in China, internal and external forces of landform processes, Danxia landscapes tourism development and its protection aspects.

The red layers of activation Diwa areas is primarily consist of sandstone, conglomerate, sandy conglomerate, mudstone, clastic rock material. In China, Diwa areas deposition had already begun since the last Triassic, the Jurassic and Cretaceous period is strongest. With the tectonic uplifting, occurred tilting, folding, fracture, and produce a series of joints, these within basins become into outflow erosion areas. Under water and wind erosion, denudation and collapse, weathering, biological, wave action, artificial role and other external force, different Danxia landform types development under the control of the different roles. Danxia landscapes is characterized by its red and escarpment.

By the end of 2012, Total 950 Danxia landscape sites hand been discovered in 28 provinces in China. Eighty percent of them are distributed in the crust uplifting red basins formed in Mesozoic and Cenozoic fault basins. Altitude from sea level to 5,000 meters, from semi-arid and arid areas to semi-humid and moist zones, fourteen climatic regions have Danxia landform distribution.

It is estimated about one fifth of national scenic spots is Danxia landscapes in China. Danxia landform is one of natural rock scenery. They are human's wealth and the earth heritage. Some endangered and famous Danxia scenic sites must be protected.

Keywords: Danxia landform; types and distribution; internal and external forces; geomorphic age; China

## Study on the genesis of danxia landform in Longhushan area, southeast China

REN F.

*Saint Louis University, SAINT LOUIS, UNITED STATES*

This study, taking the Longhushan area as an example, aims at assessing the controlling factors to the development of danxia landform, which evolved from late cretaceous continental red beds. Geomorphometry analyses are applied by using remotely sensed images and DEMs (Digital Elevation Models). Lineaments are extracted based on the global one arc-second ASTER GDEM and Landsat ETM images. The result helps to quantify the spatial patterns of the danxia mountains. Subsequent comparison of lineament frequency rose diagram and density map to structural features imply their geological significance with the development of the danxia landform. The slope angle and aspect of danxia mountains are calculated from DEMs. Slope type of the danxia mountains are reclassified from slope angle raster. Statistics show that the steep slopes are dominant in the danxia landform region with the abrupt relief change from adjacent areas. The dominant aspect groups of Northwest and Southeast orientations may be the expression of the regional rift-related geological setting. The drainage network will be delaminated from DEMs. Longitudinal profile and the stream gradient index are parameters that will be used to evaluate geological, structural, and hydro-sedimentological factors that control the configuration of the red beds basin. These parameters allow the detection of anomalies of drainage that can respond to different factors such as lithology and/or tectonics. In order to quantify the denudation rate of the danxia landform, two principal low temperature thermochronometers are used in this study, apatite fission track analysis (AFT) and apatite (U-Th)/He analysis. Eleven samples were collected in all from the clasts in the red beds basin. Hopefully it will improve the insight into danxia landform development process in the area.

Keywords: danxia landform, remotely sensed imagery, DEMs, low temperature thermochronometers

\*\*\*\*\*

## Contraverses over naming landscapes and implications ' Case of Zhangjiajie Global Geopark of China

HUANG H.(1), GU J.(1), SONG H.(2), XIAO S.(1), TIAN S.(3)

*(1) Institute of Geographi Sciences and Natural Resources Reserach, Chinese Academy of Sciences, BEIJING, CHINA ; (2) Bureau of Land Resource of Zhangjiajie City, HUNAN PROVINCE, CHINA ; (3) Jishou University, HUNAN PROVINCE, CHINA*

Recent movement on setting up geoparks at national and global scales has imposed considerable challenges to geomorphologists. The geologically and geomorphically distinct sites are of very important scientific, ecological and tourism values and provide an excellent opportunity for geomorphologists to communicate the significance and substance of the science to the community. However, few geomorphologists have been engaged into the movement, although there are urgent issues requiring them to solve, such as naming a distinct site among the variety of landscapes that have either similar landforms or similar lithology, climate, or the other similar aspects.

Zhangjiajie Geopark is located in Hunan Province of China, and has been one of the top-listed tourism sites in China. Its unique landscape has developed in Devonian sandstone over an area of ~400 km<sup>2</sup> and is characterized by more than 3000 sheer vertical sandstone pillars, peaks and walls of up to 350 m height. Due to the spectacular features, it has been declared an UNESCO Global Geopark recently. Over the years, however, considerable debates have been under way on naming the distinct landscape. To clarify the confusion and promote the application of geomorphic knowledge in managing the geopark, a research center has been set up recently. This presentation introduces the major research activities of the center, typically on the detailed investigation of the causes behind the debates over naming the landscape and the promotion of geomorphic knowledge in geopark management and tourism development.

### **'Mo Hin Khao' a sandstone geotourism site in Thailand**

SAMINPANYA S.(1), DUANGKRAYOM J.(2), JINTASAKUL P.(2), HANTA R.(2)

(1) Department of General Science, Faculty of Science, Srinakharinwirot University, BANGKOK, THAILAND ; (2) Northeastern Research Institute of Petrified Wood & Mineral Resources (In Honour of His Majesty the King) Nakhon Ratchasima Rajabhat University, NAKHON RATCHASIMA, THAILAND

"Mo Hin Khao", an attraction site, is located at the western edge of the Khorat Plateau, in the area approx. 0.32 Km.<sup>2</sup> of Phu Laenkha national conserved forest of Chaiyaphum province, Thailand. It has been created by weathering of the white sandstone namely Phra Wihan Formation (Cretaceous). The site situates on the dip slope of cuesta (strike N-S with low-angle dip, <15°E) and its steep escarpment is to the west. The highlight is a group of five sandstone pillars of up to 12 meters high and the perimeters at the base ranging from 9.5 to 27.67 meters. The other groups of sandstone outcrop are the shorter pillars and hummocks. On top of them may be covered with polygonal cracks and their vertical surfaces show structures e.g. cross beddings and small and shallow holes. A stratigraphic study indicates the deposition of at least 4 sequences. Sandstone was classified as quartz arenite, sublitharenite and subarkose with mainly medium grains and there are some granules and coarse sands at the lower part of the beds. The mineralogy proved by petrography, X-ray diffractometer and electron probe microanalysis includes quartz feldspars (albite and orthoclase) muscovite, tourmaline, zircon, magnetite, amphibole and clay minerals, suggesting that the sediment source was more likely to be the older felsic igneous rocks. Geomorphic processes of the area started from the deposition of the sediment in the fluvial environment and after lithification the tectonic movement and uplift affected the sandstone beds resulting in folding structure (fold axis of NNE-SSW) and then the anticline-crest beds suffered from the high strain of extension causing two vertical fracture or joint sets (NW-SE and NE-SW) cutting in the beds at the anticlinal zone. The weathering and erosion have taken place intensively along the fractures and joints and now been leaving the remnants including anticlinal valley, escarpment and the pillar groups of the higher resistant sandstone.

\*\*\*\*\*

### **'Rougiers' and 'Ruffes' of southern France. A comparative study of geology, landforms and landscapes in the Permian basins of Lodève and Saint-Affrique (Aveyron, Hérault)**

GIUSTI C.

UMR 8185 ENeC Espaces, Nature et Culture, PARIS, FRANCE

The Rougiers of Camarès is a geographical area coinciding with the Permian outcrops of the Saint-Affrique Basin (Aveyron) in the Massif Central, 20 km SW of Millau. This basin is limited to the east by the Mesozoic sedimentary formations of the Grands Causses, and to the south, west and north by the crystalline and metamorphic basement of the Monts de Lacaune, Albigeois and Rouergue. Though outcrops of coarse conglomeratic facies may locally be extensive, most of the landscape is developed in a thick and predominantly reddish argillite formation interbedded with centimetre-thick carbonate horizons. Landforms mainly consist of hills and gullies, with structural or erosional platforms such as glacis or erosion surfaces.

The Lodève Basin (Hérault) 45 km west of Montpellier, is defined by another group of Permian formations, limited by the Caroux-Espinouse-Mendic gneissic and granitic basement in the west, by the Grands Causses in the north, and by the Cenozoic sedimentary formations of the Languedoc Lowlands in the south and east. The landscape of the Lodévois "ruffes" (latin *rufus*, reddish) could be quite similar to that of the Camarès "rougier", except for one key difference: the presence of thick and diverse basaltic formations of Pliocene and Quaternary age. The radiometric age obtained for several outcrops belonging to the corresponding N-S Escandorgue volcanic chain provide valuable benchmarks for reconstructing the last stages of landform development in the region. Other landmarks consist in elements of a regional erosion surface, the Piedmont Surface system, and of a lower partial planation surface, the Plan de Carlencas system.

Another difference between the rougiers and ruffes landscapes is of a bioclimatic nature and concerns the floristic composition of woodland vegetation: whereas the Lodève Basin entirely lies in an area of Mediterranean climate (*Quercus*), Camarès is more exposed to Atlantic influences (*Fagus*).

## **Sandstone versus conglomerate erosional landscapes - Why similarities? Why differences?**

*MIGON P.(1), WRAY R.(2)*

*(1) Department of Geography and Regional Development, University of Wrocław, WROCLAW, POLAND ; (2) University of Wollongong, WOLLONGONG, AUSTRALIA*

Sandstones have some of the most spectacular landscapes on Earth. These erosional landscapes are most distinctive if the beds are of only low to moderate dip. Differences in lithology, rock mass-strength, or resistance to weathering and erosion between beds usually give rise to stepped topographies, with strong rocks acting as cliff-formers and caprocks. Often, though not always, sandstone terrains are typified by angular shapes of major landforms, and these are related to the predominant mode of rock disintegration into joint-bound blocks of various size. Mass movements and erosion too are strongly controlled by discontinuities and leave angular scarps, deep clefts and alcoves. Rounded landforms do occasionally occur and generally are associated with thinly-bedded, weaker, poorly cemented and less resistant sandstones, where the breakdown is predominantly grain-by-grain.

Conglomerate terrains, by contrast, are commonly more rounded, with curved towers and tors, domes, spires and convex ridges. Excellent examples are seen in Montserrat – Spain, Sisteron – France, and Meteora – Greece, but particularly in south-eastern China where they are known as Danxia. The latter have formed on Mesozoic red beds which contain various lithologies, from coarse conglomerates to siltstones and claystones. The most distinctive rounded shapes are seen where thick conglomerates dominate. In many of these Danxia areas distinct bedding and regular jointing patterns is sparse, hence breakdown proceeds via release of individual clasts and disintegration of matrix rather than joint-controlled detachment of larger blocks, as in many sandstone areas.

However, at a smaller scale, there is often a remarkable geomorphological convergence between sandstones and conglomerates. Bedding caves, tafoni, flutes, runnels and hoodoo rocks are ubiquitous features in both rock types. They seem to be controlled mainly by selective grain-by-grain breakdown and porosity differences.

\*\*\*\*\*

## **Poster presentations:**

### **A model simulation of the 'arenisation' weathering process in quartz-sandstones: a key factor for speleogenesis in the quartzite environment**

*MECCHIA M.(1), SAURO F.(2), PICCINI L.(3), DE WAELE J.(2)*

*(1) La Venta Geographic Explorations Association, TREVISO, ITALY ; (2) Department of Biological, Geological and Environmental Sciences, BOLOGNA, ITALY ; (3) Department of Earth Sciences, University of Florence, FLORENCE, ITALY*

Arenisation is considered the main weathering process driving the formation of karst-like features and cave systems in the quartzite environment. We propose a numerical model useful to understand the timing and the possible situations in which this process works. Similar models are widely used for understanding the first phases of speleogenesis in limestone. In the quartzite environment not only dissolution is involved in the speleogenetic process, and all possible other factors have to be taken into account. Our model is based on the different SiO<sub>2</sub> concentration existing between waters in the external film at the surface of an open fracture (undersaturated) and the intergranular porosity water (supposed to be at the saturation point). The chemical potential allows the removal of silica from the rock without significant movement of water. Dissolution causes an increase in porosity in the first layers of quartz grains in a water-filled fracture. When a critical value of porosity is reached in these layers, individual grains can disintegrate and be washed away by the flowing water, boosting the opening of the fracture.

The model addresses all the equations related to the chemical equilibrium of SiO<sub>2</sub>, the chemical and physical characteristics of water, the flow rate in the fracture, and the porosity of the quartz-sandstone. The original width and length of the fracture, the texture of the rock (grain size) and the hydraulic gradient, are defined by the operator in order to simulate different situations.

The same principles are applied in two other models, the first related to the effect of arenisation by a film of undersaturated water on a wall (simulating evaporation/condensation processes on cave walls) and the second related to weathering and arenisation in a flowing stream.

The results are finally compared with field observations and geochemical data from the Gran Sabana region, Venezuela, considered as one of the finest quartzite karsts in the world.

## **Distribution of red beds and classification of their erosion intensity in Guangdong Province, P.R.China's remote sensing and GIS approach**

SIMONSON S.

*School of Geography and Planning, Sun Yat-sen University, GUANGZHOU, CHINA*

Due to the lithologic character of red beds and human activity, land degradation is very common in red bed basins of humid Southern China. Extensive Cretaceous-Paleogene continental red bed basins are located in Guangdong Province, making it an ideal region for this study. The existing research on red beds is mainly limited to geology and Danxia landscape, which is a special kind of red bed landform that developed on thick, well lithified layers of red beds. However, little attention has been given to the geomorphic evolution of red beds composed of poorly lithified rocks and their associated erosion rates. By analyzing the spectral data and image texture features specific to the red beds, we intend to extract the remote sensing information of red beds in Guangdong Province from Landsat TM images taken in 2008. Once mapped, the spatial distribution of red beds in Guangdong Province can be determined. Multi-band imagery will be used in tandem with Digital Elevation Data (DEM) to map Normalized Difference Vegetation Index (NDVI), gully density and slope gradient. These parameters will be used to classify the red bed basins in Guangdong Province into different erosion intensity categories. We expect this approach to reveal the relationships between lithology, geomorphic evolution, and land degradation of red beds. We also hope this study can provide some foundation for the ecological restoration and environmental protection in red bed areas.

\*\*\*\*\*

## **Experimental geomorphology study on bedding caves at Mt. Danxiashan**

PENG H., QIU Z., PAN Z.

*Sun Yat-sen University, GUANGZHOU, CHINA*

Bedding cave is a negative landform widely distributed in Danxia landform area. It is featured by rapid weathering of soft red bed intercalations, which exert great effect on the development of Danxia slope. However, in previous studies of Danxia landform, more attention was paid to the resistant sandy conglomerate that form the spectacular Danxia escarpment, while the physicochemical properties of soft red bed intercalations and their effect on the slope evolution of Danxia landform were neglected. This study aimed to explore the weathering pattern of soft intercalations and their effects on the formation of bedding caves. Based on field investigation, three typical bedding caves were selected as study cases and some rock and water samples were collected to make further laboratory analysis.

Test results showed that the soft red bed intercalations of Danxia bedding caves belong to silty mudstone with high content of clay mineral and argillaceous cement. Due to strong absorbability, high porosity and low compressive strength, these soft intercalated rock layers were vulnerable to weathering and easily broken into loose pieces. The overlying and underlying rock layers, however, were composed of more resistant sandstone or sandy conglomerate with large particle size, which were mainly cemented by calcium and iron oxides, and they had low porosity and higher compressive strength. During the weathering process of soft red bed intercalations, more surfaces of surrounding rock mass are exposed to attack by external agents, the stress field of bedding caves changes and the overlying rocks may creep until collapse. Therefore, the lithologic character of soft red bed intercalations is a determining factor for the development of bedding caves and even the evolution process of Danxia slope.

### **China will start a national basic data survey on Danxia landform**

PENG H., PAN Z., YAN L., SIMONSON S.

*Sun Yat-sen University, GUANGZHOU, CHINA*

Danxia landform refers to erosional landscapes developed on red beds with scarp slopes. It was named by Chinese geologists and has been studied for more than 80 years in China. However, due to lack of international exchange, Danxia landform drew little concern from international colleagues until the establishment of Danxia Geomorphology Working Group at 7<sup>th</sup> IAG conference, Melbourne, July 2009. The main objectives of IAG Danxia Geomorphology Working Group included undertaking a global survey of Danxia landform on the basis of the research work by Chinese scholar, and providing a platform of information exchange between geomorphologists from different countries.

In September 2012, our project "National basic data survey of Danxia landform" received a research funding from "the Special Program for Key Basic Research" of the Chinese Ministry of Science and Technology. The purpose of this project is to collect basic data about geologic and geomorphic elements of Danxia landform in China, and establish a database with the storage capacity of PB level. We intend to do field investigation in more than 300 typical Danxia landform areas in China, and it will be completed in 5 years. Before the field investigations begin, a classification system of survey elements and a technical standard for field survey will be developed. Then, the basic data about Danxia landform, which include location, area, regional tectonic background, the age and features of strata, lithology, geomorphic type and morphology, will be stored by sorting code number to establish a database, which will be used as a data sharing platform to promote the comparison study of Danxia landform in and outside China. In addition, we expect this project can also provide technical and information services for environment protection, disaster prevention, scientific education and tourism in Danxia landform area.

\*\*\*\*\*

### **Inherited evolution of sandstone landforms in the Tadrart Acacus massif (central Sahara) and associated formation of banded iron speleothems and crusts**

ZERBONI A.(1), VERRECCHIA E.(2)

*(1) Dipartimento di Scienze della Terra "A. Desio", Universite degli Studi di Milano, MILANO, ITALY ; (2) Institute of Earth Sciences, University of Lausanne, LAUSANNE, SWITZERLAND*

Sandstones are widespread on the Earth's surface, representing the substrate for a wide range of landforms. They are common in the Sahara and have been shaped by geomorphological processes since the late Tertiary; but they are no longer in equilibrium with the present-day hydrological regime. In hyperarid central Sahara (SW Libya), the Tadrart Acacus massif is dominated by Paleozoic to Mesozoic quartzarenite. It is a NS elongated massif, dissected by a dendritic fossil drainage network and delimited eastward by a scarp with hanging valleys. To the east, it grades through a pediment to dunes of erg Uan Kasa. The walls flanking the wadis are vertical and dotted with rockshelters and caves. The main observed geomorphological features are related to etching and solutional processes occurring since the Tertiary. Etchplanation and tropical pedogenesis, which removed most of the sandstone bedrock, are the oldest processes that have taken place in the area under rainy and warm Tertiary climate. Subsequently, under the same environmental conditions, underground solutional processes occurred reaching some hundred of meters in depth. Vertical and horizontal tubes, caves, towers, pillars, and weathering pits are commonly observed features. Solutional processes were able to reach the ferruginous sandstone beds and contributed to iron leaching. Fe-rich solutions migrated within the discontinuities of the bedrock, precipitating as iron minerals within fractures, forming banded iron speleothems, and cementing gravel bodies at the mouth of underground drainage network. XRD and SEM analyses confirm that banded iron formations mostly consist of hematite, goethite, and clay minerals. Likely, Fe-rich solutions reached the deepest part of the massif and, upon resurgence, precipitated as Fe-oxy-hydroxides, probably due to biological mediation. After this period, Quaternary arid phases promoted diagenesis of Fe-oxy-hydroxides into hematite at low temperature, as well as their weathering.

## **Study on the geosciences and geotourism value of Kongtongshan Danxia Landscape in Pingliang, Gansu Province, China**

*HUANG J.(1), CHEN Z.(2), ZHANG R.(3), QI D.(4), WANG S.(4), WANG Z.(5)*

*(1) School of Geography and Planning, Sun Yat-sen University, GUANGZHOU 510275, CHINA ; (2) Department of geology Science, Lanzhou University, LANZHOU 730000, CHINA ; (3) School of Geographical Science, Nanjing Normal University, NANJING 210097, CHINA ; (4) Institute of Geographic Sciences and Natural Resources of Research, CAS, BEIJING 100101, CHINA ; (5) The Administrative Committee of Kongdongshan Geopark, PINGLIANG 744000, CHINA*

Kongtongshan Danxia landform Geopark is a natural region with geological landscape of extraordinary geosciences significance, special uniqueness and geotourism aesthetic value. With colorful natural landscape, ancient architecture and Taoism culture, Mt. Kongtongshan is not only a tourist site for sightseeing, leisure and entertainment, but also a key conservation district for geologic relics and ecological environment. It is an important base for geo-science research and education destination.

The Kongtongshan Formation conglomerate, developed under a dextral strike slip environment in late Triassic, is the material source of Kongtongshan Danxia Landform. Based on the regional dynamic environment of Mt. Kongtongshan area, we can recognize changing of Ordos Basin, gradually closing of the Paleo-Tethys Ocean from east to west and breakage of the northwestern China Craton. By means of sedimentary characteristics and structure, formation contrast, Optically Stimulated Luminescence(OSL) and Thermoluminescence(TL), the dynamic mechanism and tectonic attribute and evolution of the Kongtongshan Danxia landform can be comprehensively analyzed in this paper.

To estimate the tectonic uplifting rate of Mt. Kongtongshan area, calculate the geomorphic age of Mt. Kongtongshan and cliff retreating rates and erosion rates and so on, this paper presents four simple proposed by authors after sever years field-test. On May 18 and November 16 in 2012, we collected three gravel samples of the bottom of riverbed in the bedrock seated terrace of Jinghe River and its branch Yanzhi River. Calculating by Huangjin's Danxia Formula, the rate of tectonic uplifting here is 0.51m/10ka. The geomorphic age of Mt. Xiangshang, Huangcheng and Zhongtai is 13 Ma, 11.5 Ma and 8.7 Ma.

Keywords: Danxia landform; geosciences and geotourism value; Mt. Kongtongshan; Pingliang; Gansu

\*\*\*\*\*

## **Origin of "Rock Cities", pillars and clefts in friable sandstone: new insight from study in Sandstone Quarry where landforms recently evolve**

*SCHWEIGSTILLOVA J.(1), SOUKUP J.(2), BRUTHANS J.(2), VACULIKOVA J.(2), MAYO A.(3)*

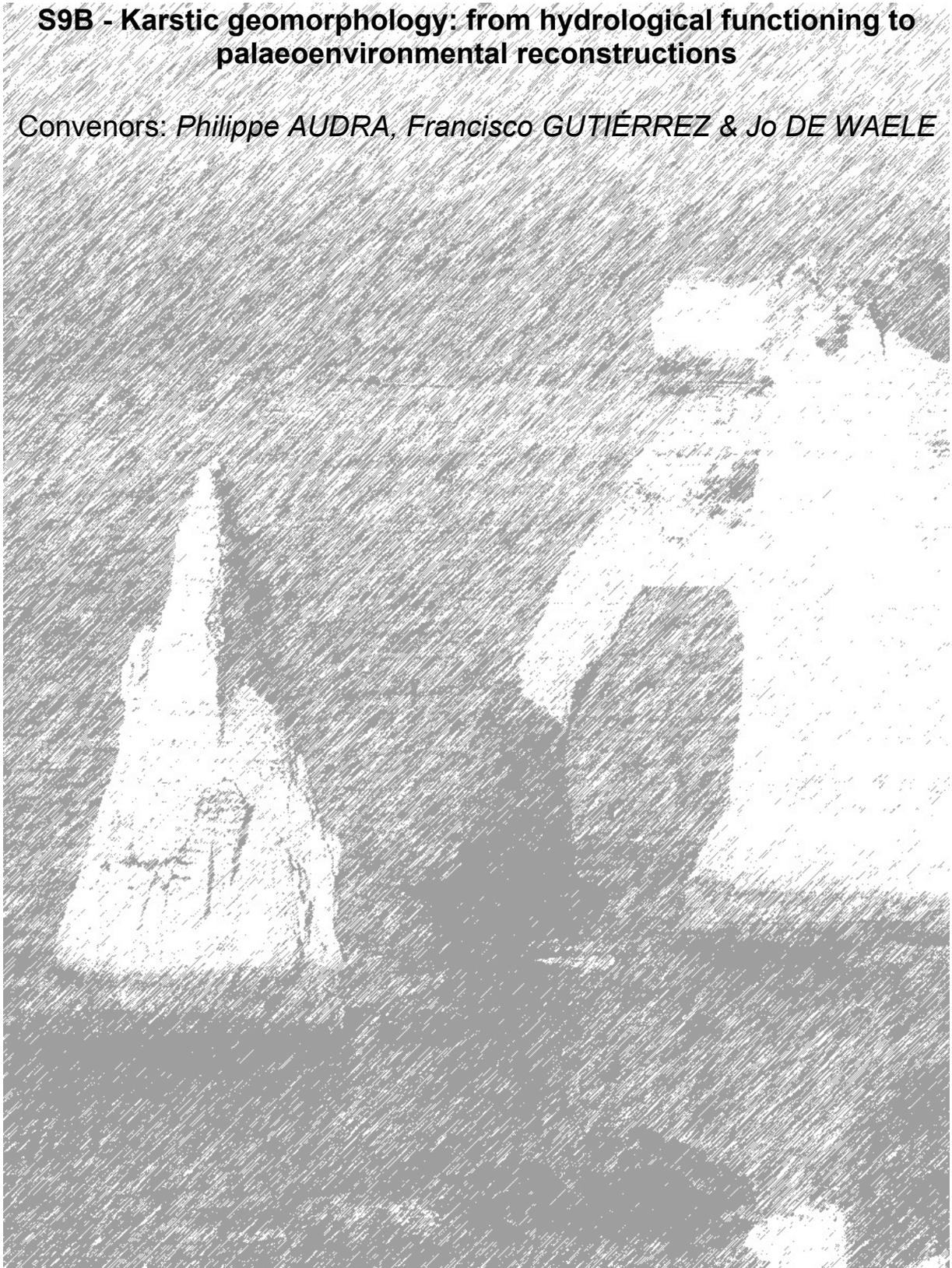
*(1) Institute of Rock Structure and Mechanics ASCR, v.v.i., PRAGUE 8, CZECH REPUBLIC ; (2) Faculty of Science, Charles University in Prague, PRAGUE 2, CZECH REPUBLIC ; (3) Department of Geological Sciences, Brigham Young University, PROVO, UNITED STATES*

Various ideas exist concerning origin of landforms like rock cities (ruiniform landscape with pillars separated by clefts and narrow gorges), rock shelters and small vaulted hollows in friable sandstone. Sandstone surfaces and processes were studied in Strelec Quarry, the Czech Republic in Cretaceous marine quartz kaolinite-bond sandstone, where forms similar to landforms at natural exposures (clefts-conduits, hollows) are evolving at present time. The quarry offers a unique opportunity to characterize the erosion processes, which may form natural landforms prior stabilization by case hardening. Based on measurements of flow velocity, hydraulic gradient, relative erodibility, ambient and water-saturated tensile strength at natural and quarry exposures and SEM three distinct kinds of surfaces were distinguished: 1) Erodible sandstone; 2) Sub-vertical fracture-bounded surfaces that are non-erodible and formed tectonically (slip faces of microfaults); 3) Case hardened surfaces that start to form after exposure. In favorable conditions case hardened surfaces became non-erodible and reach the full tensile strength in just 6 years. Flow in openings with a discharge 1 ml/s and hydraulic gradient > 0.05 exceed the erosion threshold and initiates piping. In the first phase of conduit evolution, fast concentrated flow mobilizes erodible sandstone between sets of parallel fractures in the shallow phreatic zone. In second phase the conduit opening mainly expands vertically upward into the vadose zone by mass wasting of undercut sandstone slabs. Mass wasting is responsible for > 90% of mobilized sandstone. Sides of the mature conduits are protected by non-erodible fracture-bounded surfaces. Natural landforms were probably formed rapidly by piping and possibly overland flow and fluidization during or at the end of the glacial periods when sandstone was not yet protected by case hardening. Erosion proceeded along densely fractured zones.



**S9B - Karstic geomorphology: from hydrological functioning to palaeoenvironmental reconstructions**

Convenors: *Philippe AUDRA, Francisco GUTIÉRREZ & Jo DE WAELE*





## **Oral presentations:**

### **Rare sulfate minerals (fibroferrite) and hypogene sulfuric speleogenesis in Baume Galinière Cave (Alpes-de-Haute-Provence, France)**

*AUDRA P.(1), BIGOT J.Y.(2)*

*(1) Polytech Nice - Sophia, University of Nice - Sophia Antipolis, BIOT, FRANCE ; (2) Association Française de karstologie (AFK), MONTPELLIER, FRANCE*

The oxidation of sulfides sources (H<sub>2</sub>S gas, pyrites oxidation, hydrocarbon leakages...) produces sulfuric acid that strongly reacts with its environment, with limestone dissolution and complex interaction with other minerals in presence. Such kind of cave development is referred as Sulfuric Speleogenesis, a subcategory of hypogene speleogenesis (i.e. with source of aggressivity and water rising from depth). It also produces uncommon mineral, mainly sulfates.

Baume Galinière locating in Southern France, in Vaucluse spring watershed. This small maze cave originates from the oxidation of small pyrite ores. Several speleogenetic phases are recorded, successively phreatic with calcite dykes and iron crusts, then in atmospheric environment involving sulfuric gases. Attenuated oxidation is still occurring through condensation of the air entering the nearby entrance. Characteristic features are present (especially corrosion notches), together with sulfuric speleogenesis by-products, such as sulfur, goethite, and sulfates (gypsum, jarosite, natrojarosite, fibroferrite). It is the second mention of fibroferrite, a rare cave mineral, which can develop only within low pH and RH conditions.

Together with others hypogenic caves surrounding the Vaucluse watershed, the Baume Galinière Cave owes its presence to deep water lifts along major faults, at the contact of the karst aquifer confined by impervious covers. It records the position of paleo-covers and their retreat, in relationship to the landscape evolution and the valleys incision, which responds itself to the uplifting and tilting of the Vaucluse block during Neogene.

\*\*\*\*\*

### **Interaction between the fluvial incision and the geological structures: the Torca La Texa shaft (Picos de Europa, Spain) case**

*BALLESTEROS D.(1), JIMÉNEZ-SÁNCHEZ M.(1), GIRALT S.(2), GARCÍA-SANSEGUNDO J.(1), MELÉNDEZ M.(3)*

*(1) University of Oviedo, OVIEDO, SPAIN ; (2) Institute of Earth Sciences Jaume Almera-CSIC, BARCELONA, SPAIN ; (3) Instituto Geológico y Minero de España, OVIEDO, SPAIN*

The Picos de Europa is an alpine karst that includes 270 km of large shafts and cave levels perched over the water table; nevertheless, only the speleogenesis of 4 % of the caves have been studied systematically. The aim of this work is to characterize the geomorphology, structural control and evolution of Torca La Texa shaft. The method includes speleological, hydrogeological, geomorphological, geochronological and structural techniques. Torca La Texa (4° 53' W 43° 16' N 1,305 m) is a multilevel cave (2.6 km long, 215 m depth) formed by four levels (43 % of the cave) perched at 1,273, 1,258, 1,238, 1,168 m, five *soutirage* conduits (5 %) and narrow canyons (52 %). A spring sited at 835 m represents the base level of the cavity. The cave levels show fluvial features modified by incision and often covered by speloethems. The *soutirages* include epiphreatic features and debrisflow deposits remobilized from the upper passages; the canyons were modified by gravity process in some places. Three speleothem samples from the second cave level were dated in 65, 156 and 181 ka, whereas the fourth sample is out of range of the U-Th method. The shaft is developed in a carboniferous limestone located at an antiform associated to an imbricate and overturned system thrust. Cave passages are forced by four families of joints (1: N120E/78SW; 2: N146E/52SW; 3: N100E/59SW; 4: N184W/60NW), the bedding (N123-186E/60SW) and the axis fold (N263E/41SE). The results evidence Torca La Texa was developed in relation to the progressive drop of the water table in a complex structural environment. The cave levels were developed in phreatic conditions and guided by the bedding and families of joints 2 to 4, while *soutirages*, shafts and canyons are formed downwards follow the bedding, families of joints 1 and 4 and the axis of the fold. The first and second cave levels were originated by fluvial process that probably finished 156-181 ka ago and with large flowstone should deposited until 65 ka ago.

**Alteration of the Jurassic limestones series in the Charente karst basin: Impacts for the speleogenesis by ghost-rock process and the genesis of the large Touvre aquifer**

DANDURAND G.(1), MAIRE R.(2), DUBOIS C.(3), VANARA N.(4), QUINIF Y.(3)

(1) ADES CNRS/Bordeaux 3, PESSAC, FRANCE ; (2) ADES CNRS/Bordeaux 3, PESSAC, FRANCE ; (3) Université de Mons, MONS, BELGIUM ; (4) LGP / Université de Paris-Sorbonne, PARIS, FRANCE

A new study of the karstic basin of the Touvre springs in Charente (2<sup>nd</sup> in France) shows the prominent role of alteration called "ghost-rock". This peculiar process developed during emersion of the carbonate platform during the Lower Cretaceous (45 Ma). It was demonstrated by the study of quarries, drillings and the young cave of La Fuie. These approaches highlighted the crucial role of ghost-rock process in the formation of karst landscapes of Charente.

Micromorphological analyses from altered samples shows a micro-dissolution in various forms and the likely role of bacteria. Ghost-rock features are clearly identified by Liesegang rings, the alteration way which initially attacks sparitic crystal areas and continues by the dissolution of micrite. *Siderobacteria in grap-type cocci* form iron-oxide deposits as iron micropisolithes.

This decay process explains the genesis of maze caves and also the complexity of the Touvre aquifer. For the first time an active speleogenesis by ghost-rock process is demonstrated in Charente. La Fuie Cave was used as a subterranean laboratory to highlight a new way to drain residual deposits by flooding-dewatering of galleries associated with collapses from ascending chimney in a cave system. This discovery contradicts the classical theory of the formation of caves by slow dissolution of joints and fractures. Indeed, the high fluctuations of the water table generate typical maze caves coming from the erosion of the ghost rock network in the three dimensions.

Furthermore the large water reserve (1-2 km<sup>3</sup>) of the Touvre springs is situated into the porous Jurassic limestone (slow drainage) while a small part is drained by the karst conduits (fast drainage). The erosion of porous rock is activated upstream by the losses along the valleys. Downstream there is also an headward erosion from the main spring.

The conclusion discusses three research perspectives concerning speleogenesis, hydrogeology of karst reservoirs and the role of paleogeography.

\*\*\*\*\*

**Epigenic gypsum caves as indicators of climate-driven river incision and aggradation in a slowly uplifting region (Emilia Romagna, North Italy)**

DE WAELE J., FORTI P., MARABINI S., PICOTTI V.

*Department of Biological, Geological and Environmental Sciences, BOLOGNA, ITALY*

Karst in Emilia Romagna (N-Italy) is mainly confined to gypsum outcrops. Large epigenic karst developed in several of these areas, with caves reaching up to 10 km in length. Larger cavities host active rivers and display series of cave levels. These stacked stream passages reflect both the uplifting Apennines and Quaternary climate changes, and the consequent entrenchment/aggradation of surface streams, representing local base-level.

Rivers flowing towards the Po plain adjust their stream profiles to tectonics with variable rates at the scale of >100 ky. At lower frequency, climate controls entrenching during low discharge periods, when the bedload is too limited to prevent stream erosion and vertical incision. High discharge periods allow the valley to widen by lateral erosion. These conditions enhance the carving of strath terraces and the aggradation of terrace fills. Recent datings of flights of terraces document the duration of aggradation around 2-3 ky during Late Glacial to Holocene, with surface streams remaining stable in a 5 m altitude range during which cave levels have the time to develop.

A detailed study allowed to reconstruct the entrenchment of the underground rivers in response to valley deepening. Age constraints on river straths, geomorphological observations and modeling show erosion to have occurred during cold periods. The widespread occurrence of antigravitative evolution in cave conduits is related to the aggradation of surface rivers, causing underground streams to carve upwards.

These studies indicate that detailed investigations on cave morphologies in multi-level gypsum caves may help to unravel the climatic and tectonic evolution of the area in fast and slow developing karst respectively. This evolution can be constrained by datings of terrace fills and speleothems. This model, valid for gypsum in temperate regions, can be exported to limestone in higher precipitation regimes, or to halite in arid areas.

### **The role of condensation in the evolution of dissolutional forms in gypsum caves: an example from the karst of Sorbas (SE Spain)**

*GÁZQUEZ F.(1), CALAFORRA J.M.(1), SANNA L.(1), FORTI P.(2), DE WAELE J.(2)*

*(1) Department of Hydrogeology. University of Almería, ALMERÍA, SPAIN ; (2) Italian Institute of Speleology, Department of Biological, Geological and Environmental Sciences, University of Bologna., BOLOGNA, ITALY*

The karst of Sorbas (SE Spain) is one of the most important gypsum areas worldwide. Its underground karst network is composed of over 100 km of cave galleries which are distributed in seven levels. In this work, the morphological features, developed in the upper cave systems and induced by condensation-dissolution mechanisms, have been studied by means of Micro-Erosion Meter (MEM) measurements, monitoring microclimatic parameters and direct measurements of condensation water.

Rounded smooth forms, condensation cupola and pendant-like features appear on the ceiling of the shallower galleries (less than 10 metres deep) as a result of gypsum dissolution by condensation water. Meanwhile, gypsum speleothems formed by capillarity, evaporation and aerosol deposition such as coralloids, gypsum crusts and rims are frequently observed in the lower parts of the cave walls. Monitoring of erosion at different heights in a cupola revealed that the surface of the gypsum retreated 0.05 mm/year in a MEM station located at the highest part of this cave dissolutional form, while this value was negligible at the lowest site, proving higher dissolution rates close to the cave ceiling, where warmer, and thus lighter air flows. Direct measurements of the amount of water dripping from a metal plate hanging in the centre of a cave gallery indicate that this process mainly occurs between July and November in coincidence with rainless periods, as a consequence of external moist warm air entering the cave and water vapor condensing on the colder cave walls. Microclimatic parameters show that the thermal stratification, induced by differences in temperature and humidity between the air at the bottom of the conduit (10 °C and 90% of relative humidity) and near the cave ceiling (13 °C and saturated), controls the intensity of the evaporation-condensation mechanisms occurring at different heights in the cave galleries and also the gypsum speleothem growth.

\*\*\*\*\*

### **Cave geomorphology as a record of environmental changes: the El Pindal Cave (Cantabrian Coast, N Spain) case study**

*JIMENEZ-SANCHEZ M.(1), STOLL H.(1), GIRALT S.(2), MORENO CABALLUD A.(3), DOMINGUEZ-CUESTA M.J.(1), ARANBURU A.(4), MENDEZ-VICENTE A.(1), BALLESTEROS D.(1), VALERO B.(3), CHENG H.(5), EDWARDS L.(5)*

*(1) DEPARTMENT OF GEOLOGY UNIVERSITY OF OVIEDO, 33005 OVIEDO, SPAIN ; (2) Department of Environmental Geology and Georisks, ICTJA, Solé i Sabaris s/n, E-08028 BARCELONA, SPAIN ; (3) Department of Geoenvironmental Processes and Global Change Instituto Pirenaico de Ecología (CSIC), Avda. Montañana 1005, 50059 ZARAGOZA, SPAIN ; (4) Department of Mineralogy and Petrology University of Basque Country, Sarriena s/n., 48940 LEIOA, SPAIN ; (5) Department of Geology and Geophysics, University of Minnesota, 55455 MINNEAPOLIS, MINNESOTA., UNITED STATES*

This study focuses on the use of caves as geomorphological records of regional and global events. Geomorphologic mapping, structural, sedimentological analyses and absolute dating based on U-series desintegration and OSL were applied to El Pindal Cave, located 24 m above sea level in the Cantabrian Coast (Asturias, NW Spain).

The development of the cave was controlled by E-W trending faults that would have favoured the emplacement of phreatic conditions probably associated to the evolution of the Deva River. The evolution of the cave is controlled by the following processes: gravity action, speleothem precipitation and fluviokarstic activity. A roof collapse took place prior to 6 ka and after 14 ka. Speleothem precipitation gave place to five generations of speleothems: (1) Flowstones older than 230 ka; (2) Stalagmites from the Upper Pleistocene to the Middle Holocene (37 to 4 ka), recording LGM of MIS2; (3) Stalagmites older than 7 ka; (4) Late Holocene stalagmites (from 3.3 ka to present) and (5) Stalagmites coeval or younger than 200 yr. OSL dating of detrital levels suggests: (1) the occurrence of a cave flooding episode at 120 ka (MIS 5) and (2) the activation of the alluvial fans to the South of the cave at 75-57 ka, as a response to a probable regional incision during MIS4. The comparison between geomorphological events in the cave and regional and global events demonstrates the potential of cave geomorphology as a record of environmental changes, complementing paleoclimate and palaeoenvironmental research based on other terrestrial and marine archives.

Keywords: *Cave, Karst, Marine terrace, geochronology, U-Th series, OSL dating, Cantabrian Coast.*

### **Morphogenesis reconstitution on Kelb valley, Lebanon: contribution of Jeita cave speleogenesis and karst landforms study**

NEHME C.(1), DELANNOY J.J.(2), GÉRARD J.(3), JAILLET S.(2)

(1) *Université de Savoie, BOURGET DU LAC, FRANCE* ; (2) *Université de Savoie, BOURGET DU LAC, FRANCE* ; (3) *Saint-Joseph university, BEIRUT, LEBANON*

A geomorphological study has recently been conducted in Lebanon and aims at reconstituting the palaeogeographical stages of valleys related with the downcutting of the Mediterranean hydrographic network. This study focuses on the reconstitution stages of Kelb valley incision. Whereas geomorphic indicators are rare on the surface, we used sub-surface geomorphologic indicators revealed from the speleogenesis study of Jeita cave.

The study area is located downstream of the valley and close to the Mediterranean Sea. It is characterized by: i) a geological structure controlling the phreatic zone (dammed karst), ii) a cave network with 10 km of galleries located between 60 and 250m altitude, and iii) few relict landforms (marine terraces, relict valleys). A crossover analysis between speleogenesis stages, the geology of the sector and the relict landforms suggest three stages of Kelb valley evolution from Pliocene to quaternary period. The study highlights on: i) the paragenesis process in Jeita upper galleries along with Kelb river aggradation in response to Pliocene transgression, ii) the incision of Jeita canyon due to the reorganization of the drainage (fluvial and karstic) system during Quaternary, iii) implications of the Mount Lebanon tectonic uplift and the transgression/regression of the Mediterranean sea during these episodes. The reconstitution of Kelb valley downcutting is extended to the adjacent Antelias valley, where some identified paragenetic caves are located at an altitude close to Jeita upper galleries. Finally, this study can suggest a new chronostratigraphy to marine terraces identified along the western flank of Mount-Lebanon. These terraces up to 300 m. altitude were thought to be quaternary in age while altitudinal correlation between Jeita upper galleries and marine terraces (160 to 250m) of Kelb valley suggest another chronology: Lebanon high marine terraces could be of Pliocene age, while lower terraces were formed during quaternary period.

\*\*\*\*\*

### **Thermal Carbonic and Sulfuric Acid Speleogenesis in Cave Provalata, Republic of Macedonia**

TEMOVSKI M.(1), AUDRA P.(2), SPANGENBERG J.(3), MIHEVC A.(4), BIGOT J.Y.(5)

(1) *Temovski\_m@yahoo.com, PRILEP, MACEDONIA* ; (2) *Polytech Nice-Sophia, Engineering School of Nice - Sophia Antipolis University, BIOT, FRANCE* ; (3) *Laboratoire des Isotopes Stables, Institut de Minéralogie et Géochimie, Université de Lausanne, Anthropole, LAUSANNE, SWITZERLAND* ; (4) *Karst Research Institute ZRC SAZU, POSTOJNA, SLOVENIA* ; (5) *French Association of Karstology, MONTPELLIER, FRANCE*

Cave Provalata (Republic of Macedonia) is a rare case of a successive carbonic and sulfuric acid speleogenesis, separated by complete infilling of cave passages with clays. It is a small but remarkable hypogenic cave with abundant gypsum deposits, mostly covering thick corroded calcite crust, with cupolas, ceiling and wall channels, feeders and replacement pockets as some of the most characteristic morphological features. Morphological and mineralogical analyses suggest hypogenic origin in two phases: the first by thermal CO<sub>2</sub> rich waters, the second by sulfuric acid dissolution, which were separated by complete infilling of cave passages with clays. In the first phase cave passages were formed by dissolution along fractures due to cooling of rising carbonated thermal waters. They were later covered with thick calcite crust, deposited after shifting to shallower environment. The cave was completely filled with clays in Early Pleistocene, due to deposition of pyroclastic rocks and travertine deposits in lacustrine environment in Mariovo Basin. After draining of Mariovo Lake and establishing fluvial drainage, Buturica River incised first in the lacustrine deposits, then in Cambrian marbles, creating its superimposed valley, which lowered the water table and allowed washing of the clay deposits. The second phase started after introduction of H<sub>2</sub>S in the thermal waters, which produced sulfuric acid at or near water table, rapidly dissolving the calcite crust and marble host rock. Most of the dissolution happened above water table due to condensation corrosion which produced abundant gypsum deposits as replacement gypsum crust, that later detached and piled as gypsum blocks. At the contact of sulfuric acid with the clay deposits, alunite, jarosite and natroalunite were formed. <sup>40</sup>Ar/<sup>39</sup>Ar dating gave maximum age of 1.6 Ma (alunite) and 1.46 Ma (jarosite). The cave continued to evolve downwards due to lowering of the water table as Buturica River incised its valley.

## **Flank margin caves on a passive continental margin: naracoorte and the other southern australian examples**

WHITE S.

*La Trobe University, PARKVILLE, VICTORIA, AUSTRALIA*

Flank margin caves (FMC) have been predominantly described, using the Island Karst Model, along the margins of the freshwater lenses just beneath the flanks of the enclosing land mass on carbonate islands such as in the Bahamas or the Marianas. This model has been used to explain karst development on young carbonate islands with poorly cemented eolianites. Karst in this setting differs from that formed in well-cemented limestones as usually found in continental settings. However karst on some continental margins, especially the southern Australian coast, are not in well-cemented telogenic rocks but in highly porous, highly permeable marine and eolian calcarenites. The gradual uplift over the past 50 Ma of the southern edge of the continent has resulted in Flank Margin Caves, which formed in a continental coastal setting. Many of these caves are now positioned significantly further inland and reflect the neotectonics of the Southern Australian passive continental margin rather than solely the Pleistocene glacio/eustatic sea-level fluctuations. The inter-relationship of tectonic setting, the distinctive characteristics of FMC and the speleogenesis of coastal karst assists in the understanding of the karst landscape evolution of significant karst areas of southern Australia, particularly in the Naracoorte area.

\*\*\*\*\*

## **New perspectives on the genesis of the Miocene collapse structures of the Island of Gozo (Malta)**

TONELLI C.(1), GALVE J.P.(2), SOLDATI M.(1), GUTIÉRREZ F.(2)

*(1) Università di Modena e Reggio Emilia, MODENA, ITALY ; (2) Universidad de Zaragoza, ZARAGOZA, SPAIN*

The geology of the Island of Gozo (Malta) is characterised by large paleosinkholes controlled by subvertical annular faults (traditionally called "solution subsidence structures") whose dimensions can reach hundreds metres in diameter and vertical displacement, being comparable in size to the largest sinkholes of the World. Despite their unusual dimensions, unusual structure and peculiar associated erosional landforms, varying from large depressions to rounded bays and buttes, these structures have never been investigated from a karst perspective. The theories of formation proposed in the 70's, based on sedimentological and structural observations, are still under debate. According to them, the paleosinkholes would have been formed in the sea floor due to subsidence caused by the collapse of huge cavities developed in carbonates or related to deep-seated dissolution of evaporites. The thickening of stratigraphic units in some paleocollapses, showing cumulative wedge-outs, reveal that subsidence occurred progressively in the sea floor (syndimentary subsidence). Recent detailed geological and geomorphological surveys have been carried out with the aim of revisiting the origin of these paleosinkholes. The collected data have been compared with the characteristics and geological setting of similar examples of karst collapses documented in the World. Based on our literature review and mechanical constraints, gradual subsidence resulting from progressive interstratal karstification of evaporites seems to be most likely alternative. However, the currently available subsurface stratigraphic data do not indicate the presence of significant evaporitic units. Being the Maltese paleosinkholes related to processes developed under different hydrogeological conditions than those existing today, the relationships between their formation and the Miocene paleogeographical setting have been studied to see which alternative could better explain their genesis.

### **Karstic evolution and Human occupation in the Mas d'Azil Cave (Ariège, Pyrénées, France): new research and new results**

JARRY M.(1), BRUXELLES L.(2), BON F.(3), FRITZ C.(4), LACOMBE S.(5), LELOUVIER L.A.(1), MARTIN H.(1), PALLIER C.(6), RABANIT M.(7), TOSELLO G.(8), WATTEZ J.(9), ARRIGHI V.(10), SALMON C.(10)

(1) INRAP and University of Toulouse TRACES UMR 5608, TOULOUSE, FRANCE ; (2) INRAP, University of Toulouse TRACES UMR 5608 and GAES, University of Witwatersrand, Johannesburg, NÎMES, FRANCE ; (3) University of Toulouse and TRACES UMR 5608, TOULOUSE, FRANCE ; (4) CNRS and University of Toulouse TRACES UMR 5608 (CREAP), TOULOUSE, FRANCE ; (5) Binghamton University (SUNY) and University of Toulouse TRACES UMR 5608, NEW YORK, UNITED STATES ; (6) INRAP and ASM Lattes UMR 5140, TOULOUSE, FRANCE ; (7) INRAP and PROTEE, MONTPELLIER, FRANCE ; (8) University of Toulouse TRACES UMR 5608 (CREAP), TOULOUSE, FRANCE ; (9) INRAP and Dmos UMR 5140, PARIS, FRANCE ; (10) INRAP, TOULOUSE, FRANCE

The cave of Mas d'Azil, with the Arize river running through it, is one of the most important – and impressive – karstic context in Southern France. It is also an important place for Prehistoric research, especially for the knowledge of the Magdalenian and Epipaleolithic cultures. However, few synthetic studies are available, contrasting with the celebrity of the site. Under the upstream porch, the left bank still holds cultural sequences from the end of the last glaciation to the Neolithic, intercalated with flood silts. In contrast, the right bank, where the deep galleries are located, was considered sterile or already completely excavated.

Recent preventive (rescue) archaeology operations were conducted on the right bank that have significantly restored the potential of this cave. This paper will present the first results of our work, which is the beginning of a future boarder research program. Thus, the remains of *in situ* stratigraphy offer a new history of the cave where human occupations, such as some unpublished older and recent Aurignacian, are punctuated by the evolution of the cave and its filling, during the LGM episode. Layers of fluvial sediments were deposited before the Aurignacian but also after. These sediments buried archaeological remains under several meters of deposits. They also partially filled all the lower part of the cave and closed some galleries. This event also permits us to revisit the dating of the rock paintings of the Gallery Breuil, considered anterior to the Magdalenian, by setting a *terminus ante quem*. After the re-opening of the cave, human occupations belong to the Middle Magdalenian. *In situ* cultural horizons were discovered under a layer of Mesolithic ashes. The phenomenon of floods recorded here, could be extrapolated across the regional geomorphology and gives, for the first time, strong arguments for to date the formation of the alluvial terraces of the Arize River and to link it to the Garonne valley.

\*\*\*\*\*

### **Isturitz, Oxocelhaya and Erberua Caves (Pyrénées-Atlantiques, France): geoarchaeological studies**

VANARA N.(1), GARATE D.(2), BIGOT J.Y.(3), CANEROT J.(4), LANS B.(5), MAIRE R.(5), MAGNE L.(6), DANDURAND G.(5), PARENT G.(7), LAUGA M.(7), DOUAT M.(7), BRAMOULLE Y.(7), LABARGE A.(8), RIVERO O.(2), DARRICAU J.(9), NORMAND C.(2)

(1) CNRS - UMR 8591 - Physical Geography Laboratory, Bellevue-Paris and Paris 1 - Panthéon-Sorbonne University, PARIS, FRANCE ; (2) CNRS - UMR 5608 - TRACES Laboratory and Toulouse 2 - Le Mirail University, TOULOUSE, FRANCE ; (3) French Association of Karstology (A.F.K.), MONTPELLIER, FRANCE ; (4) 3, chemin Cordeau 31200, TOULOUSE, FRANCE ; (5) CNRS - UMR 5185 - ADES Laboratory, BORDEAUX, FRANCE ; (6) Center of Karstic Studies, ROUEN, FRANCE ; (7) The "Pyrénées-Atlantiques" Regional Caving Organization (C.D.S. 64), PAU, FRANCE ; (8) "Médiations en Préhistoire" Association, SAINT-MARTIN-D'ARBEROUE, FRANCE ; (9) Gaztelu Association, SAINT-MARTIN-D'ARBEROUE, FRANCE

Isturitz, Oxocelhaya and Erberua Caves are located in the foothills of the western Pyrenees. The landscape is hilly and is crossed by a wide valley with a small river, the Arberoue. Downstream, the river disappears into the limestone of Gaztelu Hill: this underground flow created the Erberua Cave. Above this natural tunnel we observe three fossil staged caves: Oxocelhaya, Isturitz and Rocafort. The Gaztelu Caves provide a major European Prehistoric archaeological site. The first recorded data came from the Isturitz Cave (1895), then from the Oxocelhaya Cave (1929) and finally from the Erberua Cave (1973) giving evidence of human occupation during the Mid-Upper Palaeolithic period. These archaeological remains are not uniformly distributed. In Erberua, some of the paintings suggest a Gravettian use of the cave but the works date from the Magdalenian time (Middle and/or Upper). In Oxocelhaya Cave, the settlement may date from Aurignacian time but the art works generally date from the Magdalenian time. In Isturitz Cave, the importance and diversity of the Aurignacian objects are exceptional and prove the permanent nature of this settlement where numerous activities took place. Also during the Gravettian time, an enormous quantity of material is proof of a very important human presence. During the Middle Magdalenian time, the activities are marked in particular by hundreds of portable art, this is why this cave has been described as one of the most important aggregation sites of the Pyrenees. The research team is multidisciplinary and was established in 2011 around twelve main objectives. Our contribution concerns the first two stages and includes speleologists, geologists and karstologists. The first stage was the charting of the numerous listed activities and the second stage will analyze their organization according to the topographic, geological and karstologic specificities of the Gaztelu Hill.

### **Geomorphology of the paleo and recent hydrographic network on the karst plateau (example Una Korana plateau, Croatia)**

BOCIC N.(1), PAHERNIK M.(2), MIHEVC A.(3)

(1) University of Zagreb; Faculty of Science; Department of Geography; Subdepartment of Physical Geography, ZAGREB, CROATIA ; (2) Croatian Military Academy "Petar Zrinski, ZAGREB, CROATIA ; (3) Karst Research Institute, POSTOJNA, SLOVENIA

Karst plateaus generally have a complex geological and geomorphological evolution. One of the largest plateaus in the Dinaric karst is Una-Korana plateau extends along the northeastern edge of the Dinarides. Provides the Dinaric direction (NW-SE) across three countries: Slovenia, Croatia and Bosnia-Herzegovina with a length of 120 km. Width is 10 to 20 km, and the area is about 1800 km<sup>2</sup>. It is mostly built of Mesozoic carbonate rocks of the Adriatic carbonate platform, and main structures and faults extend Dinaric direction. The main morphological characteristic is flatness in the macro level. Because of the carbonate rocks, area is highly karstified. In micromorphological sense dolines prevail (with high density) on the surface and caves in the underground. Area intersected five major rivers which are cut in deep canyons and have no major tributaries. On the entire area, more or less preserved, traces of surface paleohydrographic networks were observed. The aim of the study was to reconstruct and analyze paleohydrographic network and recent features to know about its evolution, impact and development of karstification of this karst plateau. With the methods of field work we also analyzed the data from topographic maps 1:25.000. Analysis of data was performed with the GIS tools. For the first time we reconstructed paleohydrographic network in this area, we analyzed its hydromorphometry, paleo and recent network relationship with geological, structural and karst characteristics of the area and finally its morphoevolution.

\*\*\*\*\*

### **Canol, a proposed new karst international geopark in the Northwest Territories of Canada**

FORD D.

McMaster University, ORILLIA, CANADA

Arctic and sub-arctic karst terrains are little represented in the UNESCO World Heritage and International Geopark programmes. Karst is well developed in the Western Lowlands, Franklin and Mackenzie Mountains north of Lat. 60° N in the Northwest Territories. Most of this vast area was glaciated repeatedly by Laurentide continental or by Cordilleran glaciers but, due to Ice Age aridity, there was an ice-free corridor through the central Mackenzies. The postglacial climate includes a summer warm season but mean annual temperatures everywhere are below 0° C and precipitation is generally only 250 - 600 mm. Permafrost is widespread to continuous in the lowlands, continuous in the mountains.

East and west of the Mackenzie River between Lats. 65° and 67° N there are extensive spreads of platform dolomites of Cambrian-Silurian age, underlain by redbeds and salt and overlain by the remarkable Bear Rock Fm (Devonian), a re-cemented dolomite-gypsum solution breccia. A sample transect of the Mackenzie Mountain karst in these strata is being proposed for a new Geopark. It begins at 1700 m asl on dolomite plateaus in the ice-free corridor, where felsenmeere and patterned ground dominate at the surface but karst groundwater circulation via taliks produces elegant steephead valleys (*reculéés*) that were locally adapted to host small cirque glaciers. To the east, a tectonic polje and a dry canyon in the dolomites are succeeded by foundered terrains over the salt. At the Laurentide ice limit a terminal moraine created a karst basin of 90 km<sup>2</sup> with rapid underground drainage. Within the glaciated zone at 1000 m asl, glacier-scoured dolomites display the greatest extent of solutional pavement reported from arctic regions, succeeded by a possibly unique "dissolution-drape" terrain of sinkholes, dry valleys, lakes, caves and scablands on the breccia. Considered together, the Canol park karst landforms are the most varied and striking yet described from arctic regions.

### **Dissolution rate of limestone under doline in the Akiyoshidai karst plateau: Evaluation from weathering experiment and hydrological observation**

HATTANJI T.(1), AKIYAMA S.(1), MATSUSHI Y.(2), MATSUKURA Y.(1)

(1) University of Tsukuba, TSUKUBA, JAPAN ; (2) DPRI, Kyoto University, Uji, JAPAN

The spatial variation in limestone dissolution rates is significant for landform evolution of karst terrain. This study aims to estimate the current rate of dissolution in a solution doline on the Akiyoshidai karst plateau in Yamaguchi Prefecture, combining field weathering experiment and hydrological observation. In the weathering experiment, limestone tablets (rock disks of 3.5 cm in diameter and 1 cm thick) were buried in soil (depth of 50 cm and 15 cm) at four sites from the crest to the bottom of the doline. In these sites, soil moisture contents and ground temperatures were monitored at 10-min intervals, and measurements of CO<sub>2</sub> concentration in the soil air and soil water sampling were carried out manually about every two months. The experiments and monitoring were conducted over 768 days from 2009 to 2011. The dissolution rates of tablet were high (1–3%/y mass loss) at the sites where soil moisture saturated for a long time after precipitation, and low (0.1–0.6%/y) where the period of high soil moisture was short. The result of a regression analysis revealed that the dissolution rates were strongly controlled by the ratio of the duration of saturation (degree of saturation > 97%) to the whole time of the experiment ( $R^2 = 0.65$ ). Electrical resistivity tomography for the surveyed doline showed low resistivity (50–100  $\Omega \cdot m$ ) zones in soil near soil-rock interface for both wet and dry seasons, indicating that these zones were water-saturated throughout the years. In the case of water saturation throughout years, the denudation rate of limestone would be 137 mm/ky, which is slightly faster than the highest long-term denudation rates inferred from cosmogenic <sup>36</sup>Cl concentrations at the same doline. Low resistivity zones with high soil moisture also existed beneath some parts of the slope as well as the bottom of the doline, which implies that such slopes have a fast dissolution rate equivalent to the bottom of doline.

\*\*\*\*\*

### **Origin and nature of notches on the carbonate slopes of the Carmel Mountain, Israel**

SHTOBER-ZISU N.(1), AMASHA H.(1), FRUMKIN A.(2)

(1) University of Haifa, HAIFA, ISRAEL ; (2) Hebrew University, JERUSALEM, ISRAEL

Some of the best known landforms associated with the Carmel Mountain (Israel) are "Notches". The term is used to describe horizontal "C"-shaped indentations, developed on slopes or cliffs, regardless of their location or shaping mechanism. These morphological features, apparent on carbonate rocks, take the shape of half tubes that extend over tens or hundreds of meters, along stream valley slopes. Although this morphological phenomenon is worldwide observed, little is known about its origin.

The present study suggests that the notches are dissolutional cavities cut into particular limestone or dolomite beds in accordance with specific chemical and mineralogical properties of the lithic material. The rate of chemical erosion in the Mediterranean climate is estimated at 10–40 m/Ma (Gerson, 1976; Yaalon, 1997). Given these rates, notches of coastal origin should have been eroded by now; they could not have been preserved since the Miocene or Pliocene epochs. The same explanation is relevant to the theory that suggests that the notches are associated with stream banks: well developed notches have been found at an altitude of 370 m.a.s.l. along the northeastern escarpment of the Carmel, with no relation to stream valleys. Additionally, assuming that the notches did develop along channel banks during the Pleistocene epoch would imply that the rate of tectonic uplift should be double that estimated in previous studies.

It is suggested that the notches developed under subaerial conditions, formed by runoff accumulated along the slopes. The notches are not necessarily linked to past water table levels. It is possible however, that they represent past climate conditions, when abundant soils covered the slopes. As the sediments and the soils were stripped off, the notches were exposed.

At present, bioerosional processes, carried out by cyanobacteria or additional organisms, continue to act upon the carbonate substrate, contributing to the further development of the notches.

## Hydrogeological characterisation of evaporite Karst Wetlands in southern Spain

ANDREO B.(1), LINARES L.(2), CARRASCO F.(1), RENDÓN M.(3)

(1) UNIVERSITY OF MALAGA, MALAGA, SPAIN ; (2) Academia Malagueña de Ciencias, MÁLAGA, SPAIN ; (3) Consejería de Medio Ambiente de la Junta de Andalucía, MÁLAGA, SPAIN

In southern Spain there is an extensive outcropping of Triassic versicolour clays and evaporites (gypsum and halite), together with sandstones, limestones and dolomites of different ages, in variously-sized blocks, as well as Miocene sediments. All these materials are highly deformed, with a disorganized and chaotic internal structure. The Triassic materials (Keuper) have traditionally been categorised as presenting low permeability. However, the presence of evaporites generates a geomorphological karst evolution, both at the surface (exokarst) and beneath it (endokarst), which increases the porosity and secondary permeability. Thus, these materials are really a karst aquifer in the evaporite enclaves, although the existence of low permeability materials (clays, sandstones) means that the whole clayey-evaporitic unit presents some hydrogeological complexity. These aquifers are fed by the direct infiltration of rainwater and runoff through swallow holes, while discharge takes place by springs to river beds or into wetlands.

The wetlands associated with these Triassic evaporitic-clayey materials are found in different geomorphological situations: in interfluvial or watershed areas, near river beds and in intermediate positions. The origin of the basins containing these wetlands is related, most cases, to processes of dissolution/karstification of the evaporite materials. When the water table of the aquifer lies below that of the bed of the wetland, the latter is a source of recharge to the aquifer; these wetlands are termed "recharge wetlands", and are usually ephemeral and contain water of low salinity. The springs and wetlands located at lower levels are associated with longer flows, with greater residence time in the aquifer, and typically drain water of high salinity, which is sometimes saturated in NaCl. Finally, there are wetlands located in an intermediate position between the aquifer recharge and discharge areas; these are known as "transition wetlands".

\*\*\*\*\*

## Conceptual model of the hydro-sedimentary behaviour of an estuarine karst: Example of Radicatel springs in the Seine Estuary (Normandy, France)

CHEDEVILLE S.(1), LAIGNEL B.(1), RODET J.(2), TODISCO D.(3), HAUCHARD E.(4), MASSEI N.(1), HANIN G.(1)

(1) Université de Rouen, UMR CNRS 6143 Morphodynamique Continentale et Côtière, MONT-SAINT-AIGNAN, FRANCE ; (2) CNRS, UMR 6143 Morphodynamique Continentale et Côtière, Université de Rouen, MONT-SAINT-AIGNAN, FRANCE ; (3) Université de Rouen, UMR CNRS 6266 Identité et Différenciation des Espaces, de l'Environnement et des Sociétés, MONT-SAINT-AIGNAN, FRANCE ; (4) Université de Rouen, UMR CNRS 6143 Morphodynamique Continentale et Côtière ; Communauté de l'Agglomération Havraise (CODAH), MONT-SAINT-AIGNAN ; LE HAVRE, FRANCE

Karst processes occur all around the world in different bedrocks carbonated or not. These processes, related to chemical weathering in association or not with mechanical erosion, create voids on the surface (dolina) and within the bedrock (karst conduit). These voids may contain allochthonous (supply of sediments from mechanical erosion), autochthonous (insoluble residues from chemical weathering of the bedrock) karstic filling or a mixture of both, according to the hydrodynamics and sediment sources.

In order to better understand the role of karst functioning in sediment transport in chalky context it appears essential to characterize 1) erosion/deposition of intrakarstic sediments and, 2) the controlling factors of the sedimentary transfer. Both can be studied at an experimental site in Seine Estuary: the Bruisseresse spring (Radicatel). The latter is an anthropogenic gallery considered as a karstic conduit, managed by the CODAH (Communauté D'Agglomération Havraise) for water supply. The Bruisseresse is an exceptional site for studying the current karst sedimentation, comprising a sedimentary filling, rainfalls, turbidity and chalk aquifer water table time series, all dating back to 1988.

Several types of data were used: 1) the study of sediment by boreholes, 2) the use of a Suspended Particulate Matter (SPM) trap, and 3) the measurement of the current sedimentation height by an altimeter. All of these data allowed understanding of the sedimentation processes in the gallery.

The main results are: 1) the establishment of the time correspondence between sediment filling and turbidity time series, which allowed a better understanding of the sediment transfer processes, 2) the identification of controlling factors on karst sedimentation (turbid floods, variations of tidal coefficients and large-scale climate oscillations especially the North Atlantic Oscillation). The results allowed to establish a conceptual model of the hydro-sedimentary dynamic in an estuarine karst.

**Towards a better comprehension of rainfall-runoff relation in karst system at various time scales. Case study on the Lez aquifer (Southern France)**

*TAVER V.(1), JOHANNET A.(1), BORRELL V.(2), PISTRE S.(2), VINCHES M.(1)*

*(1) Ecole des Mines d'Ales, ALES, FRANCE ; (2) Universite Montpellier 2, MONTPELLIER, FRANCE*

Karst aquifers represent the largest underground resources for fresh water around the world providing it to 25% of the population [Ford and Williams, 2007]. They are still underexploited because of the difficulty to understand their behavior, they can thus be considered as a promising water resource for the future [Bakalowicz, 2005]. Due to complex processes of formation, these geomorphologic systems are very heterogeneous in space. Such a complexity leads to various hydrological behaviors, at different time scales, associated with unsaturated or saturated zones.

Due to the difficulty in measuring physical parameters and capitalizing on physical properties of such complex systems, the systemic approach [Mangin, 1975] was preferred in this study in order to improve the knowledge about these aquifers. Following such an approach, rainfall and runoff time series were considered as input-output signals of a complex system. In order to better apprehend the various behaviors operating at different time scales, the rainfall-runoff relation was studied at different time scales, by resampling signal at various dyadic time scales (2T; 4T; 8T; 16T; 32T, where T is the smaller sampling period). Resulting time series were studied using three approaches a) statistical description and normality tests of time series and their distribution, b) time series analyses (correlation, spectral analysis...) [Mangin, 1984], c) modeling dyadic rainfall and runoff time series relations using neural networks model (machine learning) [Kong A Siou et al., 2011].

Applied to the Lez karst aquifer, which provides the city of Montpellier (400 000 inhabitants, Southern France) with fresh water [Fleury, 2008], these methods allow the characterization of the aquifer's behavior at each time scale. These tools thus allow apprehending the response times of the aquifer in various conditions and provide information about its vulnerability to climate modification.

\*\*\*\*\*

**Groundwater monitoring network in the classical Karst (NE Italy, SW Slovenia)**

*ZINI L., CALLIGARIS C., GRILLO B., CUCCHI F.*

*Dipartimento Matematica e Geoscienze, TRIESTE, ITALY*

Data analysis coming from Classical karst groundwater monitoring network highlights the complex circulation of the hydrostructure. Only the collaboration between Italy and Slovenia could lead, through a reasoned groundwater monitoring network, to plan the best transboundary aquifer management and protection.

The monitoring stations are 14: Timavo, Filtri, Doberdò and Sardos Springs, Colombi, Comarie, Lindner, Giant, Massimo, Jerko, Trebiciano, Kanjaducah, Kacna, Škocjan caves. The Mathematics and Geosciences Department of Trieste University is monitoring all the water points since 1995 in cooperation with Slovenian partners (Park Škocjanske Jame and ZRC SAZU). The network permits to highlight the contribution to the flow from the different parts of the hydrostructure. During the flood the flow is conditioned by the Reka river regime while, during low-water, the circulation is more influenced by the infiltration due to the rainfall and from the Isonzo river contribution. The circuit connecting Škocjan cave sinkhole with Timavo springs is characterized by a series of large pipes that allow the flood impulse transfer within 1 to 3 days.

The monitoring carried out showed that during the floods the most part of the circuits are under pressure and only a comparative analysis of levels, temperature and conductivity permits to correctly evaluate the water transit times. In fact, if the rising water level in the caves is simultaneous due to the increasing hydraulic load upstream, the changes in conductivity and temperature are different from site to site and allow to intercept the incoming flooding water and to estimate correctly the water velocity propagation.

Different is the behaviour in the north-western sector where the circulation is dispersed and base flows are underlined. In this case, the beginning of the floods is often delayed compared to the springs outflow and it is partially due to the stop up water coming from the Reka – Timavo circuit.

## **Poster presentations:**

### **The evaluation of geomorphological features of the karstic cave discovered in Rabat, Sardasht, north-west of Iran**

KHEZRI S.

*Kurdistan university, Sanandaj, IRAN*

During excavations in the east of little Zab river and close to the site of the ancient city of Rabat, a cave entrance was revealed in 2012-06-05. For more investigation on natural and human features, a group of experts went into the cave. The results of their field survey indicate that the cave clearly originated as the result of tectonic forces and solution of limestone. The main natural features of the cave include cauliflower stalactites and pearls of cave landforms. Due to the role of tectonic, the cave was impassable and only a short distance from the entrance, about 20 meters, is now accessible. Within this part, there is no sign of human habitation. The availability of karstic features such as avens, sinkholes, vauclusien and travertine springs and karrens within ten kilometers around the Rabat cave mouth show a possibility of connection between the caves, avens and karstic springs. Thus it is possible to have a great cave in this area. This cave, along with other natural and man-made features of the areas, such as natural waterfalls and ancient hills in Rabat city and the little Zab river basin are great potentials for geotourism and archeotourism development. Therefore, further investigation is needed through field work to identify the possibility of any connection between the caves, avens, and karstic springs. In addition, another investigation should focus on the relationships between the caves and ancient civilization of the areas. This requires a group of geomorphologists, geologists and archaeologists to do more field survey on the different features of the areas.

\*\*\*\*\*

### **Exploration and recognition of the 'Dolaneh' cave, Sardasht, Iran**

KHEZRI S., ZAHERI S.

*Kurdistan university, Sanandaj, IRAN*

A cave in Sardasht, northwest of Iran, in field survey was explored in 2008 by author (Saeed Khezri). During the field study, one aven and another cave were explored within five kilometers buffer of the first cave. The first cave latter named as "Tuzhal" and second cave named "Dolaneh" cave. Tuzhal cave was introduced in 2008. But in fact, a hole as wide as 1 meter was the only entrance of the Dolaneh cave appeared from outside. Thus a team including four persons entered the Dolaneh cave in order to evaluate its dimensions. Then exploration and recognition of unknown parts of the cave was started. Further geomorphological survey in the area revealed more holes and Karstic landforms distributed as far as 2 km around the Dolaneh cave entrance. The evidence proved that there is a junction between Tuzhal and Dolaneh caves and other around avens and Karstic springs. Further caving by professionals is needed to recognize all parts of the caves and karstic landforms in the area.

### **Hydrodynamic of the Coulomp karst spring, the largest in French Southern Alps**

AUDRA P.(1), NOBÉCOURT J.C.(2)

(1) Polytech Nice - Sophia, University of Nice - Sophia Antipolis, BIOT, FRANCE ; (2) CRESPE, VENCE, FRANCE

The Coulomp Spring (elevation 1306 m) is the largest of the Var River watershed ( $Q \approx 1 \text{ m}^3/\text{s}$ ). The catchment of the Coulomp Spring is about  $30 \text{ km}^2$ . It culminates at the Grand Coyer (elevation 2693 m), which is located east to Annot City, between the Var and Verdon rivers. Karst features are almost absent due to the presence of thick covers of marly limestones (> 600 m), clays, and sandstones. 1 km of the underground river is known in the Chamois Cave, a 12 km-long cave system, which gives a partial knowledge of the flow inside the karst. 3 years of spring monitoring and dye tracings complement the understanding of its dynamic. Recharge occurs both as concentrate inputs through discrete sinkhole where canyons cut the limestone aquifer and as diffuse infiltration through marly limestone covers. Consequently, the Coulomp spring mixes complex responses with flash floods sometimes associated with turbidity peaks, large floods up to  $30 \text{ m}^3/\text{s}$  after intense autumnal precipitations, and a still significant recession discharge (> 400 L/s) in low water due to the storage in the sandstone covers and the thick vadose zone. Hydrographs study in different conditions (snowmelt cycles, storm after long recession or after long recharge periods) give a better picture of the different components of the recharge, of the flow paths, and of the velocities in the different parts of the karst system.

\*\*\*\*\*

### **Characterising tufaceous accumulations in groundwater discharge zones by means of geophysical surveying (ERT, GPR) and trenching. The Isona-Basturs complex (Pyrenees, NE Spain)**

ZARROCA M.(1), PELLICER X.M.(2), GUTIÉRREZ F.(3), CARBONEL D.(3), ROQUÉ C.(4), LINARES R.(1)

(1) Universitat Autònoma de Barcelona, ES-08193 BELLATERRA, SPAIN ; (2) Geological Survey of Ireland, DUBLIN, IRELAND ; (3) Universidad de Zaragoza, E-50009 ZARAGOZA, SPAIN ; (4) Universitat de Girona, E-17071 GIRONA, SPAIN

The Isona-Basturs spring complex constitutes the main groundwater discharge zone of a confined karst aquifer in the eastern Pyrenees, NE Spain. Here, groundwater flowing through a limestone aquifer overlain by impervious argillaceous formations discharges along fractures generating perched springs and lakes fed by upward flows. Accumulation of tufa deposits from the calcium-carbonate rich waters over the last 350 ka has generated striking tufa mounds several tens of meters thick with groundwater discharge paleolakes. Currently active groundwater discharge is associated with contemporaneous lakes. The Isona-Basturs complex is of special interest because of the coexistence of relict tufa mounds related to paleosprings and active springs with vents, lakes and mounds in their initial phases of development. The combination of detailed geomorphological mapping, shallow geophysical surveying by electrical resistivity imaging (ERI) and ground penetration radar (GPR), as well as trenching, has allowed us to propose a geomorphic and stratigraphic model for the system and obtain information about its paleohydrological functioning and the timing of soft-sediment deformations in recent lake deposits that might be attributable to paleoearthquakes.

### **Comparison of DInSAR derived displacement maps for sinkhole activity detection in the Ebro Valley mantled evaporite karst (NE Spain)**

FRANCISCO G.(1), GALVE J.P.(1), CASTAÑEDA C.(2)

(1) University of Zaragoza, ZARAGOZA, SPAIN ; (2) Agricultural Research Center of Aragón, ZARAGOZA, SPAIN

The results of various advanced Differential Interferometric Synthetic Aperture Radar (DInSAR) techniques applied to sets of ERS SAR, ENVISAT ASAR and ALOS PALSAR images covering two time spans (1995-2000 and 2003-2010) have been compared in a stretch of the Ebro River valley (NE, Spain) affected by evaporite karst subsidence. The extensive geomorphological investigations carried out in the analyzed sector reveal that active subsidence associated with sinkholes affects a significant proportion of the floodplain and lower terraces. Previous deformation data derived from ERS-1 and ERS-2 images processed by the Small Baseline Subset (SBAS) technique provided valuable quantitative deformation data for some sinkholes but missed most of the known areas with evidence of ongoing dissolution-induced ground settlement. The performance of different SAR images and interferometric techniques detecting and measuring ground subsidence has been assessed and compared using detailed geomorphological maps and the available data on subsidence rates and deformation on human structures. The improvements of the new deformation maps generated with ENVISAT and ALOS data processed with the Stable Point Network (SPN) technique include: (1) New areas affected by subsidence overlooked by geomorphological surveys have been detected. (2) The spatial density of subsidence magnitude and rate data has increased. In spite of the lack of coherence and DInSAR deformation data in a large proportion of the area affected by known active subsidence, the improvement in the spatial resolution of the new displacement maps has helped to better define the active subsidence areas. The usefulness of DInSAR displacement data in combination with data obtained by other techniques (geomorphological analysis, geophysical surveys, trenching) for managing the subsidence risk associated with different human structures (apartment buildings, industrial states, railways, roads) is illustrated through several case studies.

\*\*\*\*\*

### **Application of the trenching technique to sinkhole hazard analysis**

CARBONEL D.(1), GUTIÉRREZ F.(1), MCCALPIN J.(2), GUERRERO J.(1), ROQUÉ C.(3), LINARES R.(4), ZARROCA M.(4), GALVE J.P.(1)

(1) Universidad de Zaragoza, ZARAGOZA, SPAIN ; (2) Geo-Haz Consulting Inc., COLORADO, UNITED STATES ; (3) Universitat de Girona, GIRONA, SPAIN ; (4) Universitat Autònoma de Barcelona, BARCELONA, SPAIN

The trenching technique is generally applied to obtain information on the paleoseismic record and seismogenic potential of active faults. Recent studies carried out in the mantled evaporite karst on the Ebro Valley (NE Spain) reveal that this approach may be used satisfactorily for the characterisation of specific sinkholes and the assessment of the hazard associated with them. Backhoe trenches are excavated in locations selected on the basis of detailed geomorphological mapping. Geophysical surveys may help to increase the success rate of the trenches, constrain their extent and provide complementary subsurface information. The detailed study and numerical dating of the sediments and structures exposed in the trenches, including a retrodeformation analysis, allows the reconstruction of the deformational history of the sinkholes. The trenches may provide valuable practical information for subsidence risk management including: (1) Precise limits of the subsidence structures underlying the sinkholes. (2) The subsidence mechanisms (sagging, collapse, suffosion). (3) The subsidence magnitude and the contribution of the different structures and mechanisms. (4) The kinematic behaviour; episodic vs. progressive. (5) The age of the sinkholes and long-term subsidence rates. (6) Bracketing age of subsidence events, recurrence intervals and in some cases the identification of triggering factors. This information may be used as an objective basis to forecast the future behaviour of problematic sinkholes and select the most adequate mitigation measures.

**Contribution to the studies about the Brazilian Karstic areas: the geomorphological cartography as a subsidy to the analysis of the evolution of the Karst in the Karstic region of Currais de Pedras (KRCP)**

GONCALVES F.(1), MAGALHÃES JR. A.(1), RODET J.(2)

*(1) GEOSCIENCES INSTITUTE - FEDERAL UNIVERSITY OF MINAS GERAIS, BELO HORIZONTE, BRAZIL ;*

*(2) UMR/CNRS, 6143, GEOLOGY LABORATORY OF THE UNIVERSITY OF ROUEN, ROUEN, FRANCE*

The Brazilian karstic geomorphology has advanced significantly and one of its main tools for such development is the cartography of karstic areas. Most of the known caves in Minas Gerais' state occur in carbonates of the Bambuí Group (Neoproterozoic). This group is composed of sedimentary and metasedimentary rocks that cover a large area in São Francisco's Craton. The CPKR is located in the southeastern area of São Francisco's Craton, where carbonates outcrop from Lagoa do Jacaré formation occur. The cartographic representation of CPKR's geomorphology was elaborated based upon the interpretation of satellite images, aerial photos, topographic, geomorphological and geological maps and fieldwork. An area of 13,627km<sup>2</sup> was mapped in the scale of 1:45.000. The geomorphological units were mapped based on the similarities of the shapes, materials and their relations with the altimetry, as follows: karst exposed; residual tabular surface flat to smoothed with sections elaborated from karstification processes; wide flat to smooth undulating with sections elaborated from karstification processes; steep slopes and straight dissection presenting ravine processes; wide surface smoothed elaborated mainly from process of lateral migration of river channels; remnants of ancient fluvial deposits and alluvial plain. The morphotectonic component was added to the mapping from trace structural lineaments. Topographic profiles and cartograms containing morphometric data complete the set of elements that compose the mapping. After analyzing this set, we found out that the investigated karst can be divided into two systems, as follows: (i) that attached to the base level and (ii) that separate the base level by escarpments with gradient and slope middleweight of 200 m and 30<sup>0</sup>, respectively. This setting reflects directly on the planimetric pattern distinct of the caves that comprise each system and shows the current and past of the hydrodynamics as one of the main responsible for this.

\*\*\*\*\*

**Mapping and interpretation of karst landforms: dolines and depressions, their significance and hydrological functioning**

PARISE M.(1), PEPE M.(2)

*(1) CNR-IRPI, BARI, ITALY ; (2) University of Basilicata, POTENZA, ITALY*

Karst landscapes are strongly controlled by lithological and tectonic factors, that are crucial elements to control the rate of development of the solution process. In lowland karst, identification of the original landforms is heavily complicated, due to the subtle morphologies, and the likely interactions with man and his actions. In many cases, karst landforms may be easily modified or cancelled by human activities. The present article aims at highlighting the difficulties in the identification, mapping and interpretation of the most significant landforms in the karst of Apulia, including dolines of different origin, depressions, and different types of karst valleys. We will stress the need to make an effort in combining what is visible at the ground surface with the subterranean features (caves, shafts, etc.). This latter point is extremely important as concerns the hydrological functioning of the karst landforms, especially on the occasion of the most significant rainfall events. Through the description of karst geomorphological maps from different sectors of the Apulian karst, in southern Italy, we will discuss the problems in mapping these features and the importance in understanding their functioning.

**Lithology, rock relief and karstification processes in coral minamidaito island in the nansei archipelago, Southeast Japan**

*KNEZ M.(1), SLABE T.(1), URUSHIBARA-YOSHINO K.(2)*

*(1) Karst Research Institute, Research Center of the Slovenian Academy of Sciences and Arts, Postojna, Slovenia; Yunnan International Karst Environmental Laboratory, Kunming, China, POSTOJNA, SLOVENIA ; (2) Department of Geography, Hosei University, TOKYO, JAPAN*

Minamidaito Island is a karstified coral island located on the Philippine plate. The first karstification occurred during the Pliocene between the lower and the upper Daito Layer. The top surface of the lower Daito Layer was karstified and soils formed. During the Pleistocene, karstification continued from 1.6 Ma until the last glacial period. The terrain of Minamidaito Island, which resembles an uplifted atoll, continued to specifically karstify until the middle of the last glacial period when the sea level dropped by 100 meters. Since then karstification similar as today is taking place. Geological studies were performed to study reef carbonates in detail. Among them, biointrasparite limestone of framestone and bafflestone types with transitions to grainstone and dolomitized biointrasparite limestone of framestone and bafflestone types dominate. Calcimetric analyses established that in certain locations the distribution of limestone and dolomite differs from the distribution previously described. Although the characteristics of coral limestone and dolomitized limestone put a distinctive stamp on the rock relief, it remains an important trace of the formation and development of this unique karst landscape. Rock relief reveals the unique formation of coastal karren, the development of the surface in the interior of the island, and the most characteristic periods of cave development.

\*\*\*\*\*

**Using stochastic laws of sinkholes formations at solving construction engineering problems in karst areas**

*MAKHNATOV S., TOLMACHEV V.*

*JSC Antikarst and Shore Protections, DZERZHINSK, RUSSIAN FEDERATION*

It is established that in a covered karst the formation of the karst sinkholes in time and space under certain conditions subject to stochastic laws. In particular, distribution of independent sinkholes is close to the Poisson law. Sinkholes diameters at the large areas subject to the lognormal distribution. At the small areas like construction sites, the distribution of sinkholes diameters is close to normal distribution. These stochastic laws allow to assess the probability of the defeat areas as well as some buildings karst holes, to make efficient line structures drawing (pipelines, railways and roads) and to choose the smallest karst hazard. The experts can assess the negative consequences of the karst formations on structures. It is possible to assess the risk of karst and the relative level of the so-called relative level of karst risk. It refers to the ratio of the karst risk to the allowable karst risk. Karst risk level is the basis for the study of the anti-karst complex measures, the structural design parameters, the exploitation, the monitoring of facilities and the environmental monitoring. Examples of practical realization of the above approach are shown.

### **Clay cortex in epikarst as an indicator of age and morphogenesis - case studies from Lublin-Volhynia Chalkland (East Poland, West Ukraine)**

DOBROWOLSKI R., MROCZEK P.

*Faculty of Earth Sciences and Spatial Management, Maria Curie-Skłodowska University, LUBLIN, POLAND*

Clay cortex from the contact zone of host rock (chalk) and filling deposits was examined in palaeokarst forms (pockets, pipes and dolines of different age) from the Lublin-Volhynia chalk karst region. In the light of the sedimentological and micromorphological analyses it seems possible to work out a model forming the basis for genetic and stratigraphic discussions.

(1) Dolines with the Paleogene and/or Neogene mineral infillings are characterized by:

(a) homogeneous, residual type of massive clay diffusively passing into the chalk monolith, and at the same time  
(b) relatively thick weathered zone.

(2) Pipes with glaciogenic mineral infilling from the Saalian Glacial are characterized by:

(a) sharp contact of rock and clay, (b) narrow weathering zone of carbonate rock, (c) diffusive nature of the contact zone between residual clay and mineral infilling, and (d) contamination of clay with clastic material.

(3) Pockets with glaciogenic mineral infilling and traces of the Weichselian periglacial transformation are characterized by: (a) strong contamination of chalk with quartz grains, (b) diffusive transition between clay and infilling deposit: from clayey matrix with single quartz grains (at the contact with chalk) to clayey coatings and intergranular bridges (in the infilling deposit), (c) intensive weathering (cracking) of mineral grains in the infilling deposit.

\*\*\*\*\*

### **Gypsum's role in the sinkholes of the tagliamento River Valley (NE Italy)**

CUCCHI F.(1), ZINI L.(1), CALLIGARIS C.(1), FORTE E.(1), PETRONIO L.(2), ZAVAGNO E.(1)

*(1) Dipartimento di Matematica e Geoscienze, TRIESTE, ITALY ; (2) OGS - Istituto Nazionale di Oceanografia e di Geofisica Sperimentale, TRIESTE, ITALY*

In an area of several kilometers in the Tagliamento Valley, between the villages of Ampezzo and Villa Santina (Friuli, NE Italy), are present frequent points of absorption associated with large and deep sinkholes collapsed in the shallow cemented fluvial-glacial deposits, in the recent alluvial deposits overlying a karstified evaporitic bedrock.

In the Quinis village the situation is particularly complex, some houses are affected by failures and in the past, in the fields around the village sudden sinkholes were recorded and some buildings were demolished also in the centervillage. During the last years a tightening in the phenomena took to the necessity of a deep and multidisciplinary study in order to define the vulnerability of the different areas. For the purpose, were realized 20 piezometers (equipped with devices), 3 seismic lines, 1 electrical tomography, the establishment on the buildings of a topographical monitoring network, 2 assestimeters and a groundwater tracing test campaign.

The main vulnerable areas were identified with the presence of holes or caves in the gypsum and soft and unconsolidated alluvial horizons. The big variations in the groundwater levels recorded during the past years and linked to the regime imposed by the dam outflow, underlined an increase in the karstification processes inside the gypsum bedrock and in the above deposits.

### 3D researches on conduits and karsts networks

JAILLET S., SADIER B., DELANNOY J.J.

Laboratoire EDYTEM, Université de Savoie, LE BOURGET DU LAC, FRANCE

Underground karst is an object that can be studied using 3D approaches, and new technological breakthroughs now allow revisiting subterranean karst. Lasergrammetry in particular allows fast dense point clouds acquisition. Their protocol allows to shape analyses without any contact and to reduce the time spent within the cave. When studying underground topographic matters, pipe sections are usually considered as spindly skeletons. Stations are sampled one after another, in polar geometry (distance, direction, angle). Gallery sections allow to recognize large changes in conduit dimensions. Lasergrammetry, based on Lidars uses, help to acquire very numerous point measurements during minimal time. The point cloud is then meshed to obtain a TIN model. This one is significantly helpful to inform about neighbouring information and topology. This is of prior importance to the rest of the analyses, in particular to identify morphology breaks or segmentation operations. The model conformity must be checked. Once these treatments are achieved, it is possible to analyse the numerical clone. These analyses were applied to different objects: drains, walls, speleothems... It was shown that the use of 3D analysis on a numerical clone may be fruitful. It allows breakthroughs compared to classical approaches. First of all, it allows investigation of all the objects. Indeed, height, darkness, limited residence time, conservation constraints and limited moves within high patrimonial value objects are limiting factors to an *in situ* analysis. This completeness when investigating underground karst allows to notably statistically validate results that, used to be limited and reduced to preselected objects. The aim here was to explore the potential of 3D modelling of underground environments, keeping in mind the ever geomorphologic issues that drive our research.

\*\*\*\*\*

### Dissolution phenomena and subsidence in Bosco-San Cataldo Mine (Sicily)

LIGUORI V., MANNO G.

DICAM - Università degli Studi di Palermo, PALERMO, ITALY

Topographic surface of the central south Sicily is related by depressions, for subsidence phenomena. The rocks that form this area are Messinian evaporites, in particular they are limestones, gypsums and salts (NaCl and KCl). The solubilisation of these rocks cause morphologic changing both surface and underground landscape. The subsidences are localized mainly in the mines areas where happened the salts extraction, at the present moment their location depending by underground mines extension. Indeed the subsidence phenomena are most clear above disused mine, where the falls of the tunnel vaults, speed up sinkholes origin. An example of these phenomena is observable in the San Cataldo-Bosco mine close the Caltanissetta city. The mine began its activity with sulfur extraction in the period between 1930 and 1954. In 1956 the mine, with discovery of the salt seam, it began the salts extraction. The presence in this area of dissolution morphologies, is highlighted both areal imagery analysis and geologic-geomorphologic survey. The subsidence development is preceded by morphologies like karst sinks in the bottom of these depressions is observable an area more low with preferential adsorbent of the surface waters. The making of these sinks create inevitably changes in surface and underground water flow. The underground waters flooding the tunnel mine and dissolve the salts, this phenomena is connected also with aquifer layer. In winter time depression are usually full of water originating small lakes, on the contrary, in summer time these lakes are totally dry. In order to reduce the risk produced of the sudden developing of these depressions that change in to sinkholes, would be essential to confirm the trigger causes of these phenomena and to start a monitoring campaign. The results thus obtained can define new hypothesis of intervention for the security of these areas and to apply some techniques already tested.

## Understanding of the nature and evolutionary history of the karst of Ha Long bay

*DO T., NGUYEN XUAN N.*

*Vietnam institute of geoscience and mineral resource, HA NOI, VIET NAM*

HaLong to be awarded by UNESCO as a world natural heritage of outstanding value to the geological history, geomorphology of karst limestone. Now, Ha Long is not only belongs to Vietnam, but also the common heritage of mankind. So understanding the nature and evolutionary history of the karst of Ha Long bay is doing useful and necessary. This paper can be generalized as follows:

1. In addition to the basic conditions to Halong Karst formations such as limestone of Bac Son formation, dissolved phenomenon, rainfall in the humid tropical conditions, the role of marine, mechanical corrosive effects of the sea play important role.
2. Neo-tectonic movement to trend downward, the decision for the formation and development of the Karst landscape of Ha Long.
3. Continental development phase of Ha Long lasting and continuous throughout MZ-KZ and has created the landscape with the style Karst peak-cluster-valley, characteristic for Halong Karst.
4. Marine incursion in Halong Karst early, about 40,000 years ago and went through several stages of sea level change to the composition of the sea line and terrace types .
5. The nature and evolutionary history Halong Karst distinct nuances differ Karst south-east of China.

\*\*\*\*\*

## Geomorphological analisys of karst depression in the Yucatan Peninsula, Mexico

*FRAUSTO MARTINEZ O.(1), IHL T.(2), BUATISTA F.(2), AGUILAR Y.(2), FRAGOSO P.(1)*

*(1) universidad de quintana roo, COZUMEL, MEXICO ; (2) UNAM, MORELIA, MEXICO*

Geomorphological studies in the humid karst areas of Yucatan Peninsula give evidence that depression formation represent a mosaic of different landforms at several scales having spatial heterogeneity and all have been subjected to changing structural, rock type and climatic conditions . The methodology applied in the present work used digital elevation models (DEM) and topographic vector data to differentiate between geomorphological regions that are latter subjected to spatial and morphometric analyses to establish a typology of karstic depressions (dolines -or sinkholes-, uvalas and poljes), which will produce a more detailed differentiation of karstic relief. The objective of the present work was to analyze and explain the variations in density, distribution pattern and configuration of depressions within the relief. Our study was based on geomorphological maps of Yucatan, Mexico at scale 1: 50 000, aimed at achieving an initial zoning considering the amplitude of the relief and the slope steepness of landforms, and identifying the spatial patterns of depressions. The results increased the available knowledge of the karstic to understanding the genesis and intensity of regional processes in karts relief.

## **Towards a multicriteria approach to subsidence hazards in karst with application to French case studies**

PERRIN J.

BRGM, ORLÉANS, FRANCE

Subsidence is a major geohazard occurring in karst region such as sinkholes developing by suffosion in the overburden overlying karst or less frequently breakdown of karst void ceiling. This hazard can cause significant engineering problems and difficulties for planning and development. Therefore decision-makers request from karst scientists the elaboration of methodologies for reliable predictions of future spatio-temporal distributions of such hazards (i.e., sinkholes). Typically an objective is to carry out karst subsidence susceptibility and hazards maps in the framework of risk prevention planning.

However, karst subsidence is a complex process to characterize due to the inherent high spatial heterogeneity of karst and research actions are needed to improve our process-understanding in order to propose adequate methodologies.

The ongoing project aims at evaluating a number of potential conditioning factors for karst presence susceptibility on the one hand and for karst subsidence susceptibility on the other hand. The evaluation is carried out on three well documented case studies which are representative of contrasted geological contexts: barren karst and mantled karst. For each site, an inventory of karst subsidence and karst feature objects is carried out. Then the explanatory power of each potential conditioning factor is tested using a spatial statistical analysis that evaluates the correlations between inventoried objects and conditioning factors. Ratings of each relevant conditioning factor is determined based on their respective explanatory power and susceptibility maps can be obtained by combining the relevant conditioning factors together with their rating (multi-criteria approach).

This methodology will also be tested in the near future for karst in the chalk and gypsum.

\*\*\*\*\*

## **Fluctuations of water levels in karst lakes near Staszów (Niecka Nidziańska, Poland)**

ZIELIŃSKI A.(1), ZAGÓRSKI P.(2), SHCHERBA V.(3)

(1) Jan Kochanowski University in Kielce, Institute Geography, KIELCE, POLAND ; (2) Maria Curie-Skłodowska University, LUBLIN, POLAND ; (3) Moscow State Humanitarian University of Sholokhov, MOSCOW, RUSSIAN FEDERATION

Near Staszów, which is situated in the north-eastern part of Niecka Nidziańska, there are numerous small but relatively deep lakes. They are of karst origin. Their occurrence is connected with a specific geological feature of the area. Karsting rocks are developed in the forms of gypsum and limestone, which are covered by non-karsting, water resistant Tertiary loams and impervious fluvioglacial sediments, which are next covered by vistulian and pleistocene sands.

21 lakes were the objects of the research. Winter 2011 was the time when, by using Global Positioning System (GPS, Leica System 500). At the same time, the benchmark points were installed on the chosen bodies. Using them, 9 measuring series were undertaken in order to define the changes of their water levels. The lakes are situated between 180,3 to 217,5 meters over the sea level. The results show that among the non-tide lakes, the most sensitive are the ones which are the highest over the sea level. The amplitude of the water level was 34 cm in the lake situated to the north of the so called four Peatland lakes and 32 cm in the Lake Szyja near Lake Jasne. The most stabilized water level, 14 cm, was observed on the lakes situated between Lake Szyja and Lake Jasne and the one to the north-east of Lake Jasne. Among the non-tide lakes, the water level decreased the most, within the analysed time, on the lakes: Kacze (26 cm) and Odrodzone (24 cm). Among the lakes with outflow, the water level decreased the most on Lake Torfowe I (26 cm), and the least in Lake Łajba (6 cm). Interestingly, the flowing lakes underwent some considerable fluctuation of water level. The highest amplitude was observed in a small body lying between Lake Jasne and Ciemne. It was 69 cm. The reason of such relatively big water level changes was the activity of beavers, which have recently inhabited the area at the lake. Their tracks were also noticed at Lake Ciemne.

### **Central Algarve tufa platforms, Southern Portugal. Geomorphological characterization and genesis**

GUERREIRO P.(1), CUNHA L.(1), RIBEIRO C.(2)

(1) Centro de Estudos de Geografia e Ordenamento do Território, COIMBRA, PORTUGAL ; (2) Centro de Geofísica de Évora, ÉVORA, PORTUGAL

Modern and fossil carbonate tufa outcrops exist in the Algarve (S Portugal), where climate is Mediterranean and all modern incrusting springs are intermittent and fed by Jurassic aquifers. The major Pleistocene tufa on the Algibre flexure southern slopes are in the Cadouço, São Lourenço and Rio Seco streams basins. There were identified fluvial barrier tufas and low energy fluvial tufas.

The Algarve has three main geomorphological domains: the Paleozoic flysch mountains, the Meso-cenozoic karst hills and the littoral Plio-Pleistocene detrital platform. Located in the Eurasian-Nubian plates boundary, the whole system have been deformed by distensive and compressive tectonics, which give rise to a complex groundwater system. Neotectonical activity has been reported in many works.

Feio (1952) identified Pliocene and Quaternary marine platforms up to 160 m a.s.l., but also mature levels at 200 m along with other plain surfaces.

The largest tufa platforms lie in unconformity with the current drainage system, where outcrops are dominated by low gradient facies, v. g. detrital bedded lime muds. Machados platform is dominated by bryophytes and other rapid flow facies, and cemented riverbed upstream. These outcrops lie down on larger areas in Loulé and Lagos e Relva, at altitudes between 160-200 and 120-150 respectively.

Environmentally conformal tufas occupy some sectors of the modern Cadouço, Rio Seco and São Lourenço streams. Modern tufa range from spring dominated mounds in Lagos e Relva and barrier and low gradient fluvial dominated tufas (v. g. São Lourenço and Loulé).

The ocean proximity enables the formation of eustatic platforms, which provided substratum for tufa accumulations. Vertical movements, including salt tectonics, and lowstands promoted fluvial incision and later tufa developments in modern streams.

Acknowledgments: Financed by the Fundação para a Ciência e Tecnologia PhD grant SFRH/BD/62323/2009.

\*\*\*\*\*

### **The karst of Vang Vieng, Lao P.D.R.**

RENOUARD L.

Université Paris 7-Diderot, PARIS, FRANCE

The karstic range of Vang Vieng is situated a hundred kilometers north of the capital Viengchan. Amongst the many laotian karstic areas, it is one of those whose exploration and study are the most advanced to this day. The karst and its underground caves are efficient markers of the environmental evolutions. The underground deposits constitute perfect archives of ancient climates and environments. The story of a region is written in the architecture of underground systems. Thus in the Vang Vieng karst, the disposition of the caves on distinct levels shows the evidence of ancient water levels. These are the stages of the uplift due to Himalayan tectonic.

We shall here report progress on the latest results and the research to be pursued, while also looking at the relation between the populations and the fragile environment, which present both restraints and opportunities.

### **Tape-compass-clinometer, DistoX or total station, what is the best method to elaborate a cave survey? A case study in El Pindal Cave, Spain**

BALLESTEROS D., DOMINGUEZ-CUESTA M.J., JIMÉNEZ-SANCHEZ M., GONZALEZ-PUMARIEGA P.  
*University of Oviedo, OVIEDO, SPAIN*

Topographic bases used to carry on studies on caves linked to different aspects such as conservation, tourism, speleogenesis, engineering works, etc., usually proceed from cave speleological surveys. A cave survey is performed from data collected through 1) the classical approach involving tape, compass and clinometer use; 2) the modern technique in caving working with DistoX, a laser distance meter build-in digital compass and clinometer; or 3) the modern topographical approach based on the use of the a total station. Nowadays, the advantages and limits of these approaches are not properly established. The aim of this work is to establish which one is the best technique to archive the cave survey comparing together the survey lines elaborated with each one. The comparison was done at El Pindal Cave, Spain (43°24'N 4°32'W 24 m), with 627 m long and 27 m vertical range. The section of the cave ranges from 2x3 m to 49x8 m, including passages with less than 0.4 m diameter between both sectors. The results show that: a) the classical caving method is quick and represents a good approximation the whole of the cavity (the error is 2.84 % compared to the total station), but at local scale, the accuracy is highly variable up to 15 % (5±5 %); b) the DistoX option is the quickest and most versatile providing a survey with 0.33 % global error and 0.72±0.04 % error at a passage scale; c) the most accurate survey is performed by total station, although it is not easy to use and is restricted to broad and accessible passages. Results suggest that the three techniques provide acceptable surveys varying in its accuracy and versatility: the total station is the best method to elaborate a cave survey of the widest and more accessible passages, the DistoX is the most proper to carry out the survey of other passages and the classical method can be restricted to caves where environmental conditions (such as presence of a lot of water) hamper the use of the former two methods.

\*\*\*\*\*

### **A stalagmite record of western iberia climate from the last glacial cycle**

DENNISTON R.(1), HOUTS A.(1), HAWS J.(2), POLYAK V.(3), WANAMAKER, JR. A.(4), ASMEROM Y.(3), BENEDETTI M.(5), BICHO N.(6)

*(1) Cornell College, MOUNT VERNON, IOWA, UNITED STATES ; (2) Louisville University, LOUISVILLE, KENTUCKY, UNITED STATES ; (3) University of New Mexico, ALBUQUERQUE, NEW MEXICO, UNITED STATES ; (4) Iowa State University, AMES, IOWA, UNITED STATES ; (5) University of North Carolina Wilmington, WILMINGTON, NORTH CAROLINA, UNITED STATES ; (6) Universidade do Algarve, FARO, PORTUGAL*

Stalagmites from Buraca Gloriosa (BG) (39°32'N, 08°47'W), a cave located in west-central Portugal, track environmental change during the last glacial cycle. U/Th dating of these samples has allowed for the construction of growth models with centennial-scale precision. Growth is discontinuous, and although not yet fully developed, age models suggest hiatuses coincident with Heinrich events, likely in response to cold and/or dry conditions as suggested by regional pollen data.

The BG stalagmite oxygen isotopic time series exhibits millennial variations of 1-2‰ that are similar in structure and timing to Dansgaard/Oeschger (D/O) events as recorded in the Greenland ice core. Stalagmite oxygen isotopic values can reflect any of a suite of controls, some of which do not always exhibit a straightforward relationship with climate, but similar isotopic values and trends of coeval BG stalagmites suggest that BG stalagmite calcite crystallized under isotopic equilibrium with cave dripwater, and thus most likely reflect climate dynamics.

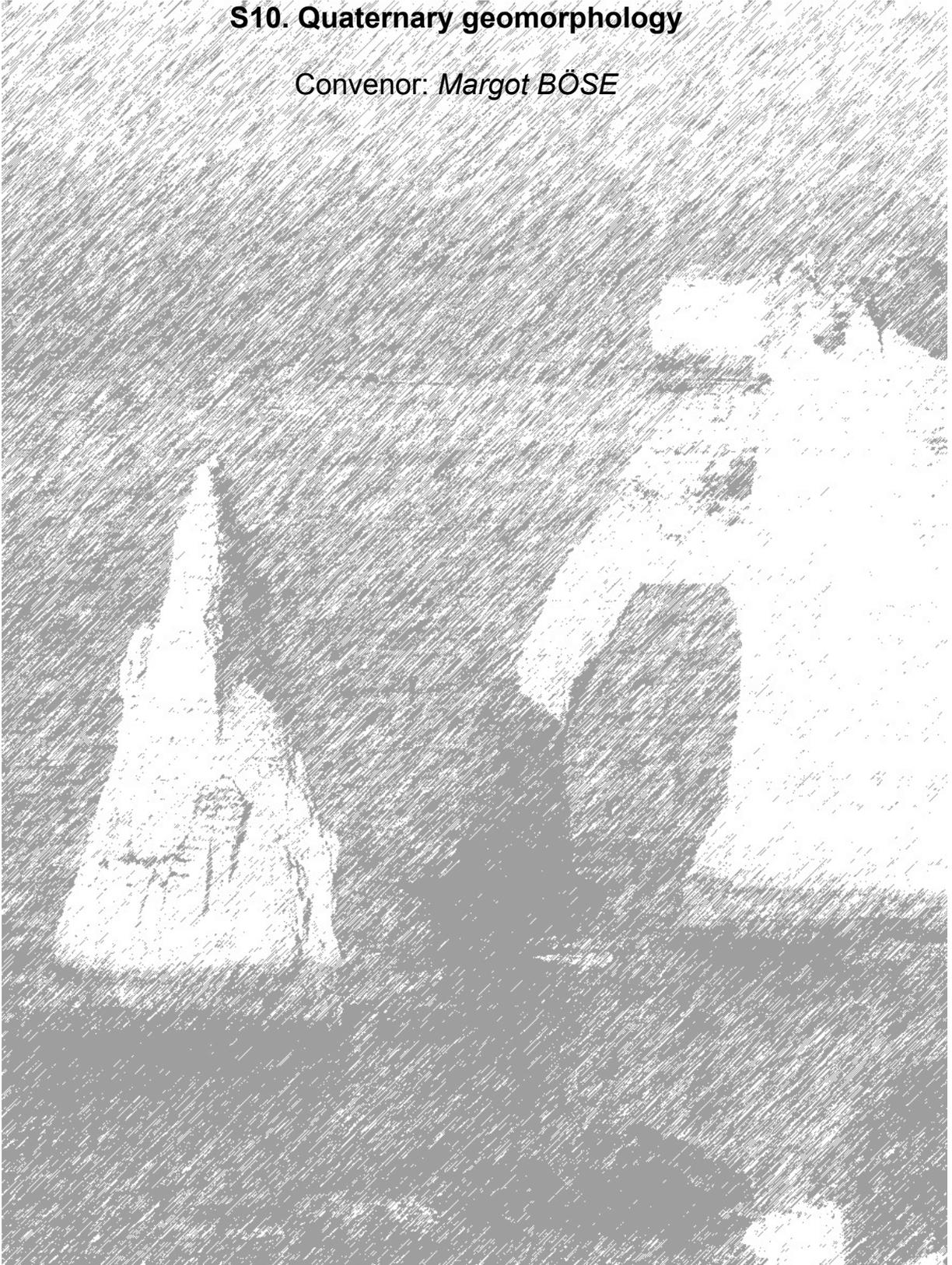
Based on the temperature dependence of oxygen isotopic fractionation that occurs during calcite crystallization, as well as modern relationships between air temperature and the oxygen isotopic ratios of meteoric precipitation, warmer (colder) regional temperatures are correlated in this regional with lower (higher) precipitation oxygen isotopic values. This observation is consistent with local oxygen isotopic minima (maxima) that characterize D/O interstadials (stadials) in the BG time series. However, the slope of the precipitation oxygen isotopic ratios/air temperature relationship is shallow and thus temperature likely exerted only weak controls on stalagmite isotopic variations. Instead, the seasonality or source of precipitation is considered a more likely mechanism.

While the BG stalagmite record is still being developed, these data have the potential to fill temporal and spatial gaps in the high-resolution continental paleoclimate record from southwestern Europe.



## S10. Quaternary geomorphology

Convenor: *Margot BÖSE*





## **Oral presentations:**

### **From Morphostratigraphy to Chronostratigraphy - Modern Quaternary Geomorphology as a Basic for Climatic Research**

BÖSE M.

*Freie Universität Berlin, Institute of Geographical Sciences, BERLIN, GERMANY*

The onset of geomorphological studies was characterized by the description and systematization of landforms, resulting in a relative morphostratigraphical order of neighbouring topographical forms. With the acceptance of climatic changes – rapidly evolving for the Quaternary owing to the recognition of repeated extended glaciations and warm phases – stratigraphy of the sediments and morphostratigraphy of the landforms complement each other, for example in former glaciated areas and other accumulation areas. Modern geomorphology is closely linked with developing research topics such as advanced knowledge about climatic changes and new methods in geochronology as well as the application of quantitative methods. Research on previous climatic changes has gained new impulses from analysis on ice cores in both polar regions and from deep sea core drillings, while terrestrial research has been refined by various methods opening new archives.

In addition, increasingly detailed knowledge of terrestrial and perimarine environments enhances the possibility to distinguish between Holocene natural, climate-driven processes, including events, and the human impact on the landscape.

As Quaternary research comprises various research approaches, including geomorphology, and nowadays offers a number of proxy data for climatic research of the past, it is indispensable for future research. Understanding the past makes it possible to develop models for the future – including climatic impact on the terrestrial surface.

One major issue at present may be the relation between global, regional and local effects of climate changes and varying, previously often very local human impact.

\*\*\*\*\*

### **Morphogenesis of SE part of the Lodz region, Central Poland, during late Saalian (MIS 6, WARTANIAN STAGE)**

WACHECKA-KOTKOWSKA L.(1), CZUBLA P.(2), GÓRSKA-ZABIELSKA M.(3), KRÓL E.(4), BARCZUK A.(5)

*(1) University of Łódź, Faculty of Geographical Sciences, Department of Geomorphology and Palaeogeography, ŁÓDŹ, POLAND ; (2) University of Lodz, Faculty of Geographical Sciences, Laboratory of Geology, ŁÓDŹ, POLAND ; (3) Adam Mickiewicz University, Institute of Geoecology and Geoinformation, POZNAŃ, POLAND ; (4) Institute of Geophysics, Polish Academy of Sciences, WARSAW, POLAND ; (5) Warsaw University, Faculty of Geology; Institute of Geochemistry, Mineralogy and Petrology, WARSAW, POLAND*

The investigated area is located on the border between the Polish Highlands and Lowlands, on the northern slopes of the remnant Mesozoic hills of the Przedbórz Highland. The main forms of landscape were formed during the last glacial episode in that region, from glaciation and deglaciation of the Wartanian Stage of the Middle Polish Glaciations, the Odranian Glaciation (Late Saalian, MIS 6, Middle Polish Complex, 180-120 kBP). We can distinguish four glacial marginal zones, connected with advance and recessional Wartanian stages, Radomsko Hills (I), Dobryczyckie Hills (II), Bełchatów Plateau (III) and Piotrków Plateau (IV).

The results obtained can contribute to a reinterpretation of the Warta ice-sheet limit and in the light of new petrographic data, heavy minerals composition, anisotropy magnetic sensibility analysis it has been proved by the authors, that the Wartanian ice-sheet reached further, by about 80-90 km to the South of Łódź, leaning against the Northern slopes of the Radomsko Hills, along the Radomsko-Przedbórz line, where it formed four glacial marginal zones.

Investigation funded by grant No N N306 721 140

### **Distribution, formation and chronology of Late Quaternary sediments in the Central Spanish Pyrenees**

*HIRSCH F., RAAB T.*

*BTU Cottbus, Chair of Geopedology and Landscape Development, COTTBUS, GERMANY*

After more than 150 years of research the Pyrenees are still object of Quaternary research aiming for a better chronology of Pleistocene glaciations. Within the scope of the research project *Post-LGM pedogenesis and geomorphodynamics in the Aragon Pyrenees*, funded by the DFG (Ra 931/3-1 & 2), soils and sediments in the Gallego and Aragon valley were used to reconstruct the Late Quaternary landscape development. Our research reveals a considerable reshaping of LGM landforms prior to the onset of the Holocene. Soil genesis is most distinct in sediments that are dated to the Late Pleistocene by OSL ages. Further phases of geomorphodynamics can be distinguished during the Holocene with truncated soil profiles and the correlate sediments of soil erosion. We associate the phases of soil translocation during the Holocene with the human impact. In both valleys the Pre-Holocene geomorphodynamics on the LGM deposits show clear analogies with findings from Pleistocene periglacial landscapes in Central Europe.

\*\*\*\*\*

### **Overview of Last Deglaciation sedimentological, palynostratigraphical and 14C chronologies in mountain lake sediments: Towards improved knowledge of the MIS2/MIS1 transition in the Mediterranean Alps**

*GUIER F.(1), BRISSET E.(2), BOURLES D.(3), BRAUCHER R.(3), ANTHONY E.(3)*

*(1) IMBE Aix-Marseille University, AIX EN PROVENCE, FRANCE ; (2) CEREGE/IMBE Aix-Marseille University, AIX EN PROVENCE, FRANCE ; (3) CEREGE - Aix-Marseille University, AIX EN PROVENCE, FRANCE*

We present a synthesis of several palaeoenvironmental studies carried out on high-altitude lake sediments in the Southern Alps (Ubaye and Tinée valleys). Twelve sequences from south and north-facing lakes located at altitudes ranging from 2000 to 2400 m were compiled. Pollen stratigraphy was correlated with the stratigraphic positions of 30 <sup>14</sup>C-dated samples as well as with sedimentological features in order to specify the regional framework of the last glacial retreat. Laminated blue clay muds observed at the base of the lacustrine profiles undoubtedly record the presence of glaciers above the considered lake altitudes, that is, 2400 m in south-facing cirques and 2100 m in north-facing ones, since the Older Dryas (ca. 21,000-17,000 cal. BP). At the end of the Younger Dryas (ca. 12,000-11,000 cal. BP), the sedimentation characteristics of the 12 studied lakes rapidly changed from organic-poor glacial till to organic-rich dark-brown gyttja. Catchments above 2000 m were then definitively ice-free. Slope soils were thus progressively colonized by vegetation while biogenic sedimentation became predominant in the lakes. These results are discussed within the regional chronological framework, supported by cosmogenic nuclide dating, and then confronted with the history of glacier retreat at a larger scale.

### **Changes in relief of the Azau Valley in Central Caucasus Mts resulting from impact of volcanic activity and glaciers' oscillations during the last 1100 years**

LAJCZAK A.

*Jan Kochanowski University, Institute of Geography, KIELCE, POLAND*

I analysed changes in the relief of the partly glaciated Azau Valley in the Central Caucasus, neighbouring to Elbrus volcanic cone (5643 m a.s.l.) resulting from intensification of volcanic activity and valley glaciers' oscillations during the last 1100 years. Field research, analysis of topographic maps and photographs from the last 140 years as well as information in literature were the basis for my work. I identified the most important geomorphological processes modelling the valley: a lava flow, floods of jökulhlaup type, glaciers' transgressions and recessions, erosion of moraines and mass movements on the slopes. I distinguished eight sections of the Azau Valley varied in their relief and being under the differentiated influence of the listed geomorphological processes. The valley under question, represents the Alpine type area of typical cascade like transfer of waste material from the slope to the valley systems and further along its floor. Hanging tributary valleys on the Azau Valley slopes are valleys exporting waste material while the main valley functions as the valley importing waste material. In the period of absence of visible volcanic activity of Elbrus, the fastest changes in the Azau Valley relief take place during the recession of the valley and slope glaciers and of ice cap on this volcano. Findings proof interdependence of intensity of material aggradation in the valley and the amount of moraine deposits which can quickly erode and be transported to the stream channel, easily accessible weathered material derived from marginal ice-free areas as well as on the volume of ice melting water discharging great loads of sediment.

\*\*\*\*\*

### **Late Holocene environmental and climatic conditions in Adventalen valley (Svalbard) based on sedimentological studies of ice-wedge polygon terrain**

OLIVA M.(1), NEVES M.(1), VIEIRA G.(1), PINA P.(2), CARDOSO M.(1), FREITAS C.(3)

*(1) Institute of Geography and Spatial Planning, Universidade de Lisboa, LISBOA, PORTUGAL ; (2) Centre for Natural Resources and the Environment, Instituto Superior Técnico, LISBOA, PORTUGAL ; (3) Department of Geology, Universidade de Lisboa, LISBOA, PORTUGAL*

Ice-wedge polygons are widespread features in the surroundings of Longyearbyen (Svalbard). Two study areas were selected in Adventalen valley in order to examine the role of the soils and sediments in the formation and development of these ice-wedge networks: (1) one located in a glacio-fluvial terrace on the northern bank of Advent river, (2) the other in the lowest part of Todalen alluvial fan, in the southern bank of the river.

Tens of pits along transects were opened in order to examine the sedimentary record in these areas where polygons are present. The study of the sediments may reveal changes in the environment, which in turn may reflect climate variability. The thickness of the active layer at the end of summer (50-110 cm) determined the depth down to which sections were examined. Moreover, in the cliffs of the Advent river we excavated exposures up to 2 m depth to better analyze the sedimentary sequence. Samples were collected from the different lithostratigraphic units for standard laboratory analyses (grain size, organic matter content, XRF). Ten samples were processed for AMS C<sup>14</sup> dating to establish the chronological framework of the environmental evolution.

Results suggest significant landscape changes in the area over the Late Holocene. The peat layer detected in the basal layer of the northern section is found widespread across the valley and it has been dated back to 3.4-2.8 ka BP. Subsequently, an alternation of organic-rich units and aeolian layers is indicative of changing environmental conditions between 2.8-1 ka BP. A more intense wind deposition is likely to have occurred during the last millennium, especially in the southern bank of the river.

Therefore, in the framework of the ANAPOLIS project, our research provides a better understanding of the environmental conditions (and climate) more favorable for the development of ice-wedge polygons in this arid Arctic environment during the Late Holocene.

## Typology and chronology of terraces around the lake Van: highlighting changes in palaeogeography of the lake basin during the Late Pleistocene

CHRISTOL A.

Laboratoire de Géographie Physique, FECAMP, FRANCE

The Lake Van (1648 m) is a palaeoclimatic and palaeoenvironmental reference for the Middle East. According to previous studies, its evolution appears close-related to climatic and palaeohydrographic changes. This presentation aims at characterizing terraces of the lake basin, which are correlated to ancient lake levels (the regional base-level), to highlighting palaeogeographic changes at the end of the Upper Pleistocene. We adopt a geomorphological approach including sedimentary facies and stratigraphic analysis, altimetric measurements on field and datings (OSL and <sup>14</sup>C). The geochronological approach is focused on fluvio-lacustrine sequences under the surface of the terraces.

The morphosedimentary archives around the lake have recorded high amplitude variations of the Lake Van and of its volume, with five main transgressions each one has been followed by important regressions. These latter are induced by an incision of the former lacustrine sediments and the development of erosional terraces on both sides of valleys and on shore for the most recent regression. Some erosional terraces are developed in the substratum and have been caused by a very low lake level. The terrace systems in the main tributary valleys show the diversity of the terraces in terms of elevation (from 1750 to 1650 m above the present lake level), surface size, edge amplitudes and volume of sediments eroded. These morphologies show in each studied valley associations of cut-and-fill terraces and stepped terraces with different ages. Our results concerning all the terraces give ages from 135 ka (MIS6) to 13.7-11.5 ka (from <sup>14</sup>C cal BP and OSL). The different types of terraces are evidences of base-level variations during a low lake level in fluvial conditions but also of conditions during the lake regression which can be more or less fast and with some intermediate lake stands or not. These aspects reveal the sensitivity of this hydrosystem to changes in palaeohydrography and to climate forcing.

\*\*\*\*\*

## Late Quaternary climate and landscape evolution in north Gujarat: a multiproxy study of the Pariyaj Lake archive, western India

RAJ R.(1), SHARMA A.(2), PRASAD V.(3), VERMA P.(3), TRIPATHI J.(4)

(1) Department of Geology, The M. S. University of Baroda, VADODARA, INDIA ; (2) School of Earth & Environmental Sciences, Central University of Himachal Pradesh, DHARAMSHALA, INDIA ; (3) Birbal Sahni Institute of Palaeobotany, LUCKNOW, INDIA ; (4) School of Environmental Sciences, Jawaharlal Nehru University, NEW DELHI, INDIA

Early Holocene in western India is marked by a regional tectonic uplift, which resulted in readjustment of drainages and formation of ponds and lakes that provides excellent archives to study past climatic changes. A multidisciplinary study was carried out on a sediment core from the Pariyaj Lake of northern part of the Gujarat alluvial plains to reconstruct climate, palaeoenvironment and tectonics and their role in the evolution of area during the late Quaternary. Based on geological, geomorphological, palynological and phytolith investigations, five climatic phases have been identified during the last ~12,000 cal. yr BP. Phase I (89-75 cm), is dominated by algal elements, moist deciduous arboreals and non arbors, indicating high lake level and wet climatic conditions. Abundance of burnt phytoliths and micro-charcoal fragments are indicative of human activity. Presence of *Artemisia* pollen and dominance of pooid phytolith morphotypes is indicative of prevalence of winter precipitation activity during this phase. Phase II (75-63 cm), shows low pollen yield, decreased algal content, indicative of low lake stand. Phase III (63-35 cm) shows large proportion of pollen belonging to deciduous and dry deciduous i.e. *Prosopis* and *Accacia* plants in the upper part of the phase indicates changing landform conditions and beginning of dry climatic condition. The decreasing trend in the pooid and multifaceted phytolith morphotypes also indicates gradual decrease in the precipitation activity. Phase IV (35-25 cm) is a barren zone which falls in the mid Holocene period, (~5000 BP) indicates excessively dry climatic phase. In Phase V (25-5 cm) there is an increase in the percentage of pollen and phytolith indicating increased precipitation as a result of amelioration in climate. The excessive dry phase of Pariyaj lake correlates well with the mid Holocene dry phase of Rajasthan lakes and climatic data of other part of the Indian subcontinent.

### **Landform Evolutions: Sedimentary Records from Lake Borsog, Eastern Shore of Lake Khuvsgul, Mongolia**

ORKHONSELENGE A.(1), KRIVONOGOV S.K.(2), MINO K.(3), KASHIWAYA K.(3), YAMAMOTO M.(3), NAKAMURA T.(4)

(1) School of Geography & Geology, National University of Mongolia, ULAANBAATAR, MONGOLIA ; (2) Institute of Geology & Mineralogy, Siberian Branch of Russian Academy of Sciences, NOVOSIBIRSK, RUSSIAN FEDERATION ; (3) Institute of Nature and Environmental Technology, Kanazawa University, KANAZAWA, JAPAN ; (4) Center for Chronological Research, Nagoya University, NAGOYA, JAPAN

This study presents landform evolutions recorded from new sedimentological, geochronological and diatom data from a 13-m core of sediment from Lake Borsog, a former bay of Lake Khuvsgul (also known as Hovsgol and Khubsugul) in northwestern Mongolia. Lake Borsog was separated from Khuvsgul during the early stages of a post-glacial transgression and possesses a high-resolution record of the Holocene. The data show three short events of higher-rate sedimentation (0.102 cm/yr, 0.085 cm/yr and 0.139 cm/yr) at 7.4–7.1 ka cal. BP, 4.8–4.5 ka cal. BP and 1.0–0.9 ka cal. BP, which are possibly related to lake level drops, reduction of lake area, progradation of the delta of the Borsog River and higher erosion of the exposed lake shores. The drops in lake level match the previously documented drops of the level of Lake Khuvsgul at ca. 7.2–7.0, 4.5–4.1 and 2.1–0.5 ka cal. BP, suggesting continued mutually-related and climatically-controlled evolution of both lakes after their separation.

\*\*\*\*\*

### **New insights on the Quaternary stratigraphy of the coarse-grained Golo river alluvial plain (east-Corsica margin)**

MOREAU J.  
IFREMER, PLOUZANE, FRANCE

The Golo river is the main river of Corsica, flowing to the Mediterranean Sea. It takes its source in the highest summit of Corsica, the Monte Cinto (2706m), runs along a small watershed (1005 km<sup>2</sup>) in a very incisive and steep profile (5.3%). The Golo river shows a well-developed terrace system on the 'Marana-Casinca plain' on the northeast-Corsica. This alluvial plain should be considered as the first depositional area shaped by the major changes of the Quaternary sediment fluxes provided by the Golo watershed. Previous studies on the deltaic plain provided a detailed geological map based on superficial outcrops. But there is no absolute delta geochronology, neither information about the depth of the substratum underneath the alluvial terraces, nor about terraces organization in depth. This study is based on new geophysical and geological acquisitions performed during 5 fieldworks since 18 month. The acquisition of an integrated dataset with several electric resistivity tomography (ERT) profiles, H/V measurements, OSL and Be10 dating were realized. The combination of the new geophysical data with the synthesis of lithological logging information available on the delta plain provides a refined stratigraphic framework of the Golo delta. As an example, we imaged a succession of stepped terraces in the upstream part of the plain. In depth, data provide constraints on the extent and the thickness of the alluvial terraces, about 20 meters for the oldest and less for the more recent ones. The H/V method confirms by a regional surface imaged on the ERT survey the existing boundary between the alluvial deposits and an undifferentiated basement. ERT data also allowed the identification in the northern part of the plain of a paleo-valley-shape underneath a topographic depression. 200 meters-width and 150 meters-depth incision can be displayed. The new evidences of palaeo-valley incisions on the deltaic plain allow to discuss the Quaternary evolution the Golo delta plain.

### **Influence of bedrock on the fluvial morphodynamics in the Pleistocene Dives River (NW France)**

JAMET G., DELCAILLAU B., DUGUÉ O.

*Université de Caen Basse-Normandie/ M2C UMR CNRS 6143, CAEN, FRANCE*

During the Plio-Pleistocene cold periods, the Dives River was an important tributary of the Bay of Seine sedimentary basin and displayed four major steps of alluvial units below the last incision of the bedrock. Unlike previous work, this study provides a comprehensive fluvial morphodynamics investigation. This study aims to establish a relative chronology of events in the Dives fluvial history and to understand the control on those events. We reviewed stepped-terraces system from previous studies and add new data based on cartography, excavations and seismic tomography (DAQLink III). Moreover, we analysed the drainage network, alluvial deposits and morphostructural data using geomorphological modelling tools (DEM). Results allowed us to 1) describe a new longitudinal profile of the last Weichselian incision, 2) establish a morphostratigraphical framework that displays the origin, the geometry and the depositional dynamics of alluvial bodies and 3) discover geomorphological anomalies that indicate reorganisations of the Pleistocene Dives streams.

The fluvial architecture displays a lithostructural control. The lower terraces exhibit a strong contrast in regard to depositional dynamics on each side of the two major knickzones in the longitudinal profile (*i.e.* Morteaux-Couliboeuf and Quétiéville). The alluvial deposits of Ecajeul is an evidence of a capture linked to an adaptation to the monoclinical structure according to eastward coastal rivers migrations. The stepped-terraces in the downstream part of the Dives basin are interpreted as the result of cyclic backward erosions and rapid adjustments of streams. These preliminary results allow to discuss the possibility that subbasins of the present-day coastal area are inherited from a palaeogeography disconnected from the present-day Dives basin. A radiochronometric approach will be required to understand the time scale of landscape response to changes in bedrock uplift rate and to record Interglacial/glacial climate.

\*\*\*\*\*

### **Late Holocene flood phases in the Upper Dniester river basin: response to climate change and human impact in the Carpathian Foreland**

GEBICA P.

*University of Information Technology and Management, RZESZOW, POLAND*

Research in the valleys of Upper Dniester, Strvjaz and Stryj Rivers, in the Eastern Carpathian Foreland, documents the occurrence of 3-4 Holocene terraces and several alluvial fills within the lowest of these terraces, 4-6 m high, dating back to the Late Vistulian, Atlantic, 3500-3000 BP, 2200-1700 BP, 5<sup>th</sup>-7<sup>th</sup>, 10<sup>th</sup>-12<sup>th</sup> and 14<sup>th</sup> – 16<sup>th</sup> centuries AD. Flood phases distinguished in the Upper Dniester basin correlate well with previously established phases of enhanced fluvial activity in the valleys of Upper Vistula, the Wisłoka and the San in the Western Carpathian Foreland. Among these periods are phases determined by climate as well as reflecting human activity and phases recording coincidence of both these factors. The Roman period (1<sup>st</sup>-4<sup>th</sup> centuries AD) was a time of enhanced human activity and flood deposition. An episode of tree fall during the 5<sup>th</sup>-6<sup>th</sup> century floods is linked to the regression of agriculture, reforestation and increase in frequency of floods connected with growth of precipitation (1500-1350 BP). Subsequent phases of greater fluvial activity (10<sup>th</sup>-12<sup>th</sup> and 14<sup>th</sup>-16<sup>th</sup> centuries AD), record increasing human activity, as well as correlation with wet and cool climate phases (the first half of the 11<sup>th</sup> century and the beginning of the Little Ice Age).

### Heinrich Events and Late Pleistocene geomorphic instability on the central Portuguese coast

*BENEDETTI M.M.(1), DANIELS J.M.(2), HAWS J.A.(3), FORMAN S.L.(4)*

*(1) University of North Carolina, WILMINGTON, NC, UNITED STATES ; (2) University of Denver, DENVER, CO, UNITED STATES ; (3) University of Louisville, LOUISVILLE, KY, UNITED STATES ; (4) University of Illinois, CHICAGO, IL, UNITED STATES*

Heinrich Events (HE) are semi-periodic iceberg outbursts into the North Atlantic Ocean from the Laurentide ice sheet that occurred in the Late Pleistocene. HE are recorded as layers of ice-rafted continental sediment in deep sea sediment cores as far south as 37°N latitude. Recent studies suggest that sea level rose by ~5m during HE, and summer sea surface temperatures dropped by more than 10°C. These conditions impacted maritime and coastal systems across the region, and especially on the coast of Portugal where HE are linked to cold/arid conditions, forest decline, hillslope erosion, marine transgression, and discontinuities in the archaeological record.

The Estremadura region of central Portugal presents several examples of HE-driven geomorphic change. Landscape instability between 11-70 ka BP is indicated by fluvial valley fills, aeolian sands, and colluvial deposits on coastal bluffs with ages that cluster around HE1, HE2, HE3, HE4, and HE6. Currently all 13 OSL ages on these deposits overlap a HE within the 1 sigma error range. These data support a biogeomorphic response model first proposed by James C. Knox in 1972, which predicts maximum hillslope erosion and sediment yield following climatic transitions from arid to humid. They are also consistent with archaeological studies reporting erosional discontinuities due to cold arid conditions during HE4, at the Middle-Upper Paleolithic transition. Fluvial deposits at Praia Rei Cortiço demonstrate a transition from meandering to braided channels at the end of the last interglacial stage, and back to meandering before the current interglacial. Many Portuguese rivers were likely braided throughout the glacial stage, given the unstable climate associated with HE and Greenland stadials. Finally, littoral deposits on raised coastal platforms in the study area record local sea level rise of at least 4m during HE4 and HE6, supporting the concept of eustatic sea level forcing by HE.

\*\*\*\*\*

### Holocene record of hydrological changes in the Nile delta using Sr isotopes: an example of climatic forcing, societal management and local geomorphological responses (Maryut lagoon, Egypt).

*FLAUX C., CLAUDE C., MARRINER N., MORHANGE C.  
CEREGE, AIX-EN-PROVENCE, FRANCE*

Understanding the Holocene drivers and timing of coastal water budget changes in deltaic settings is a key issue to constrain modern deltaic modifications in the face of relative sea level, continental waterflow and human management. In the Nile delta, these drivers act cumulatively and mediate the coastal ecosystem, agricultural activities, freshwater resources and population vulnerability to coastal changes.

The strontium isotopic composition of carbonate ostracod shells from Holocene lagoon sediments in the Maryut (NW Nile delta) have been used to quantify the interplay between relative sea-level variations and Nile flow changes in the Maryut's water budget during the past 7,500 yrs.  $^{87}\text{Sr}/^{86}\text{Sr}$  ratios allow five hydrological stages to be defined. (1) The marine transgression of the area is dated to ~7.5 ka cal. BP. (2) Between ~7 and ~5.5 ka, in the context of the so-called African Humid Period (AHP), freshwater inputs became progressively predominant in the Maryut's hydrology and coastal progradation led to the progressive closure of the Maryut lagoon. (3) The termination of the AHP is reflected in the  $^{87}\text{Sr}/^{86}\text{Sr}$  stratigraphy between ~5.5 and ~3.8 ka, by a progressive hydrological shift from a Nile-dominated to a marine-dominated lagoon. (4) From ~2.8 to ~1.7 ka,  $^{87}\text{Sr}/^{86}\text{Sr}$  ratios shift towards lower Nile-like values and is attributed to irrigation works since the early Ptolemaic period (i.e. since ~2.3 ka). (5) The final phase of the record covers the period between ~1.7 to ~0.2 ka.  $^{87}\text{Sr}/^{86}\text{Sr}$  indicate high freshwater inputs, except between 1.2-1.1 to ~0.7 ka, when a Maryut lowstand and brackish water intrusion is attested. Our work shows that strontium isotopes are sensitive to variations in the palaeo-water budget of Nile lagoons, collectively mediated by basin-scale climate change and local-scale societal impacts.

## **Poster presentations:**

### **The Geological Society of London Engineering Group Working Party on Periglacial and Glacial Engineering Geology**

*GILES D.(1), MARTIN C.(2), GRIFFITHS J.(3), MORLEY A.(4), LUKAS S.(5), EVANS D.(6), MURTON J.(7), CULSHAW M.(8), DONNELLY L.(9), DE FREITAS M.(10), WINTER M.(11)*

*(1) University of Portsmouth, PORTSMOUTH, UNITED KINGDOM ; (2) BP, LONDON, UNITED KINGDOM ; (3) University of Plymouth, PLYMOUTH, UNITED KINGDOM ; (4) Arup, LONDON, UNITED KINGDOM ; (5) Queen Mary College, LONDON, UNITED KINGDOM ; (6) Durham University, DURHAM, UNITED KINGDOM ; (7) University of Sussex, BRIGHTON, UNITED KINGDOM ; (8) BGS, NOTTINGHAM, UNITED KINGDOM ; (9) Wardell Armstrong, MANCHESTER, UNITED KINGDOM ; (10) Imperial College, LONDON, UNITED KINGDOM ; (11) TRL, EDINBURGH, UNITED KINGDOM*

The Engineering Group of the Geological Society of London has established a Working Party to undertake a state-of-the-art review on the ground conditions associated with former Quaternary periglacial and glacial environments and their materials, from an engineering geological viewpoint. The proposed final report is not intended to define the geographic extent of former periglacial and glacial environments around the world, but to concentrate on ground models that would be applicable to support the engineering geological practitioner.

The Working Party will be considering the following topics with respect to engineering geology: Quaternary Setting, Geomorphological Framework, Glacial Conceptual Ground Models, Periglacial Conceptual Ground Models, Engineering Materials and Hazards, Engineering Investigation and Assessment along with Design and Construction Considerations.

This paper will present the progress of the Working Party and will outline the approaches taken and proposed output of the group.

\*\*\*\*\*

### **Geochronology of the planning surfaces in the Center-Western portion of the Paulista Peripheral Depression (Brazil) using Optically Stimulated Luminescence**

*DIAS R.L., PEREZ FILHO A.*

*Institute of Earth Sciences (IG), University of Campinas (UNICAMP), CAMPINAS, BRAZIL*

The relief in the state of São Paulo, Brazil, is divided into five geomorphological provinces, characterized from their genesis, structure and lithology. The Paulista Peripheral Depression corresponds to one of them, with the shape of a corridor with mountainous topography of approximately 50 Km wide, located between two other provinces: the Cuestas region and the crystalline elevations of the Atlantic Plain.

The proposed study intends to identify and interpret the planning surfaces, defined by Penteadó (1968), using absolute dating and correlation of surfaces: Neogenic I, Neogenic II, high and low fluvial terrace and recent alluviums formed during the Quaternary, using the Optically Stimulated Luminescence (OSL) in different material of soil formation, located in the respective surfaces. This technique enables the attribution of specific periods of the landscape evolution to determined known or modeled using absolute dating. This method has demonstrated great potential in dating quaternary deposits, since it can reach ages of up to  $10^6$  years.

The results obtained will enable making the relations between genesis and such shapes, and possible past environmental conditions, where the semi-arid conditions were predominant, later followed by the carving of the fluvial channel in hot and moist conditions. Soon, it will be possible to build a regional scenario of the climate oscillations that occurred during the Quaternary, also taking into consideration the influence of neotectonic activities in the elaboration of such planning surfaces.

Therefore, this study intends to contribute to the discussions on the genesis of relief forms and their correspondence to climatic oscillations that occurred in recent period in nature's time scale, in the Brazilian territory.

Key-words: Paulista Peripheral Depression (Brazil), Quaternary, Climatic Oscillations and Optically Stimulated Luminescence (OSL).

### Mid-Holocene Wetland Evidences in West Coast Zone, Korea

YANG D.Y., LIM J., LEE J.Y., KIM J.Y., YI S., KIM J.K.

*Korea Institute of Geoscience and Mineral resources, DAEJEON, SOUTH KOREA*

We first discovered a natural-type wetland in the site of Kimpo Airport, which has perfect wetland characteristics of a variety of ecological environment even though it has been formed in the center of city within recent 20 years. The current wetland is formed in an unused field within the site of Kimpo Airport. The site is on the floodplain of Gulpo-stream which flows northeast and is joined the Han River flowing northwest. The most of water sources in the lowland of 4-6m in elevation of northeastern basin is originated from the southwestern mountainous part of the basin.

We found out the evidences of mid-Holocene wetland from the results of multi-proxy records of sediment core OS3 of the wetland. Three sedimentary units, from unit I to III in ascending order, are distinguished based on sedimentary textures and vertical color variation. Unit I consists mainly of dark brownish gray, fine silt with a few plant fragments. Unit II is characterized by two peat layers. It shows bluish to dark gray fine silt with some plant fragments and organic matters. Unit III is composed of mainly yellowish brown to brownish gray very fine silt. The radiocarbon ages of 5 samples from sediment core OS3 were determined by the accelerator mass spectrometer (AMS) method. There is a hiatus between units I and II by erosion. Unit I is the latest Pleistocene sediments older than 19960 cal yBP, but the sediments of units II and III were formed in 6370-4600 cal yBP. Kimpo wetland is somewhat similar to Pyeongtaek and Cheolipo wetlands in geology, geomorphology and geochemistry, which are located in floodplain and beach sites, approximately 80km and 120km southwest of Kimpo site, respectively. We will report the mid-Holocene wetland evidences of this site with comparing those of Pyeongtaek and Cheolipo wetlands. Also, we will discuss the characteristics of these wetlands comparing with East Asia Summer monsoon data and rainfall data of Dongge Cave during mid-Holocene.

\*\*\*\*\*

### Geochemical record of biogenic-carbonate sedimentation in deposits of spring mires in Poland

DOBROWOLSKI R.(1), MAZUREK M.(2)

*(1) Institute of Earth Sciences, Maria Curie-Skłodowska University, Lublin, Poland, LUBLIN, POLAND ; (2) Institute of Geoecology and Geoinformation, Adam Mickiewicz University in Poznan, POZNAN, POLAND*

Peatlands are thought to be geoarchives in which deposits and their physico-chemical parameters can be useful when studying changes in the natural environment as well as those caused by human activity. Of much value in this respect are spring mires belonging to the rare alkaline soligenous type. The deposit-building peat-calcareous tufa series are an excellent analytical material for Late Glacial-Holocene paleo-environmental reconstructions. The similarity of objects in various morphogenetic units of Poland, the uniform mechanism of their formation, encourages comparisons of depositional records and in consequence allows conclusions concerning climatic and hydrological changes. Geochemical data, correlated with radiocarbon ages, document differences in sedimentary environments resulting from conditions of circulation of groundwater and its physico-chemical properties as well as from changes in the conditions of sedimentation. Physical features and the chemical composition of deposits, especially the concentration of macro-components, are a record of the character and intensity of natural chemical denudation processes taking place in the catchment feeding spring mires. The pattern of decline in the Ca/Mg ratio is indicative of selective lessening of carbonate leaching in the catchment and a drop in Ca concentrations in the groundwater supplying the mires in question. Changes in the hydrogeochemical environment (reduction-oxidation conditions) may be conducive to the precipitation, chemical sorption, oxidation and reduction of some chemical components. Differences in the Cu/Zn and Fe/Mn rates in profiles reflect transformations of the reduction-oxidation conditions obtaining during the sedimentation of deposits. Deposits of spring mires are also a record of the history of atmospheric supply. The intensity of human impact will show in changing heavy metal concentrations in the near-surface layers of deposits, and in an increase in the eutrophication index.

**Are fluvial terraces reliable chronological markers in the history of valley development? The Ariège, north-Pyrenean piedmont, France**

*DELMAS M.(1), CALVET M.(1), GUNNELL Y.(2), BRAUCHER R.(3), GUILLOU V.(3), BOURLES D.(3)*

*(1) Université de Perpignan-Via Domitia, EA 4605 Médi-Terra, PERPIGNAN, FRANCE ; (2) Université Lumière-Lyon 2, UMR 5600 CNRS Environnement, Ville, Société, LYON, FRANCE ; (3) Aix-Marseille Université, CEREGE CNRS UMR 7330, AIX-EN-PROVENCE, FRANCE*

The treads of fluvial terraces are commonly used to reconstruct the past longitudinal profiles of graded rivers. They also constitute timelines in the landscape, marking the stages of channel incision and allowing mean rates of valley downcutting to be calculated. Based on those two assumptions it becomes possible to discuss the magnitude, frequency and relative impacts of climatic and tectonic forcing on river behaviour. However, doing so requires not only reliable means of establishing an accurate chronology of the terrace system but also appropriate clues to the graded character of the stream palaeoprofile, i.e. evidence that floodplain construction and channel incision were coeval in all segments of the valley. Here, we explore these issues in the upper Garonne basin, where a system of four glaciofluvial terrace straths formed by the Ariège river permit (i) an estimate of terrace ages based on vertical sampling profiles of the cosmogenic isotope  $^{10}\text{Be}$ ; (ii) the production of a Quaternary chronosequence for the suite of well characterized soil profiles capping the terrace treads; (iii) a correlation between the successive generations of terraces and the successive generations of frontal moraines of the Ariège glacier, which were previously dated also by  $^{10}\text{Be}$ ; and finally (iv) a discussion of conditions conducive to time-transgressive floodplain aggradation in the case of the lower terrace, which grades upstream to Würmian moraines.

\*\*\*\*\*

**The complex studies of quaternary sediments in the Yenisei River**

*MASHUKOV A.(1), MASHUKOVA A.(2)*

*(1) Siberian Federal University , KRASNOYARSK, RUSSIAN FEDERATION ; (2) Siberian Federal University, KRASNOYARSK, RUSSIAN FEDERATION*

The high speed of the river flow contributes to washing up to 5 tons of suspended solids per year from one square kilometer of the bottom surface. This is why most of the rocks forming the terrain under the influence of chemical conditions, temperature and pressure, changed their chemical composition.

There were studied the Quaternary sediments of the region close to Krasnoyarsk, whose age is no more than 10 thousand years. The samples were studied by using the X-ray and Mössbauer spectroscopy methods.

The three fractions, –namely strong-magnetic ( $\text{Fe}_3\text{O}_4$ – 87,3%,  $\text{Fe}_2\text{O}_3$  – 0,7%), soft-magnetic ( $\text{Fe}_2\text{O}_3$ – 21,7% ) and non- magnetic ( $\text{FeO}$  – 53,1%,  $\text{FeOOH}$  – 46,9% ) – were extracted by using the magnetic separation method for determining the minerals – magnetization carriers. In the strong-magnetic fraction, the main iron-containing mineral is magnetite. As to hematite, it is probably localized on the surface of magnetite grains. The carriers of the magnetization of soft-magnetic fractions are hematite grains. The  $\Delta$  and  $\delta$  values indicate strong non-stoichiometry of wüstite. The compounds of  $\text{FeOOH}$  and  $\text{FeO}$  do not contribute to the residual magnetization.

One could see the increase in the saturation magnetization within the temperature range (20 - 250) degrees C. Then there is the drastic decrease in the temperature range (250 - 300) and after that there is its increase in the range (300 - 350). The phase change are observed at 400 degrees C and 500 degrees C. By using the X-ray analysis, there were detected Albite, Ankerite, Orthoclase in the non-magnetic fraction.

The above-mentioned studies show the prospects of applying the complex research in geology. The Mössbauer spectra can identify the types of magnetic minerals in complex compounds. The identification of the iron-containing natural minerals helps to reveal the stability of the residual magnetization in geological time scales.

### **Late Quaternary depositional sequences and landforms in relation to sea-level changes in the Osaka intra-arc basin, Japan: a borehole database analysis**

*ITO Y.(1), OGUCHI T.(1), MASUDA F.(2)*

*(1) The University of Tokyo, KASHIWA CITY, JAPAN ; (2) Doshisha University, KYOTANABE, JAPAN*

Development of the upper Pleistocene to Holocene depositional sequences in the Osaka intra-arc basin was reconstructed, based on the analysis of subsurface geology and geomorphology, using numerous and high-density borehole data and GIS. The upper Holocene sequence (I) and the lower late Pleistocene sequence (II) underwent several significant phases: 1) formation of alluvial fans and terraces during regression from marine isotope stage (MIS) 5 to MIS 2; 2) formation of a boundary between the two sequences during rapid sea-level fall of during ca. 30–20 ka; 3) development of ravinement surfaces by wave and tidal erosion during the transgression from MIS 2 to MIS 1; 4) development of barrier systems and coastal cliffs during the transgression to the maximum high-stand of 6–5 ka; and 5) progradation of alluvial fans, deltas and strand plains during the high-stand since 5 ka. Depositional facies and systems of the two sequences are different among the western study area around Kobe, the central area with the Nishinomiya-Amagasaki lowland, and the eastern area with the Osaka plain, due to differences in sediment flux, wave, tide, shore current, basement and surrounding landforms. Development of the sequence II could be also affected by tectonic differences. Especially important insights are: 1) geomorphological changes with the formation of ravinement wave surfaces during the transgression, and 2) geomorphological changes of sea beds in relation to different rates of sea-level rise.

\*\*\*\*\*

### **The Nile delta : climate pacing and vulnerability to Holocene change**

*FLAUX C.(1), MARRINER N.(1), MORHANGE C.(1), KANIEWSKI D.(2)*

*(1) CEREGE, AIX-EN-PROVENCE, FRANCE ; (2) ECOLAB, TOULOUSE, FRANCE*

The Nile delta lay at the heart of ancient Egyptian civilization, however little is known of its morpho-sedimentary response to basin-wide changes in Holocene hydrology. Here, we present two well-resolved records from the Nile delta (based on around 320 radiocarbon dates) to reconstruct the timing and rhythm of catchment-scale modifications during the past 8000 years. We also use chronostratigraphic data from 194 organic-rich peat and lagoon points to quantitatively reevaluate the drivers of Nile Delta surface dynamics during the Holocene. On the orbital timescale, we find that Nilotic hydrology and sedimentation have responded to low-latitude insolation forcing while, on sub-millennial timescales, many of the major phases of deltaic modification were mediated by climate events linked to El Niño Southern Oscillation type (ENSO) variability. Between 8000 and 4000 calibrated (cal) 14C yr B.P., spatially averaged sedimentation rates were greater than subsidence, meaning that delta aggradation was the dominant geomorphological process at the regional scale. Since ca. 4000 cal yr B.P., a sharp climate-driven fall in Nile sediment supply, possibly coupled with the human-induced drainage of deltaic wetlands, has rendered the depocenter more sensitive to degradation by sea-level rise and extreme flood events. The reconstruction suggests that the Nile delta has a particularly long history of vulnerability, although the present sediment-starved system does not have a direct Holocene analogue.

## **Deglaciation and postglacial evolution of relative sea level in the western part of the Saint-Lawrence River estuary and in the Gulf of St. Lawrence, Canada**

HETU B.

*Université du Québec Rimouski, RIMOUSKI, CANADA*

Resulting from the combined effect of the general rise of global sea level concomitant with the deglaciation (Flandrian Transgression), of the glacio-isostatic uplift, that varies from one area to another depending on the thickness of glaciers, and of the migration the glacial forebulge, the postglacial evolution of relative sea level (RSL) in the Canadian Maritime provinces presents great complexity. In terms of post-glacial RSL evolution, the Maritime provinces can be subdivided into three major regions: (1) the northwest region where crustal uplift was more important than Flandrian Transgression, (2) the southeast region where subsidence of the crust and submergence associated with the Flandrian Transgression were dominant, (3) and the region in between representing a transition zone with a complex sequence of events. The middle region first experienced a phase of rapid emergence immediately after deglaciation, it was followed by a period of low sea level of variable amplitude depending on the sector and, it finally entered a phase of submergence that is still continuing. The study area overlaps the three regions. It includes the Saint Lawrence River estuary up to Rimouski, the western part of the Gulf of St. Lawrence (Gaspé area) and north shore of the Baie des Chaleurs. Several new data, including mapping of old shorelines, stratigraphic data, several new AMS dates, and four new RSL curves were used to analyze the deformation of the crust under the weight of glaciers. The data collected allow for the first time to locate the boundary between zones 1 and 2, to better understand the behavior of the crust in the northern part of the third region (Baie des Chaleurs) and, more generally, to better understand the behavior of the crust in the regions under the influence of several ice caps.

\*\*\*\*\*

## **Interfluvial negativ microform in Romanian Plain. Morphometric and genetic analysis**

GRECU F.(1), GHITA C.(1), BENABAS C.(2)

*(1) University of Bucharest, Faculty of Geography, BUCHAREST, ROMANIA ; (2) University of Constantine, CONSTANTINE, ALGERIA*

The landforms developed on loess and loessoid deposits are a common feature of the central and eastern sections of the Romanian Plain. Most of the topographic surface is covered by such deposits, which over the time have encouraged the emergence of specific landforms, in accordance with their response to the surface-sculpturing agents. From geomorphological point of view, negative microforms ("crovurile") are depressions (ease subsidences) in loess or loess deposits covered plains, having circular or ellipsoidal shape, with diameters from few meters to 1-2 km, and a depth of 1-3 m. The evolution of these landforms is further controlled by subsidence, wind erosion and raindrop impact. The main objective of the study is to decipher the dynamics of these microdepressions (from Mostistea and Central Baragan Plains) using some morphometric parameters: Surface (S), Perimeter (P), Length (L), Width (I), Depth (D) as well as microdepression's alignment and different coefficients (indicators of shape). The investigation shown big differences between the microdepressions in the two areas of study and, especially, on desopits type: Holocene sands areas and loess or loess deposits. In the Central Bărăgan Plain, on the Holocene sands in the northern section, loess dolines are smaller, less elongated and less sinuous, while in the central part of the plain they are larger, deeper, more sinuous and rounded. Likewise, in the northern part, the number and density of the microdepressions have higher values. At the same time, to the north, microdepressions are more numerous and their density is higher. Taking into account the features of the investigated loess wells one can define three "genetic" classes of microdepressions, depending on the genetic conditions and morphometric features.

### Relative sea level changes in the Magdalen Islands (Québec, Canada) since the last glaciation

*M. RÉMILLARD A.(1), HETU B.(2), BERNATCHEZ P.(3), ST-ONGE G.(1)*

*(1) Canada Research Chair in Marine Geology, Institut des sciences de la mer de Rimouski (ISMER) & GEOTOP, Université du Québec à Rimouski, RIMOUSKI (QUEBEC), CANADA ; (2) Département de biologie, chimie et géographie & Centre d'études nordiques, Université du Québec à Rimouski, RIMOUSKI (QUEBEC), CANADA ; (3) Research Chair in Coastal Geoscience, Département de biologie, chimie et géographie & Centre d'études nordiques, Université du Québec à Rimouski, RIMOUSKI (QUEBEC), CANADA*

Global sea level rise is currently at the forefront of the most potentially damaging effects of climate change and is therefore one of the major challenges humans will have to face during the 21<sup>st</sup> century. In the maritime provinces of Eastern Canada, the relative sea level (RSL) rise has been exacerbated by subsidence that followed deglaciation. The Magdalen Islands, located in the middle of the Gulf of St. Lawrence, have undergone submersion at a rate of 3.5 mm/yr since the 60s. Consequently, the coastline of the archipelago is currently at risk of submersion (70%) and erosion (65%). It is imperative to understand past and present RSL changes in the Magdalen Islands region, and throughout the Maritimes, in order to generate accurate projections and develop appropriate adaptation strategies against these hazards. Here, we present preliminary sedimentological and radiocarbon dating results from different outcrops of the archipelago in order to reconstruct 1) Wisconsinan glaciation patterns in the Magdalen Islands region in order to better understand the sea level changes related to this glacial period, and 2) RSL variations and the environmental changes in the Magdalen Islands since the last glaciation.

Our initial results revealed that the southern part of the Magdalen Islands was affected by a marine transgression during the MIS3 in a boreal environment and under periglacial conditions. During the MIS2, the archipelago was glaciated by an ice flow from the Escuminac ice cap, whose centre of dispersion was located in the Gulf of St. Lawrence. The glaciation of the MIS2 was followed by a new marine transgression reaching at least ~ 20 m above sea level, and then by a second periglacial phase. Finally, preliminary sediment core data from the southern islands will be presented and will allow a more precise paleogeographical and chronostratigraphic framework, especially for the last deglaciation.

\*\*\*\*\*

### The use of geomorphology in the paleolimnological studies

*SAPELKO T., LUDIKOVA A., KUZNETSOV D., NAUMENKO M.*

*Institute of Limnology of Russian Academy of Sciences, ST.PETERSBURG, RUSSIAN FEDERATION*

In recent decades, the number of studies of sedimentary archives from coastal lakes located at different elevations to reconstruct relative sea-level changes has been progressively increasing. In our studies, coring "staircases" of small lakes has been performed to reconstruct the lake-level changes of Lake Ladoga (the largest lake in the European Russia) and Lake Kanozero (southern Kola Peninsula, NW Russia). Four small lakes at different elevations in Putsaari Island, northern Lake Ladoga, and three small lakes in Kanozero area, have been investigated to trace major lake-level fluctuations in post-glacial time. Changing relief configuration resulted from the isostatic rebound and related reorganization of drainage system has been found most influencing on the large basins configurations and level changes. An attempt to evaluate the dynamics of small lakes paludification processes following the isolation from the large lake was also made. It has been concluded that lake's elevation and surrounding topography largely predetermined the post-isolation history of all study lakes.

### **Chronological framework for late-Pleistocene to Holocene landscape evolution in the Upper Rhine rift valley near Heidelberg/SW-Germany as based on optically stimulated luminescence (OSL) dating**

KADEREIT A.(1), MÜLLER C.(1), HOLZHAUER I.(2), MEISENBERG O.(3)

(1) *Heidelberger Lumineszenzlabor, Geographisches Institut, Universität Heidelberg, HEIDELBERG, GERMANY* ; (2) *Heidelberger Lumineszenzlabor, Geographisches Institut, Universität Heidelberg, HEIDELBERG, GERMANY* ; (3) *Helmholtz Zentrum München, Deutsches Forschungszentrum für Gesundheit und Umwelt (GmbH), NEUHERBERG, GERMANY*

The late Pleistocene to Holocene transition was a time of major changes in the geomorphological evolution of landscapes. In the Upper Rhine rift valley in SW-Germany, fluvial and aeolian pedo-sedimentary archives recorded and stored the landscape history from Upper Weichselian to Holocene times. Periglacial-fluvial systems with predominantly braided accumulating rivers in Pleniglacial times changed to late-Weichselian mainly single-channel incising rivers and to Holocene mainly meandering rivers that were fixed within their own overbank deposits. Additionally, the transitional period was favorable for the preservation of aeolian deposits on the flood-free level of the lower terrace of the river Rhine emerging in a landscape under still periglacial conditions and a sparse cover of vegetation. Contemporaneously, more intensive tectonic subsidence in the eastern part of the rift valley hampered direct connection of the tributaries from the Black Forest mountains and Kraichgau hills to the gaining river Rhine. Therefore, a secondary south-north draining Kinzig-Murg channel system evolved which connected to the river Rhine likely stepwise in Holocene times. Earlier investigations to reconstruct the landscape history and to establish a temporal framework were mainly based on pedostratigraphical and palynological analyses as well as <sup>14</sup>C-dating of organic remains mainly from peat bogs of the Kinzig-Murg channel system. Only few ages based on thermally stimulated luminescence (TL) datings of dune sands exist so far. Here we investigate the potential of optical stimulated luminescence (OSL) dating to reconstruct the history of the fluvial and aeolian landscape. We report on the methodical challenges and the adopted single-aliquot regeneration (SAR) dating protocol(s) as well as on the dating results. These will be interpreted in view of recent pedostratigraphical findings in the study area as well as results from investigations in the Hessian part of the Upper Rhine valley.

\*\*\*\*\*

### **Fluvial quaternary sedimentation in high valley of Macaé River, state of Rio de Janeiro, Brazil**

MARCAL M., RAMOS R., HINGEL R., FEVRIER P.

*Universidade Federal do Rio de Janeiro - UFRJ, RIO DE JANEIRO, BRAZIL*

The study of the forms and materials in quaternary drainage basin provides important elements for paleoenvironmental reconstruction. Along the channel occur different features that represent the history of the basin and considers them as a process-response system. It is assumed that those features can be an evidence of the relations of different parts that compose the systems, its processes, duration and intensity.

This paper aims to show the spatial distribution and morphostratigraphic characterization of fluvial terrace deposits through graphic logs in the high valley of Macaé river and it contributes. The Macaé river is located on the northern coast of Rio de Janeiro State, Brazil, and has its springs in *Sierra Macaé de Cima* mountain range, the peak is 1,560 meters high, in Nova Friburgo Municipality. The river flows east to south-east and is 136 kilometers long and discharges into the Atlantic Ocean.

The fluvial terraces mapping was done through the interpretation of aerial photographs orthorectified in the scale of 1:10,000 and satellite imagery from Google Earth software and field works. Graphic logs were constructed in the scale 1:20 and schematic sketch along the scenic outcrops were analyzed. The lithofaciological characterization was based on Miall (2006).

The fluvial terrace consists in a feature typically flat and high in relation to the contemporary channel or fluvial plain, usually separated by a recent steep slope. It was recognized three morphostratigraphic units (1) "Reafeiçoado" Terrace topographically higher, this is about 10-15 meters from the current trough, (2) Accumulation Terrace, flat features related to ancient flood plain and this is about 3-7 meters from the current trough, and (3) Flood Plain, aligned with the main channel being 1-3 meters above the current river channel. The sedimentary record of these deposits contains essential information to the geomorphological-stratigraphic interpretation of fluvial dynamics.

### Evolutionary analysis of a slope at the right margin of Mogi Guaçu river in Conchal ' SP

NASCIMENTO D., PEREZ FILHO A.  
UNICAMP, CAMPINAS, BRAZIL

The present work is an evolutionary analysis of a slope at the right margin of Mogi Guaçu river in Conchal – SP, emphasizing the spatial organization of vegetation and its relation to the distribution of soil classes along the slope. Based on the systemic approach, the importance of climate oscillations from the late Pleistocene is emphasized in relief modeled and consequently in the spatial distribution of vegetation cover.

The evidences of morphoclimatic cycles corresponding to glacial and interglacial phases materialized in the landscape according to Bigarella & Mousinho (1965) not only respond by changing the vegetation cover, but also by changing the various processes active in relief sculpture.

Absolute dating by Optically Stimulated Luminescence method (OSL) of superficial formations will allow evaluating the temporal relationships between vegetation and the respective slope segments. The method has proved to be very effective in the dating of events during the Quaternary, with time span of 100 years before present up to 1 million years, and as Corrêa (2002) highlights the advantage of OSL dating is the exploration of a physical property of crystalline solids, unlike the C14 dating, which gives greater reliability of the results obtained.

Samples were collected at a depth of 80 cm to 100 cm in different units of the slope with varied vegetation and soil types. The datings of parent material of the soils have pointed to  $9500 \pm 1130$  years to the top of the slope,  $3,650 \pm 330$  years in colluvium,  $1900 \pm 225$  and  $1150 \pm 160$  for terraces T1 and TII terraces respectively (STORANI, 2010), therefore allowing to infer ages for vegetation established in the different units of the slope and soil types.

Based on the identification of slope units associated with the types of soil and through the OSL dating is possible to verify that *cerrado* vegetation located at the top of the slope, aged approximately 12,000 years, corresponds to the Upper Pleistocene.

\*\*\*\*\*

### The Monte Netto (Northern Italy) loess-paleosol sequence: implication for the Upper Pleistocene geomorphologic and palaeoenvironmental evolution of the central Po Plain

ZERBONI A.(1), TROMBINO L.(1), LIVIO F.(2), BERLUSCONI A.(2), MICHETTI A.M.(2), SPÖTL C.(3), RODNIGHT H.(3)

(1) Dipartimento di Scienze della Terra "A. Desio", Università degli Studi di Milano, MILANO, ITALY ; (2) Dipartimento di Scienze Chimiche e Ambientali, Università dell'Insubria, COMO, ITALY ; (3) Institut für Geologie und Paläontologie, Universität Innsbruck, INNSBRUCK, AUSTRIA

The isolated topographic hills located in the central Po Plain (Northern Italy) represent the top of Quaternary growing anticlines; the pedosedimentary sequences at Castenedolo and Ciliverghe are key archives for the palaeoenvironment of the area. A new loess-paleosol sequence, resting upon fluvio-glacial deposits, is exposed in a clay pit on the top of the Monte Netto, a large flat hill consisting of Late Quaternary deposits. At the top of the hill two secondary anticlines, tens of metres in size and deforming the strata were recognized. The lower part of the sequence (fluvioglacial gravel to silt, weathered at its top) is overlain by a complex cover of loess, consisting at least of three distinct layers intercalated with pedogenic horizons, showing different degrees of weathering. The most weathered horizon is located on the top of the anticlines representing the core of the hill; it testifies a strongly rubified paleosol, developed on loess after a long cycle of pedogenesis. This is overlain by several thin paleosols developed on loess and showing a decreasing degree of weathering towards the top of the sequences. OSL and <sup>14</sup>C-AMS dates indicate an Upper Pleistocene to Holocene age of the upper part of the sequence, while geoarchaeological evidence suggests a possible Mid-Pleistocene age for the deepest paleosol. The upper pedosediments are disturbed by a gravity graben, due to co-seismic bending-moment faults, and are characterised by several sub-vertical parallel fissures, regarded as secondary brittle deformation successively affected by illuvial clay infilling. Deformation features are evidence of repeated Upper Pleistocene to Holocene earthquake surface faulting, consistent with the moderate seismic activity of the area. The sedimentation and weathering of the following loess-paleosol horizons was promoted by the continuous evolution of the gravity graben, underscoring a strong tectonic control on the stratigraphic and morphological development of the hill.

### **Analysis of long term anemometric data relating to coastal stations of Calabria**

CALISE G.(1), BELLOTTI P.(1), DAVOLI L.(1), PELINO V.(2)

(1) Department of Earth Science - Sapienza University of Rome, ROMA, ITALY ; (2) C.N.M.C.A. Italian Air Force, ROMA, ITALY

The aim of this work is the analysis of anemometric data recorded by weather stations along the Calabrian coast for a period ranging from 1951 to 2010. The data were supplied by the Italian Air Force for a total amount of 536,006 data recorded. Four stations, near the coastline, were selected because have worked longer; three stations located along the Tyrrhenian side (Capo Palinuro, in the southern Campania region, Bonifati and Lamezia Terme in Calabria) and one on the Ionian coast (Crotone in Calabrian region).

The data were organized in decades, as well as in seasonal and annual groups. Subsequently, through the use of the programming language Matlab, they were plotted as frequency histograms of classes Beaufort and circular diagrams for the direction, intensity (in knots) and frequency of the wind. The use the Beaufort scale provides simple use of these data for an application to the study of wave climate.

The final analysis showed a significant increase in wind frequency in the last two decades. For the Tyrrhenian coast this increase started in 1987 and was recorded by all the three Tyrrhenian stations. For the Ionian side the increase of the wind frequency started in 1995. In both areas the situation is not further changed. The annual plots have shown also some exceptional years for the direction, intensity and frequency of the wind, different for the various stations.

\*\*\*\*\*

### **Timing of deglaciation on the Southern Swiss Alps**

SCAPOZZA C.(1), AMBROSI C.(1), CASTELLETTI C.(1), SOMA L.(1), DALL'AGNOLO S.(2)

(1) Institute of Earth Sciences, University of Applied Sciences and Arts of Southern Switzerland (SUPSI), CANOBBIO, SWITZERLAND ; (2) Swiss Geological Survey, Federal Office of Topography swisstopo, WABERN, SWITZERLAND

The detailed Quaternary geological mapping of Southern Switzerland (Mendrisiotto and neighbouring regions in Italy) and the compilation of several radiocarbon dating data allow the reconstruction of the geometry and chronology of the Last Glacial Maximum (LGM) in the Southern Swiss Alps (Episodio Cantù). Moreover, they allow obtaining a detailed chronostratigraphy of the main recessional stadials during the Lateglacial and the beginning of the Holocene. The defined glacial stadials were correlated with the Greenland isotopic record of the borehole NGRIP.

For the LGM and the Pleniglacial, data are not exclusively from the Ticino glacier (Verbano lobe and a part of the Ceresio lobe), but also from the Adda glacier, which came from Valtellina (Lombardy, Italy) and occupied the Mendrisiotto by the Lario and Ceresio lobes. The analysis of calibrated maximal and minimal ages of the LGM allow proposing an age of the Episodio Cantù comprised between ca. 25'500 and 18'000 <sup>14</sup>C BP (≈ 30'200–21'250 cal BP). The Episodio Cantù was then correlated with the Greenland stadial GS-3, comprised between 27'400 and 22'700 cal BP.

For the Pleniglacial and the transition Pleniglacial/Lateglacial, the first recessional phases after the LGM were placed between ca. 22'500 and 21'000 cal BP, and correspond probably with the two first cold events of the Greenland stadial GS-2c. The first Lateglacial stadial was the Melide phase, and may match with one of the two cold events of 20'450 and 19'850 cal BP. Then, five glacial stadials were highlighted for the Oldest Dryas (Biasca, Faido, Airolo, Fontana and All'Acqua), two for the Younger Dryas (Maniò and Alpe di Cruina) and one (Val Corno) in correspondence with the Greenland Holocene event GH-11.2. Thanks to the correlation with the Greenland isotopic record, it was also possible to propose a relationship between the stadials defined in the Southern Swiss Alps and the "classical" glacial stadials defined in the Eastern Alps.

### **Quantitative geomorphological analysis of drumlins in four Ontario, Canada drumlin fields**

JOHN M. EYLES C.

*McMaster University, HAMILTON, CANADA*

Drumlins are enigmatic subglacial landforms that have been interpreted to form by a number of processes including incremental accumulation of till, erosion of previously deposited sediment, catastrophic meltwater floods, and sediment deformation. However, relatively little is known about the controls on drumlin formation, such as spatially variable glacial processes or substrate characteristics, and how these controls may be identified from variations in drumlin morphology within a single drumlin field. This paper explores a computational method that allows identification of drumlins and extraction of their morphological characteristics from existing topographic digital data for four drumlin fields across southern Ontario, Canada all created from various ice advances. Spatial and non-spatial analysis of the form and distribution of drumlins across the study area identifies drumlin characteristics such as size, elongation ratio, symmetry and long axis orientation and shows that drumlins are not randomly distributed across the region and their form characteristics have distinct regional trends. Kernel density analysis is used to identify the regional trends in drumlin characteristics and illustrates a trend toward grouping of drumlins with similar morphological attributes within a single field. Factors that appear to influence the form and distribution of drumlins in the study area include sediment thickness, length of time beneath the ice, bedrock topography, ice velocity and direction of ice movement. Exploration of landform symmetry includes identification of a distribution of particularly well-developed asymmetric and elongate drumlins coincides with the location of a broad bedrock low and is interpreted to identify the former location of a fast-flowing ice stream.

\*\*\*\*\*

### **Phytolith and isotopic studies applied to geomorphologic analysis in the Southern Espinhaço Mountain Range, Brazil**

COE H.

*UERJ, SAO GONÇALO, BRAZIL*

Phytoliths are particles of silica formed as a result of absorption of silicic acid in the soil solution by plant roots and then precipitate in plant cells. They enable paleoenvironmental reconstruction, indicating climate change and its effects on vegetation, offering clues about factors that may influence geomorphologic processes. Phytoliths analysis complemented by carbon isotopes in samples of two sandy soil profiles located in a slightly inclined slope in the Southern Espinhaço Mountain Range, Minas Gerais, Brazil, allowed to identify variations in environments where geomorphic processes occurred. In both profiles, phytoliths are very weathered. This makes identification of the types and calculation of phytolith indexes difficult, but highlights the intensity of erosion in the area. The results also show the dominance of big phytoliths, because they are more resistant to erosion, and low proportions of short cells phytoliths, more fragile ones. Organic carbon stocks are higher in P2 than in P1, due to the presence of an organic horizon, formed because of better conditions of accumulation and decomposition of organic matter. It does not occur in P1, where the runoff until nowadays is more effective due to the proximity of the outcrop and to the low presence of lower strata of vegetation cover. These factors accounts as well for the larger diameter of the gravels in P1, giving evidences of a more effective action of mechanical weathering near the outcrop. The stock of phytoliths of P1 follows a normal trend of decrease with depth, while P2 presents a very large increase in the organic horizon. In these profiles, the lithologic basement formed by quartzite rocks is the same, but the processes of accumulation seems to have occurred in different ways, alternating drier and more humid conditions than that of nowadays. Furthermore, the high degree of alteration of phytoliths seems to indicate high intensity of physical erosion and also gechemical loss in this area.

### **Glacial flows and deglaciation stages during the Late Wisconsinan in the Gaspé area, Québec (Canada)**

HOUDE-POIRIER M., HÉTU B., BERNATCHEZ P.

*Département de biologie, chimie et géographie, Centre d'Études Nordiques et Research Chair in Coastal Geoscience, Université du Québec à Rimouski, RIMOUSKI (QUÉBEC), CANADA*

The Late Wisconsinan glaciation model in the Gulf of St. Lawrence involves the coexistence of Laurentide Ice sheet and regional ice centers in Maritime Canada. Gaspé area, at the extreme east of Gaspé Peninsula, was at the confluence of three of these ice masses: 1) the Gaspé ice cap, centered on McGerrigle Mountains, extending east to the Gaspé Bay; 2) the Laurentide Ice Sheet, deviated into the Laurentian Channel, passing through the north of the Gaspé peninsula; and 3) the Escuminac ice cap, located in the Gulf of St. Lawrence, north of Prince Edward Island. Ice flow indicators, geochemical analysis, petrographic and stratigraphic data collected in the Gaspé area were used to specify boundaries and ice flows chronology of these three ice masses. Combined to new AMS dates, the analyses attest their coalescence at the east of Gaspé Peninsula before 15.5 to 14.8 kyr cal. BP, when deglaciation started in the area. Glacier retreat occurred until 13.9 to 13.7 kyr cal. BP, and was followed by a marine transgression which reached its maximum elevation at 32 m. This high stand was followed by a rapid land emergence and seismic data indicate a low stand at 30 m below present sea-level, followed by a long period of submergence.

\*\*\*\*\*

### **Palaeoflood history recorded by the slackwater deposits of the Dong River, Korea**

KIM S., TANAKA Y.

*Kyung Hee Univ., SEOUL, SOUTH KOREA*

Slackwater deposits are the flood sediments of river and the palaeostage indicator. These deposits have been used in many studies to estimate the magnitude and frequency of discrete flood events. Study area is located along the Dong-river in Gangwon province, the east of Seoul. Caves are formed along the both the Dong-river banks. Sites 1 and 2 are small cave that were located the cut bank of river. Site 3 is located in the margin of slip-off slope, and site 4 is located in the tributary mouth. Based on faces and colors, the sample of slackwater deposits in each site was classified. Grain-size of each special layer in sites was analyzed by using grain-analyzer. These results of slackwater deposits suggest that grain size (median,  $\phi$ ) of each layer changes according to flood events. For instance, the coarser layers indicate the occurrence of large magnitude flood events. The slackwater deposits in this area are generally covered with sand layer associating with great flood event occurred by Typhoon Lusa of 2002. The age of slackwater deposits under Lusa deposits may be estimated more exactly based on relative age methods through the trash and the data of river water level and absolute age methods through the radioisotope  $^{137}\text{Cs}$  and  $^{14}\text{C}$ . Flood slackwater sediments indicate peak stage from which the discharge of a flood can be calculated using hydraulic reconstruction methods and the Manning equation. It is able to estimate the frequency and magnitude of palaeoflood using these results such as grain-size analysis, stratigraphical description and several dating methods.

**Slackwater deposits indicating paleoflood of Kherlen river, Mongolia**TANAKA Y.(1), KIM S.H.(1), KASHIMA K.(2)

(1) Kyung Hee University, SEOUL, SOUTH KOREA ; (2) Kyushu University, FUKUOKA, JAPAN

Kherlen river flows through eastern Mongolia and enters into Hulun lake and upstream of Amur (Heilongjiang) river. Sampling site 1 is located at tributary mouth along the Kherlen river. Backflooding sediment with its depth of more than 2 m occurred at sampling site 1. Sampling sites 2 and 3 are located in the margin of slip-off slopes along the Kherlen river. Based on characteristics of sediment such as faces and colors, the sample of slackwater deposits in each site was classified. Grain-size of each special layer in the sites was analyzed by using grain size analyzer. The <sup>14</sup>C age of 175 cm depth layer was 1580±20yrBP. Coarser layers indicate the occurrence of large magnitude flood events, thus, grain size (median, Ø) of each layer changes largely associating with flood events. Based on the result of grain size analysis for site 1 sample, at least 6 times large changes occurred since 1580±20yrBP. This means that large magnitude floods occurred with the intervals of about 250 yr.

\*\*\*\*\*

**Interaction between geochemical processes texture and PH in the podzolization of arenosols in the Espinhaço Mountain Range - Brazil**ROCHA L.(1), AUGUSTIN C.(2), FIGUEIREDO M.(3)

(1) Universidade Federal de Minas Gerais, SÃO JOÃO DEL-REI, BRAZIL ; (2) UNIVERSIDADE FEDERAL DE MINAS GERAIS, BELO HORIZONTE, BRAZIL ; (3) UNIVERSIDADE FEDERAL DE SÃO JOÃO del REI, SÃO JOÃO DEL REI, BRAZIL

This study aims to understand how geochemical processes, texture and pH influence the podzolization of sandy soils in Southern Espinhaço Range (SdEM) in the state of Minas Gerais, Brazil. This rocky mountain massif is characterized by the dominance of quartzite outcrops, with varying degrees of quartz composition. These outcrops are intercalated by relatively flat depressions whose size ranges from tens of meters to kilometers forming a quite distinct geomorphologic unit. These surfaces are covered by sandy material with depths ranging from 0.5 to 1.0m almost always articulated to a very shallow superficial flow of water. We sampled three soil and rock profiles that were submitted to physical and chemical analyses. Results indicate the occurrence of soils formed of material resulting from prolonged weathering processes with silica contents ranging from 92 to 96, aluminum from 2.6 to 5.11 and iron from 0.2 to 2.9 ppm. However, soils are apparently young, poor in clay, shallow, but presenting differentiation of horizons and accumulation of organic matter in the lower horizons suggesting podzolization. Results also indicate that the soil sandy texture that results from the original rocks which is low in clay content (psammitic rocks) promotes translocation of chemical elements and organic matter. This factor, coupled with the occurrence of a permanent humid environment due to the existence of small and slow concentrated and disperse flows, favors the action of the translocation process promoting the formation of spodosols and a generalized loss of much of all chemical elements measured including the most stable. The mass balance analysis indicates a loss of 20 to 57% of silica, 33 to 41% of aluminum and 7 to 17% of iron. These data suggest that the materials which form the depressions in the domain of the outcrops of quartzite rocks of Espinhaço Supergroup in the Southern Espinhaço Mountain Range have undergone a significant depletion of geochemical elements.

**Exogenous processes and soil formation during MIS 2 and MIS 3 on geoarchaeological sites in the Angara region and Cisbaikalia**

KOBYLKIN D., RYZHOV Y.V.

*Institute of geography of the SB RAS, IRKUTSK, RUSSIAN FEDERATION*

Exogenous processes and soil formation during MIS 2 and MIS 3 on geoarchaeological sites in the Angara region and Cisbaikalia

MIS 3 encompasses the time period from 24 to 57–58 kya and is characterized by interstadial warmings and stadial coolings. An early warming period of MIS 3 showed a stage of incision in river valleys and erosional forms. Subsequently, there was taking place largely the peneplanation of topographic features caused by the removal of deposits from divides and down the slopes to river valleys. Significant climatic fluctuations during that time interval are embodied in spores-pollen spectra of deposits, and in buried soil horizons.

The buried soils on geoarchaeological sites in the Angara region and Cisbaikalia were forming during the time intervals 24–30 <sup>14</sup>C, 33–37 <sup>14</sup>C and 44–46 <sup>14</sup>C kya. The activity of the slope processes during those time spans decreased by a factor of 2 to 5. The interstadials were exemplified by a decrease of the rates of exogenous processes, and the catchments developed interlayers and horizons of buried soils. The stadials were accompanied by an intensification of erosion-accumulation and cryogenic processes.

Over the course of MIS 2 (11.7–24 <sup>14</sup>C kya), defluxion processes dominated the cryohumid phase, while aeolian-deluvian and aeolian processes were dominant in cryoarid phase. During MIS 2, The soils that had formed in MIS 3 experienced active cryogenic deformations (cryoturbations). Loess-like carbonaceous loamy sands and loams were forming. Negative landforms were actively filled with eroded material. The end of MIS 2 (11–14 <sup>14</sup>C kya) showed a stage of incision in river valleys and erosional forms to a depth of 1–10 m, and an intensification of the soil formation process.

\*\*\*\*\*

**Information decoded from the Late Holocene sedimentary records in the Outer Western Carpathians, Czech Republic**

SMOLKOVA V., PANEK T., HRADECKY J.

*Department of Physical Geography and Geoecology, Faculty of Science, University of Ostrava, OSTRAVA, CZECH REPUBLIC*

Due to the lack of other suitable data in the mid-mountain region of the Outer Western Carpathians, the landslide-related deposits (landslide-dammed palaeolakes, intercolluvial and near-scarp peat bogs) are the key sources of the Late Holocene landscape development. Using standard sedimentological analyses combined with absolute dating, we studied tens of sedimentary cores and outcrops in the study area. The most important information we got about the Late Holocene environment is the evidence about local onset and character of human activity in the study area. We dated minerogenic peat bog deposits revealing accelerated sedimentation, starting in c. the 16–17th centuries and connected with the one of the latest European colonization of nearly pristine mountainous landscape. The Wallachian colonization of the Western Carpathians centuries caused major change of the ecology of mountain ridges and subsequent increased erosion of deforested and grazed slopes. Next important information, which we were able to trace by the sediments from the landslide-dammed reservoirs, is the frequent recurrence of the slope movement activity. Absolute dating of the events correlates with regional phases of increased climate humidity. Taking into account the mapped morphological evidence and recent catastrophic failures with preceding Holocene activity we assume, that majority of slope deformations in the study area are of a recurrent character. As on an average 10 % of the study area was previously believed to be fossil slope deformations, today we can consider them as potentially active, which is important for evaluation of landslide hazards in the study area.

### Late pleistocene and holocene morphostratigraphic and allostratigraphic records in southeastern Brazil

MELLO C., PEIXOTO M.N.O., MOURA J.R.S.  
UNIVERSIDADE FEDERAL DO RIO DE JANEIRO, RIO DE JANEIRO, BRAZIL

Geomorphologic and stratigraphic studies of Quaternary colluvial and alluvial deposits have been developed during last 30 years in the Southeastern Brazilian hilly domains. Based on identification of depositional surfaces and main stratigraphic discontinuities, these studies allowed the distinction of late Pleistocene and Holocene record in morphostratigraphic and allostratigraphic units. Radiocarbon and luminescence dates are available for a chronostratigraphic order. Three main morphostratigraphic/allostratigraphic intervals were recognized, dated on late Pleistocene, early to middle Holocene, and modern times. Late Pleistocene colluvial and alluvial deposits are associated with discontinuous fluvial terrace that seems smooth low hills. These deposits are younger than 100,000 years BP and their upper limit is marked by a paleohorizon A dated on approximately 10,000 years BP. Pedostratigraphic and palinologic analysis suggest a sparse forest cover at the Pleistocene-Holocene boundary, under humid climatic conditions. A remarkable erosive episode occurred in early to middle Holocene and was responsible for a great sediment production and widespread valley filling up. This event suggests high intensity and concentrated rainfall over a landscape with sparse vegetation cover. Several geomorphologic and structural data document a very important influence of neotectonic mechanisms at this time. The early to middle Holocene record is associated with well preserved fluvial terraces. Modern colluvial and alluvial deposits are respectively associated with lower hillslope domain and lower fluvial terrace/floodplain. Modern colluvial deposits are dated on 150 years BP and related to human occupation of the studied area. The younger episode of fluvial sedimentation have started around 1,000 years BP and was intensified around 250 years BP. Thus, modern colluvial deposits and the upper interval of modern alluvial deposits document human influence on regional geomorphic record.

\*\*\*\*\*

### Sea urchin burrows in Rocky Shores as indicator of Holocene Sea-Levels at the Northern Coast of the State of São Paulo, Brazil

VILANO W.F.(1), SOUZA C.R.G.(2), CANTARELI C.V.C.(3), SILVA W.W.D.B.(4)  
(1) Universidade de São Paulo-USP, SÃO PAULO, BRAZIL ; (2) Instituto Geológico-SMA, SÃO PAULO, BRAZIL ; (3) Instituto CAÁ-OBV, SANTOS, BRAZIL ; (4) Universidade Santa Cecília, SANTOS, BRAZIL

Worldwide rocky shores are considered important testimonies of the Quaternary changes in sea level. The Holocene sea-level curve for the State of São Paulo indicates that: it was close to the current ca. 7000 yr BP; the maximum of the Holocene transgression occurred around 5100 yr BP (5600 cal yr BP) and reached ca. 4±0.5m; after that there is a recent debate on whether sea-level fell to the current position steadily, or whether there were oscillations and negative levels. For the Ubatuba County (Northern Littoral of the State of São Paulo, Brazil) some authors suggested a steady sea-level falling towards the current position after 3800 yr BP (few dated samples), but others pointed a negative sea-level after 2000 cal yr BP. This paper presents a study carried out on rocky shores at Ubatuba County, where three bands within palaeo-burrows of sea urchins, located above their present living level, seem to indicate three distinct steady phases of positive sea-level stabilization, probably intercalated by negative sea-level periods. Bands have around 1.10-1.20 m in width, and are separated by narrow (0.20-0.25 m in width) strips free from burrows; burrows diameter varies from 6 cm up to 16 cm (strongly weathered). It has been verified that the higher limit of the living sea urchins (*Equinometra lucunter*) coincides to the current ordinary spring low-tide level (OSL= -0,10-0,00 m), being the present mean sea-level around +0.66 m (Ubatuba's tide gauge). Based on these data we concluded that: the higher limit of the superior and older band positioned ca. 3.82 m above the OSL would indicate a maximum Holocene paleo-sea-level around 4.48-4.58 m above the present level; the 2.70 m above OSL for the intermediate band top would mean a positive paleo-sea-level around 3.36-3.46 m; and the inferior and younger band top at 1.40 m above OSL would suggest a sea-level ca. 2.06-2.16 m above the present.

**Fluctuations of Lake Lisan level during Marine Isotope Stage 2: implications for palaeoclimatic changes of the Jordan Valley**

ABU GHAZLEH S.(1), KEMPE S.(2)

(1) *University, Department of Geography and Urban Planning United Arab Emirates, ABU DHABI, UNITED ARAB EMIRATES*; (2) *University of Darmstadt, DARMSTADT, GERMANY*

Lake Lisan was one of several lakes that occupied the Jordan Valley during the Last Glacial (70-14 ka BP\*). It extended for ~ 300 km from Lake Tiberias in the north to > 60 km south of the current Dead Sea (DS). On the eastern coast of the DS rift, high-level terraces of Lake Lisan were identified and surveyed for the first time using DGPS. U/Th dating and geochemical analysis of the terrace stromatolites allowed resolving the lake level curve at a high resolution during MIS 2 (32-19 ka BP).

Terrace levels range between -130 m and -160 m, implying that the highest stand of Lake Lisan was at least 50 m higher than the previously reported. Comparison of several terrace profiles and correlation of their altitudes show no evidences of tectonic subsidence, demonstrating that the lake level drop was entirely climatic.

U/Th dating of stromatolites shows that Lake Lisan receded from its initial high level of -137 m at  $31.99 \pm 0.21$  ka BP to -148 m at  $30.55 \pm 0.22$  ka BP, consistent with the Heinrich event 3 and Dansgaard Oeschger Stadial 5, the coldest period in the North Greenland Ice Core record (NGRIP). Then, the lake dropped to -152 m at  $27.38 \pm 0.16$  ka BP. The Lake continued to drop to -154 m at 23 ka BP and to -200 m at 22 ka BP, corresponding with Heinrich event 2 and the cold stadial 2C, the final phase of the Last Glacial Maximum (LGM).

By the End of the LGM (~19 ka BP), Lake Lisan recovered again to a high level of -160 m followed by a regression to -200 m during Younger Dryas at ~ 11 ka BP.

Superimposing our dates on the NGRIP curve shows that several drops of Lake Lisan occurred during the cold stadials and Heinrich events 3 and 2. This suggests cold and dry climatic conditions of the Jordan Valley during the N-Hemispheric cold periods.

\*\*\*\*\*

**S10A. FLAG, GLOCOPH and PAGES-LUCIFS**

*Convenors: Gerardo BENITO, David BRIDGLAND,  
Stéphane CORDIER & Thomas HOFFMANN*





## **Oral presentations:**

### **Pliouaternary morphosedimentary evolution of the Allier valley (Massif Central, France). New contribution of K-Ar and $^{40}\text{Ar}/^{39}\text{Ar}$ datings**

*PASTRE J.F.(1), GUILLOU H.(2), NOMADE S.(2), DEGEAI J.P.(1)*  
 (1) UMR 8591 LGP CNRS, MEUDON, FRANCE ; (2) LSCE, CEA, GIF-SUR-YVETTE, FRANCE

The Allier valley offers one of the longest fluvial record in Europe. From ca. 4 to 0.01 Ma numerous alluvial deposits follow the morphosedimentary evolution. Surrounding volcanism provides an unique chronological framework. New K-Ar datings on Devès basalts allow to precise the stage of evolution of the upper Allier valley during early and middle Pleistocene. New  $^{40}\text{Ar}/^{39}\text{Ar}$  datings on the tephras of the Mont-Dore/Sancy strato-volcano upgrade the tephrochronological framework.

The three main areas followed by the Allier show very different morphosedimentary records.

- The upper Allier, incised in basement, was strongly affected by the basaltic volcanism of the Devès. At the end of the Pliocene, before the first lava flows ca. 3 Ma, its middle part was incised at a level close to the present one. The new K-Ar datings confirm the existence of two major volcanic episodes centered around 2 and 0.8 Ma. The slow evolution of the valley during all the Pleistocene can be attributed to interactions between volcanism, subsidence and cold climatic phases.

- The middle Allier valley in the Oligocene Limagne graben presents a long stepped record covering 200 m of incision since 4 Ma. The key-sequence of Perrier shows several alluvial stages dated by  $^{40}\text{Ar}/^{39}\text{Ar}$  on Mont-Dore pumices between  $3.09 \pm 0.01$  and  $2.58 \pm 0.01$  Ma.

During lower Pleistocene incision predominates and only few terraces are observed. The climatic terraces system of the Grande Limagne begins after 1 Ma and shows several correlations with the Sancy tephras until 0.3 Ma. This evolution is mainly driven by an uplift of the area.

- The lower Allier valley evolution in the Bourbonnais is strongly different. A long multiphased aggradation takes place during the Pliocene – early lower Pleistocene. Four main phases can be recognized by their mineralogical content. The Pleistocene is mainly marked by a slow incision in regard with the low subsidence and/or stability of the area.

\*\*\*\*\*

### **Links between geomorphology and Quaternary geology: evidence from fluvial archives**

*BRIDGLAND D.*  
 Durham University, DURHAM, UNITED KINGDOM

It should come as no surprise that there are clear linkages between geomorphology and Quaternary fluvial archives. The lynch pin for such linkage is the river terrace 'staircase', which, provided some form of age constraints are available, can allow progressive of valley incision to be dated, thereby enhancing understanding of landscape evolution. By these means erosional geomorphological features can also be constrained chronologically. Contrasting case-study examples will be presented, showing particularly important differences from inside and outside of Last Glacial ice limits.

### **Incision/aggradation events in river valleys of the Central Russian Plain in the Valdaian (Weichselian) ' Holocene climatic cycle**

PANIN A.(1), ADAMIEC G.(2), BUYLAERT J.P.(3), MATLAKHOVA E.(1), MURRAY A.(3)

*(1) Geography Faculty, Moscow State University, MOSCOW, RUSSIAN FEDERATION ; (2) Silesian University of Technology, Institute of Physics, GLIWICE, POLAND ; (3) The Nordic Laboratory for Luminescence Dating, Aarhus University, ROSKILDE, DENMARK*

Series of >70 radiocarbon and OSL dates on terrace and floodplain sediments of the Seim and Khoper Rivers supplemented with archaeological data on Late Paleolithic settlements located within the range of recent floods were used to establish chronology and magnitude of river downcutting and aggradation stages:

(1) >77 – <50 ka: river aggradation, accumulation of 12-16-m Terrace 1 (T1) alluvium.

(2) <50 – >27 ka BP: river incision by >10 m, formation of alluvial basement of so called intermediate, or “zero” 5-7-m terrace (T0). Incision was most probably caused by considerable increase of water discharges, which is evident from widening of valley floor due to active channel migrations.

(3) >27 – ~17-18 ka BP: low runoff, river stability/aggradation, wide occurrence of aeolian sands interplaying with deluvial loams (climate aridity, scarce vegetation). Stationary human settlements existed on the T0 terrace, i.e. at low topographic positions which are subject to seasonal flooding now.

(4) ~17-18 – ~ 12-13 ka BP: river incision 5-7 m below the present-day channel, formation of large meanders with high wavelength. Seasonal inundation of the T0 terrace resumed, which broke terrace occupation by humans and provided overlaying of cultural layers by overbank alluvium.

(5) ~12-13 – ~10 ka BP: river aggradation to the present-day levels as response to runoff decrease.

(6) >10 ka BP – present: relative stability (no incision, no aggradation).

Comparison with climate change shows that major erosion/sedimentation events occurred within the cold part of the last glacial/interglacial cycle, for which general correspondence of major temperature and runoff changes may be deduced: considerable runoff increase and corresponding river incision occurred within the relatively warm phases – late MIS 3, the Late Glacial time, while the coldest climatic phase (LGM) was characterized by lowest runoff and accretion of valley floor.

\*\*\*\*\*

### **Unraveling the Quaternary river incision in the Moselle and the Sarre valleys (Rhenish Massif, Germany): insights from cosmogenic nuclide dating (<sup>10</sup>Be/<sup>26</sup>Al) of fluvial terraces**

CORDIER S.(1), RIXHON G.(2), HARMAND D.(3), BRÜCKNER H.(2), KELTERBAUM D.(2), DUNAI T.(4), BINNIE S.(4)

*(1) Universit\_ Paris Est Cr\_teil, CRETEIL, FRANCE ; (2) Institute of Geography, University of Cologne, COLOGNE, GERMANY ; (3) Université de Lorraine, NANCY, FRANCE ; (4) Institute of Geology, University of Cologne, COLOGNE, GERMANY*

During the last decade, the fluvial terraces of the Moselle River and its main tributary the Sarre have been largely investigated. The multi-proxy research made it possible to provide an initial reconstruction of the Middle and Upper Pleistocene valley evolution. In particular, eight “middle and lower” terraces have been recognized at less than 100 m relative height. These terraces were able to be correlated from the Vosges Massif to the Rhenish Massif on the basis of sedimentological evidences and, for the younger terraces, of OSL dating.

Located at higher elevations on the valley sides of the Rhenish Massif, the well-preserved “main terraces” are characterized by a constant absolute elevation in the 150 km-long reach between the Lower Sarre/Trier area and Cochem. While several hypotheses have been proposed to explain this horizontality (updoming, faulting...) all studies assumed an age of ca.800 ka for the younger main terrace, but without reliable chronological evidence.

Recent results obtained for the Meuse River and two of its main tributaries in the western Rhenish Massif demonstrated, on the basis of cosmogenic nuclide dating, that (i) the main terraces were younger than expected and (ii) their formation was diachronic. These results are consistent with the reconstruction proposed for the middle and lower terraces of the Moselle and the Sarre. Following on from this, cosmogenic nuclide dating was applied to the fluvial sediments of the Moselle and Sarre terraces, in order to provide a chronological framework for the main terrace complex and the older middle terraces. Two distinct sampling approaches were carried out: (i) a depth profile provided that the terrace (palaeo-)surface was well-preserved and (ii) an isochron technique where the sediments were thick enough. This presentation aims to expose the preliminary results and their significance to improve the knowledge of the Moselle and Sarre Pleistocene evolution.

### **Sediment storage and evacuation episodes during the Late Quaternary in the intermontane basin of Dehradun, NW India**

SINHA S.(1), DENSMORE A.L.(2), SINHA R.(1)

(1) *Indian Institute of Technology Kanpur, KANPUR, INDIA* ; (2) *University of Durham, DURHAM, UNITED KINGDOM*

The intermontane basin in Dehradun region in NW India is bounded by the Ganga to the east and Yamuna to the west and is believed to have started to develop ~700 ka ago in response to the development of the Mohand anticline. The widespread trapping of sediments in the Dun has been mainly caused by growth and lateral propagation of the Himalayan frontal fault system and the Mohand anticline. This paper presents a GIS based approach for quantitative estimates of sediment volume accumulated and evacuated in the Dehradun intermontane basin during the deposition and incision phases respectively. Our study focuses on three major geomorphic surfaces namely, (1) proximal fan, (2) isolated hills (3) distal fan. The proximal fan has been interpreted as the oldest fan surface (41-30 ka) followed by isolated hills (23-14 ka) and distal fan surface (17-10 ka). The hypothetical surfaces representing the total volume accumulated in the area over a 50 ka time period were extracted using ASTER DEM with 30 m horizontal and 10 to 25 m vertical resolution. The total volume of sediments accumulated within the fan surfaces since ~50 ka works out to be  $1.22-0.81 \times 10^{11} \text{ m}^3$  and that eroded from the surfaces within the time span of 50 ka is estimated to be  $6.4-4.7 \times 10^9 \text{ m}^3$  and the average removal rate is computed to be  $5.3-3.9 \times 10^5 \text{ m}^3/\text{yr}$ . Comparing this with the modern sediment load of the Yamuna River, this is equivalent to ~2-3 % of total annual sediment load of Yamuna River. A first order estimate of the capacity of the Dehradun valley is  $2.72 \times 10^{11} \text{ m}^3$  and this suggests that the valley is only half-filled and can accommodate more sediments. We conclude that variations in storage or excavation on short time scales (50-100 ka to present) are mostly controlled by sediment supply from the catchments and climate-modulated changes and that the duns have acted as 'filters' for modulating the sediment supply into the plains.

\*\*\*\*\*

### **River system response to Pleistocene glaciation within a Mediterranean landsystem**

ADAMSON K.(1), WOODWARD J.(2), HUGHES P.(2)

(1) *Queen Mary, University of London, LONDON, UNITED KINGDOM* ; (2) *The University of Manchester, MANCHESTER, UNITED KINGDOM*

The fluvial morphosedimentary records of Mount Orjen, western Montenegro have been used to investigate the response of Mediterranean river basins to Pleistocene glaciation. A range of meltwater pathways and depositional contexts at 12 sites have been analysed. These include terraced alluvial valley fills, poljes and alluvial fans, which are broadly representative of glaciated river basins across the Mediterranean. The nature and timing of fluvial activity has been determined using detailed sedimentological and stratigraphical analysis, 35 U-series dates, calcite micromorphology, and soil profile analysis. This study is one of the first attempts to directly correlate Pleistocene glacial and fluvial records within the context of a single landsystem.

The fluvial record is in good agreement with the Pleistocene glacial history of Mount Orjen. The most extensive phase of alluviation is correlated to MIS 12-8 (Kotorska-Sušica Member) when the large depocentres beyond the maximum ice margins became infilled. There is only limited evidence of fluvial activity during MIS 6 (Krivošije Member) despite extensive glaciation at this time. Fluvial morphosedimentary records from MIS 5d-2 have not yet been observed in the study area. Since MIS 12, meltwater and sediment supply to the fluvial system has declined in accord with the decreasing magnitude of glaciation. Subterranean karst flows have increasingly dominated over surface flows and the Pleistocene glacial and surface fluvial systems have become progressively decoupled. Importantly, neighbouring basins surrounding Mount Orjen often contain contrasting records of Pleistocene river dynamics and/or preservation of the fluvial archive. These findings have important implications for our understanding of Pleistocene river system dynamics within glaciated catchments in the Mediterranean and elsewhere.

## Alluvial megafans along the Italian Southern Alps

MOZZI P.(1), FONTANA A.(2), MARCHETTI M.(3)

(1) Dipartimento di Geoscienze - Università di Padova, PADOVA, ITALY ; (2) Dipartimento di Geoscienze - Università di Padova, PADOVA, ITALY ; (3) Dipartimento di Scienze della Terra - Università di Modena e Reggio Emilia, MODENA, ITALY

Large fan-shaped landforms represent most of the northern Po Plain (40,000 km<sup>2</sup>) and its eastern continuation, the Venetian-Friulian Plain (10,000 km<sup>2</sup>). Major Alpine rivers which feed this Alpine-Appennine foreland basin drain a total catchment of about 100,000 km<sup>2</sup> (70,000 km<sup>2</sup> Po R. tributaries, 25,600 km<sup>2</sup> Venetian-Friulian rivers). The main depositional phase occurred during LGM (27-19 ka cal BP), when the glaciers hosted in the Alpine valleys reached the plain and fed the related glaciofluvial and fluvial systems. These latter experienced large and widespread aggradation as fan-shaped distributary systems, that have been described as alluvial megafans when their longitudinal axis is >30 km (i.e., Isonzo, Tagliamento, Piave, Brenta, Adige, Mincio, Chiese, Oglio, Adda, Olona river systems). These large landforms have an extent of 500-3000 km<sup>2</sup>.

Pede-Alpine megafans are characterized by steep (1-0.4%) piedmont sectors consisting of amalgamated gravels down to 10-30 km from apex, while the distal sector is fine-dominated and channels are sandy braided. The thickness of LGM sediments in the plain is 30-10 m, thinning to <5 m on the Adriatic Sea shelf, where depositional bodies dating to LGM or previous low-stand units (i.e. MIS 3 and 4) still largely crop out.

Following ice decay at around 17 ka cal, an erosive phase occurred in the pede-Alpine sector during Lateglacial and early Holocene. This led to river downcutting for tens of meters. Alpine tributaries of the Po River still flow in entrenched valleys down to their junction. In the Venetian-Friulian sector, where distal tract of megafans are directly connected to the Adriatic Sea, incisions have depths of 15-30 m and widths up to 2 km. Post-LGM sedimentation in the valleys consisted of predominant gravels and sands down to the present coastal area. After 8.0 ka cal sea level rise triggered the formation of the coastal wedge, the infilling of incised valleys and the widespread aggradation in the interfluvies.

\*\*\*\*\*

## Fluvial responses to climate changes, eustatism, neotectonics and anthropogenic impacts during the last 50 000 years in the Northwestern Africa: Gharb plain, Oued Sebou watershed (Morocco)

CASTANET C.(1), DEGEAI J.P.(2), DESRUELLES S.(3), ROBERT V.(4)

(1) Université Paris 8, UMR CNRS 8591 Laboratoire de Géographie Physique, PARIS, FRANCE ; (2) UMR CNRS 5140 Archéologie des Sociétés Méditerranéennes, MONTPELLIER, FRANCE ; (3) Université de Picardie Jules Verne, UMR CNRS 8185 Espaces, Nature, Culture, AMIENS, FRANCE ; (4) UMR CNRS 8591 Laboratoire de Géographie Physique, PARIS, FRANCE

This research deals with fluvial responses to the external factors, allocyclic and autocyclic evolutions and lower alluvial plains construction. The potential of North Africa fluvial archives is strong but Holocene reconstitutions have to be refined and evolutions of the last glacial period are badly known. The study area is the Gharb Plain, which is alluvionated by Oued Sebou (basin: 40000 km<sup>2</sup>). The integrated approach appeals to the morphostratigraphy (10 thick series), sedimentology (granulometry, mag. susc., heavy minerals), geochemistry (elementary analysis, C, N, electric conductivity, IR analysis, S), geomatics (DGPS, DEM, spatial modeling, GIS, remote sensing), geochronology (40 AMS<sup>14</sup>C datings), geomorphological cartography and archaeology. In the Gharb Plain, fluvial formations (Middle and Late Pleniglacial, Lateglacial, Holocene) are nested and vertically stacked. Their global architecture results from allocyclic evolutions of the fluvial system, due to i), the base level changes (erosive episode during the marine low-level of the Late Pleniglacial (OIS2), aggradation episode during the post-LGM sea level rise, Holocene transgression) ii), the climatic changes (sediment yield, Holocene organic facies and cyclic alluviation) and iii), the neotectonics (subsidence allows the storage of large formations). Autocyclic evolutions widely structured the internal architecture of formations, with fluvio-deltaic and fluvio-estuarine processes. Palaeo-hydrographical, -hydrological and -environmental reconstructions reveal meandering fluvial patterns during the end of the Middle Pleniglacial (OIS3) and the Holocene. A model of regional fluvial activity of the Oued Sebou was established. It shows multicentennial scale variability in response to climate and environmental changes and anthropogenic impacts. Interregional comparisons within North Africa were done. The palaeoenvironmental reconstruction potential of the Pleniglacial and Lateglacial formations was revealed.

### **The Loir River fluvial dynamics during the Lateglacial and the Holocene (France): multi-scaled and multi-proxy approach**

*PIANA J.(1), CARCAUD N.(2), CYPRIEN-CHOUIN A.L.(3), GANDOUIN E.(4), LEROY D.(5), VISET L.(3)*

*(1) L'UNAM -Université d'Angers UMR ESO 6590, ANGERS, FRANCE ; (2) Agrocampus Ouest, Département Paysage, ANGERS, FRANCE ; (3) Faculté des Sciences et des Techniques de Nantes.Laboratoire d'Ecologie et des Paléoenvironnements Atlantiques, NANTES, FRANCE ; (4) IMBE - UMR CNRS 7263 / IRD 237, AIX-EN-PROVENCE, FRANCE ; (5) Ministère de la Culture et de la Communication, Sous-direction de l'Archéologie, PARIS, FRANCE*

A multidisciplinary research has been initiated in the Loir River valley where investigations (3 study areas from upstream to downstream), revealed high-potential fluvial records. Coring operations (3 main cross-sections, 100 boreholes) provide the opportunity to reconstruct fluvial responses to climate, environmental and societal changes during the last 16000 years, with a multi-scaled approach and several proxies: sedimentology, soil micromorphology, geochemistry, palaeoecology (pollen, chironomidae), archaeology, geochronology (37 AMS <sup>14</sup>C datings).

The post-LGM climate warming induces an early incision episode before 15095-16343 a. cal. BP (2σ), with the erosion of older Weichselian formations. During the Bolling-Allerod period, warmer and wetter conditions, reconstructed from bioindicators, cause organic sedimentation in the plain. Tenuous evidence of the Older Dryas (colder) is locally suggested from pollen and chironomidae. The Lateglacial-Holocene transition is marked by a change from a multichannel to a meandering fluvial pattern and a calcareous and clayey-peat infilling in the secondary channels. This infilling seems to run on till the Atlantic. At the beginning of the Atlantic, an incision episode probably erodes the older Holocene deposits. From the Subatlantic, the opening of the vegetal landscape and the cattle raising activities in the valley are known by archeological and palynological results. During the 2<sup>nd</sup> Iron Age and the Gallo-Roman periods, massive silty-clay contributions rush to the plain and attest the opening of the forest and the destabilization of slope soils. Besides, the increasing rates of aquatic plants and of the clayey-silty sedimentation in the plain indicate higher groundwater level and flood frequency. Aquatic plants disappear at the beginning of the Middle Ages (drainage). Demographic growth, agricultural activities and the LIA conditions lead to strong slope erosion and aggradation in the plain.

\*\*\*\*\*

### **Contrasting influences from land use changes and climatic variations on alluvial and colluvial deposition in Southern France**

*NOTEBAERT B.(1), BERGER J.F.(2), BROCHIER J.L.(3)*

*(1) KU Leuven, LEUVEN, BELGIUM ; (2) UMR 5600 EVS du CNRS, Université Lyon 2, LYON, FRANCE ; (3) Centre d'Archéologie Préhistorique du Rhône aux Alpes, VALENCE, FRANCE*

This study aims at quantifying a temporal differentiated Holocene sediment budget for the Valdaine region (330 km<sup>2</sup>) in the Pre-Alps of S-France. This region has a long and intense history of human land use. Sediment budgeting is a tool which allow the objective and quantitative comparison of processes over different time and spatial scales, and within different regions. A growing amount of historical sediment budgets is available for C-Europe, but data from S-Europe are missing.

The sediment budget is constructed using field data and an extrapolation over geomorphologic units. Results indicate that there is ca 190 10<sup>6</sup> m<sup>3</sup> (0.85 Mt/km<sup>2</sup>) colluvial deposition, which is high in comparison with catchments in C-Europe. About 125 10<sup>6</sup> m<sup>3</sup> sediment is present in the alluvial plains, and ca 30 10<sup>6</sup> m<sup>3</sup> in the outlet's alluvial fan, which receive both also sediment from the upstream reaches outside the study area (total catchment area 600 km<sup>2</sup>). Dating results show that colluvial deposits date mainly from the last 3000 a, with highest deposition during the last 1000 a. The floodplains have a complex cut and fill history, which complicates precise temporal quantifications. Pre-Medieval deposits are mainly fine, followed by an important cut and fill phase during the LIA, with deposition of a coarse gravel originating from channel and gully erosion in the upper mountainous reaches.

From the presented sediment budget it can be concluded that anthropogenic land use is responsible for major soil erosion and colluvial deposition during the last 3000 a in the lower and middle altitudes of the basin, without conclusive data on a climate related intensification during the LIA. Floodplain deposition is controlled by land-use from the Mid-Holocene to the early Medieval period. This changes however dramatically during the LIA, with deposition of a major gravel layer, which can be related to the combination of this particular climatic period with a major deforestations in the upper reaches.

### **Evidence for a continuous fluvial activity of the Tremithos River (South Central Cyprus) during the Early to Mid-Holocene**

*GHILARDI M.(1), CAROZZA J.M.(2), CORDIER S.(3), PSOMIADIS D.(1), ZOMENI Z.(4), DEMORY F.(1), SABATIER D.(1), VELLA M.A.(1), BONY G.(1), MORHANGE C.(1)*

*(1) CNRS CEREGE UMR 7330, AIX-EN-PROVENCE, FRANCE ; (2) Univeristy of Strasbourg, STRASBOURG, FRANCE ; (3) Univeristy of Créteil UPEC, CRÉTEIL, FRANCE ; (4) Cyprus Geological Survey, NICOSIA, CYPRUS*

This article shows evidence of an important alluviation and a fast vertical accretion in Central-East Cyprus during the Late Neolithic/Early to Late Chalcolithic periods, implications for the settlement development is in parallel discussed. Cyprus has been little studied for palaeohydrological reconstruction and Holocene fluvial terrace formation. Based on the previous works undertaken on the southern (Vassilikos and Dhiazos Valleys) and eastern most parts of the island (Gialias drainage basin), recent paleoenvironmental investigations have been conducted within the Tremithos drainage basin (an area of ~ 170 km<sup>2</sup>). A stratigraphic profile of ca. 8 meters thick, situated 8.5 km west of the city of Larnaka, was studied for magnetic parameters, LASER grain size distribution and XRD measurements. In addition a chronostratigraphy sequence was obtained, based on the dating of 7 charcoal samples. Two additional stratigraphic profiles were investigated and help to better understand the Late Pleistocene to Early Holocene fluvial framework and comparisons have been established with previous studies led in the Island. For the first time, our study reveals an important and fast sediment accretion from ~ 5000 cal. BC to ~ 2800 cal. BC where mainly fine material (fine to medium well sorted sands) was deposited and a phase of high energy of deposition has been identified where pebbles mixed together with fine sands and was dated from the beginning of the third millennium BC. The results also highlight the presence of a palaeosol dated 3342-3026 cal. BC (Mid to Late Chalcolithic periods), evident alteration of an open air site is observed due to flooding of the Tremithos River. Our works show first evidence for a continuous fluvial activity in Central East Cyprus during the Early to Mid Holocene and discussions are dealing with climate and anthropogenic (forest clearance) parameters which could be combined to explain the rapid terrace formation.

\*\*\*\*\*

### **Late to final Holocene fluvial system dynamics in the Yamé valley (Mali): climatic change or human impact ?**

*GARNIER A.(1), LESPEZ L.(1), BALLOUCHE A.(2), LE DREZEN Y.(3), RASSE M.(4), HUYSECOM E.(5), DELAHAYE D.(1)*

*(1) LETG Caen -Géophen. Université de Caen Basse-Normandie, CAEN, FRANCE ; (2) LETG Angers-LEESA Université d'Angers, ANGERS, FRANCE ; (3) PRODIG, UMR 8586 CNRS. Université Paris1 Panthéon Sorbonne., PARIS, FRANCE ; (4) Laboratoire GEOSUDS, CNRS-UMR IDEES 6228, Université de Rouen, ROUEN, FRANCE ; (5) Laboratoire Archéologie et Peuplement, Département de Génétique et Evolution, Université de Genève, GENÈVE, SWITZERLAND*

In West Africa, studies on fluvial system evolution are rare and were mainly conducted to underline the role of climatic change as single driver. This presentation aims to propose a synthesis of fluvial changes of the Yamé River (Mali) during the Late to Final Holocene (5000 years BP onwards). Because of its exceptional preservation including plants and archaeological remains, the Yamé valley deposits permit a high resolution of environmental and human dynamics reconstruction, especially for the Final Holocene period (2500 years BP onwards) which is, until now, not well documented in West Africa. This study focuses on the whole fluvial system from the upstream sandstone plateau to the downstream Inner Niger Delta. Outcrops profiles and cores, correlated to eight cross sections along the 130 km of the Yamé valley and combined with sedimentological analyses on 250 samples were investigated to appreciate the general pattern of alluvial dynamics and the longitudinal complexity from upstream to downstream. The comparison of these results with regional and local archaeological and palaeoenvironmental data permits to identify the respective parts of the climatic and anthropogenic variables during the Holocene and within the catchment area.

The results highlight a contrasted response of the fluvial system to regional controls such as climatic oscillations and the general increasing impact of societies since the Neolithic. However, natural and human local variables were also identified. Then, the diversity of geological settings and geomorphological inheritance of the Yamé catchment are relevant in determining water discharge and sediment supply. Furthermore, from 3000 years, the increase of agricultural practices, the emergence of iron metallurgy and more recently the demographic pressure are relevant in determining Yamé fluvial system changes and colluvial development.

### **A 7300 year record of palaeohydrology in the Swiss Rhône River floodplain (Valais, Switzerland)**

LAIGRE L.(1), ARNAUD-FASSETTA G.(2), REYNARD E.(3)

(1) *Institute of Geography and Sustainability, University of Lausanne (Switzerland) - UMR 8591 Laboratoire de Géographie Physique, Meudon (France), LAUSANNE, SWITZERLAND* ; (2) *University of Paris Diderot (Paris 7) - UMR 8591 Laboratoire de Géographie Physique, Meudon, PARIS, FRANCE* ; (3) *Institute of Geography and Sustainability - University of Lausanne, LAUSANNE, SWITZERLAND*

Unlike the French part of the Rhône River catchment, the fluvial history of the Swiss Rhône River (Upper Rhône) is relatively unknown. In this paper, we establish the record of floodplain filling in the Upper Rhône since 7000 cal. y BP. A multimethod approach based on historical mapping, geophysical measurements, coring and C14/OSL dating allowed identification of several major hydrodynamic phases. Geophysical measurements provided information on the sedimentary architecture, location and dimensions of most of the younger buried palaeochannels, illustrating the nature of river broadening in the period before embankment. They also revealed the significant influence of tributaries on the Upper Rhône system. Four phases of major fluvial activity have been identified: (i) Prior to 7300 cal BP, coarse sedimentary facies predominated in the south of the valley and was linked to the position of the active channel; (ii) After a period of low activity, from 7270 cal. BP a multiple channel pattern with flows on the entire surface of the floodplain is observed; (iii) After a new short period of low hydrological activity, a migration of the main Rhône River from the north to the south of the valley is associated with the Early Atlantic period. Indeed, in the southern floodplain the vertical sequencing of layers suggest the functioning of an unstable channel that was probably braided. Furthermore a core drilled in the base of a tributary alluvial fan suggests an increase in tributary sediment delivery during the same period. This contributed to the migration of the channel towards the south. (iv) The last major hydrodynamic period recorded by sediments corresponds to the Little Ice Age and is characterised by the domination of pebbles and gravels. During this period, the main braided channel was back to the north of the valley with single secondary channels connected to the Rhône River still flowing in the south, as geophysical and historical mappings emphasised.

\*\*\*\*\*

### **Late Quaternary floodplain evolution in the low tableland of Transylvanian Depression, Romania**

PERȘOIU I.(1), FEURDEAN A.(2)

(1) *Ștefan cel Mare University, SUCEAVA, ROMANIA* ; (2) *Senckenberg Research Institute and Natural History Museum and Biodiversity and Climate Research Centre (BiK-F), FRANKFURT AM MAIN, GERMANY*

Here we present the evolution of a river-lake system (Pârtoș River and Știucilor Lake), tributary of Someșu Mic River in NW Romania, over the past ~15.000 years. Lithological, mineral magnetic properties, organic content and grain size observations on three cores (drilled both in the lake – C1, and in the floodplain perimeter – C2, C3) enabled us to reconstruct the evolution of the lake and fluvial system over the past ~15.000 years.

In core C1 (in the present lake), bottom sands (glacial) are followed by clay gyttia and detritus gyttia of late-glacial origine . At the bottom of core C2 (1 km upstream from the present edge of the lake), coarse sands and pebbles of alluvial origin are followed by medium to fine sands, deposited in a typical lake environment. In core C3 (~4 km upstream from the present day edge of the lake), clays and sandy clays were deposited during the Bolling-Allerod, followed by fine - medium sands during the Younger Dryas. In all three cores, the beginning of the Holocene is marked by the development of *Phragmites* peat with low minerogenic flux.

These results suggest that during the Late Glacial (LG), a larger than present lake extended at least 1 km upstream from the present day lake edge, fed by coarse materials (sands) from low tree-cover slopes. This lake continued upstream (for ca. 3 km) with, a low energetic humid area, covering the entire floodplain. During the YD and the early Holocene, the lake dramatically reduced its surface, and dried out between 11,000 and 6000 cal yr BP. A second lacustrine phase started ~6000 years ago lasting until present. Biotic and abiotic proxy data from Știucilor Lake indicate that the lake level show greatly fluctuating water table.

The model of fluvial evolution and the sedimentary records offered by this floodplain has a regional relevance in a poorly studied area from SE Europe, with high potential in investigating the fluvial system changes related to climate and human activities.

**Late Quaternary weathering, sediment production, erosion, and alluvial fan deposition in hyperarid Nahal Yael, Israel**

ENZEL Y.(1), AMIT R.(2), GRODEK T.(1), AYALON A.(2), LEKACH J.(1), PORAT N.(2), BIERMAN P.(3), BLUM J.(4), EREL Y.(1)

*(1) The Hebrew University of Jerusalem, JERUSALEM, ISRAEL ; (2) Geological Survey of Israel, JERUSALEM, ISRAEL ; (3) University of Vermont, BURLINGTON, UNITED STATES ; (4) University of Michigan, ANN ARBOR, UNITED STATES*

A conceptual model for geomorphic response to Pleistocene-Holocene climate change (Bull and Schick, 1979) was applied to the hyperarid (<30 mm yr<sup>-1</sup>) Nahal Yael. It included an event chain following this change: reduced vegetation cover, increased sediment yield from slopes, aggrading terraces and forming an alluvial fan. The model is reevaluated here with data acquired in Nahal Yael over the 30 years since the original model was proposed. Recent studies indicate hyperarid late Pleistocene climate; the transition from semiarid late Pleistocene to hyperarid Holocene did not occur. The revised chronology reveals a 35-20 ka episode (probably already beginning at ~50 ka with lower rates) of accelerated weathering and sediment production and distinct talus accretion on slopes. Coeval with accretion on slopes, sediments were also transported and aggraded in terraces and alluvial fans, without noticeable lag time or a chain of discernable events. This intensified sediment production and delivery phase is unrelated to the Pleistocene-Holocene transition. The depositional landforms were rapidly incised (20-18 ka); since this ~LGM incision, sediment yield is from storage in these depositional landforms and is not produced from bedrock in significant quantities. We propose that in hyperarid environment, the main operators are individual extreme storms; here specifically, an episode of frequent storms/floods is the driver of change regardless the mean climatic conditions. It created a pulse of intense weathering due to numerous cycles of wetting and drying on slopes and sediment transport to fluvial terraces and alluvial fans; its impact continues all the way to the present. We suggest that even if aspects of the original conceptual model of Bull and Schick (1979) are correct, it has been applied too frequently, too generally, across very diverse arid climates and settings, and for too long in lieu of collecting new data at a full basin scale and testing the model

\*\*\*\*\*

**Extending flood records in Irish and Welsh river catchments using high-resolution geochemical analysis of floodplain sediment sequences**

JONES A.F.(1), TURNER J.N.(1), DALY J.S.(1), EDWARDS R.J.(2), FRANCUS P.(3), GOODHUE R.(2), REID I.(1)

*(1) University College Dublin, DUBLIN, IRELAND ; (2) Trinity College Dublin, DUBLIN, IRELAND ; (3) Institut National de la Recherche Scientifique, QUEBEC CITY, CANADA*

Extended records of riverine flooding are required to constrain the magnitude-frequency relations of high-magnitude flood events in order to produce accurate assessments of present and future flood hazard. Analysis of vertically-accreted floodplain sediment sequences provides a means of obtaining records of major flood events through the late Holocene. We report on an investigation using high-resolution geochemical analysis to identify the deposits of major flood events within floodplain sediment sequences from catchments in Ireland and the UK. Itrax XRF core scanning is used to obtain profiles of variation in the abundance of a range of chemical elements in cores from palaeochannels and stable mid-channel islands. The effects of variation in XRF scan settings and count times on the precision of the resulting element profiles are tested. Lithogenic element ratios are employed as proxies for sediment grain size which acts as an indicator of varying flood magnitude. The suitability of the lithogenic element ratios for application as grain size proxies at each site, and the accuracy and precision of the reconstructed variability in sediment grain size are assessed through the comparison of the geochemical results with independent grain size data from laser granulometry and SEM image analysis. Instrumental and historical flood data from the study catchments provide a means of assessing the accuracy of the records of flooding derived from floodplain geochemistry. The project reports on spatial and temporal variations in flood magnitudes and frequencies during the late Holocene and historical periods.

### Obstacle marks as palaeohydrologic indicator

*HERGET J.(1), EULER T.(2)*

*(1) Dept. of Geography, Bonn University, BONN, GERMANY ; (2) Hydrotec Ingenieurgesellschaft, AACHEN, GERMANY*

Fluvial obstacle marks can be observed frequently in recent channels and along the pathways of previous floods, including Pleistocene megafloods. They are formed by the current of the flow around submerged obstacle like stones or features like trees, bridge piers and even hills reaching above the water level. Depending on thresholds of the flow velocity and steepness of the obstacle's front, they typically consist of a frontal scour hole and a sedimentary ridge in the back, where the reworked sediments are deposited. Initiated by the description of large scale obstacle marks generated by Pleistocene megafloods like those from glacial Lake Missoula (e.g. Baker 2009) or similar events in the Siberian Altai Mountains, first attempts for quantitative palaeohydrological interpretation were less successful (e.g. Herget 2005). Thus, flume and field data of classical obstacle marks are analysed to estimate flow velocities from obstacle mark geometry, especially scour depths, length, width and ridge width. These data reveal a consistency of correlations between obstacle mark morphometries across a wide spatial scale and therefore can be transferred from flume experiments via recent features back to Pleistocene large scale structures. Analytical models, basically integrating obstacle size, flow velocity as well as sediment size and grading, are transformed so that the magnitude of individual geometric parameters can be used as variables for the estimation of mean and tip flow velocities. A universally applicable practical outline is developed for palaeohydraulic reconstruction. The reliability and scale-invariance of these reconstructions is confirmed by similar results of velocity estimations by other independent approaches at the same locations.

References:

Baker, V.R. 2009 – Annu. Rev. Earth Planet. Sci. 37, 393–411.

Herget, J. 2005 – GSA Spec. Pap. 386.

Herget, J. et al. (in print): Hydrology Research.

\*\*\*\*\*

### Late Holocene periodicities of Alpine floods inferred from multi-proxy data

*SCHULTE L.(1), PEÑA J.C.(2), CARVALHO F.(1), BURJACHS F.(3), JULIÀ R.(4), LLORCA J.(1), RUBIO P.(1), VEIT H.(5)*

*(1) Department for Physical and Regional Geography, University of Barcelona, BARCELONA, SPAIN ; (2) Area of Climatology, Meteorological Service of Catalonia (SMC), BARCELONA, SPAIN ; (3) IPHES - Catalan Institute of Paleocology, Human and Social Evolution, TARRAGONA, SPAIN ; (4) Institute of Earth Sciences Jaume Almera, BARCELONA, SPAIN ; (5) Institute of Geography, University of Berne, BERN, SWITZERLAND*

Densely populated mountain river basins such as the deeply carved glacier valleys in the Bernese Alps are prone to hydrological hazards (437 floods since 1800 AD). The multidisciplinary approach provides data from natural, historical, and instrumental time series, to the study of magnitude-frequency of extreme events and their forcings over pluri-millennium time scales, thus covering several Holocene climate cycles. For the reconstruction of delta plain aggradation pulses and flood processes, high-resolution sediments from interdistributary basins were examined by XRF-core scanning, LOI, grain-size and palynology techniques, performing proxy-records outside the known range of extreme events.

Spectral analysis of the geochemical and pollen time series (4800 to 1800 cal. yr BP) from mid-size catchments and other climate proxies (e.g.  $^{14}\text{C}$  anomalies,  $\delta^{18}\text{O}$  from Greenland ice and NAO Index) evidence similar periodicities of 60, 85, 105 and 210 yrs. Thus, the mechanisms of the aggradation pulses and flood processes were strongly influenced by the North Atlantic dynamics and solar activity. With regard to the last two centuries a summer flood index of Switzerland (INU<sub>i</sub>) based on damages recorded from 1800 to 2008 AD was performed. Spectral analysis of the INU index identify the 105-yr cycle recorded in the delta plain sediments and the 11-year solar cycle (Schwalbe-cycle).

Furthermore, the chemical composition of delta plain sediments (e.g. Ca/Ti, TOC and aluminum silicate content) and mesic pollen data shows high correlation with the GISP 2 record, providing evidences that cooler climate pulses were an important external driving force of floods. Detailed information was obtained with regard the last 200 years. Correlation of the INU<sub>i</sub> with the composite annual temperature record Berne-Vienna since 1800 AD, the  $\delta^{18}\text{O}$  GISP 2 record and the summer NAO indicate that mayor flood activity occurred during short warm climate pulses during cold low-frequency periods.

**Floods, droughts and people: historical palaeohydrology and landscape resilience of a Mediterranean rambla (Castellón, NE Spain)**

BENITO G.(1), MACHADO M.J.(1), RICO M.T.(2), SÁNCHEZ-MOYA Y.(3), SOPEÑA A.(3)

(1) Spanish Natural Science Museum-CSIC, MADRID, SPAIN ; (2) Instituto Pirenaico de Ecología-CSIC, ZARAGOZA, SPAIN ; (3) Instituto de Geociencias (CSIC-Universidad Complutense), MADRID, SPAIN

Rambla de la Viuda (drainage area of 1500 km<sup>2</sup>) is a Mediterranean ephemeral river with a hydrological regime characterised by large floods. The region has a long history of anthropogenic land-use changes, which contributed to temporal phases of increased rates of sediment yield and changes in flood hydrology. Valley sides revealed important accumulations of slackwater flood deposits. These slackwater flood deposits emplaced by high stage floodwaters show a complete stratigraphy from which we can reconstruct long-term records of floods and environmental changes. Interbedded with these flood units, colluvial units can be observed, and several edaphic horizons developed on colluvial and fluvial deposits were identified.

The alluvial and colluvial chronostratigraphical, sedimentological and palaeobotanical (phytoliths) analysis of these units, together with the hydraulic flood modelling approach, made possible to determine: a) the way in which hydrological extreme events may be changing both in frequency and intensity as a result of climate variability, b) the weight of human influence (land-use) on soil hydrology, c) geomorphic channel changes, and c) the grade of resilience of landcover during this temporal scale (last 500 yrs).

\*\*\*\*\*

**Progress on the estimation of past flood discharge from dendromechanical analyses of tilted trees**

BALLESTEROS CANOVAS J.(1), BODOQUE J.M.(2), EGUIBAR M.A.(3), RUIZ-VILLANUEVA V.(1), DÍEZ-HERRERO A.(1), STOFFEL M.(4), SÁNCHEZ-SILVA M.(5)

(1) IGME, MADRID, SPAIN ; (2) University of Castilla-La Mancha, TOLEDO, SPAIN ; (3) Technical University of Valencia, VALENCIA, SPAIN ; (4) University of Berne, BERNE, SWITZERLAND ; (5) Universidad de Los Andes, BOGOTA, COLOMBIA

Tilted trees, due to the unidirectional flow pressure, constitute a common dendrogeomorphic evidence on the river floodplain of past flood events. This evidence have been widely used in dendrogeomorphology to reconstruct flood frequency by mean of the identification of reaction wood, but their usefulness for flood discharge estimation never have been investigated. We present a mechanical tree deformation-flood depth model in order to reconstruct the flood peak discharge based on the rotational stem deformation. In this model, theories from dendrogeomorphology, dendrometric, mechanical structures and hydraulic sciences are combined. Input data required are: stand forest characteristic, deformation of the stem base, root-plate characteristic and soils characteristic. The objective of this study is to validate results derived of this model with observed data derived from tilted trees located close to river gauge stations.

We have sampled and analyzed tilted trees from three gauged reach river. Dendrogeomorphological methods have been carried out to date flood events by mean reaction wood, while gauge station record were consulted in order to assign their peak discharge. On the other hand, 3D-Georadar has been also carried out in order to define a root-plate model to each tree species. We also used 1D/2D-dimensional hydraulic model in order to reproduce hydraulic conditions during flood events. Other input data like soil and wood density, drag coefficient, Strickler parameter were finally tabulated. Results indicate that there is a correspondence between deformation and flood depth although variability is also implicitly. Possible controls on these variability is being studied and could be related with the age of the tree when was titled as well as the signal-noise in deformation due to subsequent events. However we discuss the usefulness of output of this model as censored data in order to reconstruct the flood frequency in ungauged or poorly gauged catchment.

## **Poster presentations:**

### **Tectonic signals in fluvial archives Jarama River in central Spain**

FAUST D., WOLF D.

*TU Dresden, DRESDEN, GERMANY*

The aim of this project was to examine Spanish River systems concerning their suitability to serve as archives to reconstruct Late Pleistocene and Holocene environmental conditions in Spain. The sediment sequences of the Jarama River in central Spain proved to be an outstanding archive as we were able to identify stages of floodplain development covering a timeframe of 44 ka before present. About 14 outcrops were studied with profile exposures up to 600m long. Sedimentological and pedogenetic findings were supported by 32 radiocarbon ages.

It appeared that the fluvial architecture is very complex and inconsistent along specific river courses. Between 5 ka and 3 ka cal BP we find loamy floodplain sediments accumulated in one section and coarse gravels deposited in another section, both extending over nearly the entire floodplain. By all appearances, basic preconditions regarding such river dynamics are closely linked to tectonic movements within the river valley that are related to the surrounding gypsum marls. As a result of tectonic movements during the Pleistocene as well as the Holocene the longitudinal profile of the Jarama Valley shows sections of high river gradient and sections of low river gradient. Such a juxtaposition of different river gradients caused different sedimentation and erosion patterns within adjacent river sections even under the same palaeoenvironmental conditions. Beside the precondition of a tectonic movement, specific climate conditions with high discharge variability and discharge peaks are considered to be the cause of the highly dynamic sedimentation patterns in the lowermost river section. The deposition of several meters of coarse gravels in a kind of braided river sedimentation pattern during Mid-Holocene times has not been described before in the Mediterranean. The interaction of tectonics and an accentuated Mediterranean climate offers a possible explanation to these exceptional sedimentation patterns in mid- to late Holocene times.

\*\*\*\*\*

### **A palaeo-sebkha sequence near Kasserine (Central Tunisia): palaeohydrology and palaeoenvironment at the Upper Pleistocene- Holocene transition**

BKHAIRI A.

*Laboratoire de Cartographie Géomorphologique des Milieux, des Environnements et des Dynamiques, Faculté des Sciences Humaines et Sociales, Université de Tunis, CHRAYAA- SBEITLA, TUNISIA*

Located in the Central Tunisia, the basin of Kasserine was filled up by recent quaternary sediments. Fieldwork in the floodplain of Kasserine near wadi Hatab, highlights successive sedimentological phases with argillaceous silts and gypsum characterizing a palaeo-sebkha. A multi-proxy study based on sedimentological, palaeo-ecological and geo-chronological analysis carried out to reconstruct the bio-sedimentary evolution and palaeoclimatic fluctuations of the palaeo-sebkha at the Upper Pleistocene- Holocene transition.

Fifty-three samples were collected along the palaeo-sebkha sequences. Grain- size indexes, chemical and mineralogical data, micromorphological observations and magnetic susceptibility describe the morpho-sedimentary dynamics and the palaeolimnology response to hydrology and climate changes occurring in the basin of Kasserine between 20 and 10 ka cal. BP. Five episodes of sedimentation are recorded. During the two first episodes, the sedimentation in the palaeo-sebkha alternated between clayey-silty micro-sequences and sandy-gypsums laminated lentils. Within the third episodes, an alluvial sedimentation with clayey silts attests to climate and limnologic changes with increasing moisture. The 4<sup>th</sup> episode is a period of increasing aridity, and the aeolian sand with gypsum at the top of sequence is associated to maximum extended of this arid environment.

Keys-words: sebkha, Kasserine, micromorphology, morpho-sedimentary dynamics, aridification, Upper Pleistocene-Holocene transition.

### **Contribution of OSL signals for reconstructing the debris flow activity for two tributaries of the Swiss Rhône River: the Fully and Charrat torrents (Valais, Switzerland)**

LAIGRE L.(1), BÄTZ N.(2), LANE S.(2)

(1) Institute of Geography and Sustainability, University of Lausanne (Switzerland) - UMR 8591 Laboratoire de Géographie Physique, Meudon (France), LAUSANNE, SWITZERLAND ; (2) Institute of Geography and Sustainability - University of Lausanne, LAUSANNE, SWITZERLAND

In the Alps, tributary debris flow and alluvial fan systems can have a major influence on the fluvial patterns of the river into which they flow. Because of both the rapid onset of debris flow activity and the commonly abundant nature of sediment supply, they can have a dramatic effect on river and valley floodplain fill downstream, especially where the events are driven by tributary localised rainfall and the main river has insufficient capacity to transport the sediment supplied to it. The result can also be both river migration and in extreme cases avulsion. Debris flow deposits from two tributaries, the Fully and the Charrat torrents, have been identified in sediment cores in the River Rhône floodplain and these allow us to quantify and to explain the influence of tributaries on the main river. Here, we use data obtained from an OSL portable reader where the luminescence signal (total photon counts) measured in buried deposits is used to deduce the nature of transport and depositional processes. A series of debris flow events have been identified, one of which was sufficient to impact upon the main Rhône River by increasing the slope of the alluvial fan surface and forcing the channel to migrate towards the south. Subsequently, with hydrological activity in the tributaries, the Rhône, whilst remaining braided, migrated back to the north of the valley and eroded the base of the alluvial fan. This resulted in fluvial material being interspersed with fan deposits and shows how even for a large river system like the Rhône River, certain debris flow events can have a significant impact upon its dynamics.

\*\*\*\*\*

### **Using tree-ring oxygen stable isotopes for studying the origin of past flood events: first results from the Iberian Peninsula**

DIEZ-HERRERO A.(1), FERRIO J.P.(2), BALLESTEROS J.A.(1), VOLTAS J.(2), BODOQUE J.M.(3), AGUILERA M.(2), RUIZ-VILLANUEVA V.(1), TARRES D.(2)

(1) Geological Survey of Spain (IGME), MADRID, SPAIN ; (2) Dep. Crop and Forest Sciences, ETSEA, University of Lleida, LLEIDA, SPAIN ; (3) Mining and Geological Engineering Department, University of Castilla-La Mancha, TOLEDO, SPAIN

For over forty years, tree-ring studies have been used to date and quantify past flood events. On the other hand, stable C and O isotopes in tree-rings have been extensively applied for reconstructing past environmental conditions and their changes over time. So far, both approaches have not been combined and integrated. In this study we explore whether the meteorological origin of precipitation causing past flood events might be assessed through the investigation of oxygen stable isotopes in tree rings. It is well known that floods may have different origins, e.g. heavy convective rainstorms, frontal precipitations, snow melting, etc. Each of these floodwater sources bears a particular isotopic fingerprint.

This communication presents the first results of this methodology applied to recent flash flood events occurred in Central Spain. To this end, a well-known heavy-rain convective event was chosen from the recent flood record. In the forested area affected by this event, 6 cores from each one of 4 species selected (*Pinus sylvestris*, *P. pinaster*, *Quercus pyrenaica* and *Alnus glutinosa*), were sampled using a Pressler incremental borer. The wood cores were dated and the tree-ring corresponding to the event year, along with the precedent and the subsequent rings, were identified and isolated for isotope analysis. After  $\alpha$ -cellulose extraction, the oxygen isotope composition ( $\delta^{18}\text{O}$ ) was analyzed and compared with the values of other recent convective precipitations from the Spanish Network for Isotopes in Precipitation. These preliminary results are interpreted in terms of the screening ability of the oxygen isotope signature in tree rings for identifying contrasting storm events, underlining the limitations and specific requirements of the methodology, but also its potential applications. Future, more in-depth analyses will be aimed at recognizing specific precipitation sources and separating different populations of past floods according to their cause.

### **The use of microscopic study of quartz grains for establishing the origin of the Late Pleistocene river terrace deposits in the Central Russian Plain**

*MATLAKHOVA E.(1), DUBIS L.(2), PANIN A.(1)*

*(1) Geography Faculty, Moscow State University, MOSCOW, RUSSIAN FEDERATION ; (2) Kiev National University, KIEV, UKRAINE*

Late Pleistocene river terraces in the Central Russian Plain were subject to complex reworking after the alluvial sedimentation had finished. Terraces may therefore contain sediments of different origin and terrace levels may vary according to the post-alluvial reworking. To establish terrace sedimentation mechanisms we supplemented lithological data collected in the field with quartz grains morphoscopy technique – microscopic study of texture of sediment particles. The results exhibit wide participation of aeolian and slope wash sediments in terrace deposits, deep aeolian reworking of terrace alluvium during LGM that could be possible due to deep pre-LGM incision of rivers. The main difficulty in interpretation of morphoscopic results is that aeolian signals are sometimes not clear due to short duration of wind action over alluvial sands.

\*\*\*\*\*

### **Hydrological EXtreme Events in Changing Climate: The HEX Events project**

*BENITO G.(1), MACKLIN M.M.(2), COHEN K.M.(3), HERGET J.(4)*

*(1) CSIC-Museo Nacional de Ciencias Naturales, MADRID, SPAIN ; (2) Institute of Geography and Earth Sciences, Aberystwyth University, CEREDIGION, UNITED KINGDOM ; (3) Faculty of Geosciences, Utrecht University, UTRECHT, NETHERLANDS ; (4) Department of Geography, University of Bonn, BONN, GERMANY*

Fluvial records in various ways contain evidence of past hydrological events, which can be linked to Earth's climate variability. Chronological control of fluvial archives has much improved in the last decades particularly for the Holocene and Late Pleistocene records, and this is renewing their use to improve palaeoflood sequences of rivers worldwide. The INQUA funded HEX Events project aims to combine extended regional records of hydrological events (above average stream flow and discrete flood events) from multiple proxies and to establish in-phase and out-of-phase periods of hydrological activity in response to climate and atmospheric circulation variability. The project approach is based on combined meta-analysis of large sets of dates (radiocarbon, OSL, IRSL) of diverse fluvial contexts, allowing series of fluvial activity periods to be more objectively defined, better facilitating their characterization in terms of forcing hydrological conditions, once overprint effects due to 'preservation' and 'radiocarbon plateaus' are corrected. This approach is applied to records of fluvial activity in different clusters of catchments, larger river drainage basins, and countries. The approach facilitates comparison with other climate and human impact proxy records, time series and other indicators, demonstrating the value of creating aggregate fluvial-palaeohydrological databases, to explain the past and predict the future of floods and droughts in our rivers. The HEX project has established the bases for addressing this standardised methodology on five target zones: (1) Mediterranean region; (2) Central Europe and Russian Plain; (3) North America (4) South America, (5) North Africa and (6) Australia.

## Fluvial response to Holocene climate and environmental changes in NW Romania

PERȘOIU A., PERȘOIU I.

Ștefan cel Mare University, SUCEAVA, ROMANIA

Here we discuss the response of Someșu Mic river (NW Romania) to climatic and environmental changes during the Holocene.

Our analysis is based on morphological, sedimentological and chronological informations obtained from valley bottom peat bogs in the upper reach of the river, and openings scattered through the floodplain in the medium and lower reach.

The palaeoenvironmental background for the fluvial dynamics is given by decadal scale stable isotope records from Scărișoara Ice Cave (summer temperature) and pollen data (vegetation dynamics) from peat bogs in the region.

The results of our study can be summarized as follows:

(1) The adjustment of the Someșu Mic River's channel (*i.e.*, metamorphosis from braided/wandering to narrow, incised, meandering channel) to the Holocene temperate conditions was delayed by ~1500 years occurring after the massive expansion of *Quercus* dominated forests (~10.3 kyrs BP), being probably triggered by the abrupt climatic event at 10.2 kyrs BP.

(2) At ca. 4.7 kyrs BP occurred the second important change in fluvial behavior, with increasing liquid and solid discharge, preceded by a rapid shift to colder climatic conditions and large scale development of *Fagus* forests at mid altitudes (starting with ca. 4.8 kyrs BP).

(3) The abrupt climatic events at 9.6, 8.2 and 4.2 kyrs BP and the periods of longer climatic deterioration (*e.g.*, Dark Ages Cold Period, Little Ice Age), had a lower impact on Someșu Mic River behavior.

(4) Human impact (forest clearance over the past 3000 years, changes in vegetation types), and hydrotechnical interventions in the last decades, has a reduced impact, subordinated to climate and other controls (*e.g.*, tectonics).

These findings highlight the conservative character of this river, with delayed or no reactions to external forcing (most probably induced by local geologic and tectonics conditions), as well as the role of vegetation on modulating the impact of climate on the fluvial system.

\*\*\*\*\*

## The geoarchaeology of the Middle Garonne valley: first results

CAROZZA J.M.(1), VALETTE P.(2), CAROZZA L.(2), LLUBES M.(3), FERDINAND L.(2), SEVEGNES L.(4), DANU M.(5), GALOP D.(2), PY V.(2)

(1) University of Strasbourg, GEODE UMR 5602 CNRS, TOULOUSE, FRANCE ; (2) GEODE UMR 5602 CNRS - University of Toulouse, TOULOUSE, FRANCE ; (3) GET UMR 5563 CNRS, TOULOUSE, FRANCE ; (4) French National Heritage, Ministry of Culture, TOULOUSE, FRANCE ; (5) University Alexandru Ioan Cuza, IASI, ROMANIA

Despite its historical importance as a major communication axis between the Mediterranean and the Atlantic areas, very few is known about the Middle Garonne evolution during Late Glacial / Holocene time. Sedimentary architecture and chronology of the floodplain building remains poorly documented by previous works. Pluridisciplinary approach coupling geomorphology, archaeology and geophysics were carried out during the last three years in order to refine landscape evolution in relation with human settlements from Middle Neolithic to Roman period. Between Toulouse and the Tarn confluence, the Middle Garonne is characterized by an widening of its floodplain, which reached more than 4 km wide. Two test zones were investigated in the south (Castelnau-d'Estrétefonds) and in the north (Bourret) of this area of interest. They allow to highlight two main stages of sedimentation separated by a major phase of incision. The first alluvial phase associated with high sediments supply, *i.e.* the « yellow silt » occurred between 16-8.9 ky BP. This episode remains poorly constrained by radiocarbon data. Downcutting and erosion partially removed the « yellow silt » level during the 8.9 to 5.0-4.5 ky BP interval. Biostabilisation by riparian forest (mixed oak forest) documented by palynological evidences and decrease in paraglacial sedimentary supply, seems the key factor of control of this stage of evolution.

The second alluvial phase starts around 4.4 ky BP. These levels show high charcoal concentration that reflect first human impact on the riparian forest. The first archaeological evidence of settlement in the Garonne valley during Middle Neolithic are synchronous. During Bronze Age to Early Roman period, slow aggradation occurs. Late Roman period, *i.e.* 2<sup>de</sup> c. AD is characterized by increase in sedimentation rate, as well as the Middle Medieval period.

**Geoarchaeological approach of river-societies interactions: new developments in fluvial dynamics and embankments of the Loire River during the last 2000 years (Val d'Orléans, France)**

CASTANET C.(1), CARCAUD N.(2)

(1) *Université Paris 8, UMR CNRS 8591 Laboratoire de Géographie Physique, PARIS, FRANCE* ; (2) *Agrocampus Ouest, Département Paysage, ANGERS, FRANCE*

This research deals with the study of fluvial systems, heavily and precociously transformed by societies (fluvial anthroposystems). It aims to characterize i), fluvial responses to climate, environmental and anthropogenic changes ii), history of hydraulic constructions relative to rivers iii), history of fluvial origin risks and their management - (Program: AGES *Ancient Geomorphological EvolutionS of the Loire Basin hydrosystem*). The Middle Loire River valley was strongly and precociously occupied, particularly during historical periods. Hydrosedimentary flows are there irregular. The river dykes were built during the Middle Ages (dykes named *turcies*) and the Modern Period, but ages and localizations of the oldest dykes were not precisely known. A systemic and multi-scaled approach aimed to characterize i), palaeo-hydrographical, -hydrological and -hydraulic evolutions of the Loire River, fluvial risks (palaeo-hazards and -vulnerabilities) and their management. It is based on an integrated approach, in and out archaeological sites: morpho-stratigraphy, sedimentology, geophysics, geochemistry, geomatics, geochronology, archaeology. Spatio-temporal variability of fluvial hazards is characterized. A model of the Loire River fluvial activity is developed: multicentennial scale variability, with higher fluvial activity episodes during the Gallo-Roman period, IX-XI<sup>th</sup> centuries and LIA. Fluvial patterns changes are indentified. Settlement dynamics and hydraulic constructions of the valley are specified. We establish the ages and localizations of the oldest discovered dikes of the Middle Loire River: after the Late Antiquity and before the end of the Early Middle Ages (2 dated dykes), between *Bou* and *Orléans* cities. During historical periods, we suggest 2 main thresholds concerning socio-environmental interactions: the first one during the Early Middle Ages (*turcies*: small scattered dykes), the second during the Modern Period (levees: high quasi-continuous dykes).

\*\*\*\*\*

**Understanding Quaternary landscape development using numerical modelling: issues associated with making models and data 'meet in the middle'**

BRIANT R.(1), WAINWRIGHT J.(2), MOTTRAM G.(1)

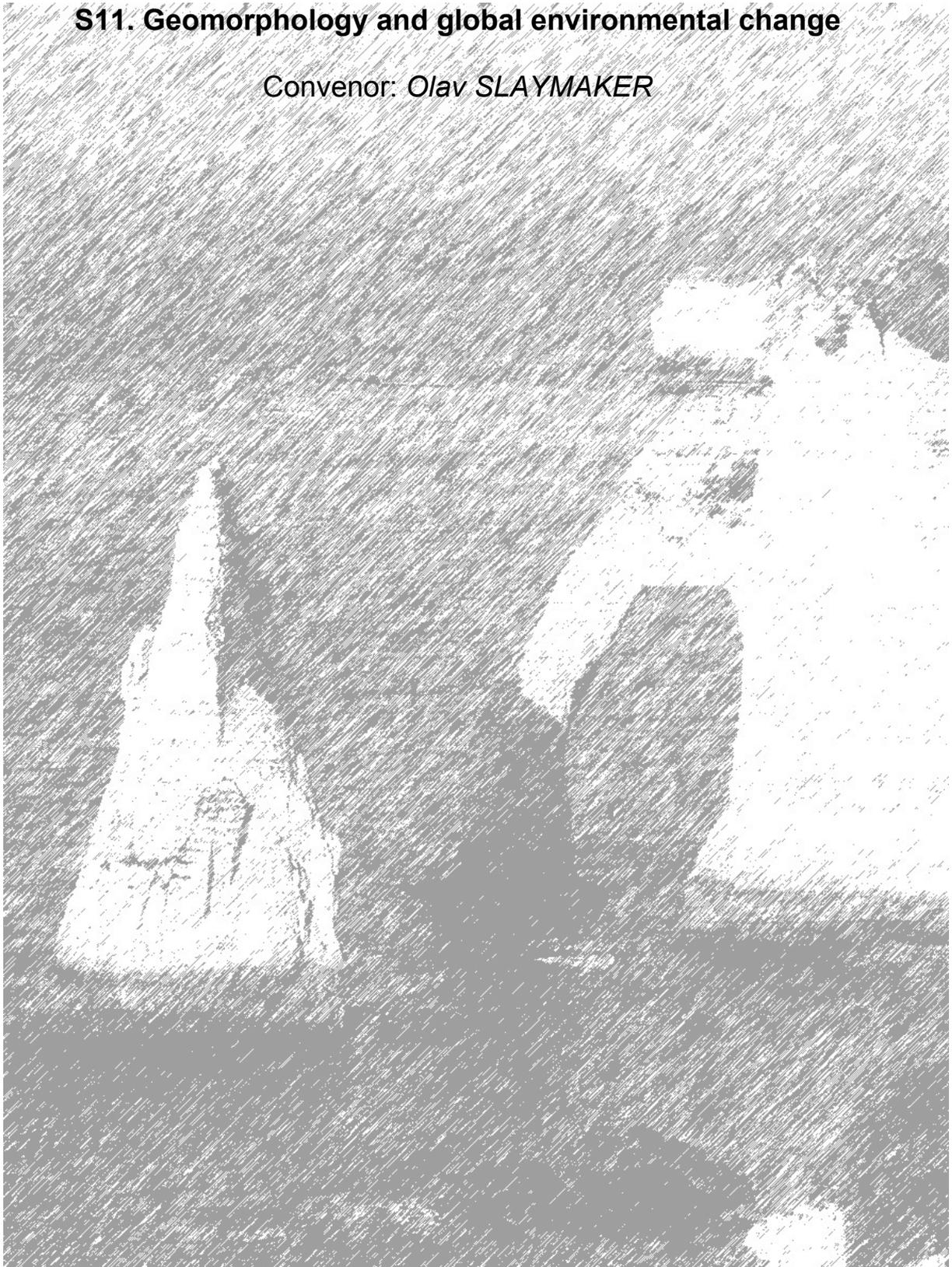
(1) *Birkbeck, University of London, LONDON, UNITED KINGDOM* ; (2) *University of Durham, DURHAM, UNITED KINGDOM*

Understanding landscape processes over long timescales is increasingly important for climate change adaptation planning. Whilst most planners plan for the near-term (c. 50 years), there is an increasing desire to embrace planning solutions that do not close off options for the future. Since even before 2100 we may see up to 6°C temperature rise it is essential to look at Quaternary scale changes. Past analogues are not close enough to future possibilities, therefore numerical modelling is an important way of creating long-term projections. However, most landscape models are designed to work over a narrow range of climate conditions. There has also traditionally been a gulf between the timescales investigated for understanding landscape processes and those relating to sediment sequences. Thus, monitoring of sediment transport occurs at scales of minutes to days, with 'long-term' monitoring programmes up to a few tens of years only. In contrast, sedimentary sequences span hundreds to tens of thousands of years. Working out how small-scale processes 'sum' to produce the sedimentary sequences that are observed is potentially a very effective use of numerical modelling but most numerical models are applied over shorter timescales. Many models are also applied to abstract landscapes. It is therefore important to apply numerical models over a longer timespan and larger climatic fluctuations, evaluating it against geological data. In this case the development of a river catchment over the last glacial / interglacial cycle (c. 135,000 years) is modelled. Through this pilot study the challenges of addressing this time-scale gap are explored. The geological sequences are from a low-lying river catchment in the northern Fenland, eastern England and contain both fossil material providing evidence of local climate change and sedimentological evidence of system change. They are dated using both OSL and radiocarbon. The modelling was undertaken using a spatially distributed reduced-complexity cellular model.



**S11. Geomorphology and global environmental change**

Convenor: *Olav SLAYMAKER*





## Oral presentations:

### **The role of geomorphology in global environmental change**

SLAYMAKER O.

*Department of Geography, University of B.C., Vancouver, CANADA*

Huge resources have been channeled into research on atmospheric and oceanic system changes. But we happen to be located on the terrestrial surface and our civilization depends heavily on the top few metres of regolith and on the ecosystem it nurtures. Both biogeochemical and social systems are built on the back of soils. Fifteen percent of global soils have been removed and an unknown but significant percentage has been degraded. Remediating degraded soils may take hundreds of years, but reconstructing soils requires thousands of years. The changing terrestrial environment, which is at the core of geomorphological research, should receive greater attention within the global environmental change community. The key geomorphological issues revolve around the changing amount and forms of energy expenditure as well as the changing amount and forms of mass fluxes at and close to the terrestrial surface. The general question that arises is "what critical, geomorphically relevant measures or indices adequately reveal conditions or trends in the terrestrial environment?"

\*\*\*\*\*

### **A Protocol to develop an environmental fragility map: a case study from angra dos reis and paraty municipalities, Rio De Janeiro State, Brazil**

GUERRA A.(1), BEZERRA J.(2), FULLEN M.(3), JORGE M.(1)

*(1) Federal University of Rio de Janeiro, RIO DE JANEIRO, BRAZIL ; (2) State University Maranhao, SAO LUIS, BRAZIL ; (3) University of Wolverhampton, WOLVERHAMPTON, UNITED KINGDOM*

A protocol to make an environmental fragility map is presented, based on a case study in Angra dos Reis and Paraty Municipalities, Rio de Janeiro State. Four types of data are considered: soils, land use, total annual rainfall and slope angle. The main characteristics include the *Sierra do Mar* mountain range, with steep slopes and shallow soils, fringed by a narrow coastal plain. Total annual rainfall ranges between 1,427-2,343 mm. The main soil types are Entisols, Inceptisols and Oxisols. Slope angles vary between 0-5 degrees on the coast and fluvial plains, to >45 degrees in the mountains. The main land uses are: urban, cattle rangeland, tropical forest and mangrove swamps. The used data were abstracted from the SRTM (2004), and the Brazilian Geographic Institute (air photos taken in 2005, at 1:25,000 scale). Using these data and ArcGis 9.3, four maps have been made, to assess environmental fragility. Using the function Raster Calculator of the Spatial Analyst tool, weights have been attributed to each variable: land use (0.3), soils (0.3), rainfall (0.2) and slope angle (0.2). Based on these weights an Environmental Fragility map has been made, with five classes: very low (38.13% cover), low (25.98%), medium (27.65%), high (3.83%) and very high (4.41%). The data show the dominant role of tropical forest, which covers ~90% of the area, protecting the environment against degradation. Therefore, >90% of the area corresponds to very low, low and medium fragility. Despite some steep mountain slopes, the forest protects these slopes from land degradation; and these environments are either in the low or very low fragility classes. The results show that high and very high classes correspond to high rainfall amounts (>2,000 mm), Entisols and Inceptisols, slope angle between 6-15 degrees and the land uses cattle rangeland and urban areas. Environmental fragility mapping has the potential of being a valuable tool to analytically target priority areas for soil conservation.

### Self-organising change? Considerations on causality

V. ELVERFELDT K.(1), EMBLETON-HAMANN C.(2), EGNER H.(1)

(1) Department of Geography and Regional Studies, KLAGENFURT, AUSTRIA ; (2) Department of Geography and Regional Studies, VIENNA, AUSTRIA

Commonly, global environmental change is understood as a matter of cause and effect: There are several external natural as well as human-induced causes which drive the processes of change within a system. This cause-and-effect-relationship is also used for the interpretation of geo-archives: An erosion event of high magnitude is assumed to be caused by external drivers like extreme rainfall events. These relationships require linear relation between driver and response. From the perspective of self-organising systems, the situation can be interpreted in a different way: Self-organisation, understood as a complex of internal processes which lead to a specific spatial structure (or pattern) of a system, can result in a similar situation of erosional deposits. Changing framework conditions may drive a system towards an instability threshold, the so-called bifurcation point. At this point, probabilistic theories fail as the system is driven "by chance": Processes can come into action without any (evident) cause. As a result, a single – and especially a single external – cause for a certain system reaction cannot be determined anymore. For example, many studies indicate that sediment transport fluctuates strongly despite steady boundary conditions. This is crucial for environmental change studies for two reasons: (1) Interpretations of geoarchives have to consider that they may have been formed without any changes of external conditions and without a distinctive (internal or) external cause. (2) Current changes of system dynamics may be the result of self-organisation. Hence, geomorphological studies on environmental change should also lay a strong focus on internal system dynamics instead of primarily focusing on external drivers. It has to be acknowledged that self-organising systems are adapted to, but by no means determined by their environment.

\*\*\*\*\*

### Can treeline dynamics in the afro-alpine north Ethiopian highlands be used as proxy to study climate change?

JACOB M.(1), FRANKL A.(1), BEECKMAN H.(2), GUYASSA E.(3), MELES K.(3), NYSSSEN J.(1)

(1) Department of Geography, Ghent University, GHENT, BELGIUM ; (2) Royal Museum for Central Africa, Laboratory for Wood Biology and Xylarium, TERVUREN, BELGIUM ; (3) Institute of Geo-information and Earth Observation Sciences, Mekelle University, MEKELLE, ETHIOPIA

Worldwide average temperatures have risen during the past century, a change that is most prominent and rapid at high altitudes and latitudes. The composition and extension of the temperature sensitive treelines within these zones are potentially responsive to climate warming. In contrast to dynamics at higher northern latitudes, treeline dynamics in the tropics are scarcely investigated. The purpose of this paper is to reconstruct the extent of the upper *Erica Arborea* limit since the 1960s in the semi-arid to subhumid mountain climate zone of the north Ethiopian highlands: Leb Amba of the Abune Yosef Mt. range (12°04'N, 39°22'E, 3952 m a.s.l.) and the Ferrah Amba Mt. (12°52'N, 39°30'E, 3939 m a.s.l.). The present upper and physiognomic treeline limits were recorded in the field (February, 2012) and compared to previous treeline elevations studied from aerial photographs (1970s-1990s) and Landsat images (1980s-present). Photogrammetric restitution of the aerial photographs resulted in DEM models and orthophotographs that enable comparison between historical and present treelines. For the Landsat imagery, an NDVI ratio based on ground truthed Landsat images is used to detect treeline dynamics as well as changes in forest density. To detect these NDVI values of treeline forests are compared to a stable reference forest. Preliminary results indicate that the elevation of the *Erica* treeline increased, which has to be understood against important land use changes on the mountains and regional temperature rise.

Key words: Treeline dynamics, Climate Change, DEM, NDVI ratio, North Ethiopian Highlands

### Increasing frequency of geomorphic disasters: climate change or geomorphic change?

BRUSCHI V.(1), FORTE L.M.(2), HURTADO M.(2), BONACHEA J.(1), DANTAS-FERREIRA M.(3), RIVAS V.(1), GÓMEZ-AROZAMENA J.E.(1), REMONDO J.(1), CENDRERO A.(1)

(1) Universidad de Cantabria, SANTANDER, SPAIN ; (2) Universidad Nacional de La Plata, Argentina, BUENOS AIRES, ARGENTINA ; (3) Universidade Federal de São Carlos, SAO PAULO, BRAZIL

Different types of data obtained by the authors in the last 20 years have led to the formulation of some concepts and a hypothesis related to the present evolution of geomorphic processes. Data gathered included landslide frequency, sedimentation rates, river discharge, rainfall and different indicators of human influence on land surface. Results obtained indicate that there is an important and growing *human geomorphic footprint*, which is causing a *global geomorphic change* reflected by the intensification of geomorphic processes. Geomorphic processes' intensification appears to be a characteristic of the Anthropocene, and is particularly marked since mid-20<sup>th</sup> century, coinciding with the great demographic and economic post World War II expansion. This "great geomorphic acceleration" does not seem to respond to climate change, but to human modification of land surface. A hypothesis, based on the driving force-pressure-state-impact-response conceptual model, was formulated to explain the results indicated.

If the hypothesis were correct, human influence and global geomorphic change should be reflected differently in the different types of natural hazards and risks. The number of all types of natural disasters registered in databases should be expected to increase with time, due to both growing human exposure and better data-gathering. Seismic and volcanic disasters should increase least. Climatic disasters, affected by the greater frequency of extreme events related to climate change, should increase more. Finally, geomorphic disasters, affected by both climate and geomorphic change, should increase most. Global data on the frequency of those disasters are presented and compared with data on potential natural and human drivers. The results obtained are to a very great extent coherent with the hypothesis and reinforce the idea that mitigation of geomorphic disasters should not focus mainly on climate, but rather on land-use issues.

\*\*\*\*\*

### La méthode du transect fixe pour la détermination du bilan sédimentaire et la caractérisation de sa variation spatio-temporelle : application dans une région aride du Sud tunisien

QUERCHEFANI d.(1), CALLOT Y.(2), DELAITRE E.(3), ABDELJAOUED S.(4)

(1) institut des regions arides, MEDENINE, TUNISIA ; (2) Faculté de Géographie, Histoire, Histoire de l'Art, Tourisme, Université Lumière, Lyon2, LYON, FRANCE ; (3) Institut de Recherches pour le Développement, MONTPELLIER, FRANCE ; (4) Faculté des Sciences de Tunis, TUNIS, TUNISIA

Les travaux sur l'hétérogénéité spatio-temporelle de la surface en relation avec l'érosion éolienne sont peu nombreux. Ce sont des mesures ponctuelles et instantanées des paramètres physiques, prenant peu en compte les formes éoliennes comme marqueurs de dynamique et de changement du milieu. Ceci constitue un handicap dans l'analyse de ces espaces, et notamment de leur fonctionnement. La conception de méthodes pour la compréhension de l'organisation spatiale spécifique des paysages éolisés et leur suivi spatio-temporel est donc essentielle. Cela pour pouvoir quantifier des bilans sédimentaires annuels et saisonniers sur des sites peu instrumentés ne bénéficiant pas d'enregistrements automatiques de variables météorologiques.

Dans ce travail, nous proposons une méthode pour la quantification multi-temporelle du bilan sédimentaire à l'échelle d'un transect. Elle a l'avantage de lier la quantité de sable déposé/érodé avec le changement des états de surface. Elle consiste à délimiter puis confronter les zones d'accumulation et de déflation du matériel sableux avec celles à bilan sédimentaire positif et négatif. Pour ce faire, les techniques d'analyse linéaire de point quadrat et de nivellement par cheminement ont été appliquées sur un transect de 500 m de longueur pendant 2 années.

Les résultats montrent que le bilan global est positif avec toutefois des fluctuations saisonnières. Les zones d'accumulation peuvent être réellement des zones de déflation, malgré la présence d'indicateurs qui témoignent du contraire. Inversement les zones de déflation peuvent être réellement des zones d'accumulation. Ce travail est un apport pour la quantification des budgets sédimentaires à l'échelle stationnelle. Il permet, dans le cadre d'observatoire, d'harmoniser les méthodes de collecte/analyse des données pour produire régulièrement une synthèse de la situation de l'environnement local dans un format qui permet de faire des comparaisons aux échelles aussi bien temporelles que spatiales.

**Response of morphoclimatic system dynamics to global changes and related geomorphological hazards: outline and perspectives of a national Italian research project**

BARONI C.(1), ANZIDEI M.(2), DALLA FONTANA G.(3), DEL MONTE M.(4), FREPPAZ M.(5), MASTRONUZZI G.A.(6), SMIRAGLIA C.(7), SOLDATI M.(8)

(1) Dipartimento di Scienze della Terra, University of Pisa, PISA, ITALY ; (2) Istituto Nazionale di Geofisica, Centro Nazionale Terremoti, ROMA, ITALY ; (3) TESAF - Dipartimento Territorio e Sistemi Agro-forestali, University of Padua, PADUA, ITALY ; (4) Dipartimento di Scienze della Terra, University of Roma La Sapienza, ROMA, ITALY ; (5) Dipartimento di Scienze Agrarie Forestali e Alimentari, University of Turin, TURIN, ITALY ; (6) Dipartimento di Scienze della Terra e Geoambientali, University of Bari Aldo Moro, BARI, ITALY ; (7) Dipartimento di Scienze della Terra, University of Milan, MILAN, ITALY ; (8) Dipartimento di Scienze Chimiche e Geologiche, University of Modena e Reggio Emilia, MODENA, ITALY

Global landscape change and trends of future change are unfilled niches in global change research. We know fairly well how climate has changed in the past with sufficient time resolution, but we do not know how various geomorphological systems in Italy replied or will respond due to their complex dynamics and resilience. Global changes have a strong influence on cryosphere dynamics, on slope evolution, on shoreline variations and, more and more frequently, provoke extreme pluviometric events, floods, sea storms and geomorphological instability.

The main themes of this research project are: i) understanding the effects that global changes have on the sensitive and wide-ranging morphoclimatic systems typical of the Italian peninsula, ii) the ability to assess the effects of these changes on the environmental system through the elaboration of hazard and geomorphological risk scenarios. The most important objectives of the project are: a) the definition of the effects of climate change on the cryosphere in the Italian Alps, b) the characterization of the instability caused by global changes in different morphoclimatic contexts, c) the collection and comparison of series of climate and environmental data sets, and d) the prediction of future scenarios of instability induced by global changes. The systematic collection of environmental data in different morphoclimatic contexts, both through direct monitoring system, and through indirect techniques of investigation, will allow us to reconstruct the historical sequence of key events that have characterized the interactions between natural environment and global changes in Italy. The variety of the morphoclimatic contexts analyzed in this project will provide a significant contribution to the knowledge of the geomorphological setting of the Italian territory in different geographic and climatic regions and of the state of activity of the morphogenetic agents that have guided and will guide landscape modelling.

\*\*\*\*\*

**Humans have impacted atmospheric C-exchange since the introduction of agriculture by changing the geomorphic cascade**

VERSTRAETEN G.(1), VAN OOST K.(2), BROOThAERTS N.(1), NOTEBAERT B.(1), DOETTERL S.(2), WIAUX F.(2), SIX J.(3)

(1) KU Leuven, LEUVEN, BELGIUM ; (2) Université Catholique de Louvain, LOUVAIN-LA-NEUVE, BELGIUM ; (3) UC Davis, DAVIS, UNITED STATES

Early human impact on the global C cycle through deforestation has been demonstrated and it is estimated that between 50 and 357 Pg C have been released from vegetation and soils to the atmosphere in the pre-Industrial era. However, the contribution of erosion and sediment storage on C exchange between terrestrial ecosystems and the atmosphere has not been accounted for, although long-term sediment budget studies show that large volumes of soil material have been mobilized since the introduction of agriculture. Furthermore, through human impact also the geomorphic setting itself has changed thus altering ecosystems such that the C exchange with the atmosphere changed as well. For the 780 km<sup>2</sup> Dijle River catchment in the western European loess belt, the impact of human induced soil erosion on C exchange with the atmosphere was quantified by combining a sediment budget with detailed inventories of C in soils and sediments. For the period 4000 BC to AD 2000 it was estimated that anthropogenic erosion induced a net C sink, offsetting 39% of the C emissions due to land cover change since the advent of agriculture. However, this sink is limited by a significant loss of buried C in colluvial settings lagging the burial: ca. half of the original C buried in the colluvial stores remains after 500 years. Contrary to colluvial settings, C burial in alluvial settings appears to be more conservative, which is most probably related to higher autochthonous production and preservation rates in wet floodplain soils. Data from the floodplain sediments also indicate that human induced high rates of minerogenic sedimentation since the Middle Ages were able to capture more C in the floodplain than the Mid-Holocene natural wetlands through peat formation. The result for the Dijle River catchment, with a long history of human impact, can be used to estimate the longer term impact of the major agricultural expansion of the 19th and 20th century worldwide on global C budgets.

## Pre-Columbian Anthropogeomorphic Impacts in North America

JAMES A.

*University of South Carolina, COLUMBIA, UNITED STATES*

The geomorphic effectiveness of humans is linked to rates of change and the resiliency of environmental systems. Concepts of Pre-Columbian anthropogenic change in the New World have been revised recently. The 'Pristine Myth' of benign land use has been challenged by recognizing large populations that substantially altered environments. Such revisions assess early anthropic changes to ecological and climate systems, but conflict with many geomorphic studies that show slight or negligible pre-European anthropic erosion or sedimentation. Numerous studies in North America and Australia, for example, document well-developed floodplain soils abruptly overlain by deep historical alluvia. Many geomorphologists have inferred relatively stable geomorphic conditions prior to European land-use changes from these alluvial records. Stream restoration projects often assume pristine geomorphic conditions by describing reference reaches as natural or undisturbed. Recognition of legacy sediment may also belie this assumption.

Studies of floodplain and lacustrine sediment in North America are summarized to compare rates of sedimentation before and after European arrival. The focus on sediment separates geomorphic from ecological impacts. Evidence of early sedimentation in North America is mapped and compared to maps of pre-Columbian agriculture. Spatial patterns of pre-Columbian anthropogeomorphic effectiveness are non-uniform. Sedimentation was substantial in some areas, e.g. population centers in Meso-America, but negligible in others. Subsequently, European deforestation, agriculture, milling, wetland drainage, and mining increased sedimentation rates by an order of magnitude in some basins but had little effect in others. Assumptions that all environmental change had geomorphic responses over-simplify and exaggerate anthropogeomorphic change, which was less than ecologic change and often far less than geomorphic changes induced later by some European settlements.

\*\*\*\*\*

## Quaternary Marine Terraces on Cyprus: Constraints on Uplift and Pedogenesis, and the Geoarchaeology of Palaipafos

ZOMENI Z.(1), NOLLER J.-.S.(2), IACOVOU M.(3)

*(1) Cyprus Geological Survey, LEFKOSIA, CYPRUS ; (2) Oregon State University, CORVALLIS, UNITED STATES ; (3) University of Cyprus, LEFKOSIA, CYPRUS*

This work focuses on the coastal environment of Cyprus and investigates coastal uplift, geomorphology, pedology and landscape change. It will address the island-wide issue of Quaternary uplift, the rates of pedogenesis in southwestern Cyprus and the landscape response to human occupation for the last 4000 years in the area of Kouklia–Palaipafos. Uplift of Cyprus during the Quaternary was estimated with dated marine terraces and varies along the coast in response to deformation on different geological structures. Rates of pedogenesis were studied and estimated using soils on these dated surfaces. Uplifted marine terraces present the opportunity to get a good estimate for the time factor in the soil-forming function because the time of subaerial exposure for these surfaces is well known. A soil-development index (PDI) served as a proxy for age. Prior soil surveys note rubification and calcium carbonate accumulation as two distinct characteristics of the area's soils and thus proved again to be strong PDI indicators. The southwestern part of Cyprus was chosen for this part of the study due to the availability of soil and new geological data and, most importantly, because the uplift evident in this area suggests numerous marine terraces well-separated in time for developing a reliable soil-age relationship (chronofunction). The last part focuses on a small part of southwestern Cyprus, the ancient polity of Palaipafos. Established in the second millennium BC, at the beginning of the of the Late Bronze Age, most probably prospered from the production and trade of copper and later became known for its temple to the goddess of Aphrodite. The diversity of the geomorphological units on the landscape of Palaipafos is evidence for the tectonic and climatic dynamics of its environment contributing to a shifting ancient harbour. Field investigations have benefited ongoing archaeological excavations by identifying new promising sites of previously unexcavated monuments.

## **Sea Level Variability, Shoreline Response and Global Environmental Change: Observations from Eastern England**

*BROOKS S.(1), SPENCER T.(2)*

*(1) Birkbeck, University of London, LONDON, UNITED KINGDOM ; (2) University of Cambridge, CAMBRIDGE, UNITED KINGDOM*

It is well known that global environmental change will drive sea level rise and it is commonly assumed that sea level rise will lead to enhanced shoreline retreat and coastal land loss. However, moving from global-scale inference to regional and local consequences continues to be problematic for several reasons. Firstly, sea-level rise can be measured on an annual timescale but its influence on coastal landforms can only be demonstrable at timescales of decades to centuries. Secondly, even the longest historical datasets on shoreline response generally do not reveal linear trends that might be associated with secular sea level rise, because signals from decadal-scale variability in other driving factors generally overwhelm any such trend. Given that coastal change is event-driven, near-future changes in the direction and intensity of wave climates, and magnitude-frequency characteristics of storms are potentially of greater significance to shoreline response. This assertion is contested (are 'superstorms' really the 'new normal'?) as well as being poorly-specified in atmosphere – ocean models. Thirdly, in addition to sea level variability, waves and storms, coastal retreat is driven by other natural factors – particularly sediment supply - which only weakly (if at all) relate to the main drivers of global change. Anthropogenic activity can intensify these controls on coastal change. Finally, the net impact of this suite of process controls ultimately depends upon accommodation space, the ability of coastal landforms to migrate to new locations in the near-coastal zone. This paper uses the rapidly-retreating soft rock cliffs of East Anglia, UK, to consider these complex challenges. The cliffs are considered in their response to sea level rise; the dynamic of a major atmospheric perturbation, the North Atlantic Oscillation; and in their changing contribution to regional sediment budgets as retreat interacts with a changing coastline topography.

\*\*\*\*\*

## **The implications of last decades sea level variations for coastal erosion: a review**

*LE COZANNET G.(1), GARCIN M.(2), CAZENAVE A.(3), THOMAS Y.F.(4), LAVIGNE F.(4)*

*(1) BRGM / Univ Paris 1 / LGP, FRANCE, FRANCE ; (2) BRGM, ORLEANS, FRANCE ; (3) LEGOS, TOULOUSE, FRANCE ; (4) LGP, PARIS, FRANCE*

Shoreline erosion is a consequence of the coupled effects of waves and currents on coastal sediments, either available locally or provided by adjacent coastal sedimentary units. In the future, sea level rise due to anthropogenic climate change is expected to exacerbate coastal erosion, but the actual role of this ongoing process in present day's shoreline mobility is still debated.

Starting from a review of papers previously published, we identified two barriers to a better understanding of the actual consequences of contemporary sea level rise in coastal erosion. First, actual sea levels along the coast are generally only known for a few areas where tide gauges are available, whereas subsidence or uplift is a common feature of many coastal areas. Secondly, there is a lack of well-established method for attributing shoreline mobility to a specific factor or to a combination of causes. At present, such methods range from field expertise, analysis of data to schematic or physical modeling. However, no model is presently able to represent accurately all processes accounting for coastal hydro-sedimentary processes.

In spite of these limitations, this review highlights that sea level rise rates in the order of a few millimeters per year are generally not considered as a dominant cause for shoreline erosion. On the contrary, most studies attribute it to the effects of waves, storms, variations in sediment supply and human activities.

## Rise and Fall of Palaeolake Megachad

*BRISTOW C.(1), ARMITAGE S.(2), DRAKE N.(3)*

(1) Birkbeck University of London, LONDON, UNITED KINGDOM ; (2) Royal Holloway University of London, LONDON, UNITED KINGDOM ; (3) King's College University of London, LONDON, UNITED KINGDOM

Palaeolake Megachad lies within central North Africa, at its peak it covered an area in excess of 350,000 km<sup>2</sup> and extended from latitude of 11° to 18° N, an area that currently spans climatic belts from hyperarid Sahara through the Sahel to humid tropical latitudes. At present the Lake Chad is reduced to less than 1% of its maximum extent and the northern sub-basin the Bodélé Depression is completely dry. During the last glacial maximum both basins dried completely. The lake record of climate change is important because it is located within the middle of the African continent far from any marine cores, and due to the extent of its catchment it is more representative of regional moisture balance than small lakes. In addition, most of the lake is shallow and thus sensitive to changes in hydrology.

In this paper we document the rise and fall of palaeolake megachad through the latest Pleistocene interglacial-glacial and the Holocene. In order to determine the timing of lake high-stands and low-stands we have obtained 31 OSL ages from lake shoreline beach ridges as well as dunes that have been flooded when the lake levels rose.

We identify last interglacial (MIS5) high-stand shorelines along the southern margins of palaeolake Megachad. This humid period was followed by a basin wide regression during the last glacial Maximum (LGM) accompanied by aridity with desert conditions prevailing. The Sahara expanded south and sand dunes driven by northeasterly winds migrated right across the basin floor. A return to more humid conditions at the end of the LGM resulted in a rise in the lake levels with lacustrine transgressions flooding over the dunes. Beach ridges provide evidence for early to mid-Holocene highstands. Falling lake levels from the mid-Holocene onwards are documented by lower elevation shorelines and a delta at the where waters overflowed from the southern Chad basin into the northern Bodélé Depression.

\*\*\*\*\*

## Aggradation/erosion stages of tufa dams during Holocene: a palaeoclimatic comparison between northern Ethiopia and central Italy

*DRAMIS F., FUBELLI G.*

*Department of Geological Sciences, Roma Tre University, ROME, ITALY*

The <sup>14</sup>C dating of buried soils and peat layers from tufa dammed swampy-lacustrine sequences allows outlining the aggradation/degradation phases of Holocene tufa dams in Central Mediterranean and East Africa. In northern Ethiopia the aggradation of tufa dams started before 9510±100 <sup>14</sup>C yr BP. From 4780±70 to 2380±50 <sup>14</sup>Cyr BP, alternating stages of dam erosion/aggradation occurred, eventually followed by dam incision down to the present valley floors. *In the first stages, the deposition rates of tufa were likely higher, enough to allow the formation of a relatively deep lacustrine basin upstream. In Central Italy the <sup>14</sup>C dating of organic-rich layers from the backfill sequences of Holocene tufa dams indicates that the deposition of tufa first occurred prior to 8240±75<sup>14</sup>C yr BP. Since 3760±60 <sup>14</sup>C yr BP a sequence of alternating periods of erosion and aggradation occurred. After 2825±60<sup>14</sup>C yr BP fluvial incision cut the dam down to the present valley bottom. Also in this case, the first stages of dam aggradation were characterized by deposition rates high enough to form a lacustrine basin upstream.* The occurrence of comparable trends of tufa dam aggradation/erosion in both Mediterranean Europe and East Africa seems to indicate that climatic fluctuations have been responsible for significant environmental changes at a supra-regional scale. *The high rates of tufa deposition in the lower Holocene and their decline in the mid-late Holocene, followed by the complete incision of the dam, seem to provide some support to the ground/surface thermal disequilibrium model of tufa aggradation/erosion (Dramis et al., Physics and Chemistry of the Earth, Part-A, 24/10, 1999). Consideration should be also given to the incidence of wet/dry climate changes and the middle-late Holocene aridification trend in both regions. In this context, the short-lived cycles of erosion/aggradation recorded in both areas could be explained by the occurrence of high frequency dry/wet climate fluctuations.*

### **Infilling constraints of the Estuary of River Alcabrichel since Middle Holocene**

RAMOS-PEREIRA A.(1), RAMOS C.(1), TRINDADE J.(1), DANIELSEN R.(2), MONGE-SOARES A.(3), PORTELA P.(3), MARTINS J.(4)

(1) Centre of Geographical Studies, Institute Geography Spatial Planning, Univ.Lisbon, LISBON, PORTUGAL ; (2) Laboratório de Arqueociências, LARC/CIBIO/InBIO, DGPC, LISBON, PORTUGAL ; (3) Laboratório Radiocarbono, IST/ITN,Univ. Técnica Lisboa, LISBON, PORTUGAL ; (4) Laboratório Radiocarbono, IST/ITN,Univ. Técnica Lisboa; Univ. Algarve, LISBON, PORTUGAL

The mouth of the River Alcabrichel (Portuguese Estremadura) is a complex estuary conditioned by a diapiric tectonic (Caldas da Rainha fault). The estuary has two alluvial plains separated by a limestone gorge, and was selected to evaluate the balance between fluvial and marine influences, the responses to climatic fluctuations and the impact of human activities in the drainage basin, during the last 5000yrs.

Several hand-operated mechanicalcores were extracted in sediments of the two alluvial plain estuary, of which two are discussed here reaching respectively depths of 7.70m and 5.03m.

A multidisciplinary approach was performed based on a detailed sedimentological analysis of 1cm core samples in order to identify: (i) sediment textural changes including their origin (marine or fluvial), helping to establish the sequence of wet and dry periods during the middle and upper Holocene; (ii) pollen and npp that provide information about the climatic and environmental changes natural or human induced ; (iii) ratios of stable isotopes in fine sediments, to define the sources of organic matter (marine or continental); and (iv) their absolute chronology using radiocarbon dating.

The results show that geomorphologic conditions constitute a strong control on the generation of new meso features and, consequently, on the estuary evolution. An old estuary exists inland the gorge, remaining active until c. 2000 BP. The genesis of the distal section occurred since then, where the 1755 tsunami play an important role. The balance between sea level change, climatic change and anthropogenic influences on landscape evolution will be discussed.

#### *Acknowledgements*

This research was funded by Project PCDT/CTE-GIX/104035/2008–FMI 5000-Environmental changes: Fluvio-marine interactions over the last 5000 yrs, from Portuguese Science and Technology Foundation (FCT-MCTES). Martins acknowledges the PhD grant SFRH/BD/45528/2008 and P. Portela the Projects scholarship from the same institution.

\*\*\*\*\*

### **Sediment fluxes on steep LIA moraine slopes in the Central Austrian Alps**

BECHT M., HILGER L., DUSIK J.M., NEUGIRG F., HECKMANN T., HAAS F.  
*Department of Physical Geography, EICHSTATT, GERMANY*

Melting glaciers and degrading permafrost lead to a weakening of moraine wall stability and as a consequence to an ever increasing availability of sediment for geomorphic processes in high mountain areas. In combination with the predicted change in frequency-magnitude relationships of summer precipitation events, this forms the basis for highly intense fluvial reworking of sediment and debris flow activity.

The work presented here is part of the joint project PROSA (High-resolution measurements of morphodynamics in rapidly changing PROglacial Systems of the Alps) which deals with the generation of the sediment budget for an alpine catchment in the Austrian Alps.

Multitemporal airborne and terrestrial LiDAR data were used for the detection of volume changes on lateral moraine slope sections within the proglacial zone of the Gepatschferner, Kaunertal, Ötztal Alps. Six test sites along a chronosequence of deglaciation on the LIA lateral moraine were selected and monitored repeatedly using a terrestrial laser scanner to acquire digital terrain models of high spatial and temporal resolution.

Sediment budgets for each time interval and lateral moraine subsection were calculated, and different glacial stages digitized from historical maps and multi-temporal orthophotos were used to estimate the respective time passed since deglaciation. This space-for-time substitution approach made it possible to calculate section specific erosion rates, to calibrate a sediment exhaustion curve for the Gepatschferner lateral moraine and to monitor the development of morphometric parameters of the gullies dissecting the lateral moraines.

## Physical Geography, Geomorphology and Global Environmental Change: Perspectives from the Developed and Developing World

*MEADOWS M.E.(1), SLAYMAKER O.(2), MOREIRA-MUNOZ A.(3), BRIERLEY G.(4), CLIFFORD N.(5), ALCANTARA-AYALA I.(6)*

*(1) University of Cape Town, CAPE TOWN, SOUTH AFRICA ; (2) University of British Columbia, VANCOUVER, CANADA ; (3) Pontificia Universidad Catolica de Chile, SANTIAGO, CHILE ; (4) University of Auckland, AUCKLAND, NEW ZEALAND ; (5) King's College, University of London, LONDON, UNITED KINGDOM ; (6) National Autonomous University of Mexico, MEXICO CITY, MEXICO*

In science there is a tension between the need for detailed, highly focused work on specialised components of the physical environment (as in geomorphology) and more generalised, integrative approaches that attempt to resolve complex multi-dimensional and trans-disciplinary problems (as in physical geography). The tension is further amplified by the requirement and, in certain situations, imperative to conduct research that is applied and addresses particular societal, governmental or corporate needs. Applied research is, however, prone to conditions set by funders and may not always encourage the pursuit of fundamental scientific problems that are essential to the advance of the discipline as a whole. The socio-economic and political context may also influence the degree to which – and type of – physical geography research that is feasible in a particular country. This paper explores the status of physical geography and geomorphology in several developing and developed world settings with a view to comparing the challenges of pursuing the science across a variety of national contexts. A number of examples of the status of the discipline in diverse contexts are provided and the trajectory of physical geography is contemplated in each of these circumstances. Physical geographers and geomorphologists clearly need to engage with issues around the wider problems of global environmental change and the ICSU/ISSC 'Future Earth' framework and this, along with other approaches, may represent an opportunity to improve the level of funding for physical geography and geomorphology and to attract higher student enrolments without slavishly bending to the obligations inherent in institutional or government contract research.

\*\*\*\*\*

### **Poster presentations:**

#### **Seven years of rockfall monitoring in the Mont Blanc massif to validate the relationship between permafrost degradation and rockfall**

*DELINE P., RAVANEL L.*

*EDYTEM Lab, Université de Savoie, CNRS, LE BOURGET-DU-LAC, FRANCE*

Rockfall is a major natural hazard in high mountain regions and its frequency is growing, especially since two decades. Given the lack of systematic data on rockfalls, the relationship between permafrost degradation and rockfall has however remained difficult to assess.

Data on rockfall were acquired for 2003 and the period 2007-2012 thanks to a satellite image of the Mont Blanc massif and a network of observers (mountain guides, hut keepers and mountaineers) in its central part (57 % of massif area), respectively. To ensure a higher completeness of the inventory, fieldwork is conducted every fall, whereas Summer 2003 rockfalls in the whole massif were identified from their supraglacial deposits. Rockfall parameters were calculated in a GIS.

182 and more than 330 rockfalls (maximal volume: 43 000 m<sup>3</sup>) occurred during the Summer 2003 heatwave and the period 2007-2012 respectively.

Most of the rockfalls occur during the hottest months of the year. Modelling suggests the presence of permafrost in nearly all of the affected rockwalls, and massive ice was observed in at least 45 scars during the period 2007-2012. The very high frequency of the Summer 2003 rockfalls can only be explained by permafrost degradation. Several other elements support permafrost degradation as main triggering factor of rockfall: mean elevation of 2003 and 2007-2012 scars (3335 m a.s.l.) is much higher than the mean rockwall elevation (2880 m a.s.l.) while very few detachments occur below 3000 m a.s.l., which suggests that the main triggering factor is not ubiquitous; most affected altitudinal belt is 3200-3600 m a.s.l., with modeled warm permafrost (> -2°C); the hotter the summer, the higher the scar elevation; sharp contrast in scar elevation between north and south faces; rockfall especially affects topography prone to permafrost degradation such as pillars, spurs and ridges. These results suggest that the permafrost warming is the major rockfall triggering factor at high elevation.

**Role of wind activity in the forest opening in Québec's southern portion of the spruce lichen woodland, Québec, Canada**

ROBITAILLE A.

Universite Laval, QUEBEC, CANADA

This study presents the impacts of wind activity following forest fires over several thousand square kilometres in the southern portion of the spruce lichens woodlands in the province of Québec. This phenomenon had not been studied, and compared to other regions of the Canadian boreal zone wind activity in this area it is unique in its intensity and progression.

Effects of wind, sand dunes and blowouts, occur in many areas between the 51st and 53rd degree of northern latitude, corresponding to the transition between the spruce-moss forest and spruce-lichen woodlands. The study uncovered huge areas composed of water-deficient sandy soils. There are indications that increased wind activity triggered by forest fires led to the development of aeolian erosion and sand dunes in this region. This phenomenon leads to the loss and degradation of forest soil and most likely contributes to opening up forest cover over a long period of time, notably by a return to a primary stage of soil development. According to our observations, wind effects increase following forest fires in this region. In addition, a hypothesis was derived that the effect of the wind in winter can damage the forest regeneration and maintains low density forests.

For the area under study as well as areas located further north, climate change scenarios predict that the 800 growing degree-day isotherm could shift northward. In theory, this would favour the northward expansion of black spruce forests. In this context of climate change, we describe the extent of wind activity to provide an overview of the situation and to understand its evolution over time, in connection with climate. For the coming decades, this extent of wind activity and the abundance of very dry soil could limit the northward expansion of black spruce forests and reduce the area of productive forest land.

\*\*\*\*\*

**Responses of *Pinus tabulaeformis* tree-ring to climatic metrics in Hasi Mountain, China**

LU R., JIA F., SHANG Y., GAO S., CHEN Y.

Key laboratory of environmental change and natural disaster, MOE, Beijing Normal University, BEIJING, CHINA

The transition zone between the Mu Us desert, the Tengger Desert and the Loess Plateau is sensitive to climatic changes. Former dendroclimatic researches have found that precipitation and temperature (especially that of the warm season) both played important roles to tree growth in this area. Therefore, it is necessary to select a suitable climatic metric as predictor of tree-ring width or to be reconstructed using tree-ring growth.

In this research, we collected *Pinus tabulaeformis* tree-ring cores from Hasi Mountain of China and analyzed responses of *Pinus tabulaeformis* tree-ring to different climatic metrics.

Correlations of tree-rings widths with precipitation and temperature suggested that most monthly precipitation had positive correlation with tree growth while temperature was negatively correlated, which indicated that precipitation and temperature both restrict the tree growth in Hasi Mountain. However precipitation or temperature alone could not well reveal the relationships between tree-growth and climate, therefore we try to look for a comprehensive index to reveal the response of tree-growth to moisture. Three indices including Walter index, de Martonne aridity index as well as PDSI were selected to further analysis.

The consistent results are found in correlations between tree-ring width and Walter index and de Martonne aridity index, but the correlations are low in single month which hardly pass the test, the correlations are stronger in combined month than in single months. Compared with these two moisture indices, the PDSI has the strongest correlation with tree-rings width during the whole period (from September of the previous year to September of the current year), all correlation coefficients were significant at the 0.01 levels, and the strongest correlation occurred in June-July. The upper analyses indicated that the PDSI was an appropriate index as predictor of tree-ring width and could be reconstructed in our study area.

**Aeolian activities during Holocene in the Qinghai-Tibet Plateau, China**WU Y.(1), ZHENG Y.(2), TAN L.(3)

(1) MOE Engineering Center of Desertification and Blown-sand Control at Beijing Normal University, BEIJING, CHINA ; (2) College of Real Estate, Beijing Normal University, ZHUHAI, CHINA ; (3) School of Geography, Beijing Normal University, BEIJING, CHINA

With the in-depth research of global change, the study of aeolian activities has become an important aspect of global change research. The aeolian deposit is widely distributed in the Tibetan Plateau, and it is significant to understand the characteristics of aeolian activities and increase the paleoclimatic data of the Tibetan Plateau with the study of aeolian activity process in Holocene. This work selected the middle reaches of Yarlung Zangbo River in southern Tibetan Plateau, and Gonghe Basin in north-eastern Qinghai-Tibet as study areas. By analyses of sedimentary facies, grain size, magnetic susceptibility, CaCO<sub>3</sub> and organic matter contents, dating with <sup>14</sup>C (including AMS <sup>14</sup>C) and OSL methods, the process of aeolian activities During Holocene was reconstructed. The results show that, 1) There are three cold events in 8.5-8.0 ka B.P., 4.3-4.2 ka B.P. and 3.5-2.6 ka B.P. in the Middle Reaches of Yarlung Zangbo River, there are four cold events in 5.5-5.0 ka B.P., 4.4-4.2 ka B.P., 3.0-2.1 ka B.P., 0.5 ka B.P. in Gonghe Basin. 2) Century-scale climatic events are similar in occurrence times both in southern and north-eastern Qinghai-Tibet Plateau, but both the start and end of the stable warm stage are earlier in southern part of the Plateau than those in east-northern part. The cold events are characterized by strong aeolian activities and sand dune activation. The stable warm stage in the warm mid-Holocene period is characterized by dune fixation and soil development.

\*\*\*\*\*

**Tree-ring based PDSI reconstruction from AD 1804 for the Hasi Mountain, northwestern China**GAO S., JIA F., LU R., SHANG Y., CHEN Y.

Key Laboratory of Environmental Change and Natural Disaster, Ministry of Education of China, Beijing Normal University, BEIJING, CHINA

A 206-year chronology was developed using *Pinus tabulaeformis* tree-ring data from Hasi Mountain in northwestern China. Based on the correlation analysis between tree-ring width and climate data, a June-July PDSI series from AD 1804-2009 was reconstructed. The PDSI reconstruction showed that periods of wet years occurred in AD 1804-1805, 1868-1867, 1887-1895 and 1948-1952, whereas dry periods occurred in AD 1926-1932, 1990-1992 and 2005-2006. The years AD 1926-1932 are the driest period in the reconstruction, coinciding with records from documents, missing rings and other reconstructions. Four significant cycles (2.3 yr, 2.6 yr, 3.4 yr and 68 yr) were found by spectrum analysis in the reconstruction, and the high frequency cycles of 2.3 yr, 2.6 yr and 3.4 yr are consistent with QBO and ENSO.

### **Assesing lacustrine sediment for environmental changes, Red Lake(Romania)**

HALIUC A.(1), HUTCHINSON S.(2), FRANTIUC A.(1), MINDRESCU M.(1), ROMANESCU G.(3)

(1) Stefan cel Mare University, SUCEAVA, ROMANIA ; (2) University of Salford, MANCHESTER, UNITED KINGDOM ; (3) Al.I.Cuza University, IASI, ROMANIA

Located in the north east of Romanian Carpathians, Red Lake is a unique valley lake formed by a landslide. The landslide occurred in the Hășmaș Massif in the Central Group of Eastern Carpathians blocking the Bicaz Brook at its confluence with the Suhard Brook. Red Lake is a significant and interesting natural barrage lake because of its origins and its multiple uses and consequently needs to be subjected to efficient environmental management. The aim of this study is to examine the proprieties of the recently taken lacustrine sediments in order to achieve a perspective on the environmental changes.

The sediments were taken in the summer of 2011 using an inflatable boat, a hand GPS and a gravity corer. Each core was sectioned at 2 cm interval, dried at 37°C, subjected to multiple analyses using: pXRF analysis (Niton XL3t 900) for elemental composition, Bartington Instruments Ltd MS2 and C sensor, Molspin Ltd Pulse Magnetiser and Minispin Fluxgate Magnetometer for magnetic characteristics, LOI (loss on ignition) to estimate the total organic matter and carbonate content, Horiba Particle LA-950V2 for particle size measurements.

The geochemical, mineral magnetic, organic and particle size characteristics of the samples reflect changes in the surrounding environment due to anthropogenic actions and natural events. The surface, basal sediments as well as cores taken near the main limbs have different characteristics. This indicates the different sources of the sediments as well as differential deposition. The longest core appears to cover a considerable part of the history of the lake confirming the high rate of infilling as well as other important environmental episodes. Even though, this well-known water body is declared a protected area this study provides an insight for the necessity of environmental management for its longevity and sustainability.

\*\*\*\*\*

### **Vegetation changes and associated climate variations during the past ~40,000 years reconstructed from the Shaamar eolian-paleosol section in northern Mongolia**

MA Y.(1), MENG H.(1), LIU K.B.(2), TAO M.(3)

(1) Key Laboratory of Environmental Change and Natural Disaster, Ministry of Education of China, Beijing Normal University, BEIJING, CHINA ; (2) Department of Oceanography and Coastal Sciences, School of the Coast and Environment, Louisiana State University, BATON ROUGE, UNITED STATES ; (3) College of Resources Science and Technology, Beijing Normal University, BEIJING, CHINA

This study presents the vegetation changes and associated climate variations at the Shaamar eolian-paleosol section in the northern Mongolian Plateau. The semi-quantitative reconstructions of paleovegetation types and temperature and moisture indices show that the vegetation in the Shaamar area was a taiga forest between ~40,000 and ~30,000 cal. yr BP when the reconstructed moisture level was the highest of the past ~40,000 years. The vegetation during the ensuing period from ~30,000 to ~22,000 cal. yr BP was mainly a steppe under low temperature and low moisture conditions. The vegetation during the period from ~22,000 to 11,000 cal. yr BP varied from a taiga forest, through steppe and forest steppe, to a desert steppe. The climate was cold and dry in the early phase (~22,000 to ~20,000 cal. yr BP), and warmer and somewhat drier in the later phase (~18,500 to ~11,000 cal. yr BP). The vegetation has been primarily dominated by forest-steppe during the past ~11,000 years with more taiga-like vegetation during ~11,000–~9,300 and ~3200–~400 cal. yr BP. The reconstructed temperature was rising from ~11,000 to ~6000 cal. yr BP and falling since ~6000 cal. yr BP. The reconstructed moisture was low from ~10,000 to ~3200 cal. yr BP and then dramatically increased during the past ~3200 years. Comparison of our pollen record from the Shaamar section with other paleoclimatic records from China and Greenland suggests that the climate changes in the northern Mongolian Plateau have been controlled or modulated by ocean-atmospheric coupling dynamics in the North Atlantic region.

### **The grain size component of winter sand and summer sand of the red sand dunes in the coast of southern China and its paleoclimatic significances**

YU M.

*School of Geographical Sciences, Fujian Normal University, FUZHOU, CHINA*

The "Old Red Sand" mainly distributed in the coastal zone of Fujian, Guangdong, Taiwan and other places of the southern China is Quaternary red sand dunes. Previous studies suggest that the Old Red Sand were coastal beach sediment, later uplift to the coastal zone. However, later studies have found that the Old Red Sand is constituted by fine sand, the monotonous material; excluding marine micro-organisms debris. Comprehensive analysis from the particle size, geochemical elements, magnetic susceptibility indicate that the Old Red Sand was the coastal sand deposition. The sources of sand is believed from the low sea level beach sand during the last glacial.

The Old Red Sand recorded monsoon changes. The sequence Old Red Sand samples from Qinfeng section in island of Pintang in Fujian province were collected. Both the winter sand and summer sand samples in the gulf near Qinfeng were also collected. Particle size for the Old Red Sand, winter sand and summer sand have been measured and shown different granularity peaks, respectively locate in  $300\mu\text{m} \pm$ ,  $400\mu\text{m} \pm$  and  $260\mu\text{m} \pm$ . Winter sand and summer sand were mixed in different proportions to simulate the particle size distribution of the Old Red Sand. It shows the ratio of 7:3 of summer sand to winter sand determine deposition Old Red Sand, that indicate the duration or intensity of the summer monsoon are stronger during Old Red Sand deposition than that in the postglacial. Moreover, Old Red Sand is in reddish range between brown-red (2.5YR4 / 8), light brown and red (2.5YR5 / 8), which is reddening than modern sand. The four dating samples for the optically stimulated luminescence show that the Old Red Sand formed at 123-62KaBP, the last interglacial. We therefore can reconstruct the East Asian monsoon changes since the last interglacial by proxy of  $400\mu\text{m}$  particle size content from Old Red Sand of the indicators of winter monsoon and  $260\mu\text{m}$  content of summer monsoon.

\*\*\*\*\*

### **Landslide inventory bimodality in volcanised tertiary basin of Puy-en-Velay (France): a geoinicator of climate change**

POIRAUD A.

*GEOLAB - UMR CNRS 6042, CLERMONT-FERRAND, FRANCE*

The inventory of more than 200 landslides in the volcanised tertiary basin of Puy-en-Velay (France) reveals a clear bimodality of their distribution. The surface magnitude/frequency curve of all the landslides determines 2 power-law adjustments i) the first one with a  $b = -1.54$ , corresponding to the ancient landslides and palaeolandslides and ii) the second one with a  $b = -0.51$  corresponding to the historical and present-day landslides. The C14 dating of 4 landslides of the first group allows us to determine that Subboreal period was significant for activation or reactivation of high mass movements. Thus, we conclude that these 2 populations of landslide are the expression of different climatic patterns characterised by different level of geomorphic activity. This geomorphic activity is expressed by the synthetic term  $b$  of the statistical adjustments. Finally, the landslides, in the study area, seem to be a geoinicator of this climatic temporal diversity.

## Sandy Desertification and its Control in Qinghai Plateau, China

ZHANG D., TIAN L., WU W.

*Beijing Normal University, BEIJING, CHINA*

The Qinghai Plateau is a fragile arctic-alpine area which is one of the places seriously suffered from sandy desertification that threaten people's living condition and impact social sustainable development in China.

Compared with other areas, the main characteristics of the sandy desertified land in Qinghai Plateau are high altitude, lower temperature, less accumulative temperature and shorter frost-free seasons. The Qinghai Plateau has the harshest natural environment in the sandy land of China. Based on field investigation, observation, experiments, and previous studies, this paper used method of multi-subjects synthetic analyses to study sandy desertification and its control in Qinghai Plateau from both macroscopic and microcosmic aspects. The sandy desertification control in Qinghai plateau must be focused on protecting the current vegetation, integrity of protection and harness, and combination of the implement of various important projects for environmental protection.

The engineering measures for sandy desertification control include setting clay sand barrier, *Salix cheilophila* sand barrier, *Tamarix* sand barrier, *Artemisia* sand barrier and straw-checker sand-barriers to fix shifting dunes; and the biological measures include closure for natural vegetation recovery, direct seeding forestation, transplanting seedlings, and so on. New plants such as *Salix cheilophila* and *Tamarix*, which are available in study area, can change from dead sand barrier to live one set in an appropriate season, changing engineering measure to biological ones directly accelerate the progress of forestation and dunes fixation. In addition, we developed new techniques of deep planting *Salix cheilophila* and *Tamarix* with their long stem, which can effectively resist drought; meanwhile it had lower cost and higher live rate. It has resolved the key problem of control sand flow speed and low efficiency, sand burying and wind erosion and low conservation rate for forestation in the sandy area.

\*\*\*\*\*

## Preliminary results of a national Italian research project: Response of morphoclimatic system dynamics to global changes and related geomorphological hazards

BARONI C.(1), ANZIDEI M.(2), DALLA FONTANA G.(3), DEL MONTE M.(4), FREPPAZ M.(5), MASTRONUZZI G.A.(6), SMIRAGLIA C.(7), SOLDATI M.(8)

(1) Dipartimento di Scienze della Terra, University of Pisa, PISA, ITALY ; (2) Istituto Nazionale di Geofisica, Centro Nazionale Terremoti, ROMA, ITALY ; (3) TESAF - Dipartimento Territorio e Sistemi Agro-forestali, University of Padua, PADUA, ITALY ; (4) Dipartimento di Scienze della Terra, University of Roma La Sapienza, ROMA, ITALY ; (5) Dipartimento di Scienze Agrarie Forestali e Alimentari, University of Turin, TURIN, ITALY ; (6) Dipartimento di Scienze della Terra e Geoambientali, University of Bari, BARI, ITALY ; (7) Dipartimento di Scienze della Terra, University of Milan, MILAN, ITALY ; (8) Dipartimento di Scienze Chimiche e Geologiche, University of Modena and Reggio Emilia, MODENA, ITALY

The knowledge of the relationship between the phenomena of instability and the climate changes is essential for an effective approach to the management of geomorphological hazards and risks in those regions, such as Italy, that are subjected to extremely dynamic and fast environmental changes. Preliminary results on the impacts of climate changes obtained within this project point out an environmental degradation which results in more frequent geomorphological hazard occurred frequently during recent years along the whole Italian territory.

The use of modern survey and measurement techniques and of innovative methods of investigation applied to the modelling and prediction of geological hazards in a broad sense, provides a powerful new tool to face consciously the consequences of the current global changes and of those that can be expected in the future in very different geographical and climatic systems, from the Mediterranean to the Alps. The morphoclimatic environments that we are investigating can be considered true natural laboratories for studying the effects of global changes, ranging from the glacial to the coastal environments. The integrated use of different monitoring techniques and prediction models provides new results extremely useful in the environmental context. The new data on sea-level changes, on phenomena of accelerated erosion and adaptation of the catchments, on changes in the cryosphere, on the ongoing instability in the territory will contribute to the advancement both of basic and applied research. Thus, new data are coming at hand for refining and/or build from the scratch spatial prediction models of geomorphological instability in several environmental contexts.

If complemented with efficient politics for mitigating the environmental risks and with aware actions for territorial management and planning, the topics addressed by this research project will help to improve the safety and sustainability of the communities potentially at risk.

**A synthesis of landscape the Pantanal of Mato Grosso from theoretical and methodological sketch of G. Bertrand**

FONSECA G.

*USP, SAO PAULO, BRAZIL*

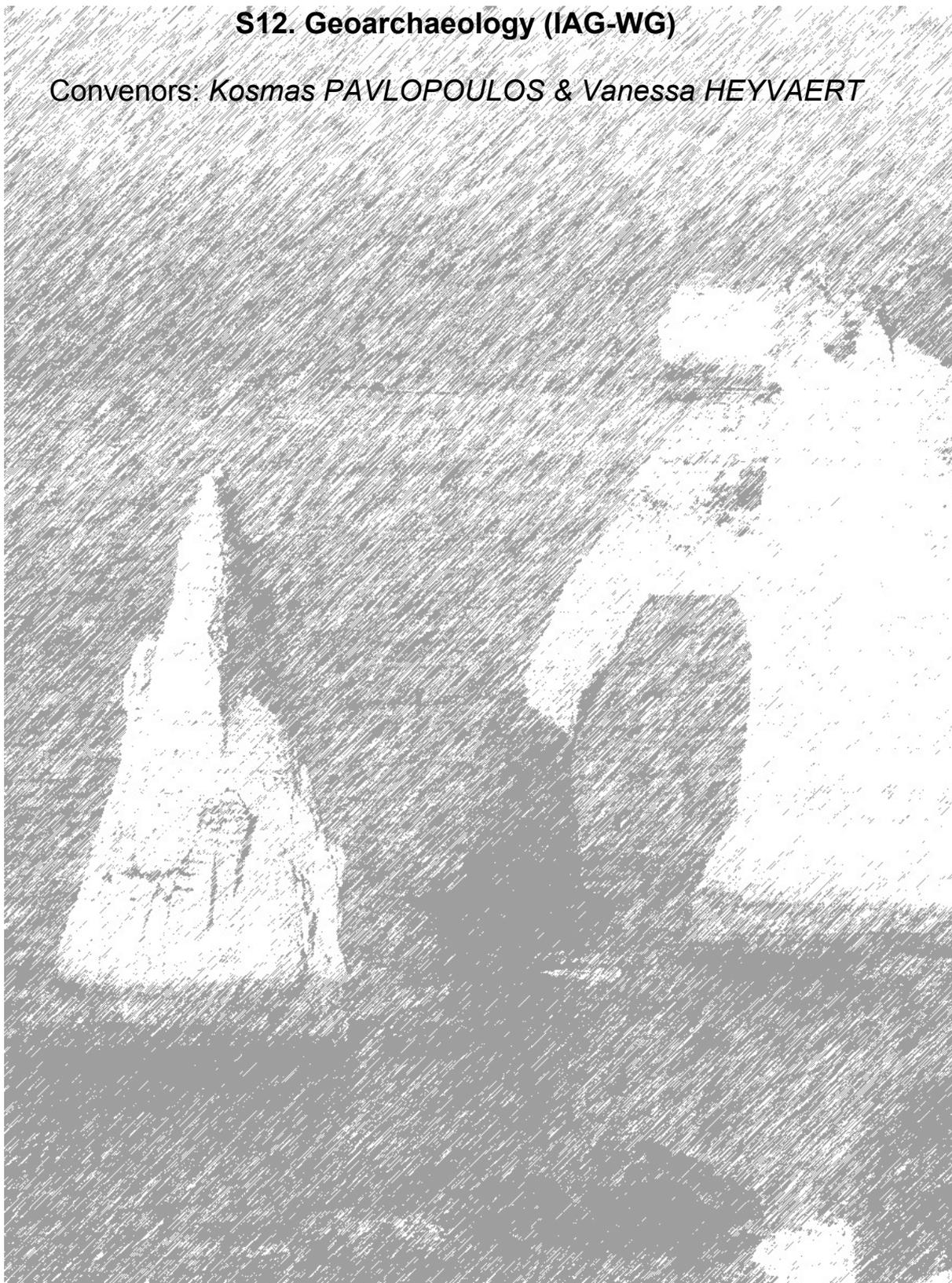
The concern in prioritizing and classifying the natural environment is based clearly systemic approach. The two principles have converged geosystems: homogeneity and differentiation, are considered a homogeneous structure containing differentiated structures, which indicates the need to take into account the scale of analysis, since the more general scale, fewer differences will be found. In order to classify the landscape of the Pantanal respecting an order scalar, ie, placing the units of this landscape according to time and space. We sought to identify the factors, conditions and the general mechanisms of the landscape with a scale greater detail as well as the linkage between the different units from different levels: geosystem and geofacies. Focusing on this case, as the Pantanal wilderness area in general, the geosystem the sub-region of the Pantanal Poconé-MT, is located in the State of Mato Grosso, in Central-West Brazil, adopting the classification of sub-regions of the Pantanal performed by Abdon and Silva (1998) and as geofacies units contained in that sub-region. The partitioning of the landscape from the theoretical and methodological outline proposed by Bertrand (1971) was a way to analyze and understand the dynamics between the different components of the same and even to identify their specific characteristics. The definition of the type of landscape found in geosystem was performed taking as elements anchors vegetation, morphological features and materials that compose them.

\*\*\*\*\*



**S12. Geoarchaeology (IAG-WG)**

Convenors: *Kosmas PAVLOPOULOS & Vanessa HEYVAERT*





## **Oral presentations:**

### **Relative sea level changes during Roman times in the NW Mediterranean, a geoarchaeological approach**

MORHANGE C.

*Institut Universitaire de France, AMU, CEREGE, AIX-EN-PROVENCE, FRANCE*

Fish tanks become fashionable throughout the Mediterranean area between the 1<sup>st</sup> century BC and the 1<sup>st</sup> century AD. Because of this narrow chronological window, and their link to former sea level, they constitute precious archives to investigate RSL since the Roman period, especially when combined with fossilized marine benthos found attached to the walls. Here, we present new results from an integrated analysis of a fish tank located in the Roman colony of Fréjus, southeastern France. The well-preserved biological remains on the fish-tank wall enable us to estimate a RSL rise of  $40 \pm 10$  cm at Fréjus since 2000 years. By contrast, the findings contradict the ~150 cm of RSL change since Roman times reported for the NW Mediterranean by some authors (eg. Lambeck et al., 2004). This contrasts with the 50 cm reported by Pirazzoli (1976). We suggest that the discrepancies between data from the southern coast of France and Italy are essentially due to methodology. Evelpidou et al. (2012) demonstrated that the sluice channels' sliding grooves are not a reliable archaeological indicator of former sea level because they can be located at any depth in the basin.

Our RSL data are in good correspondence with Evelpidou et al. (2012). This range is considerably lower than that proposed by Lambeck et al. (2004) a discrepancy that we attribute to a different interpretation of the hydraulic position of fish tank structures relative to former sea level.

In conclusion, our new data confirm: (1) that no Holocene sea level occurs above the present along the Provence coast, except in the direct vicinity of the maritime Alps near Nice; and (2) that RSL changes since Roman times have been very modest (of the order of a few decimetres). In Provence, the role of sea level in shaping coastal changes is therefore relatively minor in comparison to sediment inputs. (3) The most precise RSL results are achieved by marrying archaeological structures with biological zonation.

\*\*\*\*\*

### **Hellenistic landscapes of the sacred harbour of Delos (Cyclades, Greece): new reconstruction based on sedimentological and geophysical data**

DESRUELLES S.(1), PAVLOPOULOS K.(2), APOSTOLOPOULOS G.(3), FOUACHE E.(4), ETIENNE R.(5), HASENOHR C.(6), COSTA L.(5), TRIANTAPHYLLOU M.(7)

*(1) UFR d'histoire-géographie, Université de Picardie Jules Verne, Amiens, France et UMR 8185 ENeC (Espaces, Nature et Culture), Université Paris-Sorbonne/CNRS, AMIENS, FRANCE ; (2) Department of Geography, Harokopion University, ATHENS, GREECE ; (3) School of Mining and Metallurgical Engineering, National Technical University of Athens, ATHENS, GREECE ; (4) UMR 8185 ENeC (Espaces, Nature et Culture), Université Paris-Sorbonne/CNRS, PARIS, FRANCE ; (5) UMR 7041 ArScan, CNRS/Paris 1 Panthéon-Sorbonne/Paris Ouest Nanterre La Défense, NANTERRE, FRANCE ; (6) UMR 5607 Ausonius, Université Bordeaux 3/CNRS, BORDEAUX, FRANCE ; (7) University of Athens, Faculty of Geology and Geoenvironment, Department of Historical Geology - Paleontology, ATHENS, FRANCE*

During the Hellenistic period, the sacred island of Delos (Cyclades, Greece) was one of the major commercial centres of the ancient Greek world. This centre was linked to the "sacred harbour" which was mainly developed at the 2<sup>nd</sup> century BC in a sandy bay rather little protected from the swell. The reconstruction of the shoreline and landscapes of the main port of the island constitutes an important issue for the knowledge of the development and the economic activities of the ancient city of Delos.

The strong evolution of the port's landscapes, primarily caused by deposit of excavated material at the end of the 19<sup>th</sup> century and the beginning of the 20<sup>th</sup> century does not facilitate the reconstruction of the Hellenistic landscapes.

Most studies on the "sacred harbour" of Delos are based on archaeological studies carried out at the beginning of the 20<sup>th</sup> century, whose results are opposing. According to the cross-comparing between data obtained on the relative sea-level changes and data resulting from the investigations carried out between 1995 and 2007 (archaeological surveys, geophysical prospecting and boreholes realized with the financial support of the French School of Athens), we propose a new reconstruction of the landscapes of ancient port of Delos. The obtained reconstruction asks questions about the accessibility of this port for the deep draught boats.

## The evolution of the Bay of Elaia and the fate of the former harbour of ancient Pergamum (Western Turkey)

SEELIGER M.(1), BARTZ M.(1), FEUSER S.(2), PIRSON F.(3), KELTERBAUM D.(1), VOETT A.(4), BRUECKNER H.(1)

(1) Institute for Geography, University of Cologne, Albertus-Magnus-Platz, 50923 COLOGNE, GERMANY ; (2) Heinrich Schliemann-Institut für Altertumswissenschaften, University Rostock, 18051 ROSTOCK, GERMANY ; (3) German Archaeological Institute, ?nönü Caddesi 10, 34437 ISTANBUL, TURKEY ; (4) Institute for Geography, Johannes Gutenberg-University Mainz, Johann-Joachim-Becher-Weg 21., 55099 MAINZ, GERMANY

It was the aim of this geoarchaeological research to reconstruct the landscape history around Elaia, the harbour of ancient Pergamum, based on sedimentological evidence of 75 terrestrial and 11 semi-aquatic corings. The focus was on the history of the Hellenistic harbour basin until its total siltation.

The construction of the prominent jetty in Hellenistic times as well as the siltation process of the harbour could be verified by sedimentological criteria and <sup>14</sup>C age estimates as dating from the Hellenistic period. The first pollen diagram of the area covers the period of 800 BC to 600 AD, reflecting the human impact on the ecosystem. The quasi natural vegetation degraded due to grazing and lumbering to a maquis-type vegetation already in Hellenistic times. Along with the decreasing importance of Elaia in Late Roman times the vegetation recovered, and around 600 AD a pine forest was established.

Six coring transects helped to identify the maximum marine transgression and thereby the extend of the embayment. In the north it dates to ~2000 BC, in the west to ~1600 BC.

Wallstructures in the western part of the embayment, lying only 0.5-1 m below present sea level, were <sup>14</sup>C-dated to the Late Roman period (3<sup>rd</sup> - 4<sup>th</sup> century AD) The comparison with similar structures from other periods and places of the Mediterranean makes their use as salt works the most likely interpretation. In order to refine the chronostratigraphy, the sediments immediately below the walls are currently OSL-dated.

\*\*\*\*\*

## Relative sea-level change in the Central Adriatic during the last 2 ka years - a pluridisciplinary approach

FAIVRE S.(1), BAKRAN-PETRICIOLI T.(2), HORVATINCIC N.(3)

(1) University of Zagreb, Faculty of science, Department of geography, ZAGREB, CROATIA ; (2) Faculty of Science, University of Zagreb, Department of Biology, ZAGREB, CROATIA ; (3) Institute Rudjer Boskovic, ZAGREB, CROATIA

The study of sea-level variations today is more and more pluridisciplinarily approached. Geomorphological, sedimentological, archaeological and biological indicators are used and combined. In studying the 2 ka of relative sea-level change along the Croatian Adriatic coast, different markers have been used. One of the first markers used were the submerged archaeological remains which were later combined with geomorphological markers. In order to approach the problem pluridisciplinary we started to work on the biological markers combining them systematically to the all other available data.

The morphology of well-developed *Lithophyllum* rims combined with <sup>14</sup>C dating revealed four phases of relative sea-level changes during the last 1.5 ka. Large algal rims grew during near-stable sea-level conditions that occurred during two relatively colder periods: the Dark Ages Cold Period and the Little Ice Age. This stabilisation has at the same time its morphological reflection in the formation of the tidal notches in the studied area. During the Medieval Climate Anomaly and the Current Warm Period the sea-level rise at a much higher rate.

Our study concludes on a rise of a relative sea-level of about 60±10 cm since 1500 years ago in the Central Adriatic. Thus our results cast new light on the sea-level of Vis Island during Antiquity, which was higher than previously reconstructed on existing submerged archaeological remains. Consequently, this means that the most of the upper level blocks of the submerged Issa quays are missing. On the other side, the perforated *dolia* found *in situ* now perfectly fit in the new biologically defined sea-level (-110±25 cm) for the 1900 ± 100 yr BP period.

Our results clearly demonstrate the relationship between biological, geomorphological and archaeological sea-level markers and also environmental conditions on the studied area in the past and the clear need of such multidisciplinary approach in the study of the relative sea level changes.

### Geomorphic hazards and ancient human occupation: the Russian Altai case study

BARYSHNIKOV G.

*Altai State University, BARNAUL, RUSSIAN FEDERATION*

Modern Altaian culture has deep historical roots evidenced by numerous archaeological finds ranked as the most ancient in Siberia. At last historical phases the major driver of human dispersal was competition between different nations, their mutual ousting, blending or assimilation. As to early modern humans, no single factor governing expanding or contraction of their occupation areas might have existed, but natural environmental control was probably prevailing. The author's geological and geomorphological studies at archaeological monuments of the Russian Altai gave evidences of multiple natural hazards in the last 20-30 ka that influenced greatly on ancient human occupation and preservation of archaeological sites. Degradation of glaciation in the end of the Late Pleistocene caused multiple outbursts of glacial dammed lakes. Catastrophic flood in the Katun River about 25 ka BP changed considerably the whole geomorphic structure of the valley and destroyed all previously existed features of valley morphology together with potential archaeological sites within them. Similar event occurred in the Biya River around 20 ka BP. Mudflows and debris flows occurred in small valleys during the Holocene thermal optimum at 6-8 ka BP. They were promoted by climate warming and increase of precipitation. Given the wide occurrence of such events not only in Altai but also in a wide range of regions, they may probably be regarded as a possible source for what was preserved as "the Deluge" in human's collective memory.

\*\*\*\*\*

### Geomorphological development and early human settlement pattern of Ruhnu Island in the Gulf of Riga eastern Baltic Sea

MURU M.(1), ROSENTAU A.(2), AUNAP R.(1)

*(1) University of Tartu, Department of Geography, TARTU, ESTONIA ; (2) University of Tartu, Department of Geology, TARTU, ESTONIA*

In the low relief Baltic Sea region the sea level and shoreline changes have influenced human populations since the Stone Age. The geomorphology of Ruhnu Island in the Gulf of Riga eastern Baltic Sea was studied to understand the pattern of early human settlement and the development of the landscape in connection with the sea level changes and the post-glacial rebound.

The island emerged from the sea c. 12 000 years before present and has an area of c. 12 km<sup>2</sup> today. The oldest part of the island is surrounded by large well-developed coastal foredune systems reaching mainly 5–15 m a.s.l. The earliest human habitation on the island is dated c. 7300 years before present (Kriiska & Lõugas 2005).

Geomorphometric analysis based on high resolution airborne LiDAR data and ground-penetrating radar studies were carried out, geological profile of the Holocene deposits of the island was studied and sediment samples of the major foredune ridges for luminescence dating were taken. Combination of different methods enabled to clarify the geomorphological development of Ruhnu Island. Digital terrain model, the new data and water level change data from previous studies (Rosentau et al. 2011) were used to reconstruct the palaeogeography of the area by GIS approach, which in turn enabled better comprehension of early human settlement pattern and migration routes in the whole Gulf of Riga region.

References:

Kriiska, A. & Lõugas, L. 2005. Formation of Ruhnu Island and its early settlement history. *Estonia Maritima* 7, 119–132.

Rosentau, A., Veski, S., Kriiska, A., Aunap, R., Vassiljev, J., Saarse, L., Hang, T., Heinsalu, A. & Oja, T. 2011. Palaeogeographic model for the SW Estonian coastal zone of the Baltic Sea. In Harff, J., Björck, S. & Hoth, P. (eds.): *The Baltic Sea Basin*, 165–188. Springer-Verlag, Berlin.

## **From the hillsides to the port : evolution and management of agrarian and maritime landscapes in the territory of Fréjus since the Antiquity (Var, France)**

*PORTALIER N.(1), PURDUE L.(2)*

*(1) Service du Patrimoine, Ville de Fréjus, FREJUS, FRANCE ; (2) CEPAM-UMR 7264 / Service du Patrimoine, Ville de Fréjus, NICE, FRANCE*

Built in *Gallia Narbonensis* on the southern Mediterranean coast between 49 and 43 B.C., *Forum Julii* has had to deal constantly with the control of its coastal line in order to protect its port from silting up with sediments from the Argens River, as a result of long-shore drift.

Previous research has focussed on the coastal progradation of the Argens Ria, particularly intense during the Antiquity, and its link with inland landscape change. However, no studies have aimed to explain the sediments origin and the reason for their strong availability. Recent rescue archaeology projects along two tributaries of the Argens River (Caïs and rue Vadon) have enabled us to further discuss this issue and apprehend human occupation and land use in upstream rural areas.

At Caïs, in the rural territory of Fréjus, we conducted archaeological and geomorphic studies combined with paleobotanical and micromorphological analysis, chronologically framed by radiocarbon and ceramic dating. At rue Vadon, closer to the sea, the multiproxy analysis of a 20 m core included stratigraphic description, paleoecological studies and magnetic susceptibility.

These project have allowed us to describe and better grasp the influence and impact of lateral hydrosedimentary dynamics and sediment transport in the Argens valley (coastal line evolution with lagoons and swamps), soil management during the roman period (drainage and irrigation practices), and measure the influence of climatic fluctuations and/or human occupation on soil erosion. The importance of these results and their integration into relevant problematics related to long-term human-environment interactions in southern France highlight the fact that more systematic geomorphic and paleoenvironmental studies should be prescribed in upstream watersheds, in the framework of rescue archaeology.

\*\*\*\*\*

## **Study of a coastal sedimentary sequence containing the remains of a Roman salt-mine in NW Spain**

*TALLÓN-ARMADA R.(1), COSTA-CASAS M.(2), LÓPEZ-MERINO L.(3), BLANCO CHAO R.(4), MARTÍNEZ CORTIZAS A.(1)*

*(1) Department of Soil Science and Agricultural Chemistry, Faculty of Biology, University of Santiago de Compostela (USC), SANTIAGO DE COMPOSTELA, A CORUÑA, SPAIN ; (2) Institute of Heritage Sciences (Incipit). Spanish National Research Council (CSIC), SANTIAGO DE COMPOSTELA, A CORUÑA, SPAIN ; (3) Institute for the Environment, Brunel University, UXBRIDGE, LONDON, UNITED KINGDOM ; (4) Department of Geography, Faculty of geography and history, University of Santiago de Compostela (USC), SANTIAGO DE COMPOSTELA, A CORUÑA, SPAIN*

We present a multi-proxy characterization (geomorphological, physicochemical, mineralogical, geochemical, and palynological data), supported by radiocarbon dating, of a sediment sequence which contains the remains of a Roman salt-mine, located in the Ria de Vigo (NW Spain). The aim was to obtain information on the environmental conditions, and the role of climate and human activities in the evolution of this coastal environment, before and after the use of the salt-mine.

Our results indicate a restructuring of the coastline in the sampled area, with a progressive evolution from a marine environment to a more continentalized one. The reconstructed pre-Roman beach formations were buried by the development of a first marsh phase (with presence of Chrysophyceae and Hystrichoesphaeridae cysts indicative of brackish-marine conditions), where the Roman salt-mine was built. The exploitation of salt occurred between II BC/ III-V centuries AD. The collapse of the salt-mine structures was accompanied by a second, less saline, marsh phase (with presence of *Typha latifolia* type and Cyperaceae). A progradation of dune formations is detected during Medieval times, some of which showed a certain degree of pedogenetical evolution, thus stabilization. Additionally, a dramatic decrease in the mesophilous forest cover was also observed in this period, with a large increase in Poaceae abundance. The main changes in the pedo-sedimentary sequence and in the pollen record were synchronous with the already known Late Holocene climatic changes, although human activities may have also played a role on forest evolution (presence of cereal pollen was found in roman period and from the VIth century AD onwards). Results also enabled to propose a reconstruction of the morphodynamic changes in the coast and to discuss on the occurrence of a sea-level higher than today during Roman times, the period of exploitation of the salt-mine.

### The submerged chalcolithic landscape of Taraschina: a key data to understand early Danube delta evolution

CAROZZA J.(1), CAROZZA L.(2), MICU C.(3), BURENS A.(2), DANU M.(4), MESSENGER E.(5), RADU V.(6), LEVÊQUE F.(7), OPREANU G.(8), BALASESCU A.(9)

(1) University of Strasbourg - GEODE UMR 5602, STRASBOURG, FRANCE ; (2) GEODE - UMR 5602, TOULOUSE, FRANCE ; (3) Eco-Museal Research Institute, TULCEA, ROMANIA ; (4) ?Alexandru Ioan Cuza? University, IASI, ROMANIA ; (5) CEPAM - UMR 7264, NICE, FRANCE ; (6) National Romanian History Museum, BUCAREST, ROMANIA ; (7) UMR 7266, LA ROCHELLE, FRANCE ; (8) National Institute of Marine Geology and Geoecology, BUCAREST, ROMANIA ; (9) National Museum of Natural History, PARIS, FRANCE

Until recent works, the Danube delta was supposed to be void of any human occupation as late as late Iron Age. The discovery of a Chalcolithic (Gumelnita A1) occupation in Taraschina in the heart of the upper delta provides a better constraint on palaeogeographic evolution and formation process of the older phase of the delta, related to final sea-level rise in Black Sea.

Data collected in and around the chalcolithic settlement allows us to document the last evolution stage of the blocked delta and its transition to open delta phase. After the Black Sea reconnected to global ocean, the upper Danube delta prograde on fresh water lagoon. Between the reconnection phase ~ 8.4 ky BP to 6.0 ky BP, aggradation has dominated the delta evolution, in response to rapid sea level rise. From 6.0 ky BP, decrease in sea level rise rate initiated a stage of rapid progradation of the delta and the beginning of St George lobe formation. This phase is well documented by a series of coring around the site of Taraschina and have huge influence on human settlement occupation. During 6.5-6.0 ky BP rapid aggradation occurred in the lagoon and stops abruptly. This period corresponds to the end of the occupation of Taraschina settlement now widely silted. During this period, the whole surrounding landscape of the settlement was progressively fossilised under fluvio-lagoonal deposits.

We proposed palaeogeographical reconstitution of the settlement and surrounding area during 6.0 to 4.0 ky BP. The site was built at the edge of a loessic terrace recognized in core and correlated with other Pleistocene deposits within the delta. This terrace probably constitute the southern extend of the Bugeac plateau. During 6.5-5.9 ky BP interval high variability in fluvial regime is observed. Synchronicity between hydrological regime and settlement occupation is point out, implying rapid adaptation of chalcolithic societies to environmental changes.

\*\*\*\*\*

### Geoarchaeology of the ancient harbour of Ostia at the river mouth of the Tiber: chronology, stratigraphy and palaeoenvironmental reconstruction

GOIRAN J.P.(1), SALOMON F.(2), MAZZINI I.(3), BRAVARD J.P.(2), PLEUGER E.(1), VITTORI-VILLETTE C.(1), BOETTO G.(4), ARNAUD P.(5), PELLEGRINO A.(6)

(1) CNRS - UMR 5133 - MOM, LYON, FRANCE ; (2) UMR 5600 - Université de Lyon, LYON, FRANCE ; (3) IGAG CNR - Università Roma TRE, ROMA, ITALY ; (4) CNRS - Centre Camille Jullian, AIX-MARSEILLE, FRANCE ; (5) UMR 5189 - Université de Lyon, LYON, FRANCE ; (6) Soprintendenza archeologica di Roma, ROMA, ITALY

Since the Renaissance, many attempts to locate the river mouth harbour of Ostia were undertaken. It was not until the 19th and 20th centuries that Italian archaeologists define an area in the north of the city, near the Imperial Palace. At the turn of the century, a team of German archaeologists confirmed the probable location of the northern basin by using geomagnetic surveys.

We wanted to validate this hypothesis by extracting cores to obtain deep stratigraphy of this area, which is difficult to excavate due to groundwater.

The obtained stratigraphy shows three main units. The basal unit, called pre-harbour unit, is composed of marine sediments dating from the early 1st millennium BC. A middle unit, termed harbour unit, has a grey silty-clay facies recording alternation of marine and river influences. Finally, the uppermost unit, termed post-harbour unit, sign abandonment by generalized silting at the Roman imperial period.

For the first time, a multidisciplinary research combining French-Italian archaeologists, historians, geographers, sedimentologists, geomorphologists and biologists allows to validate the hypothesis of the location of the river mouth harbour basin of Ostia, in the north of the city and in the west of the Palazzo Imperiale. This discovery will advance our understanding of the relationship between Ostia, his river mouth harbour, and subsequently the creation of the Portus in the 1st and 2nd centuries AD.

## **Human occupation and geomorphological evolution of the Corfu strait (NW Greece) during the Holocene: submarine seismic profiles and sedimentological proxies**

*CHABROL A.(1), KAPSIMALIS V.(2), FOUACHE E.(3), LECOEUR C.(4)*

*(1) Ecole française d'Athènes, UMR CNRS 8591, Université Paris 1 Panthéon-Sorbonne, ATHENS, GREECE ; (2) Hellenic Center for Marine Research, ATHENS, GREECE ; (3) Université Sorbonne Abou Dhabi, Paris IV, Institut Universitaire de France, ABOU DHABI, UNITED ARAB EMIRATES ; (4) Université Paris 1 panthéon-Sorbonne, UMR CNRS 8591, PARIS, FRANCE*

Across the Mediterranean Basin, the glacial-interglacial transition is the transition from hunter-gatherer societies of the Upper Paleolithic and Mesolithic Final companies to Neolithic farmers. In Epirus (northwestern Greece), the lack of archaeological sites is obvious for this period: only two cave sites have yielded Upper Paleolithic occupations and one open air site was dated to the Mesolithic. During the Lateglacial and the Holocene, climate fluctuations have caused major palaeogeographic changes on the coastline evolution and the river dynamics. The prehistoric remains in a continental environment cannot be easily found: they were either destroyed by marine erosion during the post-glacial rebound/fast sea level rise, or they were buried by sediment accumulation. Our geoarchaeological study focuses on two specific areas: the delta formed by the Kalamas river, and the inlet between the island of Corfu and the mainland.

The delta formed by the river Kalamas is the smallest of Epirus (64km<sup>2</sup>). It was occupied on a continuous basis since the Bronze Age. To provide a wide study of the whole Holocene and not just the last 6000 years (global age of formation of the mediterranean deltas), a submarine geophysical surveys was conducted. The profiles obtained by seismic reflection (boomer) helped to highlight paleolandforms submerged by the post-glacial sea-level rise.

Absolute dates associated with the crossing of sedimentological data obtained by drilling (grain-size analysis, magnetic susceptibility, forams and ostracods, fire signal) with those obtained during the geophysical submarine survey, synthesized in a common GIS, permitted to reconstruct the Holocene different paleogeographies in this area. Environmental data are supplemented by intensive archaeological surveys in the Kalamas valley. The intersection of these archaeological data and the paleogeographic reconstructions thus obtained provide a methodological basis for a predictive archaeology.

\*\*\*\*\*

## **The geoarchaeology of the Talgar River alluvial fan and Iron Age history in the Semirech'ye region, Kazakhstan**

*PANYUSHKINA I.(1), MACKLIN M.(2), TOONEN W.(3), CHANG C.(4)*

*(1) University of Arizona, TUCSON, UNITED STATES ; (2) Aberystwyth University, ABERYSTWYTH, UNITED KINGDOM ; (3) Utrecht University, UTRECHT, NETHERLANDS ; (4) Sweet Briar College, SWEET BRIAR, UNITED STATES*

The Talgar River is one of the western tributaries of the Ili River that shaped the cultural landscape of the Semirech'ye- a principal region of the "nomadic world" in Central Asia for the last 5000 years. We hypothesize that population dynamics in this area were significantly influenced by multi-centennial periods of high and low river flow that impacted on floodwater farming, located on alluvial fans. River flooding and alluvial fan development are related to climate change and glaciation in the NW Tian Shan Mountains. The Iron Age chronology of Semirech'ye, which includes new radiocarbon dating of excavated archaeological sites and surveys, shows discrete short-term phases of occupation of the Talgar fluvial fan by Saka farmers and herders between 800 BC and 200 BC. Our geoarchaeological studies and refined OSL chronology indicate that the Talgar fluvial record has correlations with the contraction and expansion of Iron Age populations. The dry centennial-scale phases could be associated with the dispersal of prehistoric populations and out-migration, whereas the wet phases (e.g. ca. 600 BC and then between 300 BC and 200 BC) attracted people to the area, and might have led to increased social complexity, the emergence of local 'nomadic' elites, and increased alliances among both settled and nomadic groups. We discuss how multi-proxy records can be employed to model population-size variability (concentration and dispersal) for various Saka groups in the Semirech'ye region, which includes both nomadic and sedentary populations exploiting diverse economic and land-use strategies.

### **Luminescence dating and sedimentological investigations of alluvial archives in the Mediterranean: A case study of a prehistoric site in Morocco, Ifri n'Ammar**

BARTZ M.(1), EIWANGER J.(2), HILGERS A.(1), MIKDAD A.(3), BRUECKNER H.(1)

(1) *Institute of Geography; Universtiy Cologne; Germany, COLOGNE, GERMANY* ; (2) *Kommission für Archäologie Außereuropäischer Kulturen (KAAK) Bonn, Duerenstr. 35-37, 53173 BONN, GERMANY* ; (3) *Institut National des Sciences de l'Archéologie et du Patrimoine, 1, rue Ghandi, RABAT, MOROCCO*

The area of investigation is situated southwest of Nador in the eastern part of the Rif mountains. The prehistoric site of Ifri n'Ammar, an abris dating back to epipalaeolithic times and characterized by periodic colonization, shows human activity since 170 ka. The primary aim of this study is to determine morphodynamic active (e.g. flooding) and morphodynamic stable (e.g. pedogenesis) phases of the fluvial system. The wadi sediments provide direct information for the reconstruction of local palaeoenvironmental changes; they may also serve as an indicator for the regional climate. In order to determine the morphodynamic changes a detailed chronology of the fluvial sedimentation record is being established. First OSL data from wadi deposits in direct connection with Ifri n'Ammar with ages of  $94.0 \pm 7.7$  ka and  $60.7 \pm 5.4$  ka (potassium feldspar, postIR IRSL protocol, fine grain) demonstrate that the archive covers at least the last 100 ka. This will be supplemented by luminescence-dating four additional wadi profiles. The application of different OSL dating techniques (single-aliquot and single-grain on quartz and potassium feldspar) is used to improve the chronological classification. Furthermore, sedimentological and geochemical analyses are carried out to characterize the runoff dynamics within the fluvial system. To investigate the morphodynamically stable phases of pedogenesis, the palaeosols shall be studied with the tools of XRD (clay mineralogy) and micromorphology. Grain-size analyses and geochemistry (e.g. X-ray fluorescence of major and trace elements) are performed to document the morphodynamically active phases.

\*\*\*\*\*

### **Alluvial geoarchaeology of the palaeomeander of Ostia, Tiber delta, Italy**

SALOMON F.(1), BRAVARD J.P.(1), GOIRAN J.P.(2), ROSA C.(3), PANNUZI S.(4), KEAY S.(5)

(1) *Universite Lumiere Lyon 2 - UMR-5600, EVS, LYON, FRANCE* ; (2) *Maison de l'Orient et de la Méditerranée - CNRS-UMR-5133 Archéorient, LYON, FRANCE* ; (3) *Fondazione Ing. C. M. Lerici - Politecnico di Milano, ROMA, ITALY* ; (4) *Soprintendenza Speciale per i Beni Archeologici di Roma, ROMA, ITALY* ; (5) *University of Southampton, SOUTHAMPTON, UNITED KINGDOM*

At its peak, Imperial Rome was blessed with a great power that stretched all around the Mediterranean Sea. The link between Rome and the Mediterranean was enabled by the Tiber River and two harbour cities located on the shores of the Tiber delta: *Ostia* and *Portus*. Each city had its own genesis. *Ostia* developed gradually from a fortress (*castrum*) built in the IV c.-III c. BC at the mouth of the Tiber River. *Portus* was planned in the mid-first century AD on the left bank of the Tiber River. There are many hypotheses to justify the creation *ex nihilo* of this city. In this presentation, we will try to understand the origins of *Portus* in the light of fluvial dynamics near *Ostia*:

Is it possible that the Tiber dynamics hindered the development of the Roman *Ostia*? To what extent the harbour city of *Portus* was built to address problems met in *Ostia*?

To answer these questions, we will focus on the dynamics of the *Ostia* palaeomeander presently called *Fiume Morto*. Based on an interdisciplinary approach (archaeology and geoarchaeology) and on the analysis of sediment cores extracted from the palaeomeander, the results reconstruct the main stages of its evolution. We will consider how the migration of the river partly conditioned the urban planning of *Ostia* and obstructed its road system in the first centuries BC and AD.

In this presentation we will address the specificities of an anthropized meander, and consider its dynamics through the combination of natural processes and human activities. We will clearly identify internal control factors, at the scale of the palaeomeander (autocyclicity ...), and external control factors, at the scale of the watershed (land use, paleoclimate ...).

## **Dynamic changes in Loire, Saône and Doubs rivers in Burgundy (France) forced by the Little Ice Age: impact on archaeological site record**

*STEINMANN R., GARCIA J.P., DUMONT A.*

*UMR 6298, Université de Bourgogne, DIJON, FRANCE*

Three underwater archaeological sites have recently been studied in the Loire, Doubs and Saône rivers. Mostly consisting of accurately dated oak piles, they are interpreted as Roman bridge remains and exactly point the channel position in Roman times. However these bridges were not meant to stand in the *active* channels, depending on the considered rivers dynamics.

Geoarchaeological studies have been achieved on the alluvial valleys surrounding the sites, crossing data from various natural and human records. Very soon, it appeared that the last important change in fluvial style and deposits occurred during Little Ice Age (LIA) on the three rivers. But each system reacted differently, depending on its dynamics.

- Upstream Loire river migrated far from its antique position and came back to it, leading to its discovery under water. Trenches also revealed a buried medieval path, settled on the bank of an abandoned channel filled with coarse crevasse deposits during LIA.

- Upstream Saône did not migrate as Loire during LIA, but kept its main channel the same while reactivating anastomosis that evolved into short meanders until the middle of 19<sup>th</sup> century.

- Doubs river was a multichannelled river surrounded by a swamp that disappeared, probably due to LIA, in favour of a dynamic straight system that migrated very few but led to thick levee deposits, burying archaeological remains over banks.

To conclude, late Holocene dynamics changes had an important impact on the archaeological record of these three different alluvial systems. Loire erased its own floodplain archaeological remains, and that could mean a lack of discovery. Saône did not migrate, leading to an accumulation of sites at the same places through time. Doubs little eroded its banks but mainly buried archaeological remains under flood deposits.

Such different response to climate change have to be taken in consideration while trying to find new archaeological sites in alluvial context.

\*\*\*\*\*

## **Mid-Holocene inundation of the Lower Danube Valley - Lake sediments reflecting changing environmental conditions and human impact**

*NOWACKI D., WUNDERLICH J.*

*Institute of Physical Geography, Goethe-University, FRANKFURT/MAIN, GERMANY*

Geoarchaeological research has been conducted in the valley of the Lower Danube between Giurgiu and Oltenita to reconstruct changing environmental conditions and human impact during the Holocene with special focus on the Copper Age (5<sup>th</sup> mill. BC). Numerous settlement mounds indicate that settlements existed along the Lower Danube during this period, one of the most important being Tell Pietrele, located in the study area. Our palaeoecological research concentrates on floodplain sediments covering the valley bottom, which is about 8 km wide. More than 160 sediment cores were taken and complemented by geoelectric measurements. A multi-proxy approach consisting of sedimentological and geochemical analyses as well as analysis of microfauna (ostracodes), pollen and macro remains has been applied. The chronological frame is based on AMS-<sup>14</sup>C and OSL-dating. The results indicate that after the deposition of sands and gravels by a braided river system, lake sediments accumulated covering nearly the whole valley bottom. While the sands were dated to LGM and Late Glacial the deposition of lake sediments occurred from mid to late Holocene. The inundation of the Lower Danube valley was possibly caused by the transgression of the Black Sea. Within the lake sediments several black layers, each with a characteristic geochemical composition, appear. Those marker layers indicate changing conditions or events during lake evolution. The lowermost dark layer can be attributed to the Copper Age settlement period. It can be presumed that the development of the distinctive layer was caused by an increase of eroded soil material and/or of nutrients originating from settlements and agriculture that were washed into the lake. The upper part of the sediment record indicates that branches of the Danube prograded into the lake, starting not earlier than 2000 years ago. An anabranching river system established. Only remnants of the vast palaeolake prevailed until they were drained in the 1960ies.

### **Lithostratigraphic evidence of the paleogeographic evolution of the Athenian basin during Holocene (6.000 YBP)**

VANDARAKIS D.(1), PAVLOPOULOS K.(1), VOULALIDIS K.(2), FOUACHE E.(3)

(1) Harokopio University Athens, KALLITHEA, GREECE ; (2) Aristotele University of Thessaloniki, THESSALONIKI, GREECE ; (3) Université de Paris Sorbonne (Paris 4), PARIS, FRANCE

The Athenian basin is a very interesting area from archaeological point of view, since a large number of important archeological sites are situated. It is inhabited from Neolithic time. The human impact on the landscape is shown by the ancient constructions such as the Long Walls and the canalization of the rivers in the area of the Athenian Basin and Piraeus. In this basin the sediments are fluvial, alluvial, anthropogenic, lagoonal and coastal in origin.

The available obtained information of the depositional environments in the Athenian basin, has been received by previous studies, 217 geotechnical boreholes were collected from literature review (National Center of Documentation), 10 sampling boreholes from the area of Piraeus and 14 geotechnical boreholes from the New Opera of Athens. In addition topographic and geological maps were collected.

A GIS database established to manipulate and analyse the collected data. A DEM created through the ArcGis v. 9.3 platform, to represent the recent topography of the study area.

After the interpretation of the boreholes, six lithostratigraphic units were defined (*Anthropogenic sediments: Unit A, Holocene sediments: Units B1, B2, Pleistocene sediments: Unit C, Neogene sediments: Unit D, Substratum of the Athenian basin: Unit E*). The lithostratigraphy of the boreholes is represented through the Rockworks v. 14 software. Maps cross sections and 3d models of the lithostratigraphic units were drawn to correlate them. From the observation of these cross sections and 3d models, the Holocene evolution of the Athenian basin and the human impact on the paleo-landscape were detected.

Paleogeographic maps were created in order to represent the landscape for each lithostratigraphic unit of the Athenian basin, and extract results for the temporal and spatial changes of the paleo-landscape and the involvement of the human impact on the depositional process in the Athenian basin during Holocene.

\*\*\*\*\*

### **Mid-Holocene Environmental History of a Central Mediterranean Island**

GAMBIN B.(1), MEDAIL F.(1), ANDRIEU-PONEL V.(1), DJAMALI M.(1), MARRINER N.(2), MORHANGE C.(2), GAMBIN T.(3)

(1) IMBE UMR 7263 CNRS et IRD 237, Aix-Marseille Université (AMU) Europôle Méditerranéen de l'Arbois, AIX-EN-PROVENCE, FRANCE ; (2) CEREGE UMR 7330 CNRS et IRD 161, Aix-Marseille Université (AMU) Europôle Méditerranéen de l'Arbois, AIX-EN-PROVENCE, FRANCE ; (3) University of Malta, Department of Classics and Archaeology, MSIDA, MALTA

Through the PaleoMed project a number of cores have been taken from key locations on the Maltese Islands with the aim of establishing various aspects related to the archipelago's historical environment. A multi-disciplinary team have been investigating a number of bodies of evidence including sediments, charcoal and shells. I will present the results from pollen samples extracted from a section of one of the cores. The core, taken from Burmarrad, has a section that has been carbon dated to 7200-3200BP. Preliminary results from this site, one of the largest flood plains on Malta, will provide an indication of the local vegetation during this chronological window.

Pollen was extracted from sediment deposits following the classical treatment method (eg Moore et al., 1990). Furthermore, identification was undertaken through the use of pollen atlases of Europe and North Africa (Reille, 1992, 1995, 1998) and Beug (2004) along with IMBE's international pollen reference collection. Pollen percentages were calculated in TILIA and the pollen percentage diagram constructed using TGView software (Grimm 2004, 2005).

Current results indicate that prior to 7000BP there was a high percentage of aquatic plants, while tree and shrub counts were low. At 6900BP a large increase in Pistacia pollen is recorded, with moderate increase in Plantago (especially lanceolata), Asphodelus, Dinaflagelates and Mirco Foraminifera. At this time there is also a reduction in Cichorioideae & Charcoal in the section. A similar increase in Pistacia at around this time has also been recorded from another core in Burmarrad (Djamali et al., 2012) and in southern Sicily (Tinner et al., 2009). The date of this increase corresponds to the first recorded settlement on the Maltese Islands (circa 5500BC) as well as the climatic optimum of forest cover in the Mediterranean region (Noti et al., 2009).

## **Arsenic Exposure in Pre-Columbian Populations of Caleta Vitor, Northern Chile**

*CUPPER M.(1), SWIFT J.(2), GREIG A.(1), CARTER C.(2), WESTAWAY M.(3), JACOBSEN G.(4), WOOD R.(5), SANTORO C.(6)*

*(1) School of Earth Sciences, The University of Melbourne, MELBOURNE VICTORIA 3010, AUSTRALIA ; (2) School of Archaeology and Anthropology, The Australian National University, CANBERRA AUSTRALIAN CAPITAL TERRITORY 2600, AUSTRALIA ; (3) Queensland Museum, SOUTH BRISBANE QUEENSLAND 4101, AUSTRALIA ; (4) Australian Nuclear Science and Technology Organisation, LUCAS HEIGHTS NEW SOUTH WALES 2234, AUSTRALIA ; (5) Research School of Earth Sciences, The Australian National University, CANBERRA AUSTRALIAN CAPITAL TERRITORY 2600, AUSTRALIA ; (6) Universidad de Tarapacá de Arica, ARICA 1000000, CHILE*

Elevated arsenic levels among the pre-Columbian inhabitants of Caleta Vitor, northern Chile, may be an indication of changing environmental exposure and behaviour related to palaeoclimate, the adoption of agriculture and metallurgy.

Caleta Vitor, located on the Pacific coast some 30 km south of the border city of Arica, comprises seven hunter-fisher-gatherer habitation and burial areas. The site's location in the Atacama, the world's driest desert, leads to excellent preservation of human soft tissue. An estimated several hundred burials at the site range from simple interments of skeletal remains to bundled mummies containing grave goods. Similar settings at Arica and Caleta Camarones to the south preserve the world's oldest artificially mummified human remains, the Chinchorro mummies, which date up to 8000 radiocarbon years.

Public health consequences relating to arsenic exposure have previously be recognised in both modern and ancient populations from northern Chile, but this issue has not previously been explored in the pre-Columbian populations of Caleta Vitor.

ICPMS trace element analysis of 20 human bone samples coupled with new radiocarbon ages has established a temporal correlation for biogenic arsenic concentration in some individuals. Increased exposure to arsenic may relate to environmental variability influencing sources of drinking water, mining activities or dietary changes associated with agriculture.

\*\*\*\*\*

## **A geoarchaeological approach for assessing the archaeological potential in the city of Pisa (NW Italy)**

*BINI M.(1), ANICHINI F.(2), BINI D.(3), DUBBINI N.(3), FABIANI F.(2), GATTIGLIA G.(2), GIACOMELLI S.(3), GUALANDI L.(2), NOTI V.(1), PAPPALARDO M.(1), ROSSI V.(4), SARTI G.(1), STEFFÉ S.(3)*

*(1) Dipartimento di Scienze della Terra - Università di Pisa, PISA, ITALY ; (2) Dipartimento di Civiltà e forme del sapere - Università di Pisa, PISA, ITALY ; (3) Dipartimento di Matematica - Università di Pisa, PISA, ITALY ; (4) Università di Bologna, BOLOGNA, ITALY*

Pisa's subsurface conceals walls, floors, tombs and roads: the traces of life that the city has left behind in almost 3000 years of history. These remains – for the greater part unknown – must coexist with the life needs of modern inhabited areas. MAPPA is a project in the framework of which archaeologists, geologists and mathematicians combine their expertise to study predictive calculation instruments applied to the archaeological potential of the city of Pisa. The archaeological potential of an area is a parameter that quantifies the possibility that a more or less significant archaeological stratification is preserved in an unexplored area. In the urban and periurban area of Pisa a geomorphological survey mainly based on evidence from remote sensing analyses was carried out. It was complemented by subsurface data from 18 cores ranging in depth between 7 and 15 m, analyzed through an interdisciplinary approach. Depositional facies were reconstructed through integration of sedimentological, micropalaeontological, palinological and geochemical data, and chronologically constrained by extensive radiocarbon dating. Geophysical prospecting supported the reconstruction of palaeo-drainage network. The acquired data improved our knowledge about the palaeoenvironmental and human settlement evolution of Pisa area over the past 6000 years, highlighting the mutual interaction between landscape and human activities.

The MAPPA web-GIS is the digital mapping instrument used for the free publication of archaeological, geological and geomorphological data, obtained in the framework of MAPPA activities, on the web. On the basis of predefined parameters and a specific mathematic calculation, the map of archaeological information has been developed in order to evaluate possible remains buried in areas for which there is no existing information today.

### **Open cast mines in South Brandenburg (Germany) - Archives for Late Holocene anthropogenic landscape development**

*RAAB T.(1), RAAB A.(2), NICOLAY A.(2), TAKLA M.(2), BÖNISCH E.(3), RÖSLER H.(3)*

*(1) Brandenburg University of Technology, COTTBUS, GERMANY ; (2) Brandenburg University of Technology, COTTBUS, GERMANY ; (3) Brandenburgisches Landesamt für Denkmalpflege und Archäologisches Landesmuseum, COTTBUS, GERMANY*

Since 2010 the Brandenburg University of Technology (BTU) Cottbus and the Brandenburgische Landesamt für Denkmalpflege und Archäologisches Landesmuseum (BLDAM) collaborate to study the environmental impact of past human land use. Our study area is the opencast mine Jänschwalde, one out of four active lignite mines in South Brandenburg, Germany. Different approaches are combined for a comprehensive landscape reconstruction. Outcrops provide a view into the soil stratigraphy and are used for archaeological studies. In addition, chronological information is obtained by different methods of relative and absolute (<sup>14</sup>C, OSL, dendrochronological) age determination. To build up a model for the landscape development, data (topographical maps, historical maps, physiogeographical information, etc.) is gathered and processed. Charcoal burning is a main factor of landscape development in the last centuries. Production of charcoal was carried out from the c. 17th to the 19th century and is very well documented by about 800 excavated ground plans of circular upright kilns and more kilns are prospected. It is assumed that charcoal was produced for the smelter at Peitz nearby, where bog iron ore was processed since 1567. There is sedimentological proof of the relationship of logging and the formation of wind-blown deposits. In addition, pedological studies on test trenches show that buried plough horizons are widespread. First results of radiocarbon dating of charcoal fragments from buried topsoil horizons date to the Slavic middle ages (600-1200 AD). It is assumed that the eolian activity was triggered by deforestation and extending agricultural use. In conclusion, our results suggest that there are two major periods with eolian activity induced by human impact: the first period caused by extending agriculture during the Slavic middle ages (600-1200 AD) and the second period was induced by deforestation for charcoal burning between the 17th and 19th century.

\*\*\*\*\*

### **The late Holocene palaeoenvironment forcing on human existing and migration within SE Altai (Russia)**

*AGATOVA A.(1), NEPOP R.(1), SLYUSARENKO I.(2), MYGLAN V.(3), BARINOV V.(3), NAZAROV A.(3)*

*(1) Institute of geology and mineralogy, NOVOSIBIRSK, RUSSIAN FEDERATION ; (2) Institute of archaeology and ethnography, NOVOSIBIRSK, RUSSIAN FEDERATION ; (3) Siberian Federal University, KRASNOYARSK, RUSSIAN FEDERATION*

The issue of the Holocene chronology of the archaeological cultures in Russian Altai is still debated. In spite of the fact that these cultures can be generally regarded as a single economic-cultural type – nomads of arid piedmonts and mountains of temperate zone, the debate commonly centers both on the names of cultures and on the periods of their existence. The Holocene palaeoenvironmental reconstructions within Russian Altai also vary considerably which complicates the correlation between geomorphological events and changing of archaeological cultures. This paper presents an attempt to provide such correlation. It focuses on studying of climate changes, estimating of paleoseismicity, timing and revealing spatial characteristics of giant landslide dammed lakes within SE Altai, Russia during the late Holocene.

We report more than 60 new radiocarbon dates of dead trees from moraines and at the upper tree limit on trough slopes, peat layers that cover moraines, wood remains from proglacial forefields which allow us basing the glacier activity on this time period.

We also report dendrochronologically obtained date of a previously unknown strong medieval earthquake. Using radiocarbon method and dendrochronological analysis for trees (both dead and living ones) located on the bodies of seismically triggered landslides and seismically deformed fossil soils gave the opportunity to estimate recurrence interval of strong earthquakes for this area.

Radiocarbon and dendrochronological dates of archeological sites let us to reconstruct periods of existing and outburst of landslide dammed lake which defines the natural habitat of nomads within SE Altai. These data have been also used for reconstruction of landscape prevailing at that time.

In general, suggested chronology of the most important climatic and geological events provides insights for pattern of changes in archaeological cultures and migrations of nomadic population inhabited SE Altai in the late Holocene.

## **Irrigation on the proto-urban site of Sarazm during the Bronze Age (Zerafshan Valley, Tadjikistan): Method and results**

*FOUACHE E.(1), CEZ L.(2), WATTEZ J.(3), BESEVAL R.(4), FRANCFORT H.P.(5), BUYLAERT J.P.(6), MURRAY A.(6)*

*(1) University of Paris Sorbonne, PARIS, FRANCE ; (2) University Paris Panthéon Sorbonne, PARIS, FRANCE ; (3) INRAP, GRIGNON, FRANCE ; (4) CNRS, UMR 9993, PARIS, FRANCE ; (5) CNRS, UMR 7041, NANTERRE, FRANCE ; (6) Technical University of Denmark, ROSKILDE, DENMARK*

The UNESCO World Heritage listed site of Sarazm, located on the west bank of the river Zerafshan in the municipality of the present-day village of Avazali, is a proto-urban surface site that was occupied between 3500 and 2500 BC. It lies on the surface of a loess terrace that was dated 55000 +/- y BP by OSL, that is OIS 3.

The terrace overlooks the Holocene alluvial plain of the river Zerashan by a ten meter high abrupt. The remains of a filledirrigation canal were identified in three places on the northern edge of the loess terrace and related to the archaeological occupation of the site. A 4500 +/- y BP OSL dating confirmed that the canal was related to the proto-urban site of Sarazm. The study of the site confirms how long irrigation has been used in the region lying between the basins of the Amu Darya and the Syr Darya, in which Eneolithic canals in the delta of Tedjen (Turkmenistan) and a Bronze Age canal in Shortughai (Afghanistan) have already been identified.

The geoarchaeological study of the vestiges of the canal of Sarazm required a specific method. The vestiges of the canal were first mapped and drawn, placed within their geomorphological context, while systematic measures of altitude and slopes were carried out. Then samples for micromorphological analyses were taken systematically, as well as samples for OSL dating.

Thus we were able to reconstruct the history of the canal by relating it to the hydrological regime of the river Zerafshan on the long term but also along the shorter term of its annual use. We are presenting the method and our preliminary results.

Key words: Geoarchaeology, Mid-Holocene, Irrigation, Protohistory, Tadjikistan, Zerafshan river.

\*\*\*\*\*

## **Alpine Snow Patches as Archaeological Sites**

*CALLANAN M.*

*NTNU-Museum of Natural History and Archaeology, TRONDHEIM, NORWAY*

Snow patches are small bodies of perennial snow and ice found at high altitudes. Occasionally, archaeological objects are discovered on snow patches where the frozen conditions mean artefacts are often very well preserved. Snow patch archaeology is a global phenomenon with important discoveries made in Alaska, Canada, the Rockies, the Alps and in Norway and Sweden.

Snow patch artefacts have been collected from the mountains of central Norway for almost a century. The local snow patch record consists mainly of arrowheads, wooden shafts and bows that were either lost or discarded on alpine hunting expeditions in the past. The present collection includes finds from a long time span- c. 5500-300bp. This paper is a presentation of a case study based on one of the most productive sites in the region.

A large number of arrowheads and shafts have been discovered at the snow patch at Kringsollfonna, Oppdal (c.1500 m asl). Archaeological analysis shows discrete chronological patterns within the material-some periods are well represented, while others are not. The central question is what lies behind this patterning? Is it due to cultural factors such as changes in hunting practices and strategies through time? Or could it be due to natural factors and site formation processes specific to snow patches?

Earlier archaeological attempts at addressing this issue focused on the whether snow patches were in movement or not. However, the question could not be answered by traditional archaeological methods alone and remained unresolved. However, recent developments mean we can now revisit this question. The number of finds recovered from the site has increased. A number of finds have been 14C dated and multidisciplinary surveys at the Kringsollfonna have produced important physical observations. In this presentation, the new archaeological data will be brought together as an initial step towards modeling the formation dynamics of snow patches as archaeological sites.

### Characteristics of Norwegian ice patches and glaciers with archeological finds

JARRETT L., VATNE G., BERTHLING I.

*Norwegian University of science and technology, OSLO, NORWAY*

Ice patches are common and persistent features in the high mountain environment in the Northern Hemisphere. Over the last decade, parallel to global warming and downwasting of glaciers, they stand out as key localities for archeological finds, revealing information on local reindeer hunting traditions. Ice patches thus appear to provide ideal conditions for preservation of prehistoric organic and inorganic materials. In contrast to glaciers, data from ice patches on mass balance, temperature, deformation and paleoclimatic significance are scarce. There is further no consensus on how to distinguish between glaciers and ice patches. Ice patches are in general viewed as small perennial bodies of cold ice, frozen to the ground and with negligible movement. The melt out of very old, well preserved archeological artifacts supports the theory of limited ice flow, and suggests that they are robust to climate variations despite their presence sometimes well below regional equilibrium line altitudes. Moreover, observations of striations, flutings, and terminal moraines in front of many ice patches in southern Norway, indicate past sliding. This invites us to look at ice patches in a temporal and spatial perspective, with transitional stages between ice patch and glacier through time. Mass balance data suggests a temporal rather than spatial mass balance pattern, with the absence of a traditional mass balance gradient, and hence also the need for throughput of ice (ice flux). Increased knowledge of ice patch characteristics may reveal why they appear to be climate robust, and help archeologist interpret the spatial pattern and age structure of their finds.

\*\*\*\*\*

### Archaeomorphology and the social construction of rockshelters : Nawarla Gabarnmang (Australia)

DELANNOY J.(1), DAVID B.(2), GENESTE J.M.(3), KATHERINE M.(4), SADIER B.(1), WHEAR R.L.(4)

(1) EDYTEM laboratory - Univ. Savoie, LE BOURGET-DU-LAC, FRANCE ; (2) School of géography and Environmental Science, Monash University, MELBOURNE, AUSTRALIA ; (3) Centre National de Préhistoire-Ministère de la Culture et de la Communication, PÉRIGUEUX, FRANCE ; (4) Jawoyn Association Aboriginal Corporation, KATHERINE, AUSTRALIA

Understanding the roles of natural and human processes in the formation and construction of rock art sites has long been a major objective in archaeological research.

The focus is on the geomorphology, which, through the analysis of the physical evolution of archaeological sites, explores the roles of morphogenic processes and other agents, including anthropogenic ones. This dimension of a geomorphological approach, consists of an interrogation of the role of humans in the morphology of the sites studied, as well as the status of the objects present within them. Research conducted at decorated sites, such as the site of Nawarla Gabarnmang (Arnhem Land, Australia) lead to propose the concept of "anthropogeomorphology".

Ahigh spatial resolution geomorphological cartography as well as archaeological data and a 3D modeling tool has enable to show the important anthropogenic contribution in the modification of this site over a 40.000 years period of time.

## **New concepts and evaluation tools in conservation of prehistoric caves, hints from Chauvet and other French cavities**

*BOURGES F.(1), GENTHON P.(2), GENTY D.(3), MANGIN A.(4), D'HULST D.(1)*

*(1) Géologie-Environnement-Conseil, SAINT-GIRONS, FRANCE ; (2) IRD/HSM, MONTPELLIER, FRANCE ; (3) LSCE, GIF-SUR-YVETTE, FRANCE ; (4) ECOEX, MOULIS, FRANCE*

Preservation of cave wall paintings from Pleistocene poses the problem of robustness of remains against climate changes and recent anthropogenic impacts on cavities. Air/rock temperatures, air compositions and fluid transfers are used to test the stability of caves and to identify microclimates buffering mechanisms. Cave walls integrity deals with CO<sub>2</sub> dynamics as it pilots carbonates dissolution/precipitation and temperatures-pressure which govern water evaporation/condensation.

Long term (>15 years) monitoring in Chauvet, Pech Merle, Niaux, and Gargas caves substantiate previous evidence of underground stability. In the remote cavities, a closely equilibrated thermal environment (tenths of °C in seasonal amplitude, hundredths of °C air/rock gradient) is related to the rock volume inertia and to fluids percolation from surface. The small variations in air temperature correlated with barometric pressure were interpreted as isothermal exchanges with rock volume.

We show that large amount of gaseous biogenic CO<sub>2</sub> from soil and epikarst is transferred downward as part of biphasic flow with rainwater. In caves, it generates seepage of saturated water and air inlet equilibrated with soil atmospheres (CO<sub>2</sub> : 0.5 to 4% Vol., O<sub>2</sub> : 17 to 20.9 % Vol., humidity near saturation). Therefore, negligible physicochemical gradients at the air/rock interface protect the remains and their supports from evolution.

Air production from caves walls (Orgnac estimates from 0.007 to 0.04 l.s<sup>-1</sup>.m<sup>2</sup>) is advected along subterranean large voids networks and limits direct outside airflow influence. Near the natural openings, aerologic active interfaces separate underground confined systems where preservation conditions are optimal from cave segments open to surface influence where energy dissipation, phase changes and chemical exchanges induce intense wall weathering.

In some cases, fluid transfer quantification allows a rough evaluation of karst areas and volumes connected with cave systems.

\*\*\*\*\*

## **Poster presentations:**

### **Palaeoenvironmental reconstruction of the Mid to Recent Holocene landscape surrounding the Minoan site of Phaistos (Crete, Greece)**

*GHILARDI M.(1), PSOMIADIS D.(1), LONGO F.(2), AMATO V.(3), ROSSI A.(2), DEMORY F.(1), SABATIER D.(1), COLLEU M.(4), SINIBALDI L.(1), FLEURY J.(1), CARAYON N.(1)*

*(1) CNRS CEREGE UMR 7330, AIX-EN-PROVENCE, FRANCE ; (2) University of Salerno, SALERNO, ITALY ; (3) University of Molise, MOLISE, ITALY ; (4) University of Paris 1 sorbonne, PARIS, FRANCE*

The present work aims to reconstruct the palaeoenvironmental evolution of the Holocene landscape in the vicinity of Phaistos, one of the most famous Minoan site in Crete. Within the framework of a scientific partnership with the Italian School of Archaeology in Greece, a geoarchaeological study have been undertaken in the area. Based on the study of seven boreholes, drilled at a maximum distance of 300 meters from the archaeological site and in a maximum depth of 8.35 m below the surface, a landscape reconstruction is proposed. The analytical work included together sedimentological analyses (laser grain size analysis, magnetic susceptibility measurements, loss-on-ignition and carbonate content estimation). The facies identification is based on the micro (diatoms) and macro (mollusks) faunal identifications. The proxies were incorporated into a robust chronostratigraphic framework through 10 radiocarbon datings (A.M.S.) performed along the cores, on charcoal and organic matter samples. The results highlight the presence of a limnic environment during Middle to Late Bronze Age (ca. 2200 to 1050 cal. BC) where seasonal fluctuations of the water table are clearly observed. A period of dryness, recognized by some authors as the "Late Bronze Age collapse", is identified and dated ca 1100 to 950 cal. BC. Subsequently, the landscape evolved during Antiquity to swamps strongly affected by frequent avulsions of the Gria Sitia River. Our researches clearly help to better understand the relationships between the Minoan settling history and the landscape evolution.

### Fluvio-Estuarine Paleoenvironments and Geoarchaeology in the lower Garonne valley: example of the mediaeval site of Langoiran (Gironde, SW France)

LESCURE S.(1), ARNAUD-FASSETTA G.(2), COLIN A.(3), FARAVEL S.(3), CAROZZA J.M.(4), MATHE V.(5), LE COEUR C.(1), CORDIER S.(6)

(1) University Paris Panthéon-Sorbonne (Paris 1), LGP-UMR 8591 CNRS, PARIS, FRANCE ; (2) University Paris-Diderot (Paris 7), LGP-UMR 8591 CNRS, PARIS, FRANCE ; (3) University Bordeaux 3, AUSONIUS-UMR 5607 CNRS, BORDEAUX, FRANCE ; (4) University of Strasbourg, GEODE-UMR 5602 CNRS, TOULOUSE, FRANCE ; (5) University of La Rochelle, LIENS-UMR 7266 CNRS, LA ROCHELLE, FRANCE ; (6) University Paris Est Créteil, LGP-UMR 8591 CNRS, CRÉTEIL, FRANCE

Since 2010, an interdisciplinary team works in the research program “Peoples of the Médoc estuary and coastal fringe during Protohistorical, antic and mediaeval times”. The project focuses on the reconstruction of the past human-environment interactions in the lower estuarine Garonne valley. Historical, archaeological, geomorphological, and geophysical investigations are coupled to highlight these interactions in a geoarchaeological view. On the site of the *Castéra* of Langoiran (upper part of the estuary), a mediaeval castrum located in the present-day Garonne floodplain was abandoned around the mid-13th century to be re-established 40 m above the valley floor, on a fluvial terrace preserved. In order to verify possible environmental cause to this change, palaeoenvironmental reconstruction was carried out. This latter includes the 3 hydrogeomorphological approaches (hydrography, hydrology, hydraulics) to assess: (i) the spatio-temporal variability of hydrological hazards (diachronic mapping of hydrological network, changes in the hydrological regime), (ii) the vulnerability of past societies exposed to these hazards, and (iii) the influence of the fluvial constraint (flooding, avulsion) in terms of risk. 13 cores have been drilled on the basis of previous geomorphological and geophysical data. Sedimentological, palaeobiological (pollen, foraminifera, ostracods) and geochronological (OSL, <sup>14</sup>C) analyses allowed us to reconstruct the stratigraphy of the fluvial sedimentation before, during, and after the castrum phase occupation (end of the 12th c. up to mid-13th c.). These results were coupled with geophysical analysis to reconstruct the palaeochannel geometry and so the hydraulic parameters (channel capacity, discharge, specific stream power). Results lead to propose a first reconstruction of fluvial palaeoenvironment around and during the *Castéra*'s occupation showing the presence near the site of the main Garonne River palaeochannel or a crevasse play.

\*\*\*\*\*

### Landscape change around Minturnae and Garigliano river mouth

BELLOTTI P.(1), DALL'AGLIO P.L.(2), DAVOLI L.(3), D'OREFICE M.(4), DI BELLA L.(3), ESU D.(3), FERRARI K.(2), MAZZANTI M.(5), TORRI P.(5)

(1) Dipartimento di Scienze della Terra - Sapienza Università di Roma, ROMA, ITALY ; (2) Dipartimento di Archeologia Università di Bologna, BOLOGNA, ITALY ; (3) Dipartimento di Scienze della Terra Sapienza Università di Roma, ROMA, ITALY ; (4) IRSA AMBIENTE, ROMA, ITALY ; (5) Laboratorio di Palinologia e Paleobotanica Università di Modena e Reggio Emilia, MODENA, ITALY

The landscape evolution at the Garigliano River mouth has been drowned for the last 6 ka. In this area at the border between Latium and Campania, the Roman colony of Minturnae developed between the Tyrrhenian Sea and the Via Appia, where the latter crossed the river, during the period between the III century BC and the VI century AD. At the time there were two coastal basins on either side of the river that made the environment different from the current, as well as different was the use that man made of the land by following its evolution.

The present study is based on:

- geomorphologic analysis from sets of aerial photographs and ancient cartography ;
- several cores by manual auger and three mechanical cores (up to 4.5/6 m depth) by AF coring system to obtain continuous cores with preserved sedimentary structures;
- grain size analysis by means of mechanical sieving and laser diffractometry for > and < 62µ fractions, respectively;
- <sup>14</sup>C datings, <sup>13</sup>C/<sup>12</sup>C and C/N ratios, measured on specimens of the cored sediments selected;
- pollen, malaco and microfaunistic analysis.

The results of this study complement the archaeological knowledge acquired on the Roman colony of Minturnae allowing a more accurate reconstruction of the activities carried out in the town. Also better define the landscapes that preceded and followed the Roman expansion.

## **Magdalenian open-air site location preferences in the Carpathian and peri-Carpathian landscapes (SE Poland)**

LANCZONT M., HOLUB B.

*Maria Curie-Sklodowska University in Lublin, Department of Geoecology and Palaeogeography, LUBLIN, POLAND*

The beginning of reoccupation of the Central Europe area in the post-maximum phase of the Weichselian Glaciation during the ice-sheet retreat was associated with the activities of Magdalenian groups, which migrated eastwards in several waves. Population of this culture penetrated these terrains as far as the right-bank part of the Vistula basin, and this was the most easterly area of Magdalenian settlement. The newly-settled territories stretched between the Middle Polish Uplands and the northern slopes of the Carpathians. This zone includes three physico-geographical regions with different landscapes. In this zone the oldest traces of Magdalenian penetration were dated to the last part of the Upper Pleniglacial (even before the end of the Oldest Dryas), and the twilight of Magdalenian expansion -to the Late Glacial (probably to the Allerød warming). This time interval was characterized by climate changes, rapid and considerable especially in the Late Glacial, which resulted in dynamic transformations of bio-geosystems. Great changes occurred in river valleys where braided river channels changed into large meanders. Magdalenian settlements are not numerous but it is noticeable that most of them occur in river valleys, which were ecological corridors and probably routes of migration. Based on spatial analysis and palaeoecological data there were described the location conditions of seasonal open-air Magdalenian sites in the valleys of the rivers: Carpathian (San River in the mountain section and near the Carpathians margin), peri-Carpathian (San River in its lowland section), and upland (Opatówka River, near its confluence with the Vistula river). The analysed sites have many common morphological features. In the paper we define the factors, which influenced the open-air site location preferences in the eastern frontiers of Magdalenian Culture, in order to understand the environment exploitation strategies of this hunter-gathering population.

\*\*\*\*\*

## **Time scales and geoarcheology: stability vs instability of the ancient maritime site of Ayn Sukhna, Gulf of Suez, Egypt**

PEULVAST J.(1), TALLET P.(2)

*(1) Université Paris Sorbonne, PARIS, FRANCE ; (2) Université Paris-Sorbonne, PARIS, FRANCE*

Studied for the years 2000, the archeological site of Ayn Sukhna is located on the western coast of the Gulf of Suez, on the narrow piedmont of arid sedimentary plateaus, close to a thermal spring and at the outlet of the shortest way linking the gulf to Memphis. It was built and occupied at the times of the Old Kingdom and then of the Middle and New Kingdom, and until the Ptolemaic period, i.e. between 2600 and 300 y BC. The site is now partly obliterated and separated from the sea by modern constructions, but two parts remain accessible: remains of dwellings on colluvial fans and shore platforms of the piedmont, and a set of 10 galleries excavated in the base of the Gebel Galâla el-Baharyya. The aims of its geomorphic study, by the means of field work and image interpretation, are: understanding the potential and constraints that lead the Ancient Egyptians to use this site as a maritime base for expeditions towards the Sinai and production of copper, and defining the conditions of stability or instability that allowed its preservation until the recent period. At large- and mid-scale, we show that gravitational instability responded to faulting and uplift which probably ceased in the Late Miocene, producing a huge landslide in which part of the site is inset. Obliterating the Gulf of Suez rift faults, this landslide may have modified the underground water flow and determined the presence of a thermal spring at its foot. However, no sign of recent activity was found at the base of the mountain, else than effects of slow rock-disintegration and of episodic rock falls, gullying and sudden wadi flows. With its altitudes of 6-7 m, in the continuity of the regional Tyrrhenian shore-line, and its lack of deformation, the ancient shore platform on which part of the site is built confirms a Pleistocene and Holocene tectonic stability. Its study and that of younger shore deposits contradicts older speculations on significant variations of the shore-line since the Antiquity.

### **A reconnaissance study of a prehistoric settlement in Koyun Island, Southern Marmara Archipelago, Marmara Sea, Turkey**

ERTEK T.(1), KILIC E.(2), ERGINAL E.(3)

(1) *Istanbul University, ISTANBUL, TURKEY* ; (2) *Istanbul University, 34459, TURKEY* ; (3) *Ardahan University, ARDAHAN, TURKEY*

Rising from the southwest shelf of the Marmara Sea, NW Turkey, the Marmara Archipelago consists of 23 islands and islets as well as a vast number of reefs. The raised fossiliferous near-shore deposits on the coast of these islands and identifying tectonic uplift rates in such an tectonically active Marmara Sea.

In this study, a shell midden deposit on southwest coast of Koyun Island, a small member of the Marmara archipelago, is studied on the basis of facies characteristics, stable isotope measurements and AMS radiocarbon dating results from fossil shells. The island with an area of 1,71 km<sup>2</sup> comprises marble, schist and granodiorite. Overlying a brownish colluvial layer, shell mound including plenty of mollusc shells form waste products of the island inhabitants. The shell-laden level has a maximum thickness of 60 cm and extends between 1.5 m and 10 m above the present sea-level. Main fossil components are made up of *Ostrea edulis*, *Mytilus galloprovincialis* and *Cardium* sp. as well as animal bones and fragments of pottery, evoking residuals of consumption left from an archaeological settlement of unknown age. The calibrated AMS14C ages from shells of *Ostrea* and *Mytilus* collected from +10 m and +2 m, respectively, yielded values of 6540 – 6370 yrs BP and 6950 – 6750 yrs BP. Based on global sea-level curve, the level of the Marmara Sea during that time span was about at -4 m in proportion to the present. The studied deposit is likely a residual of an island settlement belonging likely to Late Neolithic-Early Chalcolithic.

Acknowledgements: This study is financially supported by the Commission of Research Projects of Istanbul University (Project number: 9105).

\*\*\*\*\*

### **Characteristics of ruins in the Neolithic Age in Bibong-ri, Changnyeong and their implications for sea level fluctuations**

YOON S.O.(1), HWANG S.(2)

(1) *Dept. of Geography and Research Institute for Basic Sciences, Kyung Hee University, SEOUL, SOUTH KOREA* ; (2) *Dept. of Geography, Kyungpook National University, , DAEGU, SOUTH KOREA*

Bibong-ri is located at the marginal areas of alluvial plain of Cheongdo River, a tributary of Nakdong River that is the longest river in Korea, and Cheongdo River joins to Nakdong River 70 km away from the river mouth. The sedimentary facies of the study area consist of bedrock, bottom gravel bed, Holocene gravel bed and Holocene alluvium upward. The earthenwares in the Neolithic Age are included in the Holocene gravel bed. The alluvium can be subdivided into marine deposit, terrestrial deposit, back marsh deposit upward and a great deal of shell deposits and acorn hollows are found. Based on the sedimentary facies, properties of shell deposits, topographical properties of acorn hollows, diatom analysis and AMS age dating, the sea level fluctuations during the middle Holocene are reconstructed. The floodplains in the lower reaches of Cheongdo River are the results of sea level fluctuations during the Holocene and the sea level during the maximum phase of transgression was higher than the present by approximately 1.5 m.

## **The social construction of rock art caves. Contributions of the geomorphological approach in Chauvet cave**

*DELANNOY J.(1), GENESTE J.M.(2), JAILLET S.(1), SADIER B.(1), BOCHE E.(2)*

*(1) EDYTEM laboratory - Univ. Savoie, LE BOURGET-DU-LAC, FRANCE ; (2) Centre National de Préhistoire-Ministère de la Culture et de la Communication, PÉRIGUEUX, FRANCE*

The study conducted in the Chauvet cave provides an exceptional resource for the archaeology, paleontology and geomorphology research.

The different elements of the landscape underground (accumulation, blocks aligned, moving objects, vertical bones...), have been studied only recently. Geomorphological and archaeological studies help to highlight the cultural features of the landscape and the different types of spatial organization of the site (basins, steps). The methodological approach including geomorphological mapping and 3D surveys allows to discriminate the morphogenic processes and the anthropogenic ones.

These preliminary results show that the Chauvet Cave has, apart from rock art panels, many anthropogenic features inscribed in the underground landscape. These elements offer a new perspective concerning the appropriation of the cave by prehistoric humans.

\*\*\*\*\*

## **Relations between ancient settlement and the physical environment: a case study of the area from Dora Baltea river to Scrivia river (Western Po Plain - Italy)**

*PELLEGRINI L.(1), DALL'AGLIO P.L.(2), ZIZIOLI D.(1), FRANCESCHELLI C.(3)*

*(1) Earth and Environmental Sciences Department - University of Pavia, PAVIA, ITALY ; (2) Archaeology Department - Bologna University, BOLOGNA, ITALY ; (3) Centre d'Histoire Espaces et Cultures - Université Blaise Pascal - Clermont II, CLERMONT-FERRAND, FRANCE*

As is known, since the prehistory, the interrelationship of the man with the landscape have become increasingly close. The study carried out on the western Po plain between the confluence of the Baltea and Scrivia Rivers, fully confirms this assumption. The study area is characterized by a typically fluvial morphology with Holocene terraces enclosed within the carved late Pleistocene plain (Main Level of Plain) and sometimes in direct contact with the Monferrato hills. The reconstruction of the evolution of the bed of the Po River has highlighted as, in certain reaches, it has been the prevalent tendency to digression and therefore instability, while in other reaches the bed was maintained more stable and less wide. Over the past two centuries, human activities especially of rice cultivation, largely cleared the remains of ancient morphologies and settlements. However it is possible to recognize a link between the distribution of population and landscape. In fact, the settlements, including the Bronze Age of Pobietto, lie mainly on higher terraces. In Roman and Medieval age, the Po river becomes very important related to its wideness or stability: the major road axis crossing the Po were located where the river is more narrow and more stable. For example in these areas, are located the cities of Valenza and Casale Monferrato, which correspond to the Roman *Vardacate* and *Valentia*. A similar location have many medieval "villeneuve" and the Breme and Aqualongae early medieval abbeys, which are, with Lucedio and San Genuario, the center of the re-colonization after the late-antiquity crisis. Therefore, it should be noted how are important the integrated contributions of the geomorphological and historical and archaeological study for understanding the evolution of an area.

### Study on the properties of reconstituted stones of the Orval Abbey, Belgium

NGUYEN T.(1), FUJIMAKI T.(1), NAKAYAMA T.(1), OSAWA Y.(1), OGUCHI C.T.(2), THOMACHOT-SCHNEIDER C.(3), GOMMEAUX M.(3), DEMURA H.(1)

(1) Graduate Student, Saitama University, SAITAMA, JAPAN ; (2) Geosphere Research Institute (GRIS), Saitama University, SAITAMA, JAPAN ; (3) GEGENA, University of Reims Champagne-Ardenne, REIMS, FRANCE

The Orval Abbey in southern Wallonia, Belgium, was originally built in middle age and rebuilt in modern age. The new building walls mainly made of reconstituted stones agglutinated using cement with crushed natural limestone have been suffering from salt weathering, although the medieval building walls made of natural limestone have not. Deterioration due to salt efflorescence was observed only at the ground floor wall of the modern building.

To elucidate the deterioration mechanism, environmental monitoring and rock-property measurement were performed. Color changes due to weathering are also observed using spectral colorimeter at the site. Pore size distribution, elemental distribution and mineral characterization of the stones were investigated using mercury intrusion porosimetry, scanning electron microscope and x-ray diffraction. Chemistry of groundwater near this abbey site was also determined using ion chromatography.

Temperature and humidity conditions of the investigation site, where reconstituted stones were mainly used in the modern building, fluctuated drastically. The pore size distribution of the reconstituted stones revealed that the stone consists of large fraction of microporosity, which favors salt damages. The main salt causing deterioration revealed sodium sulfate. Sulfur and sodium were detected from reconstituted stones and groundwaters.

From the above findings, the origin of the salt resulted in both stones and waters. Water-rock interaction has been occurred to crystallize sodium sulfate. The environmental condition favors the cyclic conversion between mirabilite ( $\text{Na}_2\text{SO}_4 \cdot 10\text{H}_2\text{O}$ ) and thenardite ( $\text{Na}_2\text{SO}_4$ ), which is known as the main damaging mechanism of salt weathering. The Swe-Yu & Oguchi's (2010) salt susceptibility index of reconstituted stones was much higher than the limestones using in the abbey, supporting the occurrence not only efflorescence but also salt deterioration on the site.

\*\*\*\*\*

### Erosional-detrital phases in the lower Seine Valley catchments (Normandy, France) using a geoarchaeological approach

SECHI S.(1), LAIGNEL B.(2), LEPERT T.(3), MELIS R.T.(4)

(1) Université de Rouen, UMR CNRS 6143, ROUEN, FRANCE ; (2) Université de Rouen, UMR CNRS 6143, Mont Saint Aignan, France, ROUEN, FRANCE ; (3) Université Paris I & X, CNRS, Laboratoire ArScan, UMR 7041, PARIS, FRANCE ; (4) Departement of Chemical and Geological Sciences, University of Cagliari, CAGLIARI, ITALY

Actually, the influence of the climate and man-activities in the Holocene environmental changes are still the focus of several discussions. It is obvious that both factors are implicated in changes of hydrological balance, soil erosion and terrigenous sedimentation and can be added to geomorphological factors (local and regional) and the intrinsic lithological proprieties of geosystem.

We define different geomorphological compartment characterizing the geosystem of the catchments of the Lower Seine Valley (LSV) as: plateaus, slopes, tributaries (TSR) and LSV (which can be also divided to estuarine zone, fluvial organic zone and fluvial detrital zone). There, we have found nine erosion-sedimentation phases during the last millennia. The geological approach lead to define a spatial stratigraphic evolution and the detrital distribution. The relative datation of detritals inputs was obtained by the archaeological remains. Such phases are directly or indirectly triggered by the increasing of anthropogenic pressure combined or not-combined to climate change, local and regional geomorphic processes.

During the Early Holocene climate peioration, a deep and linear under-scour of plateaus and slopes and changes in drainage network load to the "Mesolithic detritism". During the Mid-Holocene transition, the deglaciation loads to the increase in hydrologic fluxes. Forest Neolithic clearance and agricultural development, added to climate changes, became an important factor of the induced detritism found in all geomorphic compartments. After that, the Bronze Age metallurgy development and tillage practices and the Iron Age regional cultural evolution, induced another detrital phase in the whole environments: plateaus, slopes and fluvial zone of the LSV. From the Middle Age to the actual time a generalized detritism was recorded in the whole region.

## **Destructive abrasion processes of archaeological site Ostolopovskoe**

*GAYNULLIN I.(1), USMANOV B.(2)*

*(1) Sh. Marjani Institute of History, KAZAN, RUSSIAN FEDERATION ; (2) Kazan Federal University, KAZAN, RUSSIAN FEDERATION*

The problem of archaeological heritage conservation is highly relevant for the Republic of Tatarstan (RT), Russia, because most of archeological sites from the Mesolithic to the late Middle Ages, situated in the coastal zone which is due to the nature of human life in the past and 75% of the Kuibyshev reservoir shores and more than 290 km of small rivers shores in RT affected by dangerous exogenous processes.

Complex of monuments in question - Ostolopovskoe hillfort, Ostolopovsky burial and Ostolopovskie Settlements I and II - located on the shore of the Kuibyshev reservoir at the mouth of Shentala river (Alexeevsky District RT). Comparison of topographical maps and results of remote sensing data interpretation, using GIS technology allow to estimate the rate of hazardous processes and, thus, to determine the risk of destruction of the monument. The displacement of coastline (1958-2005) studied with the help of multi-temporal remote sensing data. The distance of coastal retreat varies from 0.75 to 1.4 m per year. Archaeological site Ostolopovskoe Settlement I, is mostly destroyed by permanent abrasion processes. During the study period the area of 2.74 hectares washed away, cultural layers were destroyed, maximum displacement speed is 1.4 m per year.

Cultural heritage sites monitoring, with information about the chronology, cultural layer value, settlement specifics, etc., taking into account the remote sensing methods used in landscape ecology and field archaeological survey, allows to evaluate damage and the intensity of archaeological sites destruction through the dangerous exogenous processes estimation.

\*\*\*\*\*

## **Geoarchaeology in Cantabrian Mountains (NW Spain): human activity prior to Roman occupation in the Roman Camp Site of Via Carisa?**

*JIMENEZ-SANCHEZ m., DOMÍNGUEZ-CUESTA M.J., FARIAS P., FERNANDEZ-VIEJO G., RODRIGUEZ-RODRIGUEZ L., OLONA J., BALLESTEROS D., NAVES B.*

*department of geology, university of oviedo, OVIEDO, SPAIN*

A geoarchaeological research (funded by PC10-14 Project, FICYT-Rioglass S. A.) was carried out in the Roman Camp Site of Via Carisa. The relevance of this site comes from its interpretation as a major military camp (*castra aestiva*) built in a mountain environment (1,728 m.a.s.l.) under the legate of Publio Carisio (about 26-22 a BC). The site is close to Via Carisa, a strategic historical path between the Cantabrian Coast and the interior of the Iberian Peninsula. The research aims to establish the interaction between human activity and landscape in a complex mountain environment, by combining geomorphological mapping, geophysical research (multi-technique geophysical research with seismic refraction and multichannel analysis of surface waves methods), core sampling and AMS radiocarbon dating. Landscape features result mainly from fluvial and gravity action, being outstanding the occurrence of large ancient landslides reworked by human activity and partially occupied by the Roman Camp. Several small bogs right on top of the landslides are interpreted as artificial closed structures of unknown age, subsequently filled by a sedimentary sequence, which was sampled with seven hand drill cores. Deogracias-1 core (202 cm deep) located at 1,248 m a.s.l. is composed by alternations of clay, silt and sands (interpreted as waste activity in a pond) and a unit of gravels embedded in a clay matrix (interpreted as colluvial deposits). Radiocarbon data shows that the pond infill would have extended from 2,550 ± 30 yr BP (cal BC from 800 to 570 yr) to 2,410 ± 30 yr BP (cal BC 730 to 400 yr). The results suggest that human occupation is prior to Roman times, reinforcing the strategic significance of Via Carisa as a historic pass across the Cantabrian Mountains

## Geoarchaeological aspects of quaternary geomorphology of Kazakhstan

BAIBATSHA A.

*Kazakh National Technical University named after K. Satpayev, ALMATY, KAZAKHSTAN*

Favorable conditions for the existence of hominids were fully formed in the Kazakh steppes to the late Neogene period. In the current ranges of Karatau there lived herds of large animals in the forests and woods year-round growing fruit trees and berries, strong siliceous rocks were deposited on the surface required for the manufacture of tools. All of those were favorable factors for the lives of ancient people.

Hominids inhabited the territory of the Kazakh steppe about 2,0 million years ago had long and difficult path in life, endured all the trials and overcoming all the difficulties of primitive society, came to our century. Archaeological studies have given the materials covering the long and complicated path of evolution of the first man. Early Paleolithic era covers, known as Acheulean and Arystandy culture in the Kazakh steppe [Baibatsha A.B., 2012].

Arystandy culture. Found in the valley r.Arystandy [H.A. Alpysbayev, N.N. Kostenko, 1968] near Range of Big Karatau the primitive pebble stone tools considered as cultural monuments of the earliest people in the Kazakh steppe. Based on a comparison of these crop residues with well-known in the science culture Olduvai hominids in Africa, an archaeologist A. Medoyev (1982) proved that they are coeval.

In the area of the Ridge B. Karatau most ancient instruments of a man revealed in the area of the valley r.Arystandy on its left high bank, among the preserved from erosion lower Antropogenic conglomerates. Lower Antropogene conglomerates' thickness is 9 m and more evident in a number of points as the left bank and right bank of r.Arystandy.

About the time of formation lower antropogenic conglomerates can be judged on the basis of archaeological, palynological and other data. Karatau ancient people lived in the era of the first anthropoids and Anthropogene faunal assemblage [Alpysbayev H., 1979].

\*\*\*\*\*

## Using geomorphology and physical geography in obsidian sourcing

MOURALIS D.

*Universite de Rouen et CNRS, UMR IDEES, 6266, MONT-SAINT-AIGNAN, FRANCE*

The lithic artefacts found in archaeological excavations reflect the diffusion of raw material or artefacts from their geological sources to the archaeological excavations. Since the pioneer works by Cann and Renfrew (1964), an increasing number of studies have investigated the obsidian that have been intensively used by prehistoric people all over the regions of the world where it outcrops. Obsidian sourcing is thus became a very dynamic field of research.

The obsidian sourcing is based on three proprieties. 1) First, it is possible to characterize physical and chemical properties of an outcrop. 2) Second, the intra-source variation of these characteristics may be neglected in comparison with inter-source variations. 3) And third, it is still possible to find the outcrops of the sources used by prehistoric peoples.

The physical and chemical characteristics (properties 1 and 2) of obsidian –as other volcanic materials- depend to the differentiation processes in the magma chamber and secondary to the weathering occurring after the deposition of the material. These properties are thus linked to the volcanic and morphologic evolution of the studied volcano.

Moreover, it appears that the definition of the sources (property 2) depends greatly from a researcher to another and from the scalar level. In some cases, an “obsidian source” corresponds to an entire volcanic region, whereas in other cases a “source” may be a single outcrop. In some other cases, an obsidian “source” is first of all a chemical group.

Finally, the sources used by prehistoric people for tool-chopping may be found (property 3) if they have not been later eroded or fossilized. This third property is thus directly linked to morphological evolution of the volcano since the obsidian deposition.

In this presentation, we thus demonstrate how geomorphology, and physical geography in general, may play a very important role for obsidian sourcing.

## **Holocene fluvial and coastal processes, landforms and human settlement: the case of the roman town of Sena Gallica (Marche, Italy)**

*DE DONATIS M.(1), LEPORE G.(2), SAVELLI D.(1), SUSINI S.(1), SILANI M.(2), BOSCHI F.(2), NESCI O.(1)*  
(1) *Universita' di Urbino "Carlo Bo, URBINO, ITALY* ; (2) *Università di Bologna, BOLOGNA, ITALY*

*Sena Gallica* (modern Senigallia) was the first roman colony established on the Adriatic Sea at the beginning of the 3<sup>rd</sup> century B.C., in the northern Marche region, central Italy. Since 2010 a new research project has been started by an agreement between Municipality, University of Bologna (DiSci, Section of Archaeology), University of Urbino (DiSTeVA) and Soprintendenza per i Beni Archeologici delle Marche, with the main goal to reconstruct the ancient landscape, understanding the relationship between geomorphological and historical evolution.

The adopted research method is based on combining old and new data, involving archaeological excavations, topographical and geophysical surveys, geological and geomorphological analysis. The management of all acquired data is favoured by the digital field mapping, GIS elaboration and 3D modelling. The research revealed the presence of an early Holocene coastal fan built by the Misa river. The deactivation of this fan had been followed by a partial erosive dismantling by both wave and stream erosion and then by a partial drowning of its remains.

The particular morpho-evolutionary history of the coastal fan allowed the development, in correspondence to the former fan-head, of soggy flats and depressions enclosing relatively high, isolated sectors, which later were selected for the earliest human settlement. The new environment was also modified by the fluvial action. In fact, the presence of topographic highs bounded by the Misa River meanders, and by the Penna streamlet, induced the roman colonists to found here the town. At the same time, the fluvial morphology influenced several choices in the roman urban planning, as in the case of the urban walls' route, the location of the port, and of the regularization of the Penna channel, which was transformed in a kind of artificial channel, in order to prevent the floods of the Misa river.

\*\*\*\*\*

## **S15 B: What does art can teach us about coastal geomorphological environment ?**

*MOTTE E.(1), REGNAULD H.(2), RUAULT R.(2), DAIRE M.Y.(3)*

(1) *Universite Rennes 2, RENNES, FRANCE* ; (2) *Université Rennes 2, RENNES, FRANCE* ; (3) *Université Rennes 1, RENNES, FRANCE*

Understanding present coastal environment changes and anticipation of its evolution implies some knowledge about past conditions. Available scientific data does not often go back far enough to cover long time scale. Therefore, the idea of this work is to show how art, especially pictorial representations, can be used for such an aim. A collection of paintings, engravings, watercolors and so on have been gathered together, which all deal with the coast of Brittany (western France). The dataset cover a time period from 1750 to 1940, but most of the work of art we used were painted between 1800 and 1920, as Brittany was a major source of inspiration for artists from all over the world. These paintings can bring informations to extend data bases temporally: land cover and land uses, beaches sedimentology (composition and grain size), activities on the intertidal zone. Though contemporary art is not so realistic, a few artists are presently producing works which may be added to the dataset. An other interesting point is that these works may also be interpreted as readings, expressions of past human looks and apprehension of coastal areas, offering consequently new elements to appreciate the relative importance of each type of geomorphological site regarding what is considered as a beautiful landscape. Here we join the concept of "geomorphosites" according to which socially shared affects do exist for some particular types of coastal places. This work, as it will necessary rely on some privileged places (those which have been represented many times), will help to assess how much our present "geomorphosites" result from a cultural and aesthetic progressive and ongoing construction.

### The environment of tell of Dikili Tash: anthropogenic and climatic changes

GLAIS A.(1), LESPEZ L.(2), LOPEZ-SAEZ J.A.(3)

(1) *Universite de Caen Basse-Normandie / Geophen, CAEN, FRANCE* ; (2) *Universit? de Caen Basse-Normandie / Geophen, CAEN, FRANCE* ; (3) *CSIC, MADRID, SPAIN*

The investigations carried out around the tell of Dikili Tash (Northern Greece), improve our understanding of the evolution of the palaeoenvironment from the beginning of the Early Neolithic (c. 6 500 cal BP) to the Bronze Age, the periods of its occupation. In order to investigate the human and the climatic impacts, mainly Rapid Climatic Change events, around the tell of Dikili Tash, the small-scale alluvial sedimentary archives are valuable sources of palaeoenvironmental and geomorphological information. While global climate reconstructions researches based on the study of the Tenaghi-Philippou marsh, located 7 km from the tell, have focused on forces that drive the environment at the regional or continental scales, we attempt to use the local sediment archives to identify periods of changes around the closer inhabited areas. The reconstruction of environmental changes is based on field work and more than 15 cores located in the wetland and alluvial areas near the archaeological site. Two sources of palaeoecological investigations have been conducted: geomorphological and sedimentological investigations and pollen and non-pollen palynomorphs analyses. Palaeobotanical proxy data give a comprehensive view of anthropogenic impact on the vegetation cover which can be compared to the sedimentological changes undertaken in the lowland areas. Combined with archaeological data, this information allows reconstruction of interactions and/or adaptation of the past local societies to global changes. Marsh boundaries evolution and soils erosion observed from core drillings in the sedimentary filling of the small depression gives evidence of periods geomorphological changes in response to anthropogenic since the Middle Neolithic.

The poster proposed presents the methods and the main results of this local and multi-proxy approach. The palaeoenvironmental and geomorphological investigations give evidence of early anthropogenic disturbance and climatic events impacts.

\*\*\*\*\*

### The Middle and Upper Pleistocene loess record and Acheulean-Mousterian industries of Saint-Illiers-la-Ville (78 - France)

CHAUSSE C.(1), SCHWENNINGER J.L.(2), DEBENHAM N.(3), BLASER F.(4)

(1) *Inrap (7 rue de Madrid - Paris) et Laboratoire de Géographie Physique (UMR 8591) - Meudon, PARIS & MEUDON, FRANCE* ; (2) *Luminescence Dating Laboratory, Research Laboratory for Archaeology & the History of Art, OXFORD, UNITED KINGDOM* ; (3) *Quaternary TL Surveys, NOTTINGHAM, UNITED KINGDOM* ; (4) *Inrap (7 rue de Madrid - Paris) et Préhistoire et Technologie, UMR 7055 - Nanterre, PARIS & NANTERRE, FRANCE*

A new sequence of loess / palaeosol was found in a section located at Saint-Illiers (Yvelines) in western Paris Basin (France). The excavation yielded several levels of Palaeolithic artifacts comprising handaxes. An extensive study was carried out to get a reliable chronological framework. In a first step, litho-pedological investigations including micromorphological data were compared with an equivalent succession from north-western France. Then, results were dated using a chronological luminescence framework based both on Thermoluminescence and Optically Stimulated Luminescence methods applied on burnt flints and sedimentary material. Synthesis of results allows to reconstruct successfully the chronology of deposits and the climatic fluctuations since ca 400 kyrs ago.

In summary, the Saint-Illiers sequence consists of several loamy aeolian units deposited during different cold periods. Some of them are reworked by solifluction and colluvial processes. They are related from the oldest to the most recent to MIS 10, 8, 6 and 2. They are interbedded with palaeosol levels developed during interglacial and interstadial conditions linked to MIS 9, 7, 5 and 3. Finally, each prehistoric level can be integrated within its own chronostratigraphical context. The oldest Acheulean settlement (S3N4) is dated end of the glacial stage MIS 10. The second one (S2N2) is attributed to the MIS 7 interglacial period. The third layer of artifacts (S3N2) is contemporaneous of a cold period correlated with MIS 6. The two following levels (S2N1 and S3N1), attributed to the middle Palaeolithic, are associated with various deposits assigned to the Weichselian Early Glacial (MIS 5d-a or 4) and to the Middle Pleniglacial (MIS 3) period.

## **Iron as raw material: Introduction of iron metallurgy and spatial implications on landscapes. A case study from the forelands of the Harz Mountains, NE Germany**

*BEBERMEIER W.(1), HOELZMANN P.(1), SCHIMPF S.(2), SCHÜTT B.(1)*

*(1) Institute of Geographical Science, BERLIN, GERMANY ; (2) Alfred Wegener Institute for Polar and Marine Research, POTSDAM, GERMANY*

The knowledge of iron metallurgy spreads at the declining Bronze Age from the advanced civilizations of the Hittite of present day Turkey north-westwards reaching northern middle Europe ca. in the 3<sup>rd</sup> century BC. Exploitation, smelting and processing of this new raw material requires large amounts of energy feedstock. For the centre of iron smelting in the Mediterranean Populonia, located in western Tuscany at the Tyrrhenian Sea it is assumed that iron production shifted from Elba to the Italian west coast after the island has been nearly deforested. Consequently, it is inferred that the introduction of iron metallurgy to a region is associated with additional pressure on the landscape. The aim of our presentation is to test this hypothesis for two settlement sites of the Przeworsk culture (approx. 2100 a BP) located east of the city of Nordhausen in the southern forelands of the Harz Mountains, NE Germany. The Przeworsk culture immigrated from present-day Poland to this area and possessed – in contrast to the local already existing population - the knowledge of iron smelting techniques. Their settlements are located in close vicinity to clay ironstone layers in the sandstone bedrock (Lower Buntsandstein formation).

Our study is based on the analyses of four valley sediment sequences. Drillings in these sediments bottom out on the bedrock and represent the sedimentary history since the late Pleistocene. The sediments show typical sequences of varying facies that represent periods of enhanced geomorphological activity and phases of stability during the early Holocene. After 3.600 cal a BP an increasing amount of charcoal, coarser grain sizes and angular pebbles are found in colluvial deposits. We interpret this as a consequence of clearing activities. However, up to date the resolution of the <sup>14</sup>C-chronology requires refinement to clearly validate or falsify the above mentioned hypothesis.

\*\*\*\*\*

## **Mid-Holocene changes in morphodynamics along the western Calabria coasts (Italy): geoarchaeological implications**

*RUSSO ERMOLLI E.(1), PACCIARELLI M.(2), ROMANO P.(1), CICALA L.(2), DI DONATO V.(1), RUELLO M.R.(1), TERRASI F.(3)*

*(1) DISTAR University of Naples Federico II, NAPLES, ITALY ; (2) DSU University of Naples Federico II, NAPLES, ITALY ; (3) INNOVA, CASERTA, ITALY*

The western Calabria region, overlooking the Tyrrhenian Sea, is characterized by high relief rocky coasts alternating with large plains, such as the Lamezia-St Eufemia plain. It preserves flights of Quaternary uplifted marine terraces which are dissected by steep catchments draining to piedmont areas where entrenched alluvial fans, Late Pleistocene-Holocene in age, are found.

Archaeological findings of the last decades reveal the continuous presence of human populations since Neolithic, which have found favorable conditions for their settlements both on the gentle terraces and in the large piedmonts of this area.

In order to spread light on the Holocene landscape history of the Tyrrhenian Calabria, chrono-stratigraphic and palaeoenvironmental reconstructions were carried out in the coastal plains by collecting previous and new borehole data. The first results coming from a core drilled in the Lamezia-S. Eufemia plain reveals that an open lagoon system got started in the early Holocene and was abruptly replaced by lacustrine sedimentation at around 5000 y BP, which in turn underwent progressive changing into fluvial environment. The mid-Holocene continental environment persisted until historical times with a sedimentation mainly characterized by fine sands of the fan system distal zones. As for the Lamezia-St Eufemia plain, some minor coastal plains, such the Porto Salvo sector, recorded a prograding trend during the mid-Holocene in response to alluvial fan growth. These reconstructions are the image of a deep morphodynamic change which led to enhanced slope erosion, fluvial transport and accumulation, most probably driven by concurrent human pressure and sub-Boreal climatic variability. The choice of settlement location since Neolithic seems to have been influenced by such a modification, which led to select more stable areas, as the hanging relicts of older landscapes bordering the plains.

**Lama-bordos and late Holocene agricultural engineering systems controlling sediment yield in the Mixteca Alta, Oaxaca, Mexico**

LEIGH D.S., KOWALEWSKI S.A., HOLDRIDGE G.H.  
*The University of Georgia, ATHENS, GA, UNITED STATES*

The Mixteca Alta, a high-elevation plateau in south-central Mexico, was severely gullied in response to Spanish conquest (1500s-1600s) and related population decline and land abandonment. Depopulation resulted in erosional destruction of prehistoric cross-valley check dams known as lama-bordos that were systematically constructed to facilitate valley-bottom agriculture for millennia. We establish the earliest ages for construction of lama-bordos (including some >5 m high and buried by >10 m of alluvium) and the chronology for sedimentation behind the lama-bordos. Intensive stratigraphic, sedimentologic, and pedologic sampling was conducted on several arroyo walls (up to 20 m high) alongside lama-bordos in small watersheds (<10 km<sup>2</sup>). Analytical methods include: radiocarbon and luminescence dating, geochemical/lithological sediment ascription to identify time periods of gully erosion, and correlating stratigraphy with archeology. Preliminary results include more than 60 radiocarbon dates establishing an alluvial chronology, and evidence that severe upland gully erosion had occurred prior to widespread human occupation of the area. Several radiocarbon ages date the initial construction of lama-bordos to >3400 cal yr BP, which is much older than previously known for any agricultural engineering structures in Mesoamerica. Our research reinforces the fact that climatic drivers of sedimentation often are intertwined with human influences. The lama-bordos provide clear examples of human-produced stratigraphy and artificial landscapes (stair-stepped valleys), thus informing discussion on the proposed Anthropocene epoch.

\*\*\*\*\*

**Geomorphological and sediment records of an intense climate change at the end of the late bronze age (1250-950 BC) in Anatolia: relationships with the end of the Hittite Empire**

KUZUCUOGLU C.  
*CNRS (Laboratoire de Geographie Physique), MEUDON CEDEX, FRANCE*

Since the 1990's, an increasing number of papers discussing past climate changes assume the determining role of climate change in triggering cultural changes and civilization collapses. As a contribution to this debate, the paper presents a pluridisciplinary evidence of a succession of rapid and intense climatic events between 1250 and 900 BC. Palaeoenvironmental and geomorphological indicators have been studied in various environments and space-scale contexts in association with archaeological sites. Data were collected in river watersheds and flood valleys, closed depressions and wetlands located in a variety of regions throughout the peninsula: north-central Anatolia, Cappadocia, Mediterranean coast, Syrian border. The synthesis of the sequences illustrates (a) contemporaneous occurrences of climatic events of different intensity at the end of the 2<sup>nd</sup> mill. BC; (b) a variability in the number and type of environmental signals recorded along two geographic gradients: N-S and W-E.

Results are set in relation with the end of LBA societies in Anatolia and the Eastern Mediterranean facing repeated and intense dry events at the end of the 2<sup>nd</sup> mill. BC. Based on the end of the Early Bronze Age (2200-1900 BC) in SE Anatolia and northern Syria (*Varia Anatolica*, XIX, 2007), a model interlacing cultural, climatic and environmental components is used for illustrating events related to the fall of the Hittite Empire ca 1190-1170 BC. However, focusing the cause-chain which led to the collapse raises questions: what happened, when, how? What was the exact role of climate change? of its relationships to environment? What was the role of stresses rooted in internal (political, economic) organization and waiting-to-break into socio-environmental conflicts? How much was the reaction of the State organization out of phase with the change in environmental constraints? Answers to the latter questions will depend from further scientific programs.

## Studying the impact of the Meio 1498 earthquake and tsunami on the geomorphology of the Hamana floodplain: a geoarchaeological approach

*HEYVAERT V.M.A.(1), FUJIWARA O.(2), UMITSU M.(3), SATO Y.(4), ONO E.(5), YATA T.(5)*

*(1) Geological Survey of Belgium, BRUSSELS, BELGIUM ; (2) Geological Survey of Japan, AIST, TSUKUBA CITY, JAPAN ; (3) Nara University, NARA CITY, JAPAN ; (4) Kyushu University, FUKUOKA CITY, JAPAN ; (5) Niigata University, NIIGATA CITY, JAPAN*

The objective of this research is to study the role of a tsunami, generated by the 1498 Meio earthquake (M8.2 - 8.4) along the eastern Nankai on the geomorphological evolution of the Hamana river floodplain, located along the Pacific coastline of Central Japan.

Historical sources document a sudden decline at the end of the 15th century of the harbour town Hashimoto, located along the river Hamana. Before the 15th century, this river connected the Pacific Ocean with an enclosed coastal embayment separated by a sand barrier (i.e. the present-day Hamana lake) from the Pacific.

The reconstruction of the palaeocourse of the Hamana river was carried out on the basis of detailed facies and diatom analyses of undisturbed sediment cores (geoslicer and drilling). The palaeochannel was detected along the western side of the present-day coastal embayment. It seems that the river's mouth was abruptly sealed off due to the migration of huge volumes of sand that initiated the development of a marsh environment upstream along the channel.

The identification and radiocarbon dating of these sandy high-energy flow deposits in several cores (thick sand bed of marine origin intercalated at the estuarine - marsh environmental change boundary) suggests that the river mouth closure was initiated by mass sediment transport by a storm surge or tsunami (1498 Meio tsunami and/or 1498 and 1499 large storm surges).

Historical sources document that after the 1498 Meio tsunami, the Hamana back-barrier sheltered environment was reconnected to the Pacific Ocean due to breaching of its sand barrier. Both environmental changes (river mouth closure and barrier breaching) are synchronous with the sudden decline of the harbour town Hashimoto. These data suggest that disruption of the waterway between the harbour town Hashimoto and the Pacific Ocean possibly led to the decline of the harbour at the end of the 15th century.

\*\*\*\*\*

## From point to surface. Reconstruction of a riverine urban settlement in Padova (NE Italy)

*MOZZI P.(1), ABBÀ T.(2), FERRARESE F.(3), FONTANA A.(4), GAMBA M.(5), NINFO A.(4), PIOVAN S.(3), ROSSATO S.(4), ZANGRANDO D.(6)*

*(1) Dipartimento di Geoscienze - Università di Padova, PADOVA, ITALY ; (2) Geologist freelance, BORGORICCO, ITALY ; (3) DiSSGeA - Università di Padova, PADOVA, ITALY ; (4) Dipartimento di Geoscienze - Università di Padova, PADOVA, ITALY ; (5) Soprintendenza per i Beni archeologici del Veneto, PADOVA, ITALY ; (6) Geographer freelance, VODO DI CADORE, ITALY*

Padova lies in the low alluvial plain of the Brenta and Bacchiglione rivers. The modifications of the hydrographic network greatly influenced the position and evolution of ancient settlements. The first archaeological evidences in Padova date back to the late Bronze Age, whilst the major development of the settlement took place during the Iron Age (9<sup>th</sup> – 4<sup>th</sup> century BC). This urban centre maintained its importance during the Roman period, being one of the main *Municipia* in NE Italy.

This research integrates the analysis of the alluvial and archaeological record. Methods span from remote sensing and LiDAR to GIS processing of archaeological and geological data, geological field survey, corings and radiocarbon datings.

According to our results, the Brenta River was crossing Padova during the 3<sup>rd</sup> and 2<sup>nd</sup> millennium BC. This ancient river course has been occupied since the beginning of the 1<sup>st</sup> millennium BC by the Bacchiglione River, as a consequence of the Brenta River diversion to the East. This drastic hydrographic change presumably allowed for the development of the Iron Age village on the stable banks of the river. The reconstruction of the fluvial and archaeological evolution of the area shows that the settlement was in close proximity to the river. Protection from flooding was provided by the Bacchiglione River acting as an underfit stream in the Brenta palaeochannel.

Human activities along the centuries led to the formation of an anthropogenic mound (7 m thick and 1 km<sup>2</sup> wide) which corresponds to the present city centre. The 3D modeling and spatial correlation of selected archaeological features, grouped into time-categories, have led to the recognition of the main phases of upbuilding of the anthropogenic mound. The thickest deposits relate to the Iron Age and the Middle Ages. A major remodelling of the urban surface occurred in Roman times.

### **Holocene landscape reconstruction of the Southern Sinis Peninsula area (Central-Western Sardinia, Italy): Geoarchaeological approach**

MELIS R.(1), SECHI S.(2), DEPALMAS A.(3), ZEDDA M.(4)

(1) Dipartimento Scienze Chimiche e Geologiche , University of Cagliari, CAGLIARI, ITALY ; (2) Université de Rouen - Département de Géologie Laboratoire de Morphodynamique Continentale et Côtière (M2C) UMR CNRS, 76821 MONT SAINT AIGNAN CEDEX, FRANCE ; (3) Università degli Studi di Sassari, Dipartimento di Storia, Scienze Umane e della Formazione, SASSARI, ITALY ; (4) Università degli Studi di Sassari, Dipartimento di Medicina Veterinaria, SASSARI, ITALY

The study area is located along the north-western part of the Gulf of Oristano, south of the Sinis Peninsula (central West coast of Sardinia, Italy), in the alluvial plain of the Tirso River, which is the main river of Sardinia. More exactly, this area, called Sa Osa, is characterized by Pleistocene and Holocene alluvial terraces, close to the shoreline and the Cabras lagoon. The geomorphological context makes this area particularly sensitive to climatic changes, sea level variations and human activities during the Late Pleistocene and Holocene. The archaeological remains, interbedded with alluvial sediments from the Tirso River, testify to human occupation since the last millennia: from the Neolithic to the Iron Age. Human presence was confirmed by fish remains and fruit, seeds, as some coming from cultivated grapes. A lot of grape seeds were found in cylindrical wells and hollows which were dug into the Pleistocene alluvial sediments. The Neolithic settlements were mainly located around the lagoons. Evidence of Bronze Age settlements, which coincide with the Nuragic civilization development were found in all the analysed territory. Geomorphological, stratigraphical, sedimentological, micromorphological, paleontological and archaeological studies added to <sup>14</sup>C dating lead to understand that this environment was globally unstable. Human impact was old (pre-history) and added to the natural evolution of this geographic sector.

\*\*\*\*\*

### **Geomorphological investigation in Adam Oasis (Sultanate of Oman) and the implication for the archaeology - The example of the Neolithic site Jebel al-Aluya**

BEUZEN T.(1), FOUACHE E.(2), LEMÉE M.(3), GERNEZ G.(4), GIRAUD J.(5)

(1) Université Paris-Sorbonne, PARIS, FRANCE ; (2) Université Sorbonne Abou Dhabi, Institut Universitaire de France, ABOU DHABI, UNITED ARAB EMIRATES ; (3) INRAP, PARIS, FRANCE ; (4) Université Paris 1 Panthéon-Sorbonne, PARIS, FRANCE ; (5) Institut Français du Proche Orient, PARIS, FRANCE

Like other anticlinal chain, Salakh arch acts as a natural dam in Adam region and allows the existence of Adam oasis, located in a gap created by this chain. At the door of the Rub al Khali desert, this wetter area has been continuously occupied since Paleolithic period and surely was a strategical place for seasonal migration. With the collaboration of the French archaeological team of Adam, we propose an analysis and the cartography of Pleistocene and Holocene palaeosurfaces herited from pluvial period.

Jabal al 'Aluya is a Neolithic site located at the foot of Jabal Salekh near Adam. The site extends over 65 hectares, loosely occupied with 139 structures and lithic concentrations that were found all over the surface. The numerous cherts (almost bifacial tools) collected from this area date back to the Neolithic. Geomorphological studies show that the site relies on one of those Pleistocene paleosurfaces : a glacis. The study and the cartography this Neolithic site (one of the few to be inland) permit us to conclude that this region took advantage of wetter conditions during Neolithic period even if any age dating were made yet in this region. In addition to this general research, we optimize the surveying method by adding environmental data in order to make strategic choices for covering this 3000m<sup>2</sup> area. Pleistocene fluvial formation and upper part of glacis were pointed out to be protected place where potential archaeological structures were not disturbed by ancient or present time deposits.

## **Response of upland catchments to environmental change in a temperate highland setting: initial results from the velay, Massif Central, France**

DEFIVE E.(1), GUNNELL Y.(2), GUILBERT J.(2), POIRAUD A.(3), MIRAS Y.(4), BERGER J.F.(2), CUBIZOLLE H.(5)

(1) Université Blaise Pascal, GEOLAB, UMR 6042-CNRS, Maison des Sciences de l'Homme, 4 rue Ledru, F-63057 Clermont-Ferrand, France, CLERMONT-FERRAND, FRANCE ; (2) Université Lumière-Lyon 2, UMR 5600 CNRS Environnement, Ville, Société, 69635 Lyon Cedex 07, France, LYON, FRANCE ; (3) GEOLAB, UMR 6042-CNRS, Maison des Sciences de l'Homme, 4 rue Ledru, F-63057 Clermont-Ferrand, France / Bureau d'étude "Inselberg", 261 allée des Bauges, 73000 Chambéry, France, CLERMONT-FERRAND, FRANCE ; (4) GEOLAB, UMR 6042-CNRS, Maison des Sciences de l'Homme, 4 rue Ledru, F-63057 Clermont-Ferrand, France, CLERMONT-FERRAND, FRANCE ; (5) Université Jean-Monnet Saint-Etienne / UMR 5600 CNRS Environnement, Ville, Société, 69635 Lyon Cedex 07, France, SAINT-ETIENNE, FRANCE

Field reconnaissance along 1st- to 3rd-order streams (*sensu* Strahler) in the upper Loire river watershed, France, has uncovered previously unreported alluvial sequences in upland vales and pocket-sized floodplains that record at least the last 1000 years of sedimentary response to land-use and land cover change. Based on stratigraphic field observations and <sup>14</sup>C chronostratigraphy, we find evidence of a large stratigraphic hiatus between the Upper Pleistocene glacial formations, which are widespread but poorly dated, and the historical cut-and-fill sequences located in the talwegs. The entire Lateglacial and earlier Holocene record appears to be missing. In all the catchments investigated, the stratigraphy of alluvial deposits dating back to the late Middle Ages consistently exhibits a succession of two major phases. The Middle Ages appear as a period of stable land cover, with steady accumulations of organic matter promoted by optimal climatic conditions and limited human occupation in these remote upland areas. The stratigraphy subsequently records an abrupt phase of land degradation coinciding both with the beginning of the Little Ice Age climatic downturn and the peak of population growth and farming pressure on the local environment, observed in many settings throughout Europe during and after the 14th century. Here, however, the human impact was the main trigger of catchment erosion, as documented by historical archives on hillside agricultural expansion. Further downstream, among 3rd and 4th order channels of the drainage network and beyond, the climatic signal becomes stronger and the land-use signatures are lost. This feature emphasizes the importance of catchment order when interpreting the alluvial sedimentary record, illustrating how it affects the scientific perception of environmental change and the hierarchy of driving mechanisms that we derive from it.

\*\*\*\*\*

## **Eolian dynamics and landforms in South Kharga oasis (Western Desert of Egypt): evidence for two different models before and after farming settlements in Antiquity**

CREPY M., CALLOT Y.

Laboratoire ArcheOrient (UMR 5133 CNRS - Université Lumière Lyon 2, Maison de l'Orient et de la Méditerranée.), LYON, FRANCE

Kharga oasis, in the Western Desert of Egypt, is located in the hyper-arid core of the Sahara. Agriculture depends on artesian deep wells in the Nubian Sandstone Aquifer System and on fine-grained sediment taken from yardangs. These yardangs have been interpreted by some geomorphologists as playa and loess-like deposits. But in the past, some artesian springs and some hydraulic installations enabled humans to settle. In the south of the oasis the archaeological survey and work of the IFAO (Institut Français d'Archéologie Orientale) show that human occupation in the area was nomadic until 4500BP and the pre-dynastic period. No remains of human activities or settlements dating from 4500BP to 2500-2450BP have been discovered. Sedentary settlements and agriculture began after 2500-2450BP, during the Persian domination, with many hydraulic installations for exploiting the groundwater resources (qanats, wells, aqueducts and canals).

Geomorphological survey, sedimentological analyses and archaeological results enable us to build two different models of environment and landscape evolution at the origin of thick loess-like and Saharan loess deposits in South Kharga oasis :

The first model explains the situation before sedentary human settlements (until 4500BP). Temporary human settlements and eolian deposition of silt and fine sand were linked with artesian springs and limited by their flow periods.

The second model shows how hydraulic installations between 2500-2450BP (Persian domination) and 1500-1450BP (late Roman times) modified the first model and how human sedentary occupation had a large morphogenic impact. As human activities expanded in areas of vegetation, eolian deposition became less localized and the thickness of the deposits increased more rapidly. This system lasted until the groundwater level lowered with the increase of arable land, which dried up the wells and qanats. At this time, much of the region was abandoned and ablation began to affect the entire area.

**The Holocene sedimentary records of the Lower Seine Valley tributaries as indicators of the landscape evolution during 10 000 years in Normandy: the exemple of the archaeological settlement of Brionne (Eure, France)**

GONNET A.

*Université de Rouen, ROUEN, FRANCE*

The Holocene archives of the Lower Seine Valley tributaries are indicators of the landscape evolutions during the last 10000 years in Normandy (France). They permit to evaluate the anthropic and climatic factors that influence these evolutions on each geomorphologic compartments (valley, slope, plateau). The gallo-roman occupation of Brionne (Eure), has revealed a stratigraphy interesting to understand the relationships between human practices and environment evolution. Located at the confluence between two hydrosystems, the settlement's stratigraphy show detrital sedimentation from the beginning of the Holocene, and tuffa deposits above. The extra-site study of this settlement permits to understand the origin of these detritic deposits for a local (the hydrosystem) scale. The macroscopic approach, completed with analysis in sedimentology, and micromorphology permits to apprehend the local chronostratigraphy and the process of sedimentogenesis of this site. This study is included in the regional geomorphologic context and will be correlated with other sites from the Lower Seine Valley tributaries.

Keywords: geoarchaeology, Holocene, Lower Seine Valley, Risle Valley.

\*\*\*\*\*

**First data on Holocene hydro-geomorphological dynamics in the valley of Wadi Tassa (Azilal, High Atlas, Morocco).**

LE DREZEN Y.(1), LETANG M.(1), BALLOUCHE A.(2), EL KHALKI Y.(3), LE COEUR C.(4)

*(1) PRODIG UMR 8586 CNRS, PARIS, FRANCE ; (2) 2. LETG-Angers LEESA, UMR 6554 CNRS, Université d'Angers, UFR Sciences, ANGERS, FRANCE ; (3) 3. FLSHBM, Université Sultan Moulay Slimane, BÉNI MELLAL, MOROCCO ; (4) 4. Laboratoire de Géographie Physique, Université Paris1 Panthéon Sorbonne, MEUDON, FRANCE*

Likemany valleys of the Moroccan High Atlas Mountains, the watershed of the river Tassa, at 1800 meters altitude near Azilal has undergone intense landscape changes over the past decades. Headward erosion of the valley has resulted in many badlands and digging deep gullies of 2 to 4 meters in the last century. Our studies in photo-interpretation and remote sensing have shown that these rapid changes in landscapes are mainly related to changes in land use and transformation of production systems. Changes have particularly affected the agro-forestry system in the watershed area.

The first observations on the sedimentary sections identify the main features of the evolution of the valley and the catchment hydro-geomorphological responses to environmental changes over the past centuries and millennia. The analysis of these deposits showed, in particular, the repetition of rhythmic fluvial sequences (alternation of sandy and shaly layers) whose seasonal or multi-annual periodicity remains to be documented. The current study should clarify the respective shares of hydro-climatic changes and anthropogenic factors (fire, agropastoralism, clearing...) in the described dynamics.

These first international multidisciplinary researches want allow us to propose a future research program that would focus on landscape dynamics of some valleys in the Tadra-Azilal region under the crossed anthropogenic and climate controls during the Holocene.

**The Ribeira de Bensafrim Estuary, Lagos (Portugal) - human establishment and geomorphological evolution in the late holocene**

ARA JO-GOMES J.

*Centre of Geographical Studies - IGOT, University of Lisbon, LISBON, PORTUGAL*

On the right bank of the estuary of the Ribeira de Bensafrim is located the present town of Lagos. This town in the SW area of Portugal was founded by Imperial Romans after they transfer their previous pre-Roman location from the left bank of the river to the opposite shore.

In this presentation we will try to understand the last millennia evolution of the human history in this location as well as the geomorphology of this asymmetric estuary. We will also try to understand why the Romans decided to switch their river bank establishment to continue to live in the same area. We will see that the geomorphological data as well as the geoarchaeological analysis brings us relevant information to the understanding of this subject multi-approach subject.

The main objective of this work lies in understanding of the reason why Romans changed their place from one river bank to the other. For this analysis will be used geoarchaeological methods that may help us understand what archeological science alone does not explain.

Through the sediment analysis gathered from the estuary, estuarine paleoenvironmental changes forcing that establishment change are discussed. Cross-examined sedimentological data with the archaeological sediments, malacological and mammalogical data of the pre-Roman archaeological site of Monte Molião (left river bank) will be analyzed attempting to find clearer answers. We will also add archaeoseismological data observed on the archaeological site.

This work will be presented with a chronological reading of the geomorphological evolution of the estuary in which we focus on the crucial role of alluvial sediments for the paleoenvironmental evolution of this unique and sheltered Atlantic estuary.

\*\*\*\*\*

**Late-Glacial aeolian activity in North-West Belgium: A contribution of OSL dating near the Moervaert paleolake**

VAN NIEULAND J., VANDENBERGHE D., DERESE C., GELORINI V., CROMBÉ P., VAN DEN HAUTE P.

*Ghent University, GHENT, BELGIUM*

The Moervaert area is characterized by a depression, linked with a large paleolake. It is thought to originate as a result of the aeolian formed sand ridge of Maldegem-Stekene which dammed the braided river system that drained the greater part of Flanders, also called the Flemish Valley. This has led to an exceptional geological setting with major consequences on the early human development in the region. Although the Moervaert area is one of the most intensively studied landscapes in Belgium in terms of archeology, its geological evolution is still debated, in particular owing to a lack of absolute age determinations for the windblown sediments.

This study aims to determine the time and duration of the different phases of aeolian sedimentation in this area using quartz-based SAR-OSL dating. Sequences were sampled at three strategic locations, revealing a spatio-temporal framework of the ridge, the lake sediments and the substrates.

All quartz samples (n=22) exhibit satisfactory luminescence characteristics; the OSL signals are bright and decay fast with stimulation time, and the SAR protocol passes all procedural tests (recuperation, recycling, preheat plateau, dose recovery). The SAR-OSL ages for the ridge range between ~18 ka and 12 ka. Dose rate measurements are ongoing. However, the first age determinations of the aeolian substrate in which the paleolake developed during the Late-Glacial reveal an age of ~20 ka, which is in line with classical theories. The age results will be presented at the meeting and discussed in relation to the evolution of the landscape and human development.

## Geomorphology and geoarchaeology: The Indian context

KOTAPALLI S.M.

Retired, NAGPUR, INDIA

Prof Lord Curzon visualized that it was in exploration and study of purely Indian remains, in the probing of the archaic mounds, in the excavation of old Indian cities and in the copying and reading of ancient inscriptions that a good deal of the work of the archaeologists will in future live. Truly enough, it was the excavation of the mounds near Mohen-jo-Daro and Harappa that put back the Indian civilization as much older than the others by at least three thousand years!. The geomorphic processes caused by rivers were mostly responsible for those mounds, just as the marine processes resulted in Lothal and other areas. The Buddhist Stupas were always recognized by the mound-like form, outwardly in several, parts of the country and their excavations subsequently led to the formation of the Archaeological Survey of India. The Ajanta-Ellora caves in the Deccan Traps, or the Kanheri caves on the west coast near Mumbai were clearly the result of geomorphic processes that operated then. There are also natural arches like the one near Tirumala, Andhra Pradesh that was formed by geomorphic processes.

\*\*\*\*\*

## New insights into the development of the Roman Harbour of Ephesos, Western Turkey

STOCK F.(1), LAERMANN H.(1), STESKAL M.(2), LADSTAETTER S.(2), BRUECKNER H.(1)

(1) *Institute of Geography, University of Cologne, COLOGNE, GERMANY;* (2) *Austrian Archaeological Institute, WIEN, AUSTRIA*

The ancient city of Ephesos in Western Turkey was an important harbour city during Antiquity. Around 6000 years ago, the sea transgressed up to 18 km inland. Due to the progradation of the Küçük Menderes delta since that time, the coastline has continuously shifted westwards. As a result, Ephesos lost its connection to the sea, implying subsequently the construction of a harbour canal. Several attempts to clean or dredge the great harbour of Ephesos are known from inscriptions since the 1st century AD of. However, many questions remain open: When did the siltation of the harbour started? When was the canal constructed? How long was the harbour in use?

This research aims to identify the spatial and temporal shifts in the coastline during the past millennia, to clarify the development of the harbour and the harbour canal, to calculate sedimentation rates and to reconstruct the vegetation history in this area.

In total, 30 drill cores up to a maximum depth of 19 m were retrieved from geo-bio-archives in and around the harbour and the canal. Sediments from corings were examined with geochemical, sedimentological, microfaunal and palynological analyses. The chronological framework relied on AMS-14C ages and diagnostic ceramics.

First results reveal that the Roman harbour was accessible until the 14th century AD. A core in the middle of the Roman harbour shows a stratified layer which dated between the 2<sup>nd</sup> century BC and the 5th century AD. This corresponds to the period of prosperity and an intensive use of the harbour. Detailed geochemical investigations are still in progress.



**S13. Human impacts on landscapes (IAG-WG)**

Convenors: *Asfawossen ASRAT, Andrew GOUDIE,  
Paul HUDSON & Denes LOCZY*





## **Oral presentations:**

### **The significance of small farm dams in the Karoo, South Africa**

*BOARDMAN J.(1), FOSTER I.D.L.(2)*

*(1) University of Oxford, OXFORD, UNITED KINGDOM; (2) University of Northampton, NORTHAMPTON, UNITED KINGDOM*

In the South African Karoo (rainfall 200-500mm) farm dams are commonplace and have been built since the 1840s. Their purpose is largely water provision for stock in the dry season. In the twentieth century some were built as erosion control structures across gullies.

In the Sneeuberg uplands we have recorded over 100 small dams in a sample area of ca. 100 km<sup>2</sup>. Most of the dams are earth built and almost 50% are full of sediment and store little water. As the dams fill, and are overtopped during storms, the potential for breaching is high. Almost 30% are breached and have therefore begun to release stored sediment. Many dams store <50,000 m<sup>3</sup> of sediment; the largest, recently breached dam has the potential to release ca. 320,000 m<sup>3</sup> of sediment.

The main impact of dam breaching is on downstream water storage reservoirs. In the Sneeuberg, the Nqweba dam is predicted to be full of sediment by 2025. Breaching of small farm dams will shorten its life span. High magnitude rainfall events are increasing in frequency in the region and add to the risk of breaching. South Africa has an acknowledged water crisis with 98% of its available water already allocated. Increased sedimentation in major reservoirs will add to the problem.

\*\*\*\*\*

### **Flood sedimentation during the extreme 2011 flood along the Lower Mississippi River, USA**

*HUDSON P.(1), HEITMULLER F.T.(2), KESEL R.H.(3)*

*(1) Leiden University, THE HAGUE, NETHERLANDS ; (2) Department of Geography and Geology, University of Southern Mississippi, HATTIESBURG, MISSISSIPPI, UNITED STATES ; (3) Department of Geography and Anthropology, Louisiana State University, BATON ROUGE, LOUISIANA, UNITED STATES*

The effectiveness of extreme flood events to modifying floodplain environments remains an important and inadequately understood topic, particularly in the context of humanized fluvial systems. The 2011 flood along the Lower Mississippi River established new stage records at multiple locations along the lowermost alluvial valley, and had a peak discharge of 67,394 m<sup>3</sup>/s at Natchez, Mississippi. This study documented the sedimentary deposits produced from the 2011 flood at 55 sites between Natchez, Mississippi and St. Francisville, Louisiana, and considered the geomorphic effectiveness of the event. For context, the study makes an explicit comparison with sedimentary deposits from the extreme 1973 flood, which was sampled at the same location. Results show considerable variability in sediment thickness, ranging from <1 mm to 620 mm with the thickest deposits along natural levees. Overall, most sites are characterized by less than 10 mm of overbank sediment, considerably less than thicknesses measured following the 1973 flood. Additionally, in comparison, the texture of 2011 deposits is coarser than the 1973 deposits. These data indicate relatively energetic, sediment-deprived overbank flow conditions that possibly eroded pre-existing surficial floodplain sediments and transported them to distal floodplain zones. The well-documented decline of suspended-sediment loads along the Lower Mississippi River could explain the unimpressive sedimentation in 2011, as it represents almost additional four decades of sediment reduction (due to upstream dams) since 1973. Alternatively, the event sequence could be important, as a smaller discharge event occurred prior to the maximum flood event was associated with a much higher sediment load. These results have important implications for flood control and environmental floodplain restoration efforts.

## **Human impact and rehabilitation potential on a floodplain in Hungary**

LOGZY D.

*University of Pecs, PECS, HUNGARY*

With very few exceptions, the Hungarian rivers are channelized and the communication between the channel and floodplain features is restricted to hyporheic (groundwater) flow. In addition to flood-control dykes, drainage ditches and canals, navy pits, road and railway embankments, artificial mounds and others represent manmade landforms on the floodplain. Their dimensions and distribution pattern are influential both for flood hazards and floodplain land use. Geomorphological research can contribute to flood control design through mapping floodplain features, the intersections of dykes and old filled-up channels, localizing potential boils and seepages, unstable banks, the effect of vegetation cover. The large-scale inundations following extreme rainfall events in May-June 2010 provided good opportunities for the survey of excess water hazard on the protected floodplain of the Kapos River, Southwest-Hungary. The extent of anthropogenic transformations and the rehabilitation potential are assessed for the individual segments of the Kapos floodplain, identified by a morphometric index. With improving connectivity and landscape diversity indicators, the rehabilitation measures would enhance floodplain biodiversity and strengthen nature conservation function. Foreseeable conflicts between floodplain rehabilitation (its landscape ecological benefits) and land use (negative impacts on agricultural cultivation) are analyzed. In the light of the implementation of the European Union's Water Framework Directive, the applicability of research to other small-river floodplains in the Carpathian Basin are also considered.

\*\*\*\*\*

## **Human impact on floodplain geocology. A Holocene perspective for the Dijle catchment, Central Belgium**

BROOThAERTS N.(1), VERSTRAETEN G.(1), NOTEBAERT B.(1), KASSE C.(2), BOHNCKE S.(2), ASSENDELFT R.(2), VANDENBERGHE J.(2)

*(1) KU Leuven, LEUVEN, BELGIUM; (2) VU Amsterdam, AMSTERDAM, NETHERLANDS*

Floodplain deposition rates have increased markedly under influence of human impact throughout the Late Holocene in many Western and Central European catchments. These variations in sedimentation rates have changed the geomorphology and ecology of many floodplains. In this study we discuss the human impact and its influence on floodplain geocology for the Dijle catchment (760 km<sup>2</sup>), located in the Belgian loess belt. The geocology of the floodplain and the regional vegetation was reconstructed based on sedimentological and palynological analysis. Age depth models for each of the studied sequences were obtained through 60 radiocarbon dates. Based on statistical analysis of the pollen data (e.g. cluster analysis and canonical correspondence analysis) human impact in the catchment was quantified. Our data shows that until ca. 2500 cal BP, human impact was either absent or limited to local disturbances yielding no clear influence on the floodplain geocology. The river environment was in a stable phase and consisted of a marshy environment where organic material could accumulate, which is interpreted as the natural state of the floodplain. From ca. 2500 cal BP onwards, human impact gradually increased. However, only when human impact in the catchment crossed a threshold, the floodplain geocology changed with clearing of the Alder carr forest, the creation of a single channel river and the dominance of minerogenic overbank sedimentation. Spatial variability in the coupling between increasing human impact and changes in floodplain geocology can be attributed to differences in hillslope-fluvial system connectivity and local differences in human impact. Overall, this study provides new insights of how river systems respond to environmental change. It also shows that the contemporary morphology of the floodplains, with a typical meandering river bordered by levees and mineral floodplain deposits, has an indirect anthropogenic origin.

### **The legacy of mill dams in low-order streams in central Europe**

LARSEN A.(1), JOSHUA R L.(2), FUELLING A.(3), BORK H.R.(1)

(1) University of Kiel, KIEL, GERMANY ; (2) University of Queensland, BRISBANE, AUSTRALIA ; (3) Humboldt University, BERLIN, GERMANY

Historic dams of largely unknown age are a widespread feature within German 1<sup>st</sup> to 3<sup>rd</sup> order streams. It has been proposed that accelerated slope erosion due to deforestation and agricultural land use is the reason for the aggradation of some central European floodplains, however this process only explains the delivery of sediment to these rivers. First results show that valley bottom damming was also a critical mechanism for the effective trapping of this increased sediment load. In this study we determine the onset and magnitude of this first impact of humans on riverscapes as a result of valley bottom damming, and examine the management implications. The extensive sedimentation of loam floodplains was precipitated by dam induced changes to the flow regime, and in turn caused the observed (stratigraphical) change of the channels from multithread to meandering. This floodplain loam also blankets a palaeo-wetland soil, which formed an efficient carbon sink. A modelling approach combined with the quantification of the stored sediments enables us to predict potentially remobilised sediments after dam-removal.

\*\*\*\*\*

### **Predicting and Managing Fluvial Processes: Opportunities for a Non-structural Approach**

BRIZGA S.

S. Brizga & Associates Pty Ltd, CLIFTON HILL, VICTORIA, AUSTRALIA

Geomorphological analysis supported by hydraulic modelling allows areas of land at risk of fluvial erosion and sedimentation to be predicted with sufficient confidence to enable proactive management.

This paper presents predictions of river bank erosion, avulsion and crevasse splay deposition for selected rivers and floodplains in Victoria, Australia, and discusses opportunities and constraints for non-structural management. The case studies, including the Tambo, Snowy and Bunyip Rivers, range from relatively natural to highly modified systems. One- and two-dimensional hydraulic models were used to support assessments of current geomorphological processes and future scenarios.

Geomorphologists often advocate for a non-structural approach to the management of geomorphological hazards. However, in Australia, engineering measures continue to be widely used to address conflicts between fluvial processes and land use. Non-structural measures that rely on legal or planning tools have been less often used. Floodplain land in Victoria generally has freehold tenure, with patterns of land use and infrastructure that have evolved over many decades. The statutory planning system does not impinge on existing land use as it is only triggered by land use change and new development. Regulatory changes that increase constraints without compensation are unpopular. Relocation of infrastructure or purchase of easements to accommodate geomorphological processes is expensive and has not been widely undertaken.

Interest in the use of non-structural approaches to address natural hazards is increasing, particularly in relation to climate change. Greater uptake of a non-structural approach would require changes to the Victorian planning system to better address risks from fluvial processes. There is a fundamental need for consistent and widely-accepted principles that define the circumstances in which to protect assets, accommodate fluvial processes, or retreat from at risk zones.

**Understanding sediment provenance during storm events in an eroding blanket peat catchment in the Peak District National Park, UK**

SHUTTLEWORTH E., EVANS M., ROTHWELL J.

*University of Manchester, MANCHESTER, UNITED KINGDOM*

Large areas of the UK's blanket peat are significantly degraded and actively eroding due to climatic and anthropogenic perturbations. This impacts carbon storage through the physical export of particulate organic carbon (POC). The near surface layer of many of the UK's peatlands are also contaminated with atmospherically deposited metals (e.g. lead). The stability of peatlands is therefore important for the preservation of this carbon store and limiting pollutant mobilisation. However, little is known about the contribution of various sources of sediment entering the fluvial system. Previous work in the area has identified rapid changes in lead concentration in storm runoff which is potentially indicative of changes in sediment source.

Peat erosion is widespread in the Peak District National Park, UK, and the Bleaklow Plateau has been a focus of restoration over the past decade. Time integrated mass flux samplers (TIMS) have been used to collect suspended sediment across a range of flow conditions. Electrical resistance sensors have been attached to the TIMS to give a high resolution record of stage depth. A fingerprinting approach has been developed using geochemical and environmental magnetic parameters, which is previously untested in organic systems. The contaminated nature of the near surface peat distinguishes sediment mobilised from the peat surface from that eroded from gully walls. This paper will discuss the results of the ongoing monitoring campaign.

Understanding the physical process dynamics relating to sediment flux is essential in order to identify sources of material entering the fluvial system and understand the mechanisms by which it does this. This information can be used to inform management strategies which require a clear understanding of the locus of sediment production in order to target restoration.

\*\*\*\*\*

**Changes of land use between 1979 to 2009 in the lower medium Araguari River Valley - Brazil**

RODRIGUES S.C.

*Universidade Federal de Uberlândia, UBERLANDIA, BRAZIL*

The Araguari River is located in the central uplands of Brazilian and in the last forty years these region suffered a huge change in the regional economy due to the agricultural green revolution. The medium valley of Araguari River shows a landscape which changes from a flat regional surface over deep soils developed over Quarternary laterites in the interfluves to a deep valley with outcrop rocks where the river flows over pre-cambrian rocks. The land uses varies from automated agriculture in the flat areas, to irrigated horticulture in the valley slopes, to pasture and natural vegetation on the high gradient slopes. The main changes in the landscape were the construction of four hydroelectric plants on the valley bottom, and now in the first 200km of the valley, only 9km has the original features. Even the river discharge in this small area is not the same, because the river flow was derived by a adduction tunnel and only a small discharge remain in the original channel path. The changes in the land use are derived from the insertion of technology on the agricultural production and uses of the river. New data obtained from the land use maps from 1979 to 2009 show that enviromental laws promotes the regeneration and development of areas with natural vegetation, which contributed also to the new scenario of the area.

## The Environmental Impact of Feeding One's Family

DOOLITTLE W.

*University of Texas, Austin, UNITED STATES*

Two long-prevailing theories about the origins of technology in a given place or location are independent invention and diffusion. This holds true for agriculture and resultant landscapes as well as for other types of technologies. Diffusion and independent invention both involve deliberate actions of planning and construction. Rarely, if ever, considered is the notion of agricultural technology evolving de facto out of normal everyday farming practices, and hence, cultivated landscapes developing as a natural and unintended consequence. This presentation demonstrates the role of farming as a geomorphic process. Regardless of how ecologically conscious farmers might be, their actions result in transformed environments. Recognizing the process of incremental change is paramount for planning and management purposes. Evidence is presented from Mexico, the US Southwest, Sweden, and Tanzania.

\*\*\*\*\*

## Geomorphic Impacts of Maya Civilization

BEACH T.(1), LUZZADDER-BEACH S.(2), DUNNING N.(3)

*(1) Georgetown University, Washington, DC, UNITED STATES ; (2) George Mason University, FAIRFAX, VA, UNITED STATES ; (3) University of Cincinnati, CINCINNATI, UNITED STATES*

We present a new synthesis of research on human impacts across the Maya lowlands of Central America. This presentation draws from the literature and our own field studies from 1991-2013 of quarrying for mound and temple construction, lake cores, wetland excavations, alluvial coring transects, and catena studies of soil formation. To understand geomorphic changes, we synthesize evidence for mining impacts and examine stratigraphy with relative and radiocarbon dating and a host of paleo-environmental proxies from carbon isotopic ratios, elemental analysis, pollen, phytoliths, macro-botanicals, and soil and water chemical analyses. Human impacts occurred by the start of the fifth millennium BP. Most depositional environments show impacts during the Maya period of the last 3 millennia with evidence for surprisingly severe, though variable impacts from the Preclassic Maya, nearly 3,000 years ago. Many geomorphic repositories have organic, slow deposition or stable soil formation before agriculture and fire diffused over the landscape in the third millennium BP. From 3000 to 1000 BP this led to accelerated soil erosion and deposition of "Maya Clay" layers in some areas. We also distinguish anthropogenic from geological drivers such as drought, pluvials, tropical storm intensification, water-table rise and gypsum precipitation, and volcanic eruptions. Maya farmers responded to geomorphic change with soil conservation technologies and new land-uses that had large impacts on the region's geomorphology in many areas. After the Maya Terminal Classic, c. 1000 BP, many landscapes stabilized, again indicated by organic, slow deposition rates and steady soil formation. The Late Preclassic around 2000 BP and Late Classic about 1200 BP experienced widespread droughts coupled with intensive human land uses and geomorphic impacts, but intensive climate changes of the Little Ice Ages without intensive human impacts had little effect on regional geomorphology.

### High impact: 10 000 years of human-environment interaction in the Silvretta Alps

*KOTHIERINGER K., LAMBERS K.*

*University of Bamberg, BAMBERG, GERMANY*

The beginning of a continuous human presence in high alpine zones in the Early Holocene has recently become a highly discussed topic. It is to assume that in an extreme environment like the Alps, human activity, economy and culture have always been very sensitive to climatic variations throughout the Holocene. Thus, the valleys of the Silvretta Massif in the Central Alps between Paznaun (Austria) and Lower Engadin (Switzerland) were selected as an appropriate study area for analyzing the relationship between Holocene climate, settlement dynamics and human impact on the landscape in the course of an interdisciplinary research project.

Building on archaeological research initiated by the University of Zurich in 2007, recent palaeoecological, geoarchaeological and pedological investigations aim at reconstructing human-environment interaction in the Silvretta from the Early Holocene to the modern era. For this purpose, archaeological sites as well as environmental archives such as peat bogs and soils have been documented and analyzed. Palaeoecological data indicate a climatic cold phase from about 4700 BC, leading to a decrease of the timberline by 100-200 meters. This effect was intensified by high alpine pastoral land-use, i.e. livestock grazing, from about 4000 BC. There is evidence that soil formation was disturbed repeatedly by human activity like slash-and-burn. Palaeosols like fossil podzols situated on moraines high above the modern timberline show high ratios of macroscopic charcoal resulting from the former presence of extensive vegetation cover. Current laboratory analysis will provide further information on the age, origin (autochthonous vs. eolian) and development of soils. Based on the results of this reference region, the goal is to obtain an overall view of human-environment interaction in the Central Alps in high temporal resolution.

\*\*\*\*\*

### Ethiopia in the 1930s: historical aerial photographs and their fusion with current remotely sensed imagery for retrospective landscape analysis

*NYSSSEN J.(1), FRANKL A.(1), MOHAMED S.(2), PETRIE G.(3), GEBREMESKEL G.(2), SEGHERS V.(1), HADGU K.M.(4), DE MAEYER P.(1), HAILE M.(5)*

*(1) Department of Geography, Ghent University, GENT, BELGIUM ; (2) Ethiopian Mapping Agency, ADDIS ABABA, ETHIOPIA ; (3) School of Geographical & Earth Sciences, University of Glasgow, GLASGOW, UNITED KINGDOM ; (4) Institute of Geoinformation & Earth Observation Sciences, Mekelle University, MEKELLE, ETHIOPIA ; (5) Department of Land Resources Management and Environmental Protection, Mekelle University, MEKELLE, ETHIOPIA*

The aerial photographs (APs) acquired by the 7a Sezione Topocartografica during the Italian occupation of Ethiopia (1935-1941) have recently been discovered, scanned and organised. The oldest APs of the country that are known so far were taken in the period 1958-1964. The APs over Ethiopia in 1935-1941 are presented as assemblages on approx. 50 cm x 20 cm cardboard tiles, each holding a label, one nadir-pointing photograph flanked by two low-oblique photographs and one high-oblique photograph. The four APs were exposed simultaneously and were taken across the flight line; the high-oblique photograph is presented alternatively at left and at right; there is approx. 60% overlap between subsequent sets of APs. One of Santoni's glass plate multi-cameras was used, with focal length of 178 mm, flight height at 4000-4500 m a.s.l., which results in an approximate scale of 1:11 500 for the central photograph and 1:16 000 to 1:18 000 for the low-oblique APs. The surveyors oriented themselves with maps of Ethiopia at 1:400 000 scale, compiled in 1934. The flights present a dense AP coverage of Northern Ethiopia, where they were acquired in the context of upcoming battles with the Ethiopian army. Several flights preceded the later advance of the Italian army southwards towards the capital Addis Ababa. Further flights took place in central Ethiopia for civilian purposes. As of 1936, the APs were used to prepare highly detailed topographic maps at 1:100 000 scale. These APs (1935-1941) together with APs of 1958-1964, 1994 and recent high-resolution satellite imagery are currently being used in spatially explicit change studies of land cover, land management and (hydro)geomorphology in Ethiopia over a time span of almost 80 years, the first results of which will be presented.

### **Landscape resilience and sustainability in subtropical Argentina**

SAYAGO J.M.

*Consejo Nacional de Investigaciones Científicas y Técnicas, SAN MIGUEL DE TUCUMON, ARGENTINA*

The subtropical arid / semi-arid northwestern Argentina, during the last centuries affected by deforestation, overgrazing and uncontrolled agriculture, has varying degrees of desertification. The intensity of deterioration, has been a marked decline in the productive capacity of the land, risking the possibility of a future sustainable production. In this vast region some areas apparently overcame their resilience (defined as the possibility of a return to the conditions climáticas an ecosystem after a disturbance or climate change). In order to evaluate the intensity of this process and develop management criteria to improve the productive capacity of desertified landscape, we evaluated the influence of topography, climate, vegetation and soils in the resilience of the land, expressed by the closeness or distance to the threshold of resilience. Geomorphological sectoring was performed on each unit determined the influence of climate (rainfall erosivity), soils (soil erodibility) and vegetation cover (hydrological protection of vegetation), following the criteria of the Universal Soil Loss Equation (USLE). Validation of degradation intensity was performed by measuring the seasonal changes of coverage (dry and wet) and found that in some terrain units, resilience has been exceeded and some not. The results allow to establish a first approximation of the productive capacity of the land and define criteria for sustainable management, especially against the effects of future environmental changes.

\*\*\*\*\*

### **Geomorphological and landscape impacts of the development of the port of Veracruz (Gulf of Mexico) between the 16th and 21st centuries**

MENANTEAU L., GAILLARD S.

*LETG-Nantes GEOLITOMER UMR 6554 CNRS and University of Nantes, NANTES, FRANCE*

Veracruz, the main port of Mexico since the arrival of Hernán Cortés in 1519, has played a key role in transatlantic trade between America and Spain. The configuration of the site remained almost identical until the major works between 1882 (in fact, since 1895) and 1902. The site was radically altered by being converted to a port basin. Thus, in 1887, communication with the sea to the NW, the traditional route for the galleons of New-Spain, was closed by a seawall, to which a wide container-wharf was attached in 2005; to the East, breakwaters were built around the only access to the outer harbour. The result is: the loss of the insular character of La Gallega, the coral reef opposite the city port on which the fort of San Juan de Ulloa is built; fossilisation, through infilling, of the former shore and the shallows (e.g. La Caleta reef) bordering the north of Veracruz, eventually leading to the building of a new quarter and the Malecón.

The authors evaluated the geomorphological and landscape impact of the changes by analysing and comparing several bathymetric charts of the port. The first, drawn in 1887, provides a precise view of the site before work began; others, dating from 1904 and 1911, correspond to conditions after work was completed in 1902. Each chart was geometrically corrected and georeferenced in UTM based on a 2007 (INEGI) vertical aerial photograph; next, bathymetric soundings (8715 for the 1887 document) were obtained (in x, y, z) in order to build digital elevation models (DEM). The data made it possible to produce maps of the nearshore seabed and evaluate the impacts, in terms of volume and surface area, of the developments between 1882 and 1902. The integration of data prior to 1880 (especially 18<sup>th</sup> century) as well as current allowed the authors to evaluate the impacts with greater precision.

**Old hydrotechnical constructions - their impact on present landscape and morphological processes in depopulated areas; Central Sudetes Mts., SW Poland**

LATOCHA A.

UNIVERSITY OF WROCLAW, INSTITUTE OF GEOGRAPHY AND REGIONAL DEVELOPMENT,  
GEOMORPHOLOGICAL UNIT, WROCLAW, POLAND

The Sudetes Mountains were substantially depopulated, starting from the end of the 19<sup>th</sup> century and especially after the World War 2<sup>nd</sup>. However, there are many traces of former human activities which can be still detected in the contemporary landscape. Old anthropogenic landforms and features are connected mainly with former settlements, agriculture, industry and water management. Especially the last ones are numerous in the study area. They include channel linings, bridges, culverts, drains, dams, leats and mill-ponds.

Detailed geomorphic mapping has shown that these constructions, despite not being maintained, influence contemporary morphological processes. Collapsed or uncleared constructions become artificial obstacles for water flow, leading to the development of new zones of erosion and deposition, wetlands, incisions of side-channels, channel braiding and anastomosis. However, in some places old structures have been 'fossilized' after the abandonment as a result of natural processes and their impact on the fluvial system has diminished or is no longer detectable. This is the case of some leats, which are now dry and partly filled with mineral and organic material, yet still recognizable as elements of valley floor relief.

Field analysis has revealed that past human impact is very long-lasting in the landscape. Old hydrotechnical constructions continue to influence the fluvial system, in spite of various states of their preservation and often neglect. An understanding of the role of old hydrotechnical constructions as important elements of both anthropogenic landscape and fluvial system can help in proper management of water resources in the mountain areas.

\*\*\*\*\*

**Humans as geological and geomorphological agents in the Anthropocene**

PRICE S., FORD J., COOPER A.

British Geological Survey, NOTTINGHAM, UNITED KINGDOM

Humans have become dominant forces in the transformation of the Earth's landscape and its corresponding geological and geomorphological response. The deliberate, current and historical anthropogenic modification of the landscape and its subsurface creates sediments and landforms in the form of artificial ground. Artificial ground is recognisable as distinct geomorphological landforms or where its sediments are buried in the ground.

The magnitude and rate of intentional human landscape transformation and creation of artificial ground has fluctuated through time. It is estimated that the deliberate global movement of rock and soil through mineral exploitation and processing exceeds that of sediment transport to the oceans by almost a factor of three (Douglas & Lawson, 2001). In Great Britain it has been estimated that over 66 500 M (Million) tonnes of material has been moved in about 150 year as a result of mineral exploitation alone.

Localised working for minerals and domestication of land for food production, rapidly expanded as human population grew. Subsequent industrialisation, burning of fossil fuels and rapid urbanisation in developed countries resulted in large scale land transformation as populations grew, lived longer and generated more wealth. The rate and magnitude of the creation of artificial ground has varied through time, but it is now significant on a global scale. The role of humans in shaping the landscape and creating distinctive and novel landforms and sediments is unique in Earth's history. This style of 'anthroturbation' may be one of many changes to the Earth's biological, chemical and physical systems that characterise the proposed new epoch of the Anthropocene.

Douglas, I. & Lawson, N. 2001 The Human Dimensions of Geomorphological Work in Britain. *Journal of Industrial Ecology* 4, 9-33

### **Maintaining the Integrity of the Environment in an Arctic Delta During Modernization**

WALKER H.(1), MCGRAW M.(2)

(1) Louisiana State University, BATON ROUGE, UNITED STATES ; (2) Southeastern Louisiana University, HAMMOND, UNITED STATES

Many parts of the Arctic are being modified by ever-increasing rates of political, industrial and commercial activity. Early developers gave little thought about its effect on the environment. One area now being subjected to modernization is the Colville River Delta in Arctic Alaska. Although long a key location for Inuit fishing and hunting, remnants of their presence are a few turf-house foundations. Major changes began in 1971 when Nuiqsut was founded. About the same time, the integrity of the Arctic was becoming a major concern, a concern that led to numerous governmental and industrial regulations.

Changes to the Delta include the construction of numerous buildings insulated from the fragile tundra surface, the development of two major runways, the construction of a large oil field and its pipelines, and a road system.

Successful construction in a permafrost-dominated landscape demands techniques that preserve its frozen characteristic. One procedure is to use gravel to insulate permafrost from above. Gravel, however, is in short supply across much of the North Slope. An exception is the unfrozen material present as a talik (thaw bulb) in the deep parts of river channels. In 1981, a dredge was used to pipe it to an enclosed 1500 m long site placing it directly on the surface. There was minimal disturbance to the surrounding tundra; adjacent ice-wedge polygons and a beaded stream remained intact. The next major modification came with petroleum exploration, development and production. Seismic work was done when snow protected the tundra. Further, production facilities were constructed behind protective berms. A first in the Arctic was the development of a road-less on-land drill site.

The geomorphic impact on the Delta has been minimal primarily for two reasons: strict regulation of construction on the North Slope and the recency of its development allowed developers to take advantage of the technological improvements that have accompanied arctic engineering.

\*\*\*\*\*

### **Measuring the impacts of pastoral activities on wind erosion using a grazing gradient: case study in Western New South Wales, Australia**

AUBAULT H.(1), MCTAINSH G.(1), STRONG C.(1), LEYS J.(2)

(1) Griffith University, BRISBANE, AUSTRALIA ; (2) Scientific Services Division, NSW Office of Environment and Heritage, GUNNEDAH, AUSTRALIA

Wind erosion is widespread across the World's drylands, including the arid and semi-arid rangelands of Australia. Livestock production, is thought to intensify wind erosion processes through increases in the land erodibility, i.e. the susceptibility of the land surface to wind erosion, by reducing the surface roughness (vegetation cover) and modifying the soil surface stability (break downs crust and aggregates). However, the extent to which pastoral activities accelerate rates of wind erosion remains largely unknown.

Here we present land erodibility measurements, including vegetation and soil erodibility, along a grazing gradient from a watering point to quantify the effects of stocking intensity on wind erosion of sandy open grasslands in New South Wales.

The results show that stocking intensity is highest within 0.5km of the watering point with 150 dungs/m<sup>2</sup> and reducing to 15 at 4km. Land erodibility increases with stocking intensity. Within 500 meters of the watering point, the soil is unconsolidated, no crusts and aggregates and an erodible fraction ( $d < 84\mu\text{m}$ ) greater than 80%. Despite favourable climatic conditions, vegetation offers little ground protection (<50%). As stocking pressure decreases, soil stability increases with large areas of biological crust and aggregation demonstrable with smaller erodible fraction (<20%) but remains sensitive to disturbances. The current ground cover within this zone (up to 90%) prevents wind erosion, however this cover will be reduced under drying conditions and if grazing is maintained the land erodibility is expected to increase along the gradient at a faster rate than under natural conditions.

By using a grazing gradient from a watering point to quantify the effects of stocking intensity on wind erosion has provided first measurements of the impacts of pastoral management at a landscape scale. These finding can be extrapolated spatially through the use of remote sensing techniques and further applied at a regional scale.

### **Are erosion rates relevant for soil erosion studies?**

GARCIA-RUIZ J.M.(1), LANA-RENAULT N.(2), NADAL-ROMERO E.(3), SANJUAN Y.(1), BEGUERIA S.(4)  
(1) *Pyrenean Institute of Ecology (CSIC), ZARAGOZA, SPAIN* ; (2) *Area of Physical Geography, University of La Rioja, LOGROÑO, SPAIN* ; (3) *Department of Geography, University of Zaragoza, ZARAGOZA, SPAIN* ; (4) *Estación Experimental de Aula Dei, CSIC, ZARAGOZA, SPAIN*

Recording erosion rates ( $\text{Mg km}^2, \text{yr}^{-1}$ ) has been an obsession and a main purpose for many scientists worldwide, regardless of the conditions under which they are obtained. Nevertheless, after decades of quantitative studies and experiments, the results are not convincing because of their extraordinarily high variability. Published erosion rates for different land covers and land uses do not show a clear and reasonable trend. Such variability is related to: (i) the scale-dependent character of soil erosion, and, as a consequence, the difficulties for comparing erosion rates obtained from, for instance, experimental plots and catchments, or between catchments of remarkably different size; (ii) the use of various methods also determines the results, since each method is designed to measure a particular erosion process; (iii) connectivity is a crucial factor for explaining the accessibility of soil particles to the fluvial channel, in such a manner that a catchment with a dense shrub cover may deliver more sediment than another catchment with evident eroded areas, although disconnected from the stream. It is also arguable if the values obtained from a catchment can be considered as a global soil erosion value, given the presence of sediment sources directly located on the bedrock and not on the soil. The authors propose the conditions under which soil erosion rates may be useful and necessary.

\*\*\*\*\*

### **Human impact on erosion and burial of soil carbon through time**

HOFFMANN T., STRAUCH A.  
*University of Bonn, BONN, GERMANY*

The effects of soil erosion on atmospheric carbon is governed by three key mechanisms that are i) the replacement of soil organic carbon (SOC) at eroding sites, ii) the mineralization of SOC during erosion and transport and iii) the stability of buried SOC at depositional sites. Markedly different assumptions have been made about the relative importance of the key mechanisms, resulting in a global release of  $1 \text{ Pg C yr}^{-1}$  to a global uptake of  $1 \text{ Pg C yr}^{-1}$ .

Here we present results of a sediment-associated carbon budget in a small headwater catchment in Germany, to indicate the importance of the factor time in controlling the relative importance these mechanisms. Therefore, we estimate the loss of SOC through land use change from forests to arable land and compare it with SOC losses at degraded sites and burial of SOC in colluvial deposits.

Our results show that the transition of forest to arable land (without erosion and deposition of soils and sediments) resulted in a loss of SOC from  $11.8 \text{ kg C m}^{-2}$  to  $7.2 \text{ kg C m}^{-2}$  in our study site. Eroded sites are characterised by carbon stocks of  $6.9 \text{ kg C m}^{-2}$  compared to depositional sites with  $27.9 \text{ kg C m}^{-2}$ . Thus the combined effect of soil erosion and deposition results in a net withdrawal of atmospheric  $\text{CO}_2$ , which compensates land use driven losses. We show that the net effect of SOC degradation and burial depends on the rate of soil erosion and time since the erosion commenced.

### **Pedogenic Effects of Mid to Late Holocene Conversion of Forest to Pasture in the Western French Pyrenees**

*LEIGH D.S., GRAGSON T.L., COUGHLAN M.R.*

*The University of Georgia, ATHENS, GA, UNITED STATES*

Agropastoral conversion of forest to pasture over thousands of years hypothetically redirects pedogenic processes and changes soil chemical and physical properties. We test this hypothesis using paired soil samples straddling the forest/pasture boundary on hillslopes in the western Pyrenees near Larrau, France (15 sample pairs at two separate sites).

Pastured A horizons are significantly thicker than forested counterparts, averaging 19 cm vs. 4 cm. Pastured soils lack eluvial (E) horizons, which forested soils contain, and exhibit strong granular pedogenic structure while forested soils have moderate subangular blocky structure. We suspect the pastured A horizons are upbuilding over time due to greater production of amorphous silica (phytoliths) in grasses by comparison to trees, and our paired t-tests on chemical extracts of amorphous silica indicate pastured soils do contain significantly more phytoliths than forested soils.

Efforts are underway to date the forest/pasture conversion by measuring the initial increase in amorphous silica in colluvial stratigraphic sections in zero-order hollows near paired sample sites to mark the establishment of pastures. Charcoal concentrations are also being measured in these sections as fire was commonly used to create and maintain pastures. Charcoal ages of 1.1-1.2 ka at 75 cm depth in Vallon Antchuloguia (1180 <sup>14</sup>C yr BP +/-20, UGAMS-11776) and 3.9-4.0 ka at 75-80 cm depth in Vallon Mulhedoy (3600 <sup>14</sup>C yr BP +/- 20, UGAMS-11775) suggest stratigraphic records sufficiently long to capture the paleoenvironmental history of forest/pasture conversion. In addition, a radiocarbon date from near the basal layer in a footslope peat bog (Oronitz Bog) of 4.7-4.8 ka (4200 <sup>14</sup>C yr BP +/-25, UGAMS-11774) shows further promise for paleoenvironmental reconstruction. Our data contribute to a millennial history of human influence on landscapes of the Pyrenees Mountains and inform discussion on the Anthropocene.

\*\*\*\*\*

### **Comparing geologic and contemporary erosion rates: implications for land management in the Great Barrier Reef catchments, Australia**

*BARTLEY R.(1), CROKE J.(2), THOMPSON C.(2), FIFIELD K.(3), TIMS S.(3), WILKINSON S.(4), KINSEY-HENDERSON A.(5), HAWDON A.(5)*

*(1) CSIRO, BRISBANE, AUSTRALIA ; (2) Australian Rivers Institute, Griffith University, BRISBANE, AUSTRALIA ; (3) Department of Nuclear Physics, Research School of Physics and Engineering, Australian National University, CANBERRA, AUSTRALIA ; (4) CSIRO, CANBERRA, AUSTRALIA ; (5) CSIRO, TOWNSVILLE, AUSTRALIA*

Excess sediments and associated nutrients from agricultural areas are having a detrimental impact on the Great Barrier Reef, Australia. There is a need to define the amount of erosion that is acceptable in these catchments for the purpose of sustaining healthy agricultural areas and aquatic ecosystems. This requires an understanding of the natural or pre-European erosion rates, and how much these rates have changed under agricultural land use. Such information would allow more appropriate estimates of catchment disturbance, and allow the setting of practical and achievable soil erosion and water quality targets that have taken pre-European erosion into consideration. Terrestrial Cosmogenic Nuclide (TCN) analysis involves the measurement of long-lived nuclides, particularly beryllium-10 (<sup>10</sup>Be), that have accumulated in the upper few metres of the Earth's surface as the result of cosmic ray bombardment of rock and soil. Due to the long half-lives of these nuclides (1.4 Ma for <sup>10</sup>Be), concentrations can provide quantitative estimates of the timing and rate of erosion in streams and catchments over geological time scales (0.5–5 Ma). This makes them very useful for estimating erosion rates prior to agricultural development (or European settlement). This study will present the preliminary results of the application of TCN analysis to the Burdekin catchment, Australia. The long-term erosion rates will be compared with contemporary sediment yield data collected over the last decade from hillslopes and sub-catchments within the catchment.

## **Fluvial geomorphology and landscape evolution analyzed through the cartography of a large river. The case of the Argentinian Paraná**

FORGET M.

*Université de Savoie - Laboratoire EDYTEM - UMR5204, LE BOURGET DU LAC, FRANCE*

The Paraná river, fifth river of the world when considering its flow and the size of its watershed is poorly known nowadays, despite the research programs on its course. That can probably be explained by the youth of its discovery and the difficulty of gathering information in a river watershed greater than 3 million kilometers square. The physical data available is often incomplete and generally covers a short period of time. It is then difficult to understand the changes in its morphology over a period of time that exceeds sixty years. We then wondered about the data which would permit to redraw the river dynamics and to show if the modification of the land cover over the past 200 years (the stigmas of the recent colonization are still visible) show in the river pattern?

By centering us on the Argentinian course of the river, we collected 43 old maps which scales vary from regional (1/100,000) to continental (1/18,500,000). Through their analysis, depicting a period covering the fifteenth to the early twentieth century, it is possible to trace the causes from the changes picked out in the river bed. The methodology used is a map-to-map comparison, realized in a Geographic Information System, following the theory of river systems (Schumm, 1977). Therefore, sandbanks, islands and river planforms are considered to be markers of the river dynamics, given their sizes and the degree of revegetation (Smith, 1981, Ramonell et al., 2008). The causes are themselves related to the spatial and climatic phenomena. Early maps show a braided planform in the upper reach of the Paraná and a Paraguay channel free of deposits. The current dynamics indicate an inversion in sedimentary transportation and deposit. The deforestation mechanisms in the Misiones territory and their abandonment (Levington, 2009) could lead to a shift in the sediment load. This hypothesis will be demonstrated through analysis of the maps, its validation by texts and the results of a field study.

\*\*\*\*\*

## **Palynological signals of mid-Holocene natural or human induced erosion episodes in the Alcabrichel estuary, central littoral Portugal**

DANIELSEN R.(1), RAMOS-PEREIRA A.(2), MENDES P.(1), RAMOS C.(2), ALEIXO C.(2)

*(1) Laboratory of archaeosciences, DGPC, LISBOA, PORTUGAL; (2) Centre of Geographical Studies, Institute of Geography and Spatial Planning, University of Lisbon, LISBON, PORTUGAL*

The mouth of the Alcabrichel River consists of two alluvial plains separated by a limestone gorge. This estuary was selected for the evaluation of the balance between fluvial and marine influences, responses to climatic fluctuations and impact of human activities in the drainage basin.

Samples from one borehole, situated on the inland side of the gorge, were analysed for pollen and non-pollen palynomorphs. Gradual diminution of marine influence, increased sedimentation rates and intensified anthropogenic signals were encountered through time. Pollen assemblages indicate large environmental changes and four stages of vegetation development were found.

Initially around 5900 yrs BP (conventional ages) the landscape was an open oak/pine forest with dense garrigue vegetation. The riparian zone consisted of stands of elder and ash. Marine influence was continuous and weak signals of anthropogenic influence were found. At the next stage, 4900 to 1900 yrs BP, forest cover was reduced, anthropogenic activity strongly increased and ocean influence was shifting in strength. Signs of erosion and accumulation are found both in the pollen assemblages and the sediment textures.

During the last two stages further degradation of local forest cover, garrigue and riparian vegetation took place. Increased values of pine pollen through the final stage were a consequence of regional reforestation measures implemented during the last centuries. Human impact was constant and sedimentation rate high probably as a result of increased erosion from cultivated fields in the alluvial plain and surrounding slopes. The sediment has a terrestrial source and disappearance of marine indicators is detected testifying a post-transgressive origin.

This research was funded by the project, PCDT/CTE-GIX/104035/2008 – FMI5000, from Portuguese Science and Technology Foundation (FCT). Mendes was funded by the FCT scholarshipSFRH/BT/51558/2011 and Aleixo by the FMI 5000 Project (CEG-FMI 5000-BI 2011).

**Anthropogenic Geomorphology of a highly urbanised fluvial plain: Pinheiros River, Sao Paulo, Brazil.**

LUZ R., RODRIGUES C.

*University of Sao Paulo, SAO PAULO, BRAZIL*

This research seeks to assess changes in both landforms and surface processes in a highly urbanised fluvial plain in tropical humid environment. The study area is the Pinheiros River Fluvial Plain in Sao Paulo, Brazil, that has been the site of human interventions related to the urbanisation processes of one of the biggest metropolitan areas of the Americas.

Cartographic techniques in a historical approach and selected geoindicators to measure environmental changes were utilised in an urbanised meandering fluvial system. Three geomorphological maps were produced on the scale of 1:25,000: the pre-disturbance map, the active disturbance map and the post-disturbance map.

Historical changes in the landforms and related hydrological functions that occurred over the last 80 years of urbanisation processes were analysed, measured and compared. The following geoindicators were selected: fluvial terraces and floodplain areas; flooding frequency and area; channel form and processes indicators (length, width, sinuosity, pattern, meandering belt area and flow characteristics); levees and backswamps form indicators.

The results revealed the high efficiency of human activities upon fluvial landforms and the high magnitude of changes in the hydrological processes which are comparable to medium and long-time natural events. In a decadal time-scale, the channel form and processes was completely changed, the pre-disturbance meandering channel was straightened, its length was reduced by 46.2%, its width was increased by 101.9%, and its flow was reversed. Beside this, the floodplain was eliminated and different terrace levels were created by anthropic agents.

Furthermore, those retrospective and historical studies which seek to understand the evolution of anthropogenic geomorphologic systems have produced results that can be utilised in environmental and territorial management due to their capacity to measure the negative impacts of the urbanisation processes in a changing fluvial system.

\*\*\*\*\*

**On explaining urban river morphology**

ASHMORE P.

*University of Western Ontario, LONDON, CANADA*

Geomorphologists' explanations of river morphology and characteristics have become increasingly focussed on sophisticated mechanical models of processes and development. Quantitative predictions of river response to urbanization are theoretically possible given sufficient information on of the pre-urban conditions and on hydrological changes and other relevant variables. However, these models may prove to be inadequate for because of both physical and engineering circumstances. But beyond this, a 'physical-only' explanation fails to reveal a complete understanding of why rivers may have the form that they have in these environments. Admittance of the significant influence of, for example, historical, political and cultural contingencies is necessary for a more complete understanding of fluvial dynamics. These ideas are illustrated from a case study of fluvial response to extensive urbanization in a watershed in Toronto, Canada and developed from other historical examples.

### **Possitive impacts of global geomorphic change: generation of renewable geologic materials?**

CENDRERO A.(1), HURTADO M.H.(2), FORTE L.M.(2), DANGVAS N.V.(2), GIMÉNEZ J.E.(2), M. DA SILVA M.(2), BRUSCHI V.M.(1)

(1) *Universidad de Cantabria, SANTANDER, SPAIN* ; (2) *Universidad Nacional de La Plata, BUENOS AIRES, ARGENTINA*

Work carried out by different authors during the last decade has shown that there seems to be a “global geomorphic change” caused by the direct and indirect human modification of land surface. This change, apparently not related to climate, is manifested in increasing excavation and mobilisation of geologic materials (the “human geomorphic footprint”), higher erosion/sedimentation rates, or frequency of disasters related to geomorphic processes. Most such effects have negative consequences for people, but geomorphic change perhaps also opens some opportunities.

A case study is presented showing that the acceleration of geomorphic processes in the humid Pampa (Buenos Aires province, Argentina) is generating renewable geologic resources, the exploitation of which could help solving some of the environmental problems derived from geomorphic change. Truly sustainable mining could be based on the exploitation of recent lake sediments as a raw material for the brick industry, presently based on topsoil mining. This would reduce or eliminate land degradation caused by present practices and, if sedimentation rates are high enough, renewal of the resource according to existing needs might be possible. The extraction of the growing amounts of sediment carried into the numerous shallow lakes in the region (many of which are being silted-up) would help to maintain these valuable units as well as their flood-buffering capacity. Data are presented on the suitability of lake sediments for brick-making, estimates of existing reserves and renewal rates as well as the possibility to cover present and future needs.

\*\*\*\*\*

### **Stream geomorphology is dramatically altered by small amounts of urbanisation**

VIETZ G., RUTHERFURD I., FLETCHER T., WALSH C.  
*The University of Melbourne, MELBOURNE, AUSTRALIA*

Urbanisation of a catchment induces often extreme physical responses in receiving streams: with channel enlargement most commonly reported. Common management responses, focused on localised interventions, are both ecologically and economically unsustainable and are driven by a limited understanding of explicit relationships between urbanisation and stream geomorphology. This paper addresses three weaknesses in the literature relating urbanisation to geomorphic change: (1) urbanisation is usually characterised by total imperviousness (TI) when more important is the proportion of TI connected to the stream via drainage systems (termed effective imperviousness, EI); (2) effects of urbanisation are usually explored as a binary problem (comparing urbanised and not urbanised) rather than across a gradient of urbanisation; and (3) most studies do not consider ecologically relevant changes in geomorphology (such as bedload sediments, and bars and benches). In this empirical study we relate geomorphic attributes of streams to TI and EI across a gradient of urbanised catchments near Melbourne, Australia. We demonstrate that EIs as low as 2% commonly relate to significant channel incision, low bedload sediment depths, severe bank instability, a loss of bars and benches, and little to no large wood (with little further change for a ten-fold increase in EI). This is a much lower threshold of urbanisation than previously reported, and EI provides consistently stronger relationships than TI alone. Our findings demonstrate that geomorphic attributes are highly sensitive to excess urban stormwater runoff from impervious surfaces directly connected to the stream. We suggest actions addressing urban drainage (e.g. stormwater harvesting) will have more effect on geomorphic change than addressing catchment imperviousness alone. The sustainability of cities, for people and ecological values, is dependent on water management which realises the multiple benefits possible.

### Human induced land surface alteration in and around Pune city, India

PARDESHI S.(1), PARDESHI S.(2)

(1) University of Pune, PUNE, INDIA; (2) Annasaheb Magar College, Hadapsar, PUNE, INDIA

The era of man and the machine is a phase of never before alteration of the earth's surface and processes. The parts of globe where such machines are developed initially experienced such changes first. Relatively the parts of the globe which are still going for mechanisation are in the phase of modifying the earth's surface. It's time to assess all such changes caused by human intervention in different types of landscape and their consequences on the environment. After the technological development, the rate of change of landscape has increased tremendously. To make more land available around urban centres, man is changing the nature of landscape on a large scale. Like many other urban centres, Pune city is fast growing in to a metro. Natural landscape around Pune city is greatly disturbed by human activities. Construction of roads, buildings and other infrastructures are the major causes of landscape disturbance. Present study is an attempt to identify the areas that are highly disturbed and tries to identify the areas of potentials of change in natural processes in general and geomorphic processes in particular. Based on the surveys carried out at various sites around Pune city, it was found that natural systems are partially altered or completely changed. Such alterations will cause change in natural processes and the response of the surface to these processes. If the same rate of alteration continues, the areas will be degraded with greater intensity and it will lead to decrease in aesthetic value of these areas.

\*\*\*\*\*

### Water and wastewater pipelines - geomorphological challenges

GILCHRIST D.

Sydney Water - Engineering & Environmental Services, SYDNEY, AUSTRALIA

Sydney Water is Australia's largest water utility with over 1.3 billion litres of wastewater collected and treated per day. This is done via a network of 24,000km of pipes, 670 pumping stations, 13 water-recycling plants and 16 wastewater treatment plants.

The installation of water and wastewater delivery infrastructure often presents challenges that the planner and pipeline engineer do not consider in their initial alignment design. Initially the focus of their work is upon a design with respect to meeting future growth. This basically means the pipe size and layout must allow for increased demand due to changes in population density, land use changes, and other water management strategies like recycling and wastewater mining etc. over the 50-100 year design life of the asset.

It has proven beneficial at Sydney Water to set up Potentially Unstable Areas (PUA's) as regions on our Geographical Information System (GIS). A PUA is an area that has a rapid change in slope or where the slope angle is greater than 15 degrees. Any work in these regions, whether it is the amplification of an existing pipeline or a new pipeline altogether, triggers the need to have an earth scientist involved in review. This happens early in the design and so with the earth scientist's focus being on geomorphology and ground stability, a truly more sustainable design is achieved. The number of possible routes is often quickly reduced and a geotechnically preferred and least risk alignment becomes apparent.

This multi-criteria analysis (MCA) is relevant for the design of any large piece of infrastructure and the key is to set up a process that ensures a geomorphologist or engineering geologist is involved early in design.

This paper will reference recent projects including the installation of water pipelines through talus material, a gravity wastewater system on an infilled paleo-estuary, and the assessment of an 1800mm diameter water pipeline that runs along the base of an old garbage dump.

## **Impact of the quality and spatial resolution of Holocene land cover reconstructions on geomorphic model results**

DE BRUE H., VERSTRAETEN G.  
KU Leuven, LEUVEN, BELGIUM

During the last decade, several global land cover (LC) reconstructions covering the Holocene have been produced. These are being used more and more to analyze the long-term anthropogenic impact on various environmental processes including C-dynamics, climate change and soil erosion. However, their low spatial resolution (i.e. 5 arc-minutes at best) questions their use in geomorphic models. Furthermore, existing GLC reconstructions do not differentiate the typology of human impact, although the susceptibility of different LC typologies towards erosion varies greatly. Here we assessed the sensitivity of an erosion and sediment delivery model that operates at high resolution (100 m) to the quality and spatial resolution of LC maps. First, low-resolution LC (expressed as % non-natural vegetation) maps were downscaled to 100 m resolution without spatial LC allocation. Second, estimated non-natural vegetation was spatially allocated to a high-resolution grid (100 m) using a logistic model that relates contemporary LC to slope, soil characteristics, landforms and distance to rivers. For both LC maps, different scenarios for the ratio between arable land and grassland were simulated. Analyses were performed for several time periods throughout the Holocene, for the Scheldt Basin (19,000 km<sup>2</sup>; Belgium and N France). Results indicate that low-resolution LC information, regardless of the considered arable/grassland ratio, leads to largely overestimated sediment fluxes when compared to field-based sediment budgets. Allocation of LC at higher spatial resolution yields better results. Variations in model outcomes are related to differences in landscape connectivity between allocated and non-allocated LC. Also, model results differ greatly for different arable/grassland ratios. This indicates that there is not only a need for LC reconstructions at high spatial resolution, but also that differentiation between arable land and grassland is essential for accurate geomorphic modeling.

\*\*\*\*\*

## **Dynamics of eolian processes in the geosystems of the Western Transbaikalia (South Siberia)**

KOBYLKIN D.(1), RYZHOV Y.(1), ANDREEV S.(2)  
(1) V.B. Sochava Institute of Geography SB RAS, IRKUTSK, RUSSIAN FEDERATION; (2) Baikal Institute of Nature Use, ULAN-UDE, RUSSIAN FEDERATION

The relevance of the study of aeolian exomorphogenesis is caused by the increased interest in the study of desertification and related environmental issues. This is particularly topical for the Western Transbaikalia area, which is intensively used by human being since the Paleolithic. Large data arrays were used for the research the dynamics of aeolian processes in steppe and forest ecosystems of the Western Transbaikalia: topographic maps of different time, remote sensing, historical and archival materials, radioisotope dating, laboratory analysis of rock samples, dendrochronology, etc. The time interval embraces the period from 25,000 years ago to the present. Surveys have identified several steps of enhancing of aeolian processes associated with both man-made and the natural factors. The first stage of activation of aeolian processes occurred about 21,000 - 11,000 years ago, according to the availability of ancient aeolian overlying sediments of the last interglacial period. After the onset of the Holocene optimum we reconstructed six periods of formation of aeolian deposits: more than 6000, about 5000, 2900-2200 years ago, marked by organogenic deposits of buried soils. Dendrochronological and historical data can distinguish several stages of climate aridization. Between 1650 and nowadays seven stages of aridity are identified (1725 - 1750, 1765 - 1775, 1847 - 1870 1875 - 1905 1942 - 1963 1973 - 1988.). The last three episodes are recorded on topographic maps, aerial photographs and satellite imagery in the form of newly formed aeolian forms, which suggest their formation in previous stages. Animal husbandry has been actively developing in the area under study since about 3500, and farming since about 1700 years ago. Extensive development during periods of drought due to high wind speeds, light texture and structural soil features lead to degradation of large areas and anthropogenous deserts.

### **Study on vegetation-cover change and grazing intensity in the Alai Valley, the southern Kyrgyz Republic**

LIU J.

*Hokkaido University, SAPPORO, JAPAN*

In the Kyrgyz Republic, grazing activities have brought about some significant impacts on the local environments. The main objectives of this study are to verify changes of vegetation-covered area from the 1960s to today, to examine grazing intensity nowadays, and to discuss causes of the changes of the vegetation-covered area and the grazing intensity in the Alai Valley, the southern Kyrgyz Republic. The study area was classified into basins A–I (based on mountain ridges, from west to east). Corona satellite imageries taken on 1<sup>st</sup> May 1965 for basins A–H, those taken on 20<sup>th</sup> June 1967 for basin I, and ALOS satellite imageries taken on 2<sup>nd</sup> November 2009 for all basins were used to analyze the changes of the vegetation-covered area. Grazing model (Howard and Higgins, 1987) was applied to classify the measured slopes (N=180). It has been indicated that vegetation-covered area in basins A–I has decreased from 80.3% in the 1960s to 76.5% in 2009. It is suggested that an increase in the settlements is probably one of the reasons for the vegetation decrease. Moreover, on the slopes with degree <40°, vegetation-covered area has decreased in 2009, but it has increased on the slopes with degree ≥40°. Slope degrees in most bare area range from 10° to 30° both in the 1960s and in 2009. Grazing intensity model and the result of interview in the study area were harnessed to classify 180 measured slopes into 74 overgrazed slopes with terraces, 19 slopes that can accept more livestock, and 87 slopes without terraces. The results demonstrate that families who graze livestock only in summer would have overgrazed, compared with families who graze livestock there in early spring and late autumn. Furthermore, the percentage of the overgrazed slopes decreases with the increase of the distance to the main road. The slopes that can accept more livestock are always at least 500 m away from the main road.

\*\*\*\*\*

### **An exploration of the role of human activity in the generation and maintenance of hummocky meadows ('Buckelwiesen' landscapes) in the European Alps.**

EMBLETON-HAMANN C.

*University of Vienna, Department of Geography, WIEN, AUSTRIA*

The study of hummocky meadow landscapes ("Buckelwiesen") over the 20<sup>th</sup> century has emphasized the necessary condition of calcareous substratum and the triggering effect of tree-throw events as causal factors in their origin. If these were the only factors, forest regeneration would tend to eliminate this distinctive landscape. "Buckelwiesen" landscapes appear to occur only in the European Alps and emerged at a time in history when land use intensity was accelerating. Increasing population density and forest management have played important roles in their development. The huge medieval demand for charcoal (opening up gaps in the forest and using the tree throw debris) and the grazing of cattle in the newly formed gaps in the forest guaranteed the continuity of form. The thesis of this study is that human activity has been critical both in the generation and maintenance of these landscapes. After a discussion of the nature of, and the historical context of, their formation (through archival research and radiocarbon dating) the essential nature of human activity in the maintenance of these landscapes is emphasized.

### **GeoRISK: Geo-analysis of landscape level degradation and natural risks formation**

SVOBODOVA E., JAKUBINSKY J., BACOVA R., HERBER V., KUBICEK P.

*Department of Geography, Faculty of Science, Masaryk University, BRNO, CZECH REPUBLIC*

Long-term increase trend of the human activities has negative impact on the function and landscape stability. Anthropogenic pressure influences directly or indirectly approximately 30 % of the Earth surface. Environmental problems, which are caused by inappropriate land use changes, have adverse effect on human society. This landscape degradation is demonstrated by local predisposition to occurrence of natural risks (flood events, slope instabilities).

The transdisciplinary approach was applied on the selected areas in the Czech Republic. Model areas (the Svitava River Catchment, the Leskava Brook Catchment, and the Borovský Brook Catchment) are specific by difference natural conditions and human activities. The research within the GeoRISK project solved identification of landscape level degradation, anthropogenic landforms inventory, ecosystem services evaluation, and uncertainty concept in spatio-temporal data.

The main aim of the project is presented by quantitative identification and verification of dependence between landscape degradation and propensity to natural risks formation using geographical analysis and cartographic visualization. One of the main project goals is to identify the most degraded areas, compare them with values of natural risk susceptibility. Observed characteristics are enriched with spatial and thematic uncertainty characteristics to obtaining reliability pattern. The paper's authors expect confirmation of high degree dependence between natural risks predisposition and anthropogenic landscape affect.

\*\*\*\*\*

### **Water and sediment loss from superficial runoff in areas of forest and pasture cover in southwest Amazonia Area-Acre, Brazil**

SANTOS W.(1), AUGUSTIN C.(2)

*(1) Universidade Federal do Acre, RIO BRANCO, BRAZIL ; (2) Universidade Federal de Minas Gerais, BELO HORIZONTE/MG, BRAZIL*

The southwest of the Amazon area has undergone a rapid transformation of its natural environment as a result of the substitution of forest by pasture cover. In order to identify differences in loss of water and sediments in areas of forest and in areas where the forest was transformed into pasture four parcels of 10 m<sup>2</sup> were installed, two of each type of cover in two slopes of the Judia creek basin in the state of Acre, Brazil. The data was collected from 10/2010 to 03/2011, during the rainy season. At each plot daily precipitation, vegetation, infiltration capacity, porosity and penetration resistance in soil was measured. In the pasture cover of both slopes the total precipitation reached 1172 and 1145 L/m<sup>2</sup> with a loss of 162.94 and 134.73 L/m<sup>2</sup> of water while sediment loss was 32.032 and 25.972 g/m<sup>2</sup>, respectively. In the forested plots of both slopes, the total rainfall was 936 and 935 L/m<sup>2</sup>, with water losses of 84.01 and 82.13 L/m<sup>2</sup> and sediment loss of 72.372 and 86.090 g/m<sup>2</sup>, respectively. Test of variance (*T-Student*) identified significant differences in water loss in the pasture plot compared to that of the forest cover ( $p = 0,000$ ) in the slopes 1 parcels. However, sediment loss ( $p = 0,168$ ) presented higher values for the parcels covered by forest. In slope 2 there were no significant differences in the values of water loss for the parcels with both types of vegetation covers ( $p = 0,289$ ). However, it was significant the difference in the values of sediment loss of the forested parcel in slope 2 ( $p = 0,0911$ ) at 10% significance level in comparison with that with grass cover. The higher values of sediment loss in parcels covered by forest seems to be associated to a more intense stirring up of earth material by mesofauna coupled with the intensity of precipitation caused by rain water accumulation on the leaves. On the other hand higher levels of compaction may have favored greater water loss in pasture areas.

### **Monitoring of Erosion and Slope Deformation on Agricultural Land in the Czech Republic**

SMOLIKOVA J., KAPICKA J., ZIZALA D., VANOVA V.

*Research Institute for Soil and Water Conservation, PRAGUE, CZECH REPUBLIC*

Soil is an important component of the environment and is the basic means of agriculture production. It is threatened by a number of natural and human processes that lead to reduction even destruction of soil functions. The most common type of land degradation in the Czech Republic is erosion, less common but an important type in terms of non-renewability of its functions is slope deformation. Degradation of soil is significantly accelerated during the last 30 years, because the conditions of farming in accordance with environmental protection are very mild, thus the need of collecting a data about events is highly desirable for improving the situation.

In 2011 a joint project a web portal of Monitoring of erosion was found by the Central Land Office and the Research Institute for Soil and Water Conservation to develop a spatial database, where all occurrences of erosion and slope deformation on agriculture land are recorded in depth as soon as possible. A total of 135 incidences were recorded during the first 2 years of function and the database is still expanding. The recorded data will be used to analyse causes using GIS tools and mathematical models of erosion. The results can be used to find out extremely susceptible areas that should be more protected.

The goal of the article is to introduce a methodology used to record erosion events and to present an analysis of selected events of erosion and slope deformation on agriculture land.

\*\*\*\*\*

### **Drivers of drift sand dynamics; a reconstruction for the Wekeromse Zand, the Netherlands**

SONNEVELD M., HENDRIKS C., WALLINGA J.

*Wageningen University, WAGENINGEN, NETHERLANDS*

Inland active drift sand landscapes are regarded as unique ecosystems of great historical and geomorphological value. Recent studies have highlighted the role of multiple factors in the initiation and stabilization of drift sand landscapes. To unravel the importance of different forcings (e.g. agricultural practices, climate) and their interplay, insight in the chronology of drift sand dynamics is essential. In this study, we aimed to reconstruct the dynamics of the drift sand landscape of the Wekeromse Zand (central Netherlands) and to develop a conceptual model to understand the processes involved. The Wekeromse Zand study area is located on the border of a central push moraine and is characterised by open active drift sands and vegetated hills and valleys. The surroundings are dominated by modern agricultural practices, and remnants from ancient iron age Celtic Field systems. For the study area we: i) analysed historical maps going back to the early 19<sup>th</sup> century, ii) performed a field survey to map the palaeolandscape (before drift sand activation) and iii) employed optically stimulated luminescence (OSL) dating of drift sand deposits on 11 samples from two locations to determine the timing of drift sand deposition. Analysis of the available topographic maps showed no substantial aeolean activity of the area outside its morphological boundaries. OSL dating revealed that two drift sand layers were deposited between 1373 and 1462 AD and between 1680 and 1780 AD. The Wekeromse Zand has known three relatively stable periods: i) a period between the start of the Holocene to the Late Medieval Period, ii) in between the Medieval climatic optimum and the climatic Maunder minimum, and iii) current situation. The two active phases appear to correspond with active phases in the coastal dune systems and are probably the combined result of anthropogenic land use and climatic changes.

## **Humain impact on the mountains landscape in Macedonia and Serbia**

MILEVSKI I.(1), LUKOVIC J.(2)

(1) *Institute of Geography, University "Ss. Cyril and Methodius, SKOPJE, MACEDONIA* ; (2) *Geografski Fakultet, Studentski trg, BEOGRAD, SERBIA*

Mountains are the predominant morphostructures in the checkerboard topography in the Republic of Macedonia as well as in central and southern part of the Republic of Serbia. In Macedonia there are more than 30 mountain ranges from which 13 extending above 2000 m, while the highest - Korab, reach 2753 m. The highest mountain ranges are found in the western and central part of the country, generally composed of marbles, limestones, granites and other hard rocks. Mountains in eastern part of the country are dominantly composed of more erodible crystalline rocks. In Serbia, there are about 20 mountain ranges from which the highest is Stara Planina with Midzor peak (2169 m). Here, mountains in the east part of the country are composed mostly by limestones, while in western part by crystalline rocks. These groups of mountains in Macedonia and Serbia were shaped generally during the Neogene–Pleistocene. However, as a result of demographic, socio-economic and technological changes, the level of anthropogenic modification of the mountain landscape in both countries is significant. Together with the influences of changing climate, human impact will be decisive in future mountain landform evolution. The most typical direct and indirect human interventions in the mountain landscape in Macedonia and Serbia are accelerated erosion, opencast mining, road building, canal, dams and reservoir constructions on rivers. On lower altitudes with south aspects, forests are usually degraded, destroyed or replaced by cultural vegetation. The same case is with highest parts, where winter-sport centers are built recently. Because all of that, accelerated soil erosion occurs, devastating the mountain landscape. Thus, one of the most significant tasks in mountain protection and conservation is appropriate monitoring of human impact on the landscape. Aside of numerous traditional approaches, modern GIS and satellite imagery analyses became fundamental tools for this purposes.

\*\*\*\*\*

## **Poster presentations:**

### **Slash-and-burn agriculture: establishing scenarios of runoff and soil loss for a five-year cycle**

THOMAZ E.

*Universidade Estadual do Centro Oeste do Parana - UNICENTRO, GUARAPUVA, BRAZIL*

Shifting cultivation is an age-old agricultural system that coexists with modern agricultural systems, particularly in the tropics. The history of land occupation in the study area is strongly related to the exploitation of natural resources. Today, agriculture is an important economic activity in the Guarapuava region, and is characterized by two main types of systems. The first is modern commercial agriculture that uses advanced technologies. The second is subsistence agriculture, which produces primarily corn and beans, and occupies less productive soils located on steep slopes that border escarpments and well-dissected valleys. The characteristics and effects of shifting cultivation are well documented in the literature, including: soil degradation and erosion, nutrient depletion, impacts on biodiversity, and economic trends. Although studies report soil loss during the cropping period under shifting cultivation, few studies have assessed soil erosion during a full slash-and-burn cycle. The objectives of this study were to 1) characterize runoff and soil loss patterns over a full 5-year cycle; and 2) discuss the soil loss tolerance limit for a 5-year regeneration cycle. The study area has a wet, subtropical climate with precipitation of 1,915 mm, and temperature of 17°C. The measured slope formed by contiguous land in the study area is 32°. The soil consists of Regosols formed from basalt rock, and an approximate texture size distribution of 36% sand, 20% silt, and 44% clay. The measurement of runoff and soil loss was based on a small erosion plot approach. Three agricultural plots in different stages of regeneration were monitored. The data were analyzed by month and year for the 5-year regeneration cycle. Runoff and soil loss decreased exponentially from the burned phase (6.12 t/ha) to the early stage of secondary forest (0.16 t/ha). Runoff and soil loss exhibited patterns similar to those of a forested area after only 5 years of regeneration (0.093 t/ha).

### **Late Holocene dune mobilizations in the northwestern Negev dunefield, Israel: A response to combined anthropogenic activity and short-term intensified windiness**

ROSKIN J., KATRA I., BLUMBERG D.G.

*BEN-GURION UNIVERSITY OF THE NEGEV, BEER-SHEVA, ISRAEL*

This study proposes a paradigm of anthropogenic activity and windiness fluctuations to explain aeolian sedimentation and dune mobilization in the northwestern (NW) Negev Desert dunefield. The proposed paradigm contributes a different approach to estimating the effect of climate changes on the unprecedented agricultural and urban settlement expansion during the late Roman to Early Islamic period and on the decline in the northern and central Negev Desert. Based chiefly on luminescence ages coupled with analysis of archaeological finds and historical texts, we suggest that intermittent dune mobilization during the late Holocene, at ~1.8 ka and mostly 1.4–1.1 ka, are linked to periods of human occupation. The idea that the late Pleistocene dune encroachments alone that formed the NW Negev dunefield between the Last Glacial and the onset of the Holocene is connected to northern hemisphere cold-event windy climates that may have intensified East Mediterranean cyclonic winter storms, cannot explain the late Holocene dune mobilizations. We conceptually model a connection between late Holocene dune mobilization, widespread anthropogenic occupation and activity, and windiness. We maintain that historic grazing and uprooting shrubs for fuel in the past by nomads and sedentary populations led to decimation of dune stabilizers – biogenic soil crusts and vegetation, causing dune erodibility and low-grade activity. Short-term events of amplified wind power in conjunction with periods of augmented anthropogenic activity that triggered major events of dune mobilization (elongation) and accretion have been preserved in the dune chronostratigraphy. This study demonstrates the sensitivity of dunes in arid and semi-arid regions to a combination of local and short-term fluctuations in windiness at times of widespread grazing (anthropogenic activity.) The results remind us that in similar future scenarios, sand mobilization may be similarly retriggered to varying degrees.

\*\*\*\*\*

### **Factors promoting heavy metals leaching in Cantabrian seaboard estuaries. Bay of Biscay.**

FERNANDEZ S.(1), GONZALEZ M.(2), ALVAREZ M.(2), RODRIGUEZ C.(2)

*(1) University of Oviedo, MIERES, SPAIN ; (2) INDUROT, MIERES, SPAIN*

Estuarine sediments are important sinks of heavy metals since they can be immobilized in the sediments by means of adsorption, complexation and speciation processes. However, estuarine areas also could be potential sources of heavy metals to the coastal systems promoting by changes in pH, Eh, EC or organic matter of the estuarine sediments. These variations can be caused by anthropogenic processes such as desiccation of estuaries due to land reclamation, a common practice along the Spanish Atlantic seaboard since centuries ago. The potential of the estuarine sediments to act as source or sink of heavy metals in relation to the management of the area was studied in two river basin of the Cantabrian Range with local baseline in the south coast of Bay of Biscay. Nalón River drains 7043 Km<sup>2</sup> of siliciclastic rocks. The estuarine sediments cover 53 Km<sup>2</sup>, 15 of them are reclaimed lands. The daily discharge is 56 m<sup>3</sup> s<sup>-1</sup>. Sella River drains 1272 Km<sup>2</sup> of calcareous rocks. The estuarine sediments cover 27 Km<sup>2</sup> and has 20 of reclaimed lands. The daily discharge is 43 m<sup>3</sup> s<sup>-1</sup>. 123 samples in fluvial plains and 27 in estuarine areas were sampled. Concentrations of Mn, Zn, Cr, Pb, Ba, V, Co, Ni, Cu, Ti, Sn, As, Mo, Ag, Cd, Sb and Hg were determined by means of ICP-MS. pH, organic matter (%), clay, silt and sand (%) and electrical conductivity (mS m<sup>-1</sup>) were analyzed. The highest concentrations of heavy metals as Ag, Cu, Sn or Cr are found in the natural estuarine soils and lowest concentrations are found in reclaimed areas. The reclamation of estuarine soils seems to promote the leaching of heavy metals, probably due to the increase of their mobility by the significant drop of pH. Therefore, the recovery of currently reclaimed estuarine areas, with the resulting enhancement of their role as sinks of heavy metals, could be one of the possible mechanisms for decreasing the loading of heavy metals from rivers to the transitional body waters.

**Morphodynamics studies of the relief in the watershed of the stream Feijó/ Metropolitan Region of Porto Alegre / Brazil**

REHBEIN M.(1), ROSS J.(2)

(1) *Universidade Federal de Pelotas, PELOTAS, BRAZIL* ; (2) *Universidade de São Paulo, SÃO PAULO, BRAZIL*

The watershed of the stream Feijó, located in the Metropolitan Region of Porto Alegre / Brazil, includes areas of several urban environmental impacts, many of them related to geomorphological processes. In order to contribute to understanding these processes, this study aims the identification and analysis of the relief morphodynamics in the watershed Feijó. Ab'Saber (1969), Ross (1992) and Fujimoto (2001) are presented as main theoretical and methodological references. Operating activities include literature surveys, preparation of maps, field work and analyzes. Were mapped in the watershed of the stream Feijó four standards similar forms of relief, plains, high hills, hillocks and small hills. The modifications on these relief standards forms, caused by the urbanization in the watershed, changed hydrogeomorphological dynamics, conditioning other rhythms to the erosion and deposition processes, intensifying them drastically. In the high hills, hillocks and small hills was observed an increased overland flow and a consequent reduction of infiltration. In the plains was observed collapses in the functionality of fluvial channels, with undermines of riverbanks, siltings and floodings. Trying to mitigate the floodings, rectifications are carried in waterways. This practice is necessary, but does not solve the problem of flooding and ends up intensifying erosion and depositional processes. Anyway, a significant amount of material remains transported from adjacent slopes. In order to qualify the current environmental scenario, morphodynamics studies of the relief may serve as basis for taking action in areas of the watershed Feijó.

\*\*\*\*\*

**Successive human impacts in a tropical Andean valley: the case of Medellin, Colombia**

HERMELIN M.

*Universidad EAFIT, MEDELLIN, COLOMBIA*

The Aburra valley is a deep, elongated depression which stretches in two 30 km long segments in the northern part of the Central Cordillera; its floors is at 1500 masn and it is surrounded by plateaus and summits reaching 3000 masn. Its origin is probably tectonic with an age of about 2 Ma and it is formed by a variety crystalline rocks; the slopes are covered of mass movement deposits and the floors by loosesediments with thicknesses which vary abruptly. Its climate is warm and humid, with average temperatures of 20°C and annual rainfall of 1500 mm in the center of the valley. It was originally covered by thick Andean forest.

When Spaniards first reached the area during 16<sup>th</sup> century, they found a relatively scarce Indian population, but also remnants of broad paved trails and of "earth buildings". The valley was progressively occupied by dispersed Spanish settlements dedicated to agriculture and cattle rising and became the main source of food for the surrounding gold mining districts. These activities produced the increase of commerce and wealth of Medellin and a population growth which signified its recognition as capital of the province at the beginning of 19<sup>th</sup> century. Despite of poor communications, the city continued to grow and starting in the first decades of 20<sup>th</sup> century, several major projects began to modify the topography of the valley: road cuts, railroads, streets, bridges, river deviation (for mining and later for building terrains), clay and rock extraction, tunnels and landfills. The result is not only a change in topography but also in geomorphic processes: landslides and flash floods tend to increase, as well as risks due to natural factors.

The difficulty to enforce rules restricting terrain occupation contributes to deteriorate the situation, despite of very praised efforts from the local government to improve living standards through better communications, educations and urban projects.

**Effect of past land degradation on the present shallow landslides in Yamaguchi Prefecture, western Japan**

DAIMARU H.(1), MURKAMI W.(1), KUROKAWA U.(2)

(1) Forest and Forest Products Research Institute, TSUKUBA, JAPAN ; (2) Kansai Research Center, Forest and Forest Products Research Institute, KYOTO, JAPAN

The heavy rainfall on 21 July 2009 triggered serious surface erosion on the mountains in Yamaguchi and Houfu districts. Many gullies initiated in the narrow valleys filled by granitic sand. The C14 age of the charcoal under the granitic colluvium was Cal AD 1440 – 1470 and indicates that the valley fill deposition occurred after the 15 centuries. In the middle to western Japan, there were many treeless hills called in the granitic mountain because these mountains locate in suburb area and seriously affected by such as deforestation, gathering fertilizer from forest. The old aerial photographs taken in 1947 showed much human-induced bare hill (hageyama) on the south facing mountain ridges and many small landslides occurred in the marginal area of the treeless area. Thus, the past land degradation significantly affected on the distribution of the 2009 landslides through the formation of the valley fill.

\*\*\*\*\*

**Urban constructions in deep zones. A diachronic analysis of Mexico City**

RAMIREZ NUNEZ C., PARROT J.F.

UNAM, MEXICO D.F., MEXICO

Mexico City is a good example of a chaotic development of megalopolis. The earliest urban zones were firstly located in the inner flat area of an endorheic basin belonging to a mayor system known as the Trans-Mexican Volcanic Belt. Afterwards the expansion of the city invaded the hill slopes surrounding the basin and little by little, in conjunction with a high population pressure, the tendency to build on deeper slopes increased strongly. Nowadays most of the surrounding zones are occupied. The local government is trying to limit this tendency by multiplying the regulations and decrees which define the conditions of construction and prohibitions, but the means of control remain deficient. Based on a diachronic study and Digital Elevation Model treatments, the present work shows the percentage of evolution of the land use according to the slope. In a first step, the distribution of slope ranges takes into account the whole surface actually reached by the urban development in order to follow the evolution of the space occupation over the last years. It is peculiarly clear that the number of illegal constructions increases strongly every year whatever the difficulties of building and accessibility are, leading to a sharp increase of the risk zones. It is generally considered that the maximum angle of building zones, whatever the nature of the substratum, must be lower than 16%. In fact, from 1953 to 2010 the annual surface building rate of augmentation in deeper slopes (>15%) was around 2.5 km<sup>2</sup>. The goal of such an approach is to provide the critical data that allow us proposing an extrapolation of the urban expansion coming.

**Dynamics of land use and your interference in morphohydrographic system in aera of limestone mining: a case study in the inland of Sao Paulo, Brazil.**

*PASCHOAL L.G.(1), CUNHA C.M.L.(2)*

*(1) Universidade Estadual Paulista, RIO CLARO, BRAZIL ; (2) Universidade Estadual Paulista, RIO CLARO - SÃO PAULO, BRAZIL*

Activities of open pit mining are responsible for major changes in the landscape and promote the emergence of morphologies of anthropogenic character. In the Brazilian context, approximately 73% of the mines are located in the Southeast and South. Of this total, 90% are related to the extraction of the main non-metallic minerals used by industry and construction segment: limestone, clay, gravel and sand. With the objective of identifying and analysing changes to land use imposed on dynamic morphohydrographic, through human actions linked to mining activity, was selected as the study area watersheds Córrego Marroti and Córrego Gonçalves. Together these basins totaling 9.6 km<sup>2</sup> within the state of São Paulo - Brazil, and present a broad interfluvial mischaracterized by the activity of exploitation of limestone. Mappings were performed of the land use and geomorphological features of the scenarios of 1962 and 2010, in scale 1:10.000. The mappings have identified an increase in the area of plots intended for mining activity, from 5,83% increased to occupy 25,83% of watersheds in the respective period. On this land use, it was possible to identify and quantify morphologies of anthropogenic origin in the landscape, such as the existence of levels generated in open pit mine, from 4,16 km in 1962, passed to total 34,66 km in 2010. The exploitation of limestone below the groundwater level gave rise to artificial dams, quantified by 0,04 km<sup>2</sup> in 2010. The mappings allowed to identify that mining activities occurred near the headwaters and the river beds, causing changes in its course and the type of valley bottom. Thus, this type of analysis provides parameters for a diagnosis of the area, to be used during the development of programs related to environmental planning and management of natural resources in the area.

\*\*\*\*\*

**Integrated geomorphological study of the center of Moscow**

*LIKACHEVA E.(1), ANIKINA N.(2), VOLOBOY A.(3), CHESNOKOVA I.(4)*

*(1) Institute of Geography Russian Academy of Sciences, MOSCOW, RUSSIAN FEDERATION ; (2) Moscow State University, MOSCOW, RUSSIAN FEDERATION ; (3) Moscow State University, MOSCOW, RUSSIAN FEDERATION ; (4) Institute of Water Problems Russian Academy of Sciences, MOSCOW, RUSSIAN FEDERATION*

On the territory of the megacity, which is used extensively not only the ground, but the underground space, and the depth of the impact on the geological environment is measured by many tens of meters, research of paleorelief is very importance. Paleorelief study is an obligatory stage of complex geomorphological assessment of the urban area.

On the territory of Moscow there are 2 major systems paleovalleys formed in Latecarbonic-Jurassic and Paleogene-Quaternary continental stages of the area. For the first time their presence was established in the 30th years of XX century. In the present relief in general, there is the influence of paleorelief: unchanged ratio of river valleys and interfluvial, the direction of flow. With paleovalleys mainly preglacial, related to many negative phenomena happening in the city, such as holes, subsidence, karst-suffusion processes. In addition, they are associated with areas of erosion of Jurassic impermeable clay and high water saturation zones in areas combining several aquifers.

Separately, it should be said about technocoined valleys, i.e. modern river valleys, channels which in the last few centuries, enclosed in a collector or covered with man-made deposits. They are pretty common occurrence in the central part of the city of Moscow, where so much of the converted river network (Neglinnaya, Presnya etc.). Mottled composition, unsorted and unconsolidated technogenic soil filling the valley determines a significant imbalance of relief. Therefore, there is a maximum intensity of modern geological processes. They confined the failed-sagging phenomenon, quicksand, high conductivity seismic area deformation of buildings and communications, etc.

Integrated geomorphological studies in the city included the assessment of the sustainability of the natural and modified in the course of urban development. Particular attention was paid to the attendant exodynamic processes, including man-made geophysical and hydrogeological field.

### Land use change in a Mediterranean catchment: implications for soil erosion

ROY H.(1), FOX D.M.(2), EMSELLEM K.(2)

(1) UMR 7300 ESPACE CNRS, Universit\_ de Nice Sophia Antipolis, NICE, FRANCE ; (2) UMR 7300 ESPACE CNRS, Universit\_ de Nice Sophia Antipolis, NICE, FRANCE

The Mediterranean landscape has changed greatly since 1950. Changes in vineyard area have major repercussions on soil erosion. Erosion impoverishes the soil and contributes to sedimentation in channels. The study objective was to analyze land use changes from 1950 to 2008 and evaluate their implications for soil erosion.

The catchment of 235 km<sup>2</sup> is situated in SE France. Air photos (1950, 1982, and 2008) were digitized to produce land cover maps with 4 categories: forest, vineyards, grassed land, and built areas. Initial resolution was changed from 0.5 m to 1 m to facilitate digitization. These data were complemented by a 25 m DEM and field observations.

Vineyard depletion was important for the catchment. About 2487 ha were vineyards in 1950; this decreased to 2128 ha (-359 ha) in 1982. Vineyards decreased further to 1641 ha (-487 ha) in 2008. Total loss was 846 ha in 1950-2008. Swapping was most important with grassed areas: vineyards lost 388 ha to grass and gained 169 ha during 1950-1982. Values reach 430 ha and 133 ha, respectively, during 1982-2008. Vineyards also lost 141 ha and 175 ha to built area during 1950-1982 and 1982-2008, respectively. Built area was 47 ha in 1950 and increased to 291 ha in 1982; it reached 709 ha in 2008, more than twice the area in 1982. Exchanges between vineyards and forest were roughly equal at about 650 ha in 1950-2008.

Slope and surface area of vineyards are major factors influencing soil erosion in the study area. Urbanization in the plain shifted some vineyards to foothills: increases in 1950-2008 in mean (6% to 8%) and median (4% to 6%) field slopes were observed. Values were calculated from the DEM, but observations showed that conversion of forest to vineyards on foothills was accompanied by terracing, so actual slopes are lower than calculated values. Surface area of vineyards decreased by 34% in 1950-2008, suggesting erosion probably decreased substantially.

\*\*\*\*\*

### Human impact on runoff forming and gully development in the Bug River valley side (E Poland)

GODLEWSKA A., RODZIK J., TERPILOWSKI S.

*Maria Curie-Sklodowska University in Lublin, Department of Geoecology and Palaeogeography, LUBLIN, POLAND*

In this paper the authors present the development of a modern gully, which cuts a sandy side of the Bug River valley in eastern Poland. The gully developed along the ground road separating plough fields from the "Szwajcaria Podlaska" nature reserve. The change of transversal pattern of fields into downslope one, which was made in 1972 in order to easier reaching the fields, contributed to the gully development. However, the formation of a new runoff system with flow concentration along the ground road lasted 30 years. In 2002 several factors occurred, which triggered a rapid development of the gully: heavy rainfall resulting in a sudden runoff from the largest field under potato cultivation on the ground road. The gully formed in this way was 75 m long and to 10 m deep.

Then the gully has developed by the formation of branches along balks and furrows separating individual fields. Its development has been monitored since the beginning -geomorphological survey and geodetic measurements of the whole form were made after each great change. The greatest changes occurred in the years 2004-2009 when the gully volume increased by about 30%.

Despite the gully development, the mode of land use has not been changed. The downslope fields are brought under cereals and potatoes. The road, over and over again destroyed by the gully, has been often moved at the expense of plough fields. Erosion can be considerably limited by a return to the former, transversal pattern of fields but it would demand an agreement between several land owners.

## **Changes in trends of development of microtopography: effects of oil exploration and production in NorPatagonia, Argentina**

*CIANCIO M.E.(1), TCHILINGUIRIAN P.(2), ZULETA G.A.(3)*

*(1) Dept. of Ecology & Environmental Sc., CEBBAD, Maimónides University, CIUDAD AUTÓNOMA DE BUENOS AIRES, ARGENTINA ; (2) Dept. of Ecology & Environmental Sc., CEBBAD, Maimónides University - CONICET & Dept. of Geology, FCEN, Buenos Aires University, CIUDAD AUTÓNOMA DE BUENOS AIRES, ARGENTINA ; (3) Dept. of Ecology & Environmental Sc., CEBBAD, Maimónides University - Faculty of Engineering, National University of Lomas de Zamora, BUENOS AIRES, ARGENTINA*

Oil exploration and production (E&P) create disturbances that may affect the geomorphological dynamic of the landscape. In particular, the construction of oil wells and seismic lines has an profound impact on soils and microtopography patterns. Regional geomorphological dynamics in NorPatagonia are controlled by ephemeral rivers associated to alluvial fans and playa lake deposits ("barreales"). Wind is involved in the transportation and deposition of sand and nutrients, which accumulate around vegetation and generate mounds or nebkhas. In order to evaluate the changes in trends of development of microtopography we compared the characteristics of mounds located inside 73 well locations with those in nearby natural areas (control sites). We performed a stratified random sampling, according to the geomorphological units at the local scale in the study area. We measured height (H), length (l) and width (w) of mounds, and calculated the horizontal component (L). We observed that H increases with the increase in L across all landforms (positive trend or growing phase) until a maximum H (equilibrium phase). From this value on, we detected a negative trend (degrading phase) as H decreases with an increase in L. Finally, there was an increase in the dispersion of data in both equilibrium and degrading phases, which could be explained by changes in geomorphologic dynamics within the oil wells. These results contribute to explain ecosystem regeneration and threshold variability during the post-disturbance process.

\*\*\*\*\*

## **Transformation of Earth's surface by humans**

*MARTÍN DUQUE J.F.(1), HOOKE R.L.(2), PEDRAZA J.(3)*

*(1) Department of Geodynamics and Geosciences Institute (CSIC, UCM), MADRID, SPAIN ; (2) School of Earth and Climate Sciences and Climate Change Institute, ORONO, MAINE, UNITED STATES ; (3) Department of Geodynamics, Complutense University, MADRID, SPAIN*

Earth is moved and the landscape modified, commonly degraded, by many human activities. Mining, infrastructure expansion and urban development are obvious ones. Plowing moves huge amounts of earth and leads to accelerated erosion. Grazing and logging also increase erosion. Much of the eroded sediment ends up as colluvium on hillslopes and as alluvium in floodplains, thus subtly altering the shape of the land. The rest is carried away by streams and rivers.

As of ~2007, human activities had altered the shape of ~53% of Earth's surface (Hooke et al., 2012). Most of these activities also had indirect effects well beyond the area directly affected, so the full impact of land transformation was much larger than 53%. Both the direct and the indirect impacts compromise ecosystem services that are essential for human survival, some of which are irreplaceable. Thus, these changes may be the most significant component of Global Change for decades to come.

Continued degradation of agricultural land and expansion of urban land at the expense of prime agricultural land, together with our continuing disruption of crucial ecosystem services, are likely to limit Earth's ability to provide an acceptable standard of living for even current populations. Indeed, we already appear to be in a state of overshoot. Overshoot is a situation in which a population exceeds the carrying capacity of the environment and, after a delay during which a storehouse of resources is consumed faster than they are replaced, the population crashes. This long-term sustainability issue is more serious than, but exacerbated by, climate change.

To restore sustainability we can: 1) reduce demand; 2) develop technological solutions; and 3) adopt measures that would first slow population growth and then reverse it. The first two are unlikely to solve the problem alone.

Reference: Hooke, R.LeB., Martín-Duque, J.F., and Pedraza, J. 2012. Land transformation by humans. *GSA Today*, 22(12): 4-10.

### **Suburbanization of the village Cernosice depending on the geomorphology of the terrain and transport services**

NEUBERGOVA K., HYKS O.

*CTU in Prague Faculty of Transportation Sciences, PRAGUE, CZECH REPUBLIC*

Geomorphology is one of the determining factors in the design of transport routes, important also for the further development of the area. This contribution aims at outlining the impact of geomorphology on suburbanization and transport service. The issue is first described theoretically and then demonstrated on a model locality, the village Cernosice located nearby of Prague. This village lies in the valley along the river and on the adjoining slopes. Its formation was closely related to the historic journey from Prague to the castle Karlstejn, the seat of Czech kings. At the beginning of this part of the paper, the historical context of the geomorphology, transport and community development is mentioned.

Till the second half of the 19<sup>th</sup> century, the character of the settlement was solely agricultural. Then the developing Czech upper middle class started to build summer houses along the stream, near the ford crossing the river. After the World War I, a building boom erupted with greater intensity, the character of the original agricultural community was completely changed and Cernosice became one of the most famous villa and cottage satellites of the former Czechoslovak Republic. The houses were built not only along the railway line, following the river, but a completely new residential area comprising one hundred new buildings grew up in a greater distance, thus depending on the road transport.

The second part of the contribution concerns the recent situation in this village, especially the new wave of the residential suburbanization, which began in the 1990's. The construction of family houses and apartments runs so far, bringing problems of various kinds to the municipality.

The contribution brings the detailed description of each development period, accompanied by clear maps and pictures. In the conclusion, generalized facts are detected and possible solutions of the current situation, typical also for many other localities around greater cities, are discussed.

\*\*\*\*\*

### **The "Tanger Med" harbor complex: impacts of its construction on its landslide prone hinterland (Rif Mountains, Morocco)**

PATEAU M.(1), FORT M.(1), BEN MOUSSA A.(2)

*(1) Université Paris Diderot, Sorbonne Paris Cité, PRODIG UMR 8586, 75013 PARIS, FRANCE ; (2) Université Abdelmalek Essaâdi, Faculté des Sciences, Département de Géologie, BP 2121 93000 TETOUAN, MOROCCO*

Located about 25 kilometers east from the city of Tangier, the "Tanger Med" complex is one of the largest Mediterranean harbors at the crossroads of Europe and Africa (the Strait of Gibraltar): it has three harbors, logistic and industrial free zones as well as motorway and railway networks linked to the capital town Rabat.

Its hinterland is a landslide prone area. It encompasses a zone where flysch bedrock predominates. The climate is particularly aggressive (drought period alternating with severe stormy rains) and favours both landsliding and gullying.

This work is based on a study of changes in land use over the past decade by using diachronic sets of satellite images and aerial photographs, fieldwork inventory and interviews. We show that the "Tanger Med" construction has highly modified landscapes, the way of life of country people and the intensity of geomorphologic dynamics. Numerous examples are pointed out: (i) roads built on unstable embankments; (ii) slopes excavation modifying water flows hence creating water retention with potential saturation (exceeding plasticity limits); (iii) uncontrolled drain favoring gullies. (iv) Repeated passages of large trucks, carrying materials from the quarries to the harbor, induce vibrations that can trigger landslides and earth flows during winter when soils are saturated. (v) Relocation of expropriated populations in naturally unstable areas makes them even more in danger than in their former settlements... Collectively, these developments result in an increase of landslide hazards and population vulnerability in areas with high economic potential.

## **Environmental and Social changes in the southern Balkans from the Neolithic: questions and methods of investigation**

LESPEZ L.(1), GLAIS A.(1), LOPEZ-SAEZ A.(2), LE DREZEN Y.(3), TSIRTSONI Z.(4), DARCQUE P.(4)

(1) Geophen-LETG Caen-UMR 6554 CNRS, UCBN, CAEN, FRANCE ; (2) CSIC, MADRID, SPAIN ; (3) UMR PRODIG 8586 CNRS Université de Paris 1, PARIS, FRANCE ; (4) ARSCAN - UMR 7041 CNRS, NANTERRE, FRANCE

Research on the Holocene environment in Greece compares indicators of geomorphological and palaeoecological changes. It gives evidence of both climatic, particularly Rapid Climatic Change events, and anthropogenic changes. Nevertheless, the cultural changes caused by environmental changes are more often inferred from the co-occurrence of the different changes than proved by the observation of the environmental change and their real consequences for the society at the local scale. To assess the possibility of socio-economical crises triggered by environmental changes, we need accurate appraisal of climate change and its consequences on hydrosystems and biosphere at different time scales. Furthermore, because human populations can react at local to regional or supra-regional scales, investigations must be conducted at different spatial levels in order to assess environmental changes from inhabited areas to the broader cultural group scale. This paper presents geoarchaeological investigation conducted in Eastern Macedonia (Greece) in order to understand the magnitude of the perturbation and evaluate possible tipping points. Palaeoenvironmental research (fluvial system, vegetation) are conducted from local (small watershed, pond) to regional scales in order to understand the triggers (natural and induced by human activities) and consequences of the environmental changes from local living space to the regional cultural areas. To understand the adaptation capabilities of societies in relation with their technical control and practices, they are compared with the archaeological data available locally (site of Dikili Tash). The first results covering the last 10 millennia give indices on the role of the climatic oscillations in local environmental changes but the consequences of these changes seems to have been limited for the Neolithic societies.

\*\*\*\*\*

## **Emptied beaches : example from Lebanon**

LE COEUR C.(1), LE COEUR C.(1), FEISS-JEHEL C.(2)

(1) University of Paris 1, PARIS, FRANCE ; (2) Ecole pratique des hautes Etudes, DINARD, FRANCE

Sand removal from beaches results in the retreat of large coastal spits. In the case of cove beaches, the already restricted sediment stock cannot self-regenerate.

Naqoura cove, located in south Lebanon, offers evidence of a completely sand depleted beach. In this area, located not far from the southern border, the coast has not suffered from rapid urbanization. However it has suffered from extensive and uncontrolled sand and gravel removal for more than 70 years. A railway track built along the shore in the 1940<sup>s</sup>, removed much gravel from the strand as ballast. Then illegal extractions of sand for building purposes completely emptied the small cove of Minat el ramul. Further north, the Tyr sand spit also suffered from uncontrolled extractions on the beach and dune banks.

Sedimentary destabilisation is manifested on one hand in an outline of small cliff on the pebble beach north of Naqoura pier and, on the other, in the exposed beach rock banks in the Minat el Ramul cove, and their partial demolition by winter swell.

Natural refill from river input is quite poor due to removal of water to feed large irrigation schemes. Winter floods can deliver loamy material (such as suspended load from soil erosion) that spreads into the sea and stony material can feed pebble spits. Nonetheless sandy input from water depleted rivers is restricted and cannot accumulate on the shore. In fact, beach sand feeding is only provided from gale wave erosion into a raised beach deposit (+1m) or indeed by shell debris whose production increased when dynamite fishing was stopped.

Other examples can be seen in Southern France, where ancient sand removal emptied some small coves, and induced remobilization of eemian (?) deposits from the upper parts of the beach.

### Relationship between forest use for charcoal production and landform units

SAIJO K.(1), MATSUBAYASHI T.(2)

(1) Miyagi University of Education, SENDAI, JAPAN ; (2) Tohoku Fukushi University, SENDAI, JAPAN

Charcoal production had been a major traditional use of forest in the hilly areas of Japan before the late 1950's when common fuel drastically changed from firewood or charcoal to fossil fuel. Before that, forests for charcoal production had been cleared repeatedly, mostly every 15 to 30 years. It is certain, therefore, that the forest use for charcoal production had played an important role of hill landscape development, for example the formation of secondary forest. The purpose of this study is pointing out the characteristics of the past charcoal production in hilly areas from a geomorphological viewpoint, for evaluating the effects of forest resource use as fuel on hill landscape. Although charcoal production in Japan ceased about half a century ago, we can still recognize many remnants of past charcoal production in the hills, especially abandoned charcoal producing kilns as a kind of characteristic micro-landform. The distribution of the abandoned charcoal producing kilns in several areas in Japan shows that most of the kilns, made of mud and stone collected nearby, were located on concave breaks of slope. These concave breaks of slope correspond with the boundary between the valley bottom and hillside, landslide scarp and depression, landslide deposits and depression etc. Kiln entrances are facing downhill without exception. These characteristics indicate the existence of following close relationship between working processes of charcoal production and landform units. First, it is important that the steeper slope is located on the upside of the kiln, because fallen trees can be easily gathered to the kiln by sliding. On the other hand, works for burning trees and taking out burnt charcoal from the kiln require a flat place on the downside. As a result, the kilns are selectively made on concave breaks of slope which satisfy various requirements from working processes of charcoal production. Such uses of slope should have affected the hill landscape formation.

\*\*\*\*\*

### The anthropogenic influence on vegetation and soil properties in Gorce Mts. (Polish Carpathians) during last 50 years

BUČALA A.(1), BUDEK A.(1), KOZAK M.(2)

(1) Institute of Geography PAS, KRAKOW, POLAND ; (2) Institute of Botany UJ, KRAKOW, POLAND

In Polish Carpathian socioeconomic transformations in last 50 years, especially after the 1989 year, have influence on environment components. During this period the human activity were recorded in vegetation changes and soil properties. The study was conducted in two small catchments Jaszczce and Jamne in the Gorce Mountains (Polish Carpathians). The catchment of the Jaszczce stream is a narrow valley with very steep slopes while Jamne is wider with gentler slopes. The slopes of Jaszczce valley in the upper parts are covered by forests, meadows and pastures, in the lower dominate agricultural lands. The valley of Jamne is mainly deforested and arable lands here extend up to 1100 m a.s.l. In this region Brown soil (Dystrohrept) occur, developed on loamy and sandy parent material. In slope catenas, the thickness of soil profiles increased from 1.0 m to 1.6 m in lower part of slope. Land use changes led to alteration of soil properties, especially soil structure. The studies of vegetation were compared with the phytosociological map made in the 1960's. During the last 50 years significant part of segetal communities were replaced by the floristically very poor plots of fallow communities. While on mowed for a long time and regularly fertilized sites, fresh meadows developed. Formerly widespread in the lower altitudes patches of floristically rich dry pastures with heather almost completely disappeared. They changed into dense thickets as a result of secondary succession process, caused by cessation of management. Land use changes between 1954 and 2009 years lead to decreasing of the arable land area by about 90%, and parallel increasing of forest areas.

Cessation of tillage (change of arable land to grassland) led to changes in soil properties and plant communities.

The project is funded by the National Science Center (NN 306 659 940).

## **Anthropogenic genesis and age of the Lower Bavarian sand dune landscape around Abensberg and Siegenburg**

VOELKEL J.

*Technische Universität München, Professur für Geomorphologie, FREISING-WEIHENSTEPHAN, GERMANY*

The Lower Bavarian sand dune landscape in the Abensberg/Siegenburg area (Lower Bavaria) originated in an area where the Late Tertiary deltaic sediments of the Ur-Naab are overlain by a complex system of Pleistocene Danube gravels as well as those of the Abens river. The sand dunes and aeolian sands occurring there have been known for a long time, and their mostly glacial age origin can be stratigraphically inferred. During the Holocene there were repeated phases of aeolian remobilisation, each of them related to an overexploitation of the carrying capacity of the landscape. It can be excluded that remobilisation was caused by changing climate. Today the dune fields, up to 10 m high, have partly been set aside as nature reserves, or are used for agriculture and forestry. Based on geophysical prospection, at four selected dune chains and their surroundings a distinction has been made of the underlying aeolian sand sheet, the dune cores, and younger aeolian accumulation bodies and sedimentologically characterised. The dune sands have been dated by OSL, macro-remains and the humose material of fossilised soil horizons by radiocarbon. Forest clearing of much of the landscape began during the Neolithic period, related to the operation of a flintstone mine at Arnhofen. Two significant phases of sand dune growth have been dated to the Bronze Age and the High Middle Ages, largely determining the aspect of the present dune landscape. There is evidence of younger remobilisation phases up to the 1950s. With reduced settlement pressure, each time the dunes landscape returned to a phase of morphodynamic stabilisation, without any evidence of directed reforestation or dune stabilisation measures of the sands. Today, under the name of Dürnbuch Forest, the former hunting preserve of the Wittelsbach noble family, this dune landscape is one of the largest contiguous forest areas of Bavaria. (DFG funded VO 585/13), Völkel et al. (2012): *Annals of Geomorphology* 55,4, 515-536.

\*\*\*\*\*

## **Peri-urban growth in Mexico-City. A local evaluation of the landscape damage due to a massive house production**

GARCÉS-ESCAMILLA I.(1), PARROT J.F.(2), RAMÍREZ-NÚÑEZ C.(3)

*(1) Institut des Hautes Etudes de l'Amerique Latine. IHEAL, Paris 3, PARIS, FRANCE ; (2) LAGE, Instituto de Geografia, UNAM , Mexico, MEXICO D.F., MEXICO ; (3) Posgrado en Ciencias de la Tierra, UNAM, Mexico, MEXICO D.F., MEXICO*

The increasing phenomenon of massive house production since 2000 in the peri-urban area of Mexico City has led to a quickly urbanization of the former lacustrine zone and the piedmont transition zone. The old towns and now municipalities, at the east and northeast of Mexico City are the new centers of gravity to which the city is growing around. An example of that is the Municipality of Tecámac, located in the northeast of Mexico City, where more than 71,000 houses of social interest has been constructed and 4,000 more are planning to build. New parameters based on satellite image treatments and Digital Elevation Models were developed in order to study the fragmentation intensity of the build areas as well as the attraction level between these urban areas. Taking into account the real weight of these parameters, such a model brings to an objective estimation of the urban invasion ratio through the piedmont and lacustrine remaining regions. We assume that such an approach may allow measuring the impact of the eventual damage caused to the environment and defining whether an urban policy exists or not in relation with the capital of investment.

### **Holocene Tufa changes as response to human impact on landscape (High Ebro Basin. Northern Spain)**

GONZALEZ-AMUCHASTEGUI M.J.(1), SERRANO E.(2)

(1) University of the Basque Country, VITORIA-GASTEIZ, SPAIN ; (2) Universidad de Valladolid, VALLADOLID, SPAIN

Tufa buildups of the high Ebro basin river are geomorphic elements of high environmental interest. In this area geomorphic evolution has been led by the incision of the Ebro river, the intense karstification and the tufa filling of the main valleys. The High Ebro River basin is located in Southern slope of the Cantabrian Range in Northern Spain; it is a folded calcareous cover defining a structural relief drained by the Ebro River.

The aim of the study is to establish the different tufa growing and destructive stages during the Holocene and differentiate between natural and human-induced environmental changes. Seventeen Holocene and present-day tufas have been studied. Fieldwork, geomorphological mapping, analysis of morpho-sedimentary units, and fifteen Uranium/Thorium and radiocarbon dating of tufa deposits have been made.

The different techniques applied have allowed to establish Holocene geomorphic evolution of High Ebro river, the chronology of tufa deposits and the incidence of human activity on the geomorphic evolution is considered. Five Quaternary tufa sedimentation stages have been established: the first three ones correspond to Middle-Late Pleistocene, and the others to the Holocene age. During this time, karst processes made a very intense work on calcareous places of Upper Ebro Basin and tufa sedimentation rates in the valleys were also high. During the last six millennia in the high Ebro basin, coinciding with first human settlement, expressed by frequent megaliths in the study area, tufa sedimentation stopped and the down cutting processes on valley deposits started on. The erosion process on tufa buildings may be caused both human activity and complex responses of the natural system.

\*\*\*\*\*

### **Transformation of relief in the loess areas of small denivelation under agricultural land use on the basis of soil profiles analysis (Lublin Upland, Poland)**

RODZIK J.(1), REJMAN J.(2), PALUSZEK J.(3)

(1) Maria Curie-Skłodowska University, LUBLIN, POLAND ; (2) Institute of Agrophysics, Polish Academy of Sciences, LUBLIN, POLAND ; (3) Institute of Soil Science, Engineering and Environmental Management, University of Life Sciences, LUBLIN, POLAND

The studies comprise an analysis and comparison of present and primary relief, i.e. before the start of agricultural land use. The primary relief was developed on the basis of reconstruction of soil profiles of brown-grey soils (Haplic Luvisols). Structure of undisturbed soil cores was studied in 480 sampling points in the catchment of dry basin of relatively low denivelations (max. up to 17 m) and the area of 5.6 ha (Lublin Upland, E Poland). Primary relief was reconstructed in each sampling point by comparison of soil structure in the point to the thickness of non-eroded soil in the nearest neighbourhood of similar topography.

The study area has remained under cultivation for about 200 years. The agricultural land use of the area resulted in considerable transformation of relief due to erosion of soils. Within convex part of relief, a significant reduction of soil profile was observed (max. 1.5 m), whereas on concave slopes the soil profiles were overbuilt by accumulated soil material (max. 1.75 m). Maximum denivelation decreased by 10% in the whole basin, and inclination of slopes decreased considerably. The area of inclination  $\leq 4^\circ$  increased by 50%, whereas the area of inclination  $\geq 5^\circ$  decreased twofold. In the top part area of the catchment, denivelation decreased even by about 100%, and soil erosion resulted in disappearance of small forms of relief as closed depressions and hillocks.

## Quantifying anthropogeomorphological transformation by using the concept of "hemeromorphy" a case study from Hungary

NOVÁK T.J., INCZE J., RÓZSA P.

University of Debrecen, DEBRECEN, HUNGARY

Effectiveness of anthropogenic and natural geomorphological processes could be expressed by volume or mass of dislocated material per area and time unit, and on this basis the ratio of anthropogeomorphological transformation ( $R_{ag}$ ) can be calculated as follows:

$$R_{ag} = V_a / V_n$$

where  $V_a$  = amount of dislocated material by human activities;  $V_n$  = amount of dislocated material by natural processes (both in tons or  $m^3 \cdot ha^{-1} \cdot yr^{-1}$ ). This approach allows quantifying the degree of anthropogeomorphological transformation in spatial units. However, it meets the requirement to be independent from the volume, quality and intensity of the natural and anthropogenic land forming processes, and allows the comparison of landscapes with completely different conditions. Lower  $R_{ag}$  values characterize landscapes of low moderate anthropogeomorphological transformation, while high values indicate the totally artificial surfaces, where the amount of anthropogenic dislocated material is much higher than that of natural transportation.

On the analogy of the 'hemeroby' concept, which expresses the degree of human influence on ecosystems, this approach could be termed 'hemeromorphy' which is suitable to express the degree of human influence on geomorphosystems (complexes of land forming processes) independent from their geomorphic process combinations, relief and climate. Smallest landscape units, which are homogeneous according to their hemeromorphy, could be referred to as hemeromorphotops (*ήμερος*=domesticated, educated, *μορφή*=form, *τοπος*=place, locality).

The concept itself and an application after estimating natural and anthropogenic material fluxes in the case of Hungarian landscapes will be presented, where  $R_{ag}$  values ranging from  $R_{ag} < 10$ , in the case of agricultural, hilly areas, to  $R_{ag} > 10\ 000$  in the case of quarries.

\*\*\*\*\*

## The effect of the geomorphology of terrain on transport development in the context of suburbanization

STURMOVA I.(1), KOCARKOVA D.(2)

(1) Faculty of Transportation Sciences, CTU, PRAGUE, CZECH REPUBLIC ; (2) Faculty of Transportation Sciences, CTU, PRAGUE, CZECH REPUBLIC

The proposed article will address the suitability of different means of transport for servicing suburbanized area depending on the geomorphology of the terrain. Suburbanization is a phenomenon when housing and economic activities are moved beyond the border of the core city. Most often the suburbanization processes are seen in the vicinity of large cities where afterwards the daily commuting of people to work in the core city occurs. This servicing of suburban areas is usually made by road or rail transport, or a combination of both systems. The selection of suitable transport system, respectively design parameters of each system, is limited by the shape of Earth's surface. Especially the design of railway tracks is more complicated in terms of finding an appropriate lead according to terrain. The geomorphology of terrain influenced the creation of old trade routes from historical perspective and thus the foundation of settlement. By comparing historical and current maps we can observe the similarity between the old trade routes and today's major road network. In the conclusion of the article the examples of suburban development in an area around the capital city of the Czech Republic will be presented.

**Anthropogenic geomorphology: Changes in the Hydrographic basins of river Jequitinhonha lower course main channel drainage pattern and delta**

*SILVA V.(1), PEREZ FILHO A.(2), GIGLIOTTI M.D.S.(2), SANTOS P.S.(3)*

*(1) Universidade Federal Fluminense - UFF, CAMPOS DOS GOYTACAZES, BRAZIL ; (2) Universidade Estadual de Campinas - UNICAMP, CAMPINAS, BRAZIL ; (3) Universidade Federal da Bahia - UFBA, BARREIRAS, BRAZIL*

The anthropogenic changes of the morphology of the main river channel and delta allowed to interpret the diverse dynamics to which the river Jequitinhonha system was submitted, in its lower course. The drainage pattern characterization, identification and analysis in the main channel and Delta were possible investigating the parameters: sinuosity index, channel morphology, channel neighborhood migration, optically stimulated luminescence dating, granulometric, biological and chromatic description of the sediments in the outfall and Delta. The results showed the identification of the rising systemic complexity due to the anthropogenic intervention in the hydrographic system. So, it is suggested that the delta morphology may have been modified in order to the river to establish a new geomorphological balance, to respond to the construction of the barrage and main channel rectification. It is suggested that with time the form of the delta will be altered in the way it is happening now, abandoning its bisected configuration and transforming in a single channel directed to the left margin, with the disappearance of the channel located in its right margin.

Keys-Words: Anthropogenic geomorphology; controlled system, river channel; delta

\*\*\*\*\*

**Urban geomorphology of Kolkata megacity: an interpretation of anthropocene landscape of humid tropics**

*SATPATIL*

*Department of Geography, University of Calcutta, KOLKATA, INDIA*

In India, like many other developing countries of the (humid) tropics, population base as well as growth is still very high; and most of the increase of population has been taking place in the urban areas mainly due to migration. The Kolkata Metropolitan Area (KMA) is one of the largest urban agglomerations in India, and it stands over the two levees of the River Hooghly. The KMA includes more than 15 million population (as in 2011) in 3 municipal corporations, 38 municipalities and 24 panchayat samities spreading over an area of 1850 square km in 6 districts, namely Nadia, North 24 Parganas, South 24 Parganas, Kolkata, Howrah and Hooghly in West Bengal, an eastern province of India. In 1901-2001, the cumulative growth of population within the KMA was about 381 percent, which was more than twice that of the national average (190) of India.

The urban growths, in most of the occasions, are unsystematically expansive to accommodate the influx of population; and as a consequence, there is a continuous change in the urban infrastructures, like buildings, transportation networks, water supply, drainage, waste disposal systems, etc. These necessarily alter the hydrological, geomorphic and other environmental conditions of different locations. The post-liberal drive for urban renewal heavily affects the hydro-geomorphic settings. Very often a cyclic process operates within micro-scale urban environments to keep a metastatic balance with human intervention over the landscape.

The main objectives of this paper are to identify and interpret the nature of human intervention to the natural forms of land in the KMA area, and to establish the relationship between urban renewal and hydro-geomorphic conditions under different scales of interactions. The methodology consists of close observations, some measurements, consultation of various existing maps and literatures, interviews and discussions with relevant persons and groups.

## Detection of mining subsidence in the Ruhr district (Germany) using historic maps and DEMs

HARNISCHMACHER S.

Philipps-Universität Marburg, MARBURG, GERMANY

For the first time, an area-wide and large-scale calculation of differences in elevation between 1892 and today was conducted for the Ruhr District (Germany), a metropolitan region influenced by subsidence due to deep-seam coal mining starting in the middle of the 19th century. Elevation data on historical maps from 1892 was digitised with the help of a Geographic Information System and the interpolated historical surface was intersected with a current Digital Elevation Model, in order to calculate the differences in elevation. As a result, the highest values of elevation differences, amounting to more than 25 m, were observed within the coalfields of the former coal mine "Zollverein" which is distinguished for its long mining history and its World Heritage status. Two examples from the cities of Essen and Dortmund analysed in detail reveal that not only depressions but also elevation features are affected by mining subsidence. These kinds of surface transformations are not visible in the field without a comparison of digital topographical models. The change detections allow for a correlation with mining activities, because most of the mining subsidence areas are located next to a former coal mine. Furthermore, tectonic features of the Carboniferous strata are reflected by the location of subsidence areas, since they are located along synclines with a gentle dip of coal seams or confined by the location of predominant faults. The average amount of a surface lowering was calculated for all maps digitised and analysed, resulting in a maximum value of 5.16 m for the map of Gelsenkirchen within the central Ruhr District with a total area of 128.5 km<sup>2</sup>. A comparison of single reliable elevation data, derived from surface levelling data of the land registry office, with the interpolated values from 1892 reveals an astonishing correlation with differences of not more than 1 m.

\*\*\*\*\*

## Conditions and stages of Holocene evolution of closed depressions in loess area reflected on soil-sediment sequences. A case study from Nałęczów Plateau (E Poland)

KOŁODYNSKA-GAWRYSIAK R.(1), MROCZEK P.(2), CHODOROWSKI J.(3), ZGLOBICKI W.(4), KIEBALA A.(4), PLAK A.(3), CHABUDZINSKI L.(5)

(1) Department of Geology and Lithosphere Protection, Maria Curie-Skłodowska University in Lublin, LUBLIN, POLAND ; (2) Department of Geoecology and Paleogeography, Maria Curie-Skłodowska University, LUBLIN, POLAND ; (3) Department of Soil Science and Soil Protection, Maria Curie-Skłodowska University, LUBLIN, POLAND ; (4) Department of Geology and Lithosphere Protection, Maria Curie-Skłodowska University, LUBLIN, POLAND ; (5) GIS Laboratory, Maria Curie-Skłodowska University, LUBLIN, POLAND

Closed depressions are a common landform in loess areas of Europe. Conducted studies pointed on their natural (cryogenic and piping processes) or anthropogenic origin. However, the number of information on origin of closed depressions is still very limited. About 1700 closed depressions were found on the Nałęczów Plateau, E Poland (area 493 km<sup>2</sup>). Majority of them concentrates on loess plateau tops (72 % objects). They are mostly oval in shape and 25-50 m in diameter (53% objects). Four closed depressions were chosen for detailed studies. They are located within agricultural land (3 sites) and afforested field (1 site). Examined closed depressions are filled up with soil-sediment sequences, which are 1-2 m in thickness. They consist of several layers of colluvial sediments, separated by fossil soils horizons. Research on morphometric features and soil-sediment sequences was performed. The soil-sediment sequences cover the Late Glacial-Holocene fossil soil horizon. It covers the original bottom of closed depression on loess *in situ*. The range of laboratory analysis included: physico-chemical, micromorphological, geochemical analysis and radiocarbon dating.

Four major stages of Holocene evolution of closed depressions were recognized. They occurred under changeable environmental conditions during the Holocene. Two stages are connected with stabilization of land surface by natural plants and soils development (the first: Late Glacial-Mesoholocene, the third: XI-XVII). In two remaining stages the filling of closed depression by colluvial sediments occurred (the second: Neolith-early Middle Ages, the fourth: modern times). Phases of colluvial sedimentation correlate clearly with colonization and agriculture development since Neolith to recent times, near closed depressions.

**Mine tailings dispersion and arsenic concentration. The San Antonio-El Triunfo district, Baja California Sur, Mexico**

*HERNANDEZ-CRUZ G.B.(1), PARROT J.F.(2), RAMIREZ-NUÑEZ C.(1)*

*(1) Posgrado en Ciencias de la Tierra, UNAM, MEXICO CITY, MEXICO ; (2) LAGE, Instituto de Geografía, UNAM, Mexico, MEXICO CITY, MEXICO*

In the southern part of the Baja California Peninsula, Mexico, the catchment area of San Antonio-El Triunfo registers a high concentration of arsenic. This concentration results either from the natural background values of the substratum that corresponds to a part of an oceanic crust or from the former mining activity. Nowadays, many old mine tailings are present in the study region and the dispersion of these residues would explain the observed local concentrations. A high resolution Digital Elevation Model is used to show the effect of torrential rainfall in this semiarid region. According to the simulations done, the removed material from the mine tailings arrives always to the highest arsenic concentration measured in the field.

\*\*\*\*\*

**Urban Runoff and Environmental Impact in a Mediterranean Climate Area, Ariel, Israel**

*INBAR M.(1), ANKER Y.(2)*

*(1) Department of Geography, University of Haifa, HAIFA, ISRAEL ; (2) R&D Regional Center, Shomron and Jordan Rift Valley, ARIEL, ISRAEL*

Urban impervious areas produce a large amount of water during rainy storms which may be an alternative water resource for municipal or regional environmental and recreational needs. Knowledge on the impact of urban development and patterns of building is critical to understanding the threats to the environments as well as the benefits of an expanding water resource for local infrastructure development

The city of Ariel is located in the Yarkon river watershed area, at an altitude of about 700m. The region is characterized by a developed karstic terrain. Rainfall annual average is 500mm. Several building patterns are found, from single houses to apartments blocks and public large buildings. The percent of impervious area ranges from 15% to 45% in the different sub-basins.

The main objective of the study is to find the runoff/rainfall relationship for a medium size town under different physiographic and urban patterns, to find the discharge peak flow concentration time and its relationship to the urban pattern of impervious area, the physiography of the area and the climatic characteristics of the rain storms. Another objective is to assess the urban water quality and to identify pollution sources.

An initial assessment shows that the potential storm water volume that may be harvested from the city of Ariel areas ranges between 80,000 m<sup>3</sup> to 500,000 m<sup>3</sup> over the course of an average year, depending on the contributing area, amount of precipitation and evaporation depth.

Chemical analysis of the runoff water showed that the quality of the water was good, and in general the urban runoff water may be used as a source for the enrichment of ground water, and for municipal use as well.

**Hydrological influence of an artificial channel on trees of *Picea abies* (L.) Karst. Along a tourist trail. The case of the "torrent-neuf" (Valais, Switzerland)**

IRENE B.(1), REYNARD E.(2), PELFINI M.(1)

(1) *Universita degli Studi di Milano, MILANO, ITALY* ; (2) *Université de Lausanne, LAUSANNE, SWITZERLAND*

A study on the interactions between an artificial channel used for irrigation and the surrounding natural environment, focusing especially on vegetation, are presented. The investigated site is a cultural trail recently developed in Valais (Switzerland) along the Torrent-Neuf, one of the *bisses* (irrigation channels) that have been used since Medieval times to move water resources from tributary valleys to irrigated land. The geomorphic processes inducing slope instability, along mountain sides where the channel had been built, justified the abandonment of the channel in 1934 opting for underground solutions for the water transport. As a consequence, long part of the channel was deviated during the time interval 1934-2005 when water was completely restored to flow into the channel and it was re-opened to public as tourist path equipped with informative panels about channel history and building techniques.

The Torrent-Neuf area is characterized by abundant vegetation among which *Picea abies* (L.) Karst. is dominant. Dendrochronology analysis has been conducted in order to highlight difference of behaviour in three main groups of trees located: i) in the stand but not along the channel; ii) along the portion of the channel temporarily closed; iii) along the undisturbed portion of the channel. In literature, some Authors highlighted a prolonged suffering of trees and a difficult recovery after stopping irrigation by artificial channel but herein no drastic divergences relatively among trees series have been individuated except for different growth rates. The rainfall regime may be probably sufficient to compensate for scarce water availability consequent to the deviation of the artificial channel.

The presence of an already developed tourist trail allows the possibility of proposing an integration of the data coming from scientific researches for highlighting the relation of channel building techniques with geomorphological processes, vegetation dynamics and climate.

\*\*\*\*\*

**Terracing slopes to make a living in the Darjeeling Hills**

SIL A.

*Bhairab Ganguly College, KOLKATA, INDIA*

Terracing the slopes is a common practice in the darjeeling Himalayas. The difficult terrain has poor accessibility in many places where the Gorkhas, the dominant racial group in the region have no other alternative means but to terrace the slopes in their indigenous method. Rice is the staple crop and practiced intensively in the Kalimpong subdivision of Darjeeling district, but the method of terracing sometimes invite landslides causing disaster to life and properties in many areas. Still unaware of the fact, this is the main source of living of the Gorkhas in most of the villages. But the Gorkhas of Rishov village of Ladam - Khasmahal mouza, with a little change in crop pattern, mainly cash crops have resisted this menace knowingly or unknowingly of the possible hazards. They form the focus of present study. this article deals with the socio-economic conditions of the Gorkhas in their present geomorphological settings, as a case study. Though they have well adapted it but socio-economically they still remain backward, despite much potential as human resource as an industrious race, nature's bounty with a temperate climate for altitudinal reasons, etc. Here problems like unemployment, child marriage, early motherhood etc, are still prevalent. This study aims at highlighting the problems, physical and socio-economic and to suggest some remedial measures for the socio-economic uplift of the people of the area concerned. If proper planning is done and implemented, their success in combating natural hazard may cite an example how changing crop pattern can help them keep away their poverty as well as landslide hazard of the region.

### **The effect of terrace abandonment on the restitution of the drainage network and soil erosion**

*RUIZ-FLAÑO P.(1), LANA-RENAULT N.(2), ORTIGOSA L.(2), GALILEA I.(2), LLORENTE J.A.(2), ARNÁEZ J.(2)*  
 (1) Department of Geography, University of Valladolid, VALLADOLID, SPAIN ; (2) Area of Physical Geography, University of La Rioja, LOGROÑO, SPAIN

Bench terraced areas are an essential part of the Mediterranean mountain landscapes. Terrace construction resulted in a complete transformation of the hillslopes to a series of flat sectors and almost vertical steps. This strategy, which involved a redistribution of soils and a re-organization of the drainage network, provided fertile soil over steep slopes, improved infiltration and controlled overland flow under conditions of intense rainstorms. During the XXth century, rural population declined and agricultural practices were abandoned. The maintenance and reconstruction of the terrace walls became therefore impossible and the system collapses. A small catchment was monitored in the Iberian Range (northern Spain) for studying the geomorphic evolution of the bench terrace abandonment. Wall collapse caused by small landslides affects most of the terraces, especially those located in the lower parts of concave hillslopes. Scars are frequently affected by gullying and livestock trampling. The authors investigate how, after fifty years of farm abandonment, the natural drainage network is re-established in such environment and what are the soil erosion consequences.

\*\*\*\*\*

### **Anthropogenic relief of urban areas as a factor of changes of lake landscapes**

KASHIRO M.

*Tomsk State University, TOMSK, RUSSIAN FEDERATION*

The relief of urban areas is exposed to considerable transformation. The relief has crucial importance for existence of landscapes and relief transformation influences all components of natural complexes. Water landscapes are in strong dependence a relief of a territory, and its can serve as a vivid example of interaction of natural and human components of an urbanized area. Anthropogenic transformation of a relief changes a complex of hydrological, hydrochemical and hydrobiological processes in water ecosystems, it causes chemical pollution of water reservoirs, increases the scales and rates of plant overgrowing, disrupts the ecological balance and self-regulation processes.

Lakes are representative of water landscapes and also city lakes have greater impact on the processes of urban areas development: form microclimate of riparian land, affect city construction processes, and attract a lot of those people who want to have a rest and relax.

12 lakes of a natural and anthropogenic origin in the city Tomsk (Russia) have been chosen to track anthropogenic influence on change of city water landscapes.

Genesis of city lakes hollows isn't connected with ancient geological and endogenous processes. Lake systems of the city Tomsk are modern, its arose after isolation of river terraces and interfluves in the quarter. Prevailing number of city lakes (about 90%) is in flood plain of the river Tom' and have the water-erosive genesis. A terrace and interfluves have no many lakes. About 7% of lakes is a result of human activity and 3% have eolian genesis. The morphometry of the city lakes depends on genesis of reservoirs.

Change of the city relief which more than 400 years proceed, led to increasing of exogenous processes. Run off and mud flow increase mechanical loading and chemical pollution of reservoirs (especially for lakes of flood plane) that leads to gradual reduction of lakes depth and their growth of water vegetation. As a result esthetic value of water objects is lost.

### **5 millennia of Mediterranean mountain disturbance: soil erosion and vegetation dynamics recorded in Lake Petit (2200 m, South-Western Alps)**

*BRISSET E.(1), MIRAMONT C.(2), GUITER F.(2), CARTIER R.(1), ANTHONY E.(3), POULENARD J.(4), DELHON C.(5), ARNAUD F.(4), MEUNIER J.D.(6), SYLVESTRE F.(6), PAILLES C.(3)*

*(1) CEREGE/IMBE Aix-Marseille University, AIX EN PROVENCE, FRANCE ; (2) IMBE - Aix-Marseille University, AIX EN PROVENCE, FRANCE ; (3) CEREGE - Aix-Marseille University, FRANCE, FRANCE ; (4) EDYTEM - Savoie University, CHAMBÉRY, FRANCE ; (5) CEPAM-CNRS, NICE, FRANCE ; (6) CEREGE-IRD, AIX EN PROVENCE, FRANCE*

Ancient human presence in the mountain landscapes of the Alps has been documented by archaeological and palaeoecological studies which show a change from gathering to pastoralism over the last 4 ka. Above 2000 m, landscapes have been exploited at least since the Bronze Age. Human activities rendered soils vulnerable to colluviation, increasing erodibility and erosivity. Most studies on long-term soil erosion have focused on gully and hillslope erosion especially at lower altitudes. In mountain areas, well-dated deposits are scarce. Lake sediments are therefore a valuable landscape archive because they record a broad range of proxies responding to changes in slope stability and vegetation cover.

We present high-resolution multiproxy interpretations of a cored profile from the Alpine Mediterranean Lake Petit covering the last 5 ka. Sedimentological, geochemical and botanical data from this core document weathering and erosion in relation to vegetation dynamics, climatic fluctuations and human activities. Lake Petit has recorded since 4770 cal. BP continuity of anthropogenic taxa identified by nitrate enrichment of Alpine grassland. Even though discrete, grazing activities were already extant at this time but did not lead to significant soil erosion. The first increase in anthropogenic taxa occurred at 3000 cal. BP, concomitant with an increase in Ericaceae and intensification of erosion. Soils, without tree protection and probably altered by domestic livestock, were frequently eroded. Four important detrital pulsations occurred synchronously with depletion in tree pollen, while pollen from anthropogenic-related taxa increased. Reported archaeological sites and mining activities also show the presence of Humans in the Lake Petit catchment at 1800 cal. BP and 500 cal. BP, respectively. Widespread deforestation occurred, probably to maintain Alpine pastures and to supply fuel for smelting, contributing to the continuity of anthropogenic landscape perturbation.

\*\*\*\*\*

### **Assessing the diversity of the hydro-geomorphological response of marginal territories in mediterranean mountain areas**

*LANA-RENAULT N.(1), GALILEA I.(1), LLORENTE J.Á.(1), NADAL-ROMERO E.(2), SERRANO-MUELA M.P.(3)*  
*(1) La Rioja University, LOGRONO, SPAIN ; (2) Zaragoza University, ZARAGOZA, SPAIN ; (3) Instituto Pirenaico de Ecología (CSIC), ZARAGOZA, SPAIN*

Historically, Mediterranean mountains have suffered intense human pressure, including deforestation, cultivation of steep slopes and construction of bench terraces. The decline of rural population during the 20th century and the abandonment of agricultural practices has resulted in a complex expansion of vegetation, with subsequent consequences on water resources, soil erosion, stream dynamics, and reservoir silting. The hydrological and geomorphological evolution of abandoned hillslopes is an extremely complex process affected by a variety of factors such as the time of abandonment, the type of fields (sloping fields or bench terraces) and the land management regimen following abandonment. Thus, most of the Mediterranean mountain areas are nowadays marginal territories with a high degree of uncertainty in terms of water availability, soil degradation and productivity. Research at the small catchment scale enables the understanding of the functioning of such environments and, ultimately, the prediction of the trends of water resources and soil erosion following farmland abandonment. Four experimental catchments were monitored in the central Spanish Pyrenees and the Iberian Range: a farmland abandoned catchment where sloping fields were previously cultivated, a catchment with abandoned bench terraces, a catchment afforested with pines in the 1960s and a densely forest-covered catchment. All catchments have similar lithology and size, allowing the comparison of their hydrological response against similar rainfall events. Results show the diversity of their hydro-geomorphological behaviour and highlight the need of effective and tailored policies for the management of marginal lands in the Mediterranean region.

### **Human impact in the Apennine area of the Municipality of Fiorano Modenese (Northern Italy)**

CASTALDINI D.(1), CORATZA P.(2), LIBERATOSCIOLI E.(2), TOSATTI G.(2)

(1) *Dipartimento di Scienze Chimiche e Geologiche, Università di Modena e Reggio Emilia, MODENA, ITALY ;*

(2) *Dipartimento di Scienza Chimiche e Geologiche, Università di Modena e Reggio Emilia, MODENA, ITALY*

Morphological, man-induced landscape changes, occurring from the mid-20th century to date in an area located in the western sector of the Modena Apennine margin, have been investigated. The study area has elevations ranging from about 100 to about 400 m a.s.l. From a lithological standpoint, only marine silt-clay soil types (Plio-Pleistocene in age) are exposed. The area belongs to the Municipality of Fiorano Modenese which lies in the ceramic district where hundreds of factories were built after World War 2 for the production of ceramic tiles. The materials utilized are taken from soil pits dug in the clays cropping out in the Northern Apennines.

The most evident natural morphological features to be observed on the slopes are badland landforms, slide and earth flow-type landslides.

This research was carried out according to traditional survey as well as digital processing methods on maps and aerial photographs. It led to the elaboration of schematic geomorphological maps related to changes occurred from 1954 to 2012.

Soil excavation began in an improvised, makeshift way in the 1930s. By the 1960s, though, excavation was carried out in a more organized, industrial way. The place with the most evident human impact is the Torrent Corlo valley, but several other soil pits are found. In the study area the exploitation of clayey soil for the ceramic industry ceased completely in 2008.

As concerns the hydrographic features, tens of small artificial ponds were excavated in the 1960s for irrigation purposes as well as for quarrying activities. Since the 1990s, though, they have lost their function and are now abandoned. As a consequence, many of them evolved in a natural way: some have turned into swamps whereas others have been filled by palustrine deposits.

Finally, the role played by man as a morphogenetic agent and the impact of anthropogenic activities on the natural landscape evolution are highlighted.

\*\*\*\*\*

### **Sustainable Land Management of the agro-pastoral plateaus, Atlantic Morocco**

LAQUINA A.

*UNESCO-GN Chair, Univ. Mohamed V, Faculty of Human sciences, RABAT, MOROCCO*

The research made in the framework of the DESIRE project concerns the marginal lands in the Atlantic plateaus of Morocco, where farming has as main objective to feed the livestock. Many constraints are responsible of the current spreading of land degradation mechanisms. Direct overgrazing and indirect effect related to mismanagement of land for fodder production, operate massive damages to the vegetation cover and to the soil.

Scenarios were built, based on various rates of land management inside the fragile environments, vulnerable to degradation by runoff and erosion. These scenarios try to integrate the concept of SLM into the current system of livestock to make it progressively evolve towards intensification, more income and less degradation.

The proposed changes are not easy to apply. At first, at the level of the farms, we must consider the private character of property, the dispersion of the plots and the various state and forms of degradation. At the level of the whole territory, many agro-sylvo-pastoral combinations are possible. But it's difficult to recommend a specialization of certain lands in grazing and others in farming, without rethinking the restructuring of the fragmented plots. This calls agreements between farmers and new landowners, coming from the city.

The choice for planting gullied plots with shrubs, like *atriplex halimus* demonstrated, during 2 years of monitoring, its effective potential for land rehabilitation, fodder supply of the cattle and for evolution towards a new semi-intensive breeding. But it is not easy to encourage the farmers to invest in this effort of planting, while the cost is much higher than the expected outputs during the 5 first years.

The role of the domanial forest must also be re-defined, because, in this perspective, the forest could become less used for grazing and devoted for new activities.

## Human impact on slopes and valley bottoms in iron ore exploitation areas in Minas Gerais - Brazil

SILVA C.F.A.(1), VALADÃO R.C.(2), SILVA J.R.(1), SILVEIRA J.S.(3)

(1) Instituto Federal de Minas Gerais - IFMG, OURO PRETO - MG, BRAZIL ; (2) Institute of Geosciences - IGC Universidade Federal de Minas Gerais - UFMG, BELO HORIZONTE, BRAZIL ; (3) Centro Universitário de Sete Lagoas - UNIFEMM, SETE LAGOAS, BRAZIL

Brazil is currently one of the world's leading exporters of iron ore, specially the production from the Quadrilátero Ferrífero region, located in Minas Gerais. The exploitation of iron in open pit mines in the Itabira Complex has resulted in significant impact on landform and hence on changes in geomorphological dynamics beyond the exploited areas. This impact results from the combination of two processes: (i) the removal of soil and rock opening large hollows on the slopes, and (ii) the accumulation of material in the form of tailings and mine dumps. Relief transformation processes were extremely fast compared to the speed of change that occurs in natural conditions. The anthropogenic landforms evolution in the area investigated was reconstructed from 1946 to 2008; the landscape along this period was obtained from interpreting and processing topographic maps and from remote sensing products. Along 62 years of mining activity landforms and their dynamics were greatly impacted with inversions of relief, in which ridge lines and interfluvies now are configured as depressions up to 250 meters deep; low areas, which had their surface increased up to 150 meters; decapitation of 106 drainage headwaters with the localized extinction of springs in them; redefinition of surface and subsurface hydrological flows, and heavysilting of valley bottoms. In Brazil after closing mining activities the environmental legislation requires the investigated area to be environmentally recovered by deploying the Recovery Plan of Degraded Areas (PRAD). However, we argue there is no possibility of reversing much of the geomorphological damage resulting from the exploitation of iron ore.

\*\*\*\*\*

## Landform change due to airport building

PIJET-MIGON E.

High School of Banking, WROCLAW, POLAND

Along with an increasing popularity of air transportation the number and size of airports and landing sites for commercial aircraft has grown. Local relief, site hydrology, and the presence of natural obstacles potentially affecting flights, were among factors considered at the planning stage and, if feasible and necessary, modified to suit the purpose. Hence, substantial topography and landform change has been associated with airport building, especially in recent times.

Among the most common examples of interference with natural topography are ground levelling and land reclamation. The latter has concerned wetlands, lakes and marine embayments. At an earlier stage of aviation development, alteration of coastal configuration and dredging were frequent, in order to allow mooring of hydroplanes. The Santos Dumont airport in Rio de Janeiro and the Dąbie airport in Szczecin (Poland) are the examples.

Introduction of larger aircraft required extension of runways, especially at big airports. If topography or land use rendered options of inland extension impossible, land reclamation was attempted and man-made solid ground was created to accommodate longer runways. Examples include Gibraltar, Nagoya Centrair, Tokyo-Haneda, Seoul-Incheon, or Malé in the Maldives. In densely populated regions the only option left was to build artificial islands. The most spectacular example is the Kansai airport in Osaka. Building of Hong Kong International, in turn involved levelling of a few hilly islands and filling the marine space between them.

Another type of landform change concerns hilly relief on the landing approach/take-off routes. Hills were completely planted (Tegicugalpa, Honduras) or lowered through removal of the upper part (Mulu, Malaysia). Further examples include construction of earth embankments for noise reduction and, along with an increasing role of airports as tourist attractions, of artificial hills to allow observation of airport traffic.

### Active collapse dolines: a geomorphological impact from a high-speed railway tunnel crossing the Cantabrian Mountains (NW Spain)

VALENZUELA P.(1), DOMINGUEZ-CUESTA M.J.(1), JIMENEZ-SANCHEZ M.(1), MELÉNDEZ-ASENSIO M.(2), SÁENZ DE SANTA MARÍA J.A.(3)

(1) University of Oviedo, OVIEDO, SPAIN ; (2) IGME, OVIEDO, SPAIN ; (3) GEHMA, OVIEDO, SPAIN

A 24.9 km-long high speed railway tunnels (Pajares Tunnels) were built between 2005-2009, crossing the Cantabrian Range (NW Spain) and trending NW-SE. The tunnels cross an alternation of paleozoic formations (shales, sandstones, quartzites and limestones) with a complex geological structure resulting from the deformation during Hercinian and Alpine Orogenies. The lithologies show very different mechanical and hydrogeological behaviours, some of which represent important aquifers (fractured and karstic). A section of the tunnels were built below Alcedo Valley (León, N. Spain) at approximately 450m depth.

Alcedo Valley is drained by a mountain stream that was canalized in an artificial channel built in 2008 to enhance river superficial flow and to avoid water infiltration. In the bottom of the valley, some subsidence and collapse evidence have been appearing from 2008 to present, also affecting the artificial channel. Evidence include 2 main scars hollows (5-10m long), 3 circular dolines (3-4m radius) and several minor hollows, which are developed in an area of about 20.000m<sup>2</sup> over quaternary fluvial and coluvial deposits covering karstified limestone bedrock (Láncara Fm.). Some of these active hollows work as sinkholes of surficial water, drying up all the water of Alcedo stream during the summer. The watershed, using as the baseline the collapsed area, is around 4km<sup>2</sup>, under pluvio-nival climate with average temperatures below 10°C and rainfall between 1000-1300mm/yr.

The recent development and active growing of the hollows is consistent with 1) the drop of the groundwater level by the tunnels drainage after the excavation; 2) the increase of groundwater flow across the karstic aquifer and 3) the increase of the river incision as a response to the descent of its base level.

The combination of hydrogeological, geomorphological, climatological studies and GIS management will allow us to establish accurately the role that the tunnels play in the evolution of the valley.

\*\*\*\*\*

### Erosion processes in flysch: An example from the Istria Peninsula (NE Adriatic)

ZORN M., KOMAC B., FERK M., ERHARTIC B.

Research Centre of the Slovenian Academy of Sciences and Arts, Anton Melik Geographical Institute, LJUBLJANA, SLOVENIA

In recent decades, several investigations of erosion processes in the flysch bedrock and soils of northern Istria have been carried out (NW Croatia, SW Slovenia). Numerous measurements in various environments were gathered in order to establish erosion rates for different types of land use. The presentation gives an overview of the most notable findings.

Two experimental sites for measurements on closed erosion plots were located in Abrami (Croatia) and near the village of Marezige (Slovenia). The rockwall retreat of bare flysch slopes in badlands and soil erosion on different land uses was measured in both locations. Direct measurements at the plots and indirect measurements with terrestrial photogrammetry were used. Measurements nearby suggest that bare slopes retreat at a rate of a few centimeters per year and that the interrill soil erosion on bare soil is up to 90 t/ha.

Recently, measurements of the rockwall retreat of coastal cliffs at Debeli Rtič (Slovenia) were carried out in combination with analyses of historical data on erosion on the Slovenian flysch coast. The photogrammetric measurements indicate an erosion rate of about 1 to 2 mm/yr. However, comparison between the cliffs' current position and submerged Roman artifacts suggests that the cliff retreat rate must be markedly higher, probably around 10 to 20 mm/yr.

Erosion rates in river systems can also be calculated from sedimentation rates. Therefore, sedimentation was measured behind the Letaj Dam (Croatia) and in Lake Butoniga (Croatia). The specific sediment production in the river basin behind the Letaj Dam is estimated to be 803 m<sup>3</sup>/km<sup>2</sup> per year, and in the river basin of Lake Butoniga around 2107 m<sup>3</sup>/km<sup>2</sup>. Furthermore, analysis of historical topographic maps of the mouth of the Raša River (Croatia) revealed that in the last 240 years the river mouth has moved around 4 km towards the sea and that the mouth of the Mirna River (Croatia) has moved some 350 m since the second half of the 19<sup>th</sup> century.

### Early holocene to present fluvial-coastal morphodynamics in the adriatic sector of Central Italy

ARINGOLI D.(1), BUCCOLINI M.(2), DRAMIS F.(3), FARABOLLINI P.(1), GENTILI B.(1), MATERAZZI M.(1), PAMBIANCHI G.(1), SCIARRA N.(2)

(1) University of Camerino, CAMERINO, ITALY ; (2) University of Chieti, CHIETI, ITALY ; (3) Roma Tre University, ROME, ITALY

The Holocene evolution of the Adriatic sector of Central Italy has been characterized by a complex evolution of the fluvial networks and the corresponding mouths with erosion and aggradation phases generally controlled by climate changes and, in the most recent times, also by the impact of human activities.

In the second half of the last century, after a former phase characterized by aggradation, essentially due to a prolonged period of deforestation and subsequent abandonment of slope farmlands, intensive erosive processes occurred as a consequence of widespread gravel quarrying from the river beds.

Using data from several rivers of the Adriatic sector of Central Italy, an empirical relation to quantitatively correlate the erosion capacity of rivers consequent to quarrying and the related amount of fluvial deepening has been formulated:

$$F_d = 1.5 \text{ GFP}^{0.2}$$

where  $F_d$  is the amount of Fluvial deepening in m and GFP is the *Global Fluvial Power index*, obtained by multiplying the *Fluvial Power index* (mean annual fluvial discharge in  $m^3/s$  multiplied by the mean slope of the river channel in %) by the total volume of quarried material in  $m^3$ .

The preliminary results seem to be quite encouraging even though, due to the limited number of available data, the relation needs to be further tested.

\*\*\*\*\*

### River regulation and associated degradation of landscape ecology of flood plain: case study from a subtropical controlled drainage in para-deltaic tract of Southern Bengal, India

CHAKRABORTTY D.

ASSISTANT PROFESSOR OF GEOGRAPHY, BANKURA CHRISTIAN COLLEGE, BANKURA, WEST BENGAL, INDIA, SURI, INDIA

Since the earliest civilization, rivers have been a vital resource in the landscape. Various social, cultural and economic activities are related to rivers, which are exemplified from growth and development of hydraulic civilization in flat fertile lands adjacent to rivers, but through the river uses human civilization had significant direct and indirect impact on fluvial environmental system in terms of river regulation. Impact of river regulation in the river regime is evitable through three processes: these are *first*, on channel modification included widening, dredging and straightening of channel, *second*, modification in river corridor and flood plain involves in construction of levees or flood embankments, downstream storage, and *third*, changes in catchment area included deforestation in basin, construction of large dams etc. The major processes of river regulation are dam construction, river diversion, canal construction, local channelization, irrigation, embankments, river basin planning and agricultural land reclamation. The present study proposes to analyze the impact of river regulation in the fluvial morphological structure and flood plain ecological setting in parts of lower Babla river basin, West Bengal, India using remote sensing and GIS techniques. Babla is a Yazoo drainage system which flows parallel to the mega floodplain complex of Bhagirathi- Ganga-Brahmaputra delta in North West to south and south easterly direction. The information generated would be immensely helpful in hydrological modeling and providing necessary inputs for constructing suitable developmental management plans for restoring landscape ecological setting of the Babla river basin.

### **Importance of Slope in City Planning Case Study: Southwestern Suburban Area of Kolkata, India**

JOARDAR R.

*Vivekananda College for Women, KOLKATA, INDIA*

Settlement on deltaic plains always develops on river levee, which being the highest point in the site and having slopes on both sides is naturally free from waterlogging. The future growth of settlement also follows the levee crest along the river, the result being an elongated pattern of settlement. Originally the city of Kolkata also grew over the natural levee of the river Bhagirathi for over a length of 50 km in a north-south direction following the same trend. But due to enormous population pressure it has encroached into the backswamp and marshy lands to the east and southwest by way of filling up extensive areas in unplanned manner. The physical features of the area have been dominated by surface water systems, the proximity of the sea in the south, and the human induced influence on the entire hydro-geophysical characteristics of the region. However, the latter has been the most dominant influence of all in recent decades, leading to profound subsequent implications on social and economic aspects of the inhabitants. The filling up of backswamp in a haphazard way leads to frequent waterlogging in the area paralyzing the daily chores of life in the rainy season. As the land was low, individual developers filled the land without caring to maintain the general slope of land, which is very necessary for easy draining of accumulated rain or waste water. Thus over period on the imperceptible slope of the delta, an anthropocene micro relief developed due to such reckless landuse leading to distortion of natural slope. The paper presents a glimpse of the severity of the waterlogging problem in the southwest part of Kolkata megalopolis where every individual distorts the micro-relief and natural slope of the area in the absence of any master plan.

Keywords: river levee, backswamp, waterlogging, anthropocene micro relief.

\*\*\*\*\*

### **The effects of land use changes and morphometric parameters in the gullies erosion, São Paulo, Brazil**

VIEIRA GOMES R.

*University of S\_o Paulo, S\_O PAULO, BRAZIL*

This research discussed the contribution of land use changes and the morphometric settings in gullies erosion evolution in the basin, one of the areas that are most affected by erosion processes, located in São Pedro, São Paulo, Brazil. The methodology involves the following steps: (i) aerial photointerpretation of the years, in 1972 (1:25.000) and in 2006 (1:30.000) and field trip observation; (ii) scanning and vectorization of photographs, topographic maps and digital elevation model (DEM) (resolution 4cm<sup>2</sup>, grid 2X2 m); (iii) mapping of gullies erosion (in 1972 and 2006), morphometric parameters (slope and curvature) and land use (in 1972 and 2006); (iv) quantitative and qualitative analyzes of the of gullies erosion. In the quantitative analysis we used the Erosion Potential (EP) which is the ratio between the number of cells with gullies, in each class, and the total number of cells of that same class. Using the EP indexes we observed the dirty pasture, soil exposed (land use classes), slope between 20% and 40% (5.22%) and concave slopes, (4.89%) which were the most affected by gullies erosion. The analysis of evolution, from 1972 to 2006, shows that there was a reduction of the gullies due to the reduction of pastures and the increase of vegetation and the urbanization in northwestern basin. In conclusion, the suitable land use may contribute to the reduction of erosion volume (e.g controlling runoff). Furthermore, the method applied in this study showed the importance of the aerial photointerpretation and DEM highest resolution in the gullies erosion research.

### **The distortion of alluvial plains by the mining of gravel sand**

SMOLOVA I., DUSKOVA M., MACHACEK J.

Palacky University Olomouc, Faculty of Science, Department of Geography, OLOMOUC, CZECH REPUBLIC

Disruption to a natural flow regime is a serious problem, even in consideration of the mounting risk of floods which menace human lives and property. An example of human interference in a hydrological system is the distortion of alluvial plains by the mining of gravel sand.

In the period of transformation of the Czech economy after 1989 some crucial changes were made in the mining of minerals. Those changes have been reflected at the legislative level in relation to landscape care and one area they have influenced is in the use of flooded regions.

Though mining of gravel sand is still one of the most important aspects of mineral mining in the Czech republic despite the fact that it is situated mostly in areas of alluvial plains and gravel sand alluvial terraces.

During the extraction of large volumes of stone, changes happen to the hydrological regime. This is manifested in floods. The fact that the capacity for the accumulation of subterranean waters is affected means an enhanced risk of natural hazards for inhabited areas in the neighbourhood of the flooded areas.

The phenomenon can be mathematically expressed as the relation between a certain cubage of mined gravelous sand, the hydro physical characteristics of the alluvial sediments and the volume of flood water which passes through alluvial plains as floods.

The poster chronicles the development of the exploitation of alluvial plains for sand and gravel mining in selected basins in the Czech republic over the last twenty years (1990-2010) and compares risk indexes of intervention in alluvial plains during floods.

\*\*\*\*\*

### **Rapid assessment of floodplain storage of contaminant metals using high-resolution XRF core scanning**

JONES A.F.(1), TURNER J.N.(1), DALY J.S.(1), GOODHUE R.(2), EDWARDS R.J.(2), FRANCUS P.(3), REID I.(1)

(1) University College Dublin, DUBLIN, IRELAND ; (2) Trinity College Dublin, DUBLIN, IRELAND ; (3) Institut National de la Recherche Scientifique, QUEBEC CITY, CANADA

Effective management of the hazards caused by the contamination of river systems resulting from historical metal mining requires assessment of contaminated sediment storage within river floodplains. In Ireland, to date, few attempts have been made to assess the extent of Pb, Zn and Cu storage in floodplain sediments, even in catchments severely affected by historical metal mining. The development of high-resolution XRF core scanners provides a new tool to assist in the quantification of contaminant metals currently stored within floodplains and, in particular, to rapidly evaluate variations in contaminant concentrations with depth within the sediment profile. The aim of this study is to test the utility of high-resolution XRF analysis for the rapid assessment of contaminant metal storage within floodplain sediments and to elucidate the extent and severity of floodplain Pb, Zn and Cu contamination in Irish catchments affected by historical metal mining. The selected catchments include the Avoca and the Kilmastulla, which contain two of the three most contaminated mine districts in Ireland. XRF scans of floodplain sediment cores at resolutions of 1 mm or finer are calibrated using ED-XRF analysis of subsamples. Heavy metal concentrations are evaluated with respect to depth within the floodplain, increasing distance from the active channel and distance downstream of the mine sites. The significance of catchment-scale floodplain storage of Pb, Zn and Cu and the likelihood of reworking of the floodplain sediments are assessed in the context of the other hazards (e.g. AMD, contaminated channel sediments) presented by unremediated historical mine sites.

### **Land-use changes and geomorphological development during the last millenium in the Campine area, north-eastern Belgium**

BEERTEN K.(1), VANDERSMISSEN N.(2), DEFORCE K.(3), LETERME B.(1), MALLANTS D.(4), VANDENBERGHE N.(2)

(1) *Institute Environment-Health-Safety, SCK-CEN, MOL, BELGIUM* ; (2) *Department of Earth and Environmental Sciences, KU Leuven, LEUVEN, BELGIUM* ; (3) *Onroerend Erfgoed, BRUSSELS, BELGIUM* ; (4) *CSIRO Land and Water, ADELAIDE, AUSTRALIA*

We present the results of an interdisciplinary study on the human-induced transformation of a late Holocene landscape in a ca. 6 km<sup>2</sup> large interfluvium between the rivers Kleine Nete and Grote Nete (Campine area, north-eastern Belgium). Descriptions of cross-sections and hand-drillings, soil profile analyses, palynology, optically stimulated luminescence (OSL) dating, historical archives and GIS-data were used to establish a chronology of land-use changes and their impact on the landscape during the last millennium. The first evidence of geomorphological changes in the slightly undulating deforested late Holocene sandy landscape is a thin layer of drift sand dated to between 1200-1500 AD. For the period between 1500-1750 AD, evidence of strong land-use intensification is found, including further destruction of the heather vegetation due to grazing and the use of plaggen, wind-enhanced erosion of podzol soils and the intensive use of paths for sheep drift. This phase has caused the complete reshaping of the landscape with the creation of large deflation areas of ca. 1 m deep, and the development of drift sand dunes up to 2 m in height. Between 1850-1900 AD the interfluvium became completely reforested and stabilized with ca. 85 % of the area being occupied by pine trees. The first signs of the existence of large-scale infrastructure and industrial activity is the construction of the Bocholt-Herentals canal between the Meuse and Scheldt basins, and the exploitation of quartz sand around the end of the 19<sup>th</sup> century. Further enlargement of the newly formed excavation pits, vegetation clearing, and the development of new industries around 1950 AD has led to an open landscape with only ca. 25% of the 19<sup>th</sup> century pine trees left. It is anticipated that the changes described here have induced a progressive lowering of the water-table in an already relatively dry landscape.

\*\*\*\*\*

### **Types of badlands and earth pyramids in the republic of macedonia**

MILEVSKI I.

*University "Ss. Cyril and Methodius" Skopje, SKOPJE, MACEDONIA*

As a consequence of accelerated erosion which affects large areas in the Republic of Macedonia (25713 km<sup>2</sup>), there are numerous erosion and denudation landforms in the landscape, and badlands are one of more distinguished. Field researches and analyses of satellite imagery, digital elevation models, topographic maps etc., show that badlands in the Republic of Macedonia occupies significant area. In most cases, they were created with excess erosion of erodible rocks and soils on steep slope hilly terrains. Aside of suitable natural factors, the main trigger of their formation usually is severe human impact on susceptible landscape (deforestation, overgrazing, extensive cultivation etc.). Because various factors affecting their genesis and evolution, analysed badlands shows significant morphological differences. Thus, most of the badlands in upper Bregalnica catchment created in Pliocene lacustrine sands and sandstones has particular amphitheatric shape, with 150-300 m in length and 30-100 m in height. Other badlands like those created in tuffs of Kratovo-Zletovo palaeovolcanic area has ribbed-shaped morphology with almost parallel and sometimes very long system of rills and gullies. There is another type of badlands appeared in both mentioned areas, characterized with numerous earth pyramids on the sides. Such kind of badlands is near village of Kuklica or "village of stone dolls", formed by decomposition of andesites and subsequent intensive erosion of tuffs bellows them. As a result, more than 150 human-like pillars are shaped, according to which this phenomenon is known as "jolly wedding". Similar morphology has some of the badlands in Bregalnica, Bosava and Pcinja catchments. Aside of the negative impact on land use, in recent times some badlands and earth pyramids sites are recognized as natural rarities and each year attract more tourists with potential to improve even local economies.

## **Erosion vulnerability evolution processes associated with the deforestation settlements in Western Amazon**

GOMES F.(1), MANIESI V.(2), BASTOS A.(1)

(1) CENTRO DE ESTUDOS RIOTERRA, PORTO VELHO, BRAZIL ; (2) Universidade Federal de Rondônia, PORTO VELHO, BRAZIL

The study aims to present and analyze the contents of vulnerability to erosion through thematic maps and study of the occupation modes in the area of Machadinho do Oeste municipality located in the western Amazonia portion, where there are several settlements with large deforested areas related to this kind of occupation. Were conducted literature surveys, visual interpretation of satellite images in an integrated view of climate, geology, geomorphology, soils, dynamics changes in land use and land cover and deforestation advance. The erosion vulnerability map preparation was based on the methods proposed by Crepani et al. (1996) and Tricart (1977) ecodynamic concept, using techniques that integrated thematic aspects assigning values to vulnerability based on soil loss processes. The region occupation occurred through governments colonization programs. As a result of this process, many settlements were created without adequate technical support and without knowledge about the area. There has been a gradual increase in the county's area related to unfertile soils susceptible to erosion when the vegetation is removed to intensify pasture use. The vulnerability class of erosion most representative was "moderately stable" (64.8%). The presence of moderately stable class is preserved by maintaining the natural vegetation. On the other hand, where there are great anthrop impacted areas, it shows "averagely stable vulnerable" class (30%), an intermediate index for the current conditions. This areas needs to be conserved for not change the vulnerability class for a lower one. These areas of settlement projects that no longer have natural vegetation present in proportions smaller classes "moderately vulnerable" and "vulnerable" associated principally by its soils.

\*\*\*\*\*

## **Human activities and changes in flow, width and depth in cross sections at the top, middle and lower course of the river Peixe - Western Plateau Paulista (Brazil), 1906 and 2012**

TRIVELLATO F., PEREZ FILHO A.

Unicamp, CAMPINAS, BRAZIL

This research points to changes in flow, width and depth in five cross sections along the upper, middle and lower course of the Peixe, located between parallels 21° 20' S to 22° 30' S and meridians 49° 36' W to 52° 02' W. Two moments in time are taken as parameters: 1906 and 2012. At first the watershed had its entire natural vegetation preserved and, in the second, deforestation for agricultural crops and pastures occupy about 87% of the basin area and urbanization 10%, leaving only about 3% of natural vegetation areas.

Data for 1906 were collected and mapped by the extinct Comissão Geográfica e Geológica do Estado de São Paulo (Brazil) in reconnaissance expedition to the unknown valley of the Peixe river. We emphasize that this material is the only source of environmental data from the early 20th century for the region.

In fieldwork, we return to the five cross sections, in the same climatic period characterized as dry, corresponding to the months from June to September for the study area.

Through manual ratchet counter with depth, winch and flow meter coupled to a boat anchored by a steel cable graduated in meters, it was possible to calculate flow and width of the sections.

The results show significant increase in the variables of each of the five cross sections. The discharge (m<sup>3</sup>/s) rates of 2012 are 10 times bigger than in 1906, doubled the width of the sections, the depth increased by about 50% and the average velocity of the flow tripled.

We highlight the problem of variables that interfere in such data, which were considered: publications indicate negligible increase in the area of the average annual rainfall in the past 30 years, reports from 1906 indicate dry weather and some rain episode over river valley during the expedition; operation in the trickle small hydropower plant since 1940 in the middle course of the river; studies estimate 24 m<sup>3</sup> / s water withdrawal from aquifers.

**Evaluation about the use and human occupancy in the west edge's geomorphologic unit of Potiguar Basin, Northeast of Brazil, CE**

*SILVA R., BRITO É.*

*Universidade Estadual do Ceara, LIMOEIRO DO NORTE, BRAZIL*

Throughout time man has transformed natural elements into resources to satisfy his needs. Man significantly alters the landscape and cause imbalances in the process of interaction among the elements of nature, having intensified it even further with technological advances. The goal is to examine ways of uses in the Chapada do Apodi, collecting data that can support environmental and policy management. The area covers the western portion of Potiguar Basin, located on the northeastern Brazil, which receives the name of Chapada do Apodi (Apodi Plateau). Its formation took place in the Cretaceous period of the Mesozoic era, suffering action tectonic and subsidence. The formations present in the West Edge are: Jandaira (top) and Acu (lower), their soils are Cambisols and Vertisols. The place has potential for irrigated agriculture by high soil fertility and groundwater, but with shortcomings regarding the use, irregular rainfall, because the rainy season is short, and water deep underground, making it difficult to uptake. After the 30s, the area has suffered from the exploitation of limestone and the withdrawal of vegetation, erosion and great terrain transformation, as well as the launching of effluents. The methodology is based on the geomorphologic concepts of Casseti (2005), IPECE (2012), Maia (2005) and Souza (1988 and 2000). The research procedures were reading literature and data collection, mapping and use of satellite images, field visits, analysis and synthesis. It is noticed that the activities performed in the Chapada do Apodi are inadequate for this geomorphologic unit and have caused weaknesses that intensified may cause environmental degradation, modification of the original forms of terrain through the exacerbated removal of limestone and vegetation, leading to a decreasing in infiltration capacity, as well as accelerating the overland flow and the loss of support capacity.

KEYWORDS: environmental degradation, Chapada do Apodi, geomorphologic forms.

\*\*\*\*\*

**The landscape concept in studies or the transformations of the land surface: reading geomorphologic and biogeographyc**

*MATOS\_FIERZ M.(1), REZENDE S.(2), ROSS J.(1)*

*(1) UNIVERSITY OF SAO PAULO, SAO PAULO, BRAZIL ; (2) UNIVERSITY OF SAO PAULO, SÃO PAULO, BRAZIL*

The landscape concept is present in Geography since the beginning of modern geographical science, prioritizing descriptive and narrative aspects of the natural environment, having pioneered the naturalist Alexander von Humboldt who developed and operationalized the concept of landscape as a geographical category of natural organization of Earth's surface. Since then, this concept is present in Geomorphology, in Biogeography in Pedology in many other sciences and continues to gain strength before its holistic potential. In Geomorphology this concept is very peculiar characteristics directly related to the material composition and its origin and forms. While in biogeography is directly linked to different types of vegetation in its various stages of development. However the landscape is not only described by biogeographical and geomorphological characteristics, but rather as a spatial structure that results from the interaction between natural processes and human activities, which acts with strong processing capacity of these natural spaces. Emphasis in the transformation of landscapes the processes resulting from human action also will act strongly in the genesis of the landscape. The transformation of modes of land use and production systems modifies the arrangement of habitats, the distribution of agro and forest physiognomy. The landscape structure is important for the maintenance of biological diversity, but also to human populations due to their dependence on natural resource use. Thus landscape can be understood as a result of the interconnection of natural and human history. Given this context the objective is to portray the evolution of the landscape in an area that portrays well the points raised, the region Bertioga coast of the state of São Paulo emphasizing the various methods of analysis supported the concepts of geomorphology and biogeography, and human participation this transformation.

**Understanding erosion better in a data scarce catchment in NW Jordan - A multiple response approach**

KRAUSHAAR S.(1), WILKINSON S.(2), OLLESCH G.(3), SIEBERT C.(4), VOGEL H.J.(1)

(1) Helmholtz Centre for Environmental Research - UFZ & University of Halle-Wittenberg, HALLE, GERMANY ;  
(2) CSIRO, Land and Water, CANBERRA, AUSTRALIA ; (3) Elbe River Catchment Community - Liaison Office,  
MAGDEBURG, GERMANY ; (4) Helmholtz Centre for Environmental Research - UFZ, HALLE, GERMANY

Around 65% of the freshwater used in Jordan is derived from surface waters and reservoirs. Sediment pollution harms the quality of this scarce resource in the region and plans for mitigation have to be developed. In the framework of an Integrated Water Resource Management it is therefore aspired that more rain infiltrates on the spot and recharges groundwater resources and less runoff occurs delivering sediment loads to the surface waters. Soil and its physical integrity play an important role in these tasks and erosion needs to be better understood in this context.

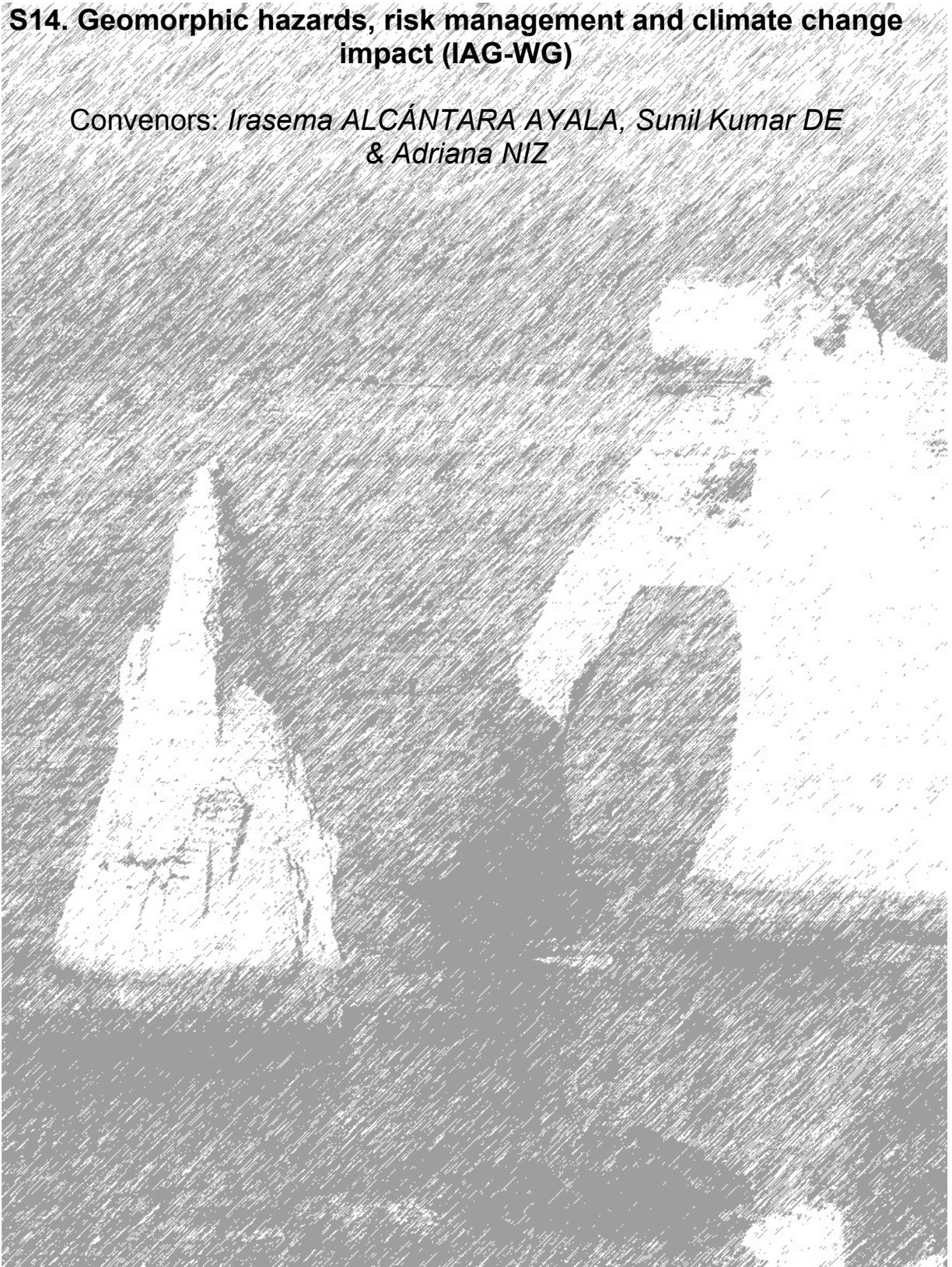
The catchment Wadi Al-Arab (263,5km<sup>2</sup>) in the north of Jordan was therefore focus of a multiple response analysis to serve as a transferable approach in erosion hot spot detection for the region. As many catchments in the region Wadi Al-Arab lays in the transition zone from the Mediterranean to the semi-arid. Carbonatic bedrocks of the Upper Cretaceous and younger dominate the catchment's geology and olive cultivation plays a major part.

Field measurements in defined land units as well as a chemical fingerprint served to get first insights into soil erosion on the slope and the deposition into the catchment's reservoir. The methods cover different spatial and temporal scales of erosion and are used to calibrate and validate the setup of the SedNet model for the catchment. Its implementation helps to cultivate more sophisticated questions to the research focus and allows a conceptual scenario development for mitigation strategies.

\*\*\*\*\*

**S14. Geomorphic hazards, risk management and climate change impact (IAG-WG)**

Convenors: *Irasema ALCÁNTARA AYALA, Sunil Kumar DE & Adriana NIZ*





## **Oral presentations:**

### **Rockfalls triggered from a rock-glacier front as a mirror of multi-centennial permafrost dynamics in the Valais Alps?**

STOFFEL M.(1), STOFFEL M.(2), TRAPPMANN D.(1), CORONA C.(1)

(1) University of Berne, Institute of Geological Sciences, BERNE, SWITZERLAND ; (2) University of Geneva, Institute of Environmental Sciences, CAROUGE-GENEVA, SWITZERLAND

Trees have been demonstrated repeatedly to be excellent recorders of rockfall activity on forested talus slopes, both in terms of their spatial and temporal activity and possible changes thereof. Rockfalls have also been described to depend, among others, on freeze-thaw cycles and the melting of winter ice in clefts, and that their temporal frequency and magnitude will likely be altered at higher elevations dominated by permafrost environments as a result of ongoing climatic changes.

This study focuses on rockfalls triggered from the frontal area of rock glacier in the Saas Valley (Valais, Switzerland) which is located above a steep cliff. It is anticipated that changes in rock glacier movements at this site will affect the production of rockfall which would in turn be recorded in the vegetation growing on the steep slopes below the cliff. Based on the study of almost 400 time series of century-old *Larix decidua* Mill. trees, we demonstrate that rockfall activity and therefore rock glacier movements have been modified significantly at the study site between the end of the Little Ice Age and today, and that such changes can be considered reflective of changing climatic conditions in general and of recent increases in temperatures in particular.

\*\*\*\*\*

### **Predicting Massmovement Processes induced in Periglacial Areas**

TOBLER D.(1), MANI P.(2)

(1) GEOTEST SA, ZOLLIKOFEN, SWITZERLAND ; (2) GEO 7 SA, BERN, SWITZERLAND

Based on glacier retreat and degrading permafrost in high alpine regions across the Bernese Oberland (central Switzerland), several new hazardous source areas for debris flows became evident within the last years. The evaluation of susceptible periglacial areas and the assignment of resulting processes by modelling will be one of the major tasks to be solved in near future. The prediction of those processes and their consequences is an interdisciplinary question. Meteorological scenarios for the next 30 to 50 years derived from climate change scenarios stand at the beginning of the decision chain. Based on those, susceptible periglacial areas which act as starting zones for debris flows or new sediment sources can be calculated through sophisticated permafrost and glacier retreat models. The bedload characterisation is based on extensive field investigation and laboratory testing subsequent to the October 2011 events in Switzerland. There many debris flows originated in periglacial areas; deep gully erosion phenomena in permafrost induced debris fans at the foot of steep rock faces have been evident. A vast basic monitoring of the permafrost by BTS measurements helps understanding on-going processes and is fundamental for the bedload calculation in in the periglacial area. This is measured by monitoring systems at representative and characteristic locations within the study area (e.g. Spreitgraben near Guttannen, Switzerland).

Dealing with large investigation areas of several 100 km<sup>2</sup> it is important to use adequate models. Well established simulation tools like dfwalk and RAMMS have been used within the project. The result is a so called periglacial hazard indication map visualizing endangered areas for debris flow processes as well as other natural hazards like rockfall, landslides and floods.

### **Understanding geoenvironmental dynamics and hazards of high mountains: the Geo-Morpho-Structural assessment of Veny Valley (W-Alps, Italy)**

*GIARDINO M., PEROTTI L., BACENETTI M.*  
*University of Turin, TURIN, ITALY*

Mountain regions have geological and geomorphological features that make them attractive for leisure and tourism activities; land occupation and seasonal population in many mountain areas are consequently increasing, together with impacts on the natural environment and geomorphological risks for human activities and infrastructures. We aim to understand the present and past geomorphologic processes in the periglacial environment of the Veny valley (Courmayeur, Ao), and to study their interaction with the morpho-structural setting, by using geomatics techniques.

First, the field data have been collected using pocket-PC and integrated GPS with mobile GIS, in order to create an ESRI-GIS based geodatabase. Considering the alpine context of the area, stereoscopic models from the '97 and '03 flights with a 4 m precision were built to map geomorphological features in inaccessible area. Contemporaneously, to support these data, LiDAR '08 images were processed to include hillshade, slope, and aspect maps.

Two areas of keen geomatics interest were identified: the potential failure surfaces of the Mont Rouge de Peuterey and the Miage glacial basin. Using the Coltop 3D software, kinematic analysis of the data were performed using the Markland test. MIVIS '99 images analysis allowed to classify the debris cover of Miage Glacier and detected the potential rock instability using the Principal Component Analysis (PCA). On the same slopes close range photogrammetry was performed to measure joint sets setting.

Data interpretation yielded to obtain three geomatics layers: a) geomorphologic, within mapped landforms b) morpho-structural, concerning the structural evolution c) debris cover of Miage glacier, for the multitemporal analysis.

The remote sensing technologies showed to be more affordable than the usual field-based approaches, in the perspective of a safe analysis of stability conditions in mountainous areas.

\*\*\*\*\*

### **The impact of debris flows on the transport infrastructure in NW-Norway**

*MEYER N.K.(1), SCHWANGHART W.(2), KORUP O.(2), ROMSTAD B.(3), ETZELMÜLLER B.(1)*  
*(1) University of Oslo, OSLO, NORWAY ; (2) University of Potsdam, POTSDAM, GERMANY ; (3) CICERO, OSLO, NORWAY*

Norwegian's transport infrastructure is frequently affected by rapid mass movements. Aside from snow avalanches and rock falls, debris flows account for high economical costs related to road damages. However, studies investigating debris flow initiation conditions at a regional scale are rarely available for Norway. Thus, we aim to identify a set of terrain attributes as predictor variables for critical topographic conditions of debris flow initiation and to develop a statistical model to obtain a regional susceptibility map for NW-Norway. A debris flow inventory and the terrain variables slope, curvature and flow accumulation derived from a DEM with a resolution of 20 m x 20 m serve as input to a weights of evidence model (WofE) that we use to estimate posterior probabilities of debris flow occurrence on a pixel basis. Thereby, we address three topics related to model quality: model adequacy, model robustness and model accuracy. Beside the susceptibility map itself, WofE offers the possibility to conduct an uncertainty map related to the posterior probabilities. This map is used for spatial error quantification. Finally, the obtained susceptibility map is generalized to the scale of terrain segments, so-called mean curvature watersheds, for the sake of comprehensibility and practicability to the end-users. Identified susceptible areas serve as input to a simple run-out model to identify transport route sections at risk. A network analysis is conducted to estimate the effects of potential road/railway closures and the related costs are quantified.

### **Changing nature of riverine hazards in Brahmaputra Valley, India**

DAS A.K., HAZARIKA N., SAH R.K.

*Deptt. of Environmental Science, Tezpur University, TEZPUR, INDIA*

Brahmaputra valley, Assam, India, is one of the most flood affected areas in the world. The authors in this paper present a factual overview of the nature of riverine hazards in Brahmaputra valley based on RS-GIS studies of selected parameters of river dynamics, field based information on human response and reports on hydro-geomorphic aspects of floods. The purpose is to re-emphasize the need for behavioural adjustment to be up in the policy agenda for flood management in Brahmaputra Valley. Such an objective overview is not only important but also becomes an urgent requirement when considered in the light of changes in precipitation pattern that have been observe and documented by scientist for this region.

Available reports on flood situation for this region show occurrence of repeated breaches in embankments that are meant to control floods during the period of rainfall maxima. Breaches leads to large scale inundation and deposition of sediments over land. This has been the most striking feature in the nature of riverine hazards of Brahmaputra valley for the last couple of decades. RS-GIS and field based studies undertaken for this work suggest that inundation and damage caused by breaches are far more damaging than normal floods.

All documentary evidences available in the form of research publications show that there is an increase in number and intensity of extremerainfall events over Indian region. An analysis of the causes of breaches indicates that these are the results of rivers' response to heavy precipitation. With the observed change in the precipitation pattern, these events are likely to increase.

Integrating the understanding of the nature of riverine hazards and probable changes in it in light of changing precipitation pattern, and the studied dynamic nature of the rivers and socioeconomic factors, this work urges that behavioral adjustments should up in the policy agenda for managing riverine hazards in Brahmaputra Valley.

\*\*\*\*\*

### **Flood hazard maps of ephemeral streams (NE Spain): the Multibasin-Multifunction approach**

FURDADA G., MARQUES M.A., MASCAREÑAS P.

*Dpt. Geodynamics and Geophysics; University of Barcelona, BARCELONA, SPAIN*

This presentation deals with hazard maps for the ephemeral streams of North Cap de Creus (NE Spain) based on the Integrated Geomorphological Method and the Multibasin-Multifunction analysis. The streams drain 11 small basins (surfaces: 0.125-28.5 km<sup>2</sup>; lengths: 14.5-0.8 km; very high medium slopes: 0.241-0.052 m/m). Flash floods are very frequent.

The Integrated Geomorphological Method is based on oriented geomorphological maps where all kind of data related to the hydrologic behaviour of the basin are integrated. From these maps, the flood hazard maps are derived. Flood frequencies and discharge calculations were impossible to obtain with classical methods: discharge data are inexistent and there are only 3 meteorological stations inside the basins (incomplete series). This led us to develop the Multibasin-Multifunction analysis. It consists of: a) to analyze and select the variables that provide information about flood frequency (including historical and field data); b) to compile, for each variable and basin, all the data (including meteorological data from surrounding areas); c) to analyze every variable; d) to compare the results; e) to establish the frequency flood. This approach allowed us to obtain the channel overflowing frequency of 2.3 years, which reaches the inhabited floodplains. These floodplains contain all the floods, from 2.3 to 500 years return period, just increasing the flow depth. With these results we obtained the hazard maps. However, it was impossible to adapt the streams real dynamics to the flood typologies indicated in the EU 2007/60/CE Directive.

Ephemeral streams flash flood dynamics and data limitations are very frequent all along the Mediterranean coast. The Multibasin-Multifunction analysis represents a good alternative to estimate the overflow frequency of such streams. The EU 2007/60/CE Directive should be modified in a way that legislation could adapt and describe the dynamics and nature of these ephemeral streams and flash floods.

## **A Proposed Method of Bank Erosion Hazard Zonation and Its Application on the River Haora, Tripura, India**

BANDYOPADHYAY S., DE S.K.

*Tripura University, AGARTALA, INDIA*

Estimation of bank erosion is usually carried out through the Bank Erosion Hazard Index (BEHI) and Erosivity Index methods, but in practice these methods have been found complicated. In this article an attempt has been made to propose a GIS based method of bank erosion hazard zonation considering 7 parameters, such as, bank slope, meander index, river gradient, river velocity, soil erosivity, vegetation cover and anthropogenic impact. LISS III (30m resolution) and Google Images have been used to determine bank slope, meander index, river gradient, vegetation cover and anthropogenic impact; Soil map of the NBSSLP, India has been used for assessing Soil Erosivity index and river velocity has been measured from the field by water current meter.

Out of those seven parameters, bank slope and meander index are given weightage of 20% each and the rest five parameters are given 12% each. Bank slope of  $<15^\circ$  is considered as gentle and  $>45^\circ$  as very steep. Meander index has been calculated as the ratio between actual meander length and axial length. The entire river has been divided into 500m stretches and the river gradient of each stretch has been calculated as the areal percentage. Soil Erosivity has been calculated on the basis of Soil Nomograph of USLE. A composite buffer map of anthropogenic activity has been prepared by superimposing individual buffer layers of different activities.

By integrating the individual values of those seven parameters a bank erosion hazard zonation map of the River Haora, Tripura, India ( $23^\circ 37' - 23^\circ 53' N$  and  $91^\circ 15' - 91^\circ 37' E$ ), has been prepared. The values have been compared with the field data of 30 cross sections taken along 56 km stretch of the river in Indian Territory and found that the estimated values are matching with the field data. The whole stretch has been divided into 5 hazard zones, i.e. Very High, High, Moderate, Low and Very Low Hazard Zones and they are covering 4.82 km, 17.07 km, 21.95 km, 9.22 km and 2.94 km respectively.

\*\*\*\*\*

## **Flood hazard mapping as a risk mitigation tool in a Moroccan urban catchment**

WERREN G.

*Universit\_ de Lausanne, LAUSANNE, SWITZERLAND*

Severe rainfall events are thought to be occurring more frequently in semi-arid areas. In Morocco, flood hazard has become an important topic, notably as rapid economic development and high urbanization rates have increased the exposure of people and assets in hazard-prone areas. The Swiss Agency for Development and Cooperation (SADC) is active in natural hazard mitigation in Morocco. As hazard mapping for urban planning is thought to be a sound tool for vulnerability reduction, the SADC has financed a project aimed at adapting the Swiss approach for hazard mapping to the case of Morocco. The Swiss method was adapted to semi-arid environments, and to other constraints specific to the study site. Following the Swiss guidelines, a hydro-geomorphological map was established, containing all geomorphic elements related to known past floods. Next, rainfall/runoff modelling for reference events and hydraulic routing of the obtained hydrographs were carried out. Finally, a hazard map was calculated using the Swiss hazard mapping matrix that convolves flood intensity with its recurrence probability. Hazard maps become effective when implemented in urban planning. We focus on how local authorities are involved in the management process. Therefore, an institutional vulnerability "map" was established, based on individual interviews held with the main institutional actors in flood management. Results show that flood hazard management is defined by uneven actions and relationships, it is based on top-down decision-making patterns, and focus is maintained on active mitigation measures.

### **Estimation of flooding potential for Chakrood catchment by SCS method**

GHANBARI H.

*University of Payam Nour, TEHRAN, IRAN*

Flood usually occurs based on natural conditions predominated in an environment and human activities like felling trees or deforestations. So physiographical and geomorphological conditions of a catchment such as form, area, slope and river bed combined with climatological conditions like 24 hrs. precipitation can cause a place to have flooding potential. This research was done in Guilan province north of Iran. According to UTM coordinate system it is located from 445096 - 449858 ms. E to 402967 – 408374ms. N in zone 39. The highest point is 3601 meter high and the lowest point is -29 meter below sea level. Total area of the catchment is 11066 hectares and perimeter of 313047ms. The annual average temperature is 10 centigrade and has 662 mms. Annual precipitation. In order to obtain geomorphological condition, from a raster data layer(DEM) of catchment, elevation, slope, area and form was extracted from arcgis10.1 and then other layers like vegetation, soil and water source were added to the base map. With regard to 1:25000 topographic map, the catchment was divided into 34 sub-catchments ( 26 hydrological H and 8 non hydrological N). to calculate flooding potential cases like rainfall excess, time base, time of concentration, peak flood , annual peak flood, CN and unit hydrograph were calculated through the SCS method. The result shows that CN in all sub-catchments varies from at least 79 to 86 hours, time of concentration 2.2 hours, peak flood 1.2 hour and flood coefficient 0.6 . because CN factors are near to 100 and smaller time of concentration and finally refer to unit hydrograph this catchment is in risk of flooding and need to be considered as a flooding potential.

Keywords: flooding potential, Chakrood catchment, SCS method

\*\*\*\*\*

### **Flood Risk Management - A Case Study of Savitri River Basin, Maharashtra (India)**

NAGARALE V., MORE P.

*S.N.D.T.Women's University, PUNE, INDIA*

Flooding is predominantly a natural event that becomes a problem when it has an impact on people. We can't stop flooding; however, we can do more to help reduce the impacts of floods when they happen. Making better use of science and information, we can plan and target our investment to protect and prepare communities and businesses more effectively. Risk is the combination of vulnerability, cost of the elements at risk and the probability of occurrence of the event, and can be expressed as follows:

Risk = Vulnerability \* Costs \* Probability

Flood risk is defined as the expected number of lives lost, persons injured, damage to property, or disruption of economic activity due to flood phenomenon. India is the worst flood affected country in the world after Bangladesh. Flood prone area of this country is 40-45 million hectares. Therefore, various problems like ecological degradation, land use changes (upstream/ downstream) and urban floods etc. arise due to increasing flood risks.

In this paper, flood problems in Savitri Basin, present status of flood risk management, measures, their effectiveness and future needs in flood risk management are covered. River Savitri is one of the major river in Konkan Coastal Belt of Maharashtra (India). A subset area was selected along the river which measured 150 km<sup>2</sup> (10 km by 5 km) and was used as the area of interest for inundation mapping. This subset was large enough to represent the river and surrounding areas. In the present paper, flood inundation map for 2005 and 2007 flood events have been prepared and analysed. For this all HFL markings of 2005 and 2007 events were recorded. The total inundated area, total villages submerged and spatial extent of respective flood events have been computed. For this purpose ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) data has been utilized for the preparation of the digital elevation model of the Savitri River basin.

### **Flood Recurrence Analysis of River Bhima at Pandharpur in Part of Maharashtra**

UNDE M., JAWARE D.

*PG Department of Geography, Ahmednagar college, AHMEDNAGAR, INDIA*

When hydrologic events are random, it is helpful to represent their frequency as an average time between past events. Therefore, the frequency analysis is important to understand Paleoflood characteristics of the river. Identifying the magnitude and frequency of potential future floods is an essential component of any river flood study. Flood frequency analysis provides an estimate of the probability of future flood events.

Present paper aims to attempt the flood recurrence interval of river Bhima at Pandharpur. The River Bhima is flowing north to south direction near Pandharpur. The river channel takes the curvature position near the city. The several high floods recorded and demarked different locations at the river side settlements. Data for the flood recurrence interval of this site is taken into consideration to understand hydrologic characteristics of the river.

The effects of development on peak flows are generally much greater for low-recurrence interval floods than for high-recurrence interval floods. HEC-RAS model is applied to find out the probable flood recurrence interval. The 30 years discharge data is used for the analysis through Gumbel's distribution. Gumbel's extreme value distribution is based on the theory that the extreme event is unlimited and therefore the most suitable distribution to the extreme value data is double exponential type. Flood frequency is the statistical method of frequency analysis for computing the magnitude frequency relationship of the event. Flood peaks corresponding to return periods of 2, 5, 10, 25, 50 and 100 years have been considered for present study. The average flood recurrence up to 12-13 times. 10 years flood recurrence is observed is only once and 25-26 interval also found one time that is in the year 2006. It is given the previous record that the maximum flood in 1956, 1961 it has recurrence interval more than 40 years.

\*\*\*\*\*

### **Vulnerability to natural hazards in the city of Bamenda**

SAHA F., TCHINDJANG M.

*University of Yaoundé I, YAOUNDE, CAMEROON*

In the early 21st century, about 300,000 people on average each year are affected by natural hazards and nearly 78,000 people are killed. At the forefront of these natural hazards, cyclones, droughts, earthquakes and storms are the most deadly and particularly affect Asian American and European continents. Africa suffers mainly droughts, floods and mass movements. In Cameroon, the abundant rainfall, the dramatic topography in some areas are at the origin of some hazards such as floods and mass movements. Bamenda is a city in the highlands of western Cameroon with a population of 496,931 inhabitants. The city is crossed by an escarpment whose slopes are now colonized by squatter particularly at risk of landslides. The occupation of the lowlands is the cause floods every year causing significant damage. Between 1995 and 2012 floods killed at least 20 people in the city of Bamenda and extensive damage. The situation of the city of Bamenda is also compounded by many other factors, including socio-economic, cultural, institutional, political, functional and even climate. After a diagnosis of the various natural hazards that affect the city of Bamenda, we present a spatial assessment of the vulnerability by combining a number of variables at once physical, social and cultural, demographic and economic, to highlight areas that have several vulnerabilities and the consequences of damaging phenomena are likely to be higher. This vulnerability assessment leading to the realization of the risk map by the superposition of three variables: slope, land use and the various hazards.

## **Climatic and anthropogenic mechanisms of the desertification process in the Santa Maria Valley, Northwestern Argentina**

COLLANTES M., GONZALEZ L.M.

*Institute of Geosciences and Environment, National University of Tucuman, SAN MIGUEL DE TUCUMAN, ARGENTINA*

Desertification is the greatest environmental challenge facing dry regions, mainly in relation to their productive potential. In this regard, the Santa Maria valley, located in the north-western quadrant of the province of Tucumán and north-eastern of Catamarca province (Argentina), presents a severe picture of land deterioration, with a highly degraded anthropic-environmental system, standing out among causal factors, the heterogeneity of the relief, an arid-semiarid seasonally contrasting climate (with permanent hydric deficit and seasonal rainfall), surface materials highly susceptible to removal by wind and water, loss or marked decrease in vegetation cover, because of logging or diverse extractive activities, overgrazing and improper management of soil and water throughout several centuries.

In that sense, in regions such as the study area, seasonal climate variability and current multiyear oscillations occurred during the Holocene, coupled with anthropic pressure for several centuries (mainly linked to over use of the land), has generated a long chain of desertification processes, leading to the destruction of the capacity for regeneration of vegetation cover necessary or sufficient to protect the soil surface from erosion, producing a "metamorphosis" in the primitive landscape, currently restricted to a sparse shrub layer and monotonous surrounded by highly degraded soils, with few trees in areas with some moisture availability

Taking into account this geoenvironmental and anthropogenic context, this investigation analyzes the influence of current and past climate variability and human occupation, as factors of desertification. We study also, the processes linked to the geomorphological mechanisms of desertification hazard, such as water erosion, salinization of soils, wind erosion and sedimentation, stoniness (pavement), etc., and its influence in the spatial heterogeneity of vegetation and soil.

\*\*\*\*\*

## **The socialization of threat information in hazardous areas: a method for the representation of susceptibility to landslides at landholder parcel scale**

COUTURIER S.(1), HUERTA-LUNA R.(2), GARNICA R.(2), ALCÁNTARA-AYALA I.(2), HERNÁNDEZ G.(2), OSORNO J.(2)

*(1) Instituto de Geografía UNAM, MEXICO CITY, MEXICO ; (2) Instituto de Geografía UNAM, MEXICO CITY, MEXICO*

Risk management in highly hazardous areas involves preventive steps such as the socialization of threat / vulnerability information to the local population.

Specifically in less industrialized countries, disaster prevention organisms face multiple difficulties for socializing threat-vulnerability-risk information. A key component is the attempt to implement a participatory process in which information stem from different actors (at local, regional and national levels). In this process, a usual input of academic and governmental institutions for threat and vulnerability representation has been national level cartography and local level statistics. Threat representations which may be delivered to the local population involve the GIS modeling of continuous, regional scale maps. We propose an enhancement of existing spatial modeling methods using a segmented representation of land use / land cover, allowing for the representation of objects relevant to local landholders. Our method includes the segmentation of satellite imagery to produce a vegetation density classification map as an input of the landslide-risk modeling chain. The segmentation was then used to partition the continuous expression of the threat product into parcel objects instead of the traditional natural breaks partition.

This method was applied to the Chichonal area, including the Chichon volcano in the state of Chiapas, South-East of Mexico. This area has been the object of interests to create the first Geopark in Mexico. An expression of susceptibility to landslide was obtained at landholder parcel scale in the highly fragmented grazing pasture landscape. This product is meant as one of the tools of a participatory process leading to the Geopark project.

## How to evaluate the extreme vulnerability of human exposure to sea flood risks? The example of Noirmoutier island (Vendée, France)

CREACH A.

LETG Nantes-G\_olittomer / Universit\_ Nantes, NANTES, FRANCE

Storm Xynthia (February 2010) was responsible for an important sea flood. 41 people died by drowning in the flooding of low lands. Xynthia was a violent storm; it has been generated by a rare combination of different factors, even if those one were not exceptional in themselves. However the number of deaths can not be explained only by the storm in itself. Human exposure on coastal areas was also an important factor. This exposure is due to the evolution of society and to political choices: coastal areas have become attractive for tourism. This phenomenon is responsible for the development of many residential areas, increasing the pressure on unoccupied areas in coastal cities. In order to meet the new demand, many low lands formerly used for agriculture were urbanized. Moreover, many constructions were built according in a traditional architecture which is not adapted to flooding. These factors led to an important vulnerability. The relationship between architecture and the location of houses is an interesting issue. The present lecture intends discuss it.

A research is at the moment in progress on Noirmoutier island (Vendée). This low-lying island is particularly concerned with the development of urbanization for tourism activities. Although Noirmoutier was not very impacted by Xynthia, it is interesting to study the potential effect of such a storm on the island. To do so, we propose creating an indicator of "exposure to extreme vulnerability". Its aim is to make the link between architecture and the potential flooding in order to identify houses in which death by drowning may be possible.

Easy to use, this tool could be applied in many places and it could have many applications, notably for decision makers. For example it could be useful in order to locate priority interventions areas or to recommend architecture adaptations.

With sea-level rise due to climate change, such matters are becoming crucially important.

\*\*\*\*\*

## DISASTER: a GIS database on hydro-geomorphologic disasters in Portugal

ZEZERE J.(1), PEREIRA S.(1), QUARESMA I.(1), SANTOS P.(2), SANTOS M.(3), VERDE J.(1)

(1) Centre for Geographical Studies, IGOT, University of Lisbon, LISBOA, PORTUGAL ; (2) Centre for Social Studies, University of Coimbra, COIMBRA, PORTUGAL ; (3) Dynat, CEGOT, University of Oporto, OPORTO, PORTUGAL

In the last century Portugal was affected by several natural disasters of hydro-geomorphologic origin with high levels of destruction. However, data on past events related to floods and landslides is scattered, increasing the difficulty associated with the implementation of effective disaster mitigation measures. The Disaster project aims to bridge the gap on the availability of a consistent and validated hydro-geomorphologic database for Portugal, by creating, disseminating and exploiting a GIS database on disastrous floods and landslides for the period 1865 - 2010.

Data collection is steered by the concept of disaster adapted to Portugal. Therefore, any hydro-geomorphologic event is stored in the database if the occurrence led to casualties or injuries, and missing, evacuated or homeless people, independently of the number of people affected and the value of the damages, using national, regional and local newspapers as sources. Sixteen newspapers were used and 145 344 individual newspaper were analysed. All the news about hydro-geomorphologic occurrences which fulfil the adopted disaster concept was converted to digital support and stored in the database.

The database contains two major parts: (i) the characteristics of the occurrences and (ii) the damages. The first part includes data on type, subtype, date, location, triggering factor, information source and reliability of source. The second part records social damages: number of casualties, injuries, evacuated and homeless people.

In this work the main results of the Disaster data base are presented. 1622 disastrous floods and 281 disastrous landslides were recorded and registered in the database. These occurrences generated 1310 dead people. The obtained results do not show any exponential increase of events in time. Floods were more frequent during the period 1936-1967 and occurred mostly from November to February. Landslides were more frequent in the period 1947-1969 and occurred mostly from December to March.

## **Assessment of direct and indirect vulnerabilities of transportation networks impacted by debris flows in the French Alps**

*UTASSE M.(1), JOMELLI V.(1), LEONE F.(2), BRUNSTEIN D.(1), GRANCHER D.(1)*

*(1) Laboratoire de Géographie Physique, UMR 8591, CNRS, MEUDON, FRANCE ; (2) Gouvernance, Risque, Environnement, Développement, UMR - IRD, MONTPELLIER, FRANCE*

The Alps are highly impacted by debris-flows triggered by heavy rainfalls and snowmelt. Such events have important consequences on societies and communication networks located in the valley floors. If most studies focus on understanding the natural process, the concept of vulnerability defined as the propensity of an exposed element to suffer damages due to natural hazards, is still unexplored and its evaluation needs to be standardized.

This study focused on different aspects of vulnerability: structural, institutional, functional and territorial on roads at local and regional scales. Owing to many landlocked valleys in the Alps, disruption of transportation networks does not only affect damaged area, but extends to all reliant areas and activities. On a territory where the economy relies mainly on tourism activity, such indirect damages represent the major economic loss for these regions.

We selected two catchments located in very touristic valleys of the French Alps that have been affected by many Debris flows over the last decades which frequently impacted transportation networks.

A method based on a feedback scenario allowed estimating direct and indirect damages in order to provide a quantitative evaluation of drawbacks due to disruptions of the network.

We analyzed physical damages on infrastructures such as road obstruction or bridge collapse. Using numerical simulation tools, we evaluated the functional disturbances beyond the impacted area in order to highlight the territorial dysfunction of activities related to the network characteristics such as temporary breaks of traffic, bypass roads. Thus, an investigation conducted among the actors of the crisis management has led to a better understanding of both the decision-making process and the risk perception.

This approach allowed us to identify the strategic value, the vulnerability of the network and possible losses of accessibility of the territory impacted by the Debris flows at different spatial scales.

\*\*\*\*\*

## **A methodological framework to assess landslide vulnerability and resilience across different temporal and spatial scales**

*SOLDATI M.(1), GHINOI A.(1), MENONI S.(2), PATTUZZI E.(1)*

*(1) Università di Modena e Reggio Emilia, MODENA, ITALY ; (2) Politecnico di Milano, MILANO, ITALY*

Current research on global change and related impacts is also dealing with the effects of climate changes on geomorphic hazards, including landslides. It is clear that climate changes will cause a series of consequences on the environment as a result of variations in temperature and precipitation, and landslide hazard is expected to undergo a significant increase under these changing conditions. Therefore policies of risk management and adaptation to climate variations should increasingly focus on reducing exposure and vulnerability, and on increasing resilience to the potential adverse effects of climate extremes that is fundamental to prevent disasters.

The current state-of-the-art in landslide hazard assessment offers a wide variety of methods, suitable for different landslide types and for different scales of analysis. However, the ongoing changes in climate patterns require multiple-scenario analyses of landslide hazard, taking into account the most probable precipitation patterns that may occur. In recent years, an ever-growing attention has been raised in Europe, also by the geomorphological community, towards vulnerability assessment methods and also towards the assessment of resilience, i.e. the capacity of a certain community of people to face and positively react to the occurrence of a certain hazardous phenomenon. Vulnerability and resilience issues related to landslide hazard have been extensively explored by the EC-funded ENSURE Project that aimed at elaborating a methodological framework to assess, across different temporal and spatial scales, vulnerability and resilience of natural, built, social and economic systems. In addressing such a variety of systems, the framework created a bridge between the natural sciences (responsible for identifying parameters and indicators related to the natural and the built environments) and the social sciences (necessary to tackle social and economic systems' vulnerability and resilience).

## **Spatial Distribution of Slope Failures, Grand Teton National Park, Wyoming, USA**

MARSTON R., BUTLER W.

*Kansas State University, MANHATTAN, UNITED STATES*

Slope failures pose a significant hazard to campgrounds and hiking trails in deglaciated mountain canyons of Grand Teton National Park, Wyoming, USA. However, few detailed maps and statistical analyses of slope failures as hazards exist for park officials and visitors. The purpose of this study is to produce a comprehensive map of slope failures in five of the most accessible and commonly used canyons of the park: Cascade, Death, Garnet, Granite, and Paintbrush.

This project combined field surveys, LiDAR imagery, aerial photography, and GIS analyses to document four primary categories of slope failures: rock slides, rock/debris flows, rock falls, snow avalanches. The frequency of each category of slope failures was examined as a function of slope gradient, slope aspect, slope curvature. Snow avalanche source areas where debris flows were not readily present occurred most commonly on slightly convex, north- and northeast-facing slopes, with a gradient of approximately 40% gradient. Debris flow source areas occurred most commonly on slightly convex, south- and southeast-facing slopes, with a gradient 42% gradient, and on slightly convex slopes. Rock fall source areas were most common on flat, north-facing slopes, with an average 55% gradient. Rock slide source points were most common on flat to slightly concave, north-facing slopes, with an average 54% gradient. Rock Mass Strength (RMS) values were sampled at a rate of every 0.5 kilometers on the hiking trail of each canyon to provide an introductory insight into rock stability conditions in each canyon. The vast majority of slope failures originate at or near the trimline/berm created during the Pinedale age glaciation. Fault-shattering and variable weathering seems to have also played a role in all five canyons. However, distance to the active Teton Fault and lithology did not provide significant additional explanation for the geographic distribution of slope failures.

\*\*\*\*\*

## **Dynamics of Tsunami Flood related with Evacuation Behavior in the City Area Enclosed with Embankments - Analysis of 'the Tsunami Movie' recorded in Miyako City on 11 March 2011 -**

IWAFUNE M.

*Shigakukan University, KAGOSHIMA, JAPAN*

Dynamics of the tsunami flood in the city area enclosed with embankments was analyzed based on "tsunami movie" recorded in Miyako City on March 11, 2011. Changes in depth of inundation and flow speed of the tsunami flood were measured on the still images taken at intervals of 0.50 seconds of the movie. The result shows important basic information not only for human evacuation behavior from tsunami but also regional planning and education for disaster prevention.

The characteristics of the tsunami overflowed into the city were as follows:

- 1) The tsunami went ahead for about 50m within 10 seconds after overflowed the embankment. This is faster than the running speed of most people.
- 2) Tsunami flow of 20cm depth at speed of approximately 4m per second moved cars. If someone stayed in this place, they were probably swept their legs and fell down before the cars moved.
- 3) The water splashed for about 2 m high in an area about 10 m along the embankment. In this zone, someone might not continue breathing.
- 4) 28 seconds after, almost the entire ground surface was flooded. In addition, the drifted cars have gathered, and started to push houses and buildings around them.
- 5) Depth of inundation reached to 1m at about one minute after tsunami overflow. If someone stayed in this place, they must be floated away.
- 6) Flow speed changed to less than 2m per a second at 2 minutes after the tsunami overflow.
- 7) The tsunami flow reached on about 3m per a second in speed and more than 300cm in depth at 4 minutes after the tsunami overflow. Many wooden houses were started to drift.
- 8) For about 1 minute after the peak flow was recorded, drawback flow occurred and its speed was less than 2 m per a second.
- 9) Stagnant water stayed inside of the embankment after drawback flow occurred, because the embankment did not collapse. At this water condition, somebody could evacuate from tsunami flooded area by swimming.

### **Resilience of huge earthquake in Taiwan ---12 years after Chi-Chi Earthquake**

LIN J.

*Department of Geography, National Taiwan University, TAIPEI, FRANCE*

It has been 13 years after Chi-Chi earthquake in 1999. The damage of earthquake together with typhoons caused Taiwan huge damage and loss since 1999. This paper try to demonstrate the impacts of earthquake and typhoon and resilience of the study area from earthquake and typhoon damage.

By comparison of satellite images and aerial photos, Tachia river catchment and Chenyeulan river catchment have been demonstrated as these two catchments are most typical examples.

It is found that the evolution of landslides could be traced by different periods of aerial photos and field study. The evolution of landslide could be clearly documented and useful for comparison of hazards.

Landslides caused by earthquake and heavy rainfalls could evolve in three types: type 1 is recovering by vegetation which is hardly to identify previous landslide in five years' time; type 2 is quite unstable. Most of the type 2 landslide could occur at the same site after each heavy rainfall event. Type 2 landslide is still unstable 13 years after Chi-Chi earthquake. Type 3 landslide is new landslide. Most of the size of type 3 landslides are relatively small.

The resilience of impact from earthquakes is still not stable. In comparison with Kobe earthquake, the sedimentation load went back to normal in five year time. However it is still higher than before the earthquake on the study area at the same periods according to the gauging station data

Typhoon together with heavy rainfall is the main factor to cause such unstable situation. This study demonstrates such complicated situations.

\*\*\*\*\*

### **EADaS: A reference system for predicting possible geomorphic disasters in Japan**

SUZUKI T.(1), SHIMAMURA M.(2)

*(1) Chuo University, TOKYO, JAPAN ; (2) JR East Professor, Department of Civil Engineering, The University of Tokyo, TOKYO, JAPAN*

The EADaS is a software to predict possible geomorphic disasters at given site in Japan by examining the combination of Environment, Agent, Disaster mode and Structure at a target site. The main part of the software contains the combinations of the elements of disaster-related environment at a site and the frequency of the 90 disaster agents which possibly occur at the site. On the environment, are listed 225 questions including a total of 1450 choices for the characteristics of environmental elements. The user of the EADaS, however, does not have to answer all the questions. The user chooses one or two answers from 2 to 20 choices for the first question concerning the characteristics of environmental element at the target site, then the next question will be shown automatically according to the previous answer by the EADaS, and so on. The frequency of 20 disaster modes caused by each agent and also the risk of 135 structures caused by each disaster modes are automatically shown by the EADaS. The results of examinations are shown by the total value of the frequency of each of the 90 disaster agents at the site (e.g. from 0 to 2,737 for landslide: The past landslides had occurred at the sites more than 1,000). Since this kind of threshold differs from each agent, such a permissible threshold is determined on the basis of the minimum value in the past disasters records, although the threshold should be carefully revised just like the medical examination. The merit of the EADaS is that the risks of every possible disaster at the target site are predicted by the values for each agent automatically, because various disaster agents are simultaneously triggered by a strong agent at a site. For examples, flood, lateral erosion, landslide and/or debris flow are possibly induced by a big typhoon. The EADaS can be modified for any regions of the world by local geomorphologists.

### **Earthquake induced landslides susceptibility assessment: Roles of topography, geology and seismology**

TAKEZAWA N.(1), UCHIDA T.(2), ISHIZUKA T.(1), HONMA S.(3), KOBAYASHI Y.(3)

(1) *Public Works Research Institute, TSUKUBA, JAPAN* ; (2) *National Institute for Land and Infrastructure Management, TSUKUBA, JAPAN* ; (3) *Kokusai Kogyo, Co.Ltd, TOKYO, JAPAN*

It has been considered that topography, geology and seismic waves gave large impacts on the size and susceptibility of earthquake induced landslide. However, to quantify these effects, we have to analyze landslide maps from a variety of earthquakes, geological settings and topography. Using landslide maps from the epicentral areas of four Japanese earthquakes, Kobe in 1995, western Tottori in 2000, Chuetsu in 2004, and Iwate-Miyagi, 2008, we have investigated the roles of topography, geological settings and seismic waves over the location of earthquake induced landslide.

We found that the slope angles, bedrock geology and the distance from fault controlled the landslide susceptibility. Moreover, relationships between the distance from fault and the ratio of landslide area were not different each slope angle and each bedrock geology. It means, the seismological factors related to landslides susceptibility were depended on slope angles.

Furthermore, we found that there were large differences in landslide area-frequency relationships. In the epicentral areas of Kobe and western Tottori earthquakes, small shallow landslides were dominant, while in the epicentral areas of Chuetsu and Iwate-Miyagi earthquakes, a number of large scale landslides were occurred.

This difference cannot explained by slope angle and the distances to fault break. While, we found that the susceptibility of large scale landslide increased with the increase of relief, indicating that topography is one of main control of seismic landslide size.

\*\*\*\*\*

### **Hazard Risk Assessment in North Cyprus: Sheet Floods, Flash Floods and Floods**

KUTOGLU S.

*Turk Maarif College, NICOSIA, CYPRUS*

The intensity and frequency of the hydro-meteorological hazards have been increased in the last two decades in North Cyprus. Together with almost all of the developing countries, North Cyprus is also highly vulnerable to natural disasters. Lack of scientific researches, limited economic resources and widespread improper land-use are the most important reasons for this vulnerability. The purpose of this paper is to present the causes and effects of sheet flood, flash flood and flood disasters and to show the evidences of improper land-use in North Cyprus. There are different factors which affect the formation and the intensity of flooding. In order to specify these factors several maps with different scales and topics such as vegetation, soil, geology, landuse, aspect, dems, slope, topography and geomorphology have been digitized and produced. To determine the degree and zoning of flooding risk in North Cyprus these maps have been overlaid in ArcGIS spatial analysis software program by using raster calculator module. The primary objective of these maps is to identify the hazard prone areas and the distributions of sheet floods, flash floods and floods in North Cyprus. Moreover, these maps are also designed to help the constitutions and corporations of North Cyprus dealing with such geomorphological problems in order to formulate the legal regulations. The implementation of such regulations will directly affect mitigation and will reduce vulnerability rate of such hazards and will increase the capacity to cope with floods. In conclusion, these attempts will contribute to the sustainable development in North Cyprus.

Keywords: Sheet Floods, flash floods, floods, improper landuse, geomorphology, risk assessment, vulnerability, ArcGIS, North Cyprus

### Urban risk in the Yaoundé VII district

GHOMSI H.D., TCHINDJANG M.  
University of Yaoundé I, YAOUNDE, CAMEROON

In developed countries, measures are taken in terms of prevention, management or forecasting risk. Paradoxically in developing countries, the challenge of a taken official awareness of the presence of the remaining risk to overcome. The evidence is that 90% of victims and 75% of the economic damage resulting from natural and health disasters occur in developing countries and especially in their cities. Indeed, the urban population believes a priceless speed (17% in 1950 and probably 57% by 2025 according to WRI, 1990). The scale of the city of Yaoundé, Cameroon to see its population increased from 1.8 millions in 2005 (RGPH) to 2.5 million in 2012. This growth ignores environmental requirements for the resurgence of the risks (landslides in Oyomabang in 2000 and Mbankolo in 2012; to Nkolbisson flood in 2008 and 2012). However, to develop strategies to reduce the harmful consequences of urban risks in the District of Yaoundé VII, susceptibility to risk is evaluated by a probabilistic bivariate (theory of obviousness) model. This model analyzes the mathematical relationships between environmental factors of predisposition and spatial occurrence of past and present risk. The mapping of the areas a risk was conducted on the basis of an amount associated with the hydro-morphological method. This approach provides a mapping exhaustive and homogeneous of the maximum allowance for potentially vulnerable areas across the borough, allowing to identify areas that may be urbanized without imminent danger, because it relies on visible topographic structures. Thus, the results of this work could contribute to the improvement of land management, urban planning and management of urban risks in Yaoundé.

\*\*\*\*\*

### Application of digital orthophotos and digital terrain models to investigate of surface evolution in Tsaoling landslides, Taiwan

CHEN R.(1), WU R.Y.(2), KUO C.Y.(2), CHANG K.J.(3)  
(1) Chinese Culture University, TAIPEI, TAIWAN ; (2) Research Center for Applied Sciences, Academia Sinica, TAIPEI, TAIWAN ; (3) Department of Civil Engineering and Graduate Institute of Civil and Disaster Prevention Engineering, TAIPEI, TAIWAN

On September 21 1999, a catastrophic earthquake occurred in the mountainous Tsaoling area in Central-Western Taiwan, at epicentral distance of about 35 km. Chi-Chi earthquake (ML=7.3) triggered two huge landslides at Jiufengershshan and Tsaoling, Killing 39 and 29 persons, respectively. We focus on the Tsaoling landslide, from the point of view of historical landslide event, the occurrence of successive landslides in the Tsaoling area during the last century. Multiple (five) gigantic landslides have been recorded in the Tsaoling landslides since 1862 and the latest landslide was triggered by the 1999 Chi-Chi earthquake. After Chi-Chi earthquake, it is found that the surface process is fast and the rapid topographic change benefits the studies of landslide mechanism, active tectonics and geomorphologic evolution. To understand the impact of earthquake induced landslide on short-lived sediment budgets and suspended sediment transported in the Chingshui River. In this paper, we use aerial orthophotos to generate high-resolution digital terrain models (DTM) are generated for the investigate period. These DTMs are inspected by three ten-year comparisons (1979-1989, 1989-1999, 1999-2009) for long-term geomorphologic evolution and followed by short-term evaluations after Chi-Chi earthquake (1999-2009). Our observations from the Chingshui River near Tsaoling indicate that despite upstream sediment accumulation resulting from landslide damming, landslides undoubtedly facilitate erosion, because disrupted landslide masses are quickly eroded. The study of the Tsaoling landslide suggests that the probability for further major landslide events is high, which deserves consideration in terms of natural hazard mitigation. Topological information in front of the orogenic belt of Taiwan and activity rates are addressed and calculated.

**Landslide identification and mapping based on the interpretation of a stereo pair of Very High Resolution satellite images (VHR) for the production of a landslide inventory for the municipality of Pahuatlan, Mexico.**

*MURILLO GARCIA F.(1), ARDIZZONE F.(2), FIORUCCI F.(2), CARDINALI M.(2), MONDINI A.(2), ROSSI M.(2), GUZZETTI F.(2), ALCÁNTARA AYALA I.(3)*

*(1) A) Posgrado en Geografía, Universidad Nacional Autónoma de México, MEXICO, MEXICO ; (2) B) Consiglio Nazionale delle Ricerche, Istituto per la Protezione Idrogeologica, PERUGIA, ITALY ; (3) C) Departamento de Geografía Física, Instituto de Geografía, Universidad Nacional Autónoma de México, MEXICO, MEXICO*

The Pahuatlan municipality is in the Sierra Norte de Puebla region, Mexico. The landscape is mountainous and is characterized by deep ravines; the highest reliefs correspond to the Sierra Madre Oriental. Mesozoic rocks outcrop in the region: conglomerated, shale, siltstones and limestone. Landslides, which are diffused and frequent in the territory, play an important role in the evolution of landscapes and represent a serious hazard for the population in this area. In this work we present a multi-temporal inventory map for Pahuatlan, which will be essential for geomorphological studies, especially in understanding the evolution of the landscape processes and evaluating landslide hazard and risk.

New remote sensing technologies are proving very useful for detecting and mapping landslides. For this study, pan sharpening fused stereo pairs of images from a Very High Resolution images satellite (VHR) were acquired from the GeoEye 1 sensor from March 2010 and were used to build a stereoscopic 3D digital model. A Planar StereoMirror™ stereoscope system was used to perceive the 3D effect. The 0.5 m spatial resolution of the images was adequate for mapping landslide features. The hardware and software systems simplify the acquisition of morphological information and directly allow the digital mapping of faults. The data obtained by the interpretation of the stereoscopic model were complemented with information from other inventory techniques and tools such as the revision of historical data, field surveys and the analysis of monoscopic images.

We obtained a digital multi-temporal landslide inventory map of the study area that shows 301 recent landslides, 170 old landslides and 22 very old landslides. The data of the landslide inventory were used, together with the Double Pareto function, to obtain the relative size-frequency distribution of landslide area. We, also, analysed the spatial persistence of the recent landslides with respect to the pre-existing landslide areas.

\*\*\*\*\*

**Geomorphic risk assessment and management in the context of global change**

*BONACHEA J.(1), FORTE L.M.(2), HURTADO M.(2), BRUSCHI V.M.(1), RIVAS V.(1), GÓMEZ-AROZAMENA J.E.(1), REMONDO J.(1), CENDRERO A.(1)*

*(1) Universidad de Cantabria, SANTANDER, SPAIN ; (2) Universidad Nacional de La Plata, BUENOS AIRES, ARGENTINA*

Natural disasters due to geomorphic processes appear to be growing in most regions of the world. This is often considered to be a consequence of climate change. Geomorphic hazard and risk management are strongly dependent on our ability to appropriately assess future frequency of potentially dangerous geomorphic events. This, in turn, depends on our knowledge of past trends and understanding of factors that determine them.

Global, continental and regional data on the frequency of hydrogeomorphic disasters during the last century are presented and compared with potential natural (rainfall) and human (activities that modify land surface) drivers. Data so far available suggest that there is a marked increase in the frequency of those disasters from around the middle of last century. Of course, there is small doubt that intense rainfall is the main immediate trigger of floods and landslides, but precipitation does not seem to explain their growing frequency. Comparisons and correlations between disaster frequency and potential drivers suggest that climate change plays a minor role in the intensification of geomorphic processes and that the observed increase is caused mainly by the alteration of the surface layer. In other words, they seem to be driven by "global geomorphic change". This change reduces surface layer resilience and enhances geomorphic processes in general. Indeed, land surface modification and consequent increase in the intensity of geomorphic processes appear to be one of the characteristics of the Anthropocene.

As the magnitude of geomorphic change is directly linked to population and economic growth, it is reasonable to assume that trends observed during the last century will continue during the present one. Therefore, it is important to verify the proposed hypothesis. If it were correct, to find clues for better managing geomorphic hazards in the future we should not look up to the clouds, but down to the ground.

## **Integrating Environmental Indicators to Diagnose Desertification Risk Zone in Indian Arid Lands using Geo-Spatial Approach**

SIDDIQUI A.

*Department of Geography, University of Allahabad, ALLAHABAD, INDIA*

Desertification is a land degradation problem of major importance in the arid region of the world. It involves long term changes in the floral and faunal characteristics, its biological potential and carrying capacity. The size, remoteness and harsh nature of many of the world's desert make it difficult and expensive to map or monitor these lands as well as to determine the effect of land use on them. Remote sensing has long been suggested as a time and cost efficient method for monitoring change to desert environment, since it can serve both to enhance monitoring efforts as well as provide valuable information on dry land degradation in specific areas. The present study has been undertaken to diagnose the desertification risk area in Churu district (27°24' to 29°0' N and 73° 51'49" to 75°40'20"E) of Western Rajasthan in India covers an area of 13,740.95 km<sup>2</sup>. The area encompass nearly 12.40% of Indian arid land, is endemic to desertification by different measure, endangering the sustainability of nearly two million population and a still larger livestock population.

The main objective of present study to develop cumulative index to measure varying intensity of desertification in the study area based on selected indicators of climate, soil and vegetation to identify desertification risk zone using remote sensing and GIS. In order to arrive a cumulative map of desertification various information layers like soil texture, soil depth, organic carbon, aridity indices, land use/land cover, wind erosion susceptibility and water table heterogeneity have been processed. Soil samples have been collected from the field to estimate soil organic concentrations in different land use systems. It has been observed that there is regular gradient of increasing desertification is seen towards western margin and north western margin of the study area due to cumulative impact fragility of ecosystem.

\*\*\*\*\*

## **Methodological approach for mapping landslide risk areas, based on brasilian public policy**

CANIL K., MACEDO E.S.D., GRAMANI M.F., MIRANDOLA F.A., SILVA F.C., CORSI A.C.

*Instituto de Pesquisas Tecnologicas do Estado de Sao Paulo, SAO PAULO, BRAZIL*

Based on the Program of Urbanization, Regularization and Integration of Precarious Dwelling Areas proposed by Brazilian Federal Government, it is presented the guidelines of methodology developed by IPT to map risk areas of landslides processes. It involves the indicators that characterize geological-geotechnical processes related to landslide risk and of the social context exposed to such risk. Landslides are natural processes, triggered or accelerated by intense or prolonged rainfall, leading to sudden changes in groundwater levels; undercutting of a slope or cliff by erosion or excavation; shocks or vibrations resulting from construction; removal of (natural) vegetation; and overburden on steep slopes. The main criteria used to map these areas are: building material (brick, wood, corrugated iron, concrete, etc.); terrain characteristics: natural and man-made slope (height and declivity); top and base distance from dwellings; type of existing deposits on natural or man-made slopes (garbage,landfill); evidences of mass movement (presence of fissures in dwellings and in the terrain; steps of subsidence; curved walls; tilted trees, poles, walls; landslide scars); water action: rainwater concentration on the surface; release of wastewater on the surface, water leaking, piping; surface drainage (enough, precarious or satisfactory); land cover vegetation (presence of trees, underbrush, grass; cultivation area, or deforestation area); kinds of instability processes expected (landslides in natural or man-made slope; landslides in landfill, erosion, debris flow, falling and rolling of blocks).After identifying the risk indicators, it is possible to evaluate the risk level on the basis of the probability of occurrence of landslides (Low, Medium, High and Very High Risk). It is worth mentioning that this mapping is valid for a year only because of the constant changes caused by the weather (in particular the rainy seasons in tropical areas) and human activities.

## Hydrogeomorphological mapping: current uses and perspectives for floodplains management

MONTANE A.(1), VINET F.(2), BUFFIN-BELANGER T.(3), VENTO O.(4)

(1) BURGEAP / Université Montpellier 3, AVIGNON, FRANCE ; (2) Université Montpellier 3, MONTPELLIER, FRANCE ; (3) Université du Québec à Rimouski, RIMOUSKI, CANADA ; (4) BURGEAP, AVIGNON, FRANCE

In France, the hydrogeomorphological mapping has been considered for over 20 years as an efficient method of flood mapping contributing to the sustainable development of territories by taking into account the occurrences of extreme events. This communication aims at providing an overview of practices related to their spatial logics, as well as future developments related to the implementation of the European Flood Directive (2007/60/CE), the progressive development of hydrogeomorphological mapping in Quebec and the gradual diffusion of Lidar DEMs. Several examples from rivers in France and Québec are used to illustrate these developments.

The use of hydrogeomorphological mapping has evolved over time from a simple knowledge to its integration in urban planning documents (PPRI). Important regional differences related to the nature of rivers, flood data availability and also to administrative divisions remain when implementing the method. This has led to the development of various hydrogeomorphological mapping.

The hydrogeomorphological mapping has shown great potential. However, many actors are critical because of the lack of quantification of water depth, but also because of the "geomorphological" skills needed for its comprehension that a general audience may not possess.

The current dissemination of Lidar DEMs and the introduction of concepts such as "extreme events" in French law after the Flood Directive caused new interest for the use of that mapping. Medium resolution DEMs have allowed for several years to develop the automatization of hydrological calculations. Lidar DEMs which are high resolution DEMs, set to develop the automatization of geomorphological forms description. The development of Lidar DEMs can also help to produce Digital Model of Flooded Area (DMFA), which represents the heights of water for an extreme flood. It appears to be a useful tool to communicate on extreme floods and to help flood risk management in floodplains.

\*\*\*\*\*

## Dendrogeomorphological research applied to flood hazard analysis in the 'Caldera de Taburiente' National Park (La Palma, Canary Islands, Spain)

DIEZ-HERRERO A.(1), GENOVA M.(2), MAYER P.(3), BALLESTEROS J.A.(1), RUBIALES J.M.(2), SAZ M.A.(4), BECERRIL L.(1), HERNANDEZ M.(1), GUTIERREZ-PEREZ I.(5), BODOQUE J.M.(6), RUIZ-VILLANUEVA V.(1)

(1) Geological Survey of Spain (IGME), MADRID, SPAIN ; (2) Technic University of Madrid, MADRID, SPAIN ; (3) University of Las Palmas de Gran Canaria, LAS PALMAS DE GRAN CANARIA, SPAIN ; (4) University of Zaragoza, ZARAGOZA, SPAIN ; (5) Ferrovial-Agroman, MADRID, SPAIN ; (6) University of Castilla-La Mancha, TOLEDO, SPAIN

Las Angustias torrent is an ungauged stream located in the 'Caldera de Taburiente' National Park (La Palma, Canary Islands, Spain), where frequent and intense flash flood events occur, even causing fatalities (such as in November 2001) and important economic damages (over 700,000 euros in the last two years). The aim of this research is to analyze the flood hazard at one of the most visited areas of this protected park (more than 60,000 hikers per year).

The classic data sources and methods (hydrological and hydraulic modelling) for flood hazard analysis have important shortcomings regarding the lack of information (i.e., precipitation and flow data) in Las Angustias basin; and due to the low statistical representativity of time series, which normally leads to under- or over-estimated results. So, a detail **dendrogeomorphological study** of the river system was carried out and 65 Canarian pine trees located at the stream bed and banks showing external evidence of flash floods damages, as scars or exposed roots, were sampled using Pressler borer. More than 150 tree-ring cores were analyzed and measured using binocular microscope and a LINTAB semi-automatic measuring table, with the TSAPWin and Cofecha softwares, looking for evidences of past flood events. In addition, a detailed topographical survey using GPS and total station allowed us to obtain the inputs for hydraulic modelling.

As **preliminary results**, two recent flood events have been well identified, corresponding to the winters 1962-1963 and 1990-1991; and evidence of flood events in other dates has been observed (1920, 1976, 1983, 1993 and 2001). The magnitude reconstruction of these events, using 2D hydraulic models, will improve the flood hazard and risk analyses and will be useful for National Park managers to land use and visitors planning. These studies are funded by the Spanish Ministry of Agriculture, Food and Environment by means of the research project IDEA-GesPPNN (OAPN 163-2010).

**Protective role of planted alder trees in capturing debris flow material, Moxi Basin, Sichuan Province, China**

*MALIK I.(1), OWZAREK P.(2), YONGBO T.(3), WISTUBA M.(1), PILORZ W.(1)*

*(1) University of Silesia, KATOWICE, POLAND ; (2) University of Wroclaw, WROCLAW, POLAND ; (3) Chengdu Center of China Geological Survey, Chengdu University of Technology, CHENGDU, CHINA*

In the Moxi Basin, at the foreland of high mountains surrounding Tibetan Plateau, moraines are strongly dissected by debris flows. At mouths of debris flow gullies vast and flat debris flow fans develop. On their surfaces – available for building development and agriculture – villages are located. During monsoon seasons debris flows are triggered by heavy precipitation and can reach inhabited fans. Flows deliver rock material and by this cause destruction of houses and death of people. At mouths of debris flow gullies alder trees (*Alnus nepalensis*) are planted by local inhabitants in order to protect villages against debris flows. In areas overgrown by alders we have found numerous boulders captured by individual trees. Many trees were injured and tilted by rock material from debris flows. This enabled dendrochronological studies on: (1) tree reaction to stress connected with debris transport and delivery, (2) frequency of debris flow occurrence recorded in tree rings, (3) role of alder planting in protection against debris flows. Dating scars and stem tilting have revealed that small flow events occur every 2-3 year in the study area. Large debris flows, threatening houses built on debris flow fans occurred two times during the last 20 years (1996, 2005), but alder trees were able to capture debris transported, weaken the energy of mass-movement events and protect houses and inhabitants.

\*\*\*\*\*

## **Poster presentations:**

### **Hazard Management in a Debris Flow Affected Area ' Spreitgraben, Switzerland**

*KULL I., TOBLER D.*

*GEOTEST SA, ZOLLIKOFEN, SWITZERLAND*

Since 2009 several extremely erosive debris flows have occurred in the Spreitgraben near Guttannen (central Switzerland). They were initially triggered by rockfall events and started with small and harmless flows. Within three years they have increased to become destructive events with an enormous hazard potential. Strong erosion along the debris flow channel caused considerable depositions in the receiving stream. A total of 650,000 m<sup>3</sup> bedload has been deposited to date. Due to the scale of the erosion and deposition processes, no constructive protection measure can be implemented to stop the process evolution.

Important infrastructures are increasingly affected; the major gas pipeline between Germany and Italy had to be relocated and two houses had to be abandoned. The main pass-road is endangered in different places and has already been locally destroyed. The only reasonable solution to confront these natural hazard processes is land use planning, in order to avoid any human activity in this increasingly dangerous area.

As a matter of urgency a vast, sophisticated early warning system has been established. A profound knowledge of the ongoing processes is the precondition for reliable hazard and risk management. Scenario-based debris flows have been simulated for the near future in order to estimate the deposit progress of depositions and to define areas at risk. These simulations form the basis for the safety and monitoring concept. A project handbook defines the role, tasks, responsibilities and cooperation among all affected infrastructure owners and public authorities.

The presentation focuses on the hazard management in a highly endangered area with enormous vulnerability. The devastating debris flows are forcing the authorities to adapt yearly to new situations. Due to the high event-frequency in the Spreitgraben, the established system has already been approved after only three years – a unique case in Switzerland.

\*\*\*\*\*

### **The assessment of the risks of gully erosion activation in urbanized areas**

*OSINTSEVA N., KWASNIKOWA Z.*

*Tomsk State University, TOMSK, RUSSIAN FEDERATION*

Scientific studies of geographers of Tomsk State University laid the foundation for systematic evaluation of activation risks of gully-formation in urbanized areas of the western Siberian South-East. The investigations were carried out in sub-taiga zone in the city and suburbs of Tomsk.

Risks factors causing gully erosion on above - mentioned territories are as following: natural and anthropogenic. Under natural conditions active gullies are scarce and are found in separate spots. The total length of gullies in natural sub-taiga landscape does not exceed 100 m/km<sup>2</sup>, and gully density is not more than 10 gully heads /100 km<sup>2</sup>.

The anthropogenic factors increase the risks of gully erosion, cause new areas of erosion and activate already existing gullies. It is ploughing, forest clearing, destruction of soil-tree cover, changes in conditions of surface runoff. Gully erosion is progressing more on urbanized territories. So, total lengths of gullies on the territory of Tomsk amounts to 1,6-2,0 km/km<sup>2</sup> on separate spots, and its density - up to 10-30 gully heads/km<sup>2</sup>.

The authors suggest evaluating of gully erosion risks in urbanized areas taking into account natural and anthropogenic factors together. As risk criteria we can consider: 1. Gully erosion rate: polygonal and time. Polygonal rate is assessed by means of the indexes of gully damage: total length, density, gully frequency, gullying (the proportion of gully area to total area), total amount of gullies. The time rate of gully erosion is assessed by means of the following indexes: linear velocity of gully increase, increase in its area, volume, anabranching, the change in total amount of gullies. 2. The index of activation of gully erosion, as a proportion of the amount of active gullies to the total amount of gullies on a certain territory. 3. The potential of developing of gully erosion, that is maximum numbers of gully erosion rate under the conditions set.

### **Susceptibility to natural hazards in two peri-urban neighborhoods Yaoundé: case study of Akok-Ndoué and Mvog Betsi**

MUJIA FOFACK G.G., TCHINDJANG M.  
University of Yaoundé I, YAOUNDE, CAMEROON

Natural hazards affect the entire planet. According to a UNDP report in 2004, nearly 75% of the world's population live in areas which recorded at least once a year a risky phenomenon, and 11% of it fits in low income countries, including Cameroon. In general the risks to the natural environment affect many cities of Cameroon (Bafang landslides in 2008, floods in repetitions in North and Far North Cameroon (Benue and Maga in 2012) or more specifically, Douala city floods. Yaoundé is particularly exposed to these risks because of its physical environment and socio-economic factors. Excessive urban growth recorded for more than three decades, is reflected in the spatial plan by humanization of the suburban area of the city mountains with steep slopes on which are piled without management plan, poorest urban population.

What is the effect different degrees exposure of these two peri-urban quarters to floods and landslides? This study aims at the mapping of landslides and floods, thus highlighting the degree of vulnerability to these risks in neighborhoods Akok-Ndoué and Mvog Betsi areas. It will achieve Prevention and Management Risk Plan (PMRP) that can reduce and minimize the level of corporal and structural damage. Choosing the Susceptibility risk approach from Malet et al, 2006, it built a map of the total risk taking in consideration several parameters: slope map after the topographic map of Yaoundé 1/10 000, soil, land occupation, infrastructure by diachronic treatment of satellite images and the population density. Finally, we crossed the results obtained above to get a total risk map with different degrees of exposure of different areas of these two districts. It appears from this study that the different sectors of the peri-urban area of Akok-Ndoué and Mvog Betsi (South-West of Yaoundé) are exposed differently to natural hazards according to the different parameters considered.

\*\*\*\*\*

### **Characterization of natural hazards in peri-urban areas: the case of Mont Febe (Yaoundé)**

YOUNDIE., TCHINDJANG M.  
University of Yaoundé I, YAOUNDE, CAMEROON

The consequences of natural hazards concerned. The occurrence of disasters to heavy balances raised the problem of security for the population. The floods in West and Central of August 2012 Africa attest to their vulnerability. The city of Yaoundé is not immune to these crises. At the Mont Febe, the loss of 3 lives following a landslide on May 15, 2012 proves it. In fact, sprawl of cities raises the problem of the fragility of the natural environment. In Cameroon, approximately 52% of the population lives in the city with more than 2 million to Yaoundé. This study aims to show how the conditions of the natural environment of the Mont Febe; Yaoundé anarchic urbanization and human activities, fit together to make vulnerable residents. The vulnerability assessment is based on a systemic approach that proceeds by steps and field surveys. After making a map of the slopes from the topographic map of Yaoundé, we made a map of deforestation of the slopes, then the soil map. From a Google earth image, found the map of land cover, and have superimposed across to make the map of susceptibility that, combined to the FTAA we informed on the problem of landslides on this site. Human surveys provide information on the history of risk in the sector and the perception of the populations of these phenomena. It is clear that the Mont Febe, heavy precipitation; steep slopes where human activities leave pockets of deforestation; shallow soil; disregard of hazard and the laxity of the authorities enable the landslides. To resolve the problem, we have from the map of susceptibility, proposed a plan of development of the site. In a context where human installation usually precedes urban planning, it is urgent to reverse the trend.

**Influence of deforestation and reforestation to landslide occurrences in the granite region—Case in Mt. Ichifusa area, in central Kyusyu, Japan—**

MURAKAMI W., DAIMARU H.  
FFPRI, TSUKUBA, JAPAN

In this research, the relation among the forest management records, the landslide occurrences and the rainstorm records of about 30 years in the past was examined in the granite region. The study area is located on the north side of Mt. Ichifusa that is on the boundary in Kumamoto Prefecture and Miyazaki Prefecture, in the central Kyusyu, Japan. We interpreted aerial photograph and mapped the vegetation change and the landslides (location of occurrence and area) in 1969, 1976, 1980, 1985, 1990, 1995, 1999, and 2005. And the normalized Soil water Index was calculated from the rainfall record for the period.

Extensive deforestation had begun since around 1967, and the forest in the site of about 70 % on the study area had been deforested by 1976. Landslides occurred frequently after the deforestation, such as during periods of 1976-1980, 1980-1985, and 1990-1995. In these periods, many landslides occurred in the deforested area, while few landslides occurred in the non-deforested area. Moreover, in the site that had been afforested after the deforestation, the tendency for the occurrence of the landslides to be suppressed was shown. In the order the normalized Soil water Index, the rainfall during the period that the landslides occurred entered the high rank, however, too much a lot. Therefore, it was suggested that the landslides had occurred by small rainfall relatively, since the deforestation.

\*\*\*\*\*

**A genetic typology of glacial lakes in regard to their hazard potential in the Cordillera Blanca (Peru)**

ITURRIZAGA L.  
Institute of Geography / University of Goettingen, GOETTINGEN, GERMANY

The presentation focuses on the environmental conditions of the formation of glacier lakes and their distribution in terms of their specific hazard potential in high mountain regions of the tropical Andes. Glacier lakes are one of the most striking landscape elements of the recent global trend of glacier retreat. Glacial lake outbursts have produced multi-stage, high-magnitude geomorphological events with considerable damage for settlements and their infrastructure located down- and upstream of the glacier lakes. Since the mid of the 20<sup>th</sup> century in the Tropical Andes proglacial lakes have formed exponentially, generally dammed by Holocene (Neoglacial / Little Ice Ages) morainic arcs. They may attain a size in the range of about several kilometres in length and a volume of up to about 100 Mio. m<sup>3</sup>. The Cordillera Blanca shows in comparison with other mountain regions extremely homogenous topographical and climatic conditions and therefore a rather systematic distribution of the lakes in their hypsometric and central-peripheral arrangement. A genetic classification of glacier lake types will be presented for the Cordillera Blanca. The environmental conditions of their formation will be discussed as a function of topographical, climatic and sedimentary influences. Glacier recession may be connected with lake formation, but only certain glaciers are prone to the formation of glacial lakes. Apart from the eye-catching and well recognizable proglacial lakes on satellite images, the more “invisible” glacial lakes and other water reservoirs, may pose a latent threat. Their prediction and the technical capabilities of their hazard management are rather limited. The investigations have been financed by the Alexander von Humboldt-Foundation.

Iturrizaga, L. (2011): Glacier lake outburst floods. In: Singh, V.P., Singh, P., Haritashya, U.K. (Eds.), Encyclopedia of Snow, Ice and Glaciers, Springer, 381-399.

### **Demarcation of landslide risk in highland of Sri Lanka using geomorphological setting, environmental and climatic conditions**

WICKRAMASOORIYA A.

*South Eastern University of Sri Lanka, SAMMANTHURAI, SRI LANKA*

Highland which has an altitude greater than 1200 m is the highest peneplain out of there peneplains in Sri Lanka. Topography and the climatic conditions of this region vary with place to place. There are different geomorphologic features such as very steep slopes, scarp slopes, valleys; etc can be observed in this region. Highland gets the highest rainfall during Southwest monsoons from May to September and during inter-monsoon period from March to April. Although the average annual rainfall of the area varies from 2700 mm to 4200 mm, occasionally at certain places on the Southwest slope record more than 5000 mm. Because of its geomorphological features and recording heavy rainfall during many months of the year, highland has been experiencing severe landslides and floods during last two to three decades. With experiencing such events, many environmental and socioeconomic issues arise in this region. Proper monitoring methods have to be implemented to minimize the impacts created by landslides and floods. Landslide risk areas have to be identified prior to monitor them. Therefore, this study is focus on demarcating the landslide risky areas in the highlands. Five main parameters influence on landslides i.e slope, rainfall, soil type, landuse pattern and population density of the area were considered to demarcate landslide risk areas. Arc GIS software has used to produce five different thematic layers for above parameters. Using Principal Component Analysis method, different weightages ( $W_i$ ) were assigned for these parameters based on the degree of their influence on creating landslide risk. Different Ranks ( $R_i$ ) were introduced for different conditions of each parameter based on their effect on creating landslides. Landslide Risk Index (LRI) was introduced based on weightages and ranks. Finally, landslide risk map was prepared based on Landslide Risk Index using Erdas Imagine software. According to the map, 15% of the study area has very high landslide risk.

\*\*\*\*\*

### **High- and low-frequency morphodynamic events and natural risks in mountain catchments of the semi-arid Brazilian 'Nordeste': Crato (Ceará)**

DE OLIVEIRA MAGALHEES A.(1), PEULVAST J.P.(2), BETARD F.(3)

*(1) Université Paris-Diderot Paris 7, PARIS, FRANCE ; (2) Université Paris-Sorbonne, PARIS, FRANCE ; (3) Université Paris-Diderot Paris 7, PARIS, FRANCE*

Usually known as prone to severe droughts, the inner Northeast Brazil ("sertão") is still hardly considered as an area of hazards and risks related to violent geodynamic events. However, such past or present phenomena are now recognized in a few humid mountains exposed to the trade-winds, such as the eastern "Chapada do Araripe", a high tabular sandstone plateau (900-1000 m) located at the border between the Ceará and Pernambuco states. Here, a 400-500 m high cuesta-like scarp covered by a dense forest overlooks drier dissected lowlands. The city of Crato (110,000 inhabitants) is built along one of its short rivers, the Rio Grangeiro, 4 km from the rim. Whereas existing works only bear on current dynamics, flash-floods, gullying, and small-scale mass movements, we consider a wider range of phenomena. So far, only the violent floods that periodically occur along the Grangeiro River have been taken into account in urban management, with the construction of a 2 km long concrete canal through the city. According to our analysis of climate-hydrological data over the last decade, big floods aggravated by this inadequate canalization have devastated the centre almost every year. Our study of landforms and deposits in the city and upstream also evidences largely distributed marks of past large-scale debris flows and landslides, showing that recurrent gravitational dynamics are usual processes in scarp evolution. Since such phenomena induced by favourable climatic and geological factors still might occur in a now densely populated area, and since some of them were catastrophic, they must be included in the list of natural hazards and risks, in spite of their absence in historical records and of the current lack of chronological data. Our results justify further integrated studies of the past and current conditions of occurrence of both high frequency-low magnitude, and low frequency-extreme events identified through short-and long-terms records.

### Stability monitoring of high Alpine infrastructure by terrestrial laserscanning

RAVANELL L.(1), DELINÉ P.(1), LAMBIEL C.(2)

(1) EDYTEM, LE BOURGET DU LAC, FRANCE ; (2) Institut de géographie et durabilité - Université de Lausanne, LAUSANNE, SWITZERLAND

Rock mass movements are dominant in the morphodynamics of high Alpine rock slopes and are at the origin of significant risks for people who attend these areas and for infrastructures that are built on (e.g. mountain huts, cable cars). These risks are increasing because of permafrost degradation and glacier retreat as consequences of the global warming. These two associated factors may affect slope stability by changing mechanical properties of the interstitial ice and modifying the mechanical constraints in these rock slopes. The monitoring of rock slopes is thus an essential element for risk management.

Our study focuses on two particularly active areas of the Western Alps:

- The *lower Arête des Cosmiques* (3613 m a.s.l., Mont Blanc massif, France) on which is located the very popular Refuge des Cosmiques. Since 1998, when a rockfall threatened a part of the refuge, observations allowed to identify 10 detachments ( $20 \text{ m}^3$  to  $> 1000 \text{ m}^3$ ), especially on the SE face of the ridge. Since 2009, this face is yearly surveyed by terrestrial laserscanning to obtain high-resolution 3D models. Their diachronic comparison shows eight rock detachments ( $0.7 \text{ m}^3$  to  $256.2 \text{ m}^3$ ) between 2009 and 2011.

- The *Coldes Gentianes* (2894 m a.s.l., Valais, Switzerland) where is located a triple cable car station. Since the early 1980s the moraine is unstable: its inner slope has retreated for several meters. Since 2007, the moraine is monitored by terrestrial laserscanning: 8 campaigns were conducted between July 2007 and October 2011. The comparison of the high resolution 3D models obtained allowed the detection and quantification of mass movements that have affected the moraine over this period. During the survey period, 7 landslides involved a volume between 87 and  $1138 \text{ m}^3$ .

Discussed on the base of geophysical and glaciological data, those evolutions probably result from the combination between permafrost activity/degradation and glacier shrinkage.

\*\*\*\*\*

### The Soil Conservation Service Method (SCS) applied to hydrological modeling: a contribution for urban flooding studies

MORAES I., CONCEIÇÃO F., CUNHA C., MORUZZI R.

UNESP, RIO CLARO, BRAZIL

Brazil is one of the countries most affected by flooding in the world, with more than 18 million people have been affected since 1960. The mainly reason for this problem is the urbanization process, which starts with the removal of vegetation, buildings in the flood plains areas, hillsides' waterproofing and channeling of rivers. The consequences are reduced rates of infiltration and floods. Thus, this work describes the evaluation of land use changes and its interference in urban flooding in the Servidão Creek, Rio Claro, São Paulo State, Brazil. The land use of this watershed was mapped for the scenarios, i.e. 1958, 1972 and 2006. The Soil Conservation Service method - SCS (United States Department of Agriculture) was used, which suggested an empirical model for runoff estimating by the curve number - CN. The CN estimative is based on hydrologic soil group, land use, and initial soil humidity. The CN values can range from 0 to 100. Higher CN indicates a higher runoff potential and lower CN indicates higher water retention in the soil. The free software IPHS1 was used to get hydrographs whose parameters were: 1 hour of rainfall and Recurrence Time of 50 years. The predominant hydrological soil group was the class C - with a clay mass lower than 40% and without impediment in the subsurface. The results indicated an increase of impermeable areas and output flow values of  $32 \text{ m}^3/\text{s}$  in 1958,  $43 \text{ m}^3/\text{s}$  in 1972 and  $53 \text{ m}^3/\text{s}$  in 2006, due to the growth of Rio Claro city, which was responsible for the first event of urban flooding in the early 1970s. In 2006, an overflow on the street has occurred in the downstream sector, with values of output flow close to  $20 \text{ m}^3/\text{s}$ . The government has been doing some engineering works and transferring most of the urban flooding in areas near the mouth, where today the floods do not occur. Thus, the hydrologic modeling to evaluate the urban flooding in the Servidão Stream was efficient and can be used in urban drainage planning.

## **Geomorphological hazards in the Tucuman Province, Northwestern Argentina**

COLLANTES M.

*Institute of Geosciences and Environment, National University of Tucuman, SAN MIGUEL DE TUCUMAN, ARGENTINA*

The territory of the Tucumán province, lying between two large morphostructural regions of Argentina, the eastern Chaco plains and western Pre-Andean mountain. Its geomorphological development presents a marked contrast between the eastern plain, the piedmont, mountainous areas and intermountain valleys. Such contrasts also manifest in climate characteristics, occupation of land and the distribution of the population, confirming the interrelationship between physical and human components of the landscape. They join them, high soil fragility, which together with unrestricted and uncontrolled land use, determine the severe environmental deterioration box affecting the region, intensifying geomorphological hazards.

In the eastern plain, the influence of soft and long flattened surfaces, loessic soils, sub-humid to semi-arid climatic conditions and lack of conservation management, determine a severe water erosion risk, especially in deforested land. In the foothills, the most slopes and subtropical climate (rainfall seasonal contrasts) increase the landslides hazard and debris flows being generated. It also intensifies the risk of flooding due to seasonal and multi-year rainfall variability and water imbalance promoted by human actions. In the mountainous areas, mass movements are more intense, characterized by landslides on slopes covered by subtropical forest and topples and falls on those without coverage. Seasonally, is possible the generation of catastrophic debris flows during rains with high intensity and short duration. In the intermountain valleys with permanent or temporary hydric deficit the desertification risk is intensified with water and wind erosion and salinization.

As such, in this paper, are described and mapped in each relief unit, the intensity and extent of the main morphodynamic hazards affecting the territory of the province: soil erosion, landslide, flood, salinization and desertification hazard.

\*\*\*\*\*

## **Environmental risks in the Coast: comparative study Brazil-Portugal**

MEDEIROS W.D.A., CUNHA L., ALMEIDA A.C.

*Universidade de Coimbra - CEGOT, COIMBRA, PORTUGAL*

The present study relates the environmental risks in the Coast through a comparative boarding between towns of the Figueira da Foz (Center of Portugal) and Areia Branca (Northeastern Brazil). The aim was the identification and assessment of environmental risks in an appliance context of territorial planning and management. The methods of study were based on empirical observations in land, contacts with the populations of study areas about the environmental risks and interpretation of satellite images. Most of the identified risks are present in both territories; however their magnitudes and expressions are different. According to the study, it is evident that Areia Branca city shows a better scenario in relation to the environmental risks, probably due to a low occupation throughout the Coast. Nevertheless, as the local tourism is growing, the local coast environment needs must be considered by the occupation planning because it points out some instability. Thus, it is still possible to minimize the future problems reducing the vulnerabilities due to the existing risks. The coast dynamics of Figueira da Foz acts as an important environmental risk specially the South of Mondego's estuary, because its consolidated occupation has been threatened by the coastal retreat, demanding urgent solutions to mitigate local risks and vulnerabilities; the mobility of the population, for example, may be seen as a solution which obliges to a different territorial organization.

**Predictive value of the geographical distribution of shrines undamaged by the 2011 Tohoku earthquake and tsunami: Identifying previous maximum disaster ranges from the distribution**

*UCHIYAMA S., SUZUKI H., HOTTA Y.*

*National Research Institute for Earth Science and Disaster Prevention, TSUKUBA, JAPAN*

Japan's shrines, which are familiar historical heritage sites, exist in regions with a long history of past natural disasters. We identified the shrines that escaped damage from the 2011 Tohoku earthquake and tsunami and compared these sites with areas previously by affected tsunamis. Considering the shrines' location as being indicative of accumulated tsunami disaster experience, we clarified the distribution of their placement. If the previous maximum disaster range is deducible from the geographical distribution of Japan's numerous surviving shrines, this information can be useful for assessing future disasters. The massive earthquake that caused the 2011 tsunami is assumed to be an earthquake of a scale that occurs once in 500 to 1000 years. In this tsunami-stricken area, many shrines with at least 300 years of history, and some with 1000 years (thus having survived previous tsunamis), suffered no direct damage. Therefore, we assume that shrines' location reflects disaster experiences of inhabitants over a period of centuries. We investigated the damage to shrines on the Pacific coast from the Tohoku district's northern region to the Kanto district's eastern region, roughly 800 km that suffered tsunami damage. We conducted a field survey of the shrines near the boundary of the tsunami flood area. Results indicate that shrines adjacent to a tsunami flood area have tended to escape damage, suggesting that shrines are placed in an area's historically safest places. Furthermore, examples of undamaged shrines exist even in low-lying areas. Thus, our findings suggest that previous inhabitants, who built these shrines at safe points identifies after the occurrence of tsunamis, applied their experience of the local geography's effect on decreasing the reach of tsunamis; thus, the shrines' placement can be useful in future disaster planning.

\*\*\*\*\*

**Dendrochronological dating of debris flow activity in the Minya Konka massif (Sichuan, China)**

*OWCZAREK P.(1), MALIK I.(2), TIE Y.(3)*

*(1) University of Wroclaw, Institute of Geography and Regional Development, WROCLAW, POLAND ; (2) University of Silesia, Faculty of Earth Sciences, SOSNOWIEC, POLAND ; (3) Chengdu Center of China Geological Survey, CHENGDU, CHINA*

Debris flows are one of the most common processes in the high-mountain areas. Dating of the frequency of these processes in the past is very important, especially in the areas with high population density. Surviving trees and shrubs react to debris flows by abrupt growth reduction. The rock particles often injure the stems. Tilted trees growing in marginal zones of debris flow tracks develop eccentric growth-ring patterns with reaction wood. These signals are very useful to reconstruction past geomorphic events. The aim of this study is to use dendrochronological methods to date debris flow activity in high-mountain areas. The study was carried out in the Daxue Mountains which are adjacent to the eastern edge of the Tibetan Plateau (Western Sichuan province, China). The detailed research site was located at the foot of the Mt. Minya Konka (7,556 m a.s.l.) in the Moxi Basin. This area is inhabited by about 4,000 people and tourists number is increasing rapidly. A combination of several factors, such large amounts of loose moraine material, high precipitations and steep slopes, affects the high risk of catastrophic geomorphic events. 49 debris flow gullies were identified in the research site. Most of the debris flows initiate at high elevation (2000-4500 m). Three of them were chosen to dendrochronological analysis. Total 200 cores and wood pieces were collected from trees (*Abies fabri*, *Alnus glutinosa*, *Rhododendron*) growing in marginal zones of the debris flows (gullies and accumulation lobes). Dating scars and abrupt growth reduction showed that small geomorphic events occur every year in the gullies. Large debris flow occur every 10-15 years (e.g. beginning of 80's, 1994-1996, 2005). Using dendrochronological methods is limited by the age of trees growing on the bottoms of the debris flow tracks (150-180 years). These trees often prevent areas located below (e.g. inhabited alluvial fans) and capture large part of the rock particles transported by debris flows.

### **Climatic trend in Central Calabria (Italy) during the last 100 years**

VELLA S.

*Sapienza University of Rome, ROMA, ITALY*

The aim of this work is to reconstruct the climatic trends of the study area in relation with the morphologic features of the landscape. The study area corresponds to the central part of Calabria region in Italy, where the distance between the Tyrrhenian Sea and the Ionian Sea is only 30 km.

The data set refers to 72 station records, with 2,100,000 daily precipitation and temperature observations for the period 1916–2011. The analysis describes the seasonal and annual distribution of rainfalls, as well as its intensity during the period under study. Statistical methods have been used to estimate the parameters of extreme values distributions and of the return periods. Moreover, data have been analyzed using the spectral decomposition of the overall climatic variability in order to identify possible stochastic trends, seasonality and short-term cycles. In our approach we consider both deterministic and stochastic components in the data set and we use stationarity tests in order to check for possible unit roots in the processes.

Both slopes show similar trend of rainfall decrease in spite of their different climatic conditions depending on the different slope attitudes. As a consequence erosive processes affecting both the drainage basins and beaches are different on the two differently oriented slopes.

\*\*\*\*\*

### **Validating an indicator-based vulnerability assessment methodology for debris flow hazards**

PAPATHOMA-KOEHLE M.

*Department of Geography and Regional Research, University of Vienna, VIENNA, AUSTRIA*

Geomorphic hazards such as debris flows often threaten built-up areas in mountain regions. Physical vulnerability assessment as part of the risk analysis is very important for the development of strategies and structural measures for risk reduction. Physical vulnerability is often presented as a function of the intensity of the process and the degree of loss (vulnerability or fragility curves). These curves are often building type specific and do not consider other characteristics of the buildings that also influence their physical vulnerability. However, a considerable amount of studies argue that vulnerability assessment should focus on the identification of these variables that influence the vulnerability of an element at risk (vulnerability indicators). In this study, an indicator-based vulnerability assessment methodology for mountain hazards including debris flow (Kappes et al., 2012) is being validated. The methodology considers a number of indicators for different types of alpine hazards that are connected to the physical vulnerability of buildings located in hazardous areas. By using damage data and photographic documentation from a debris flow event in the valley of Martell, South Tyrol, Italy, the weighting of the indicators as well as their overall significance in the physical vulnerability of buildings threatened by debris flow will be validated. The photographic documentation of individual buildings provides the necessary information on the physical vulnerability indicators but also on the intensity of the process. Information on the actual monetary damage completes the required data set for the validation of the methodology. The study shows clearly that nearly all the indicators are relevant, however in some cases some indicators may be less important as initially expected.

Kappes M., Papathoma-Köhle M., Keiler M., 2012. Assessing physical vulnerability for multi hazards using an indicator-based methodology. *Applied Geography*, 32, 2, 577-590.

## **Spatial and temporal patterns of landslide risk - a case study in Lower Austria**

PROMPER C., GASSNER C., GLADE T.  
University of Vienna, VIENNA, AUSTRIA

The spatial distribution of future landslide risk will be influenced by several dynamic factors related to global change such as variance in distribution of elements at risk or changes in precipitation patterns. The assessment of future spatial distribution of landslide risk is essential for efficient and sustainable risk management and for the development of adequate adaptation strategies to global change.

The objective of this study is to approximate landslide risk for the two future periods 2030 - 2050 and 2070 - 2100 considering the potential development of land cover and climate change scenarios. In order to link the future potential developments to current conditions and past changes, an analysis of former land use changes is also performed. This leads to a total analysis period of more than 100 years. The collection of the different datasets is based on various methods like remote sensing, field mapping and modelling. The land use is modelled with cellular automata and the climate models are statistically downscaled to 1x1km grids from global models with supplemental input of regional models. These data are part of the susceptibility mapping using logistic regression methods.

The study area is the district of Waidhofen/Ybbs in Lower Austria, Austria. It comprises about 130km<sup>2</sup>, thus a regional assessment is required. Within the study area a variety of land use types can be observed such as densely and scarcely populated areas, agricultural areas and forests. The future climate is characterized by dry summers with higher frequency of heavy rainfall events and average wet winters.

The visualization of these landslide risk scenarios can significantly contribute to the awareness of eventual problems that need to be faced in the future. Consequently, the results might contribute to the improvement of future adaption and management strategies.

\*\*\*\*\*

## **Alluvial fan flooding hazard in Southern Apennines: the state of knowledge**

SANTANGELO N.(1), DI CRESCENZO G.(2), ROMANO P.(1), SANTO A.(2), SCORPIO V.(1)

(1) Department of Earth Sciences University of Naples Federico II, NAPOLI, ITALY ; (2) Department of Hydraulic, Geotechnical and Environmental Engineering, Applied Geology Division, University of Naples Federico II, NAPOLI, ITALY

The term "alluvial fan flooding" was introduced to indicate a type of flood hazard that occurs only on alluvial fans: flooding on alluvial fans differs from most riverine flooding in that the hazard not only stems from the inundation itself, but is also intimately connected with the possibility of various sedimentation processes occurring. Along the Southern Apennines, piedmont areas made up by coalescent alluvial fans are a widespread geomorphic unit and are generally located at the foot of steep slopes bordering the main carbonate massifs of the region. The alluvial fans are fed by drainage basins with high relief energy which belong to the category of small catchments. In these basins runoff is generally low, occurring mainly during the most heavy rainfall periods. During the last few centuries until now, many of these basin/fan systems have been affected by severe flooding that has produced serious damage and loss of life. Cause to the relatively long time lags between floods and the consequent loss of historical memory, development of urban areas in recent decades has not taken into account the presence of alluvial fans. This great urban expansion makes the problem of defining flooding susceptibility increasingly urgent. Our studies faced the problem both at regional and at a local scale. Recognition of the most critical situations at a regional scale was based on morphometric analysis allowing the evaluation of the susceptibility conditions among different basin/fan systems, discriminating them in terms of the prevailing transport process (debris flow vs. water flood dominated). At local scale we focused our attention on extensively urbanized alluvial fans, trying to check the real hazard conditions. The reconstructed flooding scenarios, showing the fan portions potentially affected by different alluvial processes, may represent a useful tool for subsequent studies aimed at land hazard and risk mapping.

**Urban flood hazard assessment model using multi-criteria analysis: the case of Kifissos River (Athens, Greece)**

GAKI-PAPANASTASSIOU K.(1), BATHRELLOS G.(1), KARYMBALIS E.(2), SKILODIMOU H.(1)  
(1) UNIVERSITY OF ATHENS, ATHENS, GREECE ; (2) HAROKOPEIO UNIVERSITY, ATHENS, GREECE

Flood events have often occurred in the metropolitan urban area of Athens, capital of Greece, causing the loss of property and in many cases human lives. In this study a flood hazard assessment model for urban areas is examined. The Kifissos River flowing through the plain of Athens was the case study of the present work. The length of the main Kifissos channel is 33.7Km, flows from NNE to SSW and discharges into Saronic Gulf. Its drainage basin has an area of 374.6Km<sup>2</sup>.

The plain of Athens has been extremely urbanized during the last seventy years. As a result the nature environment has been changed dramatically and has caused several catastrophic phenomena, such as floods.

The major factors affecting urban floods were evaluated. For this purpose the lithology, geomorphological factors such as slope, elevation, hydrographic network along with anthropogenic factors like urban land uses, changes of natural and urban environment were used. Comparative observations of the urban areas from 1878 to 2012 led to the mapping of the environmental changes caused by urban expansion. Recognition and mapping of these alterations was achieved using the first topographic maps of Attica, drawn by Curtious and von Kaupert (1878-1894). In this time period urban fabric area has increased from 3.1% to 60% of the total drainage basin area. Furthermore, the total length of the Kifissos River drainage network consisted of open channel streams as well as totally covered streams were estimated and considered.

A multi-criteria analysis was applied to evaluate these factors, leading to the corresponding urban flood hazard assessment map. The resultant map classified the land surface of the study area according to the degree of actual or potential flood hazard. The major flood events that occurred within the broader area of the plain of Athens were used for the validation of the flood hazard assessment results.

\*\*\*\*\*

**Recent evolution of the Tiber River delta and future scenarios of coastal vulnerability**

TARRAGONI C., BELLOTTI P., DAVOLI L., LUPIA PALMIERI E.  
Sapienza University of Rome, ROME, ITALY

Many studies that integrate morphological, stratigraphic, sedimentological and geoarchaeological data, allowed the reconstruction of the Tiber River delta evolution during the Late Pleistocene-Holocene. The post-glacial sea level rise was the main controlling factor of delta changes until ca. 6 ka BP. Afterwards, when the modern sea-level highstand was attained, autocyclic processes prevailed during the last 5-6 ka while in the last 2 ka man activity became more and more important. We used detailed reconstructions of the past history, that reflects hydrodynamic and geomorphologic changes affecting the coastal dynamics, to delineate future scenarios and address predictive searches for the near-future, according to SLR projections and estimated sediment input. These results along with new data, deriving from the ongoing SECOA (Solutions for Environmental contrasts in Coastal Areas) European Project, allowed the evaluation of the coastal vulnerability index (CVI) relevant to storm waves in the area of the Tiber delta (from Fiumicino to Castelporziano). The variables; used to define the CVI assessment are of two different types: the "morphometric" variables, ranked on the basis of present-day measurement (i.e. beach mean elevation) and the "morphodynamic" variable, parameterized according to their changes in time (i.e. changes in the upper shoreface slope). Among the morphometric variables we also included anthropic structures that decrease the natural vulnerability. The CVI was calculated by using a multiple regression equation, in which each variable is scaled by an efficacy coefficient. The methodology was applied both to the short-term and long-term interval (up to 2100). With reference to the latter, we considered the impact of relative sea level rise according to the IPCC (4R, 2007) and Rahmstorf hypotheses (2007).

Key world: Coastal vulnerability, Tiber River, Central Italy, coastal geomorphology

### **Lake Nyos, a multirisk and vulnerability appraisal**

TCHINDJANG M., KAH FANG E.

*University of Yaoundé I, YAOUNDE, CAMEROON*

Lake Nyos, a crater lake of about 1.5km<sup>2</sup> of surface area is located in Menchum Division of the North West Region of Cameroon. It lies along the Cameroon Volcanic Line which stretches from the Atlantic Ocean to the Adamawa plateau taking a SW-NE orientation. Its formation dates back to the quaternary era through a volcanic eruption.

In August 1986, this lake released volumes of carbon dioxide (CO<sub>2</sub>) that spread across its immediate surroundings killing about 1700 people and much of fauna (wildlife, cattle, goats, sheep, birds etc). The occurrence of this gas explosion attracted a lot of attention especially from the international scientific community who developed a number of hypotheses to be investigated upon. But these seemed insufficient as they were still to settle with a similar occurrence two years before in Lake Monoun which killed 37. After the Lake Nyos catastrophe, those who survived were moved to a new sites and till today, they still express their desire to return to their former villages (Nyos, Tcha and Subum). This study therefore falls within the framework of characterizing the different risk of the Lake Nyos area in order to assess the vulnerability and degree of exposure to different types of risks (volcanic, landslide, floods) that might occur. This will then enable to authorities to relocate the plaguing survivors who are not comfortable in their present sites.

Using satellite images (radar and optical treated with ENVI software) as base data for the mapping and characterization of the landscape as well as empirical methods in data acquisition, the zoning extent of risk have been determined as well as the modeling of the floods trajectory within the area and it surrounding.

\*\*\*\*\*

### **Analyze of shallow-landslide risk and susceptibility in São Paulo city, Brazil**

DE LUIZ ROSITO LISTO F.(1), VIEIRA B.C.(2)

*(1) University of Sao Paulo, SAO PAULO, BRAZIL ; (2) University of Sao Paulo, SAO PAULO, BRAZIL*

In the São Paulo city, where about 11 million inhabitants live, landslides occur frequently, especially during the summer, causing the destruction of houses and urban equipment, economic damage, and the loss of lives. The number of areas threatened by landslides has been increasing each year. The objective of this article is to analyze the probability of risk and susceptibility to shallow landslides in the Limoeiro River basin, which is located at the head of the Aricanduva River basin, one of the main hydrographic basins in the São Paulo city. To map areas of risk, we created a cadastral survey form to evaluate landslide risk in the field. Risk was categorized into four levels based on natural and anthropogenic factors: R1 (low risk), R2 (average risk), R3 (high risk), and R4 (very high risk). To analyze susceptibility to shallow landslides, we used the SHALSTAB (Shallow Landsliding Stability) mathematical model and calculated the Distribution Frequency (DF) of the susceptibility classes for the entire basin. Finally, we performed a joint analysis of the average Risk Concentration (RC) and Risk Potential (RP). We mapped 16 risk sectors containing approximately 1872 at-risk homes and more than half of which presented a very high (R4) probability of risk to the population. In the susceptibility map, 41% of the area was classified as stable and 20% as unconditionally unstable. Although the latter category accounted a smaller proportion of the total area, it contained a concentration (RC) of 40% of the mapped risk areas with a risk potential (RP) of 12%. We found that the locations of areas predicted to be unstable by the model coincided with the risk areas mapped in the field. This combination of methods can be applied to evaluate the risk of shallow landslides in densely populated areas and can assist public managers in defining areas that are unstable and inappropriate for occupation.

**Research on the lithology response on the rock falls in the earthquake in the downstream of Yuzixi River, Sichuan, China**

XIE H.(1), YU B.(2)

(1) Chengdu Institute of Mountain Hazards and Environment, CHENGDU, CHINA ; (2) Chengdu University of Technology, CHENGDU, CHINA

The Wenchuan Earthquake occurred in the Longmen mountain fault belt with a magnitude Ms 8.0 on the Richter scale on May 12, 2008. Numerous landslides and rock falls were triggered in the earthquake-affected area. Abundant co-seismic rock falls were located in the downstream of Yuzixi River, which is a branch of Minjiang River and near the epicenter. There were 99 rock falls triggered by earthquake along the 46-km river valley. The density of rock falls was 2.15 per km.

The lithology response on the rock falls in the earthquake is different in different lithology area. The exposures of lithology in the downstream of research area (about 20 km in length) are hard rock, such as the gabbro, diorite, and quartz diorite. The topographic characteristic of this area is canon geomorphology with steep hill slope. There were 80 rock falls triggered by earthquake, and the density of rock falls was 4.0 per km. The exposures of lithology in the upstream of research area (about 26 km in length) are soft rock, such as the phyllite, quartz schist, phyllite interlated with marble, quartzite sandstone, siltstone, marl, slate, and the deposits of Quaternary. The topographic characteristic of this area is river valley geomorphology with gentle hill slope. There were only 19 rock falls triggered by earthquake, and the density of rock falls was only 0.73 per km.

The conclusions are obtained by this research: (1) the hard rock slope is sensitively broken in the earthquake, and form large scale rock falls; it is active response in earthquake; (2) the soft rock slope is broken in some part in the earthquake, and form small scale rock falls; it is weakly active response in earthquake; (3) the slipped landslide is inactive response in earthquake and stability because the energy was released before earthquake.

\*\*\*\*\*

**Disaster management of regional disasters occurred on 9 July 2012 in Samsun City, (North Turkey)**

ERSAN A., ÇOSKUNLU E., UÇARLI L., AYSU Y., ÇALISKAN K., TEKIN E., KOPARMAL E.  
PROVINCIAL DISASTER AND EMERGENCY MANAGEMENT, SAMSUN, TURKEY

In this study, disaster management of regional disasters caused by heavy rain on July 9th, 2012 in Ayvacık, Çarşamba, Salıpazarı, and Terme districts of Samsun city was reviewed. Operation was carried out by crisis desk established in Governorship of Samsun Crisis Center.

According to the last forecast by the Regional Meteorological Centre of Samsun, it was warned about heavy rain for the eastern districts of Samsun city on the evening of 9 July, 2012. And the search-rescue squads were ready in various areas. Moreover, in crisis desk, digital map of the region for notices and decisions was opened to use, and a real-time meteorological maps created by satellite images for variation of rain were followed minute-by-minute.

With a total number of 70 workers, 12 vehicles, and 2 rescue boats, alarmed AFAD (Disaster and Emergency) teams in the cities such as Samsun, Sivas, Yozgat, Ankara, as well as UMKE (National Medical Rescue Team) in Samsun were sent to the region because of 16 notices that come to News Center from the districts of Ayvacık, Çarşamba, Salıpazarı, and Terme. These notices included subject of flood, overflow, floodbound, and landslide. Additionally, in order to ensure traffic security, Samsun-Ordu highway was closed up for a period of 30 minutes, and 2 rescue helicopters, provided by the Coast Guard Command, were flown to the region.

Heavy rain having started at 7:30 P.M. was decreasingly ended at 10:30 P.M. 1 corpse and 2 injuries were pulled from the landslide wreck in Ayvacık district. Besides, 95 people were transferred to safety zones in four districts.

On 9 July 2012, disaster management of flood and landslide resulted from heavy rain in districts of Ayvacık, Çarşamba, Salıpazarı, and Terme was successfully ended by devoted efforts of the crisis desk. The whole operation and the followed procedures was a correct and reliable sample of coordination, which is worth taking into account for the future disasters.

### **Society Adaptation for coping with Mountain risks in a global change Context**

BERNARDIE S.(1), GRANDJEAN G.(2), PUISSANT A.(3), MALLET J.P.(4), HOUET T.(5), BERGER F.(6), FORT M.(7), PIERRE D.(8)

(1) BRGM, ORLANS, FRANCE ; (2) BRGM, ORLANS, FRANCE ; (3) LIVE, STRASBOURG, FRANCE ; (4) IPGS, STRASBOURG, FRANCE ; (5) GEODE, TOULOUSE, FRANCE ; (6) IRSTEA, GRENOBLE, FRANCE ; (7) PRODIG, PARIS, FRANCE ; (8) GEO-HYD, OLIVET, FRANCE

The SAMCO project aims to develop a proactive resilience framework enhancing the overall resilience of societies on the impacts of mountain risks. The project aims to elaborate methodological tools to characterize and measure ecosystem and societal resilience from an operative perspective on three mountain representative case studies. To achieve this objective, the methodology is split in several points with (1) the definition of the potential impacts of global environmental changes (climate system, ecosystem e.g. land use, socio-economic system) on landslide hazards, (2) the analysis of these consequences in terms of vulnerability (e.g. changes in the location and characteristics of the impacted areas and level of their perturbation) and (3) the implementation of a methodology for quantitatively investigating and mapping indicators of mountain slope vulnerability exposed to several hazard types, and the development of a GIS-based demonstration platform. The strength and originality of the SAMCO project will be to combine different techniques, methodologies and models (multi-hazard assessment, risk evolution in time, vulnerability functional analysis, and governance strategies) and to gather various interdisciplinary expertises in earth sciences, environmental sciences, and social sciences. The multidisciplinary background of the members could potentially lead to the development of new concepts and emerging strategies for mountain hazard/risk adaptation. Research areas, characterized by a variety of environmental, economical and social settings, are severely affected by landslides, and have experienced significant land use modifications (reforestation, abandonment of traditional agricultural practices) and human interferences (urban expansion, ski resorts construction) over the last century.

\*\*\*\*\*

### **Landslide Susceptibility in the North District of Sikkim, India**

DE S.(1), GHOSH G.K.(1), ALCANTARA AYALA I.(2), SENGUPTA A.(3), JOSHI V.(4)

(1) Tripura University, AGARTALA, INDIA ; (2) National Autonomous University of Mexico (UNAM), MEXICO CITY, MEXICO ; (3) Dumkol College, West Bengal, DUMKOL, INDIA ; (4) Indraprastha University, NEW DELHI, INDIA

Landsliding is one of the most frequent hazards taking place in the North district of Sikkim in the Eastern Himalaya. Highly susceptible geological structures, lithology, steep slopes, deforestation, unscientific and unplanned uses of land are the main causative factors for the occurrence of such phenomena, which is further aggravated by heavy and concentrated rainfall and seismicity. In spite of their recurrence, there is a lack of scientific inventories, hazards and risk maps. Therefore, this study aims at preparing a data base landslide inventory and a detailed landslide hazard zonation map, as a contribution for the further development of risk mapping and thus of landslide mitigation and management.

Based on 1963 and 1969 Survey of India topographical maps, images taken in 1997 and 2009 by the LISS III Indian sensor and GPS locations of landslides triggered by the 2011-Sikkim Earthquake, a landslide hazard map has been elaborated. The map was developed based on particular improvements to the methodology elaborated by the Bureau of Indian Standards, which comprises a guideline for using the Landslide Hazard Evaluation Factor (LHEF) rating scheme and total estimated Hazard. A total of nine data layers have been prepared and used for the elaboration of the hazard zonation map. Results indicated that the highest frequency of landslides, 74% occur in the Very High Hazard zone, followed by 9% in the High Hazard zone, 8% in the moderate and 7% and 2% in the Low and Very Low respectively.

**An integrated appraisal of flood causes in Xirolaki Torrent, Northern Greece based on geomorphological and meteorological data**

TSANAKAS K.(1), GAKI-PAPANASTASSIOU K.(1), MAROUKIAN H.(1), CHALKIAS C.(2), KATSAFADOS P.(2), KALOGEROPOULOS K.(2)

*(1) NATIONAL AND KAPODISTRIAN UNIVERSITY OF ATHENS, ATHENS, GREECE ; (2) HAROKOPIO UNIVERSITY, ATHENS, GREECE*

In this paper an attempt is made in order to integrally evaluate the natural as well as the human induced factors that cause Xirolaki torrent flash flood events focusing on the analysis of a severe flood event of the torrent which took place on October 25<sup>th</sup>, 2009. For this purpose we have quantitatively analyzed the geomorphological characteristics of the drainage basin and the drainage network. In addition a numerical simulation was performed using a non-hydrostatic limited area atmospheric model. Geomorphological and atmospheric data were imported into a Geographical Information System in order to estimate the hydrographs throughout the drainage area. The peak discharge, hydrograph, and volume, derived from the analysis of measured hydrographs in a number of non-flood causing rainfall events with operating stage gauge, were used for calibration and verification of the simulated stage-discharge hydrographs. Drainage basin characteristics such as steepness of the relief combined with a relatively short main channel of the drainage network as well as abnormalities in the hierarchical drainage by stream order are the main natural flood causes amplified of course by the intense human interference at the lower part of the drainage network with a series of constructions such as roads inside the main channel and bridges.

\*\*\*\*\*

**The Fortore river mouth: a data processing methodology for quaternary evolution trend interpretation (Puglia Region - Southern Italy)**

DI LUDOVICO A., CUCULO F., IZZO M.P., DI NIRO A., SCAPILLATI N.

*Molise, ISERNIA, ITALY*

A key prerequisite to knowledge of the changes and trends affecting the territory and in particular the surface water bodies is the correct reading and interpretation of forms and the geomorphological processes in place.

The assessment of indirect effects on watercourses by the combined changes in climate and direct human intervention should be a key element in the actions of study and planning of water resources and land.

In particular, this study is to propose a methodology of geomorphological and sedimentological approach to the analysis of the waterways of southern Italy, to assist with the canons and cognitive tools for proper programming of structural assistance and not put outstanding. To this end, the analysis applied to the case of the Fortore River mouth a representative example in that it was possible to establish a sufficiently comprehensive regarding the evolutionary trends that have affected the Fortore, allowing at the same time provide useful information to the discretization and quantization effects due to climate changes and those attributable to direct human impact. From this change is possible to have partial cognizance, even if it refers to a reduced time scale, a comparison of the official map in GIS environment of 1879 produced by the Italian Royal Institute of Military Survey, the mapping Italian Geographic Military Institute of 1957 and the CTR of the Puglia Region in 2008. Fortore River mouth evolutionary trend of the river appears even in the "Proceedings of the Interministerial Commission for the study of hydraulic and soil conservation" of 1974 which states that "*the Fortore river who was a perennial river (at the Norman time was navigable - until the fourteenth century) for the constant flooding has accumulated so many materials removed from the slopes to be forced to re-dug those materials in its course, site very distant from the place of old balance*".

**Erosion of slopes and sedimentation in streams due to forest fires Rio Los Puestos basin, Catamarca, Argentina**

NIZ A.E., OVIEDO J.A., LAMAS C.A.

NATIONAL UNIVERSITY OF CATAMARCA, SAN FERNANDO DEL VALLE DE CATAMARCA, ARGENTINA

The areas located to the West of Catamarca (NW Argentina), with a population of 4,525 inhabitants. Farmers usually burn the bushes believing that later they will grow strongly; this practice coincides with the dry season. Temperatures exceed 38° C in the summer; rainfall has a torrential regime and summer winds are from NW reaching 80 km/h. Large forest fires take place when weather conditions are not considered at the start of the bush burning.

The area climate is strongly semiarid, the vegetation is shrubby-type. Agriculture and livestock are the basis of the economy. In the last decade systematized agricultural activity has increased due to the high standard agriculture enterprise establishment.

The analysis and digitizing of satellite images were carried out where the fire focuses took place. The partial area and the total area affected by fires in the last five years were measured; the maps of surface hydrology, of slopes and of reservoir affected by degradation in the upper basin were performed.

Panoramic images of the most representative areas affected by fires were analyzed, in order to determine the vulnerability of the slopes in front of the influence of the erosive agents and the response to the impact of weather events.

The factors that contribute to land degradation presently and the potential degradation in the medium and long term were characterized, to develop recommendations in order to optimize the preservation of natural resources of the area and its influencing region.

\*\*\*\*\*

**The advance of the dunes and your influence in the migration of the human settlements in the village of Medanitos Catamarca - Argentina**

NIZ A., OVIEDO J.A., LAMAS C.A.

NATIONAL UNIVERSITY OF CATAMARCA, SAN FERNANDO DEL VALLE DE CATAMARCA, ARGENTINA

The Valley of Fiambala, characterized by a semiarid dry environment, is located to the West of Catamarca, in the Northwest of Argentina. It is part of the extensive territory considered by several world organizations as fragile areas with a desertification tendency.

As a result of centuries of unrestricted and uncontrolled human occupation, even highlighted by a strong demographic expansion in the latest decades, the landscape is nowadays vulnerable in front of the impact of diverse degrading processes that affect these regions.

The deforestation that accompanies the urban settlement, and the expansion of the vineyards, produced surfaces sensitive against the eolic activity. On the one hand, the latter has increased the processes of deflation and transport of sediments, destabilizing the dune system as well as causing the dune advance over houses and farming areas. On the other hand, the described process has eroded the fertile layer of the productive soils, what made the settlers gradually move to areas with better subsistence possibilities.

With the objective to assess and mitigate the impact of the dune movement the urban scheme has been characterized through the multitemporal analysis of aerial photographs. LANDSAT 7 satellite images have been digitized in order to produce the thematic cartography. The dune areas, the advance of dunes over productive zones and the deflation surfaces have been mapped. Finally a proposal of dune attachment using autochthonous vegetation has been designed together with a proposal of future urban development to the government authorities.

**Cause and consequences of the Seti River disaster (May 5, 2012) and assessment of a possible early warning system**

*REGMI D.(1), KARGEL J.S.(2), LEONARD G.(2), THAPA B.(3)*

*(1) The Himalayan Research Expedition (P) Ltd., KATHMANDU, NEPAL ; (2) Department of Hydrology and Water Resources, University of Arizona, TUCSON, UNITED STATES ; (3) Graduate School of Environmental Earth Science, Hokkaido University, SAPPORO, JAPAN*

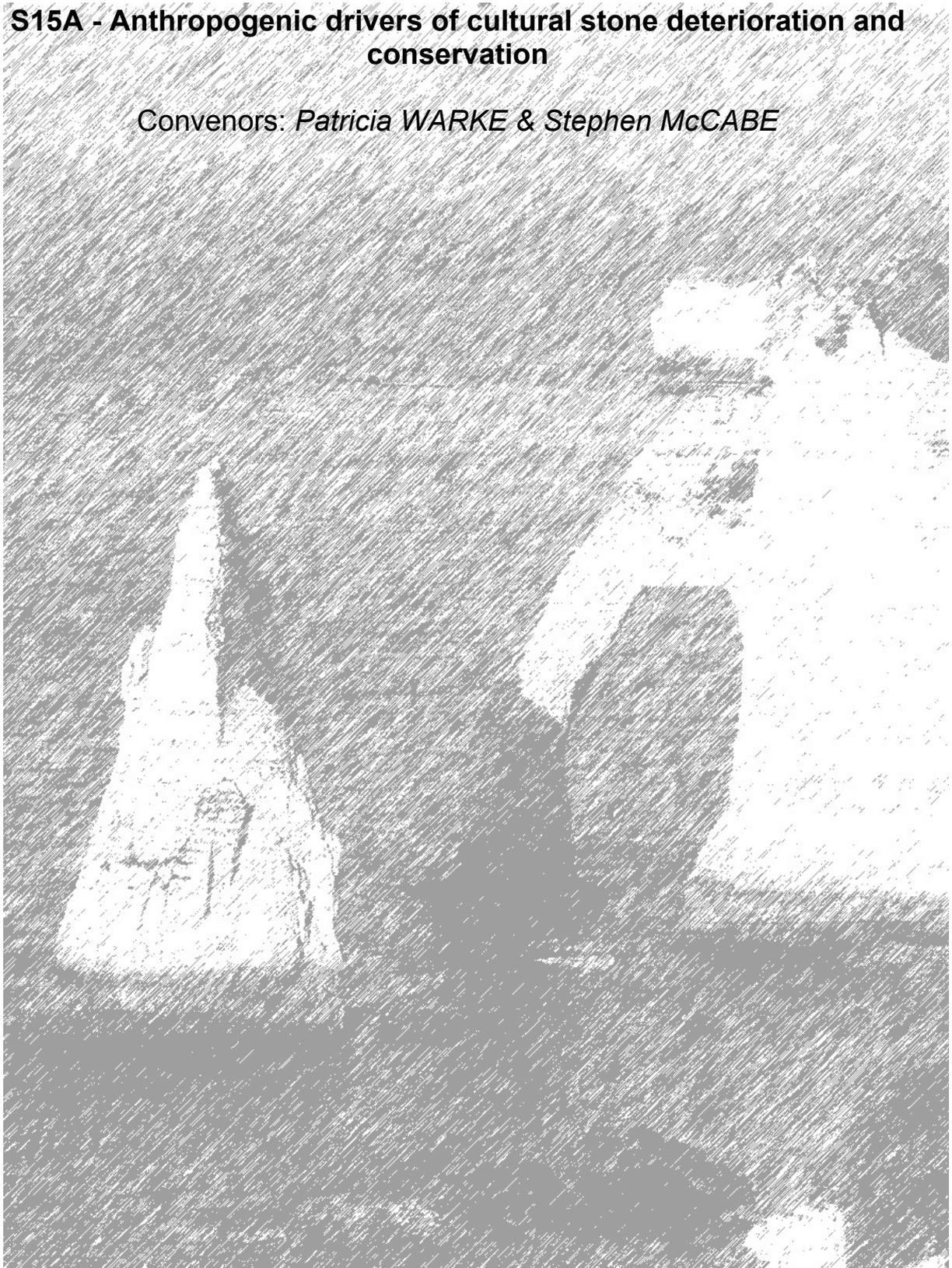
On 5 May 2012 an outburst flood on the Seti River resulted in the loss of life and property and has left terror that a similar catastrophe could occur at any time in Pokhara. Local people and government agencies were looking for the scientific explanation of some key questions, such as: 1. What was the cause of the Seti river disaster? 2. Is another similar flood likely? 3. What role might imprudent habitation have played in raising the death toll? 4. What other types and magnitudes (e.g., peak flows) of floods are possible in the future? 5. How large a population remains vulnerable? With the objective of answering the above questions, a helicopter-borne survey and ground-based field observations were carried out from November 2012 to April 2013. We have tracked down the likely sequence of events, which, in brief, consisted of a rockslide into a gorge and formation of an impounded lake in the gorge; then a huge rock and ice avalanche off Annapurna IV, which violently swept debris into the impounded lake and caused the rupture of the gorge dam, and thus unleashing of the flood. Increasing habitation along the riverbank and lowest terrace is the biggest cause for continuing concern; minor floods that probably happened before with little impact may now happen again on similar scales and cause devastation and sorrow. The possibility of floods and debris flows larger than the 5 May 2012 event cannot be discounted. A cost-effective warning system must be emplaced; this probably would involve resident involvement and use of modern telecommunications now available to most residents.

\*\*\*\*\*



**S15A - Anthropogenic drivers of cultural stone deterioration and conservation**

Convenors: *Patricia WARKE & Stephen McCABE*





## **Oral presentations:**

### **Geologic Analysis of Grenada's Carib Stones and Implications for Future Management**

*ALLEN C.D.(1), GROOM K.M.(2)*

*(1) University of Colorado Denver, DENVER, UNITED STATES ; (2) University of Arkansas, FAYETTEVILLE, UNITED STATES*

This research focuses on analysing rock decay on Grenada's (Caribbean) Carib Stones using the Rock Art Stability Index (RASI, Dorn et al., 2008)—a low-cost, yet effective assessment based on over three-dozen rock decay criteria. Representative of general West Indian rock art (petroglyph) motifs, these priceless cultural heritage resources contain more than 100 individual glyphs between two small sites. Despite this significance, nothing has been done to manage or assess the sites for longevity and geologic stability, aside from their archaeological documentation. As a first step towards a potential cultural heritage management strategy, and to further demonstrate the need for intervention, we employed RASI to assess and document each panel's overall geologic stability. The research assessed two sites in very different locations: Duquesne Bay along the northwest coast and Mt. Rich in the northern rainforest. Overall, the stability of the petroglyphs at Duquesne Bay depends almost entirely on their proximity to water: whether puddles stagnating behind the retaining walls, waves crashing during a storm, or simple residential runoff. Although the rock art site at Mt. Rich receives a considerable amount of precipitation and significantly more impact from vegetation than Duquesne Bay, the panels themselves are much more stable. Analyses show that a few of the 13 total panels exhibit a "Good" status, but the remaining are in poor condition and in danger of disappearing. This research demonstrates the need for further monitoring and lays the groundwork for continued study and assessment of the Carib Stones, while at the same time raising their profile to the international stage in hopes of securing greater recognition that will ultimately entail better management practices.

\*\*\*\*\*

### **Assessing mutual influences of environment and petrography to address the conservation of weathered Maltese stone-built heritage based on interdisciplinary materials characterization**

*TAPETE D., GIGLI G., MORELLI S., VANNOCCI P., PECCHIONI E., MUGNAI F., CASAGLI N.*

*University of Florence, Earth Sciences Department, FLORENCE, ITALY*

The erosion patterns identifiable over the Upper Coralline Limestone outcrop underneath the stone-built fortifications of Citadel in Gozo (Malta) clearly indicate still active dynamics of geomorphologic evolution of the rock mass. Indeed, the architectural surfaces are subjected to similar weathering processes, as expectable in light of the petrographic properties of the limestones used as building materials from ancient times and nowadays to replace damaged blocks.

To deal with such dual issues, we integrated minero-petrographic (i.e. thin sections under polarized light microscope, X-Ray Diffraction, abrasion tests) and geotechnical investigations (e.g., point load, tilt tests) to characterize differential weathering as represented by several samples collected from historical fortifications, dry-stone walls, restoration masonries and boreholes within the rock mass. Geospatial analysis of the retrieved measurements allowed the exterior erosion and alveolization patterns to be correlated to the inner properties of rocks and stones. Thematic maps of deterioration and related hazard indexes were thereby produced and cross-validated with a kinematic analysis of the instability mechanisms performed by terrestrial laser scanning over the whole Citadel.

The demonstration of a strong control of the inner structure and texture on stone decay led us to assess the impacts that the local microclimate and restoration strategies currently implemented at Citadel might have in the near future, in the broader context of an ever changing natural-anthropogenic environment.

Advantages and limitations of the proposed approach of interdisciplinary materials characterization are here discussed, through the benefits obtained in delivering targeted technical advice to address the consolidation project currently carried out at Citadel by the Restoration Unit, Works Division, Maltese Ministry for Resources and Rural Affairs, and Politecnica Ingegneria e Architettura.

### **Experimental study on cement mortar deterioration in sulfate environment**

OGUCHI C.(1), TAGUCHI N.(2)

(1) Saitama University, SAITAMA, JAPAN ; (2) Department of Civil and Environmental Engineering, Saitama University, SAITAMA, JAPAN

To clarify deterioration processes of sulfate attack on cement mortars, dissolution experiment using sulfate solutions was performed. Two kinds of mortars, high-early-strength Portland cement mortar and the alumina cement mortar, were immersed in different concentration of sodium sulfate and magnesium sulfate solutions. In order to evaluate the total amount of soluble ions dissolved from the mortars, electric conductivity (EC) was monitored until 1440 hours. After the experiment, rock properties of mortar specimens were analyzed. The EC values of all cases increased drastically and then decreased rapidly within 140 hours. Then the values decreased extremely slowly until 1440 hours. Higher concentration of the solutions has higher final EC values. The Equotip values of specimens immersed in sodium sulfate solution were lower than to those immersed in magnesium sulfate solution. The values gradually decrease with increasing immersion time. From the chemical and mineralogical investigation using XRD, XRF and SEM-EDS, secondary precipitated minerals were deposited on the surface of the specimen. They are thenardite ( $\text{Na}_2\text{SO}_4$ ) in the case of sodium sulfate solution, and calcite ( $\text{CaCO}_3$ ), gypsum ( $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ ) as well as hexahydrate ( $\text{MgSO}_4 \cdot 6\text{H}_2\text{O}$ ) in the case of magnesium sulfate solution. It is concluded that the sodium sulfate environment affects higher damage to mortar rather than magnesium sulfate environment.

\*\*\*\*\*

### **Chemical analysis of black crust on the Angkor sandstone at the Bayon temple, Cambodia**

SONG W.(1), OGUCHI C.T.(2), WARAGAI T.(3)

(1) The University of Tokyo, CHIBA, JAPAN ; (2) Saitama University, SAITAMA, JAPAN ; (3) Nihon University, TOKYO, JAPAN

The Angkor complex is the one of the greatest cultural heritages in the world. It is constructed in the early 12<sup>th</sup> century, designated as a world cultural heritage by UNESCO in 1992. The temples at the Angkor complex are mainly made of sandstone and laterite. However, due to the tropical climate, plants, lichens and various microorganisms are growing well on the rock surface. Black crusts are also easily found on the stone surface. The 21<sup>st</sup> technical session of the International Coordinating Committee for the Safeguarding and Development of the Historic Site of Angkor (ICC-Angkor) held in 2012 recommended that to preserve both the biofilms and the forest cover and to prohibit the biocides (chlorine-based) and organic biocides. However, there are many reports that lichens and microorganisms accelerate rock weathering. It is important to clarify that how the biofilm on the Angkor temples affect Angkor sandstones.

We sampled Angkor sandstone covered by black crust at the Bayon temple, Angkor complex, and observed the section and the surface of the rock sample by using SEM. Surfaces of the samples are not polished in order to observe the original condition. The samples are coated with gold for 180 seconds. The depth of the black crust is up to 1 mm. Many filamentous materials were found on the black crust. Average energy-dispersive X-ray spectroscopy data of the five areas of ca.  $20 \mu\text{m} \times 15 \mu\text{m}$  in the black crust shows that over 80 % of the filamentous materials are compounds of carbon. It seems that these materials are hyphae. The shape of the hypha is like a thread and its size is few  $\mu\text{m}$  in diameter and up to several centimeters in length. Black crusts are consisted of elements and compounds of carbon, Na, Mg, Al, Si, Cl, K, Ca, and Fe.

Further research has to be done to find out the better and proper way of conservation for the Angkor complex.

## **Poster presentations:**

### **The formation of hollow of sandstone pillar and heated Angkor Wat temple, Cambodia**

*WARAGAI T.(1), HIKI Y.(2), HADA A.(1), MORISHIMA W.(1)*

*(1) College of Humanities and Sciences, Nihon University, TOKYO, JAPAN ; (2) Graduate student of Nihon University, TOKYO, JAPAN*

Angkor Wat temple is in a tropical monsoon climate, and the weathering of rocks forming the temple is mainly caused by the wet-dry repetition. Sandstone and laterite blocks have a particularly low durability under the repetition. In addition, it is supposed that due to restoration involving clearing of vegetation, the exposure of building stone has accelerated its. In this study, we notice to a hollow formed on the inside sandstone pillar in the first gallery of the temple which is located most outside from the central sanctuary. The hollow is mainly formed by the wet-dry weathering and it is thought that the depth becomes an index of the weathering intensity. Therefore, environmental condition which provides the depth of hollow is analysed based on the measurement of the depth of hollow and air temperature-humidity environment in the gallery. Besides, the climatic environment at the temple is important to clarify weathering environment. The distribution of air temperature in the precincts which is composed of sandstone blocks and vegetation is observed in August 2010 and March 2011.

As a result, the depth of hollow on pillar facing to the outside which is placed in a highly wet-dry repeat situation is deeper than the inside of pillar about three times. In addition, the depth depends on the position of the gallery. Namely, the depth is deep at the eastern gallery with a rapid humidity change, is shallow at the northern gallery with high humidity and low air temperature through the year. Regarding to the distribution of air temperature, the surroundings of gallery is placed in the hot environment which is more than 2°C higher than the vegetation area in summer. Consequently, the raised temperature of the temple causes a sandstone block desiccation and the wet and dry change becomes big if the rapid moistening due to the rainfall is added. It is supposed that the clearing of vegetation is possible to accelerate the weathering of sandstone.

\*\*\*\*\*

### **Reconstructing Past Pollution Environments Using Gravestones**

*INKPEN R.*

*University of Portsmouth, PORTSMOUTH, UNITED KINGDOM*

Past levels of atmospheric pollution are difficult to quantify as standard and regular monitoring urban atmospheric compositions did not begin until the early to mid twentieth century. Atmospheric pollution in Victorian and Edwardian cities provided the aggressive erosional environment experienced by many historic buildings and monuments. Gravestone erosion rates have been measured since the Victorian period but their potential as quantifiable surrogates of historic atmospheric pollution levels has been relatively poorly explored. This presentation uses erosion rates within a modified version of Lipfert's (1989) dose response equation to calculate sulphur dioxide levels at locations across the southern UK. The limitations of this method are discussed as well as the spatial variability in historic atmospheric pollution levels its application implies.

### **Impact of cement repointing on rates of sandstone deterioration in medieval churches of the French Massif Central**

ANDRÉ M.F.(1), PHALIP B.(2), ROUSSEL E.(3), VAUTIER F.(3), VOLDOIRE O.(1)

(1) GEOLAB - CNRS / Université Blaise Pascal / IUF, CLERMONT-FERRAND, FRANCE ; (2) CHEC - Université Blaise Pascal, CLERMONT-FERRAND, FRANCE ; (3) IntelEspace /MSH, CLERMONT-FERRAND, FRANCE

Six Romanesque churches of the Auvergne region in the French Massif Central have been investigated. These are built of various sandstones and have been partially cement-repointed in the mid-20<sup>th</sup> century. Methods used to quantitatively assess weathering damage both since the Middle Ages and since the repointing operations combine terrestrial LiDAR and stone-by-stone surveys, dating of reference surfaces ('zero datum levels') based on stone-dressing marks, and petrographical analyses.

Between the 12<sup>th</sup> century and the mid-20<sup>th</sup> century, intrinsic geological factors have been the key control on sandstone weathering. Stone recession has proceeded on average 500 times faster in the poorly-cemented white sandstone compared to the iron-cemented red sandstone (4 mm per century against 0.008 mm per century). Since the mid-20<sup>th</sup> century repointing operations, a marked increase in weathering damage and resulting stone recession has affected the poorly-cemented white sandstone. This increase is up to tenfold where hard Portland cement has been applied, which confirms the deleterious effects of cement repointing on susceptible stone masonries.

Comparison with previous studies indicate that the maximum pre-repointing recession rates are similar to the ones provided by previous authors for similar temperate inland and rural areas of western Europe. As to the maximum post-repointing recession rates, they are of the same order of magnitude as the values provided for tourist sites such as Petra and Angkor which are significantly affected by human impacts.

\*\*\*\*\*

### **A study on anthropogenic and climatic induced deterioration of some stone built churches in the Transylvanian Depression**

ILIES M.(1), IRIMUS I.A.(2), ROSU C.(2), RUS M.(2)

(1) Universitatea "Babes-Bolyai", Cluj-Napoca, CLUJ-NAPOCA, ROMANIA ; (2) Universitatea "Babes-Bolyai", Cluj-Napoca, CLUJ-NAPOCA, ROMANIA

The stone built churches of Transylvania are an important part of the Romanian religious and cultural heritage. Their aesthetic and historic integrity is constantly put at risk due to the weathering processes. For the purpose of this study, the chosen religious monuments are spread throughout the wide region of Transylvania. They are located in areas with specific local climatic conditions, therefore they are being subjected to different weathering factors.

The objective of this study is twofold. First, to investigate the climatic and anthropogenic factors that favour stone deterioration. Second, the aim is to link these to a specific type of damage found on the monument.

The study is based on an analysis of the climatic data such as humidity, temperature, rainfall, wind-speed as well as an investigation of the human interventions that have influenced the monument's state of conservation. The deterioration forms were recorded using *in situ* mapping.

Results show different levels of weathering - induced damage on the studied monuments, thus demonstrating that climatic nuances play an important role in determining the forms and severity of deterioration. This study is part of a wider project that stands to develop suitable preventive and curative conservation treatments for each of the churches.

### **Linear expansion and thermal cycling of sandstones: key factors of weathering**

TOROK A., TURI N.

*Budapest Technical University, Dept. of Construction Materials and Engineering Geology, BUDAPEST, HUNGARY*

The paper describes laboratory experiments where sandstones that are used in monuments were subjected to three different thermal cycles that aimed to model natural conditions: i) annual cycle (temperatures: -15°C to +40°C), ii) winter cycle (-15°C to +5°C), and iii) summer cycle (+5°C to +50°C). Three sandstone types a fine grained ferruginous, a carbonate cemented and clayey quartz sandstones were tested. For each experimental setup 80 cycles were made by using air dry and water saturated conditions. The following parameters were measured after each 10 cycles: mass, density, water absorption, ultrasonic pulse velocity and linear thermal expansion. Compressive strength and three point load strength of samples were also recorded before and after the cycles. The largest loss in mass (11.5%) is recorded in the clayey sandstone during winter cycles, with nearly same values (11.4%) in annual cycles. The ultrasonic pulse velocities show a decrease due to the cyclic load, which is more than 27% for the clayey sandstone when it is exposed to winter cycles. It is much higher than that of the other two sandstones. The linear thermal expansion coefficients of the three studied sandstones were nearly the same before the cyclic loading ( $\alpha=13.1-13.9 \text{ 1/}^\circ\text{C}\cdot 10^{-6}$ ). After applying dry winter cycles it became less for most sandstones but when saturated samples were tested under simulated winter conditions major differences were found, with increasing linear expansion coefficient for carbonate-containing sandstone and decreasing for clay-containing one. Summer cycles decreased the linear expansion coefficient of all studied sandstones, but in various rate. The highest strength loss was recorded after winter cycles, as it was expected. The tests demonstrate that linear thermal expansion coefficient show some changes when the sandstone is exposed to different climatic conditions, thus could be used as a good indicator of weathering susceptibility of sandstone monuments.

\*\*\*\*\*

### **Quantitative assessment of decay in Mayan cultural limestone**

GENET P.E.

*Geolab - Laboratoire de géographie physique et environnementale - UMR 6042 CNRS/Université Blaise Pascal, CLERMONT-FERRAND, FRANCE*

Mayan cultural heritage is affected by deterioration due to tropical bioclimatic conditions and low durability of built limestone. Quantitative assessment of this decay has been conducted in the Rio Bec region (state of Campeche, Mexico), on the archeological sites of Becan, Chicanna, Xpuhil and Rio Bec, using photogrammetric modeling and GIS. The obtained amounts of decay have been linked to controlling factors, such as petrographical properties of built limestone, bioclimatic conditions from regional to microlocal scale, and direct or indirect human interventions. Deterioration has been quantified at different spatial and temporal scales, from the whole monument to individualized stones, and the chronology of human interventions has been taken into account. First results show that biocolonization by microorganisms and anthropogenic impacts such as restorations or forest clearing are influencing the geography of decay, being either protective or aggressive factors. Perspectives include the extension of the quantitative assessment of decay to other stylistic regions, such as the Puuc zone, characterized by drier bioclimatic conditions and better quality of built limestone. This study is conducted in collaboration with geologists, microbiologists, archeologists and conservators in order to provide a complete diagnosis regarding the causes of decay that can lead to conservation recommendations.

Key Words: stone decay, limestone weathering, cultural heritage, quantification of decay, Mayan temples, Yucatan.

**The geomorphological Units of Mount Bambouto Caldera (Cameroon Volcanic Line): an asset for geoeducation and geotourism**

TEFOGOU M.G.(1), DONGMO A.K.(2), NKOUATHIO G.D.(2), WANDJI P.(3), DEDZO M.G.(4)

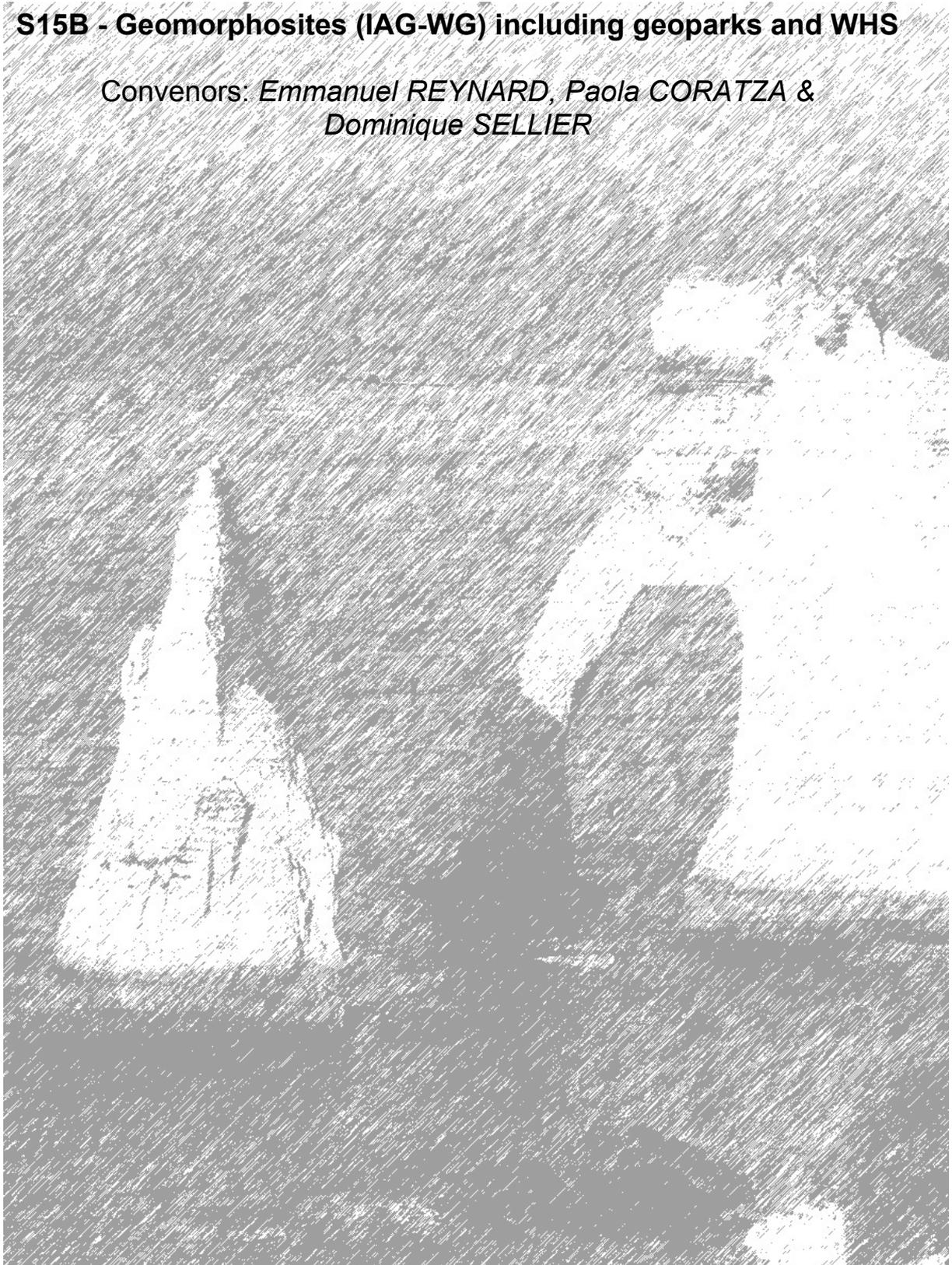
*(1) Department of Hydraulics and Water Management, Higher Institute of the Sahel, University of Maroua & Department of Earth Sciences, Faculty of Sciences, University of Dschang, MAROUA & DSCHANG, CAMEROON ; (2) Department of Earth Sciences, Faculty of Sciences, University of Dschang, DSCHANG, CAMEROON ; (3) Laboratory of Geology, High Teacher Training School, University of Yaoundé, YAOUNDÉ, CAMEROON ; (4) Department of Life and Earth Science, High Teacher Training College, University of Maroua, MAROUA, CAMEROON*

The major tectonic events in Cameroun are found in the Cameroon Volcanic Line; which is constituted of volcanic and plutonic complexes. Among volcanic complexes, the mount Bambouto appears one of the most affected by tectonic events. These events gave rise to the formation of a caldera at summit of the volcano. This caldera is sub-elliptical in shape (16x8 km). Various gemormophological units are found in the caldera and they are related to the outcrops of rocks like trachytes, basalts, ignimbrites and phonolites whom eruptions ruled the formation of caldera (Tchoua, 1972; Youmen, 1994). Thus, the landscape of the caldera is characterized by domes (Babadjou Tooth, Mount Meletan, Mount Maga, Mount Mekwop, Mount Nkon'hon etc...) and cliffs. Several valleys are found in the caldera around the deepest "V" shaped valley with altitudes ranging between 1300 m and 570 m. The dissymmetry of these geological units gave to the whole caldera, a stair-like morphology from the crest line to the bottom. The main directions of these features are N-S, N35° and N145° (Zangmo Tefogoum et al., 2011). Since many decades, the wonders the geomorphological features in the Mount Bambouto caldera foster several field trainings of students (from secondary schools and universities), tourism and recreational activities (by local and foreign people). These activities have an impact in the development of the region through local cost-effective activities led by craftsmen.

\*\*\*\*\*

**S15B - Geomorphosites (IAG-WG) including geoparks and WHS**

Convenors: *Emmanuel REYNARD, Paola CORATZA & Dominique SELLIER*





## **Oral presentations:**

### **Drawing the Line: Boundary Issues at the National Parks of the SW USA**

GRAY M.

*Queen Mary, University of London, LONDON, UNITED KINGDOM*

Delimiting appropriate boundaries for protected geosites and areas is very important. If the boundaries are poorly drawn, important features of a landform assemblage or important parts of a functioning geomorphological system may be excluded from protection thus diminishing the value of the site and effectiveness of its conservation. Factors involved in drawing protected area boundaries may include administrative boundary issues, land ownership issues, historical factors or lack of understanding of the local geoscience. In this presentation, examples of appropriate and inappropriate boundaries will be discussed at National Park units in the SW USA, including Capulin Volcano National Monument (New Mexico), Sunset Crater National Monument (Arizona), Great Sand Dunes National Park (Colorado) and Petrified Forest National Park (Arizona).

\*\*\*\*\*

### **Geomorphosites: Individual landforms or areas of geomorphological heritage**

ERHARTIC B., ZORN M., FERK M., KOMAC B.

*Research Centre of the Slovenian Academy of Sciences and Arts, Anton Melik Geographical Institute, LJUBLJANA, SLOVENIA*

This article discusses the bases for studying and evaluating geomorphological heritage and presents an example of this evaluation in the Triglav Lakes Valley (Julian Alps, Slovenia).

Studying the high-mountain karst surface revealed that this type of relief has gone through diverse development. In the Triglav Lakes Valley, the high-mountain solid-rock surface gradually entered the process of rock-base corrosion in various stages of the Holocene. A potential question that can arise in this regard is which development phase, or which phenomenon in a particular development phase, is more important or typical in terms of nature conservation. The development and character of high-mountain karst or the abundance and formation of surface phenomena always depends on local factors, including the limestone's physical and chemical properties, the elevation, location, and exposure of the surface, climate, and vegetation, and, finally, potential human impacts. Due to a multitude of relief forms that are often at various development stages, areas with a higher concentration of exceptional, rare, and typical forms connected in a complex way are deemed more important from the viewpoint of nature conservation and geomorphological heritage; these forms have great research and informative value, and have special ecological and cultural importance. Combining forms into logical units with a high density and great diversity also increases the area's importance in terms of nature protection. These units are referred to as geomorphological complexes because they represent specifically defined and typical complexes of karst and other relief forms. Based on the morphogenetic landscape and relief factors, the study area of the Triglav Lakes Valley was divided into seventeen geomorphological complexes. Following the evaluation of these units, the geomorphosites of this area were also defined.

## **A deductive method for selection of geomorphosites**

SELLIER D.

Université de Nantes, NANTES CEDEX 3, FRANCE

The aim of popularization is to communicate scientific knowledge to a public at large. Popularization of geomorphology can have two targets: to explain landforms to the public (visitors, students) and to provide to this public the basic principles to understand landforms. These objectives require to select *geomorphosites* (sites of scientific interests).

The method set out here to select such sites includes an *integrated analysis of landforms* and a *deductive selection of geomorphosites*, previously tested as part of scientific programs or master memoirs in different fieldworks in Europe. The first stage includes three parts: characterisation of the general geomorphic properties of the *concerned area*, identification of *major geomorphological components* of equal size but different properties, definition of basic geomorphological units, called *geomorphotypes*. The second stage includes two parts: selection of *geomorphosites* connected with each observed *geomorphotype* (what to see) using scientific references (general meaning, pedagogic value), choice of *points of view* related to each geomorphosite (from where to see) using touristic references. This second stage can use assessment methods worked out by the Lausanne school of geography (scientific and additional values).

This method involves scientific and pedagogic competence of popularizer. It depends of the public, institutional framework and available media too. It uses a systemic process from scientific knowledge to geomorphosite determination. It is in accordance with the concept of *geomorphodiversity* because the complementary properties of *geomorphotypes* selected inside the *concerned area*. It allows to choose sites to be visited but also to be conserved, which are two scopes of *geoheritage* making.

\*\*\*\*\*

## **Assessment of geomorphosites: methodological approach on examples of the Moravia (eastern part of the Czech Republic)**

KIRCHNER K.(1), KUBALIKOVA L.(2)

(1) *Institute of Geonics, Academy of Sciences of the Czech Republic, Branch Brno, BRNO, CZECH REPUBLIC ;*  
(2) *Department of Geography, Faculty of Education, Technical University of Liberec, LIBEREC, CZECH REPUBLIC*

For the first time in the Czech Republic, the concept of geomorphosites was used for assessment of geomorphological localities. The authors excerpted methods for the assessment of geomorphosites, which are used in some West and South European countries and have elaborated the special methodology for Czech ambient. Traditionally, in the Czech Republic, there is a wide spectrum of geomorphologic information including geomorphological maps. This geomorphological data obtained in geomorphological field research will serve as a basis for evaluation of the selected sites. The authors define geomorphosites traditionally as geomorphological landform that have acquired certain values due to human perception.

Presented methodical approach consists of four main stages: i) identification of the significant geomorphologic sites (based on the literature, maps and field survey), ii) detailed geomorphological inventory of selected sites (general information, geology, geomorphological data - morphology and genesis, environmental conditions, a description of the cultural components of the site, aesthetic aspect, availability, background, presence of touristic infrastructure, current state of the site, potential threats and risks), iii) numerical evaluation of sites (scientific and additional values, economical potential, threat and risk assessment), iv) final synthesis (classification of the sites, management proposals, possible use of the site, proposed legislative protection). The authors propose to include the presented approach in a part of the environmental geomorphology.

This concept was used for evaluating of selected geomorphological sites in the various relief types and different categories of protected areas in the Moravia: Podyjí National Park, Protected Landscape Area Zďárské vrchy (Bohemian Massif). Results of the assessment can serve as a base for proposals for rational use and management and other perspectives of the use of the geomorphologic assessment are outlined.

**Bridging Malta and Sicily through geoheritage exploitation: Identification and assessment of geosites for territorial enhancement**

*CAPPADONIA C.(1), AGNESI V.(1), ANGILERI S.E.(1), CORATZA P.(2), COSTANZO D.(1), DI PATTI C.(1), SOLDATI M.(2), TONELLI C.(2)*

*(1) Università di Palermo, PALERMO, ITALY ; (2) Università di Modena e Reggio Emilia, MODENA, ITALY*

Malta and Sicily show common geological and geomorphological features, having been also physically linked not later than the Last Glacial Maximum. At present both islands have a high tourist vocation, but their environmental potential is not fully exploited for attracting tourists and visitors. In the framework of an international research project, "Ecological Cross-border Networks Malta-Sicily" (RE.MA.SI.), a multidisciplinary study for the identification, selection and enhancement of geosites in the Maltese and Sicilian islands was carried out.

A number of sites both in Malta and Sicily have been identified and qualitatively and quantitatively assessed applying a methodology already tested in previous studies. The aim was to see whether any of these sites could be considered as geosites of geomorphological interest (geomorphosites) according to scientific, additional and use values.

In order to create a common geomorphosite inventory and a GIS-database, the standard forms of the Italian Institute for Environmental Protection and Research (ISPRA) were used. The recognised and assessed geomorphosites mainly include coastal and karst features, but also landslides, badlands and mud volcanoes are encountered due to their scientific interest and scenic value.

The research enabled us to highlight that geomorphosites can become a relevant resource for social and economic development in Malta and Sicily, and can provide the ground for bridging these islands through a new integrated approach with foresees common methods and actions for geoheritage exploitation and enforcement of conservation strategies.

\*\*\*\*\*

**Assessment of geomorphosites for recreational purposes: Case of Nalychevo Nature Park (Kamchatka, Russia)**

*BLINOVA I., BREDIKHIN A.*

*Moscow State Lomonosov University, MOSCOW, RUSSIAN FEDERATION*

Creation of a new tourism cluster or expansion of natural recreation resource, along with other scientific and applied problems of recreation, requires precise assessment of the territory. Relief often determines technological peculiarities of land use such as location and territory zoning, means of transport, safety for recreational system and people involved in recreational activity.

Attractiveness of relief, diversity and rareness were always the basic features of overall recreational attractiveness of a territory. Unique relief forms, commonly referred to natural sites, make the natural functional kernel for a recreation system which is created and exists around them.

Geomorphosites are particularly vulnerable to dangerous occurrence of endogenous and exogenous processes as guarantee of environmental stability is an essential condition for a proper system functioning. This requires a comprehensive study of relief dynamics, monitoring and forecasting its evolution in protected areas.

There are two general domains of relief and recreation mutual influence: recreational and geomorphic (RG) risk (threat) and RG attractiveness.

The impact of the various relief characteristics is determined by the objectives of holidaymakers. However, various types of recreation require different values of relief parameters. Numerical approach allows to conduct the assessment procedure impartially and to establish the ranking based on final scores.

After estimating recreational and geomorphic potential of a certain area we can analyse its structure, i.e. the set of presented or potentially possible recreational activities.

Such assessment is particularly important for prospective recreational regions. In spite of general fame of Far East recreational resources there are still areas not affected by human activities in immediate proximity to the regional center. One of them is Nalychevo Nature Park which is included in the "Volcanoes of Kamchatka" UNESCO's World Heritage List.

## **Quantitative Geodiversity Index: GIS & spatial analysis for assessment and selection of geomorphosites**

MELELLI L.

*Department of Earth Sciences, University of Perugia, PERUGIA, ITALY*

The research centered on geoconservation and geotourism stressed qualitative methods focusing on the definition, identification, study and development of geosites. Although the excellent results achieved by scientific international research, the topic of quantitative evaluation of geodiversity is still an open field.

To define a quantitative index of geodiversity is the next step required in order to quantify this parameter. Geographical Information Systems (GIS), Digital Elevation Models (DEM) and remote sensing imageries are the new instruments available to develop specific tools in order to obtain quantitative indexes.

The formula proposed in this abstract takes into account abiotic factors, contributing to the geodiversity definition, with intrinsic characteristics of spatial continuity (geological substrate, soil cover, land use) or spatial discontinuity (morphogenetic processes). Moreover the topographic parameter is strongly stressed out, modeled through the roughness or an index that measures how irregular an area is from a topographic point of view. The relevance of topography is a consequence of two points:

1. the roughness is strictly related to efficiency of geomorphological processes and generally is corresponding to a greater variability of the abiotic component.

2. The great availability of new DEMs with advanced characteristics of vertical accuracy and horizontal resolution. These models allow to manage the topographic attributes obtaining promising results and highlighting the energy relief role in the geodiversity comprehension.

The study area is the Umbria region (central Italy) and covers many lithological and morphological units, becoming an ideal representation of the conditions of geodiversity in central Italy.

The results of this approach could be not only an advance in the quantitative approach of geodiversity assessment but also a valid instrument for landscape management and geotourism and geoparks evaluation, promotion and management.

\*\*\*\*\*

## **Assessment of Mainland Portugal geodiversity**

PEREIRA P.(1), PEREIRA D.(1), BRILHA J.(1), SANTOS L.(2), HENRIQUES R.(1)

*(1) Geology Centre of University of Porto / University of Minho, BRAGA, PORTUGAL ; (2) Geography Department, Federal University of Paraná, CURITIBA, BRAZIL*

A methodology applied in the quantitative assessment and mapping of Mainland Portugal geodiversity (89,015 km<sup>2</sup>) is presented. The geodiversity concept considers the diversity of rocks, minerals, fossils, landforms and soil features and usually is being considered only as a theoretical approach with no particular use or application. GIS procedures were performed to assess all features of Mainland Portugal geodiversity and to avoid overrating any particular one, such as lithology or relief, which is a common weakness in other methods. The Geodiversity Index resulted from the combination of five partial indexes: geological, geomorphological, palaeontological, pedological and mineral occurrences. Each one of the five indexes was obtained by counting different occurrences in a 16x10 km grid cell in maps at scales between 1:500 000 and 1:1 000 000: geological, geomorphological units, hydrography, soils, precious stones and metals, energy and industrial minerals, mineral waters and springs. GIS software was used to convert vector data to raster for these spatial analysis procedures. The geodiversity map of Mainland Portugal is expressed as an isolines map joining the central points of cells sharing the same Geodiversity Index. The highest geodiversity values are related with larger diversity of stratigraphical and palaeontological Mesozoic units and mainly with rich geological and geomorphological diversity. The geomorphological diversity in connection with a lithological control seems to have an important role in the geodiversity map. This cartography is intended to have an easy interpretation by non-specialists as a tool for land-use planning, particularly in the identification of priority areas for conservation, and for the use and management of natural resources.

**The geomorphosites of Madre de Dios island (Patagonia, Chile): "marble glaciers", painting caves and hydro-aeolian karst landforms. A singular heritage unique in the world**

HOBLEA F.(1), JAILLET S.(1), MAIRE R.(2), MALARD A.(3), MOREL L.(4), FAGE L.H.(5), MARBACH G.(6), TOURTE B.(7)

(1) UMR EDYTEM CNRS-University of Savoie/Centre Terre, LE BOURGET DU LAC, FRANCE ; (2) UMR ADES CNRS-University of Bordeaux/Centre Terre, TALENCE, FRANCE ; (3) Swiss Institute for Speleology and karst Studies (SISKA)/Centre Terre, LA CHAUX DE FONDS, SWITZERLAND ; (4) UMR 5005, Lab AMPERE/Centre Terre, LYON, FRANCE ; (5) Centre Terre, CAYLUS, FRANCE ; (6) Centre Terre, CHORANCHE, FRANCE ; (7) Centre Terre, TOULOUSE, FRANCE

After four expeditions organised by "Centre Terre" (2000, 2006, 2008, 2010), the karstic desert island of Madre de Dios (50° S, Magellan channels, Chilean Patagonia) revealed natural and cultural treasures interesting several scientific fields: archeology, ethnography, botanic, zoology, and especially geosciences and geomorphology through the study of a new karst environment in subpolar wet conditions. Unknown landforms and processes have been discovered, generating an outstanding landscape, called "marble glaciers", a new kind of mega-karrenfield marked by very active hybrid hydro-aeolian processes and glacial inheritance interfering with differential weathering involving both soluble and non-soluble rocks. Criss-crossed processes give unexpected landforms as "rock comets", "rock rams", micro/mega "rock mushrooms", perched dunes and "sand firms" in cliffs... The endokarst is also well developed. The presence of big caves networks allowed some of them to record glacial deposits as well as paleo-tsunamis or human occupations from different periods (evidences of the past presence of Kawesqar nomad people).

These expeditions revealed the high natural-cultural heritage value of Madre de Dios island, presently desert excepted a quarry of limestone located for sixty years in Guarello, a nearby small island. Thanks to the work of Centre Terre, Madre de Dios is officially protected by the Chilean State since 2007. The current assessment of the heritage value of the island interests the Chilean Authorities thinking to the promotion of the site through its inscription on the WHS list and the development of eco and geotourist visits. In this frame, we present the assessment of the geoheritage and the geosites of Madre de Dios island, focusing on the numerous geomorphosites that present a relevant potential heritage regarding as well the scientific than the additional cultural-aesthetic-biotic values.

\*\*\*\*\*

**Geomorphological heritage of Samobor karst area (Croatia)**

BUZJAK N.(1), PAHERNIK M.(2)

(1) University of Zagreb, Faculty of Science, Dept. of Geography, ZAGREB, CROATIA ; (2) Croatian Military Academy Petar Zrinski, ZAGREB, CROATIA

Samobor karst area is the most eastern unit of Samoborsko gorje-Zumberak Mt. geomorphological region in NW Croatia. It is developed in a well karstified Upper Triassic and Neogen carbonate beds with numerous karst phenomena: dolines, blind valleys, caves, springs and ponors. Some of them are recognized as important geomorphosites and protected or the formal protection process is in progress. Due to the intense urbanization this fragile karst environment is under strong anthropogenic pressure with negative environmental impacts. It is reflected in geoheritage, landscape and natural resources degradation. Therefore whole area is an object of systematic geoecological study that involves geomorphological, speleological and hydrological research performed in a cooperation of scientists, researchers, authorities dealing with nature protection and water resources management and local community. The result of researches is the GIS geodatabase aimed for preparing reports, professional studies and specialized maps used in spatial analysis, planning and nature protection. It consists of two main components, general geomorphological database and speleological database, and is a part of the larger geodatabase developing inside the project of Geomorphological mapping of Croatia. Owing to its object-oriented structure and high operability such database is an effective system for geoheritage identification, evaluation, vulnerability estimation and protection. One of the recent projects example is the research of Bistrac creek valley and preparing of documentation for its protection as a geomorphological nature monument. Such system also has a goal to provide a tool for geomorphosites implementation into the education process and nature protection awareness among local population. It is partially realized in the form of workshops with school children, public presentations and projecting of educational trails with accent on geomorphosites and its role in nature system of karst.

## **Geoconservation of caves in Fiji: a case study from Volivoli Cave, SW Viti Levu Island**

STEPHENS M.(1), HODGE S.(2), PAQUETTE J.(1)

(1) *School of Geography, Earth Science and Environment, The University of the South Pacific, SUVA, FIJI* ; (2) *School of Biological and Chemical Sciences, The University of the South Pacific, SUVA, FIJI*

Caves in Fiji often contain unique ecological and hydrogeological features and archives of human, faunal and climate history. These caves therefore provide good opportunities for education, research and sustainable tourism. However, due to their unique setting several caves in Fiji are very sensitive to environmental disturbances from nearby human activities that include quarrying and logging and other impacts such as dumping of rubbish and graffiti. Volivoli Cave, SW Viti Levu Island, is a site of national importance as it contains prehistoric animal remains although in recent years the environment of Volivoli Cave has become degraded. The slopes leading down to the cave entrance have been farmed which has led to increased overland flow of water in to the cave. The result is that areas of stratified archaeological deposits have been removed from the cave entrance. In addition, significant numbers of bats once lived in Volivoli Cave but have now disappeared. A conservation plan to protect and provide sustainable use of the cave involved installation of a drainage system to divert water away from important archaeological deposits, implementation of a walkway to allow safe access and the production of a notice board displaying accurate scientific information. A preliminary survey of the invertebrate fauna was performed and recorded very few individuals and species and probably due to the lack of bat guano. The effects of large groups of people entering the cave on CO<sub>2</sub> levels were also measured. Standardized cave sensitivity and disturbance indices were applied to Volivoli Cave and the preliminary results were compared to other caves in Fiji and elsewhere in the world; providing implications for future management strategies and research. This type of study is the first in the tropical South Pacific region and it is envisaged that the methodology and approach employed here may be developed and applied to other similar caves in Fiji and the South Pacific.

\*\*\*\*\*

## **Understanding the geo-heritage value of Dwejra (Gozo) as a geomorphosite**

GAUCI R.(1), CORATZA P.(2), SCHEMBRI J.A.(3), SOLDATI M.(2), TONELLI C.(2)

(1) *University of Malta , MSIDA, MALTA* ; (2) *Università di Modena e Reggio Emilia, MODENA, ITALY* ; (3) *University of Malta, MSIDA, MALTA*

Over the last decade, the geo-heritage aspect of geomorphological sites has received unprecedented research attention, with significant scientific initiatives in landscape research undertaken in order to define, assess and map geomorphosites.

The coast of the Maltese Islands, with a series of occupiers over the last ten millennia, has led to the development of a high density of coastal uses that superimpose on both a diverse range of aesthetic natural qualities and different cultural properties that have changed over time. Low sloping limestone coast provided an ideal geological setting for salt panning production, whereas today these are main areas for swimming off-the-rocks. *Rdum* (scree slopes) are areas where fertile agricultural practices were possible and today they are zones for which their aesthetic and ecological qualities are highly prized. Sinkholes were a source of shelter on rectilinear coasts and are now areas of outstanding natural beauty.

This paper examines the bridging of the cultural landscape with the geomorphological features of a sinkhole system at Dwejra in Gozo. Dwejra area is characterised by a highly scenic landscape and a very rich natural and cultural heritage. On the other hand, the impact and pressure of diverse human activities on this area have been growing significantly, often leading to conflicting interests and resultant landscape damage. As a result, geo-conservation aspects of this site have often been at the centre of national debates. The aim of this work is to provide a better understanding of the value of Dwejra as a geomorphosite, increase sensitivity to the geomorphological value of this area and highlight which geo-conservation aspects best fit the protection measures for this site.

KEYWORDS: geomorphosite, geo-conservation, sinkhole, Dwejra, Gozo; Maltese Islands

## **Geopark's Activities and the Role of Geomorphology in South Korea**

KIM C.

*Dept. of Geography Education, Kangwon National University, CHUNCHEON-SI, GANGWON-DO, SOUTH KOREA*

The main aim of this paper is to introduce activities and the role of geomorphology in establishing (a global or national) geopark in South Korea.

In South Korea, the project on establishing Gangwon Peace Geopark was launched in 2010 by the Ministry of Knowledge & Economy, Gangwon Province and 5 local authorities of the Korean DMZ's (demilitarized zone) adjacent areas. The DMZ and its adjacent areas (cross-border regions) in Gangwon province, South Korea, have comprehensive and academic geo-scientific sites. Their historical assets, cultural uniqueness and ecological resources have still remained intact and unexplored due to the Korean War in the early 1950s and the tension between the South and North during about 60 years. Gangwon Peace Geopark has geomorphological and geological resources which are created by processes of the formation of Korean peninsula. In the geopark, there are three types of petrographical and geomorphological features such as basalt, metamorphic rocks and granites.

Within these contexts, this paper can be divided into 3 sections. Firstly, in terms of geopark's activities, the relationship between geomorphology and geology is examined. Secondly, efforts on establishing geopark by geographers are reviewed. Finally, the role of geomorphology in making and managing geopark is discussed in the South Korean Context.

It shall be argued that the geopark has aspects of the conservation of geomorphological heritage as well as geological one. Within this context, in South Korea where is in the quickening period of geopark, the discussion and agreement with the Korean name of geopark are absolutely imperative. And nowadays, discussion about using "geopark" rather than "Geological Park" is suggested to organize South Korea Geopark Network (KGN) with geographers, geomorphologist, geologists and other geoscientists. It is expected that geopark and geotourism play an important role in improving the status of geomorphology in South Korea.

\*\*\*\*\*

## **An online atlas as a collaborative and visualization tool for the geopark proposal of the Chichonal volcano area**

OSORNO J.(1), ALCÁNTARA-AYALA I.(1), RAMOS S.(2), COUTURIER S.(1), GARNICA R.(1), LOPEZ J.(1)

*(1) Instituto de Geografía, UNAM, MEXICO, MEXICO ; (2) UNICACH, TUXTLA, MEXICO*

One of the most important elements of a Geopark proposal is the inclusion of local actors in the management plan of the cultural and geological heritage. The risk assessment and other key features of the project usually are expressed through a cartographic printed Atlas. In the context of the collaborative process among local and academic actors, the use of free software and spatial data offers the opportunity of a wider access and sharing of the results.

In this work an on-line atlas is developed as a tool to enhance the participatory process leading to a Geopark proposal for the Chichon Volcano zone in the state of Chiapas, Mexico. A set of information services was implemented using open standards, which allows the use of a variety of free and/or open client applications. The benefits of this digital replica over the printed version are discussed. Particularly the advantages of using multimedia resources such as geo-referenced photographs, spherical panoramas, videos and time series.

Finally, we propose a scheme for the training of local actors in basic editing, visualization and analysis skills using geographic information technologies, in support of administrative tasks, sustainable management and touristic promotion.

## **The appraisal of geoheritage through different approaches: the lesson from the Salse di Nirano Nature Reserve (Italy)**

CORATZA P.(1), CASTALDINI D.(2), CONVENTI M.(3), LIBERATOSCIOLI E.(2)

*(1) Dipartimento di Scienze Chimiche e Geologiche, University of Modena and Reggio Emilia, MODENA, ITALY ;*

*(2) Università di Modena e Reggio Emilia, MODENA, ITALY ; (3) Riserva Naturale Regionale delle Salse di Nirano, FIORANO MODENESE, ITALY*

The Regional Nature Reserve of Salse di Nirano is located in the low hills of the Northern Apennines, about 30 kilometres south of the city of Modena. The Reserve was established in 1982 and its characteristic features are mud volcanoes, locally called "Salse". They are emissions of cold mud up to the surface through faults and fractures, due to the ascent of salty and muddy water mainly mixed with gaseous (methane) and secondarily with fluid (petroleum veils) hydrocarbons. Depending on the density of the mud, these emissions can form either cones or pools at ground level. Since its establishment, the Reserve has promoted initiatives to appraise the area from the tourism viewpoint, welcoming individual visitors and school groups with a full programme of activities. In the last decade, visitors have increased from 30,000 to 70,000 per year. The numerous facilities – excursion and educational footpaths with panels, equipped trails (one for the disabled), two visitor centres – make the area accessible to all, supporting environmental education initiatives. A good variety of educational and information materials regarding the Nirano mud volcanoes and the territory of the Reserve has been published in the last decade, representing a successful example of environmental and tourism appraisal and improvement. Among the most recent products, particularly worthy of note are geotourism and tourism-environmental maps, books in hard copy and digital format, videos, virtual flights, multimedia and audio CDs. In the present study a critical overview of all the products elaborated in recent time is presented, highlighting strengths and gaps, and also taking into account the target of visitors they are addressed to.

\*\*\*\*\*

## **Collecting and sharing geoheritage information in the digital Age**

GHIRALDI L.(1), BALESTRO G.(2), PEROTTI L.(2), GIORDANO E.(2), GIARDINO M.(2)

*(1) Natural Sciences Museum of Torino, TORINO, ITALY ; (2) Uniniversity of Torino - Earth Sciences Department, TORINO, ITALY*

Over the last few years mobile technologies and interactive Web tools have become basic needs, allowing extensive exchange of accessible and permanent information. They have acquired increasing diffusion, and today they can be considered one of main means of communication and at the same time sources of information. In this new technological and cultural environment, an important field of application is can be represented by collection and dissemination of geoscientific information, and particularly data concerning geological heritage.

Since 2008 a multidisciplinary group (the Earth Sciences Department of the University of Torino and the Natural Sciences Museum of Torino) is active in defining a method to collect and share geoheritage information of the most representative geological sites of the Piemonte region (NW of Italy). A review of inventoried geosites, collection and dissemination of new geoheritage information are carrying out in the frame the PROGEO-Piemonte (PROactive management of GEOlogical heritage in the PIEMONTE region) project, as well as in others specific works.

The proposed method involves the use of:

- Mobile tools for data collection;
- Relational database for inventory activities;
- Web-Mapping tools and mobile applications for data dissemination.

The aim of this methodology is to identify a standardized approach which allows the use of mobile devices in each step of the process. A basic inventory form has been specifically developed and imported in an open source application, which allows to collect data directly from mobile devices. Structured information are in this way sent to a relational database purposely set-up, or stored in local (e.g. in a phone card).

The database is the core of the proposed method, because it is a source of information for Web and mobile applications too. A graphical interface purposely set-up allows the user to browse data of his interest through specific queries and accessing to an easy-to-use GPS-based mapping tool.

### **In search of the cultural geomorphosites of Wales: evidence from medieval poetry**

GRIFFITHS H.(1), SALISBURY E.(2)

(1) Aberystwyth University, ABERYSTWYTH, UNITED KINGDOM ; (2) Centre for Advanced Welsh and Celtic Studies, University of Wales, ABERYSTWYTH, UNITED KINGDOM

The landscape of Wales is characterised by glacial valleys, dramatic coastlines and fluvial forms ranging from narrow upland valleys to wide floodplains, active and stable meandering reaches and wandering, entrenched and mixed bedrock-alluvial rivers. Some landforms (eg. picturesque waterfalls) have assumed a cultural significance due to their aesthetic qualities, are important sites for tourism, and are recognised by geomorphologists and artists as inspirational features. In general, however, conservation of these landscapes is based on ecological, geological and purely geomorphological characteristics. Landscapes where geomorphology and culture intersect are less frequently recognised, studied or presented to the public. Sources such as historical literature and art can provide clues to sites that were geomorphologically significant, but whose cultural importance has been lost over time due to a lack of awareness of the sources and/or modification of the landscape itself and the context in which it was lived. This paper focuses on four case studies from medieval Welsh poetry to identify cultural geomorphosites on Welsh floodplains. Selected poems by four 14<sup>th</sup> and 15<sup>th</sup> century poets—Guto'r Glyn, Dafydd ap Gwilym, Lewys Glyn Cothi and Dafydd Llwyd o Fathafarn—were analysed. We present the geomorphosites identified in these poems. These include sites where rivers in flood either prevented these travelling *troubadours* from reaching their destinations, or were used as metaphorical tools in satirical, elegiac or love poetry. The poetry presents the geomorphological features vividly, and provides glimpses of the nature and perception of floodplains in medieval Wales. These sites have now been modified either by anthropogenic activities (channelisation and drainage) or geomorphological processes. We argue that these sources should be systematically analysed in order to fully appreciate the influence of geomorphology on both historical and contemporary culture.

\*\*\*\*\*

### **The Da Vinci Landscape Code; Exploring the Panorama behind La Gioconda**

NESCI O.(1), BORCHIA R.(2)

(1) University of Urbino, URBINO , ITALY ; (2) MVR -Montefeltro Vedute Rinascimentali, URBINO, ITALY

This research, which identifies landscapes and panoramic views painted by Da Vinci in La Gioconda (Mona Lisa), uses both quantitative and comparative methods including digital terrain models, geomorphological mapping, image analysis, and detailed study of historical documents. The methods and research are an extension of a highly successful project to document the landscapes in the paintings of Piero della Francesca. The precise representation of Renaissance landscapes is important not only for cultural and historical studies, but also permits a comparison of forms of features with the present day, a type of repeat photography database that has already suggested strong hydrological contrasts. The landscapes of La Gioconda and Madonna Litta center in the high Val Marecchia area (Central Italy). The identification of these landscapes permits and enables a new dimension in cultural, historical, and geomorphological studies.

## **The geological characterization of the Landscape in movies and fictions: a suggestion to involve the society in the WHS sustainable development**

*FARABOLLINI P.(1), LUGERI F.R (2), GRECO R.(3), BOCCI C.(4)*

*(1) Scuola di Scienze Ambientali - Universit? degli Studi di Camerino, CAMERINO (MC), ITALY ; (2) Istituto Superiore Protezione e Ricerca Ambientale ? Servizio Geologico d'Italia, ROMA, ITALY ; (3) Departamento de Geoci?ncias Aplicadas ao Ensino Instituto de Geoci?ncias - Unicamp, CAMPINAS - SP, BRAZIL ; (4) Scuola di Scienze Ambientali - Universit? degli Studi di Camerino, CAMERINO (MC), ITALY*

The characterization of natural and cultural heritage, using some popular entertainment products, such as TV movies and fiction, can become an effective and original way to involve the society in protecting the territory and enhancing the local development, thanks to the dissemination of knowledge.

The aim is to make understandable to the society the complex aspects of the landscape related to its geological and ecological assessment.

The tools here proposed are the episodes of the TV series "Il Commissario Montalbano" filmed in Sicily. The stories, written by Andrea Camilleri, are located in Sicily (the biggest Italian island in the South of Mediterranean Sea), particularly in some World Heritage Sites.

One of the most important interpreters in the fiction, Cesare Bocci (co-author of this paper) is a geologist: this combination suggested us the potential of the filmic communication in the popularization of the natural and cultural heritage.

For example, the "clou scene" of the episode "Par condicio", is located in the so called "Latomie" in Ragusa. Latomia means "cut stone". These ancient quarries are lithologically composed of Tyrrhenian Calcarenes: in the SE of Sicily this kind of stones are very soft and friable: in the local dialect are called "giuggiulena" ("sesame seeds").

The natural and cultural landscapes, giving a fascinating scenery to the films, represent a meaning in the representation of history. At the same time, if recognized and understood, they become part of the cultural heritage of each component of the local community, and the society. The cognitive process activates a virtuous circle, revitalizing the links between humanity and environment. Moreover, it promotes a creative participation of the society in new policies, oriented to a sustainable development, and the tourism -especially geotourism and ecotourism- becomes an important resource, especially in these times of crisis.

\*\*\*\*\*

## **The Aeterna Urbs geomorphological heritage (Rome, Italy)**

*PICA A., VERGARI F., DEL MONTE M., FREDI P.*

*La Sapienza University of Rome Earth Sciences Department, ROME, ITALY*

The biggest European cities are characterized by millennia of urbanization. The "man-made layering" over the time modified the original setting on which the cities developed, but the geomorphological survey in the urban environment can still recognize the ancient features. We show an example of recognizing the original paleogeographical conditions by means the results of the geomorphological survey conducted within Rome. The aim of the analysis is the geotourist enhancement of the city center, telling about the paleogeography of the ancient Rome through the landforms still visibles. The geomorphological survey led to the geosites inventory and to the identification of three geosites (two geomorphosites and a geosite of stratigraphical interest). We developed an evaluation model of the Geosite Geotourist Value (GGV index) that consists of the quantification of five attributes for each geosite. The attributes evaluated are significant characteristics of scientific and geotourist interest. The GGV allowed to give a priority order for the geosites enhancement. The proposal for the tourism is a geotourist itinerary along which the geosites are joined and related to the historical and cultural features of the city. It is described in a text explaining both the geomorphological and the historical and cultural heritage of Rome city center. It is also represented on a geotourist map, set as a scientific and popularizing device. In this way we supplement the proposal for the historical and cultural tourism of the *Aeterna Urbs* with natural environment features.

Keywords: Urban Geomorphology, Rome, Geomorphosites, Geosite Geotourist Value, Geotourism.

## **Towards holistic landscape conservation within urban area: a case study of Klang gate geoheritage site in Kuala Lumpur, Malaysia**

UNJAH T.(1), CHOUN SIAN L.(2), ALI C.A.(1), KOMOO I.(2), LEMAN M.S.(3)

(1) Institute for Environment and Development (LESTARI), BANGI, SELANGOR, MALAYSIA ; (2) Southeast Asia Disaster Prevention Research Institute (SEADPRI-UKM), BANGI, SELANGOR, MALAYSIA ; (3) School of Environmental Science and Natural Resources Faculty of Science and Technology, UKM, BANGI, SELANGOR, MALAYSIA

Conservation of natural heritage within city area is very challenging, particularly in developing countries, due to rapid development and conflict arising from needs to balance economic and protection of natural environment. An attempt to protect natural heritage within the urban area in the country have been initialized by gazetting part of the Quartz Ridge area as a State Park. This ridge is known as Klang Gates Quartz Ridge, located on the northern part of Kuala Lumpur city centre. The ridge is made up of quartz mineral is by far the longest and largest in the country. In addition, the forested area provide important ecological functions; a green lung with endemic flora and fauna, and a crucial water catchment area for the surrounding urbanized areas. The urban sprawl has resulted more housing development toward the quartz ridge surroundings, some lands located on the surface expression this quartz ridge have been least-hold to private owner. Four issues were addressed in coming up with the framework of protecting and conserving the important geoheritage: integrated research; establishing mutually acceptable boundary; continuous education and awareness campaign; and stakeholder participation. Integrated research is based on the need for scientific evidence as well as identifying heritage values. Meanwhile, the establishing of mutually acceptable boundary for conservation includes understanding of the nature of the landscape and recognizing the sensitive area contributes to the integrity of the proposed site and reasonable zone for development and vice-versa. The continuous education and awareness programme for this initiative includes collaborative work with the local authorities, NGO's and other stakeholders in disseminating the knowledge towards understanding and praising their common heritage. Stakeholders' involvement is crucial in the protection and conservation of geoheritage, not just because of their proximity and association with the protected area.

\*\*\*\*\*

## **Poster presentations:**

### **Geoheritage of Fluvial Geomorphology in the Middle and Lower Reaches of the Yellow River: A Survey by Means of Remote Sensing**

LIU X.P.(1), DONG Y.(2), ZHOU L.P.(1), DONG X.C.(3), ZHU X.Z.(1), QIU F.Y.(1), CAO X.J.(2), CHEN Z.H.(2), ZHOU H.Y.(1)

(1) College of Urban and Environmental Sciences, Peking University, BEIJING, CHINA ; (2) China Institute of Geo-Environment Monitoring, BEIJING, CHINA ; (3) School of Urban Planning and Design, Peking University, BEIJING, CHINA

Yellow River is China's second largest river with a total length of 5464km. The middle and lower reaches of the Yellow River were formed during the Cenozoic and the tectonic uplift and climate change are the two key factors to shape the river's morphology and its evolution. Throughout the geological time of several million years, various forms of fluvial geomorphology were developed along the Yellow River that record the history of this river and the environmental processes of its basin evolution. Some of these landscapes form geoheritage of fluvial geomorphology. In this study, remote sensing technique is used to investigate these geoheritage landscapes. With the combined use of satellite images and field investigation, we have identified geoheritage landforms at 20 sites in different fluvial geomorphology units in the middle and lower reaches of the Yellow River, which include mountain meander, plain free meander, braider river, delta, river bed, floodplain, terrace, and anthropogenic landforms. We present detailed analysis for two geoheritage sites and show how the remote sensing approach can be used to identify the features and types of the geoheritage and to evaluate their conservation status.

## **Geopark potential in the plateaus of Parana sedimentary basin, Uberaba City (Minas Gerais), Brazil: geodiversity and geoconservation**

GODOY L.H.(1), SARDINHA D.S.(2), CONCEIÇÃO F.T.(1)

(1) UNESP - Paulista State University, RIO CLARO, BRAZIL ; (2) UNIFAL - Alfenas Federal University, POÇOS DE CALDAS, BRAZIL

Uberaba City is located in the Plateaus Geomorphologic Unit of the Paraná Sedimentary Basin, more specifically at the Septentrional Plateau sub-unit. The topography is characterized by flat or slightly undulated surfaces, formed by sedimentary and igneous rocks from the Cretaceous period (145.5 a 65.5 m.a.), with a moderately dissected relief and leveled tops between 750 and 900 m. These characteristics provide to the city a great geotouristic potential regarding its geological and geomorphological heritage. The igneous rocks from Serra Geral Formation are found in 12 points, between 650 m and 802 m of altitude, in which Ponte Alta (40 meters) and Peirópolis III (7 meters) waterfalls can be highlighted. The sedimentary rocks from Uberaba Formation were described in 11 points, ranging from 733 m to 807 m of altitude, where Giovane Cave and Waterfall (12 meters) stands out. In Marília Formation sedimentary rocks, occurring between 874 m and 918 m of altitude, the Caieira outcrop (three-meter cave with stalactites and stalagmites) and Vale Encantado Waterfall (8 meters) can be pointed out, among 8 other attractions. Furthermore, a point located on a gas station at 1020 m of altitude, has a panoramic view to the local geomorphology, constituted by tabular sierras (cuestas). After the geodiversity assessment, an environmental diagnosis was conducted throughout the geotouristic attractions, by using the Visitor Impact Management Method. The results indicate that only Vale Encantado Waterfall presents a moderate impact, the least when compared to 22 other attractions, exhibiting high or worrisome impact, and 7 with very high impact. In addition to setting the management strategies, and monitoring the environmental impact indicators, this work provides the basis so that activities in the potential Geopark of Uberaba (MG) can be conducted with environmental responsibility and geoconservation.

\*\*\*\*\*

## **Assessment of geomorphosites in the Celil Gorge (Cihanbeyli Plateau, Turkey)**

EKINCI D., DOGANER S.

ISTANBUL UNIVERSITY, ISTANBUL, TURKEY

Geomorphosite is a segment of tourism that has developed worldwide and emerging as a new global phenomenon in recent years. It is a form of special interest tourism and focuses on geomorphological features and the types of landscapes. In addition, Geomorphosite is sustainable tourism with a primary focus on experiencing the landform types in a way that fosters geomorphological and cultural understanding, appreciation and preservation, and is locally advantageous. As it state Geomorphosite is landforms to which the society confers a certain value for scientific, but also cultural, ecological, aesthetic or economic reasons. Many natural landscapes are preserved throughout Turkey due to their cultural and historical values as well as for their environmental importance. As it is state, tourism is the largest economic sector in terms of earnings and in number of people employed among Turkey. This paper aims at assessment of geomorphosites on the Celil Gorge where located central Anatolia. There are semi-arid morphoclimatic region. Celil Gorge is a large range of geomorphosites which were formed by the action of the winds. In this gorge, there are many different types of geomorphosites however zeugens are the best example. This site offers a landscape that affects and excites people. The occurrence of zeugens implies immense variations in the rates of degradational activity on the land surface. In zeugens landscapes, the active erosional processes are confined to valley sides and valley floors. These geomorphosites are at different stages of development some are established tourism destinations and some are working towards this goal. As a result, this area has important resources concerning geomorphologic heritage so it has a big geomorphotourism potential and has a unique position in the world.

**Conservation, management and valorization of geomorphological heritage in 'geological' nature reserves: the case of the Vigny quarry (Vexin, France)**

BETARD F.

*Univ Paris-Diderot, PARIS, FRANCE*

Located in the French Vexin to the NW of Paris, the Vigny quarry is a geosite of international relevance, recently classified as a Regional Nature Reserve (RNR) of geological interest (in 2009). Exposing reefal and peri-reefal limestones of Palaeocene age, the site was considered by E. Desor (1846) as the co-stratotype – together with the Danish series of the Fakse quarries – of the Danian stage. Furthermore, the Vigny limestones contain the richest Danian molluscan fauna in Europe and are the only known reefal complex of Tertiary age from the Paris Basin. As a whole, the Vigny quarry exhibits various aspects of geoheritage of great scientific and educative value: stratigraphy, palaeontology, sedimentology, tectonics... Geomorphological heritage is one of the major interests of the geological nature reserve. The site is a veritable open-air museum of palaeolandforms of various types, including palaeo-fault scarps with well-conserved tectoglyphs (striation features, coatings), palaeo-submarine landslides (slumping with olistoliths of reefal limestones, debris- and mud-flows of fluidized chalk), Pleistocene palaeosols with cryoturbation features, etc. The development of lookouts and scenic vantage points along a “geomorphological” trail still increases the interest of the site for geomorphology. Protection of geomorphological heritage and other geological features was made possible by 2003 with the land acquisition by the Val d’Oise Departemental Council, which developed an exemplary strategy of conservation, management and valorization of the geoheritage (security setting, pedagogic facilities and tools, information panels, website for school education, museography, mainstream publications...). With its recent classification as a Regional Nature Reserve, this reinforces the protection status of the Vigny quarry and extends the program of conservation, management and valorization of this unique geoheritage of the Paris Basin.

\*\*\*\*\*

**Geosites of the Al Madinah Volcanic Geopark as the first geopark proposed to develop in the Kingdom of Saudi Arabia**

NEMETH K.(1), MOUFTI M.(2)

*(1) Massey University, CS-INR, PALMERSTON NORTH, NEW ZEALAND ; (2) King Abdul Aziz University, JEDDAH, SAUDI ARABIA*

UNESCO promotes conservation of the geological and geomorphological heritage through promotion of protection of these sites and development of educational programs under the umbrella of geoparks. Here we identify significant volcanic features that could be organized and promote as the first geopark, the Al Madinah Volcanic Geopark in the Kingdom of Saudi Arabia. The Harrat Al Madinah Volcanic Field has numerous volcanic geosites relevant to broaden our understanding of the evolution of volcanic fields dominated by Hawaiian and Strombolian style volcanic cones and lava fields. The proposed geopark includes the location of the last historically erupted volcanoes in the Arabian Peninsula. A major geosite has been selected to demonstrate the diversity of volcanic phenomena associated with the intraplate volcanism of the Harrat Al Madinah, that created lava spatter and scoria cones formed in a 52 days eruption in AD 1256 just 10 km SE of Al Madinah city. The eruption formed a ~2 km long NW-SE-aligned fissure with at least seven vents, which made a chain of nested lava spatter/scoria cones. More violent explosive phases of the eruption formed an extensive ash plain. The well-preserved craters show evidences of dynamic crater formation through lava infill, drainage and cone rafting through side vents fed the major lava fields. The geosite is one of the best accessible places globally to see well-exposed lava spatter and scoria cone complexes. The Harrat Al Madinah is also located in a culturally significant place near to Al Madinah city which is one of the holiest places to Muslims. The proposed geopark is easily accessible through highways (and by train in the near future) and it would provide significant economic benefit to Al Madinah city, which also plays an important role for Muslim pilgrims visiting the holy sites in the city that would open up a cost-effective volcanic geoeducation program that could be offered as alternative geotouristic programs for visitors.

### **Sinkholes in the Island of Gozo (Malta): Geomorphosites to be protected and enhanced**

CORATZA P.(1), GALVE J.P.(2), SOLDATI M.(3), TONELLI C.(4)

(1) *Dipartimento di Scienze Chimiche e Geologiche, University of Modena and Reggio Emilia, MODENA, ITALY* ;  
(2) *Universidad de Zaragoza, ZARAGOZA, SPAIN* ; (3) *Universita di Modena e Reggio Emilia, MODENA, ITALY*  
; (4) *Universita' di Modena e Reggio Emilia, MODENA, ITALY*

The Island of Gozo is part of the Maltese archipelago which is located in the Mediterranean Sea, about 90 km south of Sicily and 290 km north-east of Tunisia. Karst processes play an important role in the Maltese archipelago due to the extensive presence of limestones, which has favoured the development of an interesting karst system on the islands and the surrounding submarine area. The effects of karst processes through time are particularly evident in Gozo, where 17 sinkholes have been recognised, some of which of notable size and high aesthetic interest. These sinkholes have been assessed applying a methodology which has been specifically set up with the aim of verifying whether any of them could be considered as geosites according to their scientific, additional (ecological, aesthetic, cultural) and use values. The geosite assessment highlighted that 6 out of the 17 investigated sinkholes can be considered as geosites of geomorphological interest (geomorphosites). Finally, issues related to their enhancement and fruition are taken into account in the frame of potential geotourism strategies. The original contribution of this study is to show that sites of geomorphological interest, such as sinkholes, can become part of a culturally accessible and shared heritage, making them a resource for social and economic development in their own territory. Indeed, the sinkholes selected as geomorphosites in Gozo can be considered as new elements that can catalyse the potential of a territory which is often neglected.

\*\*\*\*\*

### **Tufa and Heritage: Geomorphosites as main elements of Cultural and Historical Monuments (High Ebro River, Spain)**

SERRANO E.(1), GONZÁLEZ-AMUCHASTEGUI M.J.(2)

(1) *University of Valladolid, VALLADOLID, SPAIN* ; (2) *Basque Country Univesity, VITORIA, SPAIN*

The High Ebro River Area is located in the Cantabrian Range in Northern Spain. It is a folded calcareous cover defining a structural relief drained by the Ebro River. In this area there are fifteen tufaceous complexes aged from Pleistocene to Holocene and present day tufas, linked to Cultural and Historical Monuments.

The presence of tufas is the key factor to understand the emplacement of human settlements during different historical periods. The hydraulic resources, linked to springs, the defensive location and baths are the most common land use of tufas.

This area is very frequented by visitors attracted not only because of the landscape, but also of Historical monuments. In spite of the narrow relation between tufas and cultural landscape, the calcareous buildups are not included nor taken in account in touristic information.

In this work four cases have been selected (Frías, Orbaneja del Castillo, Sedano and Tubilla del Agua), two of them are National Monuments located in a Natural Protected Area -NPA-, and in all cases exist a close and valuable relationship between tufas and cultural heritage. The study implies:

- Assessing the intrinsic, extrinsic and use values of the tufas as a geomorphosites following the assessment method used in previous published works.
- Making documents and tools (mapping, dates, analysis) to land managers (municipalities, NPA) focusing on the inclusion of geomorphic values as natural heritage joint to the cultural ones.
- Propose documents (explanatory maps and leaflets, cards) to incorporate the knowledge on tufa (genesis, age, present-day dynamic) and its relationship with cultural heritage.

Inclusion of tufa knowledge as an attractive to visitors and for the touristic or land management in High Ebro river area must be undertaken from the geoconservationism; our proposal for these four examples allows elaborate a model to be applied in a wider area. Moreover, it provides useful tools for managing tourist resources.

## **Cantona, one of the largest prehispanic cities in the mesoamerican region; relations to geosites and geomorphosites**

### PALACIO-PRIETO J.

*Instituto de Geografía, Universidad Nacional Autónoma de México, MEXICO CITY, MEXICO*

Cantona is located in Central Mexico, about 160 km to the east of Mexico City. This large prehispanic city, culturally located in the Mesoamerican region, covers about 14 km<sup>2</sup>, most of the ruins are still to be recovered (only 1% is open to visitors) and few information about its original inhabitants has been gathered so far.

Cantona is contemporary with other great Mesoamerican cities including: Cholula, Teotihuacan and Monte Alban and its height ranges from 2300 to 1300 yBP. Its population has been estimated at about 100 000 inhabitants.

The entire city is located over lava flows generated in the “Los Humeros” caldera about 20-30 K years; the structure of the city is strongly determined by the rough surface of the flows and their configuration, running in a North-South direction. Due to its strategic location (half way between the Gulf of México and Central México), Cantona represented a commercial site of great importance, where obsidian was the main product. Obsidian deposits are located at less than 10 km to the northwest and up to 400 workshops have been found inside the archaeological site.

Geologically, the region corresponds to a transition area where sedimentary rocks (Mesozoic) are covered by volcanic deposits, like the lava flows mentioned above. The presence of nearby maars has also to be pointed out; six maars (locally known as “Axalapazcos”) are distributed along a flat surface, formerly a lake now under a process of progressive dissection. Other outstanding features include two large stratovolcanoes: “Pico de Orizaba” (the highest mountain in Mexico and the third highest in North America; It rises 5,636 metres) and “La Malinche” (almost 4,000 metres).

The area is under study in order to promote geotourism based on its geological, geomorphological and cultural attractions.

\*\*\*\*\*

## **The enhancement of a geotourist trail in the Adamello Brenta Nature Geopark (Rhaetian Alps)**

### PICA A.(1), BAZZOLI G.(2), DEL MONTE M.(1), MASÈ V.(2)

*(1) La Sapienza University of Rome Earth Sciences Department, ROME, ITALY ; (2) Adamello Brenta Nature Geopark, STREMO (TN), ITALY*

The high geodiversity of the Italian territory has seen, in recent years, the birth of 8 Geoparks, economic resources of the territory on which they insist, through the promotion and protection of geological heritage and culture. Among the Italian Geoparks members of the EGN (European Geoparks Network), the Adamello Brenta Nature Geopark is the only one representative of the Southern Alps geodiversity: in the geopark area we have evidences of the Adria microplate’s continental margin evolution from the late Paleozoic to his involvement in the Alpine orogenesis. The territory is divided by the Giudicarie Line into two geological and geomorphological very different landscapes and it is possibile to see igneous, sedimentary and metamorphic rocks in contact with each other, within a few miles. The Geopark has an action plan full of popularizing and educational activities, conservation actions and research. The geotourist enhancement of some valleys of the Geopark is one of the action plan aim. For this purpose these valleys have been analyzed with the help of a method proposed by the University La Sapienza of Rome, in order to assess the Geosites Geotourist Value (GGV) of the geosites in the area through data processing in GIS environment. The application of this method allows to choose an itinerary to visit the geological sites with the higher values of GGV. The geotourist itinerary is presented together with the Adamello Brenta Geopark strategies of earth sciences interpretation and popularization, designed to bring students and tourists to the interpretation of the landscape and to the understanding of the geology: guided excursions, educational projects based on the manual ability improvement, promotion of human relationships, and also experiencing innovative technologies, such as the interpretation of LIDAR images on the interactive whiteboard, are used as a tool.

Keywords: Geopark, Geosite Geotourist Value, G.I.S., Geotourist trail, popularization.

**Volcanic Geomorphosites within the large Kanawinka Geopark of southeastern Australia; identifying, describing, evaluating and managing Geomorphosites for future use in Geotourism**

JOYCE E.B.

*Earth Sciences, The University of Melbourne, PARKVILLE, AUSTRALIA*

Australia's first Geopark is on the broad Western Plains of Victoria and an adjacent part of southeastern South Australia, with some 100 well-studied volcanoes ranging in age from five million years to just a few thousand years - Mount Gambier maar erupted only 5,000 years ago. The Geopark is part of a larger area known as the Newer Volcanic Province of Southeastern Australia, one of the best studied of the world's young basaltic monogenetic lava fields. Volcanic landforms include numerous scoria cones, and some 40 maar craters with ash deposits, and extensive lava shields have been built up by Strombolian/Hawaiian eruptions, with fluid lava flows travelling for tens of kilometres down river valleys. The indigenous heritage of the Geopark includes a complex aquaculture of Aboriginal fish and eel traps, and the remains of stone houses in the stony rise flow landscapes of Budj Bim (Mount Eccles volcano). Post-contact settlement is evident in historic "bluestone" (basalt) houses and farm buildings, bridges, churches, and the many striking stone walls. Within the Geopark a Volcanoes Discovery Centre has been established at Peshurst, new reserves have been developed at Mount Elephant and Mount Rouse volcanoes, and improvements to interpretation made at other sites. The integration of volcanic research, local history study, and heritage interpretation is the key to developing a greater awareness of the Kanawinka Geopark. Within the area of the new Kanawinka Geopark are many important Geomorphosites including lava caves of International significance, open volcanic vents, major tumuli groups, and springs and waterfalls. Coastal features include limestone cliffs, calcareous dunes, basalt headlands and cliffs, drowned lava flows and a large offshore volcanic island. Since the area was recognised as a Geopark in June 2008, the Geopark has been developing new material for use by Geotourists, Geotourism operators and local government bodies.

\*\*\*\*\*

**Runoff impact on active geomorphosites in unconsolidated substrate. a comparison between earth pyramids in the swiss alps and badlands in the italian apennines**

IRENE B.(1), REYNARD E.(2), LUPIA PALMIERI E.(3), PELFINI M.(1)

*(1) Università degli Studi di Milano, MILANO, ITALY ; (2) Université de Lausanne, LAUSANNE, SWITZERLAND ; (3) Università La Sapienza di Roma, ROMA, ITALY*

The cultural value of geomorphological heritage (i.e. geomorphosites) is universally recognized and at the same time the interest on its mutability, as a consequence of both natural-climate and human pressure, is growing. At this scope the focus has been put on *active geomorphosites*, in which it is possible to observe and quantify the geomorphological processes that vary mainly as a response to climate change. In some cases a sudden increase in the velocity of processes can cause irreversible modifications threatening the survival of sites as well as their scientific value in term of integrity.

The runoff derived morphologies on unconsolidated or partially consolidated deposits may form in different geological (e.g. textural and structural) and morphoclimatic conditions, under influence of water runoff action. The study cases are: *calanchi* on marine originated clays in the Italian Apennines in Mediterranean climatic context (i.e. Crete d'Arbia, Tuscany) and earth pyramids formed on glacial heterometric deposits in mid-mountain environment (i.e. Pyramides d'Euseigne, Canton Valais, Switzerland). In both the study cases human activities (e.g. deforestation, grazing and farming, land-use changes, especially cropland abandonment) have strongly contributed to landscape evolution.

In order to investigate erosion rates, dendrogeomorphology investigations (abrupt growth changes and root exposure analysis) have been integrated to traditional quantitative geomorphology techniques, for detailing and extending to the past the direct monitoring results. Dendrogeomorphology indicators reveal stress caused by variation in geomorphic processes involving trees depending on climatic/meteorological conditions. Especially at Crete d'Arbia a correlation between average erosion rates coming from biologic ( $1.7 \text{ cm a}^{-1}$ ) and a-biologic techniques ( $1-1.5 \text{ cm a}^{-1}$ ) has been found and the results of the comparison between erosion rates in both marine and glacial deposits are presented.

## Urban geotourism

RODRIGUES M.

*Universidade de Lisboa, Centro de Estudos Geograficos, LISBOA, PORTUGAL*

The great majority of the urban centers, including some metropolis, were build in areas providing the inhabitants with natural benefits: rivers or littoral environments (rich in natural resources or transportation routes), good agricultural soils (as volcanic ones), hilly landforms (were castles or fortifications stand), natural springs to fulfill the water needs (as karst springs) and other geomorphologic, geologic, hydrologic or soil features. Although those urban centers have increased in size over the time (occupying the rural surroundings), many of that previous geodiversity still remains perceptible in the urban landscape.

Today most of the world population lives in towns leaving behind the rural landscapes (Rodrigues *et al.*, 2011) and the geoheritage that represents the values of its geodiversity. To promote the geoheritage still preserved in urban environments, establishing urban geotourism routes, could be a very good way to stimulate the urban population to fully appreciate the geoheritage and to develop geotourism.

Geotourism can be considered both in broad and in strict senses (Rodrigues, 2009, 2011). In strict sense, geotourism is a tourism segment focused on the sustainable usufruct (by geotourists and local communities) of the geoheritage fruition. In broad sense, geotourism can be considered as a tourism segment mainly focused on the sustainable usufruct (by geotourists and local communities) of the geoheritage fruition, which can be added the cultural heritage (material and immaterial) of the areas. In this sense geoheritage is the driving force of the geotourism itineraries, but the cultural heritage it is also added to increase the value of the visited regions.

This broad sense of geotourism applies perfectly to urban geotourism. In the cities we can establish geotourism routes where geoheritage can be linked with cultural heritage as we can demonstrate with examples from Lisbon city or, in a more large scale, from the Metropolitan Area of Lisbon.

\*\*\*\*\*

## Evaluation of a geotope of exceptional importance within the Cameroon coast: the Lobe Falls

TCHINDJANG M.

*University of Yaoundé I, YAOUNDE, CAMEROON*

According to Strasser *et al.*, (1995), "Geotopes are portions of territory with a value for the Earth Sciences. This term therefore includes mountains, hills, valleys, ravines, caves, riverbanks and shorelines, quarries, gravel pits, ... sites that provide information and compelling features on a situation or event that the Earth has experienced over geologic time or the history of life and climate. The geotopes help to understand the spatio-temporal evolution of a region, the significance of surface processes and the importance of rocks as part of the construction of landscape. The geotopes, in this sense, are natural monuments of great importance, even essential, for both the public and the science »

This definition is consistent with the observations made in the Lobe Falls, a geotope or geosite located along the Cameroon coast. The definition adopted for the evaluation of the geological site for tourism is broad, because it takes into account the cultural aspect and the three-dimensional representation of the communities (Batanga, Mabi and Pygmies) living around. This system of representation seems to be the element that allowed the preservation of this geotope.

In fact, geosite being any geological or geomorphological object having a certain value, whether scientific, historical-cultural, aesthetic or socio-economic, the actual value of Lobe Falls depends as much on its scientific characteristics and contextual location, its use, its historical value and its beauty. These are the criteria that will allow me to assess the importance of the Lobe Falls for tourism development and its patrimonial value in a context where the site is threatened by the management of the deepwater seaport of Kribi as well as oil and gas exploitation.

The adopted approach draw upon the environmental assessment process that will take in account sensitivity, aesthetic and ecological criteria to identify and highlight its intrinsic value.

## **Geomorphic context and active processes influencing a cultural heritage: irrigation channels in Valais, Switzerland**

REYNARD E.

*Institute of Geography and Sustainability, University of Lausanne, LAUSANNE, SWITZERLAND*

The Canton of Valais (Switzerland) is characterised by dry climatic conditions that explain the presence of an important network (about 800 km) of irrigation channels – called *Bisses* or *Suonen* – dating back to the Middle Ages. During the last 30 years these agricultural infrastructures have sparked a renewed interest for tourist and cultural reasons. Indeed, the paths along the channels are used as tourist trails and several abandoned channels have been renovated for tourist use. Based on an inventory of the *Bisses/Suonen* of Valais, the proposed poster has three aims: (1) to analyse the geomorphological context (morphometric analysis, structural geomorphology, main processes) of each *Bisse/Suon* and to show the impact of the geomorphological context on the building techniques; (2) to identify particularly active processes along the channels; (3) to classify the *Bisses/Suonen* according to their geomorphological value and to their geomorphological sensitivity. The proposed ranking will be used to prepare the candidature of the *Bisses/Suonen* network for the World Heritage List.

\*\*\*\*\*

### **A new network on mountain geomorphosites**

REYNARD E.(1), BOLLATI I.(2), CAYLA N.(3), CORATZA P.(4), GIUSTI C.(5), HOBLÉA F.(3), ILIES D.(6), MARTIN S.(1), MEGERLE H.(7), PELFINI M.(2), REGOLINI G.(1), SELLIER D.(8), ZORN M.(9)

(1) *Institute of Geography and Sustainability, University of Lausanne, LAUSANNE, SWITZERLAND* ; (2) *Department of Earth Sciences, University of Milan, MILANO, ITALY* ; (3) *Laboratory EDYTEM, University of Savoie, CHAMBÉRY, FRANCE* ; (4) *Department of Chemical and Earth Sciences, University of Modena and Reggio Emilia, MODENA, ITALY* ; (5) *Institute of Geography, University of Paris-Sorbonne, PARIS, FRANCE* ; (6) *Department of Geography, Tourism and Territorial Planning, University of Oradea, ORADEA, ROMANIA* ; (7) *University of Applied Forest Sciences, ROTTENBURG AM NECKAR, GERMANY* ; (8) *Institute of Geography and Regional Planning, University of Nantes, NANTES, FRANCE* ; (9) *Anton Melik Geographical Institute, Slovenian Academy of Sciences and Arts, LJUBLJANA, SLOVENIA*

As mountains are recognized to be natural areas with a very high geodiversity, and at the same time as areas with a great potential for the development of soft tourism, a new Network on Mountain Geomorphosites was created in October 2012 in Lausanne (Switzerland). The Network is open to all researchers active in geoheritage, geoconservation and geotourism studies in mountain areas. Research will focus on three main issues: (1) Geoheritage and natural processes: because mountains are very sensitive to climate change it is hypothesized that geoheritage will be highly impacted by global change in the future. These impacts must be better addressed by geomorphologists. (2) Geotourism: There is currently a lack of research addressing issues such as the needs of the potential public(s) of geotourism, the evaluation of the quality of geotourist products and the assessment of the economic benefits of geotourism for the regional economy in mountain regions. The collaboration with social scientists (economists, sociologists) will help to fulfill this objective. (3) Environmental education: Few studies have addressed the question of using geoheritage to communicate on more general issues like the dynamics and sensitivity of mountain environments or the impacts of climate change on mountain areas. It is, therefore, necessary to develop communication and learning methods – in particular by using new communication technologies – to improve environmental education based on geoheritage site promotion for several kinds of audiences, in particular tourists (to improve their awareness on the sensitivity of mountain environments) and scholars. These three research objectives will be fulfilled by the development of common research, in particular cross-border case studies, and by the elaboration of specific courses for Ph.D. and master students. Collaboration with existing mountain networks (scientific, nature parks, etc.) is expected.

### The Sulcis Iglesiente mining compound (Sardegna, Italy) inside the UNESCO World Heritage Tentative List

PANIZZA V.(1), CORATZA P.(2)

(1) University of Sassari, SASSARI, ITALY; (2) University of Modena, MODENA, ITALY

The Sulcis Iglesiente territory is located in the southwestern part of Sardinia and it is the most important Italian mining compound. This is a very important area from both geological and geomorphological standpoint, due to the complex geodiversity. In terms of geological aspects, other than carboniferous granites and diorites, we can also find metal limestones and dolomites where there are the main lead and zinc veins of the island. From a geomorphological point of view, the relief is predominantly controlled by geological structure and the landforms can be mainly related to different morphogenetic factors and processes: gravity-induced, karstic, coastal. There are evidence of ancient settlement since the prehistory due mainly to seams of lead, silver and zinc in the Iglesiente and to coal in the Sulcis.

Aiming at protecting the rich and unique geological, natural, historical and cultural heritage of this territory, the Italian Minister for the Environment and Land Protection established, in 2001, the geo-mining historical and environmental park of Sardinia, which include other important mining areas of the island. Moreover in 2006 the area have been submitted in the UNESCO World Heritage Tentative List on the basis of the criteria ix and x.

In present work we will highlight the geological and geomorphological values which represent the basis of all the other aspects for which the area has been pointed out and included in several proposal of protection and enhancement.

\*\*\*\*\*

### Mapping geomorphodiversity. Case study: Bucegi Mountains

COMANESCU L., NEDELEA A., DOBRE R.

University of Bucharest, BUCHAREST, ROMANIA

The present paper aims at developing a new type of map, namely the map of geomorphodiversity of the Bucegi Mts., an area that is representative for the Romanian Carpathians.

The geomorphodiversity map has been done in several stages:

- The first stage investigated the geological conditions of the study area based on specialty literature and on the existing graphic and cartographic sources (geological and geomorphological maps, as well as aerial photographs). In this respect, the geological map has a significant relevance, because structure and petrography generate specific landforms that acquire value thorough the human perception. This so-called geomorphosites lead to high values of geomorphodiversity. In order to correlate them with the geological conditions they were outlined on the geological maps.
- At the base of the geomorphodiversity assessment lies the general geomorphological map, which was developed after several field trips undertaken with the purpose of making measurements and detailed mappings using a Garmin GPS receiver. The general geomorphological map, which was filled with additional data derived from aerial imagery (the flight of 2005), also gave us the possibility to make an inventory of the geomorphosites that can be seen in the study area.
- By making a synthesis of the information collected in the previous stages we were able to compute the geomorphodiversity index based on the formula below:  $Gmd = (\sum EgXn + Gm)/S$

where  $Gmd$  = geomorphodiversity index;  $Eg$  = the number of landforms;  $n$  = the number of the genetic types of landforms;  $Gm$  = the number of geomorphosites;  $S$  = area (in sq. km)

## **Geotopes portal; A methodological approach from the field to the Web**

SKENTOS A.(1), MITROU A.(1), PAVLOPOULOS K.(1), ANAGNOSTOPOULOU O.(2)  
(1) Harokopio Univeristy, ATHENS, GREECE ; (2) University of Athens, ATHENS, GREECE

The purpose of this paper is to register and promote greek geosites through a web-gis application. The methodology is based on the calibration of a set of criteria for each geosite that covers the topics of geology, ecology, culture, tourism and aesthetics. Further analysis of these data forms a geodatabase. The web application is characterized by a user friendly interface and provides the appropriate tools that allow the user to interact dynamically with the geodatabase. The main features of the application are "map display of the geosite location over base maps", "legend panel" that enables the user to manage the layers of the map, "map interaction tools" such as zoom in, zoom out, pan, full extent, previous view, "information tool" that provides text and photos about the geosite, "search list" by name or location. Also there is a user oriented approach that enables the user to register/ login in order to add new geosites and/or comment about the already existed ones. The web application adopts the latest open source web-gis frameworks like Open Layers, GeoExt and ExtJs api's.

\*\*\*\*\*

## **Typology and repartition of geosites in Danube Gorges (Romania)**

IOSIF D.(1), FOUACHE E.(2), GRECU F.(1), GIUSTI C.(2)  
(1) University of Bucharest, Faculty of Geography, BUCHAREST, ROMANIA ; (2) University of Paris - Pantheon Sorbonne, PARIS, FRANCE

This study focuses on the main geosites from the Danube gorges in Romania (*Iron Gates*), especially on their typology and repartition. Generally, the Romanian studies on geosites are at beginnings but there are great perspectives. Presenting the geology and the geomorphology of the Iron Gates as geosites is a good opportunity to solve some of the actually questions and, in the same time, to open a perspective for the touristic valorization.

We have identified more than sixty geosites along the Danube but with the aim to make the study more concise we have chosen only forty the most important. Then we have studied every single one with the main intention to establish the typology of those geosites. According to their main geological and geomorphologic characteristics, we have classified those geosites in eight categories. The great number of geosites' categories reflects the geology complexity and especially the geodiversity of the Iron Gates region. We distinguish, among the eight categories of geosites, the petrographical, the geomorphologic and the speleological ones, each with eight elements.

The repartition of those geosites along the Danube reveals many important geological and geomorphological realities. We observed that they are not distributed uniform on our region. We can also separate three zones which are directly related with the dominant geosites. Thus, we distinguish a zone where the petrographical sites are dominant, a zone where the speleological sites are dominant and another one zone where we can find a preponderance of geomorphologic sites. This repartition is not randomly created but it corresponds to the geological and geomorphological features of the most beautiful and the most complex Danube gorges.

### **Alpine geomorphosites in protected areas and mitigation of natural hazards**

*KOMAC B., ZORN M., ERHARTIC B., FERK M.*

*Research Centre of the Slovenian Academy of Sciences and Arts, Anton Melik Geographical Institute, LJUBLJANA, SLOVENIA*

Geomorphic processes shape landforms which can be recognized as characteristic or important from specific points of view, such as scientific, ecological, cultural, economic, or aesthetic, and termed geomorphosites.

Landscapes with high number of geomorphosites are often protected but also subject to intensive geomorphic processes. In such areas, management of geomorphosites has to take into consideration both, the value of geomorphosites, and the nature of geomorphic processes that (re)shape (or may even destroy) them. Natural systems can help reduce the impacts of natural hazards. When combined with sustainable management, they represent the most economically effective part of preventive strategies.

In traditional Alpine societies, the management of high-mountain areas was an integrated system, where individuals (mostly farmers), organizations (forest- and hydro-management companies) and states (since 1880 in Slovenia) had each their own important and defined role. The traditional management system was maintained until the economic (tourism, traffic) and political changes in the middle and the end of 20<sup>th</sup> century, respectively. The change of traditional relations was accompanied by raising awareness about the value(s) of the Alpine environment. Some parts of the Slovenian Alps have been protected since 1924. Today, the function of the natural environment as a regulator of natural hazards can easily be maintained in the protected areas.

Some examples of efforts related to management of hydro-geomorphic processes in protected areas in Slovenia, related to geomorphosites and their protection are presented. It is stressed that protected areas can contribute to management of geomorphic processes, and therefore to prevention in the field of natural hazards. By maintaining the sustainable management of high-mountain Alpine areas which are important from the point of view of geomorphosites we also indirectly protect the settlements in valley bottoms.

\*\*\*\*\*

### **Assessment of the geomorphosite on salt from Ocna Sibiului (Transylvanian Basin, Romania)**

*TOMA B., IRIMUS I.A., PETREA D., ROSIAN G.*

*Babes-Bolyai University, CLUJ-NAPOCA, ROMANIA*

**Abstract:** The salt ore from Ocna Sibiu is located at the southern end of the anticline Ohaba - Prisaca - Ocna Sibiu, and is one of the oldest exploited salt massifs from the Transylvanian Depression. On its surface have been found traces of both Roman and Anteroman exploitations. This paper presents a method for assessing the geomorphosite on salt from Ocna Sibiului. In this saliferous area was identified one geomorphosite, Ocna Sibiului Lacustrine Complex. This lacustrine complex is a system geomorphosite with areal extending and with high landscaping and hydrographic relevance. The geomorphosite includes 14 salt water lakes which were formed on the back of the salt massif. Both salt morphology and tectonics and the morphology and dynamics of lacustrine basins provide to this geomorphosite high scientific value. The main characteristic that provides economic value of this geomorphosite is the very small distance, 15 km, from Sibiu airport and highway. The cultural value is given by the presence of Sibiu, which in 2007 was the European Capital of Culture, and the touristic value is given by the climate zone, aerosols and therapeutic effect of the salt water.

**Key words:** Ocna Sibiului, geomorphosite, salt, assessment, Transylvanian Basin

## **The Rakov Skocjan Karst Basin: Exceptional natural heritage**

*FERK M., ERHARTIC B., ZORN M., KOMAC B.*

*Research Centre of the Slovenian Academy of Sciences and Arts, Anton Melik Geographical Institute, LJUBLJANA, SLOVENIA*

The Rakov Skocjan Karst Basin formed in a leveled karst plain in the northern part of the Dinaric Karst. The basin is 3.5 km long and is divided into two parts: (1) the lower Rak Valley, where periodical fluctuations of piezometric level can be observed, and (2) the hydrologically inactive basin of Podbojev Laz. Complex morphological development of the basin with several development stages has been confirmed by previous studies. Changes in local water-flow directions during its genesis resulted in an exceptional variety and quantity of karst phenomena in the small basin.

The amazing scale and astonishing forms of karst features in Rakov Skocjan have attracted people of various professions for centuries. In 1949 it was proclaimed the second protected area in Slovenian territory. Since 2002, the basin has also been included in the Notranjska Regional Park. According to several methodologies for evaluating natural heritage, the Rakov Skocjan Karst Basin may have been interpreted as an exceptional geomorphological phenomenon because of its: (1) exceptional natural beauty and diversity, (2) significant importance for scientific research, (3) important ongoing geomorphological processes, and (4) specific natural habitat for indigenous flora and fauna. Therefore, Rakov Skocjan fits a wide range of UNESCO criteria for determining Natural World Heritage. However, despite its dual protection, the park's management is poorly organized and policies for its long-term preservation remain uncertain. To ensure proper protection and sustainable management of Rakov Skocjan, the Anton Melik Geographical Institute of the Scientific Research Centre of the Slovenian Academy of Sciences and Arts is starting the process for registering it in the UNESCO World Heritage List.

\*\*\*\*\*

## **3D exploration of the San Lucano Valley: virtual geo-routes for everyone who want to understand the Dolomites landscape**

*TESTA B.(1), ALDIGHIERI B.(2), DI BONA A.(3)*

*(1) National Council of Research- Institute for Dynamics of Environmental Processes , MILANO, ITALY ; (2) National Council of Research- Institute for Dynamics of Environmental Processes, MILANO, ITALY ; (3) Pangea S.r.l., BOLOGNA, ITALY*

In June 2009, San Lucano Valley (Belluno, Italy) was included in the "World Heritage" UNESCO System n.3: Pale of San Martino - San Lucano-Belluno Dolomites.

The Valley is already well known for their naturalistic attractions by hikers and tourists, but the combination between its geological, geomorphological, structural and stratigraphic features with its naturalistic values, make this site a "natural book" of global significance: because of its geomorphodiversity and of its environmental context, this Valley was selected for a broader project of scientific dissemination concerning the Belluno Dolomites.

Our work is to translate the amount of geomorphologic and geological singularities of the Valley into attractive details, useful to underline this unique area as a real key to understand the geological history of Dolomites from Triassic to present.

The purpose is to disseminate geo-scientific knowledge and reaching the most different kind of users (primary and high schools students, sightseers, amateurs, "mystical paths" pilgrims, etc.) by several facilities (GIS, WebGIS, Apps for mobile devices) used together: with a simple click you must be able to prepare for your hikes, knowing in advance the territory, bike riding first at home virtually in 3D, discover the hidden corners of the Valley and then get excited, step after step through the paths prepared for you! Each route must be accompanied by a technical card with altitude, photos, descriptions, PDF maps and .gpx files that can be downloaded. For whom wishing, just moving the mouse searching the most exciting mountain landscape, it become possible to explore by yourself. These utilities could be a starting point to stimulate and develop a sustainable geo-tourism in upland, often depopulated because of lack of expectations.

### Following the tracks of Charlemagne in the Cottian Alps. The cultural and geological heritage of the Franks trail (Susa Valley, Piemonte, NW Italy)

GIORDANO E.(1), GIARDINO M.(1), BARAL G.(2), GHIRALDI L.(3)

(1) University of Turin, TURINO, ITALY ; (2) Comunità Montana Pinerolese, PINEROLO, ITALY ; (3) Natural Sciences Museum, TURIN, ITALY

The Susa Valley is one of the Alpine valleys included in the territory of the “Alpi Cozie Geopark” (Interreg Alcotra 2007-2013), whose application to the European Geoparks Network is in progress. The Alpi Cozie Geopark also includes selected areas of the Pellice, Chisone and Sangone valleys (Italy) and of the Briançonnais and Maurienne communities of communes (France). It represents a unique and great geological section that shows all the structures and rocks involved by the Alpine orogenetic events.

Humans have populated the Alps for fifteen thousands of years; during this time, quarries have been opened and mines excavated, villages have been built as well infrastructures. We changed the natural landscapes, but we also felt climatic changes, avalanches and floods, landslides and earthquakes. The union between human actions and components of the physical environment shaped cultural landscapes. We should consider these landscapes as a heritage to be known by people and to be valorised by geotourism.

The Franks trail is a route crossing for 60 km the geopark territory. It probably follows the Charlemagne path on 773 aD planned to avoid the Langobards encamped in the valley bottom. During the centuries the trail has been used by pilgrims on their route towards Rome. The trail goes from Oulx to Saint Michael's Abbey and it runs into many sites that tell about geological, environmental and cultural heritage. It takes about three or four days to hike over the entire trail, during which tourists will visit abbeys, moraines, quarries, mines, ecomuseums and protected areas.

The Franks trail is easily connected with the *Via Geoalpina*, an international project that aims to show the wonders of alpine geology and geomorphology. On the bottom side an itinerary crosses all the Rivoli-Avigliana morainic amphitheatre, while on the top the “Colletto Verde international geological trail” leads the hiker to the ocean floor showing some pillows lava.

\*\*\*\*\*

### Geodiversity map of Valderejo Natural Park (Northern Spain)

PELLITERO R.(1), GONZÁLEZ-AMUCHASTEGUI M.J.(2), SERRANO E.(1), MANOSSO F.(3)

(1) Universidad de Valladolid, VALLADOLID, SPAIN ; (2) Universidad del País Vasco, VITORIA, SPAIN ; (3) Universidade Tecnológica Federal do Paraná, FRANCISCO BELTRÃO, BRAZIL

A 1:25.000 geodiversity map of Valderejo Natural Park is presented. Valderejo is situated in the Basque Country, N of Spain. It is only 3500 hectares extent. It is a mid-mountain environment whose peaks rise to 1241 m.a.s.l. whereas valley bottom is at 613 m.s.n.m. Lithology and morphostructures are quite simple at Valderejo. The entire park is situated within an anticline where limestones are situated at the flanks and marls in the centre. The anticline has been eroded at its centre by Purón river, an Ebro tributary. Such erosion opened a *cluse* at the southern flank of the anticline. Here tuffa terraces have developed.

Map was created following Pellitero et al. (2011) methodology but on a raster scheme. Geomorphological, geological and hydrological data coming from relevant 1:25.000 maps has been used to get the 32 geological and geomorphological classes on which geodiversity calculation is based. For geodiversity calculation we have chosen a typical diversity index, the Richness Index, which computes how many different classes exist per each 1 ha. pixel. In order to succeed calculating geodiversity it must be implemented a geoprocess which turns all features into polygons, transforms polygons into raster features, gives different values to each different element and calculates value variety.

Results show that there are two geodiversity hotspots. Cliffs are usually high geodiversity areas; here there are karstic landforms at the top and gravitational landforms and processes at the cliff itself. River margins are also high geodiversity areas where erosion and sedimentation processes, as well as sedimentary landforms as fluvial and tuffa terraces, exist. On the other hand slopes modeled on marls at the centre of the anticline are the lowest geodiversity areas.

Geomorphological protection measures should be focused at high geodiversity areas, where, besides more landforms variety, we can find active processes which are creating future geomorphology.

## Setting out the boundaries of geomorphosites on the region of the Chichón volcano in Chiapas, Mexico

HERNÁNDEZ MORENO M.G.

Posgrado, UNAM, DISTRITO FEDERAL, MEXICO

In Mexico, the concept of geomorphosites it's fairly new, therefore up to this moment there is not a zone in the Nacional territory that counts with these. So that, at the current job it's proposed to set out the boundaries of geomorphosites in the region of Chichon volcano. This is located to the North of Chiapas State, in the Southeast of Mexico; at 60 kilometers to the Southeast of Villahermosa, State of Tabasco and 70 km to the Northeast of Tuxtla Gutierrez, State of Chiapas. The area is located in the boundaries of eight municipalities in Chiapas which are inhabited by Zoque indigenous population mainly.

**Methodology:** For the development for this job, the methodology to develop consist in the elaboration of a multi hazard map, in which will consist the elaboration of a susceptibility map of landslide, susceptibility flood map, and a volcanic hazard map. On the other hand, a map of vulnerability will be elaborated according to the social-economic characteristics of the population of the surrounding entities. Afterwards, a map of risks will be created in which the physic and social topics will be included in the area of study.

To determine the geomorphosites in the area of the Chichon volcano, first and most the interpretation of the geomorphologic map and field work will be realized. This will allow the reconnaissance of the area in study, to then determine and evaluate the geomorphosites. At last a map will be generated of the mentioned sites in relation with the map of risks previously generated. To finally, generated general guidelines which tackle the risk management of disasters in each one.

**Preliminary results:** So far, the study area has already contemplated geomorphosites, which will be evaluated with additional scientific values. This will be the volcano crater, which presents evidence of two periods of volcanic eruptions, as well as an important part of the Zoque area inhabitants worldview.

\*\*\*\*\*

## A large fluvial geomorphosite: the Seine River downstream Mantes-la-Jolie (France)

GIUSTI C.(1), PEULVAST J.P.(2), BETARD F.(3)

(1) UMR 8185 ENeC *Espaces, Nature et Culture*, PARIS, FRANCE ; (2) UFR *Géographie-Aménagement Université Paris-Sorbonne*, PARIS, FRANCE ; (3) UMR 8586 *PRODIG*, UFR *GHSS Paris-Diderot*, PARIS, FRANCE

Rich in historical and cultural heritages, the stretch of the Seine valley that links Île-de-France to Normandy, between Mantes-la-Jolie and the Eure and Andelle confluence zone, belongs to one of the major sets of entrenched meanders known in the world. The valley presents steep hillsides punctuated by white chalk pinnacles alternating with deep funnels, contributing to the picturesque landscape of the valley segment.

The geomorphic history of the Seine valley is inseparable of the Quaternary bioclimatic history, with its alternating glacial-interglacial and stadial-interstadial periods. All along the Pleistocene, periglacial processes interacted with fluvial erosion, leading to the formation, deepening, exaggeration and migration of the large meanders. The resulting, present-day geomorphological landscapes are enriched by many historical landmarks.

The most emblematic sites are the medieval castles of La Roche Guyon and Les Andelys (Château-Gaillard) which were built on rocky promontories on the concave sides of two large meanders. The mid-Seine valley is also known as a high place of the impressionism, the founder and master of which, Claude Monet, settled here for the second half of his life and created the wonderful gardens of Giverny on the lower Epte river. He and many other impressionist and post-impressionist painters, sensitive to a certain harmony of the local landforms, represented and immortalized the surrounding landscapes.

Therefore, we propose to consider this relatively long valley segment as a "disconnected geomorphosite" (Reynard, 2009) at the geosystem scale owing to the unique combination of cultural and scientific values offered by its individual geotopes at the geofacies scale.

**Assessing worth in geomorphology: Earth Sciences Comparative Matrix (ESCoM) a comparative tool for nominations to the Australian National Heritage List**

*WHITE S.(1), WAKELIN-KING G.(2)*

*(1) La Trobe University, PARKVILLE, VICTORIA, AUSTRALIA ; (2) Wakelin Associates, CLIFTON HILL, AUSTRALIA*

The lack of a suitable robust and repeatable geological/geomorphological methodology for Australian conditions has been a serious constraint on assessing geomorphological sites suitable for the National Heritage List (NHL). In 2011 the Earth Science Comparative Matrix (ESCoM) was developed for a desktop heritage assessment of Australian arid zone geomorphology. This related sites' intrinsic natural values to NHL criteria, and allowed comparison of a diverse group of sites spread over a vast area.

In the ESCoM matrix, sites are grouped in process themes. Each is assessed against NHL criteria (outstanding events and processes, rarity, potential for research, characteristics of a class, aesthetics, technical/creative achievements, social values and a site's association with significant people), which are then compared with other similar places. A site scoring well across multiple themes has increased heritage significance. The overall values of a site are quantified, indicating whether it achieves the threshold of outstanding heritage value. This methodology can be used with available published and unpublished information rather than requiring fieldwork. Significance is determined based on rigorous comparisons of specific values. It is qualitative rather than quantitative, but repeatable and robust.

The commissioned study assessed the potential National Heritage values of Australian desert landforms within a defined study area. Sites were spread across 9 geomorphic themes (astroblemes, sand deserts, vertisols, karst, arid coasts, tectonic landforms, uplands, regolith, hydrology) and 29 sites were identified with high potential to pass heritage criteria demonstrating the history and development of Australia's characteristic desert landscapes.

While the study for which ESCoM was developed was focussed on arid zone landforms, it could be used for other areas of earth science values (e.g. tectonic or palaeontological heritage), with modification of matrix theme headings.

\*\*\*\*\*

**Proposals for the valorisation of alpine geoheritage and mountain cultural landscapes: the Valli di Lanzo's Geosites and the Val Grande's Geotouristic Trail**

*GIARDINO M.(1), BRANDOLINI P.(2), RE FIORENTIN G.(3), PEROTTI L.(1), TORRENO F.(2)*

*(1) University of Turin, TURIN, ITALY ; (2) Dipartimento di Scienze della Terra, dell'Ambiente e della Vita, GENOVA, ITALY ; (3) Arpa Piemonte, TORINO, ITALY*

Within a master thesis committee on Environmental – Geographical Sciences and G.I.S. for sustainable development, a cooperative project have been set up for the analysis of geological – geomorphological assets and of characteristic elements of the Valli di Lanzo's cultural landscape. These valleys are located in the Torino province (NW-Italy) along the Via Alpina's Blue Trail, an important way for the international touring in the Alps.

The studied elements talk about the geomorphological history of the area; these landforms with the cultural elements create a peculiar alpine landscape, which belongs to our heritage and need to be preserved for next generations. A concrete proposal is here presented including geoconservation concepts and geotouristic approaches or a sustainable development of the mountain territory.

As a results of geological and geomorphological studies 17 geosites have been identified in the Valli di Lanzo, then evaluated for being part of a geotouristic trail through the Val Grande's Sentiero Balcone, a trail intersecting the Via Alpina's one. The Sentiero Balcone is a hillside trail within the Chialamberto and Groscavallo's municipal territory, where 22 geotouristic element of interest have been identified: 20 geological, cultural and geopanoramic points and 2 complex geosites. Trail and elements have been represented on a dedicated geotouristic map.

A GPS-integrated palmtop equipped with ArcPad G.I.S. software allowed direct field data collection in a digital format. Dedicated forms for the geosites' inventory created by the Earth Science Department of the University of Turin allowed elaboration of information for the selection of best path and points of interest of the Sentiero Balcone geotouristic trail.

Results contributed to the popularization and valorisation of the Alpine landscape and geoheritage: they are addressed to create an added value to the Valli di Lanzo territory and to its social – economical and touristic contexts.

## **Quaternary glacial geomorphosites from the Redes Natural Reservation and Picos de Europa Regional Park (Cantabrian Mountains, Iberian Peninsula)**

*RODRIGUEZ RODRIGUEZ L., JIMÉNEZ-SÁNCHEZ M., DOMÍNGUEZ-CUESTA M.J.*  
*Departamento de Geología, Universidad de Oviedo, OVIEDO, SPAIN*

The Cantabrian Mountains is a mountain range 480 km-long with a max altitude of 2648 m (Torre Cerredo Peak) which is disposed parallel to the Cantabrian Coastline from Pyrenees to northwest Iberian Peninsula (~43°N 5°W). It is an interesting region to research the climatic patterns across South Europe during the Quaternary glaciations due to i) the presence of glacial features that evidence the occurrence of former mountain glaciations and ii) the climate transition from maritime to Mediterranean type across the mountain. The available studies in the Cantabrian Mountains stand that the recorded regional glacial maximum here is prior to ca 38 cal ka BP, and that glaciers were in some locations remarkably retreated by the time of the global Last Glacial Maximum (Jiménez-Sánchez et al., in press).

This study is focused on an area about 220 km<sup>2</sup> partially covering the Redes Natural Reservation and Picos de Europa Regional Park. A geomorphologic database in ArcGIS was produced for this area to reconstruct in detail the extent, flow pattern and chronology of the former glaciers (PhD under progress). Here we present a selection of 11 geomorphosites as examples of well-preserved glacial landforms and deposits that prove the occurrence of glacial and paraglacial processes in this region during the Quaternary glaciations.

Jiménez-Sánchez, M., Rodríguez-Rodríguez, L., García-Ruiz, J.M., Domínguez-Cuesta, M.J., Farias, P., Valero-Garcés, B., Moreno, A., Rico, M., Valcárcel, M., in press. A review of glacial geomorphology and chronology in northern Spain: timing and regional variability during the last glacial cycle. *Geomorphology*, doi: 10.1016/j.geomorph.2012.06.009.

Research funded by the project CANDELA (CGL2012-31938) of the Spanish national research program in Earth Sciences and Hydric Resources (MINECO). L. Rodríguez-Rodríguez has developed her research under a grant of the Severo Ochoa Programme (FICYT- Asturias).

\*\*\*\*\*

## **Geomorphosites within the inventory of geosites with national and international relevance in Portugal**

*PEREIRA P.(1), PEREIRA D.(1), CRISPIM J.(2), NUNES J.C.(3), BRUM DA SILVEIRA A.(2)*

*(1) Geology Centre of University of Porto / University of Minho, BRAGA, PORTUGAL ; (2) Geology Department of University of Lisbon, LISBON, PORTUGAL ; (3) Geosciences Department of the University of Azores, PONTA DELGADA, PORTUGAL*

146 geomorphosites with international or national relevance have been inventoried under the scope of the scientific research project "Identification, characterisation and conservation of geological heritage: a geoconservation strategy for Portugal", financed by the Portuguese Foundation for Science and Technology (PTDC/CTE-GEX/64966/2006). The inventory procedures were based on the ProGEO guidelines with definition of geological frameworks followed by the identification of representative geosites with national and international relevance for each framework. Overall, 322 geosites were selected exclusively based on their scientific value with about seventy geoscientists supporting geosites selection in 27 frameworks. The 146 geomorphosites were inventoried in the frameworks "Landforms and river network of the Portuguese Iberian Massif"(39), "Karst systems"(38), "Active and fossil coastal cliffs"(6), "Low coasts"(6), "Vestiges of Pleistocene glaciations"(16), "Volcanism of the Azores Archipelago"(29), and "Volcanism of the Madeira Archipelago"(10). That selection was based on the criteria representativeness, rareness, diversity, integrity, and scientific knowledge. Their protection and adequate management is essential because of specificities like large size, aesthetics and dynamics, and due to their high geotourism potential. In that scope a quantitative assessment of their scientific value and vulnerability was performed. This constitutes the first systematic inventory of geosites at national level and is now important raw data to support nature conservation initiatives. The inventory is being integrated in the natural heritage database (SIPNAT) under the responsibility of the Institute of Nature Conservation and Forestry (ICNF) as expected in the Portuguese legislation for nature conservation (DL 142/2008).

**Geomorphosites as a tool for understanding the geological history: a proposal of geo-itineraries for the National Park of Abruzzo, Lazio and Molise and Matese areas (Molise region, Italy)**

ROSSKOPF C.(1), FILOCAMO F.(1), AUCELLI P.(2), DI PAOLA G.(1), CESARANO M.(1)

(1) *Department of Biosciences and Territory, University of Molise, PESCHE, ITALY*; (2) *Department of Environmental Sciences, University of Naples Parthenope, NAPLES, ITALY*

Due to its geological-structural, orographic and climatic features, the Molise region is characterized by a high geo-diversity. Several protected areas are present which cover about 34% of the regional territory. Our contribution deals with the presentation of some geo-itineraries that embrace several of the geomorphosites which have been assessed during the recent geosite census in the Molise region aimed at contributing to the preservation and valorisation of the regional geological heritage. The selected geomorphosites are located in two areas of great naturalistic value, the National Park of Abruzzo, Lazio and Molise and the SIC (Site of Community Importance) area of Matese Mountains, respectively. These geomorphosites, which are characterized by a high scientific and didactic value, allow to appreciate the variety of environments and landscape features that characterize these mountain areas and are important for understanding several steps of their geological history and related landscape evolution during Quaternary times. They are represented mainly by glacial landforms (the glacial cirques of Mt. Miletto and Mt. Mare and related moraine deposits), exokarst and endokarst landforms (i.e. the Campo Puzzo and Le Forme polja and the Pozzo della Neve and Cul di Bove caves), periglacial/slope landforms (i.e. the talus slope of Mt. Gallinola), and fluvial landforms (i.e. the Quirino gorge). In order to enhance and promote this rich geomorphological heritage and to contribute to the development of sustainable tourism within these areas of high natural value, we have developed some geo-touristic itineraries which can be easily enjoyed also by a non-scientific audience. To improve their promotion, specific cards are prepared, enriched with photos, geomorphological sketch maps, 3D scenes, DEMs etc., to be distributed by tourist operators and other associations and institutions interested in tourist promotion and educational activities.

\*\*\*\*\*

**The remains of mining and metallurgy industry as examples of geomorphosites in the Tatra Mts. Assessment, their role in education and geotourism**

BIALY S.

*Pedagogical University of Cracow, KRAKOW, POLAND*

The aim of the paper is to present the remains of the 19<sup>th</sup> century mining and metallurgy industry in context of their attractiveness for geotourism. Historical, cultural, scientific and socio-economic values of the sites has been taken into consideration. Presented sites are located within Polish Tatra National Park (TPN) which is thought to be the most attractive mountain national park for tourists in Poland.

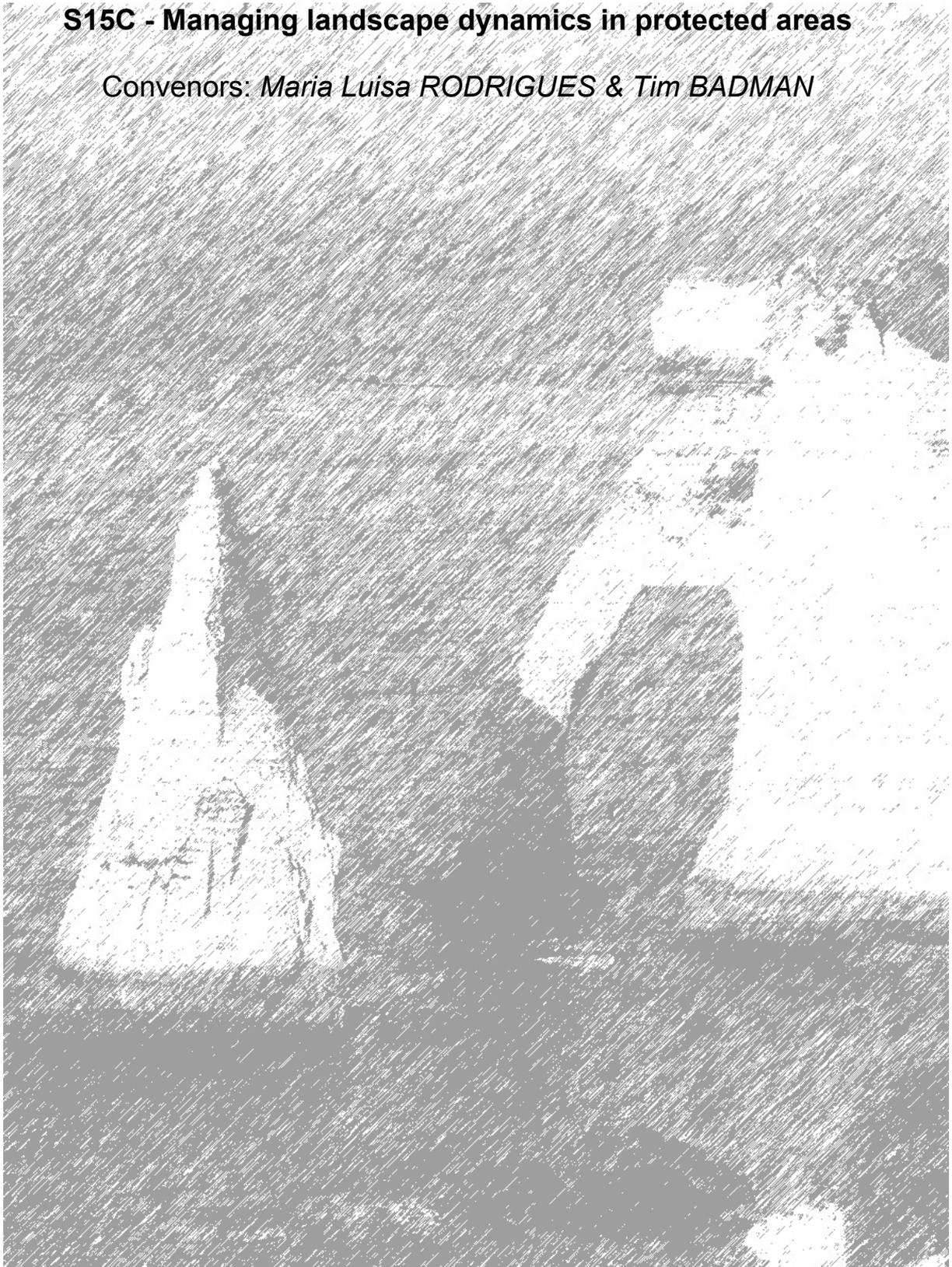
The mining company consisted of mine fields in Dolina Jaworzynki and in Kopa Magury Mt, where mine tunnels were dug. Iron ores as the concentration of hematite in shales and sandstones of upper Triassic of Fatricum were mined. The remains are still present in the field. In Kuźnice millrace, blast furnace, smithies, rolling mill and foundry was situated. Next to them workers' and officers' houses, administration building and owner palace with park have been build. Old quarry of Eocene numulitic limestone, used as flux in iron furnaces, is situated in northern part of the enterprise. The consequence of timber harvesting for charcoal production is deforestation of the valley. In 1954 TPN was established. Protection and geomorphological process acting since then on mentioned sites caused their renaturalisation. Many tourist trails in TPN are led on the old mine roads.

The Tatra Mts. are not only natural landscape as the tourists may have mistaken beliefs. In the landscape we may see many evidences of human impact, which are easily visible. Their origins, geological and geomorphological processes acting on them for over 130 years need to be explained to the tourists, which is important in educational and geotourist aspects. Without the act of cognition of their origins, tourism would have only esthetic value. However restriction makes impossible visiting all the interesting sites, the remains of mining and metallurgy activity are important elements of the cultural landscape represent industrial geological and geomorphological heritage of the region.



**S15C - Managing landscape dynamics in protected areas**

Convenors: *Maria Luisa RODRIGUES & Tim BADMAN*





## **Oral presentations:**

### **The landscape of man-made terraced slopes in Cinque Terre (Liguria, Italy): a world heritage site at geomorphological risk**

*BRANDOLINI P., CEVASCO A., FIRPO M.*

*Dipartimento di Scienze della Terra, dell'Ambiente e della Vita, Università degli Studi di Genova, GENOVA, ITALY*

Since about 1100 A.D. most of slopes of Liguria have been terraced for agricultural purposes through reworking of millions cubic meters of debris and the construction of thousands kilometers of dry-stone retaining walls. In particular the man-made terraces at Cinque Terre (eastern Liguria), due to their great extent, peculiar construction characteristics, high historical and cultural value, are one of the most famous and emblematic examples of landscape evolution in the Mediterranean area. Therefore the Cinque Terre were included in the "Cinque Terre National Park" and recognized as a world heritage by UNESCO since 1997. On an area of ca. 20 km<sup>2</sup> a total length of nearly 6000 km of terraces, which were cultivated for vineyards and olive groves, can be estimated.

Man-made terraces have represented over the centuries a basic factor for erosion control and landslides prevention at Cinque Terre, where geological and geomorphologic complex settings favor slope instabilities. Instability phenomena are increasing during the last decades consequently to the progressive abandonment and degradation of cultivated terraces, which played an important role on water control over the past centuries. Currently, entire sectors of terraced slopes - up to several hectares - have been lost.

In this framework, also taking in account the climate change, detailed studies of the relationships between geological-geomorphological conditions and the state of conservation of the terraces are fundamental both for the evaluation of slopes stability and risk scenarios.

Currently, a scenario of high geomorphological risk is rising at Cinque Terre. That can also be seen at regional, national and Mediterranean scale in other abandoned terraced areas, which primarily require conservation strategies for preserving the memory of the rural culture and its interrelations with geo-hydrological and landscape dynamics, and for promoting sustainable development of agriculture and tourism.

\*\*\*\*\*

### **Environmental fragility in the southwest amazon associated with its occupation modes the surrounding Jamari National Forest Case**

*BASTOS A.(1), MANIESI V.(2), GOMES F.(1)*

*(1) Centro de Estudos RIOTERRA, PORTO VELHO, BRAZIL ; (2) Universidade Federal de Rondônia - UNIR, PORTO VELHO, BRAZIL*

This research had as objective comprehend the dynamics and consequences of natural and induced erosion process and its associations with the land occupation in the Jamari National Forest and its surrounding, area used as a study case. Geoprocess works, thematic maps compilation, numerical terrains models and a data base were used in the research. Lately, field activities took place to verify the natural erosion vulnerability map generated, to interpret the induced erosion dynamic process facing the actual land occupations modes, to collect and analyze soil and sediments. There are soils rich in sand fraction grains and quartz mineralogy, which varies of 76 to 93% in the west, where are the biggest anthrop interference of the area. The forest installation shows that the geomorphological balance between vegetation, soil and dissected relief is fragile. Thus, the breaking of this balance by altering any of these elements can accelerate erosion processes and nutrient loss in depth to the water table. The structural and mineralogical characteristics of the soils show marked limitations for agricultural use due the reduced volume of weathered material available to physically support the cultivars. Although erosion induced process were not registered in advanced stages. There are signs of degradation, not just the soil, but in the whole area due cattle, the only economic activity observed in the region. It has been found aspects that favor the class change indices related to natural erosion vulnerability measured, making them more vulnerable, related to the occupation mode around the Jamari National Forest as deforestation activities on the tops of hills, forest and riparian areas close to sub basins water dividers.

**In situ biophysical data analysis establishing the draining process of Central African lakes whose origins are hypothetical: complementarities with an original small scale satellite based study**

NAVARO B., LEROUGE G., NETTER C., ROUSSELIN T.  
Geo212, PARIS, FRANCE

In the Sangha National Park tropical rainforest (Central African Republic), in situ sensors allowed us to study over 15 month (December 2010-February 2012) the functioning of a lake area whose origin is supposed to be karstic. Pressures and temperatures at the bottom of the lakes and in the canopy allow to estimate sub metric variations in water elevation and isolate rainy events. These measures are related to a geomorphological analysis of the watersheds. The lakes set out a synchronous and instantaneous response to the rainy events all year long. During the swelling or drop in level, this simultaneity lies with the saturation of a sandy subsoil located under the vegetable litter. The groundwater overload (rain contribution) is immediately transferred to the lakes by gravity. The lakes are drained by underground flow so the lake surface can be assimilated to a free piezometrical surface. No streaming has been observed above the ground. Therefore from one lake to another the floods move back or forward. This cannot be explained by the hydromorphic soils, but demonstrates an aquifer loading time different from one watershed to the other. The identification of those, under the canopy, needed a change of scale made possible thanks to a geomorphological analysis of GDEM ASTER V2. Dissymmetric and eroded anticline lines and faults intersecting them have been highlighted. They create morphological projections which isolate some lakes, explaining the difference between rising water levels at the beginning of the flood. The combination of in situ measures interpretation and geomorphological analysis explains the draining process of the lakes, which appears to be led by the evolution of independent aquifers. Even if this study stops short of confirming the link between lakes and a deep karst, it highlights the complementarities between two differently scaled methods.

\*\*\*\*\*

**The hazard, the geomorphologist and the lawmaker - Geomorphological dynamics as a perspective for a resilience legislations in the domain of natural hazards**

RAPISARDI E.(1), GIARDINO M.(1), CRISCI A.(2), MASCAGNI S.(3)  
(1) UNITO - Earth Sciences Department, TORINO, ITALY ; (2) CNR-IBIMET, FLORENCE, ITALY ; (3) LIPU - Riserva Santa Luce, SANTA LUCE, ITALY

The degree of vulnerability to disaster in a given area is the result of multiple factors related to the human system and to its coping capacity. Analysis and monitoring, information to the public and planning, rescue and restoration: all these issues call for actions defined by the law. We are facing environmental changes, some experiences highlight a lack of alignment between the dynamics of the environmental change and the rigidity of the regulations, impacting also on risk communications.

The case study proposes a new reading of the drying up of a small artificial lake in S. Luce - (Tuscany), wildlife reserve and SCI - Habitats 92/43/EEC - occurred in 08/2012. The case analysis will illustrate the geomorphological context, including the vulnerability [Aysan 1993], and the coping capacity (resilience) [Wisner] of the human system of the area [Alcantara-Ayala] and will illustrate the complex mutual relationships and dynamics between geomorphological, political, socio-economic, and law dimensions in the response capacity to a creeping phenomenon such as drought.

The aim is to highlight how geomorphology, as one of the building block for situational awareness, could represent the connective tissue to foster disaster risk reduction policies and actions based on interdisciplinary, open data and collaboration. In this perspective, geomorphological dynamics should be transferred to the lawmaker and to the institutions, not only in terms of accurate and analytical knowledge, but as an approach to an environmental sense-making, based on adaptation to environmental dynamics particularly influenced by climate change and soil use. In the same perspective, an open and shared geomorphological approach could represent the driving factor to switch towards the concept of adaptation in complex systems, including their inherent uncertainty [Snowden; Ciborra] so to build a more resilient and cross-discipline approach to risk analysis, communications and environmental regulations.

## Planning of the recreational trails in protected areas: application of the regression tree analysis and GIS

*TOMCZYK A.(1), EWERTOWSKI M.(2)*

*(1) Faculty of Geographical and Geological Sciences, Adam Mickiewicz University, POZNAN, POLAND ; (2) Department of Geography, Durham University, DURHAM, UNITED KINGDOM*

One of the most important tasks for managers of natural protected areas is achieving a balance between conservation of nature and recreational opportunity. This paper presents a framework based on geographic information system (GIS) and regression tree analysis of optimised recreational trail location for flexible, user-defined input parameters. The method utilizes: (1) the GIS to create a database containing field data and existing GIS/cartographic materials; (2) regression tree analysis to establish the relationships between indicators of degradation and environmental, use-related and managerial factors for existing trails, as well as to predict trail degradation for potential new trails; (3) least-cost path algorithm within a GIS framework to optimize trail route.

The framework was applied to the Gorce National Park in the south of Poland. A large sample (> 4500) of the field collected data about degradation of the existing trail network was linked with data about soil, geology, geomorphology and relief, and with information about the type and amount of recreational use. Based on the existing relationship, predicted trail degradation was calculated and routes for two examples of trails (hiking and motorized) were designated. The proposed methodology is objective and quantitative, and can also include knowledge of local stakeholders. The framework has the potential to design new trails (or to re-route old ones), characterized by the best possible solution for recreational and conservation functions to coexist, by routing visitors through trails with the lowest possible impact.

This work was supported by Polish National Science Centre (project number N N305 066940)

\*\*\*\*\*

## Poster presentations:

### **Trail impact assessment - Cairuçu Protection Area case study, Paraty Municipality - Rio de Janeiro State ' Brazil**

*RANGEL L., GUERRA A.*

*Federal University of Rio de Janeiro, RIO DE JANEIRO, BRAZIL*

Regarding the protection and rehabilitation of forest fragments, Environmental Protection Areas (EPA) have been created in Brazil. These EPAs are large areas with different kinds of human settlement, in order to protect biological diversity, to regulate the settlement and to ensure the natural resources sustainability.

In some cases, the EPA is impacted by tourism, due to its natural attraction. Therefore, this research aims to assess the impact on the trails in the southern part of Cairuçu EPA.

For this, we have made a land use and cover map, using RapidEye satellite images, for 2011. The image classification has been made in Spring Software version 5.2, and post-classification and georeferencing has been carried out in ArcGIS 9.3. Soil samples have been collected to determine aggregate stability at six sites of *Laranjeiras-Sono* trail; three on the trail and three on the forest, at two depths (0-10cm and 10-20cm).

Soil aggregation has been determined by the mean weight diameter (MWD), the geometric mean diameter (GMD) and the aggregate stability index (AS%), which were obtained by breaking the soil into aggregate classes by the wet sieving method (Yoder, 1936).

The results have been compared and they indicate that, despite the area has a high percentage of forest coverage (91.2%), the trails are affecting the fragments, as it is possible to observe rill initiation and slope degradation along the trail. Furthermore, it was found that, at some sites on the trail, the MWD was less than 1.8 mm (Site 1 - trail depth 0-10 cm: MWD = 1.78 mm), indicating the presence of micro aggregates and therefore, soil degradation.

As expected, the sampling sites in the forest at 10-20 cm deep, aggregates showed a lower value of MWD (Site 2 - Forest: MWD = 1.96) than at depths of 0-10cm (Site 2 - Forest: MWD = 2.60) where there is a higher concentration of organic matter and therefore, larger aggregates.

### **Multiannual Variability of Novosibirsk Reservoir's Morphometry**

KHABIDOV A., FEDOROVA E., MARUSIN K., KHOMCHANOVSKII A.

*Institute for Water and Environmental Problems of SB of RAS, BARNAIL, RUSSIAN FEDERATION*

The environment of relief formation and sedimentation is not uniform. It includes fluvial-dominated, wave-dominated and transitional environments. When describing the environments most attention was concentrated on wave-dominated environments distinguished by the largest water area, shoreline perimeter and the extent of coastal erosion. Less emphasis was placed on the fluvial-dominated areas; so far it is the least described environment of relief formation and sedimentation in man-made lakes. Therefore, the paper considers the fluvial-dominated environment by the example of Novosibirsk reservoir that is one of the most widespread valley man-made lakes in lowlands and low plateaus with seasonal flow regulation.

Erosion and abrasion play the main role in the relief formation and sedimentation in the basin of Novosibirsk Reservoir. These processes caused important changes of morphometric characteristics of the basin. For instance, the average thickness of accreted sediments has reached 0.94 m, the reservoir total capacity has reduced by 1.02 km<sup>3</sup>, its average and maximum depth and water area have diminished notably, but average and maximum width have increased. The shoreline length, the number and area of islands have changed too. The characters of these changes in similar to changes in other reservoirs of this type.

\*\*\*\*\*

### **Historical channel change and sediment dynamics in a heavily managed and protected small catchment: the Afon Dysynni, North Wales**

GRIFFITHS H.(1), YORKE L.(2), GRIFFITHS S.(1)

*(1) Aberystwyth University, ABERYSTWYTH, UNITED KINGDOM ; (2) School of Environment, Natural Resources and Geography, Bangor University, BANGOR, UNITED KINGDOM*

European rivers have, in general, incised and narrowed over the twentieth century as a result of a wide range of climatic and anthropogenic factors (flood frequency and magnitude changes, regulation, gravel extraction, land use change, historical metal mining). In Welsh rivers these factors have led to decreases in exposed riverine sediment (ERS) area during that time. Such morphological changes and sediment dynamics can significantly affect flood risk through changing channel capacity. The Afon Dysynni catchment (131 km<sup>2</sup>), North Wales, is particularly prone to both fluvial and coastal flooding. During the 18<sup>th</sup> and 19<sup>th</sup> centuries, the river was heavily managed through extensive flood embankments and land drainage works, but is currently protected through National Park, Landscape of Historic Interest, UNESCO Dyfi Biosphere and Sites of Special Scientific Interest designations. Geomorphological mapping, air photo interpretation and historical and contemporary OS map analysis (1888, 1891, 1901, 1964, 1974, 1981 and 2012) was undertaken in order to assess lateral channel migration rates, ERS changes, sinuosity, channel width and sediment dynamics. Anthropogenic activities during the last 300 years have resulted in the progressive confinement of the river along a significant proportion of its length, and have limited the floodplain width, across which the river is able to freely meander, to ~ 70 m. In its middle, unconfined reach (~ 2 km in length), the river has been laterally active, displaying rates of bank erosion of > 3 m yr<sup>-1</sup> (1964-1974). Between 1888 and 2012 ERS area decreased from 43,506 m<sup>2</sup> to 8425 m<sup>2</sup>. Palaeochannels, located outside the flood embankments, indicate the river was highly laterally active prior to confinement. This study demonstrates that the response of the Afon Dysynni is typical of other Welsh rivers in protected areas, where the legacy of historical anthropogenic activity continues to exert its influence on the rate of natural process change.

### **Impacts of Mountain Bike activity in Atlantic Forest, Rio de Janeiro**

CHIROL A.(1), OLIVEIRA R.R.(2), CATALÃO C.G.(2), ERTHAL L.(2)

(1) UERJ - State University of Rio de Janeiro, RIO DE JANEIRO, BRAZIL ; (2) PUC-Rio, RIO DE JANEIRO, BRAZIL

Mountain biking is an increasingly recreational outdoor activity in Rio de Janeiro, and the reasons are related both to the geomorphological characteristics of the city (two main mountainous physiographic units: the Tijuca Massif and the Pedra Branca Massif) and the city vocation for outdoor sports. The expansion of mountain biking has increased the concern about its environmental impacts, which remain poorly understood, since most of the trails are situated in the two biggest conservational units in the city: the Tijuca Forest National Park and the Pedra Branca State Park. So this research look for a better understanding of the ecological and hydrological effects of mountain biking.

The study area is situated in the Tijuca massif in the city of Rio de Janeiro, covering a total area of 118.7Km<sup>2</sup> (11.870 ha). The slopes of this massif are revegetated by late secondary vegetation. The area is inserted in the Rio de Janeiro metropolis and therefore undergoes direct interference of pressures and vectors that change the city. The chosen trail is located in a steep area (25° or higher) and surrounded by well-preserved forest.

Three main procedures have been made: soil penetrability essays and vegetation structure (diameter at breast height and height) analysis at the trail, the trail edges and a well-preserved area, and transversal trail profiles through the trail, to observe the presence of any erosive features like rills. The vegetation data showed what might be signs of some edge effects at the trail, as there are higher density of low DBH trees and dead trees, especially at the lower parts of the trail. The trail profiles showed that rill erosion is significantly more intense at the lower parts of the trail, what is a direct effect of the higher soil compactation and water velocity through the trail. So the mountain biking might be a vector of degradation and there is a need to constant monitoring in areas with high precipitation as the city of the Rio de Janeiro.

\*\*\*\*\*

### **Trail morphodynamics in the Stolowe Mountains National Park (SW Poland) - how nature helps managing erosion**

LATOCHA A., PARZÓCH K.

UNIVERSITY OF WROCLAW, INSTITUTE OF GEOGRAPHY AND REGIONAL DEVELOPMENT, GEOMORPHOLOGICAL UNIT, WROCLAW, POLAND

The Stolowe Mountains National Park comprises steep slopes of sandstone escarpments and level intervening terrain. Recent detailed geomorphic mapping revealed that morphodynamics of the area is rather low, except for human-disturbed surfaces of unpaved roads and paths. Tourist trails are especially prone to erosion. Four morphodynamic categories of tourist trails were distinguished, basing on the microrelief of their surface and vegetation cover: stabilization, low degradation, moderate degradation and strong degradation. The first two categories prevail, accounting for 92% of total trail length. The morphodynamic state of a trail section depends mainly on slope angle, intensity of tourism and type of road surface. In order to reduce erosion along the most degraded sections of the trails anti-erosion constructions have been installed such as debris traps.

The actions undertaken by the Park's authorities in order to reduce erosion are additionally enhanced by the natural processes. The area used to be densely populated. It had been also under agricultural land use, which was entirely withdrawn from the area in the 1950-60'. The road network was reduced by 10-50%. The abandoned field access roads, often transformed into road gullies, have been overgrown and evidence of present erosion can be hardly detected within them. The morphodynamics of the region has been substantially reduced, which is best evidenced by inactive road gullies, now partly filled with organic and mineral material.

The example of Stolowe Mountains shows that the most effective strategy to counter erosion would consist of closure of gullied trails, at least temporarily. However, this is an option difficult to follow on societal grounds since the area belongs to the most popular tourist destinations in south-west Poland and declaring further parts of the Park off-limits would negatively impact on the image of the Park and nature conservation.

### **Geomorphological restriction in urban landscape management. Case study: Piatra-Neamt - Romania**

ROSU C., IRIMUS I.A., ILIES M., TOGANEL C.

*Babes-Bolyai University, Faculty of Geography, CLUJ-NAPOCA, ROMANIA*

The paper approaches the issue of restriction induced by the geomorphological processes in urban landscape management from Piatra-Neamt city, Neamt district, Romania. From the entire surface of the city, 45,5% belongs to the forests, these providing protection, recreation, preservation and surrounding the studied area. As a number of four, these areas have legal status as: forest reservation- Cernegura Hill, flowers reservation: Vulpea Hill, and paleontological reservations: Cernegura Hill, Cozla Hill and Pietricica Hill.

The restriction evinced in these protected areas is provided by the slopes geomorphological processes such as: crumbling, land fallings and land slides which affects quite large surfaces on the west side of Cozla Hill, Cernegura Hill and on the east side of Pietricica Hill.

These phenomena are produced because of the clay bedrock, precipitation's water infiltration and human intervention: sky run (Cozla Hill). Another geomorphological process inducing restricted areas is soil erosion which forms gullies and rills spread especially in Cozla Hill and in Cernegura Hill because of the high declivity and Miocene and Quaternary bedrock. The processes presented has induced restrictions in urban-development projects (issues specified in General Urban Plan of the city) and they also induce the need of preservation and enhancing measures.

\*\*\*\*\*

### **Stream recovery in protected areas: planning with a geomorphological approach**

TESTA B., ALDIGHERI B., CAIELLI G., DEFRANCO R.

*CNR-IDPA, MILANO, ITALY*

San Lucano Valley (Belluno, Italy) is included in the UNESCO System n.3: award of "World Heritage" area. The land use in the valley is not intensive and there has not been interference to the riparian zone, since the flood of 1966, during which the majority of the existing trees (conifer) were uprooted. After 1966, an exceptional riparian forests of *Alnus incana* and *Fraxinus excelsior* with some Mountain Maple and Spruce, took over. These forests are of high natural interest for the E. C.: (site BL28 from Natura 2000 network), and constantly under observation and carefully preserved. For these reasons, the lower Tegnass River has become an open-laboratory to study the stream and how it adjusts from past periods to recent morphodynamic events, and to verify the applicability of the methodology referred as Watershed Assessment of River Stability and Sediment Supply (Rosgen, 2006) in the morphological context of the Alps and in their hydroclimatic environment. The stream geomorphology shows the evidence of channel changes during over 50 years. Quaternary fluvial deposits, postglacial landslides and debris flows are filling the valley bottom with a 200m thick covering. The gravel of this flat area must be periodically quarried to ensure the hydraulic protection of the sideway road, but the newly rebuilt banks are quickly eroded due to the floods and the streambed becomes impracticable and unsuitable for spontaneous fish habitats and for forest growth. The monitoring of streams over time, modeling their geomorphologic trends, gives some contribution to understand the erosion-transport-deposition process in order to reset a more stable, long-lived, riverbed with natural solutions. This may be a useful approach in restoration plans, in order to make the riverbed renaturalization more stable and improving the accessibility to the riparian zone, without disregarding the preservation of the natural environment quality.

### **Sediment movement and storage in small headwater catchments in an eroding peatland, Peak District National Park, UK**

SHUTTLEWORTH E.(1), EVANS M.(1), ROTHWELL J.(1), HUTCHINSON S.(2)

(1) University of Manchester, MANCHESTER, UNITED KINGDOM ; (2) University of Salford, MANCHESTER, UNITED KINGDOM

Upland blanket bogs in the UK have suffered severe erosion over the last millennium but there is evidence to show that this has increased in intensity in the last 250 years, coinciding with increased pressures on the land during the British Industrial Revolution. Peatlands represent major carbon stores and those in close proximity to urban and industrial areas can be contaminated with - and act as sinks for - high concentrations of atmospherically deposited lead. Erosion of these peats has the potential to release lead into the fluvial system and impact carbon storage through the physical export of particulate organic carbon (POC). Detailed quantification of sediment movements across the surface of actively eroding peatlands is important in order to understand carbon and lead storage and release in such environments.

This project aims to increase understanding of the small-scale process of sediment transport and deposition active during peat erosion. Peat erosion is widespread in the Peak District National Park, UK, and the Bleaklow Plateau has been a focus of restoration over the past decade. A handheld *Niton XL3t 900XRF* analyser was used to acquire detailed *in situ* measurements of Pb concentrations across a series of small parallel gullies at a severely degraded site on Bleaklow. A considerable proportion of sediment is not directly transferred to the fluvial system after it has been removed from its surface source, but there is significant storage of Pb contaminated sediments on gully walls and floors.

The potential for enhanced peatland erosion resulting from climatic and land use changes in peatland areas requires a fuller understanding of geomorphological controls on carbon and contaminant losses. Such knowledge can aid the construction of accurate sediment and pollutant budgets, and direct restoration strategies which require a clear understanding of sediment dynamics.

\*\*\*\*\*

### **Areas of permanent preservation and their usage planning in the watersheds context: methodology for legal pattern adjustments applied in a pilot area in Northwestern Rio Grande do Sul, Brazil**

VERDUM R.(1), GASS S.L.B.(2)

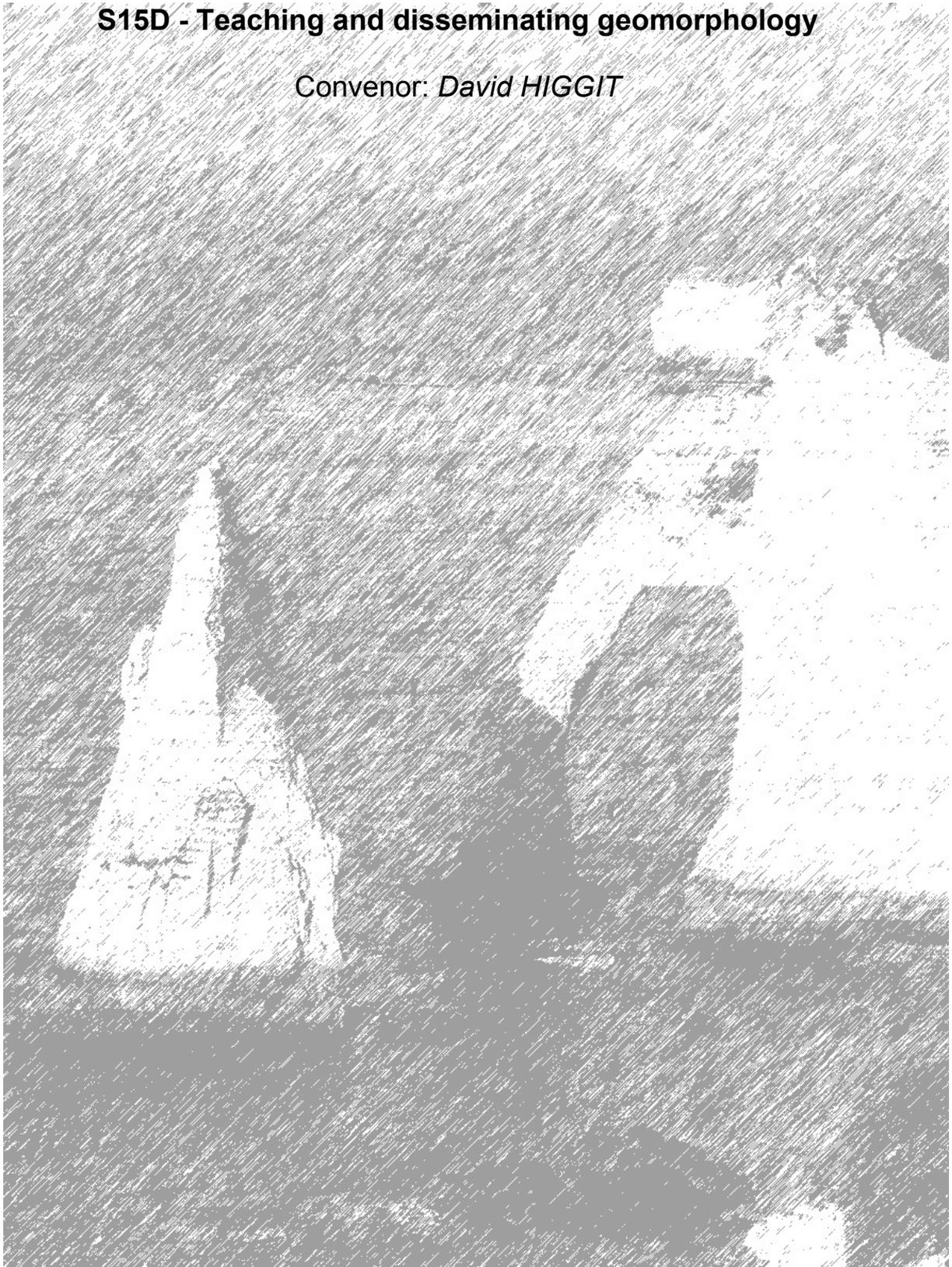
(1) Universidade Federal do Rio Grande do Sul , PORTO ALEGRE, BRAZIL ; (2) Universidade Federal do Rio Grande do Sul, PORTO ALEGRE, BRAZIL

Land usage and settlement process based on deforestation and unsystematic land management bears conflict between environment recovery and farmer's economic reproduction. This dichotomy is displayed in the effective application of the Forest Law (Federal Law 4.771/65) that deals with permanent preservation areas (APPs) in the marginal strips along water courses. We aim to present a methodology to define the waterside permanent preservation areas using elements of fluvial geomorphology and vegetal cover as an alternative to current legal patterns. We present an historical refurbishment of Northwestern Rio Grande do Sul settlement (Brazil), a theoretical interpretation of nature's conservation and discuss the permanent preservation areas in two analysis levels: the current juridical structure and the area usage in Northwestern Rio Grande do Sul. The discussion of the farm's social function is fundamental because farmers are responsables for preservation. We try to understand the public policies in the official agencies (Ibama, Fepam and Ministério Público Estadual) and how this agencies act. We chose three sectors of the Santo Cristo river to apply the methodology. In each sector, we assigned the floodplain levels and the levees by the cartographic analysis and evaluated the regional structures. As a result, we detected that the river influence areas varies from 20 up to 380 meters and concluded that permanent preservation areas can be 330 meters larger than the legal parameter. This shows the inefficiency of the metric definitions currently used. The main conclusion of the study is the need to take into account other ecological and geomorphological parameters for the definition of permanent preservation areas. We can say that conservation practices made by rural producers should be seen as positive impacts for rural property, as well as for the enrichment of biodiversity in small, medium and large properties.



**S15D - Teaching and disseminating geomorphology**

Convenor: *David HIGGIT*





## Oral presentations:

### **Geomorphological Virtual Tours: multimedia e-books for undergraduate education**

PARON P.(1), GOUDIE A.(2), SMITH M.J.(3)

(1) UNESCO-IHE, DELFT, NETHERLANDS ; (2) St Cross College, University of Oxford,, OXFORD, UNITED KINGDOM ; (3) Kingston University, School of Geography, Geology and Environment, KINGSTON-UPON-THAMES, UNITED KINGDOM

Sauer (1956) in his opening address at the Annual Conference of the AAG said that 'the principal training of the geographer should come, wherever possible by doing fieldwork'. Almost 60 years have passed and several pathways of geographical studies have developed since. Still the first approach for identifying, and being fascinated by, geographical forms, processes and their spatial interactions is primarily observational. Since 1956 the development of satellite technologies has added significantly to our ability to quantitatively observe the landscape and at scales that enable holistic understanding geomorphological processes and forms. Over the last decade a number of websites have championed aerial views of our planet, whilst the interactive exploitation of imagery demonstrated by Google Earth literally revolutionised the use of remote sensing and broadened its user base and application. Examples, using case studies, are primarily drawn from North America, Europe or Australia such as Brock (<http://tinyurl.com/9ajxduk>) or Arrowsmith (<http://tinyurl.com/8blokyg>).

We identified a gap in educational resources built around Google Earth: existing case studies are either *placemarks* or *animations* without any sort of annotation. None of the available free examples couple a Google Earth annotated animation with scientific text and a more general introduction to the environment. We present here a new and freely available resource for geomorphological education targeted at undergraduate students, where annotated video animations from Google Earth are integrated in an e-book with explanation of each virtual landscape visited. The e-book develops through 10 different morpho-climatic environments and landforms: arid, coastal, fluvial, glacial, periglacial, weathering, biogenic, human, slopes, and tectonic landforms. The examples are global and from locations that are outside the mainstream of geomorphological images used as examples from the most popular textbooks or websites.

\*\*\*\*\*

### **Landscapes, Geology and Sport: the Earth Sciences at the 'Giro d'Italia'**

LUGERI F.(1), FARABOLLINI P.(2), GRAZIANO G.V.(3), LUGERI N.(1)

(1) Istituto Superiore Protezione e Ricerca Ambientale, ROMA, ITALY ; (2) Scuola di Scienze Ambientali - Università degli Studi di Camerino, CAMERINO (MC), ITALY ; (3) Consiglio Nazionale dei Geologi, ROMA, ITALY

The "GeoloGiro" is a proposal for the popularization of the scientific knowledge, explaining the geological setting of the landscapes crossed by the cycling race "Giro d'Italia". The project is now starting, thanks to the synergy established between the Geological Survey of Italy-ISPRA, the National Council of Geologists and the "Gazzetta dello Sport", the legendary newspaper organizing the race. A better enhancement of the geological heritage of a land can be reached and shared, thanks to a simple scientific analysis of the stages of the Giro d'Italia, according to the "Landscape" methodological approach.

The morphology of the territory becomes a key component in the race context: if explained by the geologist, can offer to the public a new and interesting point of view of the landscapes, linking scientific information to the agonistic valence of the stage. Shape and position of Italy entails a wide variety of landscape types, natural and anthropic, concentrated in a long and narrow area.

The "Giro d'Italia" is one of the most loved sport event, and is here identified tool for the scientific popularization. In the project, the geo-morphologic setting of an area is also related to the local culture and tradition, always deeply linked to geology. In this sense, it can help the touristic promotion of a land: the landscape becomes an anti-crisis resource. The presence of World Heritage Site and/or protected areas, gives a further opportunity to deepen the relationship between the nature of the land and its own developed culture. The Giro d'Italia 2012 has already welcomed the presence of the geologist: the stages in the Dolomites, offered a special chance to observe the spectacular geology of the "pink mountains", UNESCO WHS.

From the Porphyry in the Pusteria Valley to Cortina, the pearl of the Dolomites, in an unforgettable "Dolomites big stage" between geological domains, telling a fascinating geological story.

### **Batur Caldera Complex, the first land-form volcanic laboratory in Indonesia**

PRATOMO I., PERMANADEWI S.

*Center for Geological Survey, BANDUNG, INDONESIA*

Batur Caldera is a composite volcanic complex situated in Bali Island, Indonesia. This caldera complex with a caldera-lake in the middle of the second caldera, is one of the most beautiful panoramic-view in the world. Batur Caldera has been declared as a member of Global Geopark Network (GGN) by UNESCO, during 11th European Geopark Conference held in Auroca Geopark, Portugal, on 20 September 2012. This caldera complex consist of two caldera formations were dated in 29.300 BP and 20.150 BP, have three active volcanic-cones situated in the center of the second caldera. The recent activity is characterized by the development the volcanic cones, which is dominated by the formations of lava flows and the stombolian-type eruptions. The successions of three actives cones followed of small fissure oriented almost on E-W direction, give a spectacular sun-rise and sun-set panoramic views. The historic-lavas flows which are flowed-down to the caldera-lake formed the lava channels, kipuca's, tumulies, pillow-lavas, and the lava tubes figured by their beautiful cave-ornaments. Famous Baliness culture with the religious-Pura buildings are presenting the traditional relationship between active-volcano and the peoples, also as excelent natural volcano-laboratory.

Keywords: Batur Caldera, Bali island, lake, active-volcanic cones, lava flows, lava tubes, pillow-lavas

\*\*\*\*\*

### **Sharing the past with students: teaching geography and history through digital palaeogeography**

GALANI L., KRITIKOS G., THEODORAKOPOULOU K., SKENTOS A., PAVLOPOULOS K.

*Department of Geography, Harokopio University, ATHENS, GREECE*

This study reports early results of a research from the department of Geography of the Harokopio University, Athens, Greece. The project focuses on Digital Palaeogeography and specifically the cartographical presentation of cultural succession in Greek "ChoroChronos" (space and time). The subject of the program is particularly important because it is closely associated with core concepts of geographic and historical education.

The pedagogic value of this project lies in the development of five distinct skills: chronological thought, historical and geographic comprehension, analysis and interpretation of geographic space, ability to perform geo-historical research, and analysis interpretation of geo-historical decision-making.

The data base as a product of the process and as an educational tool, gives the ability to create documents, to organize and present the information, to investigate and analyze quantitative data, to categorize and classify the information, based on specific criteria.

In addition, maps and 3D presentations of the sites derived from this data base have facilitated the study of factors leading to changes evolution over time. As result, the students are able to develop a multidimensional, evidence driven approach, in order to answer questions and to "rebuild" the historical "ChoroChronos" through interdisciplinary and methodological pluralism which characterizes the modern geography, suppressing the barriers between the sciences.

## **Physical Geography Must Reclaim French High-school Geography**

ECOCHARD E.

*Laboratoire de Géographie Physique Pierre Birot, MEUDON, FRANCE*

French high-school geography has lost its legitimacy in teaching physical geography. One of the reasons for it is the insufficient epistemological reflexion in the French academic physical geography. Human geographers dominate the arena of geographical epistemology. And no didactic progress can thrive without epistemological studies.

Nowadays in French secondary education, “sciences of life and earth” almost have a monopoly of teaching geomorphological, climate and biogeographical dynamics. But this perspective is not as well suited to highlight the spatial organization of human societies as the geographic one is. The absence of physical geography in French curriculum is detrimental, especially as sustainable development and environmental changes are central concepts in the new “college” and “lycée” curricula. Physical geography must reclaim French high-school geography through the concept of environment.

One avenue for this is to think about the environment along a different time frame than currently offered. The concept of environment is now taught referring to the present (resources, quality of life, risk) and future (climate change, sharing scarce resources) contexts. It must now incorporate the past, which will allow teaching environmental evolutions with emphasis on human dynamics. This would be an opportunity to highlight the relevance of teaching history and geography together, but also to promote interdisciplinary collaboration with sciences of life and earth as well as with physics and chemistry. A richer concept of the environment would emerge, no longer perceived by students as a subjectified object (to protect), but as an objectified space form, which dynamics must be understood. Additionally, the concept of natural heritage could be developed at the same time. In short, physical geography is at the heart of geographical education issues in the new curriculum: it must take its full place.

\*\*\*\*\*

## **Poster presentations:**

### **Importance of introducing visual aids and 3D models in teaching geomorphology at secondary schools in Sri Lanka**

WICKRAMASOORIYA A.

*South Eastern University of Sri Lanka, SAMMANTHURAI, SRI LANKA*

Geography is one of the main subjects included at the secondary level school curriculum in Sri Lanka. After secondary school level, students enter to universities for continue their higher studies. Therefore, secondary school level can be considered as the most important stage where the basic concepts describe in geomorphology can be introduced to students. Also teachers have the responsibility to teach these concepts using more attractive methods so that students pay more interest to study the subject at university. Geomorphology is one of the widely applied subjects teaching in Geography. Understanding the surface features, surface processes, natural hazards experience on the surface, depositional environments, etc plays an important role in finding solutions for many environmental and socioeconomic problems. Thus, producing geographers with sound applied geomorphology knowledge will be an essential step that should be completed for the betterment of the country. According to the survey carried out in different parts of the country including rural and urbanized areas, it was found that teachers follow very old traditional methods in their teaching. Nearly ninety percent of teachers use only the compulsory text book as the teaching guide. This is mainly due to lack of facilities at schools, do not have access to internet, do not aware about new teaching aids, shortage of teacher training related to new teaching techniques. After analyzing the questionnaire survey results it was clearly identified that nearly sixty to seventy percent of students imagine the concepts and processes teaching under geomorphology rather than understand them properly. This can be a main barrier to produce applied geomorphologists. By implementing new teaching approaches like introduce low cost teaching aids such as 3D surface models, visual aids like animations, video films related to geomorphology, etc this situation can be overcome in future.

## **Significance of selected teaching strategies and bilingual education in the teaching and popularisation of geomorphology**

PIOTROWSKA I.

*Faculty of Geographical and Geological Sciences, Adam Mickiewicz University, POZNA?, POLAND*

The action of external relief-forming factors (running water, groundwater and sea water, wind, glaciers), visible in each climatic zone on Earth, determines the development of a specific type of relief. At the same time relief determines the operation and effects of external processes which mould the Earth's surface. Their widespread and permanent nature can be an excellent basis for the formation of geomorphological perception, thinking, and explanation of the causes and patterns of those processes, which belongs to the tasks of geomorphology as a science. It is also important to teach geomorphology at a variety of educational levels. In order to shape geomorphological knowledge in a proper way, much attention should be paid to the selection of suitable teaching strategies. Examples include anticipatory learning and Learning by Teaching (LdL). The process of education and popularisation of geomorphology can be enriched with bilingual teaching, which is a bridge between the preparation for learning and understanding the processes occurring in the geographical environment and the ability to explain and describe them in various linguistic codes, irrespective of the scale of spatial differences. The specificity of bilingual teaching requires an integrating approach embracing substantive and linguistic aspects as well as the learning skills that pupils possess. During this process a special task is the acquisition of a basic geomorphological vocabulary in the foreign language. One can then observe in pupils a transition from the BICS level (Basic Interpersonal Communication Skills) to that of CALP (Cognitive/ Academic Language Proficiency). This mode of education can produce young people able in the future to anticipate not only the consequences of the action of relief-forming factors for the natural environment, but also their effects on the operation of the socio-economic system, and ready to act in accordance with the idea of sustainable development.

\*\*\*\*\*

## **Participatory GIS to investigate urban river habitat quality in Singapore**

HIGGITT D.

*National University of Singapore, SINGAPORE, SINGAPORE*

One of the challenges confronting the geomorphology educator is how to enthuse students about landscape processes in an increasingly urbanized environment. Singapore provides an extreme example where rapid urbanization from the 1960s onwards produced a landscape which is heavily modified by structural engineering. However, recent interest in improving the aesthetic and ecological conditions of riparian environments has opened opportunities to engage students in fieldwork activities and debate about river management. As part of a Ministry of Education project to enhance geospatial literacy, a participatory GIS approach has been adopted to engage students in data collection and analysis of information about river habitat quality in urban environments. Some of the challenges and benefits of using this approach for large introductory classes are discussed. Participatory GIS has the potential to open up new 'learning spaces' in situations where the logistics of organizing fieldwork activities would have been very difficult.

### **Difficulties encountered by professionals in training regarding geomorphology contents: a brazilian university case study**

SOUZA C.J.O.(1), VALADÃO R.C.(2)

(1) Department of Geosciences - Universidade Federal de São João Del-Rei - UFSJ, SÃO JOÃO DEL-REI, BRAZIL ; (2) Institute of Geosciences - IGC - Universidade Federal de Minas Gerais, BELO HORIZONTE, BRAZIL

In Brazil, until the late 1990s, undergraduate geomorphology courses followed the historical approach which gives emphasis to the macroforms and geological and morphoclimatic processes that favor relief description on global and regional scales. This relief approach, based on an evolutionary concept, contributed to foment problems among professionals in training regarding the interpretation of processes and forms on the scale of lived space. These difficulties were observed in field activities and reports carried out by 27 geography students, organized into 11 groups. Of this total, 18.2% confused conditions and processes; conditions and agent; agent and process. No relationship was drawn between processes and forms, nor did they know how to explain many of the processes involved in the genesis and evolution of a gully. Despite demonstrating knowledge of the processes responsible for the formation of a gully, the majority (54.5%) applied the idea of cause and effect, as in the morphogenesis concept. Only 27.3% used systemic reasoning for the processes. Environmental geomorphological studies demand that the professional in training be able to: a) identify evidence of agents, processes and conditions; b) associate form, processes and conditions; c) recognize forms resulting from specific processes; d) devise processes that act simultaneously, are integrated, and show different rhythms and velocities according to local conditions; and, e) use visible elements (deposits, erosive scarring, sediment characteristics, spatial organization of the observed elements) as references for developing hypotheses and arguments that help to explain the geomorphological processes responsible for the erosive scarring and features of the local relief. These skills must be worked on during training for the professionals to understand the functionality and rhythms of processes and the dynamics of forms.

\*\*\*\*\*

### **Recognition and development of fundamental skills and competencies for the construction of geomorphological knowledge in higher education in Brazil**

SOUZA C.J.O.(1), VALADÃO R.C.(2)

(1) Department of Geosciences - DEGEO - Universidade Federal de São João Del-Rei (UFSJ), SÃO JOÃO DEL-REI, BRAZIL ; (2) Institute of Geosciences - IGC - Universidade Federal de Minas Gerais (UFMG), BELO HORIZONTE, BRAZIL

In Brazil, geomorphology is commonly taught in higher education by instructors of Geography undergraduate courses also offering subjects of geomorphology to other professionals in training, such as geologists, environmental engineers, and urban planners. The process of constructing geomorphological knowledge demands the development of specific skills and competencies whose recognition is not always clear to instructors, nor to professionals in training. The specialized literature rarely reflects on the inherent skills to think and do geomorphology. Such is the context of the present study which, while addressing the notion of competence and resuming the path of constructing geomorphology, proposes structural concepts from this field of knowledge. The authors have developed a reference guide for evaluating the performance of professionals during their preparation, which includes fundamental skills for learning geomorphology. These skills have been organized along three axes: i) conceptual understanding and geomorphological reasoning; ii) geomorphological representation – imagetic language; and iii) language. Activities applied to a group of professionals in training have confirmed that mastering this set of skills leads to autonomy in solving situations and problems where the geomorphological dimension is present. However, this mastering can only be exercised by professionals capable of: i) broadening linear reasoning to the systemic; ii) improving or developing the perception and spatial visualization of relief landforms; iii) breaking away from preconceived thinking structures regarding concepts of erosion, relief, and spacial and temporal scales; iv) knowing the meaning of topographic map representations; and, v) understanding that Geomorphology contents, as approached in academia and literature, enable geomorphological reflection but do not constitute geomorphology *per se*.

## **Geomorphology teaching for environmental engineering from the fieldwork - theory and practice**

ALMEIDA E.(1), PENIDO F.(2)

(1) *Universidade FUMEC, BELO HORIZONTE, BRAZIL* ; (2) *ICF International, RIO DE JANEIRO, BRAZIL*

The Geomorphology has been a science increasingly exploited by the various knowledge areas. Learn to interpret the space, has become point of interest for environmental engineering since the future professionals will act in environmental studies those have as part of their scope the physical environment and within this, the geomorphology. The paper presents the results from an analysis carried out in the second half of 2012 from the geomorphology discipline taught to students of environmental engineering. The goal was to show the importance of teaching geomorphology from fieldwork. The Iron Quadrangle region was chosen because its importance and the numerous interventions that has suffered. Were covered 5 counties: Belo Horizonte, Nova Lima, Itabirito, Cachoeira do Campo and Catas Altas. Were defined 12 stop points for analysis and description of the geology, geomorphology, pedology and land use, based on maps and visual analysis. At those stop points were analyzed the environmental problems encountered and existing solutions. The basic idea was the observation of the landscape after understanding the substrate. Several issues were raised from the new look over the space. The reasoning about the viewed problems, now grounded on prior knowledge from the classroom, directed new proposals showing the non insertion of geomorphological knowledge in existing interventions. The students were able to understand the importance of geomorphology in the modification of the landscape and its future role as professional.

\*\*\*\*\*

## **Geology and Wine: Landscapes in a bottle (remembering Lucilia Gregori)**

LUGERI F.(1), ALDIGHERI B.(2), FARABOLLINI P.(3), GIANNELLA G.(4)

(1) *Istituto Superiore Protezione e Ricerca Ambientale, ROMA, ITALY* ; (2) *Istituto per la Dinamica dei Processi Ambientali, CNR, MILANO, ITALY* ; (3) *Scuola di Scienze Ambientali - Università degli Studi di Camerino, CAMERINO (MC), ITALY* ; (4) *Libero professionista, ROMA, ITALY*

The socio-economic scenario of a region is closely linked to the geomorphologic arrangement of the land. By integrating geology and land use, it is possible to study the relationship between landscape and wine areas. The production of wine is one of the most important component in the Italian culture as well as in the economy. At the same time, it is an expression of the territory: in this way it becomes a "medium" to communicate the landscape and to promote the sustainable development. In this context, the conferences on "Landscapes of Wine" created and organized by Lucilia Gregori, Professor of Geomorphology at the University of Perugia, dead in January 2012, have been for many years an opportunity for a significant and permanent dialogue between the experts (academics, producers, consumers) offering proposals for knowledge and qualified enjoyment of the best Italian wines.

One of the most important Lucilia's projects was the realization of "geological labels" on the wine bottle, describing the landscape of the production area by a geo-morphologic point of view. We are trying to continue these projects, following an integrated methodological approach, GIS based.

The Geographical Information Systems represent new tools and new ways of dialogue, aimed at an easier access to the information in a scientific and cultural way, using simple communication codes.

GIS technologies can synthesize, manage and represent large amounts of data, giving the researchers as well as the public, a complete information about wine, landscapes and territory. A further and interesting opportunity is the identification of those wine-producing areas characterized by environmental and cultural value such special to be considered as geosites.

A multidisciplinary methodology allows a complete knowledge of territory, useful in territorial planning policies oriented to a sustainable development, and contributes significantly to a better understanding of the culture of Italian wines.

### **Geodiversity of the Colorado River Delta, Baja California, México**

TELLEZ M.(1), SPELTZ R.(1), FLESSA K.(2), ARANDA F.(1)

(1) *Universidad Autonoma de Baja California, Facultad de Ciencias Marinas, ENSENADA, BAJA CALIFORNIA, MEXICO* ; (2) *University of Arizona, TUCSON, UNITED STATES*

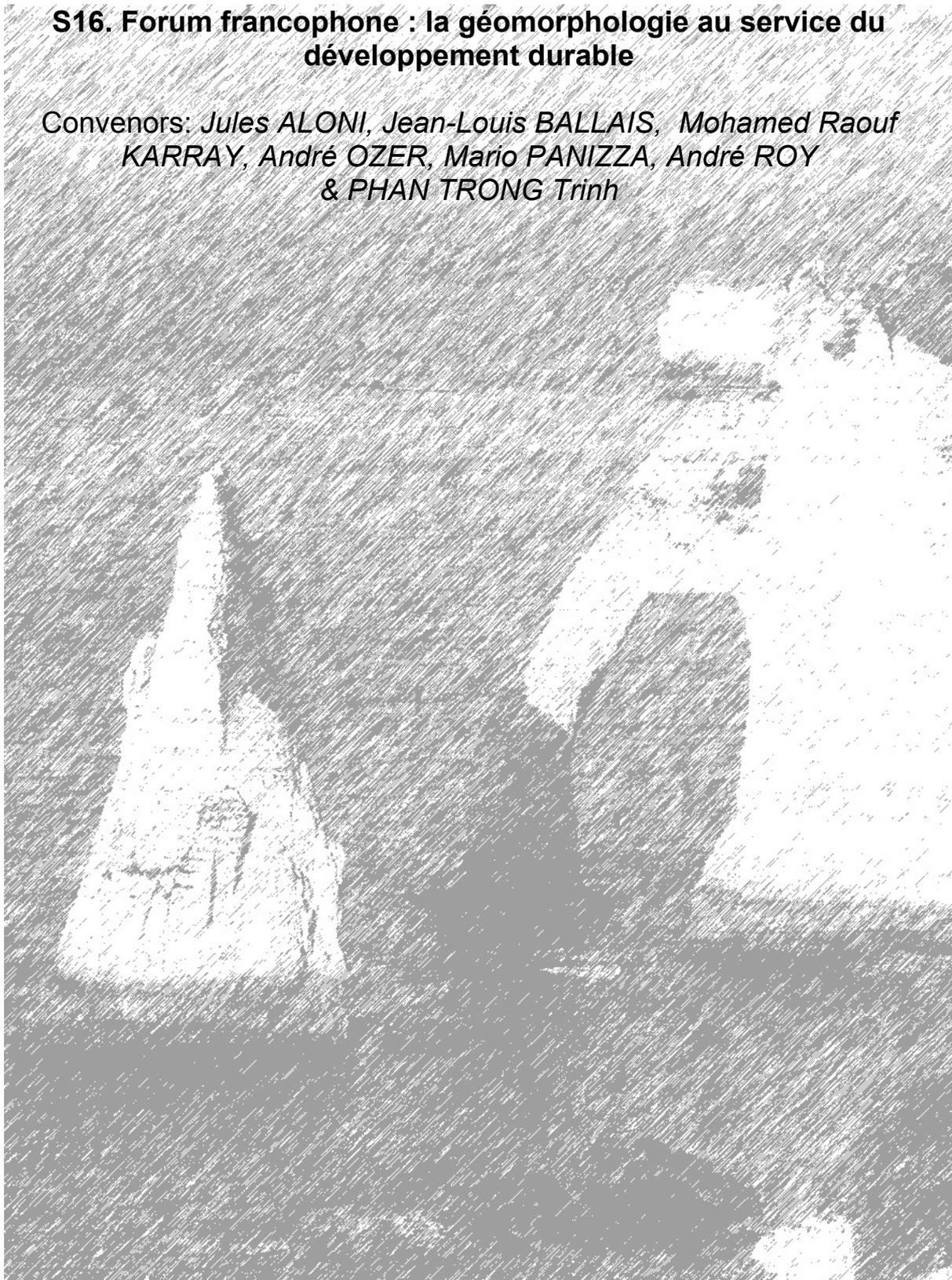
Although the Colorado River delta is best known for its diversity of birds, for its endangered porpoise and its fisheries, the delta's rich cultural and geological diversity is not well-recognized – despite its designation as the Biosphere Reserve “Alto Golfo de California y Delta del Río Colorado”. The delta's landscape is dominated by extensive tidal flats and floodplains with impressive shell beaches, coastal lagoons, abundant sedimentary and biogenic structures, dunes, cliffs and marine terraces. These features document the diversity and heterogeneity of geomorphological processes and their links with biodiversity. Nowadays they are often disturbed by human-caused stresses such as the lack of river flow and coastal erosion by the removal of dune vegetation. The surrounding area also includes intrusive and extrusive rocks, Paleozoic fossiliferous metasediments, proto-gulf bathyal diatomites and Pleistocene fossiliferous sandstones. The cultural heritage in the coastal zone is dominated by numerous prehistoric shell Indian middens with abundant stone tools and scattered ceramic sherds. Prehistoric rock paintings and petroglyphs are common in the foothills of the nearby mountains. Managing the diverse and valuable natural and cultural resources of the Colorado delta is a major challenge because of potential conflicts over water, agriculture, fisheries and tourism. The Geodiversity concept can be used in education and regional tourism to emphasize the functional integrity of the landscape, ecosystems and the maintenance of natural processes. This is a scientifically-based approach to the sustainable development of the region.

\*\*\*\*\*



**S16. Forum francophone : la géomorphologie au service du développement durable**

Convenors: *Jules ALONI, Jean-Louis BALLAIS, Mohamed Raouf KARRAY, André OZER, Mario PANIZZA, André ROY & PHAN TRONG Trinh*





## **Oral presentations:**

### **Géodiversité et Géomorphodiversité: exemples en Italie**

PANIZZA M.

*Dipartimento di Scienze Chimiche e Geologiche - Universite di Modena e Reggio Emilia, MODENA, ITALY*

Dans le but d'étudier, d'interpréter et de mettre en valeur le patrimoine géomorphologique (et géologique) selon un code de déchiffrement original, on a introduit le concept de 'géomorphodiversité' (et redéfini celui de 'géodiversité'): évaluation critique des caractéristiques géomorphologiques (et géologiques) d'un territoire, en les considérant tant au niveau 'extrinsèque' (par rapport à d'autres territoires), qu' 'intrinsèque' (dans le périmètre du territoire considéré), en prenant en compte leur qualité scientifique, l'échelle et le but de la recherche'.

Trois exemples en Italie sont pris en considération: les Dolomites, qui ont été insérées au sein du Patrimoine Mondial de l'UNESCO; les Apennins émilliens, qui sont candidats à l'inscription dans la liste des Géoparcs Européens; le Vésuve, qui fait partie du réseau des Parcs Nationaux Italiens.

En général on a exécuté une évaluation critique et spécifique des caractéristiques géomorphologiques (et géologiques) de ces montagnes, en faisant la comparaison soit entre d'autres montagnes (niveau extrinsèque), soit entre les particularités plus ou moins significatives des trois régions montagneuses considérées (niveau intrinsèque).

Pour exemple les caractères d'excellence stratigraphique dans l'espace et dans le temps (Dolomites), la complexité tectonique et sédimentologique (Apennins), la typologie des éruptions entrée dans la nomenclature volcanique internationale (Vésuve): géodiversité extrinsèque à niveau global. On peut citer le large spectre de formes du relief plurigénétiques (Dolomites), l'exemplarité de la morphologie épigée et hypogée du Karst en lithotypes gypseux (Apennins), l'émblématique didactique des formes du relief volcanique en rapport avec la pétrographie et les mécanismes d'éruption (Vésuve): géomorphodiversité intrinsèque en prenant en compte leur qualité scientifique.

\*\*\*\*\*

### **Modélisation et géomorphologie dynamique dans le nord de l'Algérie**

DAOUDI M.

*King Abdulaziz University, JEDDAH, SAUDI ARABIA*

Le processus du ravinement est le moteur de la géomorphologie dynamique. Très fréquent en Afrique, il touche particulièrement le nord de l'Algérie ce qui engendre l'envasement des barrages et diminue les potentialités des sols. Le bassin versant de l'oued Isser, d'une superficie de 4165 km<sup>2</sup>, constitue une zone d'étude d'intérêt particulier en raison des caractéristiques physico-climatiques représentatives de la zone tellienne méditerranéenne. Le présent travail propose une méthode univariée-multivariée, basée sur des données multisources, afin de déterminer les variables indépendantes significatives qui favorisent l'existence de l'érosion ravinante et calculer la probabilité des zones de susceptibilité au processus de ravinement. Pour déceler l'influence d'une variable sur le processus et comparer leur distribution, une analyse statistique et spatiale des différentes variables a été appliquée. Le test de Student et le test de Kolmogorov-Smirnov ont été appliqués aux variables quantitatives et le test de Chi carré a été appliqué aux variables qualitatives. Des variables explicatives sont retenues pour le modèle de régression logistique : il s'agit de la lithologie, la pente, l'orientation des versants, l'altitude, la morphopédologie, la couverture du sol et l'agressivité des précipitations. Elles permettent de généraliser le modèle prédictif pour des régions semblables du nord de l'Algérie ou du Maghreb.

Mots clefs : Géomorphologie dynamique, érosion ravinante, données multisources, analyse spatiale et statistique, régression logistique.

### **Erosion et impact des vagues exceptionnelles sur le littoral ivoirien à l'est d'Abidjan**

KONAN E.(1), AKA K.(2), ABE J.(3), NEUMEIER U.(4), NYSSSEN J.(5), OZER A.(6)

(1) Centre de Recherches Océanologiques, ABIDJAN, COTE D'IVOIRE ; (2) Université de Cocody, ABIDJAN, COTE D'IVOIRE ; (3) PNUD, ACCRA, GHANA ; (4) Institut des sciences de la mer, Université de Québec, RIMOUSKI, QUEBEC, CANADA ; (5) Université de Gand, GAND, BELGIUM ; (6) Université de Liège, LIEGE, BELGIUM

Cette étude estime les impacts des vagues exceptionnelles enregistrées le 14 août 2007 sur le cordon littoral ivoirien à l'est d'Abidjan (Abidjan Grand-Bassam et Assinie-Aforenou). La méthode d'appréciation est basée sur une analyse diachronique de photographies aériennes (1979-1989) et sur un important travail de terrain appuyé sur une série de profils topographiques du Centre de Recherches Océanologiques d'Abidjan (ex-ORSTOM). A partir de la superposition des courbes enveloppes obtenues, une approche quantitative des dépôts de sédiments est utilisée pour mesurer l'ampleur du recul du trait de côte. L'application de ces méthodes montre que la vitesse d'érosion de la baie de Port-Bouet et des plages d'Assinie, n'excède généralement pas 1,5 m/an, est exacerbée sur des courtes durées par des houles violentes qui naissent dans l'Océan Atlantique sud. Certaines seraient d'origine sismique comme celles qui ont submergé puis érodé une partie de la côte ivoirienne dans la nuit du 13 au 14 août 2007. La côte a reculé de 2,3 à 18 m en un cycle de marée faisant d'importants dégâts dans la baie d'Abidjan (Port-Bouet). Cette étude met en exergue que le cordon littoral étudié, qui subit de façon générale une érosion, présente une sensibilité élevée aux vagues anormales.

Mots-clés: érosion côtière, engraissement, courbe enveloppe, séisme, vagues exceptionnelles.

\*\*\*\*\*

### **Etude de la morphodynamique et de la dynamique sédimentaire de la côte atlantique de Tanger (Maroc) par l'imagerie aérospatiale**

EL ABDELLAOUI J.E.

Université Abdelmalek Essaadi, TANGER, MOROCCO

Des images satellites et des photographies aériennes, à haute et très haute résolution, ont été étudiées afin de caractériser la dynamique morpho-sédimentaire de la côte atlantique de Tanger.

Les résultats montrent que la morphodynamique présente un état modal intermédiaire avec un système à barres multiples dont le nombre, la position et la configuration sont variables en fonction des conditions d'ondes, des vents et de la géomorphologie antécédente. Les barres subtidales présentent une configuration linéaire légèrement ondulée avec des chenaux de retour. La zone intertidale présente une géomorphologie variable avec de larges terrasses et des chenaux de retour réduits, mais une morphologie prononcée avec une configuration à barres et chenaux de retour relativement développés, est souvent rencontrée.

L'évolution rapide du système à barre et l'irrégularité de sa topographie constituent un risque pour la navigation côtière et favorisent l'ensablement des ports de taille moyenne. Elle mettent en danger la vie des baigneurs à cause des forts courants de retours qu'elles engendrent.

La cartographie de la matière en suspension dans des conditions hydrosédimentaires variables a été réalisée. Elle a permis l'appréciation de la direction des courants et de leurs interactions avec les ouvrages portuaires, la morphologie sous-marine et la configuration de la côte.

La dynamique de la matière en suspension montre qu'au large de la plate forme continentale, le courant est de direction N-E pendant le flot. En s'approchant du rivage, la direction du courant change vers le N-NE. Ce changement forcé par la configuration de la ligne de côte conduit à une forte concentration de la matière en suspension au niveau de la frange côtière. Au cours du jusant la matière en suspension longe la côte au nord avec une direction S-SW parallèle à la ligne de rivage et s'étale ensuite au large de la plate forme continentale avec une direction S-W.

## **Apports et résultats de l'imagerie radar SAR et l'interférométrie InSAR/DinSAR dans les études géomorphologiques dans la région subcarpatique de Buzău (Roumanie)**

HACHEMI K.(1), OZER A.(2)

(1) CNRS LGP, MEUDON (PARIS), FRANCE ; (2) Université de Liège, LIÈGE, BELGIUM

La région de Buzău, située sur la région subcarpatique en Roumanie est le siège de deux grands types d'aléas naturels; géologiques-géomorphologiques (glissements, séismes, ...) et climatiques/hydrologiques (phénomènes d'inondation accentuant souvent l'érosion des sols). On peut alors s'interroger sur le moyen le plus adapté pour établir un suivi permanent de ces risques, en établissant une cartographie aussi fidèle que possible et estimer, éventuellement, les dégâts et les modifications du paysage qui en résultent. L'un des avantages d'imagerie radar (amplitude/phase) est la possibilité d'enregistrement par tout temps indépendamment des conditions météorologiques (jour, nuit, nuages). Cet outil nous a permis d'obtenir plusieurs résultats géomorphologiques dans la région : 1) l'analyse diachronique a permis de mettre en évidence les variations de surface, notamment au niveau des lacs et de la plaine; 2) la réalisation d'un MNA de Buzău (100x100km<sup>2</sup>) avec une résolution de 20 m et précision verticale globale inférieure à 17m; 3) l'association des images diachroniques avec le MNA réalisé a donné des images en 3D (différentes dates); 4) l'exploitation des images de cohérence des différents intervalles (1995/2005), nous a permis de distinguer plusieurs constructions qui se sont multipliées au périphérique et à l'extérieur de la ville de Focșani. Par contre, le centre de la ville avait subi des rénovations se traduisant par des espaces verts; 5) la comparaison entre le MNA réalisé et le DEM-SRTM a donné une différence de morphologie au niveau du glissement du Shela; 6) le volcan de boue nord (Paclele Mici) est plus actif que le volcan sud (Mari) dans cette période (octobre 2004/avril 2005); 7) la détection des déformations près de la ville de Saranga (déplacements d'environ 24,08cm/70j et 11,70cm/105j); 8) les trois lacs de Buzău apparaissent nettement dans l'image de cohérence. Les deux lacs au nord et sud diminuent et le lac du milieu s'agrandit durant cette période (1963/1995).

\*\*\*\*\*

## **Tourisme, privatisation des littoraux et érosion des côtes: cas de Phan Thiet, Vietnam**

OZER P.

Département des Sciences et Gestion de l'Environnement, Université de Liège, ARLON, BELGIUM

Avec ses plus de 3200 km de côtes, le Vietnam fait partie des pays les plus exposés aux effets du réchauffement climatique : élévation du niveau des mers, augmentation de la fréquence des typhons et des inondations.

Début 2009, 27 maisons situées dans le village de pêcheurs de Phan Thiet se sont effondrées. Selon les médias internationaux et les autorités locales, une forte marée de tempête –conséquence du réchauffement climatique– était la cause de cette rapide érosion littorale.

Cet article montre comment, en utilisant la fonction multi dates Google Earth, il est possible de nier cette argumentation et de mettre en évidence les vraies causes de ce rapide et inéluctable retrait des côtes au niveau de ce village de pêcheurs, à savoir la construction anarchique de la station balnéaire de Mui Ne, quelques kilomètres à l'est.

La création de ce désormais haut lieu touristique est extrêmement récente, le premier établissement étant sorti de terre en 1994. Vu le succès croissant des plages de sable blanc, la côte a depuis été lotie sur près de 5 km. Mui Ne a modifié son espace pour accueillir les touristes occidentaux : les cocoteraies ont été abattues, les liserons des sables ont été arrachés, le sable a été égalisé et les infrastructures hôtelières ont recouvert les dunes pour être en contact direct avec la plage.

Ainsi, le fragile équilibre littoral a été rompu et le bilan sédimentaire est devenu négatif. Entre 2006 et 2009, la plage de 30 m a totalement disparu. Or, la plage étant vitale pour ce lieu, les promoteurs ont eu recours à la construction d'épis qui interrompent le transit sédimentaire pour recréer les plages. La dérive littorale est ainsi stoppée ce qui engendre la disparition des plages suivantes et l'effondrement des maisons de pêcheurs.

Cette analyse montre la rapide modification géomorphologique qui résulte d'une conversion économique locale non encadrée répondant aux processus de mondialisation sans tenir compte des externalités négatives.

## **Une cartographie du risque "instabilités de terrain" au service du développement durable : l'exemple du complexe portuaire "Tanger Med" et de son arrière-pays (Rif septentrional, Maroc)**

PATEAU M.(1), FORT M.(1), BEN MOUSSA A.(2)

(1) Université Paris Diderot, Sorbonne Paris Cité, PRODIG UMR 8586, 75013 PARIS, FRANCE ; (2) Université Abdelmalek Essaâdi, Faculté des Sciences, Département de Géologie, BP 2121 93000 TETOUAN, MOROCCO

Le nord du Maroc, longtemps marginalisé (Protectorat espagnol de 1912 à 1956, isolement suite aux révoltes du Rif à la fin des années 1950), connaît un développement sans précédent porté par de grands projets tels que le complexe portuaire « Tanger Med ». Ses aménagements imposants (trois ports, zones franches et logistiques, réseaux autoroutier et ferroviaire) ont profondément bouleversé à la fois les dynamiques de versants de l'arrière-pays et la vie des populations locales. En se basant sur une étude de terrain approfondie et une cartographie de l'occupation du sol, notre travail propose un inventaire et une description précise des secteurs et infrastructures fortement exposés aux instabilités de terrain (prédominance de terrains flyschéux).

Deux études de cas seront présentées. La première expose le problème du stockage des déblais sur des versants naturellement sujets aux instabilités de terrain. Ces dépôts massifs sont situés en bordure des principaux oueds et entraînent, en cas de fort épisode pluvieux, une charge sédimentaire grossière vers l'aval, aggravant ainsi la vulnérabilité des exutoires anthropisés. Le second cas traite du relogement des populations expropriées par l'aménagement du complexe. Certaines se sont vues proposer une habitation neuve construite sur un secteur géologiquement sensible à l'érosion (solifluxion dans un flysch argilo-calcaire détritique). Ces constructions (majoritairement des villas et une imposante mosquée) ont bloqué les écoulements naturels de l'eau (imperméabilisation des sols) et amené une concentration du ruissellement, engendrant des phénomènes de ravinement intense et une déstabilisation de certains bâtiments.

La cartographie de synthèse ainsi produite pourra servir, à l'avenir, de document de référence pour les futurs aménagements, afin de ne pas répéter les erreurs déjà commises et ainsi assurer une gestion durable de cette zone aux potentialités économiques et touristiques croissantes.

\*\*\*\*\*

## **Seuils topographiques des ravins dans la haute ville de Kinshasa (RD. Congo)**

MAKANZU IMWANGANA F.(1), MOEYERSONS J.(2), NTOMBI M.(3)

(1) Laboratoire de Géomorphologie et Télédétection, Centre de Recherches Géologiques et Minières (LAGEOT/CRGM), KINSHASA, CONGO (THE DEMOCRATIC REPUBLIC OF THE) ; (2) Division of Geomorphology and Remote Sensing, Royal Museum of Central Africa, TERVUREN, BELGIUM ; (3) Département des Sciences de la Terre (Géographie-Géologie), Faculté des Sciences, Université de Kinshasa, KINSHASA, CONGO (THE DEMOCRATIC REPUBLIC OF THE)

Le ravinement constitue un processus important de l'érosion des sols en Afrique centrale. Ce sont surtout les villes qui en sont victimes. Le ruissellement incise les sols à partir d'un point où une combinaison critique de la pente (S) et de la surface drainée (A) est dépassée. L'objectif de ce travail est de connaître ces combinaisons critiques, de façon de les utiliser dans la prévention de l'érosion en ravine dans une zone urbanisée. La haute ville de Kinshasa avec ses 240 km<sup>2</sup>, en est la zone d'étude.

Des mesures de S et de A ont été faites pour 308 ravins de >5 m de large inventoriés sur une image SPOT 2007. Selon leur genèse, une typologie des ravins a été faite. Les ravins dits axiaux se produisent par érosion régressive des structures urbaines. Les ravins de débordement sont provoqués par une érosion progressive aux abords de ces structures. La relation statistique de S et A de ces ravins a été vérifiée sur un graphique à double échelle logarithmique. Pour ces ravins, l'équation de l'enveloppe est  $Scr=0,0001A-1,329$  avec Scr en m/m et A en ha. L'enveloppe qui décrit la relation entre S et la longueur des routes L montre une relation semblable. Cette équation représente le seuil topographique de l'apparition de l'érosion en ravine dans cette région. En comparaison avec les seuils trouvés dans d'autres régions en Afrique et ailleurs, le sol sableux de Kinshasa apparaît comme l'un de plus vulnérables du monde face au ruissellement. Dans certains cas, la configuration des routes fait aussi accroître la surface de drainage et les routes mêmes sont des grands producteurs de ruissellement. Une pluie même de faible intensité occasionne du ruissellement.

La relation qui existe entre la pente critique et la surface de drainage est un outil qui pourrait contribuer dans la gestion de l'eau, la conservation des sols et dans la lutte anti-érosive dans les milieux urbains à l'instar de la haute ville de Kinshasa.

Mots clés : Seuil topographique, surface drainée, ruissellement, ravin, Kinshasa

## Quatre lits pour un cours d'eau. Conséquences pour le risque d'inondation et l'aménagement

BALLAIS J.L.(1), CHAVE S.(2), DELORME V.(3), ESPOSITO C.(4)

(1) Université d'Aix-Marseille, AIX-EN-PROVENCE, FRANCE ; (2) Prédicit-Services, MONTPELLIER, FRANCE ; (3) Fluvialis, BRIENNE-LE-CHÂTEAU, FRANCE ; (4) Centre d'Etudes Techniques de l'Équipement, AIX-EN-PROVENCE, FRANCE

La tradition initiée par les chercheurs étatsuniens du milieu du XX<sup>ème</sup> siècle a permis de distinguer d'une part la *channel* et, d'autre part, la *floodplain*. Cette distinction a suscité un très grand nombre de travaux, surtout parmi les anglo-saxons, et a montré son efficacité pour l'étude des processus hydrogéomorphologiques.

L'irruption de la problématique des risques d'inondation en France et sa concrétisation en termes d'aléa a conduit à s'intéresser à nouveau aux formes, longtemps négligées au profit des processus. C'est ainsi que plusieurs centaines de kilomètres de plaine alluviale fonctionnelle ont été cartographiés en France, en Tunisie et en Chine. S'il est certain que, sous climat tempéré océanique et semi-continentale, le lit mineur (*channel*, ou mieux *low water bed*) et le lit majeur (*floodplain*, ou mieux *high water bed*) constituent bien, généralement, les deux seuls lits d'un cours d'eau, il n'en est pas de même sous d'autres climats. C'est ainsi que nous avons été conduits à définir un lit moyen (*mean water bed*), généralement placé entre le lit mineur et le lit majeur, et un lit majeur exceptionnel (*exceptional high water bed*), en position distale, pour traduire la complexité de situations observées en domaine méditerranéen (France, Tunisie, Roumanie), tempéré continental (Xinjiang) ou tropical sec à cyclones (Australie du Nord-Ouest).

Ainsi, la réduction du nombre des formes de lit à seulement deux, nécessaire pour l'application de la modélisation hydraulique il y a 50 ans, se révèle être un des derniers avatars de la conception davisienne de l'érosion normale, c'est-à-dire tempérée. De plus, la possibilité de l'existence de jusqu'à quatre lits impose de ne pas considérer les limites externes du lit majeur ordinaire comme limites de la zone inondable, au risque de négliger des surfaces unondables très recherchées par les aménageurs.

\*\*\*\*\*

## Vulnérabilité de la plaine d'inondation du fleuve Hathanh (Centre Viêt-Nam) face aux changements environnementaux

GRIVEL S.(1), NGO A.T.(1), ZANINETTI J.M.(1), LUONG T.V.(2)

(1) Université d'Orléans, ORLÉANS, FRANCE ; (2) University of Quynhon, QUYNHON, VIET NAM

Le fleuve Hathanh, dans la province de Binh Dinh (Centre du Viêt-Nam), est un hydrosystème fluvial peu étudié : un court linéaire (58 km), entre les hauts bassins et le delta; une plaine deltaïque alimentant la lagune de Thinaï; un contexte hydroclimatique de type tropical de mousson avec une saison des pluies centrée sur juillet et une période cyclonique en octobre-novembre. Depuis la libéralisation économique du pays, de la fin des années 1980, la croissance urbaine de Quynhon est soutenue. Les projets d'aménagements de cette ville se réalisent dans le delta du fleuve Hathanh. Or, la plaine d'inondation constitue un écosystème et un agrosystème très fragiles et sensibles aux perturbations. Elle est directement affectée par les changements environnementaux comme les modifications hydroclimatiques et la montée du niveau de la mer. Selon le rapport du Ministère des Ressources Naturelles et de l'Environnement du Viêt-Nam (2009), le centre du Viêt-Nam pourrait connaître, en 2100, une élévation moyenne du niveau de la mer d'un mètre et une augmentation des températures de près de 3°C (augmentation générale du nombre de jours > 35°C; augmentation de la fréquence et de l'intensité des précipitations; augmentation de la saison sèche). La faible distance entre les hauts bassins et son delta engendre des écoulements très rapides et contribue à aggraver les conséquences des inondations dans la plaine deltaïque, comme en novembre 2009 après le passage de la tempête tropicale Mirinae. Cette communication présentera l'évaluation environnementale de la vulnérabilité physique de la plaine d'inondation à travers des méthodes hydrogéomatiques et géomorphologiques (SIG, télédétection, modélisation). La crue de novembre 2009 servira également d'évènement hydrologique de référence pour appuyer l'analyse de la vulnérabilité. Cette évaluation permettra de mieux anticiper les changements environnementaux (naturels et anthropiques) à venir.

### **Hydrogéomorphologie et risque d'inondation dans la vallée de la Karakash Darya (Xinjiang, Chine)**

*WULAMU M.(1), BALLAIS J.L.(2), DELORME V.(3)*

*(1) Université Normale du Xinjiang, URUMQI, CHINA ; (2) Université d'Aix-Marseille, AIX-EN-PROVENCE, FRANCE ; (3) Fluvialis, BRIENNE-LE-CHÂTEAU, FRANCE*

Le bassin versant de la Karakash Darya est situé dans la partie méridionale du Xinjiang, sur le piedmont septentrional du Karakorum et des Kunlun, au sud du désert du Takla Makan. Dans ce bassin versant, les crues se produisent en été et détruisent les cultures irriguées qui sont la principale ressource des populations. L'applicabilité de la méthode hydrogéomorphologique de détermination des zones inondables, mise au point en France méditerranéenne, a été prouvée pour le bassin versant de la Karakash Darya. La cartographie hydrogéomorphologique fournit des informations qui peuvent permettre un aménagement spatial pour prévenir et réduire les risques d'inondation. De plus, cette cartographie montre que la plaine alluviale fonctionnelle de la rivière est en cours d'ajustement aux débits maximaux en diminution depuis la construction du barrage d'Ulugata. En conséquence, le risque d'inondation diminue sur le lit majeur de la rivière.

\*\*\*\*\*

### **Etude des processus morphodynamiques et leur impact sur le modelé dunaire dans le sud-ouest de la Mauritanie par imagerie satellitale optique et radar**

*NIANG A.J.(1), OZER A.(2)*

*(1) Université Nouakchott, NOUAKCHOTT, MAURITANIA ; (2) ULG, LIEGE, BELGIUM*

Les processus morphodynamiques consécutifs ou inhérents à la désertification représentent un sérieux défi qui aggrave l'état de dégradation environnementale dans les zones arides et semi-arides. Dans le sud-ouest mauritanien, l'érosion éolienne est devenue, depuis les années 70 et 80, un élément essentiel de la dynamique morphogénétique des formations dunaires.

Plusieurs traitements ont été appliqués aux images satellitales pour la mise en évidence des changements environnementaux qui ont affecté le secteur étudié et les caractéristiques morphologiques et morphodynamiques des systèmes dunaires.

L'utilisation de l'imagerie satellitale radar a été également très efficace pour l'identification et la localisation des sables en mouvement.

Les traitements appliqués aux images satellitales optiques montrent une dégradation généralisée des ensembles dunaires et une exacerbation de l'activité morphogénétique impliquant des remaniements successifs des dunes ogoliennes.

L'application de certains filtres nous a permis de discriminer les crêtes vives qui se forment sur les sommets des cordons dunaires, comme des sifs orientés N-S (obliques par rapport aux dunes ogoliennes) et sur certaines parties des interdunes. La réactivation des anciennes dunes s'exprime par la multiplication et la migration des crêtes vives dont l'agencement transforme les cordons dunaires en dunes longitudinales complexes.

Par ailleurs, l'évolution temporelle de la cohérence des images Radar sur de longues périodes indique que la majeure partie de la zone d'étude est composée de sables vifs qui participent à l'édification des nouvelles formes dunaires et qui sont en général situés à proximité des installations humaines. Des auréoles de dénudation apparaissent quasi-systématiquement autour des villages, les zones qui sont restées les plus stables sont celles qui ne sont pas directement dans le voisinage des installations humaines.

## **Le contexte urbain et climatique des risques hydrologiques de la ville de Butembo (Nord Kivu/ RDC)**

SAHANI M.(1), OZER P.(2), MOEYERSONS J.(3)

(1) *Faculté des Sciences Agronomiques, Université Catholique du Graben, BUTEMBO, CONGO (THE DEMOCRATIC REPUBLIC OF THE) ; (2) Département des Sciences et Gestion de l'Environnement, Université de Liège, ARLON, BELGIUM ; (3) Unité de Géomorphologie et Télédétection, Musée Royal de l'Afrique Centrale, TERVUREN, BELGIUM*

Butembo constitue un cas typique de zone urbaine en région tropicale humide rencontrant une explosion démographique exceptionnelle. La concentration spontanée des populations, due à l'exode incontrôlé sur un territoire assez restreint, a conduit à une urbanisation sans cesse croissante. L'imperméabilisation des vastes étendues de terres consécutive à une expansion spatiale rapide de la ville a généré des problèmes environnementaux qui affectent la structure urbaine. La ville est actuellement confrontée à des risques hydrologiques diversifiés : ravinements progressif et régressif, inondations, et remobilisation d'anciens glissements de terrain.

Après avoir réalisé la carte de la ville de Butembo, ce travail aboutit notamment à la production d'une carte des risques hydrologiques sur base d'approches combinant la télédétection et travaux de terrain.

Les résultats révèlent une expansion urbaine exceptionnelle. L'emprise urbaine de la ville de Butembo est passée de 2,39 km<sup>2</sup> en 1957 à 85,83 km<sup>2</sup> en 2008. Son accroissement est consécutif à l'augmentation de la population qui est passée de 9 653 à 581 449 habitants entre 1957 et 2008. Cette urbanisation a abouti à une nouvelle affectation du sol avec des conséquences sur le paysage urbain. Depuis 1957, le ravinement de fond de vallée ainsi que celui sur les versants sont toujours restés confinés à l'intérieur des extensions urbaines respectives. L'urbanisation précède le développement des ravins et ceux-ci sont confinés dans les zones où le coefficient d'écoulement est accentué par elle. Les inondations pourraient s'étendre sur tous les fonds plats de vallées en cas d'inaction. Quant aux 16 glissements de terrain actifs, ils se trouvent dans la phase de creep et 11 sont partiellement co-engendrés par l'asismicité. La pluie n'est pas à la base de l'accentuation des problèmes environnementaux qui perturbent la structure urbaine de Butembo. C'est bien l'urbanisation qui en est la principale cause.

\*\*\*\*\*

## **Poster presentations:**

### **Le « Voyage en Italie » de J.W.Goethe et le paysage de la géologie**

PANIZZA M., CORATZA P.

*Dipartimento di Scienze Chimiche e Geologiche - Universite di Modena e Reggio Emilia, MODENA, ITALY*

Le voyage que Goethe effectua en Italie il y a 225 ans est de nouveau parcouru en établissant une comparaison entre ses observations géographiques et surtout celles géologiques avec les résultats les plus modernes et les théories les plus avancées de la Science de la Terre.

De nombreux chercheurs adhérents à différents Instituts de recherches géologiques, repropose l'itinéraire des Alpes à la Sicile que le fameux écrivain allemand fit en fiacre, à pieds, ou en bateau.

La recherche est composée d'une série de fiches standard. Celles-ci contiennent des informations préliminaires de caractère strictement géographique, cartographique et iconographique (photos, dessins etc...); elles indiquent aussi le thème géologique affronté, en spécifiant l'importance scientifique. Le paragraphe original de Goethe est confronté avec la description géologique moderne en l'encadrant dans le contexte originale et en mettant en relief les caractéristiques scientifiques (théories, découvertes, roches, formes du relief, fossiles etc...). Ensuite les informations de type logistique, bibliographique et d'intérêt culturel (archéologique, historique, architecturales, artistiques etc...) y sont citées.

De cette façon il en résulte une description fascinante et savante: celle des paragraphes de Goethe et celle moderne. La description est faite de façon rigoureuse du point de vue scientifique, mais aussi, accessible à ceux qui ne sont pas experts en matière géologique. Le tout accompagné d'une riche iconographie tirée des dessins originaux du poète et d'autres artistes, mais aussi de sources modernes.

**Taferdoust: la merveille du méandre et du douar perché sur le "Calcaire-corniche" (Moyen Atlas plissé, Maroc)**

*ALDIGHERI B.(1), DI GREGORIO F.(2), CHARRIÈRE A.(3), OUARHACHE D.(4), EL HAMZAOUI O.(4), HESSANE M.A.(4)*

*(1) IDPA - CNR, MILAN, ITALY ; (2) Università di Cagliari, Dipartimento Scienze Chimiche e Geologiche, CAGLIARI, ITALY ; (3) Université Toulouse III, TOULOUSE, FRANCE ; (4) Université Sidi Mohamed Ben Abdellah, FSDM, FÈS, MOROCCO*

Le géosite de Taferdoust est situé dans la région de Fès-Boulemane-Skoura, dans la profonde et sinueuse vallée de l'Oued Guigou, loin des principales voies de communication.

L'emplacement de la petite forteresse de Taferdoust dans la partie axiale du synclinal de Skoura, ses singulières caractéristiques géomorphologiques, confèrent au lieu un intérêt scientifique doublé d'une valeur esthétique supplémentaire.

Dans le synclinal de Skoura se retrouvent les différentes formations du Dogger du Moyen Atlas central, qui constituent le comblement du sillon moyen-atlasique. Le douar est bâti sur la partie supérieure du "Calcaire corniche", dépôt de calcaires de plate-forme épi-récifale (F. de Recifa). Au-dessus, se développent des dépôts marno-calcaires et marneux correspondant aux fluctuations d'environnement marin de plate-forme (F. Bou Akrabène-Ich Timellaline).

Le douar est placé sur un éperon rocheux constituant le lobe d'un méandre de l'Oued Guigou, accessible uniquement par un sentier étroit. Pour les constructions on a utilisé les matériaux disponibles sur le site même : les pierres, les poutres en bois de cèdre, l'eau, la terre, la paille.

La vue au NE de Taferdoust donne une première approche en contre-plongée de ce douar pittoresque, entouré de falaises abruptes dues à l'érosion fluviale du "Calcaire corniche". En contrebas apparaît un pont étroit et en rive droite grimpe le seul chemin d'accès à ce site naturellement fortifié. Un second point de vue, au SW du douar, permet une vue plongeante sur le douar et le méandre encaissé qui l'entoure dans son contexte géologique.

Le géosite de Taferdoust ne représente pas un cas isolé. Plusieurs sites forts intéressants sont échelonnés dans la vallée reliant les villes de Skoura et de Boulemane, présentant ainsi un grand potentiel qui pourra être exploité avec des projets visant à un «géo-écotourisme scientifique» associé à un développement durable de cette région hors des circuits touristiques traditionnels.

\*\*\*\*\*

**Paysages, géosites et patrimoine géologique dans le Massif Central du Maroc comme nouvelles ressources pour le géotourisme**

*ALDIGHERI B.(1), DI GREGORIO F.(2), EL WARTITI M.(3), ZAHRAOUI M.(3), FADLI D.(3)*

*(1) IDPA - CNR, MILAN, ITALY ; (2) Università di Cagliari, Dipartimento Scienze Chimiche e Geologiche, CAGLIARI, ITALY ; (3) Université Mohammed V-Agdal, Laboratoire de géologie appliquée, RABAT, MOROCCO*

La présente étude propose l'inventaire des sites naturels géologiques et géomorphologiques dans le paysage extrêmement diversifié du Massif Central du Maroc. La région est caractérisée par des morphologies contrastées, en relation à la grande diversité lithologique des terrains paléozoïques (schistes-grès, quartzites, calcaires, granites, vulcanites, etc.), et liées aux longs et complexes processus géomorphologiques qui les ont édifiées au cours du temps. Ces terrains ont été déformés, métamorphosés et intrudés par des granites pendant l'orogénèse hercynienne et, par la suite, ont été sujets à pénélplanation à partir du Permo-Trias jusqu'au Plio-Quaternaire.

En plein massif central il y a le batholite granitique hercynien de Ment (279Ma), intrus dans des terrains ordoviciens et viséens. À côté il y a le paysage de la région d'Oulmès, constitué de grès, de pélites et de schistes d'âge cambro-ordovicien, déformés pendant l'orogénèse hercynienne engendrant des structures synschisteuses plurikilométriques déversées vers le SE, également intrudés par une masse granitique hercynien allongée selon la direction NNE, qui a développé une large auréole de métamorphisme.

Ce paysage géologique est caractérisé d'une large surface d'aplanissement d'où émergent des culminations modestes de piles de blocs des formes rudérales (tors) ou des rochers de grande intérêt scénographique dans le domaine granitique, et aussi nombreux appareils volcaniques (Plio-Quaternaire) en forme de cônes de scories rouges ou grises essentiellement, des coulées de laves, aussi avec typique fissuration prismatique, qui se sont épanchées directement sur les incisions latérales du socle.

Le travail vise à promouvoir des initiatives de développement durable dans une région à prédominance économique agro-pastorale.

## **Téledétection géomorphologique au nord-est de Jeddah (Arabie Saoudite)**

DAOUDI M.

*King Abdulaziz University, JEDDAH, SAUDI ARABIA*

La télédétection optique constitue un outil précieux et fondamental pour les études géomorphologiques des zones désertiques où l'accès sur le terrain est difficile. Le présent travail s'intéresse au traitement numérique des données satellitaires TM et ETM+ de Landsat qui couvrent une zone de Harrat, au nord-est de Jeddah, complété par d'autres documents cartographiques et appuyé par les observations de terrain. Par les différents traitements : composition colorée, classifications combinées utilisant la texture des images, divers indices, etc., et grâce à la vue synoptique que permet la télédétection, une carte morphologique a pu être dressée à partir de l'interprétation visuelle des images satellitaires. Afin de mettre en évidence les linéaments, la méthode des filtres directionnels a été appliquée.

Mots clefs : Télédétection, zones désertiques, géomorphologie, Harrat, linéaments.

\*\*\*\*\*

## **Le risque d'effondrement de carrières souterraines dans la région parisienne : quelle gestion pour demain ?**

ZITOUNI S., FORT M.

*Université Paris-Diderot, Sorbonne et UMR 8586 PRODIG CNRS, PARIS, FRANCE*

En région parisienne, plus de 3000 hectares de terrains sont affectés par le risque d'effondrement d'anciennes carrières souterraines. Ces carrières, de calcaire, craie, gypse, argile ou sable, ont été intensément exploitées à Paris et ses alentours pour répondre à des besoins industriels, économiques et architecturaux. La création de l'Inspection Générale des Carrières (IGC) dès 1777 a permis le recensement, la cartographie, la surveillance et la consolidation des cavités sous le domaine public.

Nous avons étudié la perception du risque lié à l'effondrement potentiel de ces carrières dans vingt communes du département des Hauts de Seine (ouest de Paris). Dans la majorité des cas, nous avons constaté que la connaissance par les responsables de l'emplacement et des caractéristiques des cavités était très lacunaire, données pourtant servant de base à toute politique efficace de prévention (information préventive, zonage réglementaire, gestion de crise). De plus, les disparités économiques entre communes ne facilitent pas la mise en œuvre de mesures de traitement de ces cavités, et ce au détriment des mairies pauvres, sauf pour des projets rentables.

Seule une implication réelle dans l'élaboration du dispositif de prévention de tous les acteurs, privilégiant échanges de compétences techniques et administratives, mettant de côté toute instrumentalisation politique ou tout conflit d'intérêt, peut permettre une évaluation fiable de ce risque. La consolidation des carrières souterraines n'est sans doute pas politiquement rentable sur le court terme, mais devient une nécessité pour un développement « durable » des zones urbanisées de Paris et de sa périphérie.

**Cartographie, pétrographie, géochimie et dynamisme de mise en place des coulées basaltiques cénozoïques: cas de la ville de Bukavu et ses environs. (Sud-kivu,RDCongo)**

BIRHENJIRA M.

*Université Officielle, BUKAVU, CONGO (THE DEMOCRATIC REPUBLIC OF THE)*

Situé dans le système du Rift Est Africain (EARST), la ville de Bukavu et ses environs présentent des affleurements des formations volcaniques d'âge miocène à actuel (Kampunzu et Al. 1986).

L'étude cartographique montre bien que les affleurements basaltiques ne sont pas plus distribués dans notre région et que la grande partie de ses formations présente un important recouvrement conduisant ainsi à une altération avancée.

Les affleurements sont soit massif soit en orgues.

Plusieurs phase des coulées on été remarquée : coulée supérieure plus saine reposant sur un paléosol d'environ 3 m d'épaisseur et la coulée inférieure étant la plus altérée expliquant ainsi l'activité volcanique non continue.

Les basaltes présentent des phénocristaux relevant d'un caractère basique (Olivine + Pyroxène (clino pyroxène) + Plagioclase) et un mesostase faite des Oxydes opaques. La majorité des nos échantillons montre que lors de la différenciation magmatique le processus s'est arrêtée au pole basique (teneur en SiO<sub>2</sub> comprise entre 45 et 54 %).

Les analyses géochimiques ont conduit a classer la grande partie des nos basaltes dans la série tholeitique et certaines dans la série calco-alcaline.

Le caractère serial permet aussi de confirmer que nous sommes dans la série transitionnelle située dans la zone d'extension caractérisée par le magmatisme anorogénique.

\*\*\*\*\*

**Erosion littorale et migrations forcées de réfugiés environnementaux. L'exemple de Cotonou, Bénin**

OZER P.(1), HOUNTONDI Y.C.(2), DE LONGUEVILLE F.(3)

*(1) Département des Sciences et Gestion de l'Environnement, Université de Liège, ARLON, BELGIUM ; (2)*

*Département Aménagement et Gestion des Ressources Naturelles, Université de Parakou, PARAKOU, BENIN ;*

*(3) Département de Géographie, Université de Namur, NAMUR, BELGIUM*

Situé dans le Golfe de Guinée, le littoral béninois est soumis –sur certains tronçons– à une érosion assez rapide ces dernières décennies. Cette érosion côtière est principalement due actuellement aux activités humaines parmi lesquelles les perturbations sédimentaires occasionnées par la construction de divers barrages dont celui de Nangbéto sur le fleuve Mono ; le blocage du transit littoral par les ouvrages portuaires de Cotonou ; les carrières de sable exploitées à même la plage ; et la diminution d'apports sédimentaires provenant de l'ouest suite à divers travaux de protection des côtes.

En utilisant la fonction multi dates disponible dans Google Earth, cet article estime la superficie érodée à Cotonou entre 2002 et 2011 à l'est de l'exutoire du Lac Nokoué. En outre, il évalue le nombre de maisons détruites ainsi que le nombre de personnes contraintes à une migration forcée. Les figures sont importantes puisque de l'ordre de cent mètres de zone côtière ont totalement disparu au cours des dix dernières années sur un tronçon de près de six kilomètres de long en pleine ville ou en proche périphérie.

Cette analyse montre qu'actuellement les dommageables modifications géomorphologiques résultent essentiellement de l'addition non envisagée d'activités humaines couplée à l'absence de gouvernance. Par ailleurs, nous sommes en droit de nous interroger sur les risques d'érosion côtière dans les décennies à venir avec l'amplification annoncée de l'augmentation du niveau des océans due au réchauffement climatique.

## **Evaluation des processus géomorphologiques en région montagneuse: utilisation des ondelettes pour la modélisation du terrain à de multiples échelles**

NAPARUS M.(1), GOLAY F.(1), PATRU-STUPARIU I.(2)

(1) EPFL-ENAC-LASIG, LAUSANNE, SWITZERLAND ; (2) University of Bucharest, Faculty of Geography, Transdisciplinary Research Center Landscape - Territory - Information Systems, BUCHAREST, ROMANIA

La précision des modèles numériques de terrain (MNT) a beaucoup augmenté ces dernières années. Dans le domaine de la géomorphologie, ces modèles permettent ainsi de mieux prédire les risques et les dangers naturels, ainsi que la vulnérabilité du paysage. Cette augmentation de la précision a permis de réduire l'incertitude sur les terrains complexes. Les modèles numériques de terrain (MNT) à haute résolution (1m) nous donnent l'accès aux structures géomorphologiques les plus détaillées. Ces petites structures constituent la base des grandes structures géomorphologiques et sont souvent leur moteur au niveau des phénomènes multi-échelle.

Cette étude s'inscrit dans un projet de collaboration entre la Suisse et la Roumanie. Elle s'appuie sur l'analyse à plusieurs échelles d'un MNT obtenu par un levé LiDAR dans une zone cible, dans les basses Carpates, dans le sud-ouest de Roumanie. La complexité du terrain requiert l'emploi de techniques adaptées pour la filtration des données et pour l'analyse des processus géomorphologiques.

On a choisi de représenter le terrain avec la technique des ondelettes, qui provient de l'analyse d'images. L'utilisation des ondelettes en géomorphologie aide à comprendre les phénomènes particuliers qui apparaissent dans les sous-espaces spécifiques du continuum d'échelles. D'une part, nous utilisons la procédure de filtrage progressif des coefficients d'ondelettes pour représenter la hiérarchie complexe d'éléments topographiques caractéristiques des processus géomorphologiques considérés. On obtient un modèle détaillé caractérisant la vulnérabilité du paysage avec le MNT à plusieurs échelles. Le modèle contient des propriétés réunies de la zone d'étude (analyse de surface topographique, contraintes, limites et facteurs d'agression du paysage) et a pour ambition de servir de base méthodologique pour une future évaluation du potentiel écologique du paysage et de la vulnérabilité de la région entière des Carpates roumaines.

\*\*\*\*\*

## **Contexte d'évolution des terrasses limoneuses quaternaires du bassin inférieur de l'oued Moulouya comparés aux étagements quaternaires aperçus sur ses affluents (Maroc oriental)**

BOUMEAZA T.

*Universit\_ Hassan II mohammedia -Casablanca, MOHAMMEDIA, MOROCCO*

Dans son bassin inférieur, l'oued Moulouya est drainé par des affluents issus des montagnes proches. Ces affluents, encaissés dans des substrats géologiques, sont restés perchés, avec des niveaux étagés traduisant les étapes quaternaires bien préservés qu'on trouve spécialement à l'amont sur la rive gauche descendant des Kbdana, et sur la rive droite, sur l'oued Cherrâa. Leur évolution est liée à une tectonique locale comparée à l'oued Moulouya qui a subi une influence importante pour la mise en place des terrasses limoneuses qui sont en liaison directe avec les fluctuations du niveau de la mer depuis la dernière période glaciaire il y a 18 000 ans. Au cours de la dernière glaciation, quand le niveau marin était beaucoup plus bas qu'aujourd'hui le lit de la Moulouya était à -57 m, 3.5 km en amont de son embouchure actuelle. La remontée du niveau de la mer, qui a atteint son niveau actuel vers 7 ka cal BP, a fait apparaître une ria de 19 km de longueur qui a ensuite été colmatée par les sédiments fluviaux, déterminant la formation d'une épaisse terrasse limoneuse. La surface de cette dernière, que l'on suit sur plus de 45 km, surmonte de 22 m le lit actuel de la rivière à 20 km de l'embouchure. Cette terrasse de remblaiement est constituée de limons en couches horizontales bien stratifiées. Des terrasses d'érosion y ont été dégagées lors de l'encaissement de la Moulouya depuis 2000 ans. La datation <sup>14</sup>C des limons permet de comprendre comment cette terrasse s'est déposée. Après la remontée du niveau de la mer, le comblement de la ria et l'avancée concomitante de l'embouchure ont accumulé progressivement les limons. L'arrivée d'une charge limoneuse importante autour de 7 ka cal BP est probablement d'origine climatique. Après 3.5 ka cal BP, l'intense érosion des sols déclenchée par la déforestation. Depuis 1.9 ka cal BP, l'encaissement final de la Moulouya dans la terrasse résulte probablement d'une diminution des apports limoneux.

**Approche méthodologique de cartographie des zones à risque potentiel d'érosion des sols du bassin versant du Srou (Moyen Atlas, Maroc)**

EL BOUQDAOUI K.(1), EZZINE H.(2), ZAHRAOUI M.(3), LOUKILI M.(4), OZER A.(5)

(1) Hassan II Agronomic and Veterinary Medicine Institute, RABAT, MOROCCO ; (2) Royal Centre for Remote Sensing (CRTS), RABAT, MOROCCO ; (3) University Mohammed V, Faculty of Science, RABAT, MOROCCO ; (4) National School of Agriculture, MEKNES, MOROCCO ; (5) University of Liège, Faculty of Science, LIEGE, BELGIUM

La modélisation de l'érosion appuyée par l'analyse et l'observation sur le terrain s'avère nécessaire pour l'évaluation rapide et générale de l'érosion et la délimitation des zones sensibles à l'érosion des sols dans une région.

La première partie de la présente étude se base sur le modèle « Land Erodibility Assessment Methodology, (LEAM) » développé par Manrique (1988). Le modèle intègre l'érodibilité des sols, l'inclinaison des versants et l'érosivité climatique pour l'évaluation des zones à risque potentiel d'érosion. Le modèle ne tient pas compte du couvert végétal. Ce dernier joue cependant un rôle considérable dans l'évaluation du risque d'érosion, afin d'inclure ce facteur, une carte d'occupation des sols élaborée de l'imagerie satellitaire, a été utilisée pour améliorer le processus de la méthodologie.

La deuxième partie, se base sur l'étude d'un sous-bassin versant du Srou, celui du Chbouka, qui a été choisi comme secteur représentatif de l'ensemble du bassin du Srou. Il s'agit d'une approche méthodologique basée essentiellement sur le modelé du relief qui constitue le principal facteur de la structuration du paysage et des types de sols correspondants, ce qui a permis de dégager les grandes unités morpho-pédologiques du bassin du Chbouka et leur caractérisation, qui ont servi de base pour l'élaboration de la carte de susceptibilité à l'érosion des sols du bassin du Chbouka, mettant en évidence les zones instables, nécessitant une intervention prioritaire.

La confrontation de cette carte avec celle obtenue par le modèle LEAM confirme les résultats du modèle et appuie son efficacité.

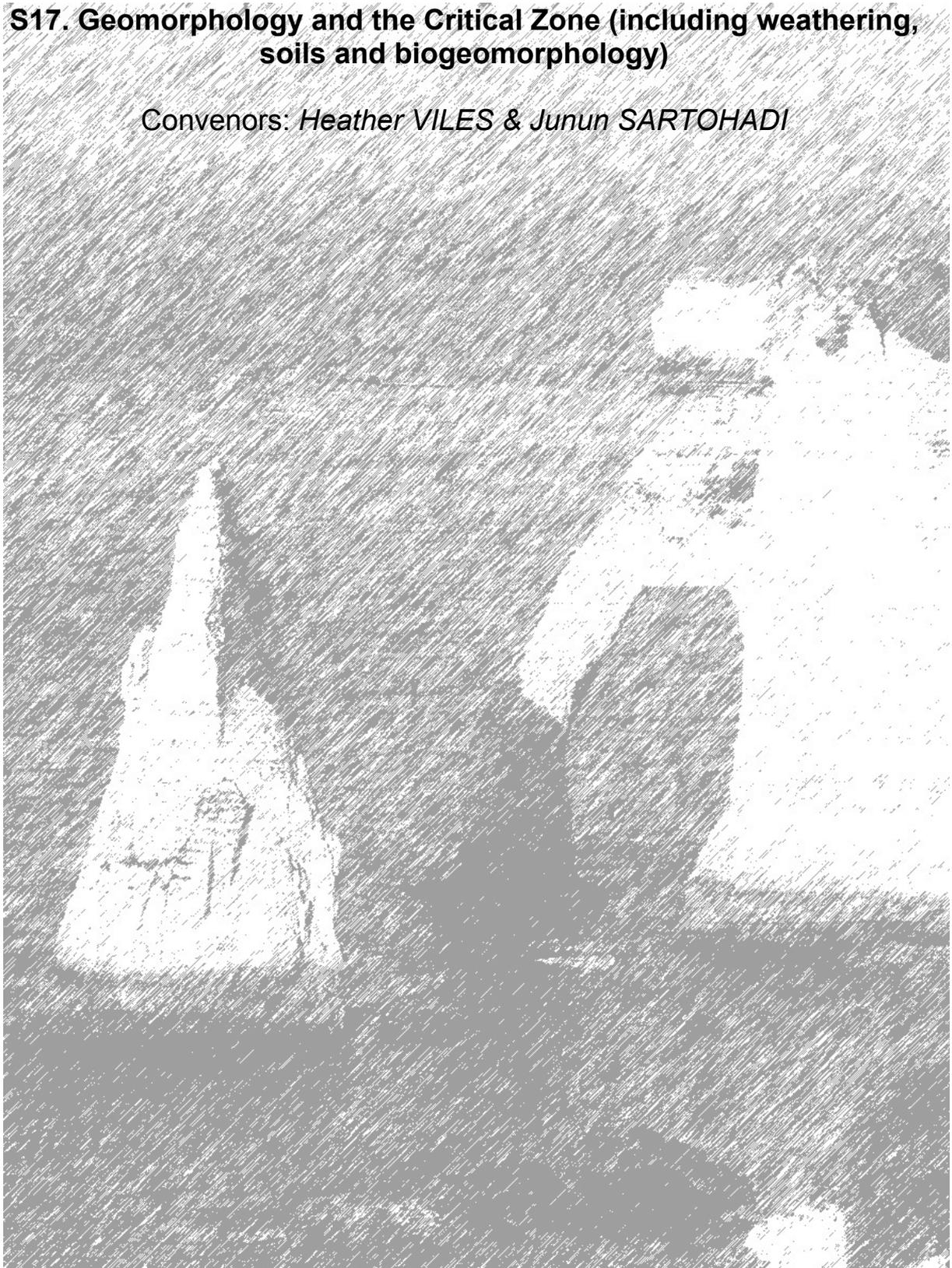
Le système d'information géographique (SIG) a servi pour l'analyse, la combinaison, la modélisation et la cartographie des différentes couches d'informations.

Mots clés : Bassin versant, Srou, Chbouka, cartographie, érosion, SIG.

\*\*\*\*\*

**S17. Geomorphology and the Critical Zone (including weathering, soils and biogeomorphology)**

Convenors: *Heather VILES & Junun SARTOHADI*





## **Oral presentations:**

### **Landscape evolution models and the critical zone**

KIRKBY M.

*University of Leeds, LEEDS, UNITED KINGDOM*

Geomorphological models for landscape evolution generally subsume the influences of weather and climate within general expressions of response to topographic drivers, ignoring both our detailed process knowledge for particular environments and the need to acknowledge the frequency distribution of event sizes. Although it is still at a broad brush level, it is now possible to incorporate processes more directly, so that rates and styles of sediment transport respond directly to average climate and may be integrated explicitly over the underlying event distributions.

One of the key processes that should be made explicit in models is weathering, which is also linked to climatic drivers and acts, through the critical zone, to modify landscape and regolith evolution. Chemical and physical evolution of the critical zone affect, inter alia, soil hydrology and grain sizes, and so interact dynamically with hillslope sediment transport, modifying landscape form. Under past and prospective climate change, these interactive relationships themselves evolve, creating landscapes that are, in many cases, far from even a quasi-equilibrium with current conditions. Aspects of these inter-relationships are explored through numerical models.

\*\*\*\*\*

### **Altitudinal variations in the size and flux of eroded sediment revealed by cosmogenic nuclides and detrital thermochronometry**

LUKENS C.(1), RIEBE C.(1), SKLAR L.(2), SHUSTER D.(3)

*(1) University of Wyoming, LARAMIE, UNITED STATES ; (2) San Francisco State University, SAN FRANCISCO, UNITED STATES ; (3) University of California, BERKELEY, UNITED STATES*

Quantifying the size and flux of sediment in landscapes is central to understanding the interplay of climate and tectonics in erosion and weathering. Although sediment flux is widely quantified using cosmogenic nuclides, there is no complementary method for measuring how the size of eroded sediment varies across landscapes. Here we present a new technique that couples cosmogenic nuclides and apatite (U-Th)/He (AHe) dating in stream sediment to simultaneously solve for how the size and flux of sediment vary with altitude. As a proof of concept we present data from Inyo Creek, which drains the steep eastern range front of the Sierra Nevada, California, USA. AHe ages from detrital apatite are markedly higher, on average, in gravel than in sand. This shows that gravel originates from higher elevations than sand, and thus that particle sizes in eroded sediment increase with altitude in the catchment. We find that  $^{10}\text{Be}$  concentrations in gravel are roughly half those measured in sand, despite higher  $^{10}\text{Be}$  production rates implied by the higher gravel source elevations. This suggests that erosion is faster at higher elevations. Together, our  $^{10}\text{Be}$  and AHe data are consistent with an exponential increase in erosion rates with hillslope gradients, which increase with elevation in the catchment. Hence erosion at Inyo Creek is broadly consistent with threshold slope behavior. In addition, our analysis calls for caution in interpreting spatially averaged erosion rates from cosmogenic nuclides measured from a single grain size; in Inyo Creek, the  $^{10}\text{Be}$  concentration in sand alone under-predicts the catchment-averaged erosion rate that we infer from the full suite of data by nearly a factor of four. Our results show that measuring  $^{10}\text{Be}$  and AHe ages in multiple sizes of stream sediment can resolve altitudinal variations in both the size and flux of sediment eroded from slopes and thus may permit considerable advances in understanding of geomorphic processes and landscape evolution.

### **Impact of biological soil crusts on the infiltration / runoff balance along a rainfall gradient in south-eastern Tunisia**

GUIDEZ S.

*Université Paris 7 (LGP de Meudon) / Université de Bologne (IGRG de Ravenna), MONTPELLIER, FRANCE*

Mediterranean Africa is increasingly vulnerable to climate change. We focus on the desertification risk in a rural arid environment due to a decline of traditional agriculture. In the mountains, this translates into a lack of maintenance in some structures and lands, it results in increased water erosion. In the plain, intensive irrigation and overgrazing caused some soil degradation and sand encroachments reflecting a more intense wind erosion. We set out to determine the hydrological impact of the presence of Biological Soil Crusts (BSC). They have an important role by the existence of control strategies against land erosion and of compensatory logics against climatic aridity.

The BSC play a major ecological role on the hydrology because they have a great ability to take advantage of small rainfall events. They change the infiltration of water into the soil and influence the production of surface runoff, therefore the amount of water erosion.

We studied the topography, hydrography and geology but also of the structural and dynamical geomorphology and pedology of this region. Then, we carried out measurements of surface infiltration/runoff, analyzed humidity contents in soil and studied the BSC rates and properties.

We noticed that there was less runoff for the bare soil plots than for the BSC. The hydrological balance may not be accounted for by the rates, the roughness and thickness of BSC but by their typology. The high rates were correlated with mixed crusts (cyanobacteria-lichens-bryophytes), the average rates with biological crusts dominated by bryophytes or by lichens and the low rates with the crusts dominated by cyanobacteria. The evolution of infiltration may also be accounted for by BSC: the high and constant infiltration is represented by cyanobacteria-BSC, the bryophytes-BSC have linear and slow infiltrations, the lichen-BSC know infiltrations which decrease by stages, the mixed-BSC correspond to the infiltration decreasing immediately and sharply.

\*\*\*\*\*

### **Non-lateritic red soils of the Brazilian drylands: pedogenic processes and landscape evolution**

BETARD F.(1), PEULVAST J.P.(2)

*(1) Univ Paris-Diderot, PARIS, FRANCE ; (2) Univ Paris-Sorbonne, PARIS, FRANCE*

Non-lateritic red soils cover vast areas of the semiarid region of Northeast Brazil, or "sertão", whereas laterites remain currently scarce in the landscape and are confined to ancient summit surfaces and/or to more humid areas along the coast. The land cover of the Brazilian drylands is dominated by dry deciduous woodland, or "caatinga", in areas with mean annual rainfall and temperatures of 400-800 mm/y and 24-26 °C, respectively. According to morphological descriptions and analytical data, the red soils of semiarid Brazil mainly classify as Luvisols (chromic) in the WRB soil correlation system, and Alfisols in the USDA Soil Taxonomy. In all cases, their formation is strongly controlled by clay illuviation, allowing the diagnosis of a Bt (argic) horizon. Contrary to lateritic soils extending over large tracts of tropical South America, the red soils of NE Brazil are high-activity-clay soils with high cation exchange capacity and moderate to high base saturation ratios. The pedogenic interpretation for their development is that of a fersiallitic pedogenesis, which involves high contents of free iron and the prevalence of 2:1 clays in the soil mineral assemblage. In the regional setting, the red fersiallitic soils typically formed above shallow, grus-type weathering mantles developed from crystalline parent rocks, under pedoclimatic conditions of low, but irregular, deep drainage. In many ways, they are very similar to the red, decalcified fersiallitic soils formed on the crystalline shield of dryland peninsular India, but are very different from tropical ferruginous soils of semiarid West Africa developed from lateritic paleoweathering mantles. As in the Indian setting, persistent epirogenic uplift of the Brazilian margin during the Neogene steered the landscape towards the stripping of most of the paleoweathering mantle, favoring the development of a primary fersiallitic pedogenesis under the newly established semi-arid conditions.

**Sandization in Southern Brazil Campos (Ibicuí Basin, Rio Grande do Sul State)**

VERDUM R.(1), CORBONNOIS J.(2), MESSNER F.(2), LAURENT F.(2), SOARES V.G.(1)

(1) Universidade Federal do Rio Grande do Sul, PORTO ALEGRE, BRAZIL ; (2) Université du Maine, LE MANS, FRANCE

In Southern Brazil, erosion is now damaging large pieces of land on sandy soils that are overexploited by agricultural activities. These erosion processes are called "sandization" and have been studied by Brazilian researchers for 15 years. In the Ibicuí watershed, sandization takes place on mountain sides and in small valleys dug in sandstone, on the top of which lays loose sand, because of herbaceous vegetation. This process is worsened with agricultural intensification. Eventually, it can lead to a landscapes shift, all the more as the remedy usually used on the eroded lands is eucalyptus plantations. The analysis of erosion characteristics, based on Brazilian research results, is lead with satellites images and on the field. It allows to identify and to locate the different forms of sandization and to explain their formation, especially in the recent years. The research will also focus on the way the local populations take into account the erosion process, in an economic change context, related to a new organization of farming activities.

\*\*\*\*\*

**Cenozoic evolution of the critical zone on Kangaroo Island, South Australia: a framework of landscape geochemical and biogeochemical evolution and the effect of contemporary anthropogenic landscape change**

STOATE K.(1), HILL S.M.(2), BAROVICH K.(2)

(1) The University of Adelaide , ADELAIDE, SOUTH AUSTRALIA , AUSTRALIA ; (2) The University of Adelaide, ADELAIDE, SOUTH AUSTRALIA, AUSTRALIA

The study considers the critical zone within the context of landscape geochemistry and biogeochemistry. Kangaroo Island is a 4400 km<sup>2</sup> area off the south coast of Australia, where chemical surveys of bedrock, ferruginous regolith, and vegetation (*Eucalyptus* and *Xanthorrhoea* grasses) have been conducted. Results from these surveys show the interaction hosted within the critical zone between bedrock, weathered substrate and plants. Of particular interest are the strong expressions of gold and base metal mineralisation associated with the major shear zone which extends across the central part of the island. This has major implications for utilising critical zone processes for mineral exploration within highly weathered landscapes, in particular the chemical expression of buried bedrock lithologies in ferruginous regolith geochemistry and plant biogeochemistry.

The ferruginous regolith has been evolving in the area since the Permian, and remnants of these materials are mostly expressed within a 'lateritic plateau' across most of the island. Since the onset of the Neogene ferruginisation has continued but depositional and weathering processes on the island have been dominated by carbonates (i.e. limestones and calcretes). European settlement only occurred in the late 19<sup>th</sup> century, but large-scale vegetation clearance has only been significant since the late 1940's. This has had a major impact on hydrological processes within the critical zone and a major shift in the landscape geochemical processes has occurred. This includes increased catchment salinities and associated trace element mobility, mostly triggered by the absence of deep-rooted vegetation and erosional incision into saprolitic weathering profiles underling the ferruginous regolith.

The discrete nature of systems on Kangaroo Island provides an ideal area for a case study into the landscape geochemical and biogeochemical evolution of the critical zone and how this is influenced by anthropogenic activity.

## **Analysis of Relief-Rock-Soil Relationship in the Contact Atlantic Plateau - Peripheral Depression of Sao Paulo**

*NADAL JUNQUEIRA VILLELA F.(1), ROSS J.(2), MANFREDINI S.(2)*

*(1) Universidade Federal de Sao Carlos, SAO PAULO, BRAZIL ; (2) University of Sao Paulo, SAO PAULO, BRAZIL*

This work aims to establish the integrated approach to landscape factors according to the landforms, bedrock and soils. A geomorphopedological compartmenting is made in a detailed scale of an area between two major geomorphologic units in southeastern Brazil, one being the Atlantic Plateau, crystalline shield of rough landforms, and the other the Peripheral Depression of Sao Paulo, a transition unit from Plateau to the Sedimentary Basin of Parana, whose smooth landforms are generally sculpted over sedimentary terrains. The transitions of these two macro-compartment domains create contrasts of relief forms according to the basement structure and soils originating from weathering and erosion. Smooth landforms supported by sedimentary lithotypes alternate with small hills of more dissected slopes sustained by igneous or metamorphic rocks, and Red Oxisols located in areas of flat summits change to Inceptisols in areas of smooth hills. This is a common situation at the research area, a small hydrographic basin and its rural surroundings in Sorocaba, a county undergoing remarkable urban expansion. To reach an understanding of the above mentioned factors relationship, aiming at a diagnosis of the physical environment under research, it was necessary to carry out geological, geomorphological and pedological surveys in order to search for the relief-rock-soil relationship to the area considered. The work resulted in geomorphological and geomorphopedological compartments and the better understanding of some functional characteristics of the physical environment, such as the control of landforms and drainage system by lithostructure, the combination of exogenous processes, slope morphology and lithologic variations in forming soils and the possibility of relief being degraded by geochemical erosion.

\*\*\*\*\*

## **Relation of soil depth and slope degree in Loano District, Central Java Province, Indonesia**

*PULUNGAN N.(1), SARTOHADI J.(2), STOETTER H.(1)*

*(1) Innsbruck University, INNSBRUCK, AUSTRIA ; (2) Gadjah Mada University, YOGYAKARTA, INDONESIA*

Loano District is an area in Central Java Province having hilly up to mountainous topographic. Generally, this area has steep slopes up to very steep slopes which are 20° - 40°. Topographic condition becomes the controlling factor in this area. Loano District is characterized by structural and denudation processes. As the result, mass movement events dominate this area. Material resulted by mass movement occurrences produces colluviums material to the lower part. The colluviums become parent materials for further soil development in this area. Therefore, this process mostly leads to the residual soil to be buried by recent materials.

Method used in this research is field survey. The sampling method applied is stratified random sampling. Slope classes are used as strata for defining sampling area. The areas which have different slope classes are sampled. Deep of soil in each different slope class is measured. The numbers of samples in each slope class are depended on relief variation and width area.

The result of this research is about a relation of slope degree and soil depth in Loano District. This research indicates that there is no correlation between slope classes and soil depth in the research area. Theoretically, the steeper slope is the thinner depth of soil as well the more flat slope is the thicker depth of soil. In fact, this theory did not work for Loano District. Colluviums material due to denudated processes has a crucial role to develop soil in this area. Combination materials in colluviums cause various development of soil. They determine the speed of soil development. As a result, in a buried soil area, the depth of soil does not be depended on the degree of slope.

Key words: soil development, soil depth, slope degree, buried soil.

**The layered Critical Zone (CZ)' established geomorphic concepts but a novelty for Critical Zone Observatory (CZO) Science?**

VOELKEL J.

*Technische Universität München, MUENCHEN, GERMANY*

By literature and common definitions the Critical Zone (CZ) is described as monolayered. At best a line is given on so-called moved regolith. In fact the CZ is often characterized by stratified and multilayered slope deposits with thicknesses exceeding 1 m. These stratified slope sediments play a significant role in the nature of the physical and chemical properties as well as on soil forming processes in the CZ. Examples are given for CZ sediment sourced chemical elements and common clay minerals, and the significance of slope sediments as both barriers and pathways for interflow that moves through the stratified sediments. Examples are also taken from latitudinally different geographic areas, as well as from varying altitudes. The stratified CZ is often datable by numeric age techniques showing up how sediment features contradict weathering effects and meaning e.g. for soil genesis. In the mid latitudes, geomorphic and sedimentologic evidence supports a periglacial origin, involving solifluction, for the origin of these CZ slope deposits.

Literature: Völkel, J., Huber, J. & Leopold, M. (2011): Significance of slope sediments layering on physical characteristics and interflow within the Critical Zone... - Applied Geochemistry 26: 143-145.

\*\*\*\*\*

**$\delta^{18}\text{O}$  isotopic signature of glacier meltwaters in the tree rings: basis for long-term high-resolution hydrological reconstructions in glacial environments**

LEONELLI G., PELFINI M.

*Università di Milano, MILANO, ITALY*

Glacial environments on the Alps are experiencing a generalized shrinkage phase mainly driven by the thermal perturbation related to global warming. As a result, after a higher runoff from snow and ice melting in a first phase, a large runoff reduction is expected in the mid to long term. Changes in glaciological features and in meteorological conditions influence the hydrological regimes of the glacial environments (and in particular of the glacier forefields), inducing also alterations in the water stable isotopes distribution in the soil. Glacier streams and hydrological conditions at the glacier terminus are characterized by a great variability concerning melt water runoff and the directions taken by the glacier streams along the glacier forefields.

The  $^{18}\text{O}/^{16}\text{O}$  ratio in the tree rings is mainly driven by the source water isotopic signature and isotope fractionation processes at the leaf level related to stomatal conductance and the amount of depleted soil water replenishing the transpired water. The analysis of  $\delta^{18}\text{O}$  and  $\delta^{13}\text{C}$  in the tree rings from glacial environments from the Miage Glacier and the Forni Glacier forefields has demonstrated the potential of using tree rings for the high-resolution reconstruction of hydrological changes occurred over long time periods. In fact trees growing in proglacial areas (mainly fed by glacier melt waters that flow down valley from the glacier) resulted more depleted in  $\delta^{18}\text{O}$ , whereas trees growing on the slopes or on the moraines were more enriched, thus allowing long tree-ring chronologies to be potentially used as a proxy of past and ongoing climatically-driven hydrological changes in glacial environments. The opportunity of reconstructing past long-term changes in  $\delta^{18}\text{O}$  signature in glacier melt waters occurred over time in the Alpine glacial environment is a critical issue both for understanding glacier responses to climate warming and for assessing water availability in the Alpine environment.

### **Effects of bedrock nutrient density on life and topography in granitic landscapes**

HAHM W., RIEBE C., ARAKI S.

*Dept. Geology and Geophysics, University of Wyoming, LARAMIE, UNITED STATES*

In hilly landscapes, the competition between soil erosion and bedrock weathering determines whether rock retains a mantle of soil or is stripped bare. When rock is bare, it tends to break down more slowly, retarding nutrient supply to overlying ecosystems and impeding pedogenesis. Hence, the presence/absence of soil may often be central to the interplay of erosion, weathering and vegetation in Earth surface dynamics and biogeochemical cycling. Yet the factors that regulate whether soil is present are poorly understood, especially in granitoids, which are often dichotomous in their soil cover. Here we present evidence of a feedback in which the presence of soil is regulated by bedrock nutrient concentrations through their influence on vegetation. Across our field area, in unglaciated portions of the Sierra Nevada, California, the concentrations of essential plant nutrients such as phosphorus (P) vary markedly in bedrock, often changing abruptly at pluton contacts that coincide with ecotones between forest and bare rock. Moreover, we find that vegetative cover is strongly correlated with bedrock [P] across climatically and topographically diverse sites within the batholith. The proposed biologically-mediated coupling between lithology and soil cover may have key implications for landscape evolution; our measurements of cosmogenic nuclides reveal that erosion is slower when soil is absent, implying that areas with low nutrient concentrations should tend to rise in relief relative to their more heavily vegetated, soil-mantled counterparts. The paradigm for nutrient evolution in physically stable soils is that bedrock-derived P becomes depleted with time to the point that it is limiting to the overlying ecosystem. Our analysis from the Sierra Nevada presents a counterexample in which ecosystems developed on nutrient-poor granitoids may experience P limitation under conditions of dynamic equilibrium and during incipient stages of weathering and pedogenesis.

\*\*\*\*\*

### **Variability of SOC stabilization with the mineral phase along a slope transect**

DOETTERL S.(1), OPFERGELT S.(2), CORNELIS J.T.(2), VAN OOST K.(1), SIX J.(3)

*(1) UCL/ELI-C/TECLIM, LOUVAIN-LA-NEUVE, BELGIUM ; (2) UCL/Eli-E, LOUVAIN-LA-NEUVE, BELGIUM ; (3) UC Davis, Plant Sciences, DAVIS, CA, UNITED STATES*

Research in the Belgian Loam Belt has shown that, driven by soil redistribution, the quality and quantity of soil organic carbon (SOC) in sloping cropland differs with topographic position. These differences were most visible in the subsoil, while the size and composition of topsoil SOC pools were similar along the hillslope. Here, we present an analysis that aims to clarify the chemical and mineralogical components involved in stabilizing SOC at various depths and slope positions. For this we analyzed soil samples from different soil depths along a slope transect applying a sequential extraction scheme of the reactive soil phase using pyrophosphate, oxalate and dithionite-citrate-bicarbonate and a semi-quantitative and qualitative analysis of the clay mineralogy.

The results show that pyrophosphate extractable soil compartments, especially Manganese are responsible for stabilizing SOC in the bulk soil and with non-aggregated silt and clay fractions. Pyrophosphate extractable Iron and Aluminum components are largely abundant in water-stable soil aggregates, but show no strong correlation to SOC, indicating importance for aggregate stability but not for SOC retention. Oxalate extractable amorphous and poorly crystalline minerals are a temporally limited but important compartment to stabilize SOC at the depositional site, especially for the more recalcitrant SOC fractions, but are of minor importance for SOC stabilization at other slope positions. Non-expandable clay minerals experience a relative enrichment at the depositional site and expandable clay minerals at the eroding site and these changes in clay mineralogy along the slope are partly responsible for the abundance of silt or clay associated SOC. Current rates of soil erosion and the associated rejuvenation of soils at eroding sites and burial of soil at depositional sites provide a temporally limited local net sink for atmospheric C.

**Contribution of tree uprooting to the evolution of hillslopes and soils - on the examples from the Sudetes Mts., SW Poland**

PAWLIK L.(1), MIGON P.(1), KACPRZAK A.(2)

(1) University of Wrocław, WROCLAW, POLAND ; (2) Jagiellonian University, CRACOW, POLAND

Forest dynamics is an important factor of geomorphic change within the forested hillslope domain. Self-organization of forest community is controlled by various kinds of disturbance (e.g. fire, wind) which occur during the lifespan of trees. These disturbances initiate structural changes in the forest which in turn activate and/or alter the course of surface processes and have direct impact on forest soils. Tree uprooting is a major biotic factor influencing geomorphological and pedological processes in the forest and we aimed to recognize its geomorphic role in the forested environment of the Sudetes (SW Poland).

Our results indicate that tree uprooting is widespread and causes an increase in surface roughness of the forest floor, giving origin to specific associations of microforms called pit-and-mound microtopography. It also results in uneven redistribution of soil material and alters the stratigraphy of inherited Pleistocene slope materials. There are long lasting consequences for sediment transport, water retention, accumulation of organic matter and plant succession. These processes control soil evolution, which in turn makes the investigation of soil profiles a useful tool to infer the origin and age of pits and mounds within slopes.

Even if distinct pit-and-mound forms are no longer observed, we propose that tree uprooting may have been the process initiating further re-shaping of slope morphology, ultimately leading to step-like hillslope profiles (teracettes) and the appearance of stone blankets on slopes, usually attributed to periglacial processes in the Pleistocene.

Our studies show that tree uprooting occurs at two scales. One is catastrophic, connected with single events affecting large sections of hillslopes, while the other one is connected with fall of individual trees. The latter, although less spectacular, may also lead to significant transformations of hillslopes and slope materials, including soils, over the time scale of the entire Holocene.

\*\*\*\*\*

**What do organisms do on rocks? A multi-methods approach to evaluating biodeterioration and bioprotection in the critical zone**

COOMBES M.(1), NAYLOR L.(2), VILES H.(1), GOWELL M.(1)

(1) University of Oxford, OXFORD, UNITED KINGDOM ; (2) University of Exeter, PENRYN (CORNWALL), UNITED KINGDOM

There is increasing evidence that some organisms have protective functions with respect to rock decay as well as contributing to bioweathering and bioerosion. The challenge, therefore, is evaluating the relative importance of these conflicting roles so that a balanced judgement can be made about their overall geomorphic function. This is particularly true when making management decisions (e.g. whether to remove an organism to minimise decay, or encourage further colonisation to facilitate bioprotection).

We describe an approach in which multiple methods are used in a coordinated way in the assessment of the impact of macroorganisms on rock decay in the coastal zone. Field monitoring, laboratory simulation and microscopy are used to evaluate the influence of seaweeds and barnacles on: weathering conditions (i.e. microclimates); the efficiency of particular deterioration processes (i.e. salt weathering); changes in material properties (i.e. hardness) and; the direct breakdown of colonised materials (e.g. decay artefacts and loss of mass).

We conclude that the relative importance of the studied organisms for bioprotection and biodeterioration is heavily contingent on rock type and local environmental conditions, consequently varying in time and space. This makes generalisations about their bioprotective or biodeteriorative roles especially difficult. However, our observations indicate that marine epibiota can have a significant role in reducing the efficiency of mechanical decay processes. From the perspective of environmental management, if particular decay mechanisms or modes of breakdown are known to be paramount (e.g. loss of material strength for a coastal structure, or ingress and egress of moisture for a historic stone wall), methods of evaluating the role of organisms in decay and protection can be more effectively targeted (e.g. direct measurement of rock strength or stone moisture regimes, respectively).

**Landscape self-organization of tidal floodplains by bio-geomorphic feedbacks between vegetation growth, flow hydrodynamics and sedimentation-erosion**

TEMMERMAN S.(1), VANDENBRUWAENE W.(1), DIJKSTRA J.(2), VAN DUREN L.(2), DE VRIES M.(2), VAN DE KOPPEL J.(3), HERMAN P.(3), BOUMA T.(3)

(1) University of Antwerp, ANTWERP, BELGIUM ; (2) Deltares, DELFT, NETHERLANDS ; (3) Royal Netherlands Institute for Sea Research, YERSEKE, NETHERLANDS

Fluvial and tidal floodplains form and evolve as a consequence of bio-geomorphological interactions between plant colonization, hydrodynamics and sediment transport. We study to what extent these interactions lead to the spatial self-organization of both geomorphic and vegetation patterns that are observed in a tidal floodplain. Intertidal flats may be colonized by patches of plants with contrasting morphologies, such as flexible sea grass species and stiff salt marsh species, and this is expected to have different outcomes on the landscape self-organization. Firstly, we show results of field and flume experiments, showing so-called scale-dependent interactions: on a small spatial scale within patches of stiff vegetation, flow velocities are reduced, which stimulates local sedimentation and has a positive feedback to plant growth; on a larger scale next to vegetation patches, the flow is accelerated around the patches, which can there initiate channel erosion and have a negative feedback effect on plant growth. The strength of these scale-dependent feedbacks is much weaker for flexible vegetations, since they can bend with the flow and in such a way exert less friction on the flow. Secondly, these effects are up-scaled using a coupled plant growth, hydrodynamic and morphodynamic model, showing that the patch-scale feedbacks lead to landscape-scale self-organization. For stiff salt marsh vegetation, plant colonization of an initially bare flat floodplain results in vegetated elevated platforms dissected by a dense network of non-vegetated channels. For flexible seagrass vegetation, the model shows a more homogeneous development of vegetation while landform changes are minor. The simulated landscape patterns qualitatively agree with observations from salt marsh and seagrass landscapes, demonstrating that plant-flow-landform feedbacks and the morphological properties of plants have a determinant effect on the self-organization of tidal floodplains.

\*\*\*\*\*

**How biogeomorphic approaches can be used to identify ecosystem processes and services: using rock weathering studies as an example**

NAYLOR L.(1), COOMBES M.(1), VILES H.(1), GOWELL M.(1), THOMPSON R.(2)

(1) University of Oxford, OXFORD, UNITED KINGDOM ; (2) University of Plymouth, PLYMOUTH, UNITED KINGDOM

Biogeomorphic processes serve important mediating functions in most geomorphic systems. Key species or communities have been found to stabilise sediments (e.g. soil crusts, vegetated dunes); alter microclimates (e.g. seaweeds); absorb pollutants (e.g. ivy); sequester carbon (e.g. saltmarshes); or increase sediment mobility in rivers (e.g. crayfish). They are therefore important components of ecosystem processes, which often produce final ecosystem services (FES) and ultimately goods (G) that have a value (V) to society. For example, wave attenuation by saltmarshes regulates tidal waters (= FES) providing flood protection (G) for less money with wider benefits (V) than a hard engineering approach. Our rock weathering research in conservation, urban and coastal built environments is used to critically examine and quantitatively demonstrate how a biogeomorphical approach can improve our understanding of ecosystem processes – and identify previously unrecognised ecosystem services. Thermal and moisture regimes are known to affect mechanical and chemical weathering rates. Field and experimental trials examining seaweed and barnacle bioprotection have determined that extremes and fluctuations in temperature in the critical zone are reduced by up to several degrees. Ivy on limestone walls provides thermal and hydrological buffering and absorbs pollutants. Soft wall capping of ruined buildings also has been proven to provide a thermal blanket and act as a sponge reducing moisture ingress to old, unroofed walls. Biota typically serves to reduce the weathering potential and/or rates of decay; in some cases biota causes weathering. Thus, biogeomorphic approaches can be used to help identify key ecosystem processes at the biotic-abiotic interface, which also provide FES. Field and laboratory experiments testing ecological enhancement of walls demonstrate that these benefits can be encouraged and increased, through biogeomorphologically influenced engineering designs.

## **Poster presentations:**

### **Landscape morphology and the spatial variation of critical zone processes in the Luquillo critical zone observatory of Puerto Rico**

SCATENA F.

*University of Pennsylvania, PHILADELPHIA, UNITED STATES*

It has long been recognized that tropical montane environments exhibit remarkable geologic, hydrologic, and biogeochemical heterogeneity in critical zone (CZ) properties. To explain this heterogeneity, many researchers have embraced the conceptual model that critical zone properties, like soil properties, result from a combination of climate, topography, organisms, parent material, and age. While this general conceptual model has been widely used in diverse environments, most studies have focused on isolating the influence of one state factor on a limited number of CZ characteristics. How the spatial distribution of state factors and their inter-relationships influence multiple critical zone properties across various spatial and temporal scales is poorly constrained. This paper summarizes a series of inter-related studies conducted in the NSF-funded Luquillo Critical Zone Observatory (LCZO) in Northeastern Puerto Rico that address the relative importance of different state factors on a suite of critical zone properties. State factors include 2 distinct bedrocks, 4 forest types, 3 hillslope positions, and a climate that ranges from subtropical moist to wet. CZ properties including vegetation structure and composition, soil bulk density, organic matter and exchangeable cations. In general, hillslope position (ridge, slope, valley) is significantly correlated to stand structure and soil properties in all combinations of lithology, forest types, and climate. Quartzdiorite vs volcaniclastic lithology have distinct weathering regimes, soil textures, and exchangeable cations within and between forest types. While bedrock lithology influence soil organic matter concentrations it has less influence on total soil organic matter content. For most soil properties, combinations of abiotic state factors can explain between 20-30% of the variance between sites. However, when vegetation type and stand age are included the amount of variance that can be explained can double.

\*\*\*\*\*

### **Drainage network evolution during the initial phase of ecosystem development - observations from an artificially-created catchment**

RAAB T.(1), SCHNEIDER A.(2), GERKE H.H.(3), MAURER T.(2), NENOV R.(2)

*(1) Brandenburg University of Technology, COTTBUS, GERMANY ; (2) Brandenburg University of Technology, COTTBUS, GERMANY ; (3) Leibniz-Centre for Agricultural Landscape Research (ZALF), MÜNCHENBERG, GERMANY*

The initial phase of landform development is characterized by non-equilibrium conditions, high geomorphic process rates, and high variations in geomorphic patterns and can therefore have a lasting influence on patterns of soils, hydrology, and biota in developing ecosystems.

This study attempted to reconstruct and analyze the first five years of hydro-geomorphic evolution in the 6 ha artificial catchment 'Hühnerwasser', which serves as a real world-laboratory to study patterns processes of initial ecosystem development. The first years of surface development in the catchment were characterized by intensive sediment redistribution and the formation of a network of erosion rills.

Our approach was based on the analysis of remotely-sensed data. We analyzed morphometry from a time series of ten Digital Elevation Models (DEMs) and mapped surface structures for four states of development from high-resolution aerial photographs. DEMs and aerial photographs of the initial surface and meteorological monitoring data were used to assess the effect of initial and boundary conditions on surface development. Further network parameters, e.g., energy dissipation in the rill network and connectivity of the surface, were characterized by combined analyses of rill network maps and DEMs.

After a rapid growth of the erosion rill network during the first two years of development, a reduction of the area of actively eroding rills was observed. Differences in precipitation characteristics, the growth of vegetation cover, and locally evolving feedback cycles between flow accumulation and erosion were identified as drivers for this development. Results of the DEM time series analysis show that geomorphic patterns in the catchment were established during the first years of development and remained relatively stable afterwards.

**Soil erosion and carbon redistribution in slopes under different lithologies and land uses: the effect of fires.**

MENENDEZ-DUARTE R.(1), SANTIN C.(2), FERNANDEZ S.(1), NAVAS A.(3), GASPAR L.(3)

(1) *INDUROT-Oviedo University, MIERES (ASTURIAS), SPAIN* ; (2) *University of Swansea, SWANSEA (WALES), UNITED KINGDOM* ; (3) *Estación Experimental de Aula Dei(CSIC), ZARAGOZA, SPAIN*

Rates of soil erosion and soil carbon redistribution are being studied in slopes under different lithologies and different land uses in an Atlantic mountain area (Cantabrian range, NW Iberian Peninsula). For this purpose, four slopes, two with quartzarenitic bedrock and two with calcareous bedrock have been sampled. Rates of soil erosion are being quantified by the fallout radionuclide  $^{137}\text{Cs}$ . Soil carbon concentrations and characteristics are being determined by elemental analyses and thermogravimetry-differential scanning calorimetry.

For each of the lithologies, a forested hillside (beech forest) and a hillside covered with scrub (heather) and herbaceous vegetation was selected. In each hillside, samples were taken along a transect, from the top to the bottom of the slope (12- 30 sampling points per transect). At each sampling point a bulk sample of the whole soil profile was taken for  $^{137}\text{Cs}$  analyses and a surface soil sample (first 5cm) was taken for carbon analyses, adjacent to the bulk sample. In addition to this,  $^{137}\text{Cs}$  reference samples (whole soil profile in flat location) were taken for each of the four lithology-land use combinations.

In this Atlantic region, forests are the 'natural vegetation cover' or 'undisturbed situation', whereas the presence of scrub and grass is the result of human alteration of this natural vegetation cover, mainly due to the use of fire as a management tool for pasture maintenance. The results of the present study will allow us to determine 1) rates of soil erosion, 2) distribution of  $^{137}\text{Cs}$  in the soil profile, 3) effect of fire on the soil organic carbon pool and, 4) if there is a redistribution of organic carbon in the hillsides associated with the processes of erosion induced by fire as a land management tool.

\*\*\*\*\*

**Biogeomorphological interactions in formerly glaciated terrain: the overlooked role of disturbance processes.**

BÄTZ N., LANE S.

*Institute of Geography and Sustainability - University of Lausanne, LAUSANNE, SWITZERLAND*

Research over many decades has demonstrated that the revegetation process in formerly glaciated terrain is exceptionally slow (decades to centuries) not least because of the time it takes for the coupled evolution of the soil-vegetation system. Glacigenic materials, notably morainic materials, commonly have poor moisture retention and relatively slow weathering rates. This reduces fine material availability for pedogenesis, hence hampering the related vegetation succession. However, especially in Alpine glacial systems, such research has tended to overlook the role played by hydro-geomorphological processes, such as linked to alluvial fans, in locally modifying habitat conditions in ways that can substantially speed up the revegetation process. Alluvial fans can introduce substantial amounts of finer material, locally increasing moisture retention capacity and allowing pioneer vegetation colonisation, necessary to add organic matter to the soil system. A positive feedback starts, which improves local habitat conditions and increases local weathering rates. Nevertheless, powerful fan events can locally reset the system. Here we describe what we call a 'high risk – high reward' vegetation colonisation strategy in formerly glaciated terrain linked to interactions between disturbance processes and soil development. This strategy rapidly speeds up vegetation successional processes but also appears to feedback into the dynamics of alluvial fans, notably at fan heads. We present: (1) an extensive survey of these phenomena for Alpine deglaciated terrain; and (2), based upon a case study fan in the Val d'Héréns, Switzerland, a conceptual model for the role of fan related disturbance processes in conditioning vegetation succession and its feedback onto the fan dynamics.

**Chemical weathering rate in a steep mountain basin of Northern Japanese Alps: Estimation from in situ cosmogenic nuclides and geochemical mass balance model**

HATTANJI T.(1), MATSUSHI Y.(2), KITAMURA Y.(1), OGUCHI C.T.(3), HACHINOHE S.(4), MATSUZAKI H.(5)  
(1) University of Tsukuba, TSUKUBA, JAPAN ; (2) DPRI, Kyoto University, UJI, JAPAN ; (3) GRIS, Saitama University, SAITAMA, JAPAN ; (4) Center for Environmental Science in Saitama, KAZO, JAPAN ; (5) University of Tokyo, TOKYO, JAPAN

Chemical weathering rate in steep alpine environment has not been evaluated by using the recent approach of *in situ* cosmogenic nuclides and geochemical mass balance model. We have estimated chemical weathering rate at nine major sub-catchments of the Ashima River basin, located in Northern Japanese Alps, central Japan. Climate varies from humid temperate with mean annual temperature (MAT) of ~10°C and rainfall of ~1500 mm/y at the bottom of the basin, to cold environment with MAT of ~0°C at the 2300-m high divide. *In situ* <sup>26</sup>Al for river sediment in these sub-catchments showed that denudation rate ranges from 200 to 2000 mm/ky, which basically depends on mean slope of each catchment. We have measured chemical compositions of bedrock and sand (grain size of 0.25~2.0 mm) in stream sediment with X-ray fluorescence analysis, and calculated chemical depletion fraction (CDF), which is defined as the ratio of chemical weathering rate to total denudation rate. Titanium was treated as an immobile element for calculation of CDF. The results showed that CDF ranges from 0.08 to 0.6 and chemical weathering rate ranges from 100 to 400 mm/ky. Some catchments located at the middle of the basin have high denudation rates (~1000 mm/ky) and relatively high chemical weathering rates (~400 mm/ky), which exceeded other reported rates in the previous studies for granitic mountains. In the upstream most catchments with very high denudation rates (~2000 mm/ky), the contribution of chemical weathering declines because physical denudation processes such as landslides predominate.

\*\*\*\*\*

**Interactions between floristic diversity and organisation and alluvial fan morphodynamics**

BORGEAUD L.(1), LANE S.(2), VITTOZ P.(3)  
(1) IGD, Université de Lausanne, LAUSANNE,, SWITZERLAND ; (2) IGD, Universit? de Lausanne, LAUSANNE, SWITZERLAND ; (3) DEE, Université de Lausanne, LAUSANNE, SWITZERLAND

Recent research has recognised that there is a critical co-evolution between geomorphic systems and ecosystems in which vegetation exerts a crucial role as an 'engineer' of geomorphic response, whilst the nature of that geomorphic response has profound impacts upon ecosystem dynamics. Here, we present results that combine a 70 year reconstruction of alluvial fan dynamics for an active fan system in the Vallon de Nant, Canton Vaud, Switzerland. The work is based upon a combination of: dendrogeomorphological records and aerial imagery analysis; and over 100 quadrats in which plants were identified and recorded to species level, and additional environmental parameters (e.g soil characteristics) were measured. Statistical ordination was used to identify the spatial structure of the plant communities. Fractal type approaches were used to identify the spatial scale dependence of emergent alpha- and beta-diversity. These two sets of data were then tied back into the geomorphologic history of fan development. The work showed that distinctive spatial and temporal patterns emerge in fan vegetation communities that can be related to both spatial and temporal properties of fan dynamics, and notably the accommodation space available to fan surface channels. The latter sets the magnitude and frequency characteristics of channel occupancy and causes a down fan shift in community organisation biodiversity from being discrete 'on-off' driven in the more constrained fan head to being more spatially continuous where accommodation space is greater.

**Sustainability, vulnerability and geodynamic hazard in geomorphologic systems of urban territories of the Russian Far East**

MIASNIKOV Y.

*Pacific Geographical Institute, VLADIVOSTOK, RUSSIAN FEDERATION*

The issues of sustainability, vulnerability and geodynamic hazard in geomorphologic systems (GMS) of urban territories (UT) of the Russian Far East (RFE) were approached on morphostructural base. The conclusion was made that the combination of the studied parameters provides quite an efficient assessment system to the environmental and geomorphologic condition of the RFE UT. The GMS parameters of sustainability, vulnerability and geodynamic hazard are based on complex data of endo-dynamics, exo-dynamics and techno-dynamics. The following stages of the study should include research of the detailed composition, development and applied features of the GMS, including monitoring of hazardous endo-dynamic, exo-dynamic and techno-dynamic processes aimed to the efficient management of relevant risks.

\*\*\*\*\*

**Periglacial Slope Deposits and the CZ - on their genesis and influence on soil water content by a case study from the Bavarian Forest, Germany**

HUBER J., VOELKEL J.

*Technische Universitaet Muenchen, MUENCHEN, GERMANY*

Periglacial slope deposits (PSD) are widespread in mid latitudes' Pleistocene non-glaciated areas. In the mid-mountainous regions of Germany like the Bavarian Forest these sediments appear as characteristic layered material on any slopes. Typically, the PSDs consist of three different layers: Upper, Middle and Lower Head. Their properties are governed by their genesis at different climates and according to periglacial morphodynamics. Additionally, bedrock lithology and source of strata are influencing factors. The PSDs are crucial part of the critical zone as the uppermost layer between surface and the lowest groundwater level and responsible for layer-characteristic soil water movements. The latter are hydrological processes, like interflow and storage, depending on the PSDs.

In this investigation (DFG funded, VO 585/15-1) selected profiles of the Otterbach catchment are analysed in consideration of the pedological and sedimentological properties. Stratigraphical features and numerical dating techniques (OSL) help to interpret landscape evolution and genesis of its critical zone. In addition, soil water measurements within the single PSDs show the influence of the layers on soil water movement and the importance of the periglacial slope deposits as part of the critical zone.

### Estimation of Soil Formation Rate from Vegetation on Tertiary Rock Area in Japan

TODA M.(1), WATANABE T.(2), KOBAYASHI S.(3)

(1) Freelance, HACHIOJI, JAPAN ; (2) Freelance, FUKUSHIMA, JAPAN ; (3) JOHNSON TRADING COMPANY,LIMITED, SAGAMIHARA, JAPAN

In the Boso Peninsula of central Japan there are frequent slope failures in spite of the low relief hilly area. The geology of this area is Tertiary sandstone and mudstone. One of the proposed reasons of the failures is an unstable early formed soil layer. Therefore we were able to estimate the rate of the soil formation from the relation between soil thicknesses on the collapsed slope and the age of the trees on the slope.

The pioneer tree in the collapsed slope of this area is *Cleyera japonica* or *Eurya japonica*. Ages of the trees were measured with an increment borer and the soil thicknesses under the trees were obtained by a dynamic cone penetration test. As a result, the soil was thicker so that the age of tree was older. The relationship between the thickness of soil,  $D$  (cm), and age of tree,  $A$  (year), was  $D=1.6A+47$ .

From observation we assumed that there was no soil on collapsed slope just after failure. Then new soil formed through the weathering of the bedrock. The pioneer trees then grew after the formation of the soil layer. Due to the growth of the pioneer trees there was no evidence of the soil movement due to slope failure. Therefore, the above equation shows that the rate of soil formation is 1.6cm a year and the pioneer trees spread on collapsed slopes after soil formed a 47cm layer.

The rate of soil formation provided here is considerably bigger than other studies. This is due to relative high rate of the bedrock weathering. We also performed the weathering tests using rock samples from this area. The wet-dry test was for an index of the physical weathering and dissolution test was for chemical one. As a result, the rock of this area was weak for slaking and was dissolved earlier than limestone. As the geology is weak for both physical and chemical weathering the rate of soil formation of this area is fast.

\*\*\*\*\*

### Bedrock weathering and Biogeomorphic processes in the Ouachita National Forest, USA

TURKINGTON A.

University of Kentucky, LEXINGTON, UNITED STATES

The effects of vegetation on soils and geomorphic processes have long been recognized. Studies of these effects have traditionally emphasized biological and chemical effects on pedogenesis, and the relationship between vegetation cover and soil erosion. This study focuses on the direct and active geomorphic roles of biota (rather than indirect and passive). Tree growth, and uprooting, is an important influence on not only pedogenesis, but also bedrock weathering. This research seeks to examine how tree roots can directly weather the bedrock in this area, and how tree throw mines bedrock and delivers it to the surface.

The field site is the Ouachita Mountains in Arkansas, southern USA. The Ouachita's are parallel east-west trending ridges, with intermontane basins. Local relief is 75-530m. The climate is humid subtropical, mean annual precipitation is 1400mm. The sites are dominated by a mixed oak-pine cover, and the geologic setting is typically alternating layers of sandstone and shale, with lesser amounts of quartzite, novaculite and chert. Exposed shales are deeply weathered and highly erodible; sandstones are less altered and more durable.

This study demonstrates that trees directly weather bedrock and subsoil rock fragments, causing biochemical weathering of siliceous sandstone, which was previously understood to be resistant to chemical attack. Processes of root weathering include biochemical and biophysical processes, which dominate at the grain scale and the outcrop scale, respectively. Further, trees can mine large amounts of fresh bedrock to the surface, both sandstone and shale, driven by a number of uprooting mechanisms.

### **Redox front effect on the adsorption of cesium and strontium on pumice tuff**

RAJIB M.

*Saitama University, SAITAMA, JAPAN*

The part of host rock of a waste repository could always be vulnerable to weathering slowly by contacting the surface/subsurface water and weathered zone or redox front can be formed. This long term weathering processes in the geosphere surrounding the repository might have significant effect on the adsorption of certain nuclides that could be released from the radioactive wastes. Since this phenomenon is quite frequent in subsurface, adsorption characteristics of two strategically very important nuclides from radioactive waste, cesium and strontium were investigated on fresh, unweathered rock and on weathered or oxidized part, collected from redox front zone of pumice tuff, which is already been selected for hosting low and intermediate radioactive wastes in Japan. Batch sorption study was carried out to explore the difference of adsorption mechanism at wide range of pH 4-12, varying nuclide concentration from  $10^{-4}$  to  $10^{-7}$  M and different ionic strength of 1.0, 3.0. Powder of 150-300  $\mu\text{m}$  size and approximately  $1 \text{ cm}^3$  blocks of pumice tuff were used as two phases of rock. Pore size distribution and specific surface area of the fresh and weathered pumice tuff were determined as supporting analysis. Mineralogical composition was done by XRD and optical microscopy; and elemental analysis by SEM-EDX. Solution chemistry was determined by ICP-MS and finally data were simulated with IgorPro 6.2. Since a slight weathering of a fresh mineral surface leads to the formation of available exchange sites and an increased sorption, higher distribution coefficient values were found in the weathered part than fresh pumice tuff. The distribution coefficient difference between block and powdered rock is expected to be caused by the effect of diffuse electric double layer, long equilibrium period and the physical property of fracture during experiment.

\*\*\*\*\*

### **Retracing signals of historical soil erosion in peatbog archives as an indicator for landscape resilience in the context of future landuse changes and weather fluctuations (TUM-CZO, Ammer Mts.)**

WINKELBAUER J., VOELKEL J.

*Technische Universitaet Muenchen, MUENCHEN, GERMANY*

As an example for recent research attempts within the Critical Zone Observatory of the Technical University of Munich (TUM-CZO), located in the Ammer Mountains of the Bavarian Alps, we present a project which deals with the investigation of possible soil loss triggers and dynamics in alpine landscapes. As soils represent the central part of the heterogeneous interaction system of the Critical Zone, they hold an essential relevance for a broad variety of up-to-date questions concerning the long-term sustainability of numerous natural resources and ecosystem services. Soil loss consequently causes serious, irreversible loss of vital soil functions and thus ecosystem services. Hence, determining risks of soil degradation and soil loss is a major task within the Critical Zone research.

The reconstruction and analysis of past erosion incidents is an essential key to understanding the driving factors of soil erosion or landscape resilience as reaction to external triggers (both natural and human). Peat bogs containing interlayered strata of mineral colluvial fillings are ideal archives for such reconstructions. Within the Ammer catchment, we investigate a total of twelve peat bogs distributed across an altitude gradient from alpine to subalpine and lowland landscapes. In addition to the extraction of conventional drilling cores, Ground Penetrating Radar is used as a non-invasive method of highlighting the internal stratification of the peat bogs. Various dating techniques can be applied to both organic and mineral layers ( $^{14}\text{C}$ , OSL, pollen analysis). Pollen analysis adds additional proxy data on vegetation and climate. The results then allow the correlation with well known, prominent climatical stages (e.g. Little Ice Age) and extreme weather incidents in the past as well as with historical records on land use. By this, valuable insight on characteristic regional landscape dynamics and thresholds is provided.

### Simulating vegetation dynamics within Landscape Evolution Models: a simplification too far?

TRUEMAN A., WAINWRIGHT J., DENSMORE A., TURNBULL L.  
Durham University, NEWCASTLE UPON TYNE, UNITED KINGDOM

The influence of ecology upon geomorphological processes has long been recognised (see Lyell, 1830; p. 113), however the complex feedbacks between the two have only recently begun to be understood. Recent studies have illustrated the importance of riparian vegetation in: the reinforcement of the underlying soil matrix (e.g. Pollen-Bankhead & Simon, 2010); and the mediation of shear stresses related to overland flows (e.g. Liu *et al.*, 2010). Moreover, the influence of geomorphological processes in affecting landscape ecology has been made evident in the role of geomorphological processes in: controlling the spatial distribution of riparian plants through hydrochoric dispersal of seeds/propagules; altering abiotic conditions suitable for seed germination and plant growth; and controlling plant stress through varying the disturbance regime. Indeed, it is now believed that a widespread transition of channel morphologies during the Devonian Era can be attributed to the widespread colonisation by vascular plants (see Gibling & Davies, 2012).

Despite these advances in our understanding of ecogeomorphological feedbacks and their role on landscape evolution, modern Landscape Evolution Models (LEMs) still simulate vegetation change simplistically. Commonly, within LEMs, ecological components experience no spatial/temporal variability in root structure; seasonality; and/or function during simulation. Through these simplifications, an un-quantified level of uncertainty is associated with the conclusions made.

This poster presents an overview of our current understanding of ecogeomorphological interactions and the gulf between this and the current simplified level of sophistication of ecogeomorphological modelling within present-day LEMs. The poster will conclude with an outline of the work currently being undertaken by the presenter concerning the development and coupling of a spatio-temporally dynamic vegetation component within an existing LEM.

\*\*\*\*\*

### Four-dimensional reconstruction of gully processes in a sandy badland of the Spanish Central System

STOFFEL M.(1), STOFFEL M.(2), BALLESTEROS CANOVAS J.A.(3), CORONA C.(1), LUCIA A.(4), MARTÍN-DUQUE J.F.(5), BODOQUE J.M.(6)

(1) University of Berne, Institute of Geological Sciences, BERNE, SWITZERLAND ; (2) University of Geneva, Institute for Environmental Sciences, CAROUGE-GENEVA, SWITZERLAND ; (3) Geological Survey of Spain (IGME), MADRID, SPAIN ; (4) Faculty of Science and Technology, Free University of Bolzano, BOLZANO, ITALY ; (5) Department of Geodynamics and Geosciences Institute (CSIC, UCM), Complutense University of Madrid, MADRID, SPAIN ; (6) Mining and Geological Engineering Department, University of Castilla-La Mancha, TOLEDO, SPAIN

Soil erosion is a key driver of land degradation in various environments worldwide and heavily affects sustainable land management. An appropriate quantification and localization of “hotspots” of soil erosion are therefore critical, as sediment loss has been demonstrated to have drastic consequences both on soil productivity and fertility. The evolution of gully retreat has repeatedly been addressed through short-term field monitoring of headcuts or the interpretation of diachronic aerial photographs, but has rarely been studied with dendrogeomorphology in the gully itself. The only existing study using growth-ring series from anatomical changes in exposed gully roots in southeast Spain estimated medium-term gully-head retreat rates to  $6 \text{ m}^3 \text{ yr}^{-1}$  and gully sidewall erosion to  $0.1 \text{ m}^3 \text{ yr}^{-1}$  per unit sidewall length.

Floating *Pinus pinaster* roots spanning incised gullies have also been observed in sandy badlands of the Spanish Central System's piedmont, where averaged retreat rates of merely  $0.53 \text{ m yr}^{-1}$  have been observed through repeat surveying. The advantage of the roots at the study site in the Spanish Central System lies in the arrangement of roots with respect to the gully, since they not only allow determination of gully-head retreat and sidewall erosion, but also permit documentation and reconstruction of vertical incision and channel widening within the gully over time. The site is also characterized by abundant exposed roots in a ~100-m long gully segments, therefore allowing analysis of changes with time and the identification of extreme erosion events. Based on anatomical changes identified in almost 120 roots and TLS data, we documented, quantified and mapped, for the first time ever, changes within the gully with high spatial resolution, over the past 40 years and in four dimensions.

## **Biofilm Formation on Sediments is an Adaptive Feature for *Vibrio cholerae*: A Bio-Geo Interaction Phenomenon**

GHOSH C.

Vidyasagar University, MEDINIPUR, INDIA

*Vibrio cholerae*, the gram negative bacterium is the causative agent of devastating diarrhoeal disorder cholera, considered to be one of the major public health concerns in the developing world. This human pathogen is an aquatic bacteria, can be isolated from freshwater, estuarine and marine environment. Besides its planktonic free living form in aquatic reservoirs, a section of *Vibrio cholerae* organisms remain associated with sediment structures in aquatic bodies. The basic mode of association with abiotic surfaces like sediments, have been established to be by formation of biofilm. Biofilm, a three-dimensional surface structure of bacteria, is considered to be an adaptive advantage to the bacteria as it extends protection against several bactericidal effects and thus, enhances their expectancy for long survival in nature. Secretion of exopolysaccharide (EPS), a glucose or galactose-rich polysaccharide structure plays a key role in establishing the abiotic-surface attachment. Besides several environmental factors, a cell-cell communication mechanism known as quorum sensing has been identified to be a major regulator for biofilm formation and subsequent virulence expression. In a recent study parallel but convergent cellular signalling pathways have been identified in an epidemic clone of *Vibrio cholerae* driven by quorum sensing signalling molecules, autoinducers and flagellum (the structure governing motility in bacteria), respectively. Moreover, sodium motive force driven flagellar motor has been found to act as an essential regulator for EPS production. Based on involvement of extracellular signalling system including sodium motive force in EPS expression and suggestion of involvement of flagellum in encountering solid surface for establishing biofilm, we predict an interrelationship of physico-chemical prosperities of sediment structures with EPS biosynthesis. This, in turn, may influence bonding of sediments and influence their entrainment and erodibility.

\*\*\*\*\*

## **Saline lakes degradation in the Pantanal wetland, central-western Brazil**

FURQUIM S.A.C.(1), SAKAMOTO A.(2), BONOMO B.C.M.(1), SOBREIRA M.S.(1)

(1) Universidade Federal de São Paulo - UNIFESP, DIADEMA, BRAZIL ; (2) Universidade Federal de Mato Grosso do Sul - UFMS, TRÊS LAGOAS, BRAZIL

In the Nhecolândia, a sub-region of the Pantanal wetland, shallow saline lakes have been formed by evaporative concentration of subsurface freshwaters. These lakes are in the higher topographic position of the landscape. Consequently, they are not reached by the surface freshwaters that flood the Pantanal and are enclosed by dense savannah vegetation. However, many of these lakes have received flooding waters, mainly due to deforestation and erosion of their surroundings. Our study performed a detailed soil survey under and around a deforested saline lake in order to understand the effects of freshwater introduction in the lake environment. The sequence of horizons of the surveyed soil is: brown, sandy A; pale brown, sandy E; very dark gray, sandy loam and organic-rich B; gray, loamy sand Bkng; and green, sandy loam and impervious Bnxg. This soil morphology is similar to the preserved saline lake soils, as described in previous studies, with the exception of both the presence of the very dark gray B horizon, marked by organic matter illuviation, and the less extension of the Bkng and Bnxg in the deforest lake. Besides, whereas the deforest lake soil is neutral and strongly acid in the A and organic-rich B, respectively, and alkaline below, the preserved lake soils are entirely alkaline, being submitted to solonization processes. These differences suggest the dominance of solodization over solonization in the deforested lake soil, indicating the degradation of the typical soils of the preserved lakes. The acid organic-rich horizon is likely responsible for the destruction of the alkaline Bkng and Bnxg, mainly by clay hydrolysis and oxidation. The green and impervious Bnxg horizon has an important role in the Nhecolândia salinity origin because it allows the seasonal isolation of waters and, consequently, very high rates of evapotranspiration in the lake depression. Thus, the destruction of this horizon may lead to the complete degradation of the saline lakes.

### **Time and Again: Fire, Tree Root Decay and Slope Stability**

MARTIN Y., JOHNSON E., KROEKER S.  
*University of Calgary, CALGARY, CANADA*

Mechanical reinforcement of shear strength in shallow soils by tree root networks has been documented for steep slopes (Schmidt et al., 2001; Roering et al., 2003). Tree death by recurring crown wildfires results in the decline of root reinforcement in shallow soils and may affect occurrence of debris slides and debris flows (e.g., Benda and Dunne, 1997; Martin, 2007; Jackson and Roering, 2009). Despite recognition of tree root decay following wildfire, to our knowledge no annual continuous measurements have been made in a post-wildfire setting to document tree root decay over time. Suggestions have been made that root decay following timber harvesting may provide a reasonable analogue, although this idea remains largely conjecture. Herein, we present our annual field measurements of post-wildfire tree root strength made over the past 9 years at a post-wildfire site in the Canadian Rockies. In these subalpine forests, fire return intervals are shorter than the potential lifespan of trees, making wildfire critical to tree population dynamics. The recurring nature of wildfire leads to a recurring decline in tree root decay in immediate post-fire years and an increased likelihood for mass wasting. Our field measurements of tree root strength were undertaken in the burned subalpine forest of Hawk Creek, British Columbia, Canada. In July 2003, two large crown fires were ignited by lightning in Kootenay National Park and merged to burn 17 000 ha. Annual measurements of post-wildfire tree root strength have been made from 2004 until the present. Each year, tree root measurements, including vertical root depth, root diameter and tensile force at breakage, were made in 15 soil pits located within five slope gradient classes. Results show that when measured in the same year, tree roots of larger diameter require a greater tensile force for breakage. Most importantly, the gradual decay in tree root strength over time has been meticulously documented and quantified.

\*\*\*\*\*

### **Volcanic hazard assessment in the bromo volcano aera, East Java (Indonesia)**

BACHRI S.(1), STÖTTER J.(1), SARTOHADI J.(2)  
*(1) Institute of Geography, University of Innsbruck, INNSBRUCK, AUSTRIA ; (2) Department of Geography and Environmental Science, Faculty of Geography, Gadjah Mada University, YOGYAKARTA, INDONESIA*

The Bromo eruption in 2010 had modified human environment in the area surrounding. The villages around the crater of Bromo experienced severe impact of erupted materials. Large agriculture areas were covered by ash for a long period, thus decreasing its productivity significantly. Despite suffering from this devastating impact of the volcano, the people in the Bromo region decided to live and adapt to the recurring phenomenon. Identification and assessment of hazard areas due to volcanic eruptions is a necessary pre- requisite to design suitable adaptation strategies in the region.

This paper aims at identifying areas vulnerable to volcanic eruptions in Bromo. The combination of GIS techniques and geomorphological field survey was applied to assess the vulnerability of study area. Factors such as landform, source of hazard and population density were considered for the identification of hazard processes. This objective is addressed in two steps: 1) by deriving a 3D map from contour lines using the implementation of FOSS SAGA-GIS software, and 2) by exploring the considering factors in the field in order to understand the vulnerability patterns.

The results show that the volcanic ravine bottom is the most densely inhabited area. This area is characterized by intensive mass movements of the volcanic deposits, especially during the rainy season. Furthermore, the areas with an elevation over 2000 msl are relatively safe from volcanic ash due to the protection of the caldera wall. The morphology of Bromo Volcano plays important role in controlling some processes of volcanic materials redistribution. About 40% of the study is categorized as volcanic prone area, whereas the rest is vulnerable to other volcanic redistribution processes.

Keywords: Volcanic hazard, landform, Geographic Information System, Bromo Volcano Indonesia

**Urmia Lakes, affected with the water level vacillations and critical increase the salt deserts, expectant of aid for again birth**

*AGHAJANY K.(1), ROOSTAEI S.(2), POURASGHAR F.(3), REZAEI MOGHADAM M.H.(4)*

*(1) - Ph.D.Student of Physical Geography(Geomorphology), Tabriz University, TABRIZ, IRAN ; (2) Prof, Department of physical Geography,Tabriz Univ., TABRIZ, IRAN ; (3) East Azarbaijan general Bureau and Applied Meteorological research center., TABRIZ, IRAN ; (4) Prof,Department of physical Geography,Tabriz Univ., TABRIZ, IRAN*

Urmia Lakes lies northwest of Iran and between the eastern and the western azarbaijan province and the largest internal lake and to take into account the second salt water lake of world. Urmia Lakes indebted its formation to ancient faults revenue. Tectonic agent cause former formation lakes with gradual revenue in location of lake border mountains. This basin is one of value centers of agriculture and animal activities in Iran. National park of Urmia Lakes is the most value natural environment of animales after Anzaly lagoons in Iran.

This province has semi-arid climate and its mean rainfall state is about 250 mm annually. Continuous and lengthy droughts in last years decreased the water level of Urmia Lake and cause saltiness of around agricultural land wells that treated for agricultural activities and natural environment of emigrant birds.

In this research have been distinguished by using satellite images(ETM<sup>+</sup>), GIS and coastal geomorphology that Urmia lake has retreated in south of lake until 10 km to be extent that remains from 5700 km<sup>2</sup> area of lake only 2700km<sup>2</sup>.

The synoptic patterns show that most of the wind direction in the study region is south and south west so wind will carry out salts to the adjacent regions from the dried surface of lake. Urmia Lake drought causes the agricultural, social and health problems in the region.

Keywords: Urmia Lakes; salt deserts;retreated; synoptic patterns

\*\*\*\*\*

**Morphological, micromorphological and analytical properties in a toposequence with haplic cambisols in the Nova Lima group - Quadrilatero Ferrifero, minas gerais state, Brazil**

*COSTA F.(1), BACELLAR L.D.A.P.(1), CASTRO S.S.(2), RESENDE F.R.M.(1), SILVA S.F.(1)*

*(1) Federal University of Ouro Preto, OURO PRETO, BRAZIL ; (2) Federal University of Goias, GOIANIA, BRAZIL*

The Quadrilatero Ferrifero is a region of archaean and proterozoic rocks located in the Minas Gerais State, Southeastern Brazil. There are many geological studies about this region which is rich in mineral resources, such as gold and iron, but the pedological information is still scarce because of its high relief, with steep slopes and poorly developed soils. It is important to understand the distribution and evolution of these soils, with the pedological systems evaluated as a continuum, to identify the effect of geological and geomorphological phenomena related to the regression of erosive scarps and pedogenesis. This work aims to contribute to the understanding of the evolutionary dynamics of a typical pedological system of this region that consists of Haplic Cambisols developed on schists of Nova Lima Group (Rio das Velhas Supergroup). Soil borings were conducted along a 32 % slope for description and sampling along a toposequence, whose results confirmed that this is a system composed of 3 Cambisols in different evolutionary stages, represented by 5 soil profiles Soil (P1, P2, P3, P4, P5) located from medium slope to low slope. Cambisols are deep, 8 and 2.5 meters thick in the medium and lower slope, respectively, and contain a stone line (consisting of quartz and schist fragments and ferricrete from the escarpment top) behind a Bi horizon developed on colluvium. Analytical and micromorphological data showed a vertical transformation system (without lateral matter transfer) for Bi horizons below the stone line and C horizon. A younger Bi horizon developed on the colluvium over the stone line. The first three profiles (P1 to P3) are similar to each other, indicating that they developed simultaneously and are in a more advanced pedogenetic stage when compared to low profile (P4 and P5); P5 profile is the least developed. This typical slope evolved at least in two major morphopedogenetic erosive stages and the upper one is younger.

### **Relationship between soil, relief and the distribution of gullies in Northwestern Parana - Brazil**

CORDEIRO SANTOS L., GONÇALVES MANGUEIRA C., VITOR DO COUTO E.  
*Universidade Federal do Parana, CURITIBA, FRANCE*

The northwestern region of Paraná, in Southern Brazil, is distinguished by presenting accelerated processes of gullies since the 1950s. The significant presence of areas under the influence of gullies in this region, long since, has aroused the interest and mobilized professionals from different fields and was the main reason for their choice in the study. The aim of this research was to map the gullies found in this area and identify the physical conditions - soils and relief - that influence such gullies. The study area, located in sedimentary rocks in the Upper Cretaceous, covers a total length of 22,057 km<sup>2</sup>, which corresponds to approximately 11% of the total territory of Paraná. The relief is uniform and mild, stepped plateaus, sloping slightly toward the river Paraná valley. For this work, we used 52 images from SPOT and Landsat ETM +7 dated between 2006 and 2008, remote sensing SRTM and soil map. The data were processed in GIS and images from Google Earth ® also were used for helping the identification. To analyze the concentration of gullies, we use the index proposed by SALOMÃO (1994), correlating soils and characteristic relief to the number of features mapped (ICE - Index of Concentration of Total Erosion). Its calculation is given by the ratio between the total number of erosive occurrences and area, multiplied by 100. We have therefore the number of occurrences per 100km<sup>2</sup>. Have been mapped and classified 918 gullies, with 63% located on Ultisol and 36% on Oxisol. The spatial features distribution found allowed us to establish a significant differentiation between the soils, noting higher concentrations of gullies on Ultisols (ICE = 3.77), followed by Oxisols (ICE = 1.99). The association between relief and soils, as well as its relation to the conditions of water circulation is fundamental for understanding the dynamics of the modern gullies at the area.

\*\*\*\*\*

### **Ornithogenic soil toposequence on Rata Island, Fernando de Noronha Archipelago, South Atlantic and quaternary paleoclimatic implications**

OLIVEIRA F.(1), SCHAEFER C.(2), ABRAHÃO W.(2), CLEMENTE E.(3), SIMAS F.(2)

*(1) Universidade Federal de Minas Gerais, BELO HORIZONTE, BRAZIL ; (2) Universidade Federal de Viçosa, VIÇOSA, BRAZIL ; (3) Embrapa Solos, RIO DE JANEIRO, BRAZIL*

The formation of highly phosphatized soils on sites of avian activity is a common feature of oceanic islands. We characterized a toposequence of phosphatic soils on Rata Island, to evaluate the soil genesis based on local topographic variations. For this purpose, four soils ranging from the upper hill down to the lowest landscape position on the island, representing a range of parent materials (basalt and calcareous sands), were analyzed. In the lowest landscape position a shallow Entisol was identified, strongly influenced by birds and marine sprays (Litholic Neosol), developed on "karstified" Pleistocene calcarenites; the three other soils in the upper part of the toposequence are Ornithogenic Inceptisols (Cambisols), ranging from a deep Cambisol profile on Basalt lava to intermediate Cambisols on mixed colluvial sediments of the basalt/calcareous. The lowermost Litholic Neosol is associated with a rugged landscape with strong calcarenite dissolution and karstification, related to a former wetter climate. The soil phosphatization is clearly an inherited process of the Late Quaternary age, when climate conditions were different. Initial weathering took place in the last interglacial period, under wetter conditions during which the Tertiary basalts were strongly weathered, leaving corestones in a saprolitic, oxidized mass. In the late Pleistocene, a gentle surface distributed these weathering products along the pediment slopes as colluvial materials, whereas in the coastal areas aeolian processes formed large sand dunes composed of reworked calcareous sands from marine sources during a time of very low sea level. During this time, widespread bird activity accounted for secondary apatite formation on the surface of calcareous oolites. Finally, the Holocene warming was accompanied by increasing sea level, enhanced tropical weathering, Fe and Al mobility and variscite formation superimposed on degraded Ca-phosphates, forming two phase phosphatic aggregates.

**Paraglacial adjustment and vegetation succession in the forefield of an actively retreating glacier - a biogeomorphological perspective**

EICHEL J.(1), SCHMIDTLEIN S.(2), DIKAU R.(1)

(1) *Institute of Geography, University of Bonn, BONN, GERMANY* ; (2) *Department of Geography and Geoecology, Karlsruhe Institute of Technology, KARLSRUHE, GERMANY*

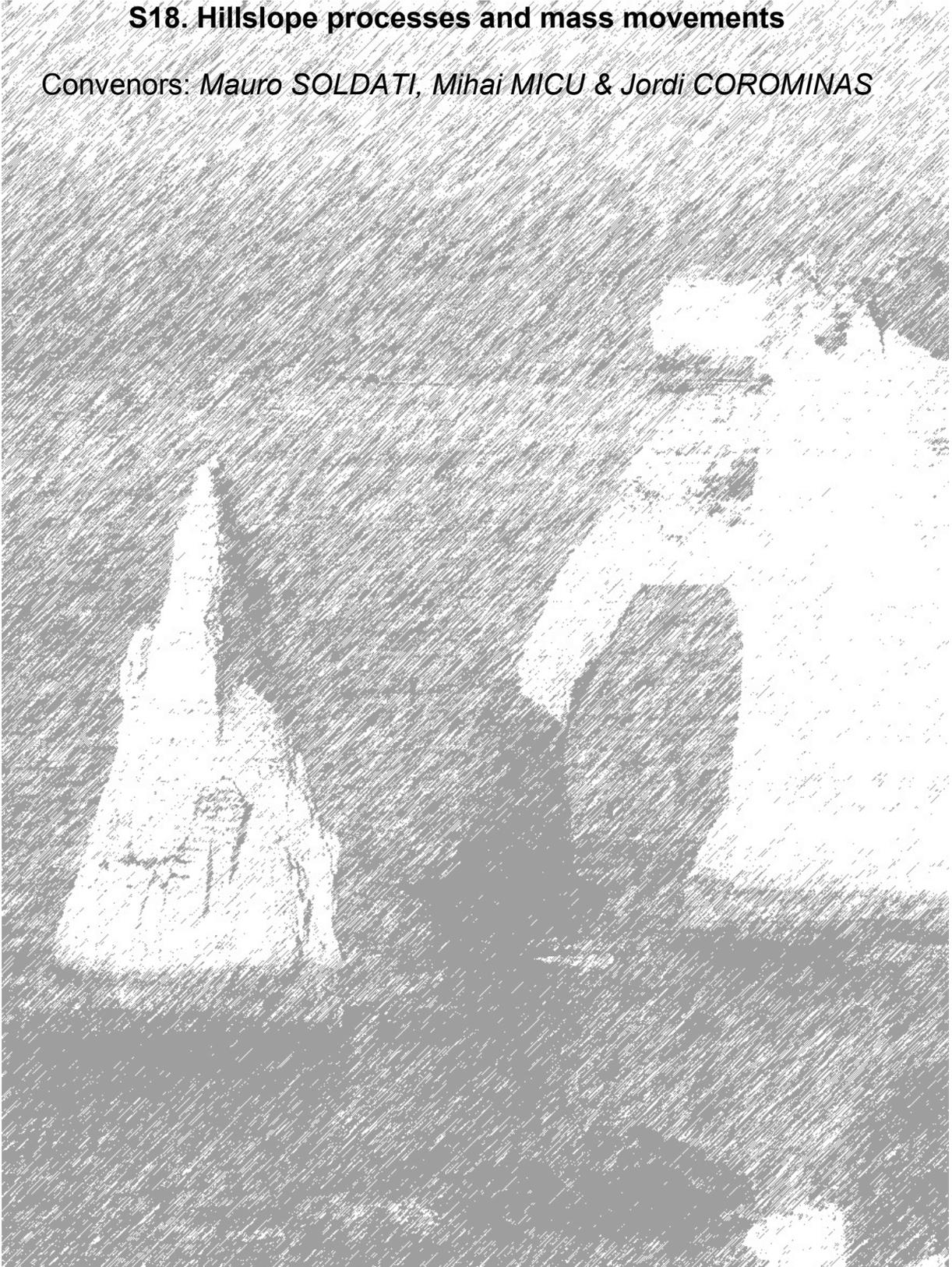
Within the last years, scientific interest in glacier forefields increased in both geomorphology and ecology as these environments are changing at an accelerated pace due to climate change. Geomorphological research focusses on the paraglacial adjustment of the forefield with accelerated geomorphic activity and increasing sediment yields triggered by the retreating glaciers. Ecological research explores vegetation and microbial succession processes in the glacier forefield and their potential future changes. In previous studies, it has been shown that on the one hand, geomorphic processes possess a strong impact on ecological processes while on the other hand, vegetation influences geomorphic processes, e.g. by stabilizing sediment. These feedbacks between the geomorphic changes since the Little Ice Age and the simultaneous vegetation succession are our research interest, which falls into the strongly evolving discipline of biogeomorphology.

The key aims of our study are (a) to assess the paraglacial impact on vegetation succession in our study area, (b) to identify relationships and feedbacks between geomorphic activity and vegetation patterns, and (c) to explain detected relationships and feedbacks using recently developed biogeomorphic concepts. In the forefield of the Turtmann glacier (Turtmann valley, Valais, Switzerland), we used a biogeomorphic approach including methods from vegetation ecology and geomorphology. Our results showed a paraglacial impact on vegetation succession which could be differentiated according to degree of geomorphic activity and attributed to specific species compositions. This sequence of corresponding geomorphic and vegetation change was mostly found on the lateral moraines and interpreted as biogeomorphic succession. We believe it is driven by biogeomorphic interactions at smallest scale. These are mediated by geomorphic-engineer species such as dwarf shrubs and controlled by the ratio between geomorphic disturbance and the relaxation time of the vegetation according to the biogeomorphic transient form ratio. The interactions at small scales result in a co-dependent paraglacial adjustment and vegetation succession at large scale and can thus explain the detected corresponding patterns.

\*\*\*\*\*

## **S18. Hillslope processes and mass movements**

Convenors: *Mauro SOLDATI, Mihai MICU & Jordi COROMINAS*





## **Oral presentations:**

### **Rainfall control of debris-flow behavior: motion and deposition at Mount Yakedake, Japan**

SUWA H.

*Center for Spatial Information Science, University of Tokyo, KYOTO, JAPAN*

Processes of debris flows have been monitored at a slope of Mount Yakedake, a volcano in Japan since 1970. Number of surge is counted as more than 200 episodes from 91 events. The studies from the data supplied a general concept of debris flows and their geomorphic effects on volcanic slopes as follows. Debris flows are triggered by a large intensity of rainfall in a short duration as long as 10 minute. Threshold of rainfall intensity for debris flows increases with time after the end of volcanic eruption, while it drastically decreases with the eruption. Three types of debris flows were found: Large flows with boulder dam without openwork structure (Type I), small flows with boulder dam with openwork structure (Type II), and small flows with boulder dam without openwork structure (Type III). Rainfall conditions were found to have controlled the difference between these types through water availability to debris flows at the source and the growth reaches of debris flows. Mass and boulder focusing to the flow front are marked, and due to the focusing the flow radiates elastic waves whose energy is from the potential energy of the flow. The energy conversion efficiency from the potential energy to elastic-wave energy is a magnitude of  $10^{-3}$  much smaller than the efficiency for earthquake at  $10^{-1}$  from the strain energy to the elastic-wave energy. Debris flows terminate in the fan leaving two types of debris-flow lobes: swollen lobes and flat lobes. The flat lobes is attributed to the Types I and III, while the swollen lobe to the Type II. It would be important to understand this concept for volcanic debris flows from its initiation to termination for the mitigation of debris-flow hazards.

\*\*\*\*\*

### **Developing of a standard methodology to characterize and modeling debris flows**

BOCCALI C., CALLIGARIS C., LAPASIN R., ZINI L.

*Universita' degli Studi di Trieste, TRIESTE, ITALY*

Debris flows affect frequently the mountain regions and, because of their speed and destructive force, threaten roads, buildings and human lives. The reconstruction of debris flows paths has long been studied and several simulation models have been implemented, but a believable scenario can be obtained only by resorting to real parameters, suitable to characterize the involved material.

The research presented in the paper is aimed at individuating a standard methodology that from field survey, through different laboratory analysis, comes to the assignment of numerical values to the basic parameters of the debris flow simulations (yield stress and viscosity). After obtaining these values, simulations were performed to validate the methodology. To this purpose a basin sited in the Northeast Italy has been studied and sampled. The chosen test site is located in the Val Canale valley already involved, since 2003, in at least three alluvial events.

The present project started with a sampling phase. In order to ensure the representativeness of the sample, it is important to identify significant collection points, in the source, transport and depositional areas, and to collect a huge quantity of heterogeneous material.

In the laboratory samples were subjected to grain-size, mineralogical and rheological analysis. Suspensions of the fine fractions were prepared at equal solids concentration and studied using a controlled stress rheometer. Different experimental methods were proved to individuate an appropriate methodology suitable to characterize the plastic behavior of the fine particle suspensions derived from the different sampling points.

With the range of values obtained, numerical simulations, using FLO-2D software, were performed in order to verify the consistency of the parameters and their representativeness even if a back analysis is not available.

## Debris Flow Process Reconstruction Based on UAV Remote Sensing Imagery of Disastrous Scenario

LIN J.

*Institute of Mountain Hazards and Environment, Chinese Academy of Sciences, CHENGDU, CHINA*

Debris flow is a moving mass of loose mud, sand, soil, rock, and water that travels down a slope under the influence of gravity. Two main characteristics of debris flow are high velocity and presence of wave front. The Newtonian fluid approach is no more valid as the flowing debris is a non-homogenous and non-Newtonian fluid. The rheological properties and bed friction of the debris are different. Therefore, the debris flow process is significant for researchers to find out its special mechanisms. The process reconstruction of debris flow is generally on the basis of qualitative principles and quantitative data obtained from field observations. It is also the prerequisite for exact numerical modeling and simulation of debris flow and prediction of its occurrence. However, due to the factors of safety, timeliness, and cost, the data acquired from field observations is limited in spatial coverage and accuracy.

With the advantages of low cost, flexible launch and landing, safety, under-cloud-flying, hyperspatial image resolution, Unmanned Aerial Vehicles (UAVs) are more suitable for obtaining remote sensing imagery of debris flow events in the mountainous areas. However, it is a very challenging task to reconstruct the debris flow process with raw imagery of disastrous scenario.

First of all, three-dimensional terrain of disastrous scenario can be reconstructed with UAV imagery.

Secondly, some kinetic parameters and damage information can be directly or indirectly interpreted from UAV imagery.

Thirdly, those values of key parameters acquired from UAV imagery can be integrated into the finite element model to reoccur the process of debris flow, including the stages of launching, transporting, and depositing.

\*\*\*\*\*

## The debris slide in the Móafellshyrna Mountain on the 20th of September 2012. Was it triggered by intense precipitation and earthquake activity or simply by melting of the permafrost?

SAEMUNDSSON T.(1), HELGASON J.(2), PETURSSON H.(3)

*(1) Natural Research Centre of North-western Iceland, SAUDARKROKUR, ICELAND ; (2) Met Office - Avalanche Center, Sudurgata 12, ISAFJORDUR, ICELAND ; (3) Icelandic Institute of Natural History, Borgum við Nordurslod, AKUREYRI, ICELAND*

A large debris slide fell from the Móafellshyrna Mountain in the Fljót area in Central North Iceland on the 20<sup>th</sup> of September 2012. The slide occurred after a month of intense precipitation followed by an earthquake cycle in N-Iceland. About 440 mm of precipitation fell in the area from the 20<sup>th</sup> of August to the 20<sup>th</sup> of September, where the annual precipitation is around 670 mm.

The slide originated in a 200 m wide cirque at 750 m height in the NW slope of the mountain where a frozen solid debris cone slid / crept off a 100 m high rock face into a steep talus slope. Frozen blocks of sediments fell on the water saturated talus slope and triggered another debris slide. It is estimated that around 300.000 to 350.000 m<sup>3</sup> of debris were removed from the talus slope.

An earthquake cycle started in N-Iceland on the morning of the 19<sup>th</sup> with two earthquakes M4 and M4.3 followed by number of smaller ones. Around 9:00 am on the 20<sup>th</sup> of September another earthquake M4.2 occurred. The debris flow activity started around 12:30 pm in northern part of the cirque, where frozen blocks of sediments began to fall down the rock face. The debris flow activity continued with increased activity for at least 1<sup>1</sup>/<sub>2</sub> hour, as large blocks of frozen sediments fell onto the talus slope below the southern part of the cirque.

The frozen sediments at 750 m height give clear indication of mountain permafrost in loose sediments at this altitude in the northern part of the Tröllaskagi peninsula. These observations are in good agreement with former calculations.

The cause of this debris flow activity is primary believed to be the intense precipitation followed by the earthquake activity. Melting of the permafrost can also have played a significant role as a triggering factor. The 30 year average temperature (1980-2010) is the highest for almost a century and the summer of 2012 was extremely dry and warm. The summer was also the sunniest in the past 80 years, with the record amount of sunshine hours.

### When Debris Flows Run Upslope: Tsunami Induced Debris Flows

WASSMER P.(1), W.M. ISKANDARSYAH T.Y.(2), GOMEZ C.(3), LAVIGNE F.(1), HART D.(3), PRATOMO I.(4), BEL J.(5)

(1) Laboratoire de Géographie Physique, UMR 8591, MEUDON, FRANCE ; (2) Universitas Padjadjaran, Fakultas Teknik Geologi, BANDUNG, INDONESIA ; (3) University of Canterbury, College of Science, Department of Geography, CHRISTCHURCH, NEW ZEALAND ; (4) Museum Geologi, Pusat Survei Geologi, BANDUNG, INDONESIA ; (5) Université de Strasbourg, Faculté de Géographie et d'Aménagement, STRASBOURG, FRANCE

Debris flows are usually considered to be forced by gravity and triggered by the combination of intense rainfall on mountain slopes characterised by readily mobilised clastic materials. Slope steepness increases the energy of the water. Strong erosion ensues, feeding the flow with clastic materials of various sizes, in turn increasing the flow density. Rheology ranges from hyper-concentrated to debris flow. In coastal areas, when a tsunami rushes inland the movement of the flow is not forced by gravity but by energy transferred to the water column when it is suddenly displaced, for example, by an earthquake, submarine eruption or landslide, volcano flank collapse, or meteoritic impact. When a tsunami moves landward, its progression and duration are controlled by several factors including topography, wave velocity, wave height, and position of the wave-train. The flow behaves in the same way as water flowing downslope. The turbulent front is progressively fed from coastal sediment eroded from beaches, sand dunes, and soils. The fluid takes onboard a huge amount of additional debris (e.g. rocks, concrete, wood, vegetation, vehicles), increasing its density. Depending on the depth of the flood, the importance of the run-up (which is a function of coastal morphology), and on the amount of mobilized material, tsunami waves can start to behave like 'debris flow'. Observations of tsunami deposits in Indonesia, Morocco and the Canary Islands evidence deposits of large clastic rocks mixed with coarse bioclasts in an unsorted matrix that could be interpreted as a debris flow deposit. Frame analysis of numerous urban video records of tsunami, from helicopters in Japan (Sendai 2011) and from building level in Indonesia (Banda Aceh 2004), support the idea that the global behaviour of the flow front resembles that of a gravity-driven debris flow.

\*\*\*\*\*

### Scale Amplification of Natural Debris-Flows Caused by Cascading Landslide Dam Failures

ZHOU G.

*Institute of Mountain Hazards and Environment, Chinese Academy of Sciences , CHENGDU, CHINA*

Debris-flows are typically caused by natural terrain landslides triggered by intense rainfalls. If an incoming mountain torrent collapses a series of landslide dams, large debris-flows can form in a very short period. Moreover, the torrent can amplify the scale of the debris-flow in the flow direction. The catastrophic debris-flows that occurred in Zhouqu, China on August 8, 2010, were caused by intense rainfall and the upstream cascading failure of landslide dams along the gullies. In the wake of the incident, a field study was conducted to better understand the process of cascading landslide dam failures and the formation of debris-flows. This paper looks at the geomorphic properties of the debris-flow gullies, estimates the peak flow discharges at different locations using three different methods, and analyzes the key cascading landslide dam failure modes and their effect on the scale amplification of debris-flows. The results show that 5 key modes (i.e. different landslide dam types) in Luojiayu Gully and 2 modes in Sanyanyu Gully accounted for the scale amplification of downstream debris-flows in the Zhouqu event. This study illustrates how the hazardous process of natural debris-flows can begin several kilometers upstream, as a complex cascade of geomorphic events (failure of landslide dams and erosion of the sloping bed) can cause to, can scale to become catastrophic discharges. Neglecting recognition of these hazardous geomorphic and hydrodynamic processes may result in high cost.

### **Study on Surge Triggered by Debris flow Plunging into Reservoir**

MIZUNO H.

*University of Tsukuba, TSUKUBA, IBARAKI, JAPAN*

Typhoon Ma-on brought a large amount of precipitation to Muroto Peninsula in Kochi Prefecture, Japan, on July 19, 2011, and caused a severe deep-seated landslide on the mountain slope on the right bank of Hiranabetanigawa, a side stream of the Nahari River. The material of landslide formed a debris flow and plunged into the reservoir of Hiranabe Dam, whose gates were opened in order to discharge. The debris flow generated waves, and the waves traveled not only downstream but also upstream, destroying the machines for opening gates of the Hiranabe Dam in the downstream and a suspension footbridge in the upstream. Records from the rain gauge station at Yanase indicate that the rain series began at 16:00 on July 17 and that 1035 mm of rainfall had accumulated by the time the washout occurred. At that time, the flow rate of the Nahari River was at the maximum, or in other words, had already begun to flood. Although changes in water level rarely propagate upstream, such changes induced by debris flows entering the mainstream can be propagated at the other side of the river, downstream, and upstream. Therefore, in this research, hydrologic conditions at the time the debris flow entered the Nahari River are estimated, and the effect of debris flows momentum influx on the propagation of the increased water level to the upstream area is clarified.

By analyzing the recorded data and hydraulic conditions, the estimated value of Froude number was in the range of 0.5 to 2.3. It was found that the wave traveled upstream uneasily. Next the process of changing water surface after the plunge of debris flows into the reservoir was analyzed by solving the two dimensional shallow water equations. It was found that the water surface at the suspension footbridge was raised to the bottom of the footbridge. It was found that the wave likely occurred and propagated toward the upstream part of the Nahari River because the momentum of the debris flow was added to the river's normal flow.

\*\*\*\*\*

### **Development of a geomorphological model for field instrumentation design, Tai O, Hong Kong**

NG K.Y., MILLIS S.W.

*Ove Arup & Partners (Hong Kong) Limited, HONG KONG, HONG KONG*

Geomorphology has been increasingly recognised as an essential component for natural terrain hazard assessment in Hong Kong. Whilst most studies have utilised geomorphological models to estimate the design volumes of potential landslide hazards for the mitigation measures, there are very few applied geomorphological studies for the design of field instrumentation works to monitor landslide movements. The aim of this study is to develop a geomorphological model to define the scope of instrumentation works for landslide monitoring with due regard to the morphological setting, slope/fluvial processes and geological materials.

The study area is located on a natural hillside overlooking Tai O on Lantau Island. The geomorphological model was developed by a comprehensive review of aerial photos available from Year 1963, geological publications, past instability records and further refined by detailed field mapping and intrusive ground investigation to reveal the depth and thickness of geological strata and processes.

The findings suggest that the hillside comprises areas of intermittent rock outcrops, talus, colluvium, as well as volcanic tuff and meta-siltstone/sandstone with various degrees of weathering. The key landslide mechanisms at the site appear to be associated with headward erosion of drainage channels, retrogressive mass movements and historical deep-seated movements associated with lithological control of weathering between the more resistant tuff and the weaker sedimentary strata.

The geomorphological assessment has identified areas of potential surface and sub-surface ground movements within a large landslide complex that facilitated the selection and design of the spatial arrangements of instrumentation systems to further confirm the landslide mechanisms at the site and investigate the rate of ground movements and their relationship with hydrogeological conditions.

**Quantification of mass movement and sediment flux at the decadal scale for Alpine mountain basins: the critical role of sediment connectivity**

MICHELETTI N., LANE S.N.

*University of Lausanne, LAUSANNE, SWITZERLAND*

Our understanding of mass movement and sediment flux is well established at both the event scale through direct measurement and over longer timescales through erosion measurement techniques (such as those based upon cosmogenic methods). However, there remains a significant dearth of information at the timescale of decades to centuries, despite this being the timescale over which significant hypotheses are raised over human impacts upon climate change and hence geomorphic systems. Extensive coverage of mountain environments by aerial imagery commonly begins in the 1940s, before the period of most rapid climate warming linked to human activity. Here we show how information contained in such imagery can be unlocked using archival digital photogrammetry to reconstruct quantitative histories of mass movement and sediment flux in high mountain Alpine systems, over the timescales of decades, through the quantitative comparison of successive digital elevation models, including the propagation of error to identify locations and volumes of significant erosion and deposition. We then combine this with classical geomorphological mapping to quantify the distribution of these erosion and deposition rates between different elements of the sediment flux system. We show that whilst particular elements of the sediment flux system prove to have been much more sensitive to climatic warming than others, their net impact is driven by their spatial organization and crucially, through connection between system elements. The presence of warming-driven sediment signals in the short-term dynamics of river basin systems is then highly location specific, as shaped by sediment connectivity.

\*\*\*\*\*

**Bayesian modeling of rainfall-triggered landslides using weather forecasting systems**

SANDRIC I.(1), CHITU Z.(2)

*(1) University of Bucharest, Faculty of Geography; Esri Romania, BUCHAREST, ROMANIA ; (2) National Institute of Hydrology and Water Management; Spiru Haret University, Faculty of Geography, BUCHAREST, ROMANIA*

This study is focused on modeling the rainfall-triggered landslides using a rainfall forecast with the WRF model. The main objective is to forecast the daily changes in landslides probability occurrence in Curvature Subcarpathians, Romania. The WRF (<http://www.wrf-model.org>) model is used to generate daily estimate of rainfall data and the Bayesian modeling is used to predict the landslides probability. The weather forecasting model is downscaled and estimates of soil moisture content are performed on a daily basis. The uncertainties from the weather forecasting model as analyzed in a Bayesian sensitivity model. Because mapping landslides is always associated with uncertainties in spatial delineation of landslides bodies uncertainties analyses are performed on the predisposing factors derived from digital elevation models have also uncertainties, coming either from the interpolation algorithms either from GIS data. All these uncertainties have been modeled using Monte Carlo simulations and for each simulation a new landslides probability map has been created. For all simulations the minimum, maximum, mean, median and standard deviation have been extracted, saved and analyzed. Thus, for each pixel and estimation of uncertainty for landslides susceptibility as assessment is obtained and spatially visualized

**Relations between landslide activity and fluvial erosion: slope-channel coupling recorded in tree rings and relief (Western Carpathians and Eastern Sudetes, Czech Republic)**

WISTUBA M., MALIK I.

*University of Silesia, KATOWICE, POLAND*

We have analysed slope-channel interactions in selected 3 stream valleys in Western Carpathians and Eastern Sudetes. With the use of dendrochronological tools we have dated occurrence of fluvial erosion in stream channels – basing on wood anatomy of roots exposed in eroded banks. We have also dated the occurrence of landsliding on slopes directly above studied channels – using eccentricity of tree-rings developed in spruce stems tilted and bent by ground movements. In order to recognize cause-effect relations between landsliding and fluvial erosion we have compared their temporal variability in the last decades with precipitation record (monthly totals and extreme daily totals). Comparison have shown that in analysed valleys these three phenomena appear asynchronously – they alternate. We have determined two types of cause-effect sequences (3-8 years long) of landslide-bank erosion coupling: (1) rainfall-landsliding-erosion – precipitation causes landslide activation, colluvia are delivered into the valley floor, then narrowed valley floor is a subject of intensified erosion (2) rainfall-erosion-landsliding – precipitation causes erosion in the valley floor, then erosion disturbs the equilibrium of a slope, which causes landsliding. Obtained dendrochronological datings also show that these processes can be a subject of a feedback: once the coupling have started it can continue without appearance of heavy rainfalls. We have analysed signs of coupling visible in the relief of studied valleys. Observations indicate that described slope-channel coupling, recorded in tree-rings, in longer periods can lead to gradual widening of valley floors (due to bank erosion and removing delivered landslide colluvia) and can lead to relief evolution from V-shaped into flat-bottomed valleys. Conducted studies prove the presence of landslide-erosion coupling in studied valleys and suggest its importance for general evolution of studied mountain areas.

\*\*\*\*\*

**Landslide hydrology: modelling the dynamic interactions between slope deformation, preferential flow and hydrology**

BOGAARD T.

*Delft University of Technology, faculty of Geosciences and Civil Engineering, Department of water management, DELFT, NETHERLANDS*

Hydrology has long been recognized as a crucial factor in the (re-)activation of landslides. It is well-known that fissures as well as other preferential flowpaths are very important for groundwater recharge within a landslide. However, this heterogeneous recharge results in local pore pressure increase whereas many model approaches in landslide hazard analysis assume a more homogeneously distributed recharge and thus pore pressure increase. Moreover, the specific dynamics within a landslide induces changes in fissure distribution due to differential movement. Feedback exists between changes in fissure properties, the hydrological behaviour and differential movement. So far, shifts and hysteresis in landslide activity have not been linked to these feedback mechanisms. This research aims to investigate the dynamic interaction between fissures and the resulting infiltration, storage and preferential flow and spatial and temporal variations in displacement.

Key to this research is the notion that differential displacement can open and close fissures acting as storage capacity, preferential pathways for infiltration and lateral groundwater drains. We studied these interactions both at the single fissure scale using coupled unsaturated-saturated flow models and we also modelled the dynamics at field scale in a distributed model coupling hydrological and stability dynamics developed in the PCRaster environmental modelling software package. Both approaches have been confronted with field data from slow moving landslides. The results show the importance of fissure characteristics in the hydrological behaviour of landslides. This approach results in increased insight in hillslope and landslide hydrology and provided a first step towards the quantification of the complex feedback between changing soil/fissure hydraulic characteristics and differential displacement. Furthermore, this study can help improving hazard assessment and mitigation works for slope stabilisation.

### **Variations in soil hydraulic conductivity as triggering factors of shallow landslides in the Serra do Mar, Brazil**

VILLAÇA GOMES M., VIEIRA B.C.  
*University of Sao Paulo, SAO PAULO, BRAZIL*

Periodically, widespread landslides events occur at the Serra do Mar Mountain Range, a geological and geomorphological compartment located on the Brazilian southeast coast. The slopes, with high angles and shallow soils, are mostly achieved by shallow landslides, and associated with rainfall events of greater magnitude, by debris flows. In the summer of 1966/67, rainfall reached a great extent of the Serra, triggering some of the most catastrophic events recorded in Brazil, among which stands out that occurred in Caraguatatuba City, São Paulo State. Previous works undertaken in the area showed that the 535 mm of rainfall recorded on 17 and 18 March, 1967, have left the soils, which range between 1-10 m depth, with a high degree of saturation and that shallow landslides were preferentially bound to two types of contact where generally are located the perched water table: mature soil (A and B horizons) - partially decomposed rock (C horizon) - bedrock. This fact shows that the mechanic discontinuities between these materials, with different constitutions and degrees of weathering, played a major role in the hillslope hydrology, favoring the occurrence of shallow landslides. Thus, the aim of this work is to identify the role of hydraulic discontinuities in soil mantles that triggers shallow landslides. Therefore, saturated hydraulic conductivity ( $K_{sat}$ ) tests were performed with the Guelph Permeameter, inside and outside of shallow landslide scars in the following depths: 0.25, 0.50, 1.00, 1.50, 2.00 and 2.50 m. Although the values were relatively homogeneous (between  $10^{-5}$  and  $10^{-6}$  m s<sup>-1</sup>), some hydraulic discontinuities were observed along the profiles, being more frequent between 1.00 to 2.00 m depth. It is noteworthy that, for the Serra, in these depths are triggered most shallow landslides, i.e. the mechanisms responsible for the instability at this depth reached critical levels, which may be caused by the development of saturation zones in such discontinuities.

\*\*\*\*\*

### **Mass movements characterization in the disaster occurred in the Morro do Baú Complex, Santa Catarina, Brazil, in November, 2008**

BAUZYS F., EGAS H.M.  
*Universidade Federal de Santa Catarina, FLORIANOPOLIS, BRAZIL*

This study aimed to characterize and analyze mass movements occurred in the Complexo Morro do Bau, Vale do Itajai, Santa Catarina state, Brazil, in November 2008, through the geoenvironmental aspects and geological-geomorphological compartments. This mass movements happened so widespread and were triggered by an extreme rainfall event, totaling more than 500 mm in 3 days, preceded by rainfall accumulated over time. This disaster caused a significant change in the landscape, large material losses and tens deaths. This research analyzed the geology and geomorphology of two watersheds located in this area: Ribeirão do Baú e Belchior Alto. The landslide inventory map and the types of landslides characterization, associated with environmental features mapped, provide an overview of the effects of extreme event in this watersheds. It was identified three geological areas: (A) Luiz Alves Complex (Archean and Proterozoic), with rocks like gneiss and hypersthene; (B) Itajai Group (Late Proterozoic), with sandstones, conglomerates and pelites, and (C) Quaternary sediments: deposits with slopes, alluvial terraces and river current. Geomorphologically, the dissection features a strong structural control, marked by faults, lineaments and drainage headwaters, that originate deep valleys and well fitted. The surface coverage develops by a deep chemical weathering, leading quite thick mantles of up to 30 meters deep, especially in Luiz Alves complex. As a main result we carried out the geological and geomorphological mapping of this watersheds and the analysis and reconstruction of the event by mapping processes and mass movements classification and debris flows.

### **The Catastrophic Landslide Event of January 2011 in Rio de Janeiro: Geomorphological and Geological Controls**

AMARAL C.(1), SILVA A.(2), LIMA I.(2), RAMALHO J.(2), VAREJÃO L.(2), RODRIGUES J.(2), LAGO L.(2), CORREIA R.(2), CORRÊA S.(2), PORTOCARRERO H.(3), MOTTA M.(4), VARGAS JR. E.(4), DE CAMPOS T.(4), DOURADO F.(3), SILVA L.(5), ARAÚJO J.(5), FERNANDES N.F.(5), VIEIRA B.(6)

(1) UERJ & DRM, RIO DE JANEIRO, BRAZIL ; (2) DRM-RIO DE JANEIRO GEOLOGICAL SERVICE, RIO DE JANEIRO, BRAZIL ; (3) RIO DE JANEIRO STATE UNIVERSITY, RIO DE JANEIRO, BRAZIL ; (4) CATHOLIC UNIVERSITY, RIO DE JANEIRO, BRAZIL ; (5) FEDERAL UNIVERSITY OF RIO DE JANEIRO, RIO DE JANEIRO, BRAZIL ; (6) UNIVERSITY OF SÃO PAULO, RIO DE JANEIRO, BRAZIL

In January 2011, intense rainstorms triggered thousands of landslides in the Serra do Mar mountainous region in the state of Rio de Janeiro. Cities like Nova Friburgo, Teresópolis, Petrópolis and Sumidouro, located about 50-100 km north/northeast from Rio de Janeiro city, were severely affected by rainstorms that lasted for about 10 hours, with total volumes of about 350 mm in 24 hours. This catastrophic event, the greatest natural disaster of Brazil, caused about 1300 deaths (350 people still missing) and 20,000 people homeless. During the disaster, the Rio de Janeiro Geological Survey together with three universities (Catholic University, Federal University of Rio de Janeiro and Rio de Janeiro State University) started an intensive research program in order to map landslide scars and define the most important conditioning factors. The results attested a widespread landslide distribution in this event, including hillslopes with different forms and steepness, different lithology types, rural and urban sites as well as transported and "in situ" soils. Mass movements were classified in four major groups: landslides initiated at the soil-rock boundary at the convex hilltop of rock escarpments; torrential flows, hyper-concentrated flows and debris flows (some about 10 km long); shallow translational slides with scars located in the upper portion of the residual soil (affecting the concave portions of gentle hillslopes); and landslides in urban areas (where most of the deaths occurred). However, the consequences of this event could have been much worse because most of the landslides did not take place in the areas of higher risk. Therefore, it is urgent the implementation of effective methodologies that will contribute to landslide disaster mitigation in the state, reducing deaths and economic losses associated with landslides and debris flows.

\*\*\*\*\*

### **Relation between the precipitation intensity and duration that originated the debris flows in Puebla, México**

CARDOSO-LANDA G.

*Instituto Tecnológico de Chilpancingo, CHILPANCINGO, MEXICO*

The debris flows are particularly dangerous for the life and the properties due to its high speeds and great destructive force, destroying houses, ways, bridges, trees and cultures, currents and ecosystems throughout its trajectory.

The extraordinary precipitation events are one of the predominant physical processes that produce the genesis of the debris flows. The empirical thresholds of precipitation are based on the historical analyses of the occurrence relation precipitation/debris flow, for example statistical analyses. At the present time a limited number of this type of empirical thresholds exists and have been used different diagrams to represent them, depending on the combinations of precipitation parameters more commonly used: antecedent precipitation, duration, accumulated intensity and rain, and the most commons are that obtained by Caine and Aleotti.

An analytical presentation of the concept of threshold of precipitation of a debris flow was recently introduced by Iritanno et al. (1998), who introduced the called function of mobilization  $Y(t)$ , indirectly describing all the factors that contribute to trigger a process of landslides and that is dependent, in every moment of time  $t$ , the amount of water infiltrate on the ground before the time  $t$ .

In the full article was applied the Iritanno's function of mobilization to the records of precipitation that produced the debris flows in the north of Puebla State, in the country of México, obtaining relationships intensity of rain-duration for these debris flows are greater from 3.43 to 2.1 times over empirical thresholds of precipitation generators of debris flows proposed by Caine and Aleotti in other regions of the world.

**The combined effect of complex rupture mechanism and topography in regional distribution pattern of the landslides triggered by the 12 January 2010 Haiti earthquake**

GORUM T.(1), VAN WESTEN C.(2), KORUP O.(3), VAN DER MEIJDE M.(2), FAN X.(2), VAN DER MEER F.D.(2)

(1) Natural Sciences Research Center, Yildiz Technical University,, ISTANBUL, TURKEY ; (2) Faculty of Geo-Information Science and Earth Observation (ITC), University of Twente, ENSCHEDE, NETHERLANDS ; (3) Institut für Erd- und Umweltwissenschaften, Universität Potsdam, POTSDAM, GERMANY

The 12 January 2010  $M_w$  7.0 Haiti earthquake occurred in a complex deformation zone at the boundary between the North American and Caribbean plates. Combined geodetic, geological and seismological data posited that surface deformation was driven by rupture on the Léogâne blind thrust fault, while part of the rupture occurred as deep lateral slip on the Enriquillo-Plantain Garden Fault (EPGF). The earthquake triggered >4492 landslides, mainly shallow, disrupted rock falls, debris-soil falls and slides, and few lateral spreads, over an area of ~2150 km<sup>2</sup>. The regional distribution of these slope failures defies those of most similar earthquake-triggered landslide episodes reported previously. Most of the coseismic landslides did not proliferate in the hanging wall of the main rupture, but clustered instead at the junction of the buried Léogâne and EPGF ruptures, where topographic relief and hillslope steepness are above average. Also, low-relief areas subjected to high coseismic uplift were prone to lesser hanging-wall slope instability than previous studies would suggest. Here we show that a combined effect of complex rupture dynamics and topography primarily control this previously rarely documented landslide pattern. Compared to recent thrust fault-earthquakes of similar magnitudes elsewhere, we conclude that lower static stress drop, mean coseismic displacement, and blind ruptures of the 2010 Haiti earthquake resulted in fewer, smaller, and more symmetrically distributed landslides within inter-fault blocks (i.e. hanging and foot wall), thus differs from previously documented surface rupture thrust faulting-earthquakes.

\*\*\*\*\*

**Relationships between large landslides and late orogenic antiforms in the Northern Apennines (N Italy): geomorphological, structural and thermochronological data**

CHELLI A.(1), VESCOVI P.(1), CARLINI M.(1), CLEMENZI L.(1), ARTONI A.(1), TELLINI C.(1), TORELLI L.(1), BALESTRIERI M.L.(2)

(1) University of Parma-Department of Physics and Earth Sciences, PARMA, ITALY ; (2) CNR-Geosciences and Georesources Institute, FLORENCE, ITALY

In active mountain belts, landslides occurrence is also connected with tectonic activity. Besides, denudation processes may be related to the response of the slopes to topographic disequilibria induced by tectonic uplift.

The Northern Apennines is an active fold and thrust belt made by convergence, since Late Cretaceous to present, between European and Africa plates.

Neotectonic activity is testified by seismicity, geologic features and landforms evolution. Northern Apennines experienced uplift since Pliocene with a remarkable increase in Late Pliocene and middle-upper Pleistocene.

This work aims to explore, through several case studies, the relationships between tectonic structures and large landslides (Ossella, Mt. Cervellino and Corniglio-Braia landslides). In the area between Enza Stream and Taro River catchment basins (in the Emilia Romagna region), north of the Apennine watershed, geological, geophysical and thermochronological data allowed to relate the surface uplift to antiforms representing the most recent tectonic structures in the area. Based on AFT thermochronological data, late orogenic uplift was active between 9 and 3 Ma, becoming younger from inner to outer portions of the mountain ranges; geological data constrain the activation of surface erosion processes since around 5 Ma.

The spatial relationship among the antiforms and large landslides and DSGSD has been established through the use of GIS. Detailed structural and geomorphologic analyses allowed to infer that landslide mechanism and type is controlled by the tectonic features. In fact, rock slides and huge complex landslides affect mainly the antiforms' forelimb. Thus, the disequilibria and steepening of the slopes, in response to surface uplift and folding, can be regarded as a main causes for most of the studied landslides which represent one of the latest (at least since 30000 yr BP) surficial process shaping late orogenic antiforms of this portion of the Apennine.

### **The apply of digital photogrammetric techniques in the generation of landslide inventories of high temporal frequency for villafufre area (Cantabria, Spain)**

GONZALEZ-DIEZ A.(1), FERNANDEZ-MAROTO G.(1), DOUGHTY M.W.(1), DIAZ DE TERAN J.R.(1), REMONDO J.(1), CARDENAL J.(2)

(1) DCITIMAC, UNIVERSITY OF CANTABRIA, SANTANDER, SPAIN ; (2) DEPARTMENT OF CARTOGRAPHIC, GEODETIC AND PHOTOGRAMMETRIC ENGINEERING. HIGHER TECHNICAL SCHOOL, UNIVERSITY OF JAEN, SPAIN, JAEN, SPAIN

The landslide inventory of Villafufre area (Cantabrian Range, Spain), is a good example of multitemporal landslide inventory because it has information about the existing landslides dated between 150,000 years to 1989, as well as their triggering factors. Recently, this inventory has been strengthened with data from a new inventory of high temporal frequency, obtained in recent years from aerial images taken from 2003 to 2009, every two or three years, treated through digital photogrammetry, image processing techniques, and with field methods. The images used have high geometrical accuracy (25 cm of pixel size), radiometric amplitude (color and infrared) and are in digital format. Using digital photogrammetric treatments, a reference system for the digital stereoscopic models obtained, by means the different flights used, was done which enables the right measurement between the geomorphic vectors identified. The metric and semantic capacities of images, allows the extraction of geomorphic information about the landscapes depicted. Beside, it is possible to apply this technique with historical aerial images in order to the analyses of landslide modifications. This technique allows to measure thousands of points in a short time, obtaining precise high point density models. With the use of such methods it is possible to reduce many of the errors associated with landslide inventories: to improve the accuracy in the position of the landslides identified; a correct identification of the affected area; a proper assessment of the volume involved; reduce the uncertainties concerning the loss of landslide mass by erosion or rehabilitation of the affected area. Moreover, it is possible to know precisely the role of trigger factor in the genesis of slope processes, obtain relevant data for landslide hazard models, and to know which is the paper of the recent (a few years) small landslides in slope instability and how these processes are contributing to geomorphic mass transfer.

\*\*\*\*\*

### **Defining digital signatures of landslide types for semi-automated landslide mapping**

EISANK C., HÖBLING D., FRIEDL B., BLASCHKE T.

*Department of Geoinformatics - Z\_GIS, University of Salzburg, SALZBURG, AUSTRIA*

In visual image interpretation experts delineate and categorize landslides manually by analyzing a series of qualitative characteristics that can be recognized in satellite images, aerial photographs or DEMs. Most criteria an interpreter would employ in manual mapping can be modeled with computer-based approaches such as object-based image analysis (OBIA). Due to the lack of standards, the selection of adequate criteria and rules for semi-automated digital mapping of landslides is usually performed in a subjective and time-consuming manner. To speed up the process and to make it reproducible, the implicit knowledge experts employ in manual interpretation has to be conceptualized and made explicit *prior* to semi-automated landslide modeling. The proposed strategy for conceptualizing landslide knowledge is two-fold: firstly, we analyze the available literature with respect to the knowledge and criteria that researchers applied to the mapping of landslides; secondly, we organize an expert workshop where the outcomes of the literature review will be critically discussed and a set of digital signatures of landslide types defined. These signatures should specify (i) the optimal combinations of spectral and morphometric layers for OBIA, and (ii) the optimal set of spectral, spatial, morphometric, textural and contextual features, as well as the feature-dependent thresholds and value ranges for the semi-automated mapping of landslides. We anticipate that the digital landslide signatures will heavily support the development of transparent and standardized landslide analysis workflows that are based on remote sensing data and implemented in OBIA frameworks.

### Age-dependent footprint of landslides in airborne laser scanning digital terrain models

*BELL R.(1), PETSCHKO H.(1), BRENNING A.(2)*

*(1) Dept. of Geography and Regional Research, University of Vienna, VIENNA, AUSTRIA ; (2) Department of Geography and Environmental Management, University of Waterloo, WATERLOO, CANADA*

To assess the frequency and magnitude of landslides and their role in landscape evolution and sediment budgets as well as to analyze the hazard and risks posed by them, it is crucial to compile substantially complete landslide inventories as a first step. Airborne laser scanning digital terrain models (ALS DTM) provide an excellent source for mapping landslides. However, nothing is known about the age if only an ALS DTM is used as data source. In some cases the relative age can be determined from the freshness of the of landslide features. This is of course not possible for landslides that have disappeared from ALS DTM due to natural erosion or human impact. Thus, field- or ALS DTM-based methods for analyzing the time span taken to modify and blur landslides are needed. In this study, examples from the Swabian Alb in southwest Germany and the Austrian province of Lower Austria are examined regarding possible relationships between landslide age and features detectable in the ALS DTM. Landslides were mapped based on the interpretation of ALS DTM hillshades and combined with landslide age information from other sources (e.g. historical archive analysis, aerial photographs, archive on damaging landslide events of the Geological Survey). The oldest dated landslide occurred approx. in 1690. Landslide age was compared to various roughness parameters derived from the ALS DTM. Furthermore, relationships between human land management and landslide features were analyzed. The resulting correlations suggest that ALS DTM-derived roughness parameters may have promise in assessing the age of landslides that are relatively unaffected by human land management. Many landslides disappeared completely within the analyzed sources due to human impact which may have a strong influence on the correct assessment of frequency and magnitude of landslides for a given study area.

\*\*\*\*\*

### Long-term monitoring of slow-moving landslides: examples from the Island of Malta (Central Mediterranean Sea)

*DEVOTO S.(1), FORTE E.(2), MANTOVANI M.(3), MOCNIK A.(2), PASUTO A.(3), PIACENTINI D.(1), SOLDATI M.(1)*

*(1) Dipartimento di Scienze Chimiche e Geologiche, Università di Modena e Reggio Emilia, MODENA, ITALY ; (2) Dipartimento di Matematica e Geoscienze, Università di Trieste, TRIESTE, ITALY ; (3) CNR-IRPI, Consiglio Nazionale delle Ricerche, Istituto di Ricerca per la Protezione Idrogeologica, PADOVA, ITALY*

Slow-moving landslides are widespread along the north-western coast of the Island of Malta. They mainly consist of rock spreads and block slides which are strictly linked to the geological setting of the area, namely the overposition of limestones and clayey terrains.

Despite their slow speed rates, these types of landslides may cause damages to infrastructures and favour the onset of faster mass movements, such as falls, slides, topples and flows. Therefore a quantitative analysis of rock spreading and block sliding evolution and their relationships with collateral slope movements are crucial in terms of hazard assessment.

This paper illustrates the results achieved by means of a multidisciplinary and multitechnical approach aiming at defining quantitatively the rates of displacements of the above-mentioned landslides, by combining the outcomes of a traditional geomorphological survey with the outputs of different monitoring techniques and geophysical investigations.

In particular, the state of activity and kinematics of landslides were determined by using GPS observations acquired over a 7-year-time interval, approximately every 6 months, at the end of wettest and driest seasons. The GPS networks, installed at Ghajn Tuffieha Bay and Il-Prajjet, consist of a series of benchmarks distributed on the limestone plateaus affected by rock spreading and on a series of blocks displaced by block sliding.

At Il-Prajjet, research activities have been integrated by GPR and ERT geophysical investigations and by the installation of two automated fissurimeters, which record continuously surface deformations related to two persistent discontinuities caused and enlarged by block sliding movements.

Finally, the multidisciplinary approach implemented enabled a deeper understanding of slow-landslide kinematics to be achieved and provided an essential basis for an improved coastal hazard assessment and management.

### **Monitoring of large mass movements on El Hierro, Canary Islands, Spain**

*BLAHUT J.(1), KLIMES J.(1), YEPES J.(2), GALINDO I.(3)*

*(1) Institute of Rock Structure and Mechanics, ASCR, PRAGUE, CZECH REPUBLIC ; (2) Department of Civil Engineering, University of Las Palmas de Gran Canaria, LAS PALMAS DE GRAN CANARIA, SPAIN ; (3) Department of Geoscientific Research and Forecast, Geological Survey of Spain, LAS PALMAS DE GRAN CANARIA, SPAIN*

Coastal and submarine landslides around volcanic islands are the largest known mass movements on Earth. Canary Islands in Spain are one of the places where they regularly occurred during last 300 thousand years, also triggering several tsunamis. In summer 2011 intense seismic activity begun and continues along a volcanic rift on the El Hierro island, the youngest and most tectonically active island of the archipelago.

The presentation aims to show first results from the newly set-up monitoring within a National Geographic Society/Waite Grants Program project: "Mega-landslides: imminent hazard or sleeping giants? Monitoring the landslide hazard related to ongoing volcanic activity around El Hierro, Canary Islands, Spain". The monitoring consists of precise TM-71 dilatometers capable of recording three dimensional movements between rock blocks, including rotations, at predefined time intervals and have a precision of better than 0.007 mm. Such precision allows recording micromovements along the faults and fissures that form potentially active landslide shear planes. Relation of the recorded movements to the seismic and aseismic activity on El Hierro will be presented and discussed.

\*\*\*\*\*

### **Landslide monitoring, temporal analysis and susceptibility assessment at Machu Picchu, Peru**

*VILIMEK V.(1), KLIMES J.(2)*

*(1) Charles University in Prague, Faculty of Science, PRAGUE, CZECH REPUBLIC ; (2) Academy of Sciences, Institute of Rock Structure and Mechanics, PRAGUE, CZECH REPUBLIC*

Since the alarming news about landslide threat for the Machu Picchu historical site has been revealed, net of dilatometric measurements monitors possible gravitational movements within the Inca city. Landslide occurrence information for its surrounding was acquired by multi-temporal aerial photo interpretation and field mapping. This showed that the coarse time resolution of the historical landslide information may lead to inaccurate interpretations regarding landslide occurrence frequencies in some parts of the study area. Also the assumption that the past landslide frequency can be used to describe the future landslide occurrence was not proved. Thereafter, unique conditional analyses were undertaken to assess landslide susceptibility using a limited number of preparatory factor maps. It showed that large majority of the Inca City is located on least susceptible areas within the region. The results of the susceptibility assessment combined with landslide occurrence frequencies may serve as a basis for the landslide hazard mitigation in the studied area. For these purposes, pixel based susceptibility maps were generalized into expert defined landslide management units. These units provide site managers with easily understandable and applicable hence reliable information about future landslide occurrences. An approach describing usage of the resulting susceptibility maps for on site mitigation purposes was described with respect to the needs of Machu Picchu site managers.

### **Landslides and erosion times on the Batchingou massive (West Cameroon)**

*MBATCHOU MBATCHOU S.(1), TCHINDJANG M.(2), WAKPONOU A.(1)*

*(1) University of Ngaoundéré, NGAOUNDERE, CAMEROON ; (2) University of Yaoundé I, YAOUNDE, CAMEROON*

Usually considered as the breadbasket of Cameroon for its rich farmlands, the Western Region Cameroon, densely populated, today faces accelerated erosion and run off linked to the agricultural and pastoral activities that provoke mass movements on exposed slopes. This is what we observed on the flanks of the Batchingou - Bana mountains. Heavy rainfall recorded in recent years due to climate variability (rainfall) also cause times erosion. This situation have resulted in the destruction of crops, obstruction of communications traffic and cut, then the destruction of sociocultural and art works (water tower). Also, these threats are due to increased of human activities.

This paper aims to assess the causes of the occurrence of these risks and vulnerability of exposed populations. Indeed, farming, deforestation (for heating), cattle rearing and digging of pits are growing enough to cause deep lacerations on the slopes. If the purpose of this article is a summary assessment of these phenomena, the methodology used consisted of a direct observation of erosion scars that we measured and spatialized on a map using a GPS (maximum precision 4m) and a double tape measure (50m). We also assessed the erosion rate by collecting eroded material for laboratory analysis.

The results show that the 50 scars observed and measured depended not only on human activities, but also the worsening climate which is a signal of climate variability and climate change that people still fail to adapt. Indeed, for them, the reduction leads to decreased on productivity due to late and misleading rainfall, and a significant crops exposure to dryness. Rainfall becomes scarce as in the past, but rare and violent.

Finally, it appears important to adopt anti erosion measures on this mountain such as seedling local species adapted to improve the cohesion of the soil with a good root system, reducing the effects of heavy and aggressive rainfall and ensuring better slope stabilization.

\*\*\*\*\*

### **Geomorphological evolution in some clayey small catchments of central and Island Italy during the last 15,000 years**

*AGNESI V.(1), ARINGOLI D.(2), BUCCOLINI M.(3), COCO L.(3), DEL MONTE M.(4), GENTILI B.(2), MATERAZZI M.(2), PAMBIANCHI G.(2), SCIARRA N.(3)*

*(1) University of Palermo, PALERMO, ITALY ; (2) University of Camerino, CAMERINO, ITALY ; (3) University of Chieti, CHIETI, ITALY ; (4) University of Rome, ROME, ITALY*

In this work the geomorphological evolution in some clayey small catchments of Italy has been recognized. The most important element of space-time correlation is the contemporary starting of the last phase of deepening of the hydrographic network, during the end of Late Pleistocene. More in detail, the four areas considered, representative of the clayey landscape of Italy, are located respectively on the Adriatic (2) and on Tyrrhenian (1) side of central Italy and in the central-western Sicily (1). All these areas are not so large (up to 12 km<sup>2</sup>) and are characterized by a similar composition of bedrock, similar relief and, in general, by analogous morphodynamic characteristics. These areas are affected by strong erosional processes of mixed type (landslides and/or runoff effects, like badlands). Basing on geomorphological correlations (locally supported also by radiometric dating), between surfaces considered coevals, it seems realistic to hypothesize an analogous temporal evolution of the hydrographic network among the different areas. These chronological/geomorphological constraints, allowed us to reconstruct, by means of topographic processing and GIS analyses, the geomorphological evolution of the sample areas and to estimate (in some cases) the soil erosion rate for the considered time span (last 15,000 years).

The results obtained are consistent with the data available in literature both for Italy and the Mediterranean Europe and, more in particular, confirmed that very intense erosion processes occurred as a consequence of the Holocene climatic improvement.

**Impacts of post glacial rebound on landsliding at a regional scale in Northern Iceland (Skagafjörður): spatial distribution and mechanisms involved**

COSSART E.(1), MERCIER D.(2), DECAULNE A.(3), FEUILLET T.(2), JONSSON H.(4), SAEMUNDSSON Þ.(4)  
(1) Paris 1 University (Panthéon-Sorbonne) - UMR Prodig CNRS, PARIS, FRANCE ; (2) Nantes University - UMR Geolittomer, NANTES, FRANCE ; (3) UMR Geolab, CLERMONT-FERRAND, FRANCE ; (4) NNV, SAUDARKROKUR, ICELAND

Paraglaciacion has often been considered as a main predisposing factor in landslide occurrence; its consequences have been particularly well identified at a fine scale (especially on bedrock jointing). However, the impacts of paraglaciacion on hillslope dynamics at a regional scale have never been discussed. We focus here on the Skagafjörður area (Northern Iceland) to compare the role of paraglaciacion with that of classic factors (topography, lithology etc.) in landslide occurrence, using a spatial analysis (based upon a chi-square test). The results highlight that landslides are over-represented in areas where post-glacial rebound was at its maximum (i.e. there is a concentration of landslides in the northern part), which fits well with the first chronological benchmark we obtained. Thus, landslides occurred during the first half of the Holocene, when the post-glacial uplift was at its maximum. Finally, the mechanisms that link post-glacial rebound and landsliding are discussed. On the one hand, post-glacial rebound is identified as an efficient process to generate slope instabilities, leading to a concentration of landslides in the northern part of the fjord. On the other hand, the expected role of glacial debuitressing cannot be demonstrated here, although it is often considered one of the most important paraglacial influences on landsliding.

\*\*\*\*\*

**Long-term slope instabilities of southern slopes of the Crimean Mountains (Ukraine), the role of karstification and slope-disequilibrium phases of the Late Quaternary**

HRADECKI J., PÁNEK T., SMOLKOVÁ V., ŠILHÁN K., LENART J.  
University of Ostrava, Faculty of Science, Dept. of Physical Geography and Geoecology, OSTRAVA, CZECH REPUBLIC

A giant system of various types of gravitational slope deformations was recognized in the area of the southern slopes of the Crimean Mountains. In this area we cantest the impact of palaeoenvironmental changes on the acceleration of slope processes and the role of preparatory and triggering factors. Main target of this paper is to determine time constraints of the slope deformations within coastal escarpments and adjacent lower parts of the slopes. With the use of various dating approaches we are able to focus on the timing of different slope instabilities. Individual phases of Late Quaternary landslide instabilities have been revealed by means of numerical dating. The dating methods of U/Th series, <sup>14</sup>C dating and <sup>36</sup>Cl exposure dating were used. We are working with a hypothesis that the period of slope instabilities was preceded by a variable-length pre-sliding phase which was connected with the weakening of the masiff as a result of weathering. In the studied region this phase was brought about by deep karstification and genesis of speleothemes within cave environment. In the case of the resulting landsliding, the caves opened putting an end to the development of speleothemes (unroofed caves). New CaCO<sub>3</sub> cements that formed in porespaces of block accumulations can be dated using U/Th series. The fact that the Crimean Mountains lie in a seismically active region stands for one of the possible triggering factors of the slope instability (esp. rockfalls, rock avalanches). One of the most important preparatory factors is karstification of the limestone masiff together with its tectonic features. Interrelations between karstified rocks and deep-seated ridge disintegration leading to slope instability propagation are studied on the basis of structural measurements and detailed geomorphological analyses.

### The 'El Forn' landslide, Principality of Andorra: a survivor of the late Pleistocene glacier activity

COROMINAS J.(1), PLANAS X.(2)

(1) *Universitat Politècnica de Catalunya, BarcelonaTech, BARCELONA, SPAIN* ; (2) *Ministeri d'Ordenament Territorial, Govern d'Andorra, ANDORRA LA VELLA, ANDORRA*

Landslide deposits are typically found blanketing the floor of valleys which were previously occupied by Pleistocene glaciers. Because of this, it is often assumed that such landslides occurred during the Holocene. The El Forn landslide is a complex large slide-earthflow located next to the Canillo village in the upper Valira river valley which age and instability process has been associated to the retreat of the Valira glacier (Soutadé, 1988; Corominas, 1990; Santacana, 1994). In this communication we present a new interpretation of the geomorphic evolution of El Forn landslide from the detailed analysis of a set of drilling cores, laboratory analysis, field reconnaissance and review of previous studies. The main phases of the emplacement of the landslide are discussed considering the sedimentological interpretation of the drill cores and dating of the organic remnants. At least, three main instability phases have been identified and several evidences indicate the existence of an on-going slope deformation in the landslide head. The first one started in the Upper Pleistocene. The relationship of the landslide with the Pleistocene glaciers has been revisited and we conclude that the oldest landslide deposits have been partially reshaped by the advance episodes of Valira glacier although some uncertainties still remain. Finally, present day stability of the landslide is discussed based on the existing geomorphic indicators, borehole inclinometers and DInSAR measurements. The results show the pattern of the present landslide activity is complex and that the different landslide units behave in a non-homogeneous way. The DinSAR results have also shown that the deformation of the rockmass extends beyond the "El Forn" boundary.

\*\*\*\*\*

### The morphogenesis of deep-seated landslides in the Romanian Curvature Carpathians as a proxy in regional landslide hazard assessment

MICU M.(1), JURCHESCU M.(1), MICU D.(1), BALTEANU D.(1), ZAREA R.(2), LEAU L.(2)

(1) *Institute of Geography, Romanian Academy, BUCHAREST, ROMANIA* ; (2) *Romanian Waters Company, Buzau-Ialomita Branch, BUZAU, ROMANIA*

The deep-seated landslides in the Curvature Carpathians of Romania are showing complex occurrence patterns, favored by the regional structural, lithological, neotectonic, climatic characteristics or land-use changes. The combination of the numerous predisposing, conditioning and triggering factors lead to a large spectrum of landslide types (e.g. shallow translational slides in the outer Subcarpathian hills, deep-seated debris and rock-slides in the Carpathian range), with different morphogenetic features. Landslide complexity is enhanced by the active seismicity of the area alongwith the results of an intense and long-lasting habitation (e.g. deforestation). Rainfalls are commonly a primary factor in landslide triggering in the study region (subsequently followed by freeze-thaw episodes and earthquake events) and depicts three patterns of manifestation: i) spring showers overlapping snowmelt, ii) torrential heavy summer rainfalls and iii) long-lasting autumn showers. The aim of this contribution is to reveal the morphogenetic and morphodynamic complexity of these processes, which may induce important uncertainties in the regional landslide hazard assessment. The paper also outlines the seasonal distribution of rainfalls, imprinting the dynamic character of the movement, which further controls the landslide morphology. The role of temperature in landslide failure is also discussed in this work, focusing on the spatial and temporal variability showed by the frequency and intensity of freeze-thaw cycles. Relationships between the main meteorological variables involved in landslide initiation are investigated herein (based on in situ measurements during several relevant episodes), which are discussed in terms of frequency-magnitude correlations. This study can be considered a step forward to a reliable hazard assessment by including more properly such complex processes in the regional landslide inventories.

### Repeated rock avalanches onto the Brenva Glacier (Mont Blanc massif, Italy) during the Holocene

DELINÉ P.(1), AKÇAR N.(2), IVY-OCHS S.(3), KUBIK P.W.(3)

(1) EDYTEM Lab, Université de Savoie, CNRS, LE BOURGET-DU-LAC, FRANCE ; (2) University of Bern, Institute of Geological Sciences, BERN, SWITZERLAND ; (3) Institute of Particle Physics, ETH Hönggerberg, ZÜRICH, SWITZERLAND

Rock avalanching represents a potential high risk for growing infrastructure and people living in high mountain areas. This hazardous process is due to steep slopes, high relief, intensive rock fracturing, seismicity, paraglacial control, periglacial climatic conditions and the presence and interaction of snow, glaciers, and permafrost. The timing of rock avalanche recurrence intervals is essential.

Numerous rock avalanches (RAs) have affected the south-east side of the Mont Blanc massif (European Alps) in the late Holocene, especially the basin of the Brenva Glacier, where the low-friction substrate offered by the glacier caused excessive run-out distances. As in 1920 and 1997, RAs (volume > 1 million m<sup>3</sup>) that travelled onto this glacier mobilized a large amount of ice and snow, and reached the valley floor. Historical (e.g. etchings), geomorphological evidences (e.g. concave slope of the lateral moraine distal flank), and datations (<sup>14</sup>C, <sup>10</sup>Be, lichenometry) suggest their high frequency during the Late Holocene. Besides the two 20<sup>th</sup> Century RAs, several RAs have been dated to: shortly before 1767 AD; the 14<sup>th</sup> Century (which will give sense to the legend of the destruction of the village of Saint-Jean de Purthud); the early Middle Ages (after 426–615 AD); and around 3 ka.

As suggested by the several decametre-thick sediment accumulation at the base of the south lateral moraine and the 1-m-thick rock deposit of the ice-RAs of 1920 and 1997, probably more than 10 RAs of this type occurred during the Neoglacial. In some cases, large debris flow were triggered by the catastrophic drainage of the lake resulting from the ice-rock damming of the Val Veny, as suggested by the matrix-supported diamicton of granite boulders exposed downstream in excavations over a 3 km distance and dated to 2.7–2.3 k.yr BP. With the current degradation of rockwall permafrost due to the global warming, Brenva RAs could therefore threaten again the valley floor in the next future.

\*\*\*\*\*

### Giant landslides at Late Pleistocene highstands of the Caspian Sea

PANEK T.(1), HRADECKY J.(1), MINAR J.(2)

(1) University of Ostrava, OSTRAVA, CZECH REPUBLIC ; (2) Comenius University, BRATISLAVA, SLOVAKIA

Late Pleistocene transgressions of the Caspian Sea, which culminated during the Early Khvalynian stage (+50 m a.s.l.), caused massive inundation of low-lying landscapes at the northern and north-eastern margin of the basin. Pronounced escarpment (with length ~1500 km and height 100 – 150 m) attributed to Khvalynian transgressions, is contemporarily situated mostly far from the Caspian Sea shoreline, in the semi-desert area of the western Kazakhstan in the Ustyurt plateau and Mangyshlak peninsula. Satellite image and DEM analysis together with field inspection revealed that the escarpment is affected by more than 300 giant landslides, >100 of which are characterized by the volume exceeding 10<sup>8</sup>m<sup>3</sup>. The landslides form distinctive amphitheater-shaped scarps and long-runout lobes accumulated on very gently (<5°) inclined slip surfaces. Deep-seated (>50 m) proximal rotational deformations affecting horizontally-bedded Miocene limestones, marls and claystones contrast with rather shallow (<10 m thick) lobes formed by completely mixed and thrust material with the signs of flow-type emplacements and liquefactions. A majority of landslide toes are clearly cut by Late Glacial and Holocene shorelines (e.g. +50, +22, 0, -20, -22 m a.s.l.), dated by AMS to particular stages occurring between Late Glacial – Middle Holocene. The age of these abrasion levels determines the minimum age of the landslides. Most of them originated most likely during the maximum highstand of the Early Khvalynian transgression (13.6-11.8 ka BP). However, distinct erosion of some landslides indicates their pre-Khvalynian age - probably attributed to earlier Late Khazar transgression (122-91 ka BP, -10 m a.s.l.). Based on our findings, ancient landslides occurring along the cliffs of the Late Pleistocene highstand of the Caspian Sea form the world's largest cluster of giant landslides situated entirely in the low-topography settings outside the mountain belts.

### Long term evolution of 'Les Vaches Noires' cliffs and spatio-temporal occurrence of landslides (Calvados, Basse-Normandie, France)

MAQUAIRE O.(1), AFCHAIN P.(1), COSTA S.(1), DAVIDSON R.(1), FRESSARD M.(1), LETORTU P.(1), LISSAK C.(1), THIRARD G.(1), THIERY Y.(2)

(1) LETG-Caen GEOPHEN, UMR 6554 CNRS, University of Caen Basse-Normandie, CAEN, FRANCE ; (2) EURO-ENGINEERING, PAU, FRANCE

Along 4.5 kilometers between Houlgate and Villers-sur-Mer (Calvados, Lower-Normandy), the 'Vaches Noires' cliffs evolve under the action of various sub-aerial weathering and marine processes. The main scarp is formed by a thick layer of limestone that recedes by rotational landslides and rockfalls. The downslope part presents a chaotic morphology affected by mudflows flowing between pinnacles.

The aims of the study are (1) on global scale, to analyze the historical and morphological evolution of these slopes, and (2) on local scale, to study a large landslide that occurred in the first part of the XX<sup>th</sup> century.

To analyze the historical and morphological evolution of the slopes, we used a diachronic method to quantify the displacements and the evolution of the coastline position since 1759. The analysis is based on numerous historical documents (archives) and spatial data (maps, cadastral surveys, air-photo images from the French national geographic institute (IGN) and GPS) which uncertainties and accuracies were quantified. In function of the nature of the materials, the toe erosion rate ranges from 10 to 15 cm per year which appears relatively low on human scale. However, at numerous places, the sea action is balanced by the materials provided by the active mudflows. The 'toe coast line' is then temporarily in progression during the necessary time for the sea action to put off the loosed and softy materials.

On local scale, for the 'Ermitage landslide', morphodynamic maps were performed in the field using cartographic GPS in order to define the surface morphology and the estimated landslide activity. These field measurements were completed with the analysis of all available air-photo images, in order to identify the occurrence dates and the possible landslides reactivations. The back calculation modelling allow the proposition of an evolution scenario, the position of the slip surface and the relative weight of the different triggering factors.

\*\*\*\*\*

### Magnitude-frequency scaling of a long-term inventory of landslides in Great Britain

HURST M.D., ELLIS M.E., ROYSE K.R., LEE K.A., FREEBOROUGH K.

British Geological Survey, NOTTINGHAM, UNITED KINGDOM

The link between the size of landslides and how often they occur is important to constrain both for the assessment of hazards associated with a particular event, and for understanding the long-term mass flux within a landscape. Landslide inventories are usually compiled following a particular triggering event such as an earthquake or storm, and their statistical behaviour is typically characterized by a form of power-law with a small-magnitude rollover. Here we explore the statistical behaviour of a geomorphic landslide inventory for Great Britain, consisting of mapped landslide deposits of unknown age. We use a subset from a high-quality database of over 10,000 landslides which have been verified by geological mapping of Great Britain over the last century. This landslide dataset exhibits magnitude-frequency scaling similar to that observed for event-triggered inventories. In this case, magnitude refers to the area of the deposit ( $A$ ) and frequency refers to how many have occurred in the geologically recent past (probably post-last glacial maximum). The resulting probability distribution is well approximated by both a double-Pareto distribution and a truncated inverse gamma function. This means that for medium-large landslides ( $A > 5000 \text{ m}^2$ ) the frequency of landslides decreases as a negative power-law function of the size of the event. Conversely for small landslides ( $A < 5000 \text{ m}^2$ ), frequency decreases with decreasing landslide size. The position of the peak in frequency ( $A \approx 5000 \text{ m}^2$ ) is offset towards larger events, compared with inventories where the record can be considered complete, which may suggest that the record is under-sampled with respect to smaller landslides. We split the data into broad lithologic groups to identify which rock/deposit types are most susceptible to landsliding. Finally, we categorise the type of mass movement to explore whether the scaling relationships vary for different failure processes.

**Tree-ring analysis in the reconstruction of slope instabilities associated with earthquakes and precipitation (the Crimean Mountains, Ukraine)**

ŠILHÁN K., PÁNEK T., HRADECKÝ J.

*University of Ostrava, OSTRAVA, CZECH REPUBLIC*

The Crimean Mountains in Ukraine constitute a seismically active region that is abundant in various types of mass movement. The limestone escarpments that rise above the Black Sea coast in the vicinity of the town of Yalta are particularly subject to considerable rockfall, landslide and debris flow processes that often endanger infrastructure and human life. One of these very active slopes is the area of the ancient Taraktash rockslide, characterized by active block-type movement (lateral spreading, toppling, incipient sliding), rockfall, ongoing sliding activity and debris flow. The aims of this study were (i) to employ tree-ring analysis to reconstruct a record of slope instabilities (mainly block-type movement, rockfall, landslide and debris flows) within the Taraktash slope deformation over a period of more than two centuries and (ii) to establish the degree of correlation between periods of enhanced slope activity and both historical earthquakes and climatic data. The temporal frequency of significant slope processes was addressed through a tree-ring analysis that took 738 increment cores from 255 Crimean pine trees (*Pinus nigra ssp. pallasiana*). The tree-ring record reveals periods of increased activity of block-type movements, rockfall and sliding during major earthquakes in 1790, 1875, 1927 and 1986. Although the slope processes studied are predominantly driven by seismic activity, their intensity and duration is also dependent on climatic factors.

\*\*\*\*\*

**Analysis of high magnitude mass movements on January 2011 rainstorm - Nova Friburgo, Brazil**

LIMA R., MARÇAL M.

*UFRJ Federal University of Rio de Janeiro, RIO DE JANEIRO, BRAZIL*

On January 11<sup>th</sup>, 2011, the Mountain Region of Rio de Janeiro State was hit by 240 mm rain in 24 hours. This event caused high magnitude landslides and floodouts, which displaced 2.354 people and damaged seven cities infrastructure. A role of actions from Brazilian authorities was mobilized to assist communities located in the most impacted areas.

The Mountain Region of Rio de Janeiro State is placed within the morphoclimatic context of "Serra do Mar", presenting scarped reliefs and 1.283mm annual precipitation. The rain concentration in the months of summer associated to susceptible soil types makes this region prone to the occurrence of mass movements.

This study aimed to identify the mass movements occurred during 2011 rainstorm, and to evaluate their geographical distribution, connectivity to the drainage system, stream channel morphology adjustments, as well as correlations with physiographic settings such as precipitation, land use and soil types.

The Dantas catchment (53km<sup>2</sup>) was the most affected area with 197 landslides mapped through Google Earth™ images. From this total, 44% reached river bed and 66% were disconnected to the channel. However, the sum of connected landslides represented a 4 times larger area than the disconnected ones (2 km<sup>2</sup> and 0,5km<sup>2</sup> respectively). The huge soil volume that reached river bed in different locations caused impoundment followed by sequential disruptions of high viscosity debris flow.

The landslide mapped areas were analyzed on a GIS environment, due to assess the relation of these occurrences with the land cover, soil type and precipitation. The results presented that 55% of the landslides occurred in areas with rainforest cover; 64% of events occurred in areas of Latosol Red Yellow alic; and 70% occurred in areas within 200-240mm precipitation.

Channel rehabilitation programs are being implemented on strategic sites of Dantas catchment due to reestablish geomorphic equilibrium condition.

**Spatio-temporal landslide dynamics and their contribution to the channel system from 1946 to 2011, Southern Ruahines, New Zealand**

*RIEDLER R.A.(1), FULLER I.C.(2), GLADE T.(1), BELL R.(1), MARDEN M.(3)*

*(1) University of Vienna, VIENNA, AUSTRIA ; (2) Massey University, PALMERSTON NORTH, NEW ZEALAND ; (3) Landcare Research, GISBORNE, NEW ZEALAND*

In New Zealand's North Island, where mountains occur in close proximity to densely populated areas, landslides strongly influence human activity and infrastructure. Shallow landslides frequently cause extensive damage to transport routes and contribute to the loss of fertile agricultural land further downstream.

The Southern Ruahine Range, reaching up to a height of 1710 m.s.l, is such an environment. While detailed investigations on landslide activity and sediment flux from this Range were carried out in the 1970's and 1980's there have been no follow-up-investigations since then. Our aim is to better understand the reasons for the spatio-temporal change in landslide distribution patterns, their connectivity to streams and their contribution to the sediment flux from the 221 km<sup>2</sup> study area over a 65-year period (1946 to 2011). In addition, these relationships were studied in greater detail within a 11.3 km<sup>2</sup> sub-catchment. Methods used to identify landslide locations and determine their connectivity to the channel system included aerial photograph interpretation and data capture using Geographic Information Systems supported by field measurements using RTK-dGPS and tacheometric surveys to derive landslide area and volumes.

Using six sets of aerial imagery (1946, 1974, 1977, 1999, 2005, 2011) more than 8,500 individual landslides were mapped. Landslide distribution is temporally and spatially variable. Total landslide area ranges from 0.24 km<sup>2</sup> (1999) to 2.25 km<sup>2</sup> (1974) and largely reflects the timing and influence of high intensity rainfall events. For the same reason hillslope-channel connectivity is similarly variable ranging from 38% of landslides in 1946 to 78% in 2005.

A better understanding of the drivers of these spatio-temporal changes in the Southern Ruahine Range will benefit policy decisions on remediation strategies required to limit future off-site damage as a consequence of landsliding and excessive sediment flux downstream of this Range.

\*\*\*\*\*

**Slope movements shaping the landscape in the Daunia Apennines (Southern Italy), and their effects on the built-up environment**

*PARISE M., VENNARI C.*

*CNR-IRPI, BARI, ITALY*

The southern Apennines of Italy are characterized for wide sectors by outcropping of clay materials, highly prone to slope movements. This determines a high susceptibility to landslides, which, combined to expansion of the urban areas during the second half of the last century, bring to high vulnerability, too. In Daunia, the hill-to-mountain sector of Apulia, a transition area between the Apulian plain and the Apenninic Chain, slope movements represent the main agent modelling the landscape. They are mostly in a dormant state of activity, which nevertheless can change to active, generally due to rainfall or seismic triggers. A further triggering factor, which is quite often under estimated, is represented by the human action. Lack in the identification of ancient slope movements, and planning of engineering works and construction in landslide-prone areas, has often resulted in partial or total re-activations of ancient slope movements. In the present article, through analysis of an historical database about landslides in Daunia, we intend to investigate the control exerted by gravity-related phenomena on the landscape, the interaction between slope movements and human activities, and the effects produced by landslides on the anthropogenic environment. The issue of rainfall-triggered slope movements is also dealt with, with a first attempt in identifying pluviometric thresholds for the study area.

### **Constraining relative chronologies of mass movements using soil characteristics**

KACPRZAK A.(1), MIGON P.(2)

(1) Jagiellonian University, Institute of Geography and Spatial Management, KRAKOW, POLAND ; (2) University of Wrocław, Department of Geography and Regional Development, WROCLAW, POLAND

There have not been too many attempts to use soils as indicators of the age of landslides. The Kamienne Mts (SW Poland) are a mountain range which abounds in morphological evidence of past mass movements, often suggesting processes of relatively recent date. However, no historical records of landslide activity are available. On the other hand, it is usually assumed that in this part of Europe most slope materials owe their origin to processes acting in the Pleistocene, while soils are largely products of Holocene pedogenesis altering periglacial slope materials.

We put up a working hypothesis that landslides in the Kamienne Mts, or at least some of them, may have occurred in the Holocene, hence under conditions similar to those of today, but prior to historic times. To verify this hypothesis a study of cover materials and soils on landslide-affected hillslopes was undertaken. It followed an assumption that, if soil material is not removed by erosion, the degree of soil profile development increases with age. If landslides predate the Holocene, soils within and outside landslide-affected slopes should have similar characteristics. Conversely, differences in the degree of soil development on individual slope facets may indicate that they are of different ages, supporting the hypothesis of Holocene age of landslides with poor soil development.

The main investigated soil characteristics included horizonation i.e. the number and thickness of specific soil horizons, the degree of development of soil structure, the content of organic carbon and its distribution in the soil profile, soil texture i.e. particle size distribution, the content and lithology of rock fragments. The results indicate that some slopes have been evidently unstable in the Holocene and different generations of landslides are recognized. Estimation of the absolute age of the landforms is not yet possible. So far we are able to discern Pleistocene forms from the ones originated in the Holocene.

\*\*\*\*\*

### **Crevice-type rockslide caves and their relation to the slope deformations**

LENART J., PÁNEK T.

Department of Physical Geography and Geoecology, Faculty of Science, University of Ostrava, OSTRAVA, CZECH REPUBLIC

Crevice-type rockslide caves are developed in a different types of rocks (sediments, granites, limestones) where some kinds of slope deformations are established. The rockslide caves originate by the process of fissure propagation within the landslide body. The different types of mechanisms are enforced such as toppling, spreading and rotational movement. Each of them is accompanied by the genesis of typical shapes of underground crevices. Some crevice-type cave systems reached the tens of meters depth and thousands of meters length. The caves occur in the different parts of landslide body such as initial crevices above the landslide headscarp, within the slid blocks in the transport zone of the landslide and within the doubled ridges. We investigated some of the typical localities with occurrence of landslides and crevice-type caves: e.g. Crimean mountains (limestones), Outer Western Carpathians (flysch rocks – sandstones, shales; limestones) by several methods: electrical resistivity tomography, microstructural measuring, speleological and surface mapping, digital elevation model and cave maps comparison. By using these techniques we can investigate the internal and external structure of the landslide just in place and discover the genesis, succession and origin of the slope deformation.

**Cliffs and screes: the Reverend Fisher, Bakker and Le Heux, Statham and Kirkby and DEM***RICHARDS K., BITHELL M.**University of Cambridge, CAMBRIDGE, UNITED KINGDOM*

The evolution of cliff-scrree systems is a geomorphological problem with a long pedigree. Fisher (1866) and Bakker and Le Heux (1947) first proposed geometrical solutions to the problem. In these, unit cliff recession generates a volume of particles that define incipient scree at the foot of the cliff, and as successive units of recession occur and the scree grows, the depositional layer becomes progressively thinner. This results in a convex rock core being formed beneath the scree as the cliff retreats. This geometric argument lacks consideration of the detailed process mechanics of scree development. Statham and Kirkby (1975, 1976) therefore focused attention on the rockfall process involved in determining scree geometry and surface sediment sorting; and explain how the scree slope increases as the cliff is buried, the scree tends to have a concave profile rather than being a series of surface-parallel layers, and coarser particles tend to accumulate at the scree foot. In this paper, we present results of Discrete Element Model simulations which reproduce the hypothesised character of the underlying rock core, but suggest that individual rockfall events play a rather limited role in determining bulk scree properties. Scree-head accumulations of rockfall debris instead trigger a sequence of mass failure events of varying scale that redistribute particles, lower the surface gradient temporarily, and generate a quasi-layered internal structure (with layers of sediment at lower gradients than the surface slope). Some of these events may mobilise a substantial proportion of the scree volume. The concavity of scree surface profiles is temporary, and more dependent on scree-head accumulation than on basal run-out; and the effect of mass movement on the scree geometry may only be seen intermittently (and very rarely in stable post-glacial screes). To test the hypothesis that mass movement is critical in scree evolution requires analysis of the internal stratigraphy.

\*\*\*\*\*

**Geomorphometric assessment of large mass movements in Afghanistan and Pakistan***SHRODER J.(1), BISHOP M.(2)**(1) University of Nebraska at Omaha, OMAHA, UNITED STATES ; (2) Texas A&M University, COLLEGE STATION, TX, UNITED STATES*

The discovery and investigation of large landslides in the Hindu Kush and western Himalaya over the last three decades has demonstrated the significant influence of mass movement phenomena on coupled systems and landscape evolution. In particular, large landslides influence fluvial and glacial systems, as well as regulate catastrophic flood flushing of sediment. Nevertheless, we still lack a systematic quantitative approach for assessing the character and influence of landslides on the geomorphic system. Consequently, the objectives of this research were to investigate the utility of geomorphometry to characterize landside surface topography. Specifically, we used an ASTER GDEM 30 m digital elevation model (DEM) and generated primary and secondary geomorphometric parameters to examine altitudinal variations associated with erosional and depositional landslide zones. Altitude profiles of slope and curvature indicate significant changes in the topography associated with erosion and deposition zones. Planarity and concave profile curvature characterize the upper zones, whereas hummocky topography and highly spatially variable curvature is characteristic in lower depositional zones. Collectively, the hypsometry and altitude profiles may be useful for differentiating landslides and evaluating landscape dynamics. In situations where large mass-movement toes have moved into active glacier or river valleys, the lower altitude mass-movement mass may have been removed by the active glacial or fluvial processes, which can limit analysis. Nonetheless, geomorphometric assessment of mass movement in the Hindu Kush and western Himalaya offers the prospect of quantitative assessments that may more adequately characterize processes than other methods used heretofore.

**Geomorphological processes affecting the conservation of the Shahr-e Zohak archaeological site (Central Afghanistan)**

*MARGOTTINI C.(1), FIDOLINI F.(2)*

*(1) Department of Geological Survey of Italy, ISPRA, ROMA, ITALY ; (2) Department of Earth Sciences, University of Firenze, FIRENZE, ITALY*

The remains of the Shahr-e Zohak fortress are located on a steep hill at the confluence of the Kalu and the Bamiyan rivers, about 15 km east of the city of Bamiyan (Central Afghanistan). The site is thought to have been founded in the Buddhist period (6th-7th century A.D.), even if the fortification is dated to the Islamic period. Its position provided excellent measures of natural defence and control of the valleys as communication routes.

The fortress is protected by ramparts built along the steep cliffs bounding the site and equipped with several watchtowers. The access to the fortress is located on the eastern flank of the hill and the path leads to a triangular plateau enclosed within ramparts and different kind of buildings, at the northern end of the hill. The citadel is located on the topmost part of the hill, on its southern side, separated from the plateau by a NW-SE oriented valley and it is protected by three more orders of walls.

Buildings are mainly made of mud-bricks, obtained by the clayey red mud resulting from the weathering of the local terrain, placed on top of gravelly foundations. Due to the prolonged exposition to weathering, the lack of conservation measures and the misuse during war periods, many buildings have collapsed or are prone to collapse. The main problem endangering the site is the lack of and adequate drainage system ruling the runoff. Ramparts located on the steep flanks of the hill are severely affected by gully erosion and siphoning and building-related material is accumulated in the depressions. The access path is locally eroded or buried by debris cones. The western margin of the plateau is rapidly retreating due to collapses, while the citadel is in danger due to diffuse or gully erosional processes developed on all its sides.

All available information will be used to develop a conservation plan, integrating measures against soil erosion and erosion of mud-bricks walls. Solutions will include mainly the use of traditional techniques to solve deeply investigated geomorphological processes.

## **Poster presentations:**

### **A 10-year record of erosion on badland sites in the Karoo, South Africa**

*BOARDMAN J.(1), FAVIS-MORTLOCK D.T.(1), FOSTER I.D.(2)*

*(1) University of Oxford, OXFORD, UNITED KINGDOM ; (2) University of Northampton, NORTHAMPTON, UNITED KINGDOM*

Badlands are developing in the South African Sneeuberg uplands on Holocene colluvia which are up to 6 m deep on footslopes and valley bottoms. The area was overgrazed by sheep from 1850 to 1950; stock numbers have been declining for the last 60 years. A farm raingauge within 5 km of the research sites gives annual average precipitation of almost 500 mm for the last 24 years, making this a relatively wet period.

Relatively long datasets of erosion (ten years or more) are rare in geomorphology. Such datasets are necessary to assess the impact of extreme events, and increasingly important as geomorphological studies place greater emphasis on the impacts of future climate change.

Ten sites with 25 erosion pins at each site were monitored annually from 2002 to 2012. Average rates of net erosion (average loss at eroding pins – average gain at accumulating pins) at each site range from 3.3 mm yr<sup>-1</sup> to 8.7 mm yr<sup>-1</sup>. These are approximately equivalent to erosion rates of 56 and 148 t ha<sup>-1</sup> yr<sup>-1</sup> respectively. At most of the study sites erosion rates are reasonably well correlated with amounts of rainfall within periods of measurement.

Badlands and seriously degraded land occupy less than 15% of the land surface. Most badland sites are well connected to valley-bottom gullies and, hence, small dams. Eroded sediment from a minority of sites is stored on footslopes and in fans and only intermittently moved to valley bottoms. Rates of sedimentation in small farm dam catchments without badlands are of the order of 5 t ha<sup>-1</sup> yr<sup>-1</sup> over the last 70 years. These rates rise to ~16 t ha<sup>-1</sup> yr<sup>-1</sup> when badlands are better connected to downstream dams. Over the last 50 years rainfall amounts on raindays have increased significantly and this 'climate change signal' is likely to have influenced erosion rates. The increase in rainfall intensity is also likely to influence erosion in the future. However, any climatically-driven increase in future erosion may be offset by falling stock numbers.

\*\*\*\*\*

### **Le site archéologique El Tajin (Etat de Veracruz, Mexque) serait situé sur un ancien dépôt gravitationnel pouvant être à nouveau affecté par de futurs glissements de terrain**

*VENCES SANCHEZ D.A.(1), OCHOA TEJEDA V.(2), OROPEZA OROZCO O.(1), PARROT J.F.(1)*

*(1) UNAM, MEXICO D.F., MEXICO ; (2) Université de Strasbourg, ESTRASBURGO, FRANCE*

La région étudiée comprend le site archéologique de l'une des villes les plus importantes de la Mésoamérique de la Période Classique (600 à 1200 de notre ère), El Tajin et son environnement qui correspond à la partie supérieure d'un micro-bassin. El Tajin se situe dans la région septentrionale et centrale de l'Etat de Veracruz, Mexique. On estime en première hypothèse que cette zone archéologique s'est édifée sur un paléo-talus de débris provenant d'un glissement de terrain qui aurait affecté les formations instables de l'Oligocène de la région (épaisses couches de conglomérats et lits de grès peu consolidés et de schistes argileux). La région présentant de nombreuses traces de glissements de terrain anciens ou actuels, le but de ce travail concerne la recherche des traits structuraux qui permettent de vérifier notre hypothèse. Un Modèle Digital d'Élévation de haute précision sous forme d'image matricielle (2 mètres de résolution au sol, échelle hypsométrique en centimètres) a été engendré à l'aide d'une interpolation multidirectionnelle à partir de données vectorielles couvrant la zone d'étude. Ce Modèle Digital montre indubitablement que la zone archéologique se situe effectivement sur un paléo-talus dont il est possible de reconstituer le mouvement en utilisant une simulation tridimensionnelle spécialement développée à cette fin. Il est ainsi possible de comprendre comment se produisit le glissement de terrain, quelle est l'épaisseur des dépôts et jusqu'où ceux-ci se sont étendus. De plus, la formation en arrière-plan d'une nouvelle zone d'arrachement semi-circulaire laisse présager en l'absence de mesures préventives la répétition dans un avenir plus ou moins proche d'un évènement semblable recouvrant alors les traces de cette zone archéologique de première importance.

### **Large Landslides in the Nepal Himalayas and their significance: The Phoksundo lake (Dolpo District, Western Nepal)**

*FORT M.(1), RIMAL L.N.(2), BOURLES D.(3), GUILLOU V.(3), BAILESCU S.(4), HUOT S.(5), LAMOTHE M.(5)*  
(1) Université Paris Diderot, UMR PRODIG, Sorbonne-Paris-Cité, PARIS, FRANCE ; (2) Department of Mines and Geology, Lainchaur, KATHMANDU, NEPAL ; (3) Aix-Marseille Université, CEREGE CNRS UMR 6635, 13545 AIX EN PROVENCE, FRANCE ; (4) Laboratoire Halma Ipel, UMR 8164 (CNRS), Université de Lille 1, 59655 VILLENEUVE D'ASCQ CEDEX, FRANCE ; (5) Laboratoire de Luminescence LUX de Montréal, Département des Sciences de la Terre et de l'Atmosphère, Université du Québec à Montréal, MONTRÉAL, QC H3C3P8, CANADA

Giant landslides are common features in active orogens. They are one of the most powerful processes of mountain slope denudation; they exert a strong control on upper watersheds morphology and sediment cascade. Their occurrence is generally considered as resulting from three main potential triggers: earthquakes, post-glacial debuttressing, permafrost melting. The Phoksundo lake (3600 m a.s.l.; area of 4.5-to-5 km<sup>2</sup>) is the second largest lake of Nepal; it owes its origin to the damming of the Suli Gad River by a large (4.5 km<sup>3</sup>) collapse of a mountain wall culminating at 5148 m, SE of the lake. The landslide morphology presents a series of mounds (metres to tens of metres high) and depressions of varying size. Its mass is composed of large blocks of massive dolomites found as far as west of Ringmo Village and down to the southern rim of the landslide dam. The coarse debris is widely mantled by a thick (up to 10 m) cover of silts, well prominent downstream above the Suli Gad gorges. Most of the Suli scarp is uphold by limestone's outcrops, but along the central part, where the former Phoksundo gorge is filled in by dark grey, fine sediments (till material), and overlain by orange conglomerates (including dolomites boulders), then by yellowish, unsorted conglomeratic material composed of blocks and calcareous silty matrix. This indicates the damming of the lake was caused by rockslides bodies derived from different parts of the rocky face bounding the lake in its SE part. The presence of glacial till at the very base of the sequence suggests the rockslide event is post-glacial. This assumption is now confirmed by cosmogenic dating: two consistent <sup>36</sup>Cl ages of 20,885 ±1675 argue for a single, massive event of paraglacial origin, that fit well with the last chronologies available on the Last Glacial Maximum in the Nepal Himalaya. OSL dating of silts ranges from Late Pleistocene to Holocene, and suggests a progressive trend to dryness of these Northern Himalayan regions.

\*\*\*\*\*

### **Geomorphological characterization and long-term monitoring of slope movements between Salurn and Neumarkt (Adige Valley, Italy)**

*BOCCALI C.(1), DEVOTO S.(2), KEIM L.(3), STRADA C.(3), ZINI L.(1)*  
(1) Università' degli Studi di Trieste, TRIESTE, ITALY ; (2) Università' degli Studi di Modena e Reggio Emilia, MODENA, ITALY ; (3) Provincia Autonoma di Bolzano, BOLZANO, ITALY

In collaboration with the Autonomous Province of Bolzano a detailed geomorphological survey was started to identify and describe the slope instabilities of a mountainside along the Adige river, that was indicated by the authorities because it wasn't already study in detail and because of the presence, directly under the slope, of elements at risk.

The study area is located in the Autonomous Province of Bolzano (Northern Italy) and extends 35 km<sup>2</sup>, fully on the left bank of the Adige river, from the border province of Bolzano - Trento until the beginning of the town of Neumarkt (BZ) in the North. The zone is dominated by two dolomitic massifs (Monte Madrutta and Monte Prato del Re), which are limited by high vertical walls and debris cones as connection with the valley.

The whole slope is affected by different types of landslide: primarily rock falls, topplings, slidings and, on large scale, lateral spreads. These last phenomena involve huge volumes of rock material. The described instabilities were identified in field by geomorphological and geological evidences: trenches of various sizes, cliff ledges, highly fractured rock masses and presence of ductile layers which underlie hard rocks.

During autumn 2009 a monitoring campaign was started in collaboration with the Autonomous Province of Bolzano. The first phase of monitoring activities has been consisted in a simple technique to measure periodically any movements of the detected fractures, i.e. the installation of fixed points inside the trenches.

In order to survey the surface displacements of the Monte Madrutta, GPS benchmarks have been installed on July 2012. This massif was long discussed by the experts because of a large landslide that generated the great dolomitic wall overlooking the Adige Valley.

This work illustrates the results of long-term monitoring and tries to identify the triggering factors that generate the above mentioned landslides.

### Features of gravitational slope deformation in Mizunesawa Basin, west Tokyo, Japan

SAWABE K.(1), KARIYA Y.(2)

(1) Graduate School of Literature, Senshu University, KAWASAKI, JAPAN ; (2) Senshu University, KAWASAKI, JAPAN

We describe the geology and geomorphology of Mizunesawa Basin (MB), in the upper reach of Tama River, from the viewpoint of gravitational slope deformation. MB is surrounded by several mountain peaks at heights in the range ca.1000–1600 m ASL, and the azimuth of the main course of Mizunesawa River is in the NW–SE direction. The bedrock of MB mainly comprises Cretaceous sedimentary rocks of Shimanto Group that strike NW–SE and dip 60° to 80° east. Further, ridge-top linear depressions usually <10 m deep and up to 450 m long and anticarps parallel to the main ridge are present in the MB. Valley bulging with minor anticarps and gentle slopes are observed along the valley side slopes immediately below ridge-top depressions and anticarps; rock deformation caused by toppling can also be observed along these side slopes. The radiocarbon ages of buried soils taken from a ridge-top linear depression indicate that the initial gravitational slope deformation might have occurred before 8000 cal BP and secondary progressive depression commenced after 3400 cal BP. Although MB exhibits well-developed features of gravitational slope deformation, neither accumulation terraces nor natural dams are present here; this fact points to the necessity of further study of long-term geomorphic development in the MB from the perspective of middle to large landslides resulting from rock deformation.

\*\*\*\*\*

### Historical rock avalanche in the east side of Mount Jizo, the Southern Japanese Alps, central Japan

KARIYA Y.

Senshu University, KAWASAKI, JAPAN

Bouldery deposits are present along Dondokosawa River in the east slope of Mount Jizo, the Southern Japanese Alps. Without any chronological and lithological evidence, it has been considered that these deposits were attributed to an ice-mass collapse that occurred during the Last Glacial maximum and resulted in considerable river aggradation at the foot of Mount Jizo. However, this study shows that these deposits have features indicative of a rock slide origin. Initial failure occurred on slopes ca. 2300 m ASL; the debris then travelled a distance of 3.6 km and was deposited around the valley floor of Dondokosawa River 1100 m ASL. The volume and H/L ratio of the deposits are estimated to be  $1.8 \times 10^7 \text{ m}^3$  and 0.32, respectively. The rock avalanche deposits comprise a thick gravel layer with granitic rock clasts only, though its present-day location is in a region with sedimentary bedrock. The rock clasts have characteristic jigsaw-puzzle structures, which indicate strong deformation by a landslide runout. The rock avalanche deposits immediately overlie a humic soil. Along the Marukawa River parallel to Dondokosawa River which had been blocked by a natural dam formed by the accumulation of rock avalanche deposits, these deposits are covered by fluvial sand layers and drifted wood trunks. Radiocarbon dating of drifted trunks and the wood fossils in a buried soil indicate the ages of the rock avalanche to be cal 778–793 AD. No large earthquakes have been reported in any historical document corresponding to this period. However, *Shoku Nihongi*, a national historical document, describes major losses resulting from floods in September 779 AD in ancient Shizuoka Prefecture just south of the study site; the heavy rains that occurred then may have triggered the rock avalanche. This study stresses on the importance of the chronological and lithological reevaluation of bouldery deposits in mountainous areas on a tectonically active margin.

### **Optimisation of Landslide monitoring based on geomorphological characterization**

MARCATO G.(1), DIXON N.(2), SPRIGGS M.(2), PASUTO A.(1)

(1) IRPI - CNR, PADUA, ITALY ; (2) School of Civil and Building Engineering, 2 Loughborough University, LEICESTERSHIRE, UNITED KINGDOM

The left flank of the Tagliamento River Valley, at Passo della Morte along the National Road 52, is affected by several hill-slope processes, characterized by different typologies and different states of activity. These phenomena were mainly caused by debuttressing due to melting glacier, which occupied the valley until 15000 years ago. The different instability processes involve two road tunnels and can interfere with the Tagliamento River, through a serious risk of valley damming.

The present research is focus on two geological features: blockslides developed in the past as a rock avalanche and a limestone rock mass characterised by a structural setting which presents predisposition to instability.

Geomorphological survey techniques allowed definition of the most critical zones and the points to be monitored for hazard assessment. In particular, the field investigation produced extensive information to enable rigorous decisions in terms of optimum sensor types to be employed taking into account the expecting outputs and a cost and benefit analysis.

After two years of data collection it can be concluded that the choice of sensors has been appropriate to define the geometric characteristics of the unstable masses, and hence to better understand and define the possible evolutionary scenarios of the slope instability. Moreover, it is possible to confirm that the sensor selection and monitoring layout design derived from the geomorphological characterisation could be used in the future as an alert/alarm system for risk mitigation.

\*\*\*\*\*

### **Contemporary hillslope processes sediment budgets in two glacier-connected drainage basins in western Norway**

LAUTE K., BEYLICH A.A.

Geological Survey of Norway (NGU), TRONDHEIM, NORWAY

Hillslopes in defined drainage basin systems function as key elements for sediment production, storage and transfers from sources to sinks. Rates of hillslope processes are exceptionally varied and affected by numerous influences of varying intensity, especially in sensitive cold climate environments. This research has been conducted over four years (since 2009) and focuses on (i) contemporary geomorphic process rates and sedimentary mass transfers within the drainage basins Erdalen (79.5 km<sup>2</sup>) and Bødalen (60 km<sup>2</sup>) in western Norway, (ii) the absolute and relative importance of the identified relevant denudational processes and (iii) the importance of sediment delivery from slope systems for the drainage basin sediment budgets. Relevant denudational processes are analysed by combining geomorphologic mapping, geophysical subsurface investigations, terrestrial laser scanning and spatial data analysis with process monitoring. For monitoring contemporary surface processes a designed program has been applied at selected hillslope test sites including e.g. installed nets for collecting freshly accumulated rockfall debris, remote cameras for monitoring rapid mass movement events (avalanches, slush- and debris flows), stone tracer lines for measuring surface movements as well as temperature loggers both in rock walls and talus slopes for analysing rock temperatures and mechanical weathering. Slope wash traps for analyzing slope wash denudation have been installed and measurements of solute concentrations at small hillslope drainage creeks for investigating the role of chemical denudation have been conducted. Results show that snow avalanches and rock falls are comparably important processes regarding geomorphic mass transfers. The level of slope-channel coupling is altogether limited. It is higher in Bødalen as compared to Erdalen causing comparably higher rates of sediment delivery from slopes into channels in Bødalen. Both drainage basins represent supply-limited systems.

### **Analysis of rainfall-induced shallow landslides in Jamne and Jaszcz stream valleys (Polish Carpathians)**

*BUCALA A.(1), ZYDRON T.(2), DEMCZUK P.(3), GRUCHOT A.(2)*

*(1) Institute of Geography PAS, KRAKOW, POLAND ; (2) Department of Water Engineering and Geotechnics Agricultural University, KRAKOW, POLAND ; (3) Department of Geomorphology, UMCS, LUBLIN, POLAND*

The subject of this paper is the analysis of stability loss of slopes in the Jaszcz and the Jamne stream valleys (the Gorce, the Flish Carpathians), that were caused by heavy rains in July 1997 and 2008, during which maximum daily precipitation was accordingly 70 mm and 76,3 mm. Both streams catchment areas are characterized by V-shaped deeply incised valleys, narrow channels and occurrence of numerous rock steps. More than 61% of slopes have the inclination above 18°. The Jaszcz stream catchment area is a narrow valley with steep slopes exposed mainly to south and north-east, where higher parts of slopes are covered by forests, meadows and pastures. In the lower parts of the catchment area arable lands dominate. The Jamne stream valley is wider, exposed to the south and mostly deforested or agriculturally used. Precipitation from the mentioned period caused activation of a number of landslides that were mostly shallow, translation and rotational slides. Field tests showed that the thickness of weathered clayey gravels was from 1.0 m to 1.6 m in lower part of slope. These formations have medium permeability, which is connected with low content of fine fractions. For determination of slope stability conditions in both catchment areas integrated calculations of infiltration and stability in GIS environment were carried out. For that purpose two calculative models were used, which describe infiltration process of rainfall in soil differently. In the first one – model SINMAP - steady subsurface flow was considered. In the other model – TRIGRS – infiltration of rainfall and changes of stability conditions related to diffusion process of water in soil as well as changes of pore water pressure are considered. The project is funded by the National Science Center (NN 306 659 940).

\*\*\*\*\*

### **An outline of landslide-triggering rainfall thresholds in the Flysch Carpathian Chain**

*BIL M.(1), DLUGOSZ M.(2), MICU M.(3)*

*(1) Transport Research Centre, BRNO, CZECH REPUBLIC ; (2) Institute of Geography and Spatial Organization, Polish Academy of Sciences, KRAKÓW, POLAND ; (3) Institute of Geography, Romanian Academy, BUCHAREST, ROMANIA*

The Carpathian Mountains is the most representative mountainous chain of the Central and Eastern Europe, extending along some 1,500 km from the Vienna basin (Austria) until the Timok Valley (Serbia). Compared with their highest altitude (2655 m), the flysch belt of the Carpathians, which borders the chain towards exterior, forms low and medium-altitude mountains reaching only 1400-1800 m. The climate, lithology (different strength sandstones, schistose marls and clays alternating with sands or gravels), together with the morpho-structural traits (intensely folded and faulted mountains, sometimes with steep slopes and large valley corridors) and active neotectonic movements, on which overlaps an intense and long lasting habitation, resulted in a wide variety of slope processes.

The landslides represent potential threats to a very large typology of elements at risk, and reliable risk management strategies should be based on proper susceptibility and hazard mapping and assessment. The determination of precipitation quantities leading to soil, regolith or bedrock saturation is difficult, due to diversified conditions of water infiltration and underground circulation and also due to their spatial distribution.

The purpose of this study is to outline, through local case-studies and regional evaluations, certain landslide-triggering rainfall thresholds, which will represent the basis for a proper landslide frequency-magnitude relationship assessment. Intense summer rainfalls, together with long-lasting autumn rains and spring showers (sometimes overlapping snowmelt) reflected by daily-monthly-annually average and maximum values were analyzed in areas like the Vizovice hilly land near the Czech–Slovak border, Beskid Niski Mts., Poland, and the Curvature Carpathians of Romania, also outlining the landslide-triggered typology.

The importance of this study is that gives the background of a regional landslide hazard assessment for one of Europe's most landslide-prone areas.

## **Analysis of spatial distribution of piping forms in Bieszczady Mts., Carpathians**

BERNATEK A.

*Institute of Geography and Spatial Management, Jagiellonian University, KRAKOW, POLAND*

Piping as a process of mechanical flushing of particles by underground streams leads to the formation of surface and subsurface forms. It has an influence on the mountain relief. The knowledge of spatial distribution of piping forms allows to recognize a role of piping in the shaping of mountain relief.

This paper presents first results of research on spatial distribution of piping forms in Bieszczady Mts. (Carpathians). Four areas were selected to the detailed investigation – two in High Bieszczady Mts. (Tyskowa and Wolosatka catchment) and two in Low Bieszczady Mts. (Cisowiec and Bereznica catchment). The detailed geomorphological mapping was carried out. Moreover the detailed geodesic measurements using electronic total station were undertaken.

Piping forms occur in groups of several forms. They develop on the slopes with inclination approximately 10-20 degrees, both on the slopes covered by forest and by grasslands. Moreover, they exist both on the abandoned slopes and slopes used for agriculture (mainly pasture).

According to the morphological relation with landforms, piping forms can be divided into three groups. The first group includes forms which are developed independently of the existing gullies. They are supposed to be an initial stage of formation of the gully. The second group presents forms already connected with gullies. They are in upper part of them, which confirm that they could begin the formation and development of gullies. The last group consists of forms related to the gullies transformed by landslides. They appeared because of the colluvial deposits in channels, where water infiltrates underground to adjust to new condition of runoff.

The analysis of spatial distribution of piping forms enables to recognize the role of piping in shaping of mountain relief. In addition, the geomorphological maps with marked piping forms allow to identify areas where potentially gullies can be developed.

\*\*\*\*\*

## **Impact of climate change on landslide reactivations in the French Alps**

LOPEZ SAEZ J.(1), CORONA C.(2), STOFFEL M.(3), BERGER F.(1)

*(1) Irstea, SAINT MARTIN D'HERES, FRANCE ; (2) CNRS UMR6042 Geolab, CLERMONT-FERRAND CEDEX, FRANCE ; (3) Laboratory of Dendrogeomorphology, Institute of Geological Sciences, University of Berne, BERNE, SWITZERLAND*

Past process activity on seven landslide bodies of the Riou Bourdoux catchment (southeastern French Alps) was reconstructed with an unusually large number of samples (3036 increment cores) from 759 conifers affected by past landslide reactivations. Based on 1298 growth anomalies identified in the cores, we identified 61 landslide phases since AD 1890. Logistic regressions and threshold analyses using monthly rainfall data and temperature anomalies indicate that landslides used to occur after wet winters with subsequent positive temperature anomalies in spring in the past, and thereby point to the crucial role of snowmelt in landslide triggering at the catchment scale. Since 1990, however, landslide activity in the Riou Bourdoux catchment shows an excessive and unprecedented increase in activity (12.5 events 10 yr<sup>-1</sup>), which is, in addition, favored by positive temperature anomalies in spring. This evolution suggests a shift from snowmelt induced landslides (controlled by winter precipitation) to events controlled by spring temperatures and add evidence to the hypothesis that climate change (and warmer springs) could further enhance landslide activity in the course of the 21<sup>st</sup> century.

### Hydrometeorological triggers of debris flows in the Tyrol region (Austria) since 1910

CORONA C.(1), STOFFEL M.(2), KAITNA R.(3), HÜBL J.(3)

(1) GEOLAB, CNRS UMR6042 Geolab, CLERMONT-FERRAND, FRANCE ; (2) Laboratory of Dendrogeomorphology, Institute of Geological Sciences, University of Berne, BERNE, SWITZERLAND ; (3) Institute of Mountain Risk Engineering, University of Natural Resources and Life Sciences, VIENNA, AUSTRIA

Through their unpredictable and sudden occurrence, debris flows represent a major hazard in many mountainous regions of the world. The understanding of the triggering factors of such events is crucial for hazard assessment, the forecasting of potential future events and for early warning systems. In the recent past, many studies have been published on debris-flow triggering, rainfall conditions, minimum thresholds, duration-intensity relationships or on antecedent moisture conditions. Yet, these studies often covered a rather limited temporal dimension and remained rather isolated for single torrents.

In the study we present here, the definition of triggering rainfall events is based on an unusually dense database, containing 1047 events and dating back to AD 1008. The assessment is based on a historical database of 181 debris-flow channels located in three different regions, 26 torrents and 36 meteorological stations, all located in the Austrian Alps. We report on the (i) timing and (ii) duration of precipitation events, (iii) the amount of rainfall involved, (iv) changes in the seasonality of events, (v) define minimum precipitation thresholds needed for the triggering of past debris-flow events and (vi) assess the percentage of rainfall events with certain thresholds leading to the triggering of a debris flow.

Results show that the debris-flow season in the Austrian Alps lasts from April to November with July being the month with the highest occurrence of events (30%) whereas events in April and November remain very scarce with 2% and 4%, respectively. The triggers are very sensitive to the selection of the meteorological dataset and to the region. Some 70% of the events were released after persistent advective rainfall of more than 3 days. Total precipitations sums involved in the triggering range from below 20 mm for short-duration events generally occurring in a single torrent to up over 180 mm for the long-lasting events.

\*\*\*\*\*

### Landslide development within the Barlad Plateau of Eastern Romania

NIACSU L.(1), IONITA I.(2)

(1) University "Alexandru Ioan Cuza", IASI, ROMANIA ; (2) University, ,

The Barlad Plateau, extending about 8,230 square kilometers is considered as the most typical unit of the Moldavian Plateau of the Eastern Romania. The Miocene-Pliocene clay-sandy layers are inter-bedded with shallow sandstone and limestone seams. These sedimentary layers that have outcropped as a result of erosion are gently dipping toward S-SE in the form of a monocline. Landslides have been recognized as an important environmental threat in the major subunits of the Barlad Plateau, namely: Central Moldavian Plateau, Falciu Hills and Tutova Rolling Hills.

Four main areas of monitoring landslides were explored such as successive aerial photographs of the 1960, 1970, 2005 and 2009 flights, repeated field surveys for a thorough reconnaissance of the study area, classical levelling work and GIS software applications as TNT Mips and Arc GIS. Also, the Caesium-137 technique has been used to get information on documenting sedimentation rates in some small catchments.

Results have indicated that the landslide development is strongly controlled by the northern and western looking steep faces of cuestas, by changes of rock composition and by human impact. Also, it showed great pulses in conjunction with the rainfall distribution. For example, half of the Upper Barlad catchment that drains an area of 22,560 ha is covered by landslides. Furthermore, the active landslides amounted 11% of the total (2,317 ha) after the rainy 1968-1973 period and since 1982 under drier conditions they gradually limited to 444.0 ha (2% of the total).

### **Landslide Distribution Induced by Large-scale Earthquakes in 2011, in Iwaki City, Japan**

SATO G.(1), HAYASHI K.(2), YAGI H.(3), HIGAKI D.(4)

(1) Teikyo Heisei University, TOKYO, JAPAN ; (2) Okuyama Boring Co., TOKYO, JAPAN ; (3) Yamagata University, YAMAGATA, JAPAN ; (4) Hirosaki University, HIROSAKI, JAPAN

Iwaki City in eastern Japan experienced two large-scale earthquakes in 2011: the Great Tohoku earthquake that occurred on March 11 and an active-fault earthquake that occurred on April 11. We developed a landslide distribution map of Iwaki City using aerial and satellite images; this map shows that the number of landslides induced by the April 11 aftershock alone accounted for 70% of all landslides induced by both the March 11 and April 11 earthquakes. In particular, we show that the distribution of landslides caused by the April 11 earthquake was determined by the structure of the fault and the lithological characteristics. The distribution of landslides was relatively concentrated around the hanging wall side of faults that appeared to be normal faults, and the large-scale landslides were concentrated in areas of Paleogene sedimentary rock.

\*\*\*\*\*

### **The unstable area of Ajanedo, Cantabria (Spain): A proposal for inclusion in Global Landslide Database**

FERNANDEZ MAROTO G.(1), GONZALEZ-DIEZ A.(2), DOUGHTY M.(2), MARTINEZ CEDRUN P.(1), DIAZ DE TERAN J.R.(2), REMONDO J.(2), CARDENAL J.(3)

(1) Universidad de Cantabria, TORRELAVEGA, SPAIN ; (2) Universidad de Cantabria, SANTANDER, SPAIN ; (3) Universidad de Jaen, JAEN, SPAIN

Inventories are a tool of special interest in the analysis of landslides hazard because through them you can get information from the spatial and temporal occurrence and the magnitude of landslides involved. Using LiDAR and photogrammetric techniques allows to make high-precision inventories, as it improves the spatial characterization of the event eliminating many of the errors that are attached to the mapping of landslides.

Ajanedo area (Cantabrian Range, Spain) is an area of great interest as it has many types of sliding as rock slides, rock falls and lateral spreads affecting the substrate, with clear signs of recent activity allow proposing to form part of a Global Landslide Database. This area is located at the junction of two tectonic accidents featured within the Cordillera, such as "El Escudo de Cabuérniga" Fault and the "Selaya-Arredondo" Fault, which currently show clear seismic activity, with some energetic episodes recorded during the past 11,000 years and emission of high doses of Radon<sup>222</sup> in the waters of the springs associated with these fractures. However, recent weather events (heavy rain, frost, etc..) have revived some of rock avalanches in the area.

Inventory developed has identified a large unstable area of over 212ha where deep landslides are numerous spatially related, among them are a large unstable area covered by forest, a graben area, areas with falling rocks linked the trace of the fault that crosses the zone and a zone of rock avalanches that it has presented numerous events of recent activity. The last event cut in 2006, the road leading to a neighboring locality, leaving her isolated. Besides the inventory has allowed to know the relationships between areas affected by landslides and the volume involved in the same, these data verify models frequency distributions of size-volume proposed in the literature.

### **Anatomy of a landslide: a study case in the vineyard of Champagne (France)**

BOLLOT N.(1), PIERRE G.(1), SAMYN K.(2), FRANCOIS B.(2), MARRE A.(1), GRANDJEAN G.(2), ZORNETTE N.(2), GARCIA O.(3)

(1) GEGENAA - EA 3795, Université de Reims Champagne-Ardenne, REIMS, FRANCE ; (2) BRGM, Risk Division, ORLÉANS, FRANCE ; (3) CIVC, Services techniques, EPERNAY, FRANCE

Mass movement, though unstudied and even unknown until the eighties, is the major process in the development of the hillslopes of the vineyard of Champagne. Thus far, they have been monitored by means of surface analysis, leading to large scale cartography of their relief. Slumps and associated earth flows are mostly concerned. Relative age of these processes is also known: oldest slumps occurred before the last glacial period, some of them (slump and earth flow) are reactivated during the Holocene, and the actual downslope movements, of various sizes, lead to major damages throughout the vineyard. Three of the most important recent slides occurred in Rilly la Montagne (1986), Cuis (1988) and Boursault (2000).

Surface analysis of these mass movements is not sufficient to understand the actual factors of slope instability. Such a study requires considerations of the following criteria: the thickness of the displaced material, its internal structure and its hydrogeological behaviour. Geophysical investigations (seismic surveying and electrical resistivity profiles) made on the rotational slide of Reuil (Marne valley) allow to specify these three points. First of all, and unexpected considering the low energy relief of the vineyard of Champagne, it is a deep-seated slump (60 m thick). Secondly, the knowledge of the internal structure of the displaced material, coupled with piezometric and pluviometric data, leads to a hydro-mechanical slope-model. As planning operations, often consisting in hydraulic managements, are conducted without taking into account slope processes (though most of the vineyard stands on mass movements!), it results in frequent reactivation of the landslides. Thus, a better knowledge of slope instability should permit to assign more means to correction and hazard prevention.

\*\*\*\*\*

### **Internal structure and triggering conditions of two recent shallow landslides in the Pays d'Auge plateau (Normandy, France)**

FRESSARD M.(1), MAQUAIRE O.(1), AMORESE D.(2), FONT M.(3), DAVIDSON R.(1), THIERY Y.(4)

(1) UMR 6554 CNRS, LETG-GEOPHEN, University of Caen Basse-Normandie, CAEN, FRANCE ; (2) Observatoire Volcanologique et Sismologique de Guadeloupe, IPGP, GOURBEYRE, FRANCE ; (3) UMR 6143 CNRS, M2C-Caen, University of Caen Basse-Normandie, CAEN, FRANCE ; (4) EURO-ENGINEERING, PAU, FRANCE

This study concentrates on the identification of the structure and the mechanical properties of two shallow landslides located in the Pays d'Auge plateau (Normandy, France). They are representative of the 180 shallow landslides inventoried on the region. The main objective is to understand the landslides dynamics and behaviour in order to quantify triggering thresholds that could complete the scarce historical data on the region for the hazard analysis.

For the landslide morphology and structure identification, a multi-method approach was selected. Morphodynamic maps were performed in the field using cartographic GPS in order to depict the surface morphology and map the estimated landslide activity. These field measurements were completed with the analysis of all available air-photo images from the French National Geographic Institute (IGN), to identify the occurrence dates and the possible landslides reactivations. For the landslides structure identification, multiple electric tomography profiles combined with augurings and penetration tests were conducted. Despite a globally low electric resistivity of the landslides materials (i.e.  $\pm < 80$  ohm.), the electric profiles show good agreement with the interpreted structure using the direct observations (augurings and penetration tests). They have then permitted the identification of the slipping surface, internal morphology and paleotopography of the landslides.

In combining the internal structure and the materials mechanical properties the safety factor was assessed using a finite slope model. The evolution of this safety factor according to the rainfall and the ground water levels show that the landslides are more likely to occur after long episodes of moderate precipitation with an important role of the preliminary conditions. These results are finally well in accordance with the prior general assumptions and the few available well dated landslides.

### **Morphometric and morphologic parameters and the occurrence of debris flow in Serra Do Mar (SP, Brazil)**

DIAS V.C., VIEIRA B.C.

*Universidade de Sao Paulo - USP, SAO PAULO, BRAZIL*

The occurrence of mass movement is related to several controlling factors, such as morphometric characteristics of the watershed (density and drainage type, number of fluvial channels and hierarchy) and morphology of the slope (lithology, vegetation and soil), wherefore these studies are clearly important for the elucidate the dynamic of the aforementioned factors. In Serra do Mar, a mountain range that extends for about 1,500 km along the southeastern coast of Brazil, the occurrence of landslides and debris flow in some basins is quite common, due to the relief characteristics and the high rainfall indexes. Thereby, the aim of this research is to identify the main morphometric and morphological factors that contribute to the occurrence of debris flow in the city of Caraguatatuba (SP), in the Serra do Mar. Because of intensity of debris flows processes that occurred, the Guaxinduba basin was selected for the study. The morphological and morphometric analysis were made by the elaboration of digital elevation model (DEM), the digitalization of topographic maps and the use of the ArcGis 10's tool (Hidrology). The location of the debris flows deposits was detected by the analysis of aerial photographs dated from 1973 and fieldworks. The major morphological and morphometrics characteristics indicated a strong structural control caused by the presence of geological faults, which influenced the river flow and the distribution of deposits. Besides, due to presence of many concave slopes, there is an accumulation of water in these curvatures, increasing the surface and subsurface flow, as well as sediments into the drainage. This research can contribute for risk potential of debris flow being useful for developing a better land use management, since this is an area with a large number of houses, which are subject to the possible losses arising from the occurrence of debris flow; moreover, the studies about those processes are scarce in Brazil, despite its high frequency.

\*\*\*\*\*

### **Mass movements, landscape and river morphology evolution around Bujumbura City in Burundi**

NKURUNZIZA P.

*Universite du Burundi, BUJUMBURA, BURUNDI*

The landscape around the Capital city of Burundi, Bujumbura, is subsequent to the forming of East Africa Rift Valley. This is constituted of the Rusizi-plain which is dominated by mountain ranges on both sides. The later are subject to vertical erosion which produces a landscape in V which characterizes a young phase of peneplanation in the spirit of the Davis theory.

Another important phenomenon to observe is the landslides and gullies which affect the landscape on a significant scale. The later are stimulated by river flow on the one hand and intense runoff on the other hand but also by anthropogenic action which is related to a high deforestation and bad agricultural practices.

The objective of this study is to demonstrate that in addition to the natural geomorphic change related to the meteoric action, the anthropogenic influence is a factor which has a negative impact on the geomorphology of the studied area. Thus, due to the bad agricultural practices, we can observe an accelerate erosion of the catchment area which endangers the future generations. Indeed, the mass movements which occur through the reduction of the vegetal coverage and bad agro-technical practices will quickly exposed the rocks at the surface. Moreover, the lack of vegetal coverage combined with the climate change produce dramatically heavy erosion, floods and increases the sediments rate in the Tanganyika Lake.

Another aspect to be analyzed in this study is the impact of a quick and planning loss urbanization of Bujumbura City related not only to rivers morphology but also to the environmental and socio-economic problematic. Indeed, the rivers flow is disturbed because of intensive buildings material exploitation and household waste discharge in the rivers.

Those phenomena which can be considered as "geohazards" will be analyzed with modern methods using combined methods of remote sensing and mapping using the software ArcGis 10, real photos and direct observations on the field.

**Environmental fragility of watershed of Serido River (RN/PB - Brazil): subsidies for territorial environmental planning**

*PEREIRA NETO M.C., FERNANDES E.*

*Federal University of Rio Grande do Norte, NATAL, BRAZIL*

There are many applications coming from geomorphological studies and their different constitutive and inter related elements, to the implementation of public politics of planning and environmental management. This paper presents an analysis of the environmental fragility of the watershed of Seridó River, situated between the states of Paraíba and Rio Grande do Norte (Brazil), including the identification of possible unstable areas. It is based on the methodological approach of Ecodynamics of the French researcher J. Tricart (1977) and on the operationalisation proposal advocated by the Brazilian J. Ross (1994), related to the Potential and Emerging Ecodynamic Units, grounded in the index of relief dissection or the topographic roughness, soil, rainfall and land use/vegetal cover. Under a quantitative perspective, the results obtained from the analysis of the watershed can be divided into classes of potential fragility: around 2.613,0 Km<sup>2</sup> of low intensity, 5.188,4 Km<sup>2</sup> of medium intensity and 2.585,5 Km<sup>2</sup> of high intensity. Concerning the emerging fragility, the results are close to 2.212,0 Km<sup>2</sup> of low intensity, 6.191,23 Km<sup>2</sup> of medium intensity and 2.062,34 of high intensity. The collected data is relevant for the territorial and environmental planning of the watershed, once we can still verify a close association of the cities on the central area of desertification with the areas of high environmental instability/fragility. This is an important tool to the understanding of the potential susceptibility of the natural and anthropic environments related to the advance and/or intensification of the erosion process, rock falls, mass movements, among other phenomena inside the potential unstable areas. From this perspective, the continuity of this research becomes extremely important to the understanding and arrangement of the process, together with the engendering and sustainability of the system in its totality.

\*\*\*\*\*

**Monitoring of sediment movement in an artificial forest, Japanese steep mountain**

*NISHII R.(1), IMAIZUMI F.(2), UENO K.(3), KUROBE K.(3)*

*(1) University of Tsukuba, SHIZUOKA, JAPAN ; (2) Shizuoka University, SHIZUOKA, JAPAN ; (3) University of Tsukuba, TSUKUBA, JAPAN*

Artificial forests are widely distributed in steep slopes, Japanese mountains. On such steep artificial forests, sediment is easily transported by surface flow as well as gravity acting on the sediment itself. Therefore, sediment movement near ground surface can be sensitive to rainfall and freeze-thaw action. The processes and weight of sediment movement near ground surface were evaluated in an hinoki (Japanese cypress) artificial forest, Ikawa University Forest (about 1400 m a.s.l.), by sediment trap survey from June 2011 to March 2012; Six traps were set up on the slopes of three types which are convex, concave and planer slopes. Sediment accumulated in the traps was collected and weighed 10 times during the period. Concurrently, data loggers monitored meteorological parameters, including precipitation, air and ground surface temperatures and soil moisture. The total weight of sediment indicated large variations from 3 kg to 250 kg depending on the traps. Such a difference in the weight seems, in addition to the slope shapes, to be caused by materials (grain size) composing the ground. During the observation, the sediment movement indicated temporal variation. Timing of active sediment movement corresponded with the intense rainfall events (>50 mm/day). This result suggests that surface flow is important for sediment movement.

**Assessing of soil loss caused by active landsliding at the catchment scale: comparison of two different methods in Japan and Italy**

OKAMOTO A.(1), UCHIDA T.(1), HAYASHI S.I.(1), CAVALLI M.(2), MARCATO G.(2), PASUTO A.(2)

(1) National Institute for Land and Infrastructure Management, IBARAKI, JAPAN ; (2) IRPI - CNR, PADUA, ITALY

Sediment transport rate in mountainous streams is strongly controlled by sediment yield due to erosion and landslides, therefore giving a valuable contribution in the definition of the state of activity and potential impact of active landslides. However, a comprehensive monitoring system of sediment dynamics is usually very expensive, time consuming and above all technologically complicated. In this paper we compare two different approaches used in two test sites in Japan and Italy.

The difficulties in directly monitoring of traction processes have been widely recognized and prompted research towards indirect monitoring techniques, including acoustic and seismic methods. Recently, a new method to indirectly measure the volume of bedload transport from sound pressure data, provided by hydrophones, was proposed. The preliminary results of the measurement campaigns in the Japanese test site will be here presented showing that the bedload transport rate evaluated by hydrophone fit very well with the data gathered by direct sampling for both long- and short-term time spans.

In the Italian test site, a geomorphometric approach, consisting in computing the difference of DTMs derived from LiDAR data acquired at different times, has been carried out at catchment scale helping assessing the loss of soil caused by erosion processes and in the identification of areas of sediment deposition during a specified time span. This approach is suitable for the study of processes with higher magnitude than sediment transport causing morphological variations higher than the propagated DTMs errors (i.e. debris flow).

The possible integration of these approaches can cover a wide range of sediment transport processes (from suspended sediment to debris flow) that affect mountain basins. Therefore, the results so far obtained clearly show that these analyses can be functional in establishing a comprehensive management plan for a sustainable land use, and in designing of mitigation works.

\*\*\*\*\*

**Statistic/cartographic approach to the geomorphological analysis of slope instabilities in the periglacial environments of the Aosta valley (Western Alps, NW-Italy)**

PALOMBA M.(1), GIARDINO M.(2), RATTO S.(3), POGLIOTTI P.(4)

(1) Dipartimento di Scienze della Terra - Università di Torino, TORINO, ITALY ; (2) Dipartimento di Scienze della Terra - Università di Torino, TORINO, ITALY ; (3) Centro Funzionale Regione Autonoma Valle d'Aosta, AOSTA, ITALY ; (4) Arpa Valle d'Aosta, AOSTA, ITALY

Geomorphological studies have been performed at a regional scale in the Aosta Valley Region (a small alpine region located in NW Italy) to better understand landslide spatial and temporal frequency and to investigate the main controlling factors of instability in high mountain areas of possible permafrost degradation. A comparison between the high mountain areas and the rest of the territory has been also performed. A great amount of data collected and analysed into a GIS system: different landslides inventories (IFFI Project Database, "Catasto Dissesti"), permafrost distribution maps and several geothematic maps produced within the research for the analysis of environmental controlling factors of instability (i.e. slope and aspect maps derived from the Digital Elevation Model for topographic factors and geological maps for litho-structural ones). Then, spatial analysis and statistical studies have been applied to 255 identified landslides within the areas with permafrost: mainly rock falls, corresponding to a landslide density equal to 0.48 events/km<sup>2</sup> and a landslide index of 11%. Data considerably lower than the analogous values calculated for the whole region (respectively 1.18 events/km<sup>2</sup> and 19%). Furthermore, in these areas it has been observed that, in terms of landslides mean areal extent, the obtained values are higher than those of the rest of the region for almost all types of movement (i.e. rock falls increase in the mean areal extent is more than 40%). Only in the case of Deep-seated Gravitational Slope Deformations the values are considerably inferior, because of their lower evolution degree in high mountain areas. The landslide index calculated for all the classes of the controlling factors considered within the research highlighted how, almost in all cases, areas with permafrost show lower values than the rest of the territory.

### Topographic controls and mathematical modeling of landslides in Southern Brazil

*SILVA L., ARAÚJO J., BRAGA B., FERNANDES N.*

*Federal University of Rio de Janeiro, RIO DE JANEIRO, BRAZIL*

Mass movements are natural phenomena that occur on the slopes and are important agents working in landscape development. In addition to the mass movements occurring in natural slopes, there is also a large number of accidents induced by human action in the landscape. The change of use and land cover for the introduction of agriculture is a good example that have affected the stability of slopes. In Brazil, especially in the southern and southeastern regions, areas of original natural rain forest have been continuously replaced by agriculture during the last decades. In November 2008, a major landslide event took place in a rural area with intensive agriculture in the state of Santa Catarina (Morro do Baú) where many catastrophic landslides were triggered after a long rainy period. In this area, the natural forest has been replaced by huge banana and pine plantations. In this study, based on field mapping and modeling, we characterize the role played by geomorphological and geological factors in controlling the spatial distribution of landslides in the Morro do Baú area. In order to attain such objective, a digital elevation model of the basin was generated with a 10m grid in which the topographic parameters were obtained. The spatial distribution of the scars from this major event was mapped from another image, obtained immediately after the landslide event. Numerical simulations with the SHALSTAB model were carried out in the basin and the results compared to the original location of the scars in the field. The results suggest that the combination of field mapping with the numerical simulation scenarios may contribute to the definition of better land management practices in such environment. Besides this, the replacement of the natural rain forest by huge banana plantations in this environment may have played a major role in defining the spatial distribution of landslides scars and the magnitude of the landslides generated.

\*\*\*\*\*

### Landslide Inventory in Ialomita Sub Carpathians, Romania

*CHITU Z.(1), ISTRATE A.(2), SANDRIC I.(3)*

*(1) National Institute of Hydrology and Water Management; Faculty of Geography, Spiru Haret University, BUCHAREST, ROMANIA ; (2) Faculty of Geography, Valahia University, TARGOVISTE, ROMANIA ; (3) Faculty of Geography, University of Bucharest, BUCHAREST, ROMANIA*

Landslides are a common geomorphic process in Ialomita Sub Carpathians, producing numerous damages to the infrastructure every few years (1970, 1972, 1975, 1978, 1980, 1986, 1992, 1995, 1996, 1997, 1998, 2005, 2006, 2010 and 2012). This area is located in the western part of Curvature Sub Carpathians, one of the most complex geological units in Romania. In order to reduce landslide consequences, a landslide inventory was carried out for landslide susceptibility and hazard assessment. In Ialomita Sub Carpathians, information about spatial and temporal landslide distribution was recorded (from 1965 to 2000) as point features by Istrate et al. (2006). Beginning with 2007, a landslide inventory, represented by polygon features, was carried out combining geomorphic field mapping and visual interpretation of aerial oblique images. Geomorphic field mapping was done during 2007-2010, using a Total Station SOKKIA, PDA Asus with Garmin Receiver and SIRF III antenna. The oblique images were collected during three flights over the study area between 2008 and 2010 using a small aircraft, model Cessna F172H and a DSLR camera Canon 400D, 10 Megapixels with Tamron lens 18-250mm. Over 1800 landslides were mapped and classified. The landslide inventory was used to generate two landslide susceptibility maps, based on expert knowledge and Weight of Evidence methods. The validation of the two landslide susceptibility maps using ROC method revealed that the ROC curve value (0.76) for the map based on expert knowledge method presents a value close to the ROC curve value (0.82) for the map carried out with Weight of Evidence method. This result leads us to believe that expert knowledge method for landslide susceptibility assessment can be used successfully, saving time and money, when there is a reliable inventory of landslides.

**Geomorphic coupling of deep-seated landslides and channels: Paltineni case-study (Buzau Carpathians, Romania)**

*BELL R.(1), MICU M.(2)*

*(1) Dept. of Geography and Regional Research, University of Vienna, VIENNA, AUSTRIA ; (2) Institute of Geography, Romanian Academy, BUCHAREST, ROMANIA*

The impact of deep-seated landslides on river network has a long history within the Curvature area of the Romanian Carpathians. Several such processes were recorded since 1883, consisting of deep-seated rock and debris-slides and debris-flows, which caused river shifts, blockages and lake occurrences. Developed mostly between 600-900 m a.s.l., they formed permanent lakes (Balatau lake, on Uz river) or temporary lakes (on Basca Rozile, Slanic, Teherau, Hartagu, Zabala, Buzau rivers). Such a landslide occurred at Paltineni, along Buzau river, in a geomorphological setting marked by older and younger similar processes having an obvious impact on the coupled slope-channel system. With just the accumulated landslide tongue covering an area of 29 ha, the landslide affected the entire slope profile and caused a 400 m westwards shift of the river, followed by the build-up of a new alluvial plain. Detailed analysis of this landslide include geomorphological mapping, 2D-resistivity analysis and terrestrial laser scanning. The geomorphological map indicates that 5 ha of the landslide are regularly reactivated due to lateral erosion by the Buzau river and precipitation. The 2D-resistivity results clearly show that below the landslide tongue alluvial sediments can be found. Repeated terrestrial laser scanning display only minor reactivations during the period August 2011 - March 2012 (further such studies will be carried out in March 2013). This contribution is aiming at a better understanding of the behavior of such processes' reactivation, therefore improving the hazard assessment for deep-seated landslides in the study area.

\*\*\*\*\*

**A complex landslide: the case of Andoin (Basque Country, Spain)**

*IBISATE A., ORMAETXEA O., DÍAZ E., SÁENZ DE OLAZAGOITIA A.*

*Dpt. Geography, Prehistory and Archaeology, University of the Basque Country, UPV/EHU, VITORIA-GASTEIZ, SPAIN*

The study case of a long lasting unstable hillslope process activated with rainfall events in Andoin (Basque Country) is presented. Other factors as the alternate lithology, infiltration, slope and rock fractures triggered mass movements, rotational slides and flows with differentiated progressions in a surface of around 5 ha.

Through historical aerial photographs and GPS techniques more than 50 years of the evolution of the process were delimited. Additionally this evolution has been related to rainfall frequency and annual distribution by the analysis of several meteorological stations located in the surrounding area, as well as the analysis of documents related to the process, available photographs and interviews to local population.

During the last 10 years field measurements have been done in May (after the maximum rainfall period) which has allowed the reconnaissance, characterization and the cartographical representation of many different movement typologies.

**Method for estimating the volume of sliding soil mass generated by deep catastrophic landslide: Application to the disaster in the Kii mountain range, 2011**

*ISOGAI N., MORITA K., ISHIZUKA T.*

*Public Works Research Institute, TSUKUBA-CITY, IBARAKI-PREFECTURE, JAPAN*

In Japan, 72 deep catastrophic landslides were generated because of heavy rain by Typhoon Talas in the Kii mountain range at the beginning of September, 2011. As a result, extensive damage was done of 82 dead, 16 missing person, 379 completely-destroyed houses, and 3,159 partially-destroyed houses.

The estimation of the volumes of sliding soil mass is very important, because it is crucial information or parameters 1) to evaluate the damage which might be caused by deep catastrophic landslide, and 2) to decide assumed external force applying to the design of constructional measures.

The recent laser surveying technique has made possible to estimate the volume of landslide mass briefly and easily, calculating the difference of the digital elevation model (DEM) between before and after deep catastrophic landslide. However, in some cases, the estimation could be inadequate because of the following reason.

In the case of deep catastrophic landslide, collapsed soil mass generally reaches out of original landslide area. Meanwhile, upper part of landslide mass could deposit at the lower part of the original landslide area, especially in the case that deep catastrophic landslide forms natural dam downward of the slope. In this case, the volume of landslide mass can be underestimated because of the overlap of yielded soil mass and deposited one, if the analysis of the difference of the DEM before and after landslide is directly done.

To improve the estimation in the above cases, we applied the following method to the deep catastrophic landslides caused by typhoon Talas in the Kii mountain range. 1) to make the cross section at intervals of 20m (indicating the cross section of before and after mass movement), 2) estimation of the sliding surface shape, 3) to calculate soil mass between each section using average cross section, 4) to accumulate the calculated volumes.

\*\*\*\*\*

**Using fallout <sup>210</sup>Pbex, <sup>7</sup>Be, sediment yield and modeling to assess soil erosion at different temporal and spatial scales in southeastern Brazil**

*FERNANDES N.(1), SANTOS A.C.F.(1), PINTO C.S.B.(1), BHERING S.(2), GODOY J.M.(3), FONTES R.L.P.(1)*

*(1) FEDERAL UNIVERSITY OF RIO DE JANEIRO, RIO DE JANEIRO, BRAZIL ; (2) EMBRAPA, RIO DE JANEIRO, BRAZIL ; (3) PUC-RIO, RIO DE JANEIRO, BRAZIL*

Soil erosion is a major problem in southeastern Brazil, especially in the highly degraded hillslopes of the northwestern Rio de Janeiro state agriculture fields, where the original rainforest has been continuously replaced by farming activities throughout the last three centuries. This is the case of São José the Ubá region, where the combination of intense farming, steep slopes, erodible soils, sparse vegetation, fires and downhill soil ploughing favored the increase of surface runoff and soil erosion (sheet wash, rilling and gullying), causing a significant decrease in soil productivity, especially in the last few decades. In this study, we assessed the effects of different temporal and spatial scales on soil erosion combining different techniques, including the measurement of fallout <sup>210</sup>Pbex and <sup>7</sup>Be (a convex-concave 100 m long transect along an agriculture field – from the flat top to the bottom of the hillslope), the continuous monitoring of rainfall, discharge and sediment yield at an experimental drainage basin (during 5 years), and the application of the SWAT model to simulate different future (and past) scenarios of land-use and cover changes. The initial results suggest that at the upper and mid-portions of the hillslope, most of the <sup>210</sup>Pbex is concentrated in the first 20 cm of the soil profile, while at the bottom of the hillslope it is concentrated in the first 30 cm of the profile. Besides, at the mid-portions, the inventories of <sup>210</sup>Pbex are about 18% smaller than the ones measured at the flat top of the hillslope, suggesting intense soil erosion during the last 100 years. On the other way, sediment deposition is suggested by an increment of the <sup>210</sup>Pbex inventories (about 30% greater than the flat top) at the bottom of the hillslope (concave portion). The results obtained from the simulations with the SWAT model attest that land use and cover changes play a major role in controlling soil erosion responses in the different scales.

## **Mass movements in mountainous region in southeastern Brazil from the disaster of January 2011 as landscape transformers in the Atlantic forest Biome**

SOUZA J.M.D.(1), ASEVEDO L.A.(2), BERTOLINO A.V.F.A.(2), FREITAS M.M.D.(1)

(1) Pontifical Catholic University, RIO DE JANEIRO, BRAZIL ; (2) University of State of Rio de Janeiro, SÃO GONÇALO, BRAZIL

In 2011 January, the mountainous region of southeastern Brazil suffered intense mass movements. The research aims to mapping scars of events to make a diagnosis of this and his triggering mechanisms.

The continental collision process makes the predominance be metamorphic rocks in the Atlantic border in the south American continent, generating the track mobile Ribeira and comprise a belt of complex folds and high temperature formed during the collision making magmatism. This afforded granitic rocks with high silica content, resistant to weathering yielding mountaintops (HEILBRON et al, 2004), commons in Serra do Mar. The geomorphologic unit divides in: Mountain cliffs and mountainous domain (DANTAS, 2000) with a relief very rough, shallow soil and topographic amplitudes above 400m.

The rain diary values in the area were obtained through the conventional rain gauges and the automatic station THIES TLX-MET. The data shows a high rain above the average in November and December 2010 and January 2011. On 01/11/2011 was a rain with 209 mm, representing 63% of month precipitation. The rain which done the sliding was between 21:50h (01/ 11) and 7:10h (01/12) reaching 145,2 mm.

Was mapped 33 scars where the mass movements were: 85% landslides, 9% flow, 3% rock fall and 3% rock slide and 43% of scars was in high slope (>47%), its represents areas with greater instability with shallow soils and/or soil/rock contact abrupt, conditions where could make occurs increase positive pressure of soil (MONTGOMERY et al, 1997). Of the totalscars, 17 were in the forested area, 6 in the area of traditional agriculture, 5 in the fallow, 1 in pasture area and the other in an urban area.

The data shows which the conditional factors to mass movements in 2011 January in the mountainous region of southeastern Brazil was a combination between antecedent moisture in the soil, high intensity rain of January 11 and slopes with shallow soils with high gradient. This is related with landscape evolution.

\*\*\*\*\*

## **Resistivity measurements in slope geomorphology: recognition of deep-seated mass movements**

TÁBOŘÍK P.(1), PÁNEK T.(2)

(1) Institute of Hydrogeology, Engineering Geology and Applied Geophysics, Faculty of Science, Charles University in Prague, PRAGUE, CZECH REPUBLIC ; (2) Department of Physical Geography and Geoecology, Faculty of Science, University of Ostrava, OSTRAVA, CZECH REPUBLIC

Mass movements belong to the prevailing processes forming mountain landscapes, ranging from slow deep-seated gravitational slope deformations to the fast relocation of shallow colluvial deposits. Genesis of deep-seated gravitational slope deformations (DSGSD) is affected by a combination of many factors, such as hydroclimatic conditions, weathering intensity and particularly morfostructural and structure-geological predisposition. Their recognition is crucial for correct interpretation of earth surface processes. Application of geophysical techniques, as a basic indirect method of subsurface surveying, is very suitable, especially in hardly accessible areas. Resistivity imaging has proved universal utilization in many different tasks and various geological substrates and also offers very valuable subsurface information on DSGSD. Presented study summarizes results from multi-electrode measurements (Electrical Resistivity Tomography, ERT) carried out on the DSGSD phenomena during 2006-2012. The study also evaluates applicability of different types of electrode array and its configuration (electrode spacing, depth range etc.) on specific tasks within DSGSD research. The ERT method was used especially due to sufficient resolution and depth range. Based on the interpretation of the resistivity sections, we were able to distinguish between extremely high/low resistive parts of the landslide bodies which represent different quality (e.g. various lithology, intensity of disruption and weathering, water content or presence of argillaceous minerals). The ERT was mainly used in order i) to confirm tectonic predisposition, iii) detect and track rock discontinuities (fissures and fissure-caves, tension cracks), iii) to detect or confirm shear surfaces and range and thickness of landslide deposits, and iv) to distinguish inner structure of landslide body (e.g., deep-seated blocky rockslide vs. shallower colluvial deposits in the distal part of the complex landslide).

### Shallow slope deformations triggered by extreme rainfall: case studies from Czech Republic

SMOLIKOVA J.(1), BLAHUT J.(2), ZIZALA D.(3), VILIMEK V.(1)

(1) Charles University in Prague, Faculty of Science, Department of Physical Geography and Geoecology, PRAGUE, CZECH REPUBLIC ; (2) Institute of Rock Structure and Mechanics AS CR, PRAGUE, CZECH REPUBLIC ; (3) Research Institute for Soil and Water Conservation, PRAGUE, CZECH REPUBLIC

In 2010 considerable precipitation occurred in the Czech Republic and caused floods and slope deformations at several locations. Two distinct areas were chosen for this study, where rapid and shallow mass movements were triggered by extreme rainfall. Torrential debris flows were investigated within the area of the Jizerské hory Mts. as an exceptional phenomenon at the local conditions and earthflow in the Javorníky Mts.

The following methods were used to examine the deformations: a detailed geomorphological mapping; creating a DEM of the body of the deformations using a total station; monitoring of movements by laser scanning and using installed geodetic points; analysing precipitation amount measured by rain gauge; measuring of soil moisture; investigation of properties of taken soil samples; obtaining geophysical profile by electrical resistivity tomography; analysing water concentration using runoff lines; reconstruction of debris flows using empirical model, etc.

The mentioned methods are briefly described and their applications are discussed with respect to their contribution to the issues of shallow deformation. The obtained results should be used to identify hazards in the investigated areas.

\*\*\*\*\*

### Morphometric analysis of landslides using Gis: the case of d'antas watershed in Serrana region in the state of Rio De Janeiro, Brazil

CARVALHO ARAUJO J.(1), MARIA DA SILVA L.(1), DOURADO F.(2), FERREIRA FERNANDES N.(1)

(1) Federal University of Rio de Janeiro, RIO DE JANEIRO, BRAZIL ; (2) Estadual University of Rio de Janeiro, RIO DE JANEIRO, BRAZIL

Mass movements are recurrent phenomena in the whole Mountain Region of the State of Rio de Janeiro in Brazil. These events actively participate in the relief evolution and are also responsible for many damages and loss of human lives. The triggering of these events depends on the natural environment and the preparatory and immediate action of the physical, biotic and human agents responsible for these processes. This work is based on the hypothesis in which the topographical conditions have a major effect on the spatial distribution of translational landslides caused by decreased of the internal resistance of the material mobilized. Therefore, the purpose of this study is to identify the topographical conditions favorable to landslide triggering based on morphometric analysis in a pilot watershed - D'anta's watershed - located in the mountainous region of the State of Rio de Janeiro. The indices include the topographic wetness index (TWI), contributing area, slope angle and elevation and were derived from 5-m grid digital terrain model, computed on a Geographic Information System (GIS). The maps produced allowed the analysis of topographic influence on the landslides distribution from the indices of frequency classes (F), concentration of scars (CS) and potential of landslide (PL). The landscape sectors that are more likely to be affected by landslides were the ones where the elevation ranges from 1070m - 1187m, slope angle between 40.95° and 47.77°, contributing area between ( $\log_{10}$ ) 1.32 m<sup>2</sup> - 1.95 m<sup>2</sup> and topographic wetness index between 7.11 to 9.59. This work provides important information which may help in the decision-making process, using fewer data and indices of easy application. Finally, the results obtained will subsidize of a landslide susceptibility map through the implementation of the conditional probability method aimed at predicting and mitigating of the damage caused by landslides.

**Influence of the mass movement on the vineyard fragmented. Case study of the Côte de l'île de France (Champagne - France)**

COMBAUD A.(1), BOLLLOT N.(2), CHALUMEAU L.(2), BATAILLER A.(1), CHARBONNIER K.(1), DOURLAT E.(1), EMERIAU G.(1)

(1) Institut Polytechnique LaSalle Beauvais, BEAUVAIS, FRANCE ; (2) Université de Reims Champagne-Ardenne, REIMS, FRANCE

The vineyard of Champagne is typically a north one :for growing vine needs long and strong slopes and porous stones, like on the Côte de l'île de France. Mass movement is the major process in the development of these hillslopes. Slumps and associated earth flows are mostly concerned. Relative age of these processes is also known: oldest slumps occurred before the last glacial period, some of them (slump and earth flow) are reactivated during the Holocene. The actual downslope movements, of various sizes, lead to major damages throughout the vineyard stands on mass movements.

The aim of this study is to determinate if landslides influence the fragmented of the vineyard. Plots limits are extracted by remote sensing analysis and merge with the cartography of mass movement for two sectors of the Marne Valley.

\*\*\*\*\*

**Study of Landslide hazards and Assessment of Associated Risks in the West-Cameroon Highlands (Central Africa)**

TEFOGOU M.G.Z.(1), NKOUATHIO G.D.(2), DONGMO A.K.(2), WANDJI P.(3), DEDZO M.G.(2)

(1) Department of Hydraulics and Water Management, High Institute of the Sahel, University of Maroua & Department of Earth Sciences, Faculty of Sciences, University of Dschang, MAROUA & DSCHANG, CAMEROON ; (2) Department of Hydraulics and Water Management, High Institute of the Sahel, University of Maroua, MAROUA, CAMEROON ; (3) Laboratory of Geology, High Teacher Training School, University of Yaoundé, YAOUNDÉ, CAMEROON

The West-Cameroon highlands (WCH) are a part of Cameroon Volcanic Line. WCH are a succession of horsts and graben covering an area of more than 50,000 km<sup>2</sup>. The region is overlaid by volcanic lava flows and pyroclastic deposits, dated from Actual to 31 Myr (Nkouathio et al., 2008). The best fertility of the soil attracts various active people although the occurrence of mass movement hazards. WCH and neighborhood are tormented by landslide hazards; the most disastrous were recorded in the Limbe and Maga localities respectively in 2001 and 2003 (Zoning et al., 2007). In this work we highlight the most recent landslides that occurred and damaged WCH' localities notably Kékem (2007), Bana (2008), Limbe (2009), and Bamenda (2009), Nteingue (2007, 2011). These landslides occurred generally in response to the combination of important factors:

- The climate in the region is subequatorial under the influence of mountainous reliefs;
- steepest slopes (up to 60%);
- the high thickness of the mantle rock;
- the vegetable cover (meadow);
- anthropogenic activities (deforestation, bushfire, buildings, farming and road traffic).

During the landslides, the movement of materials was generally rotational, translational or the combination of the both models depending on the region.

The impact of recent landslide in WCH is relevant; there is loss of human beings, disruption of human activities, destruction of buildings and roads (around several millions USD) and biodiversity (plantations, livestock and wild lives). In view of the perpetuity of landslides in that region, it is suggested to respect a better land use system, lead a suitable geotechnical surveys prior to the road construction, avoid the settlement of population on the risks zones, prohibit bushfires and the deforestation and sensitize the exposed populations through scientific documentations that highlight the effect of landslides in the region.

**Recent landslide hazards in the Ba catchment, NW Viti Levu Island, Fiji**STEPHENS M.*School of Geography, Earth Science and Environment, The University of the South Pacific, SUVA, FIJI*

This paper reports on a reconnaissance investigation from the Ba River catchment, NW Viti Levu, Fiji, of the processes and causal factors of landslides that were triggered on 25 January 2012 following two days of exceptionally heavy rainfall associated with a nearby low pressure weather system. More than forty individual landslides were recorded, not including several small road-cut slumps, and mass wasting on this scale has reportedly not been witnessed before in the Ba catchment. Rural village settlements occur sparsely in the area and there were casualties in one village where a landslide had directly hit a house. Other impacts were soil erosion and siltation of the nearby streams and the blockage of roads affecting access to some villages and to markets.

The heavy rainfall that occurred on the preceding two days was the major triggering factor and also likely to be in combination with antecedent moisture following heavy rainfall events in recent years (Tropical Cyclones Mick and Tomas, December 2009 and March 2010, respectively). Many of the landslides were shallow debris flows which tend to be common types of failure in mountainous volcanic islands in the South Pacific. The landslides ranged in size from several metres up to dimensions of more than 200 metres long and 100 metres wide. The landslides occurred on a variety of slope angles and in a variety of land uses although many of the larger failures occurred in areas of steep slopes covered by a monoculture of mature pine forest (Caribbean pine, *Pinus caribaea*).

Many of the landslides started at the upper parts of hillsides as typical of failures caused by the downward percolation of rainwater. The back scarp walls of several of the landslides were found to occur in association with pine logging tracks which create slope instability. Previous studies of landslides in Fiji and the tropical South Pacific are few and this work adds to the body of knowledge on this natural hazard in the region.

\*\*\*\*\*

**Storage coupling and sediment connectivity in a high-alpine cascading system (Val Mütsch, Swiss National Park)**MESSENZEHL K., HOFFMANN T.*University of Bonn, Department of Geography, BONN, GERMANY*

Sediment transport from hillslopes to streams follows a cascade of different storage compartments. The exchange of sediment between these compartments via different geomorphic processes thereby determines the internal coupling mechanism of the sediment cascade. However, decoupling between adjacent storages may go along with long-term disconnectivity between significant parts of hillslopes and the fluvial system. With regard to sediment budgets and management activities a profound understanding of cascading systems is important even more today.

We studied the alpine sediment cascade of Val Mütsch (6.18 km<sup>2</sup>) in the Swiss National Park. The glacial legacy of Val Mütsch is demonstrated by its glacial trough and abundant glacial and paraglacial deposits. By combining traditional geomorphic mapping in field and interpretation of aerial photos and hillshades, we compiled a comprehensive inventory of sediment storages. For a qualitative assessment of the (de-)coupling between compartments of the sediment cascade, we applied the concept of toposquences and examined the functional relationships between neighbouring storage units. To analyse the sediment connectivity on a catchment-wide scale, we used the numerical algorithm by Cavalli et al. (2013), a modification of the approach by Borselli et al. (2008).

The modelling results indicate that the present-day sediment connectivity is dominantly controlled by the specific valley morphometry being the result of the Pleistocene glaciation. Within the upper hanging valleys, the connectivity to the stream is reduced noticeably. Nevertheless, the numerical algorithm fails to calculate decoupling between neighbouring DTM-pixels and may overestimate the overall connectivity degree. Our qualitative study reveals that most of the toposquences of the upper trough contain a buffering element in-between decoupling around 28 % of the basin surface. Therefore, our findings highlight the great potential of numerical approaches for the study of high-alpine cascading systems, but concurrently emphasize the need of systemic knowledge derived from geomorphic mapping for the model validation.

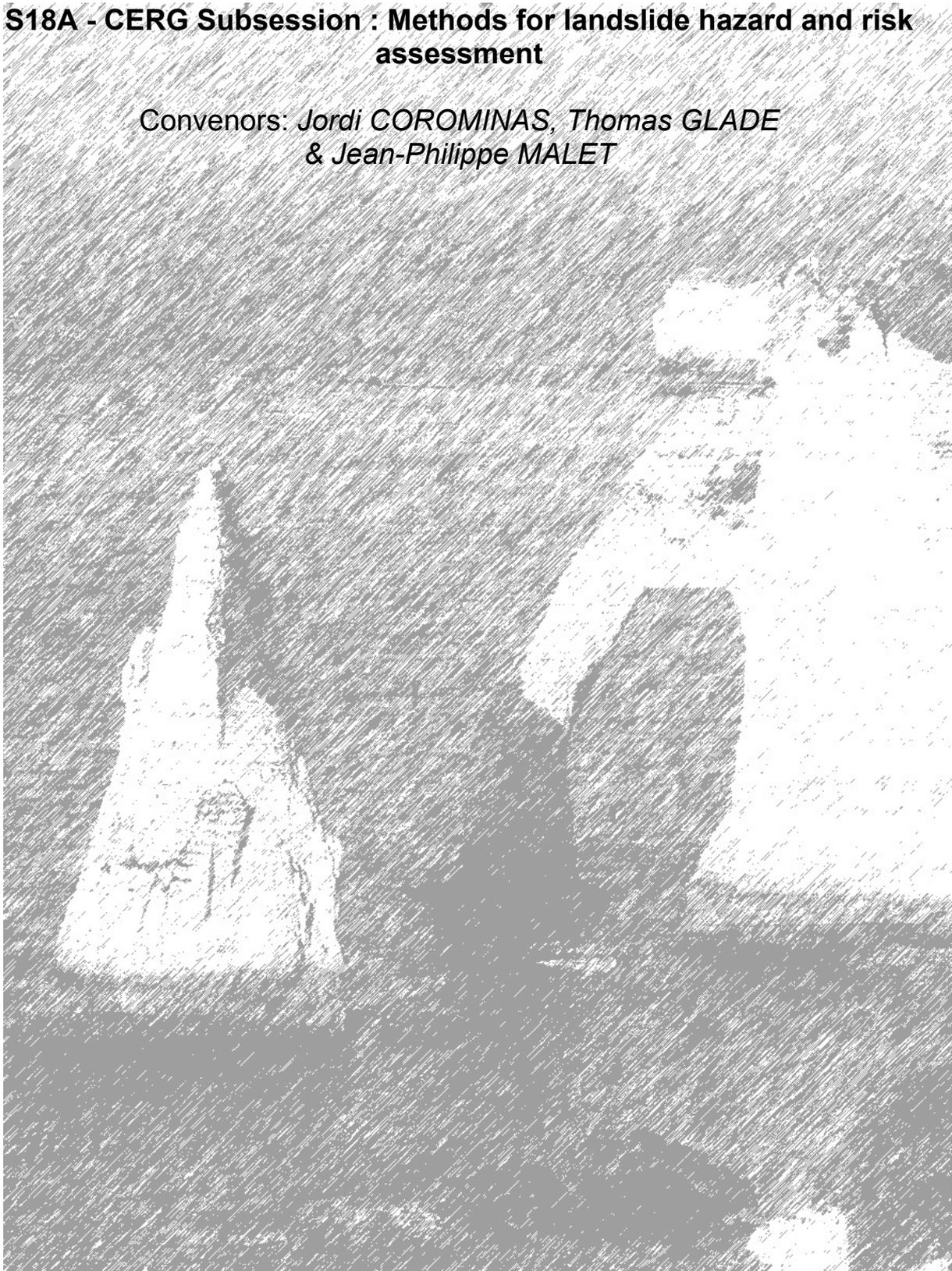
Borselli, L., Cassi, P. & D. Torri (2008): Prolegomena to sediment and flow connectivity in the landscape: a GIS and field numerical assessment. In: *Catena* 75: 268-277.

Cavalli, M., Trevisani, S., Comiti, F. & L. Marchi (2013): Geomorphometric assessment of spatial sediment connectivity in small alpine catchments. In: *Geomorphology* 188: 31-41.



**S18A - CERG Subsession : Methods for landslide hazard and risk assessment**

Convenors: *Jordi COROMINAS, Thomas GLADE  
& Jean-Philippe MALET*





## **Oral presentations:**

### **The use of engineering geomorphology in landslide assessments: a Hong Kong case study**

PARRY S.

*GeoRisk Solutions Ltd, SHEUNG WAN, HONG KONG*

Hong Kong has considerable experience in the assessment and upgrading of man-made slopes, resulting in significant reduction of landslide risk. As a consequence of this Hong Kong has recently embarked on an ambitious programme to systematically evaluate and mitigate "natural terrain" landslide risk. This paper discusses the use of engineering geological/engineering geomorphological mapping for natural terrain landslide hazard assessments. These techniques allow the relative age of the landscape to be evaluated; the identification of both landforms and processes related to different climatic conditions; the development of terrain specific landslide magnitude and frequency data; evaluation of entrainment potential; and, assessment of debris run out. This information allows for a rational derivation of landslide design events for individual terrain components, for analytical modelling and subsequent mitigation design. As such, it assists in reducing uncertainties and allows the evaluation of appropriate and defensible design events.

\*\*\*\*\*

### **Characterizing the complex morpho-structure of coastal landslides combining airborne and ground-based investigations**

LISSAK C.(1), MAQUAIRE O.(1), MALET J.P.(2), BITRI A.(3), BOURDEAU C.(4), DAVIDSON R.(1), GRANDJEAN G.(3), REIFFSTECK P.(5)

*(1) LETG-Caen Géophen, CAEN, FRANCE ; (2) Ecole et Observatoire des Sciences de la Terre [EOST], Institut de Physique du Globe de Strasbourg [IPGS], STRASBOURG, FRANCE ; (3) BRGM - Bureau de recherches géologiques et minières, ORLÉANS, FRANCE ; (4) IFSTTAR, PARIS, FRANCE ; (5) TERRASOL, PARIS, FRANCE*

In Normandy (North-West France), active landslides occurring along the coasts are large, deep in marly, sandy and chalky formations. All are characterized by a seasonal activity (1-10 cm.y-1) and regularly affected by brutal accelerations inducing pluri-decimetres to pluri-meters horizontal/vertical displacements and the main scarp recession to upstream. The result of this complex dynamic pattern is a composite morphology with a succession of horsts, grabens, counter slopes and several sizes scarps, representative of multiple rotational landslides. The previous studies highlighted the importance of the nested chalk panel composing the landslide and the superficial deposits in the landslide dynamics.

To understand the slope dynamic heterogeneities, this study focused on the landslide current morphology and the internal structure of the slope through the integration of multi approach and multi-source data. The results have been based on data relevant from punctual investigation of the internal structure of the landslide and data interpretation to devise a geometric model of the slope based on a model of distribution chalk blocs. First, a detailed and high resolution morphological maps supported by remote-sensing (airborne LiDAR) and ground-based surveys (differential GPS measurements, field mapping) have been lead. Then, geophysical methods combined with conventional geotechnical methods and geomorphological observations provided a 2D/3D subsurface imaging delineating the landslide in depth. Data allow to propose a complex landslides model composed by several compartments (heterogeneous size and volume) associated to a highly fractured slope and controlling the deformation patterns and the mechanisms of the landslides.

### **A geomorphologic and probabilistic approach to the number and size of blocks of fragmental rockfalls**

MOYA J., COROMINAS J., MAVROULI O.C.

*Technical University of Catalonia (UPC), BARCELONA, SPAIN*

Rockfalls are frequent phenomena in steep rock slopes. Many rock masses when detached from cliffs undergo fragmentation after the first impacts with the ground. Rockfall fragmentation is a complex process that has received little attention in the literature. It controls the sedimentation rate on talus slopes and the rockfall risk. The incorporation of fragmentation into the rockfall analysis involves the calculation of the number and size of the rock blocks after the breaking of the initial rockfall mass. Due to its complexity, physical modelling of this process appears to be difficult. In this work, we present an approach to assess the number and volume of fragments based on geomorphological observations and on probabilistic simulation. This approach assumes that the volume of blocks resulting from fragmentation follows a defined probability distribution, which is the same with the one observed for the blocks accumulated in the talus slope. Consequently, the volume distribution of blocks accumulated in talus slopes can be used to generate random sets of rock blocks, each one simulating a rockfall event. For each event, the individual block volumes are summed until they reach the specified volume of the detached rock mass. This approach is applied to a talus deposit of the Solà d'Andorra la Vella (Andorra) and the results were compared with the block volume distribution of inventoried rockfall events in the area. The comparison showed that the only difference between the two data sets is the lower proportion of small blocks in the inventoried set, likely due to undersampling of these sizes. For blocks with volume greater than  $0.3 \text{ m}^3$ , both sets follow the same probability distribution: a power law with an exponent close to 1 and a scale parameter close to 0.3. We conclude that the proposed approach can be applied to sites where no process causing size reduction (e.g. gelifraction) affected the blocks after rockfall deposition.

\*\*\*\*\*

### **A modelling approach of the large, rapid Yigong rockslide ' debris avalanche, Southeast Tibet**

VAN ASCH T.(1), XU Q.(2)

*(1) Faculty of Geosciences Utrecht University , UTRECHT , NETHERLANDS ; (2) State Key Laboratory of Geohazards Prevention and Environment Protection, CHENGDU, CHINA*

The Yigong rock slide – debris avalanche (YRA), which occurred on 9 April 2000, received worldwide attention as one of the largest non/seismic landslides in recent years, with a volume of  $0.3 \times 10^9 \text{ m}^3$ . a run-out track with a total elevation difference of about 3300 m, and a length of nearly 10 km with a mean slope gradient of 31.3%. According to several witnesses, the total duration of the event lasted 3 minutes. Sixty-two days after this landslide event, a catastrophic flood happened because of a landslide dam failure. One of the special features of this debris avalanche is liquefaction, which plays an important role in the entrainment and long run-out distance and high-speed movement of the debris avalanche. Numerous sand boils were found in the deposition zone, providing strong evidence for liquefaction. The YRA provides the first actual evidence for a theoretical model which is proposed here, where the mechanisms of excess pore pressure and liquefaction induced by undrained loading, and entrainment and dissipation control the run out and deposition of the debris avalanche. The position and amount of eroded and deposited material and the run out time are in good agreement with the observations made in the field.

The damage mode to trees and the presence of debris cones or molards with a rounded top is proven to be the result of strong air waves and eddies. These features all imply that the YRA is a solid–liquid–air mixed-debris avalanche.

## **Physical and geotechnical properties of soils and shallow landslides, Serra Do Mar Mountain Range, Brazil**

CARVALHO VIEIRA B., SOUZA FERREIRA F.  
*University of São Paulo, SÃO PAULO, BRAZIL*

The physical and geotechnical properties of soils can be studied by field study and laboratory, measured at different depths to assessing their influence on water flows, especially during periods of intense rainfall. The aim of this study was to determine the influence of some soil properties in the shallow landslides in the Serra do Mar, a mountain range located along the southeastern Brazilian coast, often affected by different types of landslides, especially during the rainy season. In this area there are few studies about relationship between soils and landslides. We selected a basin (24Km<sup>2</sup>), located in the Caraguatatuba city, with steep slopes and heterogeneous lithology (gneisses, metasediments) and structural features with orientation NE-SW. On 17 and 18 march 1967 the rain gauge registered 535mm and many shallow landslides were triggered and the debris flows reached the gentle areas causing about 400 deaths and many social and environmental damages. We selected three shallow landslides scars of this event and, in each scar, collected sample in three points, one within the scar (material removed by the process), one lateral and another one on the top scar (with preserved material). 37 soil samples deformed and 6 undisturbed samples (soil block) were collected to analyze the following properties: soil grain size distribution, atterberg limits, density porosity and soil cohesion. The results showed high amounts of sand (80%), mainly in the surface horizons (up to 0.60m), and low percentages of clay and these were considered nonplastic or inactive (values below 0.75%). The average values of the density and the void ratio were 2.55 g/cm<sup>3</sup> and 1.151 g/cm<sup>3</sup>, respectively. The friction angles were smaller in surface horizons (29.1° and 25.8°), and higher in overlying layers (31.9° and 36.8°) and the cohesion ranged from 0 to 12 kPa. We hope that this study can subsidize understanding of failure mechanisms of shallow landslides in the Serra do Mar mountain range.

\*\*\*\*\*

## **A reappraisal of field geomorphology in landslide hazard investigation**

GHINOI A.  
*Università di Modena e Reggio Emilia, MODENA, ITALY*

This contribution highlights the relevance of geomorphological expert knowledge in landslide hazard assessments. A recent project, funded by the Emilia-Romagna Region, has led to the revision of the official landslide maps of a large sector of the Romagna Apennines (Northern Italy), which were initially based on pure geological field surveys. Most of the mapped landslides needed significant revision in terms of extent, type of movement and frequency of occurrence. In particular, large-scale landslides, defined as "complex" in the maps, had to be reinterpreted updating the mapping and the landslide database by means of geomorphological investigation. It became clear that landslide accumulations were not normally related to single events, but to the cumulative action, through time, of hillslope processes, also related to different morphoclimatic conditions. The mapped landslide bodies may be currently active not as a whole, but rather just in some smaller sectors and in relation to different causes. Regarding smaller-scale landslides, from the Seventies up to now they show relevant reduction in the extent of the active portions, and new occurrences are few. The outputs of the research showed that the results of many current landslide susceptibility assessments used for wide areas, whose algorithms are based on existing landslide inventories, can be strongly influenced by an improper mapping of existing landslides and by an outdated information on their type of movement and state of activity. Therefore the value of traditional geomorphological survey should be reasserted within landslide susceptibility and hazard assessments, since the proper knowledge of landslide cause-effect relationships through time and under the current changes in climate becomes crucial.

**Comparing binary logistic regression and stochastic gradient boosting techniques in debris-flows susceptibility modelling: application in North-Eastern Sicily**

LOMBARDO L.(1), CAMA M.(1), CONOSCENTI C.(1), HOCHSCHILD V.(2), MÄRKER M.(2), ROTIGLIANO E.(1)

(1) Dipartimento di Scienze della Terra e del Mare (DISTEM), Università degli Studi di Palermo, PALERMO, ITALY; (2) Department of Geography, University of Tuebingen, TUEBINGEN, GERMANY

On October 1, 2009 the area around the village of Giampilieri (Sicily), on the Ionian side of the Peloritan belt, suffered thousands of landslides triggered in few hours, causing 36 victims, over 100 injured and more than 0.5M € of damage to structures. This phenomenon was caused by an extreme meteorological event, recorded at the foothills areas with 250mm of rain in just 8 hours.

Due to the peculiar trigger and geomorphologic setting, debris flows and avalanches involved the shallow weathered layer of the outcropping lithologies consisting of medium to high grade metamorphic rocks.

The purpose of this study was to prepare and compare susceptibility models for two catchments (the "Torrente Briga", TB, and the "Torrente Giampilieri", TG, catchments) stretching in the storm centre area, by means of two different methods: binary logistic regression and stochastic gradient boosting.

Besides, the possibility to model susceptibility condition in one of the two hydrographic units, by importing a model trained in the adjacent one, was explored.

The susceptibility models were prepared using a large set of predictors derived from a 2m cell DEM, two thematic maps and the landslide archive built on the basis of direct (on the field) and remote (Google Earth™) surveys, including 871 landslides in the TB and 1121 landslides within the TG.

We focussed on exporting procedures for susceptibility models because of the importance in optimizing the survey costs as well as or, particularly, when facing phenomena which are locally triggered, such as the ones activated under extreme rainfall events. In this cases, the landslide scenario used to train the statistical model is locally and spatially more limited than the extension of the whole investigated area, so that suitable training areas are to be searched for out of the study area.

The modelling has proved to be highly stable comparing the two different techniques, factor selection and exportation procedures.

\*\*\*\*\*

**Landslide susceptibility modelling for extreme rainfall-triggered multiple landslides: a key study from the 2009 event in the Giampilieri Aera (Sicily, Italy)**

ROTIGLIANO E., CAMA M.E., CONOSCENTI C., LOMBARDO L.

University of Palermo, Italy, PALERMO, ITALY

On the late afternoon of 1<sup>st</sup> of October 2009, the area (about 50km<sup>2</sup>) centred on the village of Giampilieri (Messina, Sicily), along the Ionian front of the Peloritan belt, was struck by a storm which triggered about three thousands of landslides in the time lapse of few hours, causing 36 victims. A huge number of debris flows and debris avalanches occurred, as a downhill evolution of pure debris slides and debris flows at the head, involving the shallow (0.5-2.5m thick) weathered layer of metamorphic rocks (phyllites and mica schists).

Extreme rainfall events in Mediterranean areas are typically very local phenomena, so that storm-triggered landslide archives, which are mandatories for preparing stochastic susceptibility models, are made of clusters of events, randomly scattered both in time and space. As a consequence, areas that potentially can be involved in multiple landsliding events, frequently do not show past landslide scenarios, simply because recent storms passed some kilometers away. This contribution explores the possibility of modelling susceptibility in these still unstressed areas, by importing models prepared in already struck similar areas, where training landslide inventories are available.

The study focuses on four small adjacent hydrographic units (the Itala, Scaletta, Giampilieri and Briga creek basins), which extend for about 10km<sup>2</sup> each, in the centre of the storm area. By applying forward logistic regression on two landslide archives (before 2009: ALFA; after 2009: BETA) and a set of predictors, which were derived from a 2m cell DEM and a geologic map, different types of susceptibility models were prepared for each unit: model A, trained with ALFA; model B, trained using a random partition of BETA; model C, imported from the other units, using BETA. Validation tests confirm that susceptibility modelling for storm-triggered landslides can be best achieved, by importing models trained in areas, that have been already struck by storms in the past.

**Assessment of rockfall susceptibility in different morphostructural frameworks, Abruzzo Region, Central Italy**

*PIACENTINI T., MICCADEI E., DI MICHELE R.*

*Dipartimento di Ingegneria e Geologia - Università degli Studi "G. D'Annunzio" Chieti-Pescara, CHIETI, ITALY*

Among the types of instability, different for typology, evolution and dimension, rockfalls represent a constant hazard for structures, buildings and inhabitants because of their extreme speed. Rockfalls have been studied all over the world in several geographical and morphostructural settings, from huge mountain escarpments to small cliffs, with different approaches (from standard geomorphological analysis to multidisciplinary analyses including geology, geomorphology, geomechanics, geophysics, modeling/ software simulation, etc.).

This work is focused on the rock fall distribution in central Italy (Abruzzo Region), in a complex morphostructural setting characterized by the junction of chain area to piedmont and piedmont hills to coastal sectors with wide coastal cliff.

The study began from the consideration that rockfalls were 67% of the mass movements triggered by the 2009 L'Aquila earthquake in the mountain area; other episodes were recorded during weather extreme events that caused floods in the piedmont and coastal area.

The analysis of rockfalls in Abruzzo has been conducted through: historical analysis of past events, multitemporal and multiscale analysis of aerial photos, geological and geomorphological field surveys, geomechanical analysis and software modeling.

Analyzing several case-histories, involving different morphostructural contexts and different rocks (calcareous, arenaceous-pelitic, arenaceous-conglomeratic), the role of geomorphological factors in determining propensity to instability has been highlighted. The analysis of these factors has allowed for the evaluation of susceptibility and the outlining of rockfall propensity maps (in terms of detachment areas and fall areas).

These maps provide indications: at regional scale for preventing instability phenomena and reducing rockfall risk; at local scale for a correct land management and as tools for predicting in advance the scene of a disaster and its impact on the anthropized landscape.

\*\*\*\*\*

**Assessing for deep-seated catastrophic landslide susceptibility of Japan: Application and verification for Kii mountain range, Japan**

*MORITA K.(1), ISOGAI N.(1), ISHIZUKA T.(1), UCHIDA T.(2), OCHI H.(3)*

*(1) Public Works Research Institute, TSUKUBA-CITY, IBARAKI-PREFECTURE, JAPAN ; (2) National Institute for Land and Infrastructure Management, TSUKUBA-CITY, IBARAKI-PREFECTURE, JAPAN ; (3) Ministry of Land, Infrastructure, Transport and Tourism, CHIYODA-KU, TOKYO, JAPAN*

In steep mountainous regions, landslides may include both soil and underlying weathered bedrock (hereafter, "deep-seated catastrophic landslides"). The velocities and volumes of deep-seated catastrophic landslides are often very large, so these landslides may cause serious damage such as Shaolin Village, Taiwan, in 2009 and Leyte Island, Philippines, in 2006. Reducing these hazards requires the development of objective methods to assess and map potential sources of deep-seated catastrophic landslide.

We proposed the deep-seated catastrophic landslide frequency map of Japan and the method for estimating spatial patterns of deep-seated catastrophic landslide susceptibility for many small catchments in a study area around Mount Wanitsuka, Japan. This method is based on the concept that deep-seated catastrophic landslide susceptibility are related to the ancient deep-seated catastrophic landslide scars, microtopography and other topography-related factors.

In the Kii mountain range, Japan that have caused serious damage by deep-seated catastrophic landslides in 1889, we have assessed the deep-seated catastrophic landslide susceptibility for catchment-scale (ca., 1 km<sup>2</sup>) applying the method above mentioned.

After the assessment, the heaviest rain brought by Typhoon Talas generated 72 deep-seated catastrophic landslides in this area at the beginning of September, 2011. Then we verified the applicability of the method with this data, and found certain correlation of them.

Here we report spatial patterns of deep-seated catastrophic landslides occurred and the verification of the applicability of the method for estimating spatial patterns of deep-seated catastrophic landslides susceptibility using the data of disaster caused by Typhoon Talas in 2011 in the Kii mountain range.

### **Debris Flows in Rio de Janeiro: Mapping, Modeling and Dating**

FERNANDES N.(1), AMARAL C.(2), BIERMAN P.(3), SILVA L.M.(1), ARAÚJO J.P.(1), VARGAS JR. E.(4), DE CAMPOS T.(4), DOURADO F.(5), LOPES M.(1), PEIXOTO M.N.(1), NUNES A.(1)

(1) FEDERAL UNIVERSITY OF RIO DE JANEIRO, RIO DE JANEIRO, BRAZIL ; (2) DRM-RIO DE JANEIRO GEOLOGICAL SERVICE, RIO DE JANEIRO, BRAZIL ; (3) UNIVERSITY OF VERMONT, BURLINGTON, UNITED STATES ; (4) CATHOLIC UNIVERSITY, RIO DE JANEIRO, BRAZIL ; (5) RIO DE JANEIRO STATE UNIVERSITY, RIO DE JANEIRO, BRAZIL

In the last few decades, the state of Rio de Janeiro in Brazil has been affected by many catastrophic landslides leading to equally devastating mud and debris flows. The combination of intense summer rain storms, soil-mantled steep slopes, and largely uncontrolled occupation of slopes and stream-side valley bottoms, generates the conditions not only conducive to landsliding but to disaster as the floodplains of streams and rivers become more densely populated. Despite the many scientific advances in prediction and warning systems the number of deaths and the economic losses in the state continue to grow. For example, in one night in January 2011, more than 1300 people were killed in Rio de Janeiro, both on hillslopes and in adjacent floodplains when an intense summer rainstorm (about 350 mm/24h, after a long rainy period) triggered debris flows that were more than 10km long generating huge debris deposits (some more than 7m thick). Therefore, the main objective here is to improve our ability to predict landslide locations, both in space and in time, thus providing a system by which resulting debris flow hazards can be reduced in the state of Rio de Janeiro. In this study we combine field mapping to delineate the extent of that debris flow deposits in selected catchments of Rio de Janeiro state, soil sampling and field experiments to characterize soil properties, dating of debris flow deposits using measurements of <sup>10</sup>Be and <sup>14</sup>C to constrain the age and recurrence interval of flows, and modeling of landslides and debris flows initiation and propagation using a combination of different mathematical models. The results, although preliminary, attest the effects of local factors in controlling debris flows initiation and propagation. Besides, they also suggest that the quantitative methodologies used here, based on physically-based procedures, are capable of predicting the location of unstable sites to landslides in dense populated areas of Rio de Janeiro.

\*\*\*\*\*

### **Accelerated landsliding due to climate warming? Modeling results from western Germany**

GRUNERT J.(1), KRAUTER E.(2), KUMCERICS C.(2)

(1) Department of Geography, Mainz University, MAINZ, GERMANY ; (2) FSR (Landslides Research Center), MAINZ, GERMANY

In the 4th edition of the IPCC report the climate change expected until the end of this century is described by different scenarios. For this study, the moderate version A1 B was chosen and, as a tool, the statistical model REMO (Regional Modeling of Present and Future Climate) was taken. The modeled climate evolution of the two periods 2021-2050 and 2071-2100 was compared with the reference period 1961-1990. The model which has been developed by the MPI for climate research in Hamburg is based on pixels of 10x10 km covering central Europe. For each year the following parameters have been calculated: days per months mean temperature lower than 0 °C, and -5°C; daily and monthly precipitation rate and rainy days with P more than 20 mm. As field examples were taken: the vineyards-covered Wissberg in Rheinhessen, built up of tertiary sediments and known as an old landslide area, and a steep slope of the Mosel valley near Puenderich, built up of various devonian rocks. Here, an important railway has been threatened by landslides and rockfalls since 1880. First results are as follows: In both cases frost periods will be eliminated towards the end of this century. Summer rains will be more sparse but more intensive than today. Contrary, winter rains will become more abundant until 2100 with the effect of growing destabilization of the slopes especially by a higher pore water pressure. Roads and railways will therefore become generally more threatened by mass movements than today.

### **Update of rainfall thresholds for landslide activity in the Lisbon area (Portugal)**

OLIVEIRA S.C., ZÉZERE J.L.

*Centre for Geographical Studies, University of Lisbon (CEG-UL), LISBOA, PORTUGAL*

Landslides have a clear climatic signal in the Lisbon area and rainfall triggered the 25 regional landslide events that occurred since the late 50's of the last century. Traditionally the reference rain gauge of São Julião do Tojal has been used to collect daily rainfall data and to establish the regional empirical relationships between rainfall and landslide activity.

In order to update and to improve the regional rainfall thresholds two pragmatic approaches are used exploring empirical relationships based on the antecedent rainfall records for time periods ranging from 1 to 90 consecutive days prior to landslide events.

The first approach is based on the regression between the critical cumulative rainfall amount and the corresponding rainfall event duration associated to each landslide event occurred during the last 30 years. A regression model is used to automatically derive the minimum daily rainfall necessary to reach a rainfall triggering threshold in 5 meteorological stations located north of Lisbon. A particular attention is ascribed to the critical rainfall duration because short rainfall periods are typically associated with shallow landslide events while deep landslide events are more frequently associated to long lasting rainfall periods.

The second approach is used to assess the maximum, minimum and pre-warning thresholds for the study area. The maximum rainfall threshold is the empirical limit above which no false positive landslide events are expected; the minimum threshold defines the minimum empirical relationship between rainfall amount and rainfall duration below which any landslide event is expected to occur; and the pre-warning threshold is a limit base on a certain percentage rainfall necessary to occur in order to be reached the minimum threshold. For rainfall combinations falling between the minimum and maximum rainfall thresholds the probability of occurrence of a landslide event is calculated based on the ratio true positive/false positive.

\*\*\*\*\*

### **Quantitative landslide hazard assessment in the hilly valleys of the Pays d'Auge plateau (Normandy, France)**

FRESSARD M.(1), THIERY Y.(2), MAQUAIRE O.(1)

*(1) UMR 6554 CNRS, LETG-GEOPHEN, University of Caen Basse-Normandie, CAEN, FRANCE ; (2) EURO-ENGINEERING, PAU, FRANCE*

A quantitative shallow landslide hazard assessment model is presented for a 24 km<sup>2</sup> region of the Pays d'Auge plateau. The data required were mostly obtained from field work investigations, completed by scarce historical records. Due to the relative infrequent occurrence of the landslides on the study area, the susceptibility map was obtained using the rare events logistic regression with replication model. This multivariate statistical technique permits the correction of the overestimation of the final probabilities that is often observed in using the ordinary logistic regression. The data introduced in the model: (i) landslide data, (ii) topographic derived data (slope, aspect, curvature etc.), (iii) landuse, (iv) landuse trajectories since 1947 and (v) surficial formations were obtained from the extensive field investigations and air-photo interpretation on a set of five historical images series.

The temporal probability of landslide triggering was estimated using the exceedance probability of rainfall and ground water level threshold. Due to the scarce historical records on landslides in the study area, the triggering thresholds were defined by combination of the available data and detailed analyses of three representative case studies. These analyses are based on the landslide structure identification and safety factor modelling. Since there is no well established classification system of the landslide magnitude prediction, the estimated landslide volume was used as proxy of the magnitude probability assessment. A quantitative landslide hazard evaluation was then obtained from the combination of the landslide initiation, occurrence and magnitude probability. Finally, four landslide hazard maps are proposed considering different return periods of the triggering event (i.e. 5, 10, 20 and 50 years).

The results should allow improving the quality of the operational mapping in Normandy and permit a more robust risk assessment.

### **Quantitative Risk Analysis for shallow slides: the case of S. Marta de Penaguião (Douro Valley, Portugal)**

*PEREIRA S.(1), SILVA M.(2), GARCIA R.A.C.(1), ZÉZERE J.L.(1)*

*(1) IGOT-CEG, University of Lisbon, LISBOA, PORTUGAL ; (2) CEGOT, Dynat, PORTO, PORTUGAL*

In this work a quantitative risk analysis is applied for buildings and roads exposed to shallow slides in the Santa Marta de Penaguião municipality, located in the Douro valley (northern Portugal).

767 shallow translational slides dating from 2000 to 2010 were inventoried in the study area using aerial photo interpretation and field work. Seven landslide predisposing factors were weighted and integrated using the Information Value Method supported by the landslide partitioning using temporal and random criteria. The landslide susceptibility models were validated using standard ROC curves and AUC (Area Under the Curve).

The probability of landslide size, which is a proxy for landslide magnitude, was estimated using a probability density function. In addition, a landslide hazard scenario was defined based on a rainfall-triggered landslide event occurred in January 2001 with a 3-years return period.

A detailed inventory of buildings and of the road network was made at the 1:1000 scale. 303 km of roads and 8295 individual buildings were inventoried and classified according to the construction technique, type of material, number of floors and conservation state. Furthermore, the function associated to each building was assessed and classified. A vulnerability curve was constructed for each type of building and road taking into account both the structural properties of exposed elements and the proxy of landslide magnitude (landslide area).

The economic value of the road network was derived from the typical cost of road construction provided by the Portuguese Road Institute. The value of buildings was assessed by considering: (i) the typical construction cost per square meter in Portugal; (ii) the area of the building; (iii) the function of the building; (iv) the location of the building; (v) the quality index of the building; and (vi) the age of the building.

The landslide risk was assessed for each individual building and road path and the final result is expressed in euro.

\*\*\*\*\*

### **Probabilistic modelling of uncertainties in vulnerability assessment - application to hydro-meteorological hazards in the municipality of Malborghetto-Valbruna, Italy**

*CIUREAN R.(1), HUSSIN H.(2), FRIGERIO S.(3), GLADE T.(1)*

*(1) University of Vienna, Dep. of Geography and Regional Research, VIENNA, AUSTRIA ; (2) CNR-IRPI, National Research Institute for Geo-hydrological Protection, PERUGIA, ITALY ; (3) CNR-IRPI, National Research Institute for Geo-hydrological Protection, PADOVA, ITALY*

In mountainous European regions hydro-meteorological hazards develop often to disastrous events responsible for considerable losses in the society and the environment. Whilst many risk assessment applications and research has focused on vulnerability to hydro-meteorological hazards in the last years, few studies considered the uncertainties inherent in the vulnerability assessment and their propagation in its successive process stages.

This contribution proposes a methodology for vulnerability assessment of buildings to hydro-meteorological hazards, in particular debris flows, with a focus on the parameter and model uncertainties and their effects on the final vulnerability estimates. Herein, vulnerability is defined as the degree of loss to a given element or set of elements within an area affected by a given hazard. The model uses exceedance probability functions (fragility curves) to describe the damage as probability distributions for each intensity of the hazard using empirical data. In this study, the intensity of the hazard is expressed as flow depth. The fragility functions are then used for the uncertainty analysis in a Monte Carlo (MCS) framework which is structured in two components representing two different sources of uncertainty, aleatory and epistemic uncertainty. Emphasis is placed also towards indicating the sources of uncertainty within the analysis process in relation to data requirements.

The developed methodology is applied in Malborghetto-Valbruna, a municipality in the Province of Udine, Friuli-Venezia Giulia, a region in Italy which experienced extreme precipitation events leading to the occurrence of damaging flash floods, hyper-concentrated flows and debris flows.

The results of the proposed methodology can serve as input in a Probabilistic Risk Assessment (PRA) framework as a more rational support for decision making.

Keywords: quantitative vulnerability assessment, uncertainty, hydro-meteorological hazards, Malborghetto-Valbruna, Italy

### **Landslide risk models on the basis of recent occurrences**

*REMONDO J., BONACHEA J., BRUSCHI V.M., GONZÁLEZ-DÍEZ A., DÍAZ DE TERÁN J.R., CENDRERO A.  
Universidad de Cantabria, SANTANDER, SPAIN*

Mass movements, or landslides, are one of the most common and frequent processes affecting the Earth's surface. This type of process produces important economic losses when affecting vulnerable elements. Therefore, it is necessary to develop methods and/or tools that make possible risk assessment and prediction mapping for these processes. During recent decades significant progresses have been made in this field, developing and applying different methodologies to model landslide susceptibility and hazard. However, procedures for landslide risk modelling are scarce.

The occurrence of landslides in the Bajo Deva area (Guipúzcoa province, Spain) has been studied at length. For this reason a complete inventory of shallow landslides in the zone for the last 60 years has been obtained. In a lesser extent, data on landslide damage could be obtained.

In this work the economic losses caused by two landslides occurred in the study area due to heavy precipitations have been analysed. The study of these slope movements and their effects has been compared with landslide susceptibility, hazard and risk models elaborated in previous works.

\*\*\*\*\*

### **Landslide risk assessment and management in the archaeological site of Machu Picchu Inca citadel (Peru)**

*SPIZZICHINO D.(1), MARGOTTINI C.(1), SOLDATI M.(2)*

*(1) Department of Geological Survey of Italy, ISPRA, ROMA, ITALY ; (2) Dipartimento di Scienze della Terra, Università degli Studi di Modena e Reggio Emilia, MODENA, ITALY*

The archaeological site of Machu Picchu, designated by UNESCO as a World Heritage Site since 1983, is affected by frequent landslides which threaten its security and tourism exploitation. Even an alarm about a possible collapse of the entire citadel was launched in March 2001. Since then, the attention of the international community has been focused on the site investigation and research, to prevent such "catastrophic landslides". The necessity to fully understand the potential and present phenomena in the area of Machu Picchu led international and Peruvian experts to the development of an interdisciplinary research project based on field survey and monitoring activities with low environmental impact (remote sensing techniques). The results of these investigations have not proved the existence of a single catastrophic landslide events, but highlighted the presence of numerous geomorphological processes which may have severe implications for the security of the archaeological remains and its visitors. In order to contribute to a proper site management, further research activities have been developed, on a local scale; these, combined with previous field surveys, monitoring and analysis, have contributed to the definition of a geomorphological model of selected relevant phenomena, in order to assess the related landslide risk. In the present work the following analysis has been implemented on a local scale: geomorphological and geomechanical characterization, passive seismic technique application for stratigraphic purposes and stability analysis implementation. The research outputs allowed the implementation of a more general evolutionary model including the definition of landslide hazard, exposure and vulnerability of the entire archaeological area, in terms of response to geomorphological stress. The main result of the above mentioned activities is the landslide risk assessment for the site and the implementation of a preliminary master plan for the definition of mitigation measures and policy for the archaeological park management.

**Retrieving high resolution deformation patterns of slow moving landslides by COSMO-SkyMed SAR data: a sustainable long term monitoring system using artificial reflectors**

IASIO C.(1), MULAS M.(1), PETITTA M.(1), CORSINI A.(2)

(1) Institute for Applied Remote Sensing - EURAC, BOLZANO, ITALY ; (2) Earth Science Dept. - University of Modena and Reggio Emilia, MODENA, ITALY

To monitor slow moving landslides affecting broad areas in mountainous regions with high resolution over long time may be very expensive, although this might prevent recurrent and serious losses and damage to infrastructure. The complexity of these phenomena, usually characterised by different sources and interlaced runout areas, adds further difficulty to the understanding of their dynamics and forcing factors. Communities affected by such hazards should be provided with continuous monitoring systems which should be economically sustainable in the long term.

This paper describes a method for monitoring wide complex landslides characterised by slow deformation rates, irrespective of land cover and bedrock lithology. It redefines the approach to monitoring slope displacement based on satellite SAR data, including the validation by sporadic GPS surveys.

The workflow consists of: i. a preliminary study for the selection of relevant points to be instrumented by Artificial Reflectors (AR); ii. data processing by multi-interferometry techniques; and iii. the particular spatio-temporal analysis of the obtained time series for displacement.

This approach has been tested on a well-studied complex earthflow earthslide, 3.5 km long and with an estimated volume of 30 Mm<sup>3</sup>, threatening the renowned touristic community of Corvara in Badia on the Dolomites (South Tyrol, Italy). The effects of the main forcing factors on deformation have been quantified by the post-processing of time series from 11 measurement points, improving the landslide zoning.

Starting from the lessons learned from this revised remote-sensing application, we show how strengths and weaknesses of a classical persistent scatterers interferometry approach have been addressed by introducing geomorphological criteria in the selection of points to be adequately instrumented with ARs, and how this approach may be further improved.

\*\*\*\*\*

**Landslide monitoring: Analysis of displacement data of different landslides in Wanzhou District, Three-Gorges Reservoir, China**

GUI L.(1), YIN K.(1), GLADE T.(2)

(1) Faculty of Engineering, China University of Geosciences (Wuhan), WUHAN, CHINA ; (2) Dep. of Geography and Regional Research, University of Vienna, Austria, VIENNA, AUSTRIA

Analysis of displacement monitoring data of landslides plays a significant role in the assessment of landslide stability and deformation stage judgment. Numerous methods have been applied to deal with the monitoring data in order to estimate and predict the movement of landslides, including the fractal theory. It has been proved that the displacement of monitoring points on landslides reflects the fractal characteristics. In this study, the goal is to perform an analysis based on fractal principles to gain characteristics of landslide displacement, and to estimate the deformation stage of different landslides. This study is carried out in Wanzhou District, the Three-Gorges Reservoir, China, where a lot of landslides are being monitored and exhibit different degree of displacement. The data is received from the Three Gorges Geohazard Control Headquarters, based on landslides surface GPS monitoring carried out by the staff of the local environmental monitoring station.

In this study, fractals are applied to analyze the characteristics of different landslides displacement. At first the relationship between landslide displacement and landslide influencing factors, as changes of reservoir water level and precipitation, need to be analyzed to get a general idea about reasons of deformation of those landslides. Then the characteristic of landslide displacement is analyzed on fractal theory. The result of each landslide is compared with each other in order to generalize the characteristics of landslide displacement in this area. Finally, the deformation stage of each landslide is estimated. The results from this study will help the involved institutions to get the information of the stability and the deformation stage of these landslides. Additionally, they can transfer this local knowledge to other landslides using this method. It will be meaningful for those who work with early warning system and are in charge of policy making.

**Continuous monitoring of a slope affected by shallow landslides in North'Eastern Oltrepo Pavese (Northern Apennines, Italy) for landslide susceptibility assessment: preliminary results**

MEISINA C.(1), ZIZIOLI D.(1), BORDONI M.(1), VALENTINO R.(2), BITTELLI M.(3), CHERSICH S.(1)

(1) *Earth and Environmental Sciences Department - University of Pavia, Italy, PAVIA, ITALY* ; (2) *Department of Civil, Environmental, Territorial Engineering and Architecture - University of Parma, PARMA, ITALY* ; (3) *Department of Agro Environmental Science and Technology - University of Bologna, BOLOGNA, ITALY*

Shallow landslides are slope movements, due to extreme rainfall events, affecting superficial deposits of small thickness; their failure surface is, generally, located within the soil-bedrock interface. Although they involve small volumes of soil, due to their close proximity to urbanized areas, they cause significant damage to structures and infrastructures and, sometimes, human losses.

Therefore, identifying at slope scale the soil hydrological and mechanical processes which control the shallow landslide triggering mechanisms is becoming of crucial interest in order to assess the shallow landslide susceptibility using physically based models and to develop early-warning system.

For this purpose an experimental monitoring station was installed in an area of the North–Eastern Oltrepo Pavese where several shallow landslide events occurred in the last years.

The test site slope is representative of other sites in Northern Apennines subjected to shallow landslides: it is characterized by medium-high gradient (more than 15°), the land use is constituted by trees and shrubs developed on abandoned vineyards, the bedrock is made up of gravel, sand and poorly cemented conglomerates.

The experimental station consists in a pluviometer, a thermo-hygrometer, a barometer, a sonic anemometer and a net radiometer. Six TDR probes are placed at 0.2, 0.4, 0.6, 1, 1.2, 1.4 meters from ground level to measure the soil water content. To measure soil matric suction three tensiometers and three heat dissipation sensors are installed at 0.2, 0.6, 1.2 meters from ground level. The data are collected by a datalogger every 10 minutes.

In this work preliminary results obtained from 12 months of monitoring are presented: emphasis is given to the response of the cover materials after dry and wet periods in terms of soil water content and matric potential. These results will be linked to determine the hydro-geotechnical processes that could predispose the triggering of shallow landslides.

\*\*\*\*\*

## **Poster presentations:**

### **Zoning and analysis of landslide risk in the urban watershed of the stream of independencia, in the city of Juiz De Fora (MG/BR)**

*ZAIDAN R.(1), FERNANDES N.(2)*

*(1) Universidade Federal de Juiz de Fora, JUIZ DE FORA - MG, BRAZIL ; (2) Universidade Federal do Rio de Janeiro, RIO DE JANEIRO - RJ, BRAZIL*

The landslides are very frequent geomorphological processes in nature. Brazil, by presenting a vast extension with varied relief forms, added to the different climatic regimes, is the stage for a wide variety of these processes. Many are the news about this theme, which are portrayed in the media, mainly in the southeast region of this country, where areas of very mountainous relief are located. When the landslides happen in areas without urban occupation, they do not become target of news, however, when the population growth, followed by the expansion of urban areas, reaches the areas susceptible to the occurrence of these processes, areas of risk can be defined. In this work, an application was presented, demonstrating how to detect and classify the occurrence of slippage in these areas of risks, supported by a deterministic mathematical method called SHALSTAB, in a watershed basin in the process of urban occupation. The results showed that more than half of the areas classified as susceptible to landslide occurrence are not occupied yet, which means that public policies that inhibit their occupation can still be adopted in order that these areas might not be configured as areas of risk to the population. In areas where the risk of landslide was determined, a classification was performed, followed by a geographical analysis.

\*\*\*\*\*

### **Assessment of landslide susceptibility using landslide map in Japan**

*DOSHIDA S.*

*National Research Institute for Earth Science and Disaster Prevention, TSUKUBA, JAPAN*

Landslide disasters have been taking our precious lives and assets by occurring in various locations and situation each year. So, it is necessary for us to acknowledge the high-risk landslide locations and situations. National Research Institute for Earth Science and Disaster Prevention (NIED), Japan, have published the landslide distribution map "landslide map" for preventing and mitigating landslide disasters. The landslide map have mapped the 350,000 or more landslide topographies in whole Japan by interpretation of aerial photographs. The objects of this research are to clarify geological and geomorphological features of landslide by analyzing the landslide map and to make the landslide susceptibility map for the assessment of landslide in whole Japan.

I propose the method of the wide area landslide assessment used by the features and distributions according to of geological setting . I calculate the landslide body ratio in each geological unit. The landslide body ratio is that the rate of the landslide body area in each geological unit and the whole area in each geological unit. The landslide body ratio can be considered that landslide susceptibility (occurrence probability of landslides) in each geological unit.

As a result, an average of the landslide body ratio is about 5.6 % in whole Japan. The area consist of the accretionary complex based on volcanic rocks and plutonic rocks have comparatively high-risk landslide susceptibility, and the area of Neogene rocks and Paleogene rocks have the high-risk too. On the other hand, the area of plutonic rocks and Quaternary rocks have low-risk landslide susceptibility. The results show that the landslide susceptibility is greatly different according to geological unit. In the future, I want to assess the landslide susceptibility that accuracy is more high-resolution and better by adding some parameter respectively.

## The characteristic features of landslides in the 2011 off the Pacific Coast of Tohoku Earthquake

DOSHIDA S., UCHIYAMA S.

National Research Institute for Earth Science and Disaster Prevention, TSUKUBA, JAPAN

In the 2011 earthquake off the Pacific coast of Tohoku, the loss of human life resulted not only from the direct shaking of the earthquake and resulting tsunami, but also from many landslides that occurred in the region. However, these landslides were few and small, considering the magnitude of the Tohoku earthquake. Furthermore, many of the catastrophic landslides occurred inland instead of in coastal areas near the epicenter. In this research, we consider the underlying cause of this deviation of the landslide distribution by comparing the landslide distribution with various other parameters such as geomorphological features, geological features, the precipitation before the Tohoku earthquake and the peak ground acceleration (PGA) and velocity (PGV) of the seismic waves.

We also compare the landslide distribution produced by the Tohoku earthquake with past landslide distributions (landslide maps published by National Research Institute for Earth Science and Disaster Prevention, Japan). As a result, it is presumed that because of its geomorphological features and geological features, catastrophic landslides do not occur easily in the Tohoku area along Pacific Ocean, the area mainly consist of granite rocks. This is thought to be one of the reasons why there were few reports of catastrophic landslides in spite of the of the Tohoku earthquake. The PGA and PGV of the seismic waves of the Tohoku earthquake had greater values inland than in coastal areas. This is one of the factors that contributed to the large number of catastrophic landslides that occurred inland. An underground structure may have caused these high values in inland regions, although it is necessary to further research this hypothesis in the future.

\*\*\*\*\*

## Slope instability at Ischia Island (Gulf of Naples): scenarios for tsunamigenic landslides and coastal vulnerability

DELLA SETA M.(1), ZANIBONI F.(2), TINTI S.(2), PAGNONI G.(2), FREDI P.(1), MAROTTA E.(3), ORSI G.(3)

(1) Dipartimento di Scienze della Terra - Sapienza Universita' di Roma, ROMA, ITALY ; (2) Dipartimento di Fisica e Astronomia (DIFA) - Università di Bologna, BOLOGNA, ITALY ; (3) Istituto Nazionale di Geofisica e Vulcanologia - Osservatorio Vesuviano, NAPOLI, ITALY

This study focuses on tsunami hazard assessment in the Gulf of Naples connected with landslide occurrence at Ischia volcanic island. Ischia is an active caldera affected by an intense resurgence that has generated a maximum uplift of about 900 m over the past 33ka, at the Mt Epomeo block. Such a deformation implies steepening of the relief flanks that, together with seismic shaking, triggers frequent slope failures. A large number of offshore landslide deposits, highlighted by bathymetric surveys, and occurrence of corresponding scars, mainly along the northern and western slopes of Mt Epomeo, testify for numerous past landslides having reached the sea. Previous simulation procedure has shown the tsunamigenic power of some of such landslides.

The potential slide of Mt Nuovo Deep Seated Gravitational Slope Deformation has been assumed as the potential tsunami source. Moreover, given the high population density and tourist value of the island, the coastal vulnerability has also been analysed.

The landslide simulation, based on data collected during a geomorphological field survey, shows that the mobilized rocky mass would attain considerable velocity (30 m/s) being then deposited offshore, close to the coast (up to about 150 m b.s.l.). The generated tsunami would affect the entire northern coast of the island in about 10 minutes with 10-m-high waves. Furthermore, it would approach the continental coast with an almost parallel positive front. Castel Volturno, a coastal town about 30 km north of the island, would be hit after 20 minutes, with inland penetration of more than 1 km.

Preliminary results of tsunami vulnerability study focused on the northern coast, show that almost all the buildings of the Casamicciola and Lacco Ameno towns, located at less than 10 m a.s.l., would be hit by the simulated tsunami, with some light structures completely destroyed. In addition, more than 3,000 buildings would be affected by the slide motion.

### **The impact of landslides in urban areas. Case study ' the city of Baia Mare**

*IRIMUS I.A., MAGUT F., ZAHARIA S., POP O.T.*

*Babes-Bolyai University, Faculty of Geography, CLUJ-NAPOCA, ROMANIA*

The city is based on Neogene sedimentary deposits of the Pannonian depression, consisting mostly of alternating marl, grey clay, sandstone, tuff and volcanic pyroclastic materials. The covering Quaternary deposits can be found in the southern terraces and the glacis which borders the volcanic mountains in the north of the built up area. In the northern built up area, mostly due to the high slope values and the geologic characteristics, rainfall and land use changes trigger landslides. Their spatial distribution has been analysed using logistic regression in order to determine the susceptibility of the area to landslide processes. In addition, an analysis has been performed using the heuristic method described in the Romanian legislation (Governmental Decision 447/2003) and the technical regulation GT-019-98. This method uses expert opinions in determining the influence of eight factors on landslide susceptibility. The main impact of landslides in urban areas is the direct damage to buildings which require complex geotechnical measures to be stabilised and repaired. In urban areas these damages are more extensive due to the close vicinity of buildings and the complex infrastructure network which leads to indirect damages related to the disruption of urban functionality. Furthermore, the areas which could have been used for new buildings lose their economic value without stability measures.

The process of predicting landslide prone areas becomes an important factor in reducing the costs of stabilizing active movements and their effects. In this respect the statistical method depends on a very good inventory of landslides and gives better results on small areas, whereas the heuristic method can also be applied to a larger area in order to determine the general landslide susceptibility, but has a certain degree of subjectivity.

\*\*\*\*\*

### **A comparative study between Weight-rating and Analytical Hierarchical Methods of Landslide Susceptibility Zonation and Geotechnical Investigation of Some Individual Landslides in Dhalai District, Tripura, India**

*DE S., GHOSH K.*

*Tripura University, AGARTALA, INDIA*

Identification of landslide potential areas by Landslide susceptibility Zonation (LSZ) map is considered as the first step for landslide hazard management. The present study is focused on the spatial analysis of landslide susceptibility zonation using GIS as well as geotechnical investigation of some individual landslides occurred on the slopes of Surma deposits (Lower-middle Miocene) in Dhalai District of Tripura, India (23°25'19"N- 24°15'37" and 91°45'01"E - 92°10'26"E).

Two different landslide susceptibility zonation maps have been prepared on the basis of weight-rating and analytical hierarchical methods considering 8 causative factors (layers), such as, lithology, road buffer, slope, relative relief, rainfall, fault buffer, land-use/landcover and drainage density. Geotechnical investigation of some individual landslides has been carried using Total Station and clinometer. Terrain modeling, area and volume of such individual landslide have been estimated through LISCAD software. Soil samples have been tested in the laboratory to determine soil texture and pH values.

The LSZ map produced from weight-rating system shows that only 1.64% and 16.68% of the total study area is falling under very high and high susceptibility zones respectively. LSZ map produced on the basis of the analytical hierarchical method also shows the similar kind of result. Both susceptibility maps show that the high susceptibility zone is restricted within the structural hilly areas and low susceptibility zone is in flood plain areas of the district. Results obtained through geotechnical investigation revealed that unconsolidated sandy materials with occasional intersection of silt or clay layers, high amount of dip of rock strata, continuous seepage through the fractures are considered as the preliminary causes of such menace which is further aggravated by anthropogenic activities and triggered by abundant precipitation during monsoon season.

### **Landslide susceptibility analysis and mapping: Pahuatlán-Puebla, Mexico**

MURILLO GARCÍA F.(1), ROSSI M.(2), REICHENBACH P.(2), MARCHENSINI I.(2), ARDIZZONE F.(2), GUZZETTI F.(2), ALCÁNTARA AYALA I.(3)

(1) A) Posgrado en Geografía, Universidad Nacional Autónoma de México, MÉXICO, MEXICO ; (2) B) Consiglio Nazionale delle Ricerche, Istituto per la Protezione Idrogeologica, PERUGIA, ITALY ; (3) C) Departamento de Geografía Física, Instituto de Geografía, Universidad Nacional Autónoma de México, MEXICO, MEXICO

Analysis of landslide susceptibility is one of the most important issues in landslide hazard studies. We present the results of the application of various statistical multivariate techniques for the estimation, comparison and validation of landslide susceptibility in the municipality of Pahuatlán, Mexico.

We compiled a multi-temporal landslide inventory by analysis of a digital elevation model (DEM) of Pahuatlán area and through field surveys in the period 2011-2012. The DEM (10m×10m spatial resolution) was derived by use of ERDAS IMAGE© and a stereo-pair of Very High Resolution satellite images GeoEye1.

The susceptibility analysis used a partition of the territory into slope units generated with the DEM and a tool developed through GRASS. The tool identified 259 slope units within the study area and calculated for each of those their different morphometric thematic variables such as slope angle, slope aspect and slope profile. Other thematic variables were derived that associated with each slope unit its geological, structural and land use information. The landslide area in each slope unit was used to classify it as stable or unstable (grouping variable).

The derived grouping and thematic (or explanatory) variables were used to estimate landslide susceptibility by use of three statistical multivariate models: (a) linear discriminant analysis, (b) logistic regression, and (c) a neural network. We used a Logistic Regression Combination Model to combine the results of the three models and obtain a final estimate of susceptibility. The models were validated spatially and temporally. The spatial validation used two slope unit datasets randomly selected: the first (larger) to train the models and the second (smaller) to validate them. The temporal validation was performed similarly but used two periods: the first covering the period 1999-2010 was used to train the models and the second covering the period 2011-2012 to validate them.

\*\*\*\*\*

### **Fluvial sediment transport: the effect of deposition behaviour on vulnerability of elements at risk exposed**

FUCHS S.

*University of Natural Resources and Life Sciences, WIEN, AUSTRIA*

Fluvial sediment transport repeatedly causes damage in mountain environments to elements at risk exposed. Recent empirical studies suggested a dependency of the degree of damage on the hazard impact, and respective damage-loss (vulnerability) functions were deduced for individual torrent fans. However, until now only little information was available on the spatial process characteristics causing the damage. Considerable ranges in the loss ratio only provided the hint that there might be a dependency on the spatial behaviour of the process intensity in the run-out area during individual events. Moreover, frequency-magnitude relationships developed for torrent processes do not deal with such spatial deposition characteristics on a local scale.

Based on data from the Austrian Alps the spatial pattern of depositions was studied with a particular focus on the question whether or not settlement structures have effects on the clustering of high process intensities, and thus high loss ratios for buildings exposed. Using spatial scan statistics, clusters of high and low values of process intensities and loss ratios were analysed. Methodologically, in order to include uncertainties, threshold values concerning the amount and composition of data points necessary for such an approach were studied. It is shown that – within a certain range – the significance and spatial position of clusters of high and low process intensities remains stable over the torrent fans under investigation.

This study contributes to the discussion of the applicability of the frequency-magnitude concept within applied geomorphology, and links fundamental research to applied natural hazard and risk management. It is argued that an approach using spatial statistics may be used to increase our understanding of the spatial dynamics in the run-out areas of torrent processes, and as such to the development of sustainable land-use policies in mountain environments.

### **Structural Control of landslides movements in the uplifted area of NW Peloponnese (Greece)**

GOURNELOS T., TSAGAS D.

University of Athens, ZOGRAFOU, ATHENS, GREECE

In general, rapid uplift is connected to tectonic forces. The geomorphology of such uplifted areas is characterized by steep margins, high valley incision and slope instabilities.

In this paper we relate the general neotectonic and recent activity to landslide movements. Such movements are numerous in the study area, of different types and affect many villages, regional and local roads and infrastructures. The different stages of this work are

1 - data collection

2 - data analyses

3 - creation of different thematic map in a G.I.S platform

A database has been created including 181 landslides cases of the study area, the geology, the drainage network, the time and space rainfall distribution, the structural elements such as faults, fractures, fold axes, inclination of bedding planes and the historical and instrumental earthquakes have been considered. The principal mechanisms, for triggering landslides are earthquakes and heavy precipitations. A major fault system is situated in the northern margin in this uplifted area (faults of Dervenii, Platanos, Rodini, Eliki, Psathopyrgos). The structural induced landslide movements are directly related to reactivation of faulted zones produced by the repeated occurrence of earthquakes.

It is concluded that there is a very good correlation between the spatial distribution, of the structural elements and the locations of landslide areas. Finally human activities such as road construction and land use changes have proved to favour landslide movements.

\*\*\*\*\*

### **Critical rainfall thresholds for triggering debris flows in a human-modified landscape: the case of Carrara Marble Basin (Italy)**

GIANNECCHINI R.(1), GALANTI Y.(1), D'AMATO AVANZI G.(1), BARSANTI M.(2)

(1) Department of Earth Sciences, University of Pisa, PISA, ITALY ; (2) Department of Civil and Industrial Engineering, University of Pisa, PISA, ITALY

In the Carrara Marble Basin (CMB, Apuan Alps, Italy) quarrying has accumulated widespread and thick quarry waste, lying on steep slopes and invading or damming valley bottoms. The Apuan Alps area is one of the rainiest in Italy and rainstorms often cause floods, landslides and debris flows: on September 2003 a rainstorm hit the CMB, inducing more than 500 slope failures and causing damage and casualties.

The stability conditions of quarry waste are difficult to assess, owing to its textural, geotechnical and hydrogeological variability. The waste mainly includes boulders and cobbles, together with a matrix formed of a mixture of sand, silt and clay. Therefore, an empirical approach, basing on properties of rainfall able to trigger debris flows, may be effective in assessing landslide hazard and planning warning systems.

Aiming at defining the critical rainfall thresholds in the CMB, a detailed analysis of the main rainstorms was carried out. The hourly rainfall recorded by three rain gauges from 1950 to 2005 was analysed and compared with the occurrence of debris flows. Critical threshold curves were defined in terms of duration, intensity, cumulative rainfall and normalized by the mean annual precipitation. The curves were obtained applying statistical techniques (logistic regression) in order to separate rainfall events which trigger debris flows from events that do not.

The curves obtained for the CMB were compared with the threshold curves proposed for surrounding areas, finding that the rainfall thresholds for quarry waste can often be lower than those obtained for natural slopes. These curves were also compared with global curves proposed by various authors. Finally, the rainfall thresholds obtained for the CMB were validated using rainfall events occurred in 2010 and 2011, obtaining encouraging results.

## **Coupling terrestrial and marine datasets for coastal hazard assessment and risk reduction in changing environments - A EUR-OPA Major Hazards Agreement Project**

*SOLDATI M.(1), MAQUAIRE O.(2), MICALLEF A.(3), COSTA S.(2), DELACOURT C.(4), FOGLINI F.(5), JABOYEDOFF M.(6), LETORTU P.(2), LISSAK C.(2), PASUTO A.(7), PRAMPOLINI M.(1), TONELLI C.(1)*

*(1) Università di Modena e Reggio Emilia, MODENA, ITALY ; (2) Université de Caen Basse-Normandie, CAEN, FRANCE ; (3) University of Malta, MSIDA, MALTA ; (4) Institut Universitaire Européen de la Mer (IUEM), PLOUZANÉ, FRANCE ; (5) CNR-ISMAR, BOLOGNA, ITALY ; (6) Université de Lausanne, LAUSANNE, SWITZERLAND ; (7) CNR-IRPI, PADOVA, ITALY*

The European and Mediterranean Major Hazards Agreement (EUR-OPA) of the Council of Europe is a platform for cooperation between European and Southern Mediterranean countries in relation to na-tech risks. The main objectives are to provide closer cooperation among member states in order to ensure better prevention and protection in case of disasters and to develop new methodologies and tools for risk management.

This contribution outlines the aims and perspectives of a research project funded within this framework. The project, managed by the Euro-Mediterranean Centre on Insular Coastal Dynamics (ICoD) in collaboration with the European Centre on Geomorphological Hazards (CERG), is aiming at linking and integrating terrestrial and marine datasets along the coastlines of Malta and Lower Normandy (France). The investigations carried out so far have contributed to the reconstruction of coastal geomorphological evolution and to a better definition of the kinematics of active landslides that determine risk situations.

The study areas show different morphoclimatic and tectonic setting, but have both been subject to significant changes in sea level since the LGM, when the sea level was some 120-130 metres lower than present. Previous research carried out in the frame of the CERG 2009-11 Project "Coastline at risk: methods for multihazard assessment" has shown that several landslides along the coastlines of Normandy and Malta are likely to extend well below the sea level and therefore coupling subaerial and submarine datasets is likely to provide useful information for their hazard assessment.

The Project is expected to deliver an original contribution and new directives for risk reduction in coastal areas taking into account historical and possible future climate changes by means of the application of a multidisciplinary approach aiming at the recognition of landforms which are presently under the sea level, but which were emerged in very recent geological periods

\*\*\*\*\*

## **Evaluation of mitigation measures to reduce shallow-landslide hazard induced by extreme rainfall events: analysis of the road network in the Vernazza catchment (Cinque Terre, Italy)**

*BRANDOLINI P.(1), GALVE J.P.(2), CEVASCO A.(1), SOLDATI M.(3)*

*(1) Dipartimento di Scienze della Terra, dell'Ambiente e della Vita, Università degli Studi di Genova, GENOVA, ITALY ; (2) Departamento de Ciencias de la Tierra, Universidad de Zaragoza, ZARAGOZA, SPAIN ; (3) Dipartimento di Scienze Chimiche e Geologiche, Università di Modena e Reggio Emilia, MODENA, ITALY*

The severe Mediterranean storm occurred on 25 October 2011 triggered several shallow landslides in the Cinque Terre area (eastern Liguria, Italy) that disrupted transportation routes causing significant direct and indirect economic losses. In the Vernazza catchment the high-intensity rainfall event (472 mm/6h at Brugnato, Vara valley, and 349mm/6h at Monterosso, Cinque Terre) generated more than 500 shallow landslides and all provincial roads connecting the village of Vernazza to the inland were closed due to severe damages. The reparation works on roads has been estimated at more than 10 million Euros. Indirect economic losses related to road closures are unknown but, although difficult to estimate, are likely to be higher than the direct losses, being this area a very famous tourist resort. A quantitative procedure has been applied for estimating shallow-landslide risk along the road network of Vernazza catchment in case a similar event occurs again. Firstly, a landslide hazard model has been produced analyzing statistically the spatial relationship between the landslide-event inventory and several conditioning factors. Secondly, the potential economic losses on roads have been estimated defining damage scenarios. The risk estimation has been calculated by combining landslide occurrence probability and expected losses on every road stretch. Additionally, the following aspects of the risk estimation, assessment and management have been analyzed simulating different solutions for hazard mitigation: (1) Impact of land use changes on landslide hazard and risk; (2) Identification of suitable engineering mitigation measures to reduce possible future economic losses; (3) Cost-effectiveness of proposed solutions. The presented method will be adapted to analyze other elements at risk in the study area to provide decision makers with the basis to select the most adequate mitigation solution considering both economic and societal factors.

**Landslide susceptibility validation using multitemporal inventory of landslides in the Moldavian Plateau, Romania**

*NICULITA M., MARGARINT C.*

*University Alexandru Ioan Cuza, IASI, ROMANIA*

Applying quantitative methods for estimating susceptibility to landslides is based on their spatial distribution. In many cases there is an obvious dynamic areas affected by landslides. On the one hand, given the temporal frequency of triggers, sliding surfaces growths is evident, on the other hand, land use changes often hinders accurate mapping of landslides. This reality translates into a high degree of One of the possibilities to improve these results is to consider several temporal landslide inventories. For an area of approx. 80 km<sup>2</sup> decreasing of landslide mapped surfaces. This happens for the inventory of landslides made from photo-interpretation of 2008 aerial images. The 2008 situation susceptibility map was validated using the landslides of 1978, 0.9 AUROC value indicating a good correlation of current delluvial classes susceptibility of the original map.

\*\*\*\*\*

**An integrated model to assess rain fall thresholds for critical run-out distances of debris flows in the Wenchuan Eartquake area, SW China**

*VAN ASCH T.(1), TANG C.(2)*

*(1) Faculty og Geosciences Utrecht University , UTRECHT , NETHERLANDS ; (2) State Key Laboratory of Geohazards Prevention and Environment Protection, CHENGDU, CHINA*

The 2008 Wenchuan Earthquake in the Sichuan Province, SW China generated many co-seismic landslides, which delivered a lot of loose material. It caused a dramatic increase in debris flow occurrences in the subsequent years.

For the development of early warning systems it is necessary to use integrated models which establish a link between rain input, initiation and entrainment processes, propagation and deposition processes. A preliminary model was designed, with entrainment processes driven by run-off water as the main triggering mechanism, to describe the relationship between rain input and debris flow run-out with the intention to assess rainfall thresholds for the start of debris flows and critical run out distances.

The model was calibrated on the depositional volumes of two debris flow events which occurred in two catchments on August 2011 The calibrated model was used to construct a rainfall intensity –duration threshold curve. This curve describes the thresholds for a critical run-out distance, determined by the outlet of the catchment, which was considered as the limit beyond which elements at risk situated in the main river plain are threatened. The calculated thresholds curves were compared with a threshold curve, which could be constructed for the Wenjia catchment on the basis of a number of debris flow rain events with a varying intensity and duration. In this catchment it became evident by field observations that a number of debris flows were triggered by intensive run-off erosion of loose co-seismic rock avalanche material. It appeared that the power functions of the calculated and observed threshold curves for these catchments have the same exponential value, which may indicate that the debris flows are triggered by the same mechanism.

In addition, a method is proposed to estimate the time duration for the depletion of the loose co-seismic source materials for these debris flows.

**Assessment of susceptibility for small landslides in the Secchia Basin (Modena Province - Italy) by means of statistical analysis**

LIBERATOSCIOLI E.(1), SOLDATI M.(1), VAN WESTEN C.J.(2)

(1) Dipartimento di Scienze Chimiche e Geologiche - Università di Modena e Reggio Emilia, MODENA, ITALY ;

(2) Faculty of Geo-Information Science and Earth Observation (ITC) - University of Twente, ENSCHEDE, NETHERLANDS

The present work is an attempt to assess susceptibility for small landslides in an area of 492 sq km located in the River Secchia Basin (Northern Apennines - Italy). The Secchia Basin extends for almost 2,300 sq km, but the current analysis focuses only on the hilly and mountain portion of the Modena Province as a prevention tool for local Civil Protection. The altitude of the study area ranges between 125 and 1700 meters a.s.l., and landslide processes represent one of its most important natural hazard. The susceptibility analysis concerns the landslides classified as slide according the Emilia-Romagna Region (RER) Landslide Inventory Map (LIM). The slides are 1081 (76% of which is active) and show the smallest surface among the different landslide types affecting the study area. The Weight of Evidence (WofE) method, a statistical approach, has been selected for performing indirect landslide susceptibility assessment. The choice of the training set, based only on active landslides, takes into account two main possible limitations: 1) the depletion areas are usually not mapped in the RER LIM which reports only the accumulation part of the mass movements; 2) in the RER LIM the term slide includes both earth and rock movements. In order to evaluate the fitting performance of the model, the final training set is randomly divided into two groups: the calibration set (80% of the occurrences) to compute the model itself and the validation set (20% of the occurrences) to estimate its quality. The analysis is based on the following predisposing factors: lithology, slope and other geo-morphometric parameters, aspect, land use and cover, distance from roads. Considering the above mentioned limitations, the resulting model predicts an acceptable number of landslides. However, possible future improvements of the results and their usability for Civil Protection purposes are discussed.

\*\*\*\*\*

**Dunes dynamics and potential risks of mass movements in Natal-RN City, Brazil**

FERNANDES E., CESTARO L.A., PEREIRA V.H.C.

Universidade Federal do Rio Grande do Norte, NATAL, BRAZIL

Coastal aeolian dune fields in Natal-RN city are inserted in the same dune complex that focuses like a band proximal oceanic eastern coast of the state of Rio Grande do Norte-Brazil, which has been highlighting the scenic-landscape and spatial relationships establishing with the local society and featuring varied uses of these environments. This association between the natural and socioeconomic processes that act on these dunes have promoted changes in the features of the relief from the instability of the steeper slopes, especially those leeward (lee side) that generate induced processes such as mass movements and that endanger these communities. The Environmental Protection Areas of Natal city are as territorial units of the natural environment planning and management regulated by Natal city's master plan. However, these protection zones are distinguished by use conflicts and occupation on these massive dunes. The objective of this study was to understand the dynamics of dune fields in some areas of Environmental Protection in order to identify areas of potential risk to mass movements on slopes of dunes occupied by local population. The modeling of land (slope, elevation) were prepared from contour lines of equidistance 1 meter vectorized using the Spatial Analyst module of ArcGIS 9.3 (ESRI). Sediment analyzes were performed in laboratory in order to determine their morphological characteristics and their maximum angle of friction between the grains. Besides, observations were made in situ indicators of landslides in homes. As a result, the Maps of Potential Risk to Mass Movements presents the following risk classes: NO RISK (slope 0 °); LOW RISK (slope from 1 to 10); RISK MEDIUM (slope from 10 ° to 25 °); HIGH RISK (slope from 25 to 31) and IMMINENT RISK (slope > 31 °).

**Between spatial autocorrelation and representativity: Seeking the 'optimal' sample size for a statistical spatial prediction model of debris flow initiation**

HECKMANN T., GEGG K., BECHT M.

*Catholic University of Eichstaett-Ingolstadt, EICHSTAETT, GERMANY*

Statistical approaches to predictive modelling on the catchment scale are used very frequently compared to heuristic and physically based methods. In many case studies, we find basic assumptions of statistical models neglected or violated. In case of logistic regression, e.g., problems caused by spatial autocorrelation, multicollinearity and the normally unfavourable ratio of "non-event" to "event" elements have often been ignored. Recent work employing the methodology of "rare event logistic regression" tackles the bias induced by the latter problem, but suggestions concerning the necessary sample sizes (for "non-events") seem to be based mostly on the literature, without having been thoroughly checked.

We present a case study of a prediction model for slope-type debris flow initiation. Using Monte Carlo analysis with stepwise logistic regression on raster data, the effect of sample size on model results is investigated by estimating 1000 models for a range of sample sizes. The "optimal" sample size is constrained by the requirement of model stability on the one hand (with sample sizes too small, the factors contained in the stepwise analysis and hence the model results are highly dependent on the sample) and sample independence on the other (with sample sizes too high, the raster cells in the sample are too close, on average, and spatial autocorrelation causes the sample to violate the independence assumption). The analysis yields not only the "optimal" sample size, but also the "optimal" geofactor combination (which forms part of most models). The optimal parameters in this respect are used to estimate a logistic regression model for a 15 km<sup>2</sup> study area in the Austrian Central Alps, which is then validated in a neighbouring area. Moreover, we explore the magnitude and spatial distribution of model uncertainties using an ensemble of 100 models calculated from independent samples.

\*\*\*\*\*

**ChangingRISKS: Assessment and communication on possible effects of global changes on landslide risks**

MALET J.(1), BÉGUERIA-PORTUGUÈS S.(2), PROMPER C.(3), GLADE T.(3), PUISSANT A.(4), REMAÎTRE A.(1)

*(1) Institut de Physique du Globe de Strasbourg, STRASBOURG CEDEX, FRANCE ; (2) Estación Experimental de Aula Dei, EEAD-CSIC, ZARAGOZA, SPAIN ; (3) Department of Geography and Regional Research, University of Vienna, VIENNA, AUSTRIA ; (4) Laboratoire Image, Ville, Environnement, STRASBOURG, FRANCE*

Landslides across the Alpine countries are recognised by practitioners, politicians and scientists as having a major socio-economic impact, and may represent a significant risk for the population and the properties in particular locations. The ChangingRISKS project intends to develop an advanced understanding of how global changes (related to both environmental and climate change as well as socio-economical developments) will affect the temporal and spatial patterns of landslide hazards and associated risks in two territories of the Alps, and how these changes can be assessed, modeled and communicated (through mapping procedures) to stakeholders.

The project work is focused on two mountain study areas located in France (*Barcelonnette Basin, South East France*) and in Austria (*district Waidhoffen/Ybbs, Lower Austria*). These research areas, characterized by a variety of environmental, economical and social settings, are severely affected by landslides, and have experienced significant landuse modifications and human interferences over the last century.

Results on the influence of changing landuse conditions and changing climate are presented through the application of a process-based modeling chain able to simulate transient groundwater hydrology and slope instability from observed and simulated climate data sets. Further development of the modeling platform to the calculation of intensity parameters (e.g. runout distances, sediment heights) are described.

## **Methods for landslide susceptibility assessment, concepts and applications for spatial planning in Lower Austria**

*PETSCHKO H.(1), BELL R.(1), GLADE T.(1), GRANICA K.(2), HEISS G.(3), LEOPOLD P.(3), BAUER C.(2), PROSKE H.(2), POMAROLI G.(4), SCHWEIGL J.(5)*

*(1) University of Vienna, VIENNA, AUSTRIA ; (2) Joanneum Research Forschungsgesellschaft mbH, GRAZ, AUSTRIA ; (3) Austrian Institute of Technology, TULLN, AUSTRIA ; (4) Office of the Lower Austrian Provincial Government, Department of Spatial Planning and Regional Policy, ST. PÖLTEN, AUSTRIA ; (5) Office of the Lower Austrian Provincial Government, Geological Survey, ST. PÖLTEN, AUSTRIA*

Landslides pose threats not only for specific localities, they are also influencing larger areas and consequently require spatial analysis methods for assessing the susceptibility to landslides. The decision on the most appropriate model is dependent on many factors. These include the size of the study area, the spatial resolution and quality of the input data sets, the usability and flexibility of spatial analysis methods, and the model performance. Geospatial statistics help to estimate the model performance, however, the model should also be assessed based on geomorphic plausibility, checked in the field or within GIS.

This contribution will present a study design for determining the best suited landslide susceptibility map for spatial planning in Lower Austria. As the maps will be implemented in spatial planning practises it was decided that the resulting maps are categorized in three classes. These classes are based on the percentage of slides contained in each class which is defined by the spatial planners and geologists of the provincial government. Considered landslide types in this study include rock falls and shallow or deep-seated slides. Rock fall susceptibility is modelled using the Conefall approach, as the data on rock fall starting zones did not give enough information for statistical modelling. For modelling the susceptibility of shallow and deep-seated slides the generalized additive models (GAM) and the Weights of Evidence method (WofE) are tested. The resulting area under the ROC, which was used as a statistical quality criterion for comparing model performance, does not show significant differences between the GAM and WofE. The final decision of model choice is mainly based on the geomorphic plausibility of the classified map. Therefore, for all landslide processes, the expert is still of major importance not only to obtain detailed spatial input data, but also to provide a final judgement on the quality of the map beyond statistical indicators.

\*\*\*\*\*

## **Debris flow susceptibility assessment in the avio valley (adamello-presanella massif, Central Alps) through multitemporal and conditional analysis**

*SALVATORE M.(1), BARONI C.(1), CARLONI I.(1), DELLA SETA M.(2), DEL MONTE M.(2), VERGARI F.(2)*

*(1) Dipartimento di Scienze della Terra, University of Pisa, PISA, ITALY ; (2) Dipartimento di Scienze della Terra, University of Roma La Sapienza, ROMA, ITALY*

Alpine areas, especially those at the highest elevations, are particularly sensitive to climatic changes inducing relevant modifications in the cryosphere extension and occurrence, as well as in frequency and intensity of slope processes.

We present results of a multitemporal analysis of slope processes conducted in a high mountain area by applying a method traditionally used for landslide susceptibility assessment, with the aim of defining the proneness to debris flow occurrence.

The study area is the Avio valley (Adamello-Presanella Massif, Central Alps), among the main tributary valleys of Valcamonica, which has recorded Late Glacial and Holocene glacial fluctuations, and, more recently, the glacial retreat following the Little Ice Age. In the newly forming climatic-environmental condition, the active geomorphic agents are affecting recently deglaciated areas, older glacial and slope deposits, clearly increasing instability processes.

The multitemporal analysis of slope processes, and in particular of debris flows, started from a geomorphologic map surveyed in 1985, and was updated with aerial photographs (1994 and 2006). All data were organized in a geomorphologic database in GIS environment.

The susceptibility evaluation method furnishes an unbiased procedure for causal factor selection based on some intuitive statistical indices, aimed at detecting among different potential factors the most discriminant ones in the study area. Conditional analysis allows to determine the susceptibility index value for a combination of selected causal factors (or vUCU, vector Unique Condition Units).

The multitemporal debris flow database allowed the validation of the obtained susceptibility model, in which many areas estimated as highly susceptible coincide with the area actually affected by debris flows in the period following that considered for the susceptibility evaluation, giving rise to encouraging results.

### **Deformation and prediction of landslides with step-like deformation in the Three Gorges Reservoir**

LI D., YIN K., CHEN L.

*China University of Geosciences(wuhan), WUHAN, CHINA*

It is very difficult to predict deformation tendency and general failure of landslides with step-like deformation in the Three Gorges Reservoir due to deformation complexity and lack of the failure criterion. The landslide deformation in the reservoir is notably influenced by the coupling effect of rainfall and reservoir water level. The deformation characteristics including local failure, multi-layer sliding and abrupt acceleration are firstly researched in detail based on the monitoring information and geological environment. In order to establish appropriate failure criterion, the three-dimensional prediction model is established through the multi-dimension body based on the landslide multi-factor. The landslide multi-factor is proposed on the basis of the alert velocity, earth crack of landslide surface and macroscopical evidences. The alert velocity could be obtained from the Voight's model. The three-dimensional failure criterion is proved by Baishuihe landslide and Xintan landslide.

\*\*\*\*\*

### **Landslide Susceptibility Mapping Using SINMAP model, Serra do Mar, Brazil**

NERY T.(1), VIEIRA B.C.(2)

*(1) Cemaden, CACHOEIRA PAULISTA, BRAZIL ; (2) Universidade de São Paulo, SÃO PAULO, BRAZIL*

The process-based mathematical model have been used to evaluate the relative susceptibility to shallow landsliding in mountain regions of Brazil. In these regions, especially, the Serra do Mar mountain range (located along the southeastern Brazilian coast), shallow landslides are usual features associated with intense summer storms causing catastrophic damages. On 23 and 24 January 1985, a summer storm (380mm/48 hours) triggered thousands landslides and debris flow in the River valley Moji, in Cubatão, São Paulo state. In this study, we evaluated the shallow landslides susceptibility in the Ultrafértil basin used SINMAP model, that is a probabilistic mathematical model, which defines the relative susceptibility to shallow landsliding. We used high resolution (4m<sup>2</sup>) Digital Elevation Model (DEM) obtained from a topographic map (1:10.000 scale). The soil parameters (geotechnical and hydrological) and precipitation were extracted from the others works in the Serra do Mar and the governmental agencies. Were proposed three scenarios varying the soil thickness (1 m, 1.5 m and 3.5 m). The results suggest high shallow landslide susceptible, with stability indexes exceeding 60%. The landslides occurred mainly on slopes of more than 30° and under conditions of partial saturation. The lower threshold class concentrated the largest number of landsliding (> 100) for the three scenarios. On scenario 2 (1.5 m soil thickness) was concentrated the most part of shallow landslides below the 1 threshold, which corresponds the unstable areas. The ratio (transmissivity/steady state recharge) was the most sensitive parameter of the model, showing that this ratio and the soil thickness were mainly important for these processes. The process-based model is an important tool to understand the landslides spatial distribution and to predict shallow landslide in steep tropical areas. Therefore, this tool can help the public administrators to reduce the damage in future events.

### **Multi-scale regional landslide susceptibility assessment in Sicily (Italy): The Sufra Sicilia Project**

ROTIGLIANO E.(1), AGNESI V.(1), ANGILERI S.E.(1), ARNONE G.(2), CALÌ M.(2), CALVI F.(2), CAMA M.E.(1), CAPPADONIA C.(1), CONOSCENTI C.(1), COSTANZO D.(2), LOMBARDO L.(1)

(1) University of Palermo, Italy, PALERMO, ITALY ; (2) Assessorato Territorio e Ambiente - Regione Sicilia, PALERMO, ITALY

The SUFRA ("SUscettibilità da FRAna") project, moves from the same multi-level approach of the TIER JRC European protocol. But, in light of the availability for the Sicilian territory of highly detailed geological I.s. and landslide data, SUFRA diverges both in the worked data and in the model building methods, selecting a more detailed three level landslide susceptibility assessment scheme: SUFRA100 (1:100,000), SUFRA50 (1:50,000) and SUFRA25/10 (1:25,000/1:10,000). All the three mapping levels exploit climatic, soil use and seismic informative layers, while differing: in the details of the core data (geology and topography); in the quality and resolution of the landslide inventory; in the modelling approach.

SUFRA\_100 is based on the heuristic modelling of a 1:100,000 geologic layer and a 250m cell DEM (IGMI) 250m; the mapping units are 1km side square cells and the models are validated with respect to the available regional landslide inventory (PAI). SUFRA50 is based on the stochastic modelling of 1:50,000 (CARG) geologic maps and 10m DEM; the mapping units are 50m cells and hydro-morphometric units, while the landslide inventory is specifically produced by means of a remote systematic landslide mapping. SUFRA10/25 is based on stochastic modelling of field checked geologic maps and 2m DEM; the mapping units are the slope units (SLUs), which are derived by further partitioning the hydro-morphometric units so to obtain closed morphodynamic units. The landslide inventories are produced by means of field and remote surveys (on focus). SUFRA50 and SUFRA25/10 models are validated by exploiting both random spatial partition and temporal partition methods.

Examples of SUFRA\_100, SUFRA\_50 and SUFRA\_25/10 are presented for some representative key sector of Sicily (northern chain and southern fore-deep sectors). First results attest for the feasibility and goodness of the proposed protocol.

\*\*\*\*\*

### **Landslide susceptibility map of the Mauritius Island**

MICCADEI E.(1), MARSALA V.(2), PIACENTINI T.(1), ROCCA M.(2), SCIARRA M.(1)

(1) Dipartimento di Ingegneria e Geologia - Università degli Studi "G. D'Annunzio" Chieti-Pescara, CHIETI, ITALY ; (2) SGI Studio Galli Ingeneria Spa, PADOVA, ITALY

The landslide susceptibility map of the Mauritius Island is the result of a comprehensive project for the Development of an Inundation, Flooding and Landslide National Risk Profile for the Republic of Mauritius carried out in collaboration with the Ministry of Environment and Sustainable Development that provided the data for this research.

Mauritius is a volcanic islands located in the western part of the Indian Ocean and constructed by three distinct main episodes of volcanic activity from 10 to 0,02 M.y.

The mapping of landslides driving factors was carried out combining digital terrain models, geological, soil map and land use data. An analysis of the orthophoto data was conducted for the main mountainous/hilly areas of the island. The identified landslide prone areas were corroborated through a field geomorphological survey and expert knowledge based analysis. The landslide susceptibility and hazard study of Mauritius was based on a mixed heuristic and statistical analysis with multidisciplinary approach incorporating: 1) definition and GIS mapping of geology and geomorphology factors, directly or indirectly linked to slope instability (slope, aspect, profile curvature, planar curvature, drainage pattern, vegetation, lithology, soil, rainfall), by means of bibliographic data and photogeology analysis; 2) mapping of the existing landslides and superficial deposits by means of photogeology and field mapping; 3) GIS modelling of landslide susceptibility based on the statistical relationships between factors and instability process, calibrated through field surveys.

The adopted methodology defined a different susceptibility for different type of instabilities (rock falls, landslides, rapid earth flows). The ensuing maps were overlaid to obtain the overall instability map, analysed using the cumulative distribution function and reclassified in four main classes. The overlay of these maps produced the comprehensive landslides susceptibility map of the Mauritius Island.

### **Regional-scale debris-flow modelization for hazard mapping in alpine basins using a high-resolution DTM and events geodatabase**

CREMA S.(1), CAVALLI M.(1), MACCONI P.(2), MARCHI L.(1)

(1) CNR-IRPI, PADOVA, ITALY ; (2) Hydrographic Office, Autonomous Province of Bolzano, BOLZANO, ITALY

A very detailed geodatabase of floods, landslides and debris flows is available and kept up to date for the territory of the Autonomous Province of Bolzano, in northeastern Italy (7400 km<sup>2</sup>). The database is fed by field surveys carried out after the occurrence of instability phenomena and reports locations and attributes of the events for the last 15 years. The on-site analysis grants the gathering of important information and documentation resulting from field measurements and interviews to witnesses of the events. Particular attention is paid to the recognition of location, magnitude and path of landslides and debris flows.

Data on shallow landslide locations and debris-flow initiation sites have provided the input to a regional-scale debris flow model aimed at the assessment of debris flow paths and inundation areas. A simple mass propagation model based on topographic attributes (Huggel et al., 2003) has been applied to simulate mass movement phenomena for selected basins using initiation sites listed in the regional database. In the model, debris-flow propagation is given in probability-related values representing the hazard potential for the selected locations. All the simulations have been carried out using a high-resolution (2.5m) LiDAR-derived Digital Terrain Model (DTM).

The combination of a georeferenced database of landslides and debris flows and a simple topography-based model constitutes therefore a reliable tool for a fast and preliminary debris-flow hazard estimate, assessment and mapping.

References: Huggel C, Kääh A, Haeberli W, Krummenacher B. 2003. *Regional-scale GIS-models for assessment of hazards from glacier lake outbursts: Evaluation and application in the Swiss Alps*. Natural Hazards and Earth System Sciences 3(6):647–662.

\*\*\*\*\*

### **Multi temporal LiDAR-DTMs as a tool for modeling a complex landslide: a case study in the Small Dolomites (Rotolon catchment - Italy)**

BOSSI G.(1), CAVALLI M.(1), QUAN LUNA B.(2), FRIGERIO S.(1), MANTOVANI M.(1), MARCATO G.(1), SCHENATO L.(1), PASUTO A.(1)

(1) CNR-IRPI, Research Institute for Geo-Hydrological Protection, Italian National Research Council, PADOVA, ITALY ; (2) NGI, Norwegian Geotechnical Institute, ICG, International Centre for Geohazards, OSLO, NORWAY

The geomorphological change detection through the comparison of repeated topographic surveys is a recent approach that greatly benefits from the latest developments in topographical data acquisition techniques. Among them, airborne LiDAR makes the monitoring of geomorphological changes a more reliable and accurate approach for natural hazard and risk management. In this study, the analysis of multi temporal LiDAR-DTMs acquired just before and after a complex landslide event (4<sup>th</sup> November 2010) in the Rotolon catchment (Small Dolomites, Italy), was used to set up the initial condition for the application of a dynamic model.

The 2010 event detached a mass of 320.000 m<sup>3</sup> from the south slope of Mt. Rotolon partially evolving in a debris flow that stretched for 4.5 km threatening some villages. Pre- and post-event DTMs derived from LiDAR with 2 m resolution were available. The comparison between the DTMs was carried out considering the error propagation. The resulting differential DTM was analyzed in order to identify erosion and depositional areas related to the event and to quantify them in terms of volume.

The knowledge of the dynamics of the phenomenon allowed to back-analyze the event with a dynamic numerical 3D model. DAN3D code was selected because it allows to modify the rheology and the parameters of the moving mass during the run-out. This behaviour was observed along the path of the debris-flow where the mobilized mass encountered rheological modifications due to the hydric contribution of tributary streams and the entrainment of eroded material. Considering these aspects a sound simulation of the 2010 event was computed.

Nowadays some portions of Mt. Rotolon flank are still moving and showing precursor signs of detachment. The same soil parameters used in the back-analysis model were used to simulate the run-out for three possible landslides flows allowing to generate reliable risk scenarios that could be used for creating civil defense emergency plans.

## **Comprehensive Utilization of SAR and Optical Data for Landslides Investigation in the Bailongjiang Basin, China**

CHENG C., BAI S., WANG J., WEI Y.  
Nanjing Normal University, NANJING, CHINA

The Zhouqu–Wudu segment of the Bailongjiang Basin in Northwest of China with a total area of 8917 km<sup>2</sup> lies in the transition zone among Tibet plateau, loess plateau and Sicuan Basin. It has already been strongly affected by landslides for a long time, it is one of the most severely landslide affected regions in China. There are more than 2000 large and medium-sized landslides which are greater than 3×10<sup>4</sup>m<sup>3</sup> before the Wenchuan earthquake in this regions, numerous additional slope failures were triggered by the 2008 Wenchuan earthquake.

This case study has two main objectives: (i) Landslides recognition and mapping using space-borne SAR and Optical imagery; (ii) long term monitoring (from 1995 to 2012) of deformation based on persistent-scatter (PSI) techniques. The landslides recognition which using supervised classification, change detection and texture analysis method. Interferometric synthetic aperture radar (INSAR) data from ERS and ENVISAT sensors were utilized in the analysis of the deformations. Causing by temporal decorrelation the PS which located inside the landslides is lacking sometimes, the adjacent landslides with sufficient number of PS were analyzed by transformation of the line of sight displacements recorded by the sensors to the slope vector direction. This procedure allowed identification of the precise boundaries of the actively moving landslide parts and the updating of the landslide inventory in this region.

\*\*\*\*\*

## **Hydroelectric power generation, tropical river flood hazards and mitigation plan for better investment in Uttaranchal, India**

CHHABRA N.(1), ROY N.G.(2)  
(1) University of Petroleum & Energy Studies, DEHRADUN, INDIA ; (2) Presidency University, KOLKATA, INDIA

The hydraulic performance of the Tons River demonstrates significant flood damage potential in agricultural, industrial and residential areas adjacent the river in this region. Therefore, the design of flood control strategies is one of the main focuses of hydroelectric power projects in this region. This article presents the results of flood analysis in the Tons River catchment at several sites and impact flood control measures of the operational and under-construction dams. We also present the evaluation of structural flood control plans downstream of dams and floodplain areas. In this regard, inundation level and inundated area was calculated by using flood routing model (dynamic) in different situations, without and with different flood mitigation alternatives. Flood damages were determined versus inundation levels by using field survey results and from reports. Then, the expected annual damage for each alternative scheme was calculated by elevation – damage function. Expected annual damage reduction through proper flood control, which is the benefit of investment plan was also determined through all alternatives (scenario analysis). Then, economic indices (NPV in our case) were calculated and justification was evaluated by determining initial investment cost, operation and maintenance cost and also annual benefit of damage reduction using data from existing project.

The results of this study is the integrated flood mitigation plan in the Tons rivers system which includes one operational dam in Mohammadpur, one under-construction dam in Chibro and one development dam in Kalsi. All selected alternatives were economically feasible and environmentally protected.

Keywords: river engineering, flood control, risk analysis, damage analysis, investment.

## How can fiber optic technology be used in early warning systems for natural hazards?

BOGAARD T., WENKERS K.

*Delft University of Technology, faculty of Geosciences and Civil Engineering, Department of water management, DELFT, NETHERLANDS*

In order to reduce the societal risk associated with natural hazards novel technologies could help to advance in early warning systems. In our study we evaluate the use of multi-sensor technologies as possible early-warning systems for landslides and man-made structures, and the integration of the information in a simple Decision Support System (DSS). In this project, particular attention will be paid to some new possibilities available in the field of distributed monitoring systems of relevant parameters for landslide and man-made structures monitoring (such as large dams and bridges), and among them the distributed monitoring of temperature, strain and acoustic signals by FO cables.

Fiber Optic measurements are becoming more and more popular. Fiber optic cables have been developed in the telecommunication business to send large amounts of information over large distances with the speed of light. Because of the commercial application, production costs are relatively low. Using fiber optics for measurements has several advantages. This novel technology is, for instance, immune to electromagnetic interference, appears stable, very accurate, and has the potential to measure several independent physical properties in a distributed manner.

The high resolution spatial and temporal distributed information on e.g. temperature or strain (or both) make fiber optics an interesting measurement technique. Several applications have been developed in both engineering as science and the possibilities seem numerous.

We will present a literature review that was done to assess the applicability and limitations of FO cable technology. This review was focused but not limited to application in landslide research. Furthermore, field and laboratory experiments will be discussed. Several examples of current practices will be shown, also from outside the natural hazard practice and possible application will be discussed.

\*\*\*\*\*

## Critical hydro-climatic thresholds for triggering slow-moving landslides along Normandy coasts (France)

LISSAK C.(1), MAQUAIRE O.(1), MALET J.P.(2)

*(1) LETG-Caen Géophen, CAEN, FRANCE ; (2) Ecole et Observatoire des Sciences de la Terre [EOST], Institut de Physique du Globe de Strasbourg [IPGS], STRASBOURG, FRANCE*

In Normandy (North-West France), landslides occurring along the coasts are large, deep in marly, sandy and chalky formations. All are characterized by a seasonal activity (1-10 cm.y<sup>-1</sup>) and regularly affected by brutal accelerations inducing several meters slope displacements.

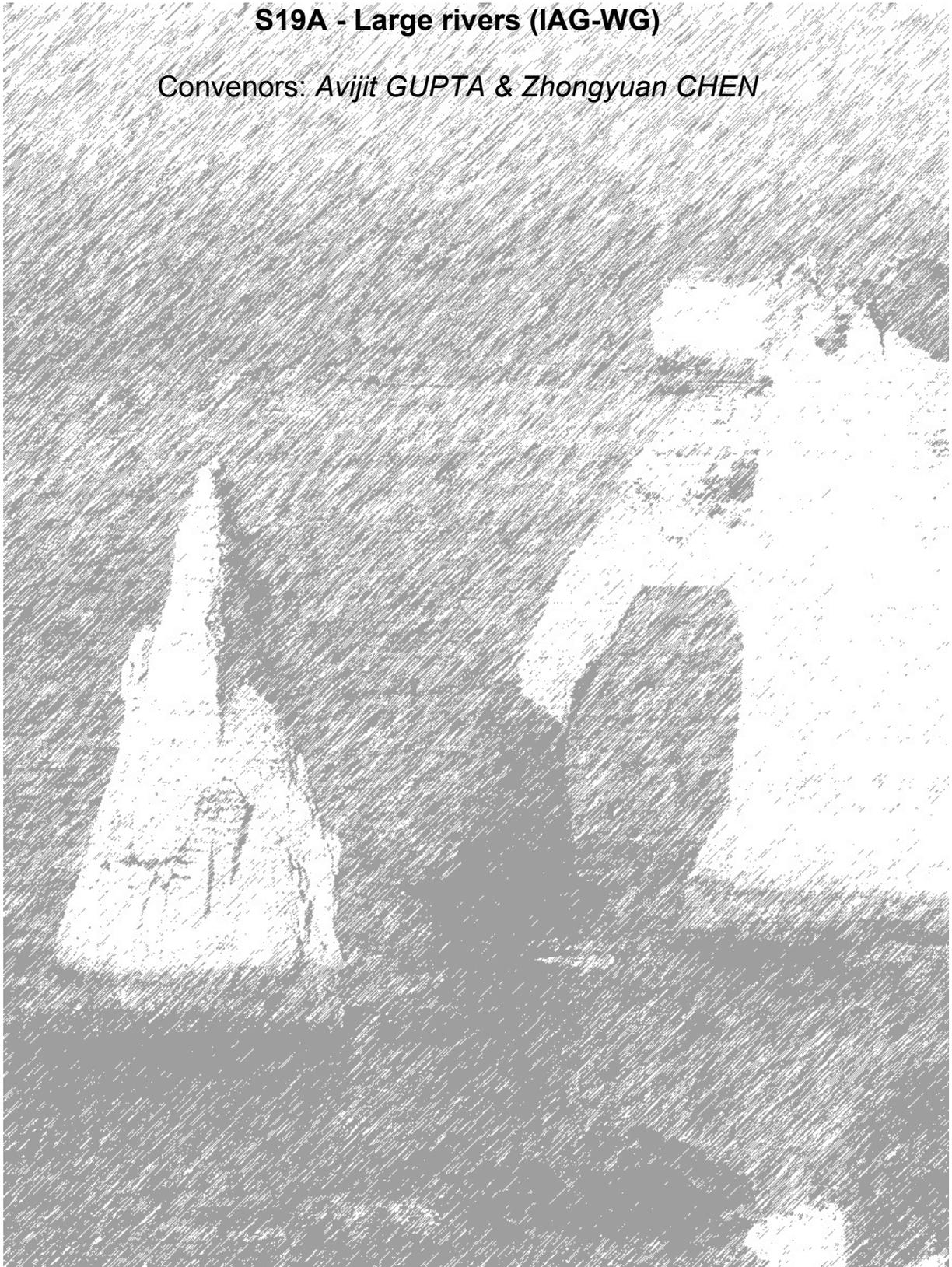
The first investigations after the reactivation of the landslide (January 1982) showed that the several accelerations (January 1982, February 1988, January 1995 and march 2001) were closely related to hydro-climatic conditions.

To improve upon knowledge on slope dynamic associated to rainfall and groundwater level fluctuations, the combination of historical data and punctual or permanent field measurement were necessary. The monitoring system has been implemented to observe the triggering factors (twenty-eight available piezometers whose five with permanent sensors) and very low amplitude displacements through the implantation of three permanent GPS receptors and twenty-three cemented benchmark. These investigations highlight the morphostructural control of the landslide kinematic but also the seasonal variations of the landslide velocity. Finally, groundwater level has been associated to the landslide kinematic to define critical thresholds towards an early warning system to differentiate the permanent activity of the landslide from precursors of major accelerations. Investigations were first conducted on the plateau, a few kilometers from the site, to define early warning piezometric thresholds.

Two main situations were identified: (1) a long-lasting rainfall episodes (several month) with groundwater water elevation of more than 2 meters causing major accelerations (return period of over 5/10 years); and (2) a moderate-intensity rainfall period with a limited groundwater rise responsible for a moderate seasonal kinematic (return period of about every years) with a lag time between groundwater rise and slope acceleration about 1 and 4 days.

**S19A - Large rivers (IAG-WG)**

Convenors: *Avijit GUPTA & Zhongyuan CHEN*





## **Oral presentations:**

### **Sedimentary Processes in Large Source-to-Sink Systems Forced by ENSO**

AALTO R.

*University of Exeter, EXETER, UNITED KINGDOM*

Sedimentation patterns and processes are summarized within three large rivers that border the tropical Pacific region responsible for the El Niño/Southern Oscillation (ENSO), a global phenomenon affected by future climate change. The research investigates the supply, transport & deposition of sediment, employing field documentation of accumulation processes, surveys, and inundation mapping.

The rivers are: 1) The Beni-Mamore system in the Bolivia that supplies the majority of sediment and water to the Madeira River, in turn the largest contributor of the  $\sim 1 \text{ Gt Mt yr}^{-1}$  of sediment discharged by the Amazon; 2) The Fly River in Papua New Guinea (PNG) that comprises the largest river basin in Oceania, ranking among the top 25 rivers in the world for water and sediment discharge, at  $1.9 \times 10^9 \text{ m}^3 \text{ yr}^{-1}$  and  $85 \text{ Mt yr}^{-1}$ , respectively; & 3) The Mekong River, investigated in Cambodia, that also exhibits a runoff-ENSO relationship and supplies sediment to maintain the delta. Because the tectonically active, tropical watersheds of Oceania account for half of the global sediment flux to the ocean, the impact of climate oscillations on sedimentary processes is of particular interest.

In both PNG and Bolivia the majority of the sediment is delivered from mountain headwaters during ENSO oscillations, with sediment accumulation across the lowland floodplains primarily during infrequent, episodic events – not during regular seasonal inundations. These rapid transfers of sediment mass from the active orogeny to the lowland depocenters occur primarily during cold-phase ENSO events immediately following strong warm-phase ENSO conditions that have dried out the floodplains. The impact of ENSO on the accretion of Cambodian floodplains is somewhat less dramatic. Over timescales of centuries to millennia, ENSO may therefore modulate the rates and mechanisms for construction of lowland river floodplains, creation of geological strata, and ultimately the export of material to deltas.

\*\*\*\*\*

### **Climate change and large tropical rivers**

GUPTA A.(1), LIEW S.C.(2)

*(1) University of Wollongong, WOLLONGONG, AUSTRALIA ; (2) National University of Singapore, SINGAPORE, SINGAPORE*

Large tropical rivers tend to have a common set of properties: a polyzonal basin, longitudinal variations in channel and valley characteristics, a seasonal pattern of discharge, episodic sediment transport, almost the entire sediment derived from the headwaters, large deltas. The Fourth Assessment report of the Intergovernmental Panel on Climate Change lists certain consequences of climate change that should impact these rivers. These include retreat of mountain glaciers, early melting of snow and ice, changes in annual rainfall, enhanced seasonality, regional increase in droughts, increase in the strength of large storms, high rainfall from extreme events, and sea-level rise. It is possible to evaluate the robust changes in stream morphology and behaviour using principles of fluvial geomorphology and past analogues. Although we limit this discussion to the large tropical rivers, generalisations are difficult beyond a point and individual rivers may adjust individually. Anthropogenic activities have modified almost all rivers, and in certain cases, the noise from anthropogenic alterations may override signals of climate change. In spite of these constraints it may be possible to construct a new set of rules for understanding, utilizing and managing rivers. Such attempts are worthwhile as, following climate change, rivers are likely to lose stationarity and also undergo drastic changes, such as avulsion in certain parts of their basins such as mountain-front fans and lower valleys and deltas. As a very large population live in these areas, it is imperative to design a new style of management and adaptive behaviour in order to live near large tropical rivers.

## **Interactions between global warming, flooding and fluvial form adjustment on the Lena River, Central Siberia**

GAUTIER E.(1), FEDOROV A.(2), COSTARD F.(3), KONSTANTINOV P.(2), BRUNSTEIN D.(4)

(1) Paris 8 University - CNRS Lab. Géographie Physique, MEUDON, FRANCE ; (2) Russian Academy of Sciences - Permafrost Institute, YAKUTSK, RUSSIAN FEDERATION ; (3) CNRS UMR 8148 Ides, ORSAY, FRANCE ; (4) CNRS UMR 8591 LGP, MEUDON, FRANCE

The study examines impacts of the current climatic change on a large periglacial hydrosystem, at different spatial and temporal scales. The fluvial dynamics of the Lena River is controlled by a periglacial environment, characterized by a very cold and dry climate and by a deep permafrost. For these reasons, the hydrology of the Lena is characterized by an irregular fluvial regime and a spectacular flood. During the flood, thermal and fluvial erosion jointly cause important retreat of frozen banks, mainly on island heads. In Yakutia, previous studies clearly show significant signs of a climatic change since the end of the 1980's: increase of temperatures, up to 5°C during winter for the air, up to 1°C for the permafrost, and up to 2°C for the stream water during summer.

A first part analyses historical hydrologic data (daily discharge since the 1930's) to detect a possible change of hydrology. We examine flood peaks, flood duration and date of beginning of the outburst. Because of the strong impact of rapid outburst, we also try to detect precisely rapid water elevation to identify exceptional events.

Second, we present the results of field surveys conducted during five years on different sites, in order to determine interactions between flood intensity and duration, water temperature, ice-jam, alluvial vegetation and erosion / deposition processes. The equipped sites were chosen in the upper part of the active floodplain, where there is no direct anthropogenic influence: i) data loggers are installed at different depths in the permafrost; ii) annual topographic surveys associated with sediment trapping system precisely inform on erosion and deposition; iii) captors inform on the height of the water level during flooding. All these data are correlated with water discharge and water temperature at Tabaga gauging site. The study highlights the contrasted effects of a rapid and intense outburst and of a long duration of flooding.

This study is supported by ANR Climaflu.

\*\*\*\*\*

## **Recent changes in the morphology of river channels in the Mekong delta: natural or anthropogenic?**

BRUNIER G.(1), ANTHONY E.J.(2), PROVANSAL M.(1), DUSSOUILLEZ P.(1), GOICHOT M.(3)

(1) Aix-Marseille Univ., CEREGE UMR CNRS 7330, AIX-EN-PROVENCE, FRANCE ; (2) Aix-Marseille Univ., CEREGE UMR CNRS 7330, Institut Universitaire de France, AIX-EN-PROVENCE, FRANCE ; (3) Sustainable Hydropower and River Basin Management, WWF Greater Mekong Programme, VIENTIANE, LAOS

The world's river deltas are threatened by hydroelectric dam constructions, embankments, channelling off low, and aggregate extraction. The Mekong delta, in Vietnam, is the world's third largest delta. Changes in the morphology of the Mekong proper and the Bassac, the two main distributaries in the 250 km-long deltaic reach from the Cambodian border to the coast, were analysed using maps and Landsat® and SPOT® satellite images from 1965 to 2008/2009. The results show a significant increase in the mobility of the riverbanks since the early 1990s, with important accretion. The geometry and morphology of the two channels, analysed from bathymetric data for 1998 and 2008, display important irregular bed incision, with expansion and deepening of numerous pools. These changes probably explain the more rapid bank mobility. The mean depth of both channels increased by more than 1.5 m between 1995 and 2008. Mean longitudinal bed incision rates in the Mekong are similar to those in the Bassac even though the former conveys more than 15 times the liquid discharge of the latter. Correlations between bed incision and hydraulic parameters are extremely weak, suggesting that the marked morphological changes are not in equilibrium with flow and sediment entrainment conditions, and are therefore not related to changes in river hydrology. We assume that aggregate extraction, currently practised on a very large scale in the two channels, is the main driver of these recent morphological changes. Future large-scale hydropower dam development on the Lower Mekong mainstream will have cumulative effects, leading to increased morphological changes that should be felt rapidly as the system is already impacted. These changes are already affecting the Mekong delta shoreline, which currently shows significant erosion, following extremely rapid progradation over the last 3000 years, a pattern of recent destabilization not unlike that of other Asian megadeltas.

## Regional scale analysis of natural vs. anthropogenic controls on sediment fluxes

BALTHAZAR V., VANACKER V.

*Université catholique de Louvain (UCL), LOUVAIN-LA-NEUVE, BELGIUM*

Spatial variability in sediment yield (SY) and its controlling factors are often analyzed on the basis of local or global sediment flux data but are rarely based on a regional dataset. As the biophysical and anthropogenic determinants of soil erosion largely depend on the spatial scale under study, extrapolations of plot-scale erosion analyses often lead to inadequate conclusions. A regional assessment of the spatial variability in SY allows filling the gap between detailed, process-based understanding of erosion at field scale and empirical sediment flux models at global scale.

In this study, remote sensing data are used as proxies of biophysical and anthropogenic site characteristics. The Blue Nile and Atbara River basins were selected for this analysis, as they are characterised by a large spatial variability in SY. First, correlation analyses are used to identify the environmental factors that are controlling spatial variability in SY at the regional scale ( $10^1$  to  $10^4$  km<sup>2</sup>). Regression techniques were then used to develop an empirical SY model that predicts erosion as a function of site characteristics. Second, the outcome of this empirical, site-specific model is compared to the prediction of the global sediment flux model, *BQART* (Syvitski and Milliman, 2007), and a new modified version of the *BQART* that takes into account the human impact on sediment production. The modified version of the *BQART* model estimates the human influence on SY based on a high resolution composite measure of local human impact instead of countrywide estimates of GNP/capita. The comparison shows that the global predictive sediment flux model is less suited to capture the spatial variability in area-specific sediment yields (SSY), but is very efficient to predict absolute sediment yields (SY). Our modified version of the *BQART* is able to explain 80% of observed variation in SY for the Blue Nile and Atbara basins and performs only slightly less than locally adapted regression models.

\*\*\*\*\*

## Quantification and Modeling of Runoff and Suspended Sediment Transfer Paths in Instrumented Mesoscale Catchments in Spain and Brazil

BRONSTERT A.(1), ARAÚJO J.(2), BATALLA R.(3), GÜNTNER A.(4), FÖRSTER S.(4), FRANCKE T.(1), MÜLLER E.(1), BROSINSKY A.(1), DELGADO J.(1), LÓPEZ-TARAZÓN J.(3), SOMMERER E.(4), VERICAT D.(3), WERB S.(1)

(1) University of Potsdam, POTSDAM-GOLM, GERMANY ; (2) Universidade Federal do Ceará, FORTALEZA, BRAZIL ; (3) University of Lleida, LLEIDA, SPAIN ; (4) GFZ German Research Centre for Geosciences, POTSDAM, GERMANY

This work addresses the relation of transfer, storage and re-entrainment processes that determine the distribution of water and sediments among different landscape components. Selected insights into the ongoing research project "Generation, transport and retention of water and suspended sediments in large dryland catchments: Monitoring and integrated modeling of fluxes and connectivity phenomena" (SESAM) are presented. These encompass the quantification and modeling of runoff and suspended sediment transfer paths in dryland regions and of the connectivity processes in instrumented meso-scale catchments in Spain and Brazil.

The main methods applied in the project are (1) water and sediment tracing based on both spectral fingerprinting and Radio Frequency Identification (RFID) (2) field monitoring of water level, turbidity, precipitation and of changes in hillslope, river bed and nested catchment topography (3) modeling of runoff and suspended sediment transfer paths with WASA-SED (a spatially semi-distributed model for water and sediment transport), including sediment retention in reservoirs and small dams and bed-load transport. To the present day, the comprehensive measurements from plot to meso-scale by field works and remote sensing campaigns has been achieved. The measurements include flight campaigns with hyperspectral and laser sensors onboard, repetitive terrestrial laser volume-scans, as well as several hydrological observations.

The findings of this project are used to extend the WASA-SED model to account for the process understanding of connectivity at the intersections of hillslopes, rivers and reservoirs. Large-scale pilot parameterisations for parts of the Ésera Basin in Spain and the Upper Jaguaribe in Brazil will be conducted. The expected results will improve the knowledge and modelling capability of water and sediment fluxes and their connectivity mechanisms in drylands at spatial scales relevant for water and land management.

### **Understanding recent change in river-floodplain connectivity in the Baviaans catchment, Eastern Cape: implications for floodplain restoration**

*JOUBERT R., ROWNTREE K., ELLERY W.*

*Rhodes University, GRAHAMSTOWN, SOUTH AFRICA*

The concept of landscape connectivity broadly refers to the degree of hydrological and sedimentary linkage between different landscape compartments (e.g. hillslope-channel and channel-floodplain linkages); in river catchments, connectivity determines the ease with which sediment is transferred through a catchment and the response (erosion or deposition) of rivers to disturbances (Brierley *et al.*, 2006). Recent (last 30 - 40 years) channel incision along a reach of the Baviaans River, in the Eastern Cape of South Africa, has resulted in dis-connectivity between the river and adjacent floodplain through reduced over-bank flooding together with effective channelling of water and sediments away from the main floodplain during flood events. This has resulted in floodplain wetland desiccation and decreased capacity of the river to attenuate flood flows and provide water to local and downstream communities. In this study we investigate the role of human and natural disturbances in driving recent channel incision and floodplain degradation in the Baviaans catchment, and the role of connectivity in determining river response. Preliminary findings suggest that changes in catchment land-use (and associated land cover), human engineering of the main river and tributary streams, and changing rainfall regimes have been important in promoting recent channel incision. We also suggest that the response of the river (through channel incision) to these disturbances has been determined by the nature and degree of connectivity between the main river and large tributary streams along the degraded floodplain reach. These findings have been important for appraising planned floodplain restoration strategies for the Baviaans catchment.

References: Brierley, G., Fryirs, K. & Jain, V. (2006) Landscape connectivity: the geographic basis of geomorphic applications. *Area*, 38(2): 165-174.

\*\*\*\*\*

### **The Hydrology of the Yangtze (Changjiang) River, China**

*FINLAYSON B.(1), CHEN J.(2), WU X.(2), WEI T.(2), LI M.(2), CHEN Z.(2), WEBBER M.(1)*

*(1) The University of Melbourne, ASCOT VALE, AUSTRALIA ; (2) East China Normal University, SHANGHAI, CHINA*

The Yangtze flows from the Tibetan Plateau to the East China Sea (6300 km); total drainage area  $1.808 \times 10^6 \text{ km}^2$ . Here we describe the main hydrological characteristics of the Yangtze (precipitation, runoff, variability, seasonality, floods, low flows) both for the whole catchment and the upper, middle and lower sections, since 1955. Briefly, the Yangtze has mean annual precipitation (runoff) of 1037(517) mm, both with a marked summer dominance. Interannual variability of precipitation (runoff), as measured by the coefficient of variation, is low by world standards at 0.066 (0.126). The variability of floods is similarly low: flash flood index 0.18.

The upper catchment has the most marked summer precipitation dominance. It is both the driest and least variable section and with no statistically significant trends in either precipitation or runoff. Both precipitation and runoff increase downstream through the middle and lower basins, variability increases, as does winter precipitation. There is a statistically significant increase in runoff in the middle basin and both runoff and precipitation in the lower basin after 1987. Meanwhile, the runoff ratio shows an obvious increasing trend in the mid-lower basin, possibly caused by changes in the nature of the catchment surface due to rapid urbanization and dam construction. In all cases the magnitude of the trend is small.

The Yangtze has a long (~8,000 yr) history of human occupation and human impacts have increased dramatically since the economic reforms began in China in the late 1970s. The changes since 1980 that would be expected to have a significant hydrological impact include population growth, agricultural intensification, increasing urbanisation, dam construction and industrial development. We find little direct evidence in the hydrology of the Yangtze that reflects these changes. Similarly there is no clear evidence of impacts that could be related to climate change.

### **Post-dam assessment for change in riverbed and delta-coast morphology following impoundment of Three Gorges Dam of the Yangtze (Changjiang) River**

CHEN Z., YUAN W.H.

East China Normal University, SHANGHAI, CHINA

The impacts of a dam on the river downstream in terms of hydrology and morphology is determined by a complex mix of variables that include the patterns of release of water through the dam and the characteristics of the downstream channel. Scour of the downstream channel is a common response since large dams cause a significant interruption to sediment continuity. Here we show that in the case of China's Three Gorges Dam on the Yangtze River the outcome is more complicated than in other cases. The downstream channel and floodplain system is an area of long-term sediment accumulation and unstable channels with seasonally contrasting erosion and deposition patterns related to the migrated seasonal monsoon rainfall zones. It is also the case that in achieving one of the main purposes of this dam, that of flood control in the middle and lower basins, the pattern of flows released from the dam will closely resemble those seasonal flows that are responsible for channel instability in the middle catchment thus effectively making erosive conditions the most common during a year. There is obviously concern about the ultimate impact of sediment storage in the dam on the dynamics of the delta and adjacent coast and we show that this depends on the trajectory and duration of the erosive responses in the middle Yangtze basin. In this particular case, the outcome is of great significance to the well being of the densely populated riparian to delta-coastal areas of the river catchment.

\*\*\*\*\*

### **Model of reservoir regulations and their impacts on river fragmentation in the Yangtze River Basin, China**

YANG X.K., LU X.X.

National University of Singapore, SINGAPORE, SINGAPORE

The water regime of the Yangtze River (Changjiang) has been altered by intensified reservoir construction over the past decades because more than 42,000 reservoirs have been built in the Yangtze River basin over the past five decades. In recent years, the Yangtze River is being dammed at a dazzling pace; there are even more than 10 cascade dams built on some major tributaries. Under this condition, modeling to quantify the degree to which the river and landscape are fragmented by dams is crucial to identify environmental risks associated with further impacts on large river systems. In this study, we used three metrics to assess the impacts caused by dam construction. (1) River free-flowing rate is defined as the ratio of the length of sections that remain "free flowing" to the total length of the river; (2) catchment connectedness provides insights into how different smaller catchment classes are distributed across a large river basin and how they relate to each other in terms of spatial configuration; and (3) stream division, presenting the cumulative segment length distribution, indicates the degree to which the tributary is divided. This study reveals that free-flowing streams are vanishing on the mainstem and major tributaries, such as the Jinshajiang, Wujiang, Dadu, Yuanjiang and Jialingjiang rivers because of dam construction. The most severely impacted tributaries are Wujiang, Yuanjiang and mainstem. However, the situation could be worsened as additional large hydropower projects are completed in this basin. Through river fragmentation assessment we can be proactive in reservoir management decisions rather than reactive. This will make it easier to develop the Yangtze basin with a much lower environmental footprint.

### **Geochemical compositions of the late Cenozoic sediments in the Jiangnan Basin: Implications for sediment source and evolution of the Yangtze River**

SHAO L.(1), LI C.(2), YUAN S.(3)

*(1) Wuhan Center, China Geological Survey; China University of Geosciences, WUHAN, CHINA ; (2) China University of Geosciences, WUHAN, CHINA ; (3) China University of Geosciences; College of urban planning & environment science, Xuchang University, WUHAN, CHINA*

The Yangtze River is one of the most important components of the East Asia river system. Understanding the evolution of these large rivers is important to understanding the process of orogeny. The uplift of the mountains and plateaus where these large rivers originate are proposed to profoundly affect the global climate system. Consequently the reconstructions of these rivers are important to understand the global change and its regional response.

Although study of the evolution of the Yangtze River has a long history of more than 100 years, it is still controversial. In this study we applied bulk geochemical analysis to identify the sediment provenance in the Jiangnan Basin, middle Yangtze River and tried to reconstruct the evolution of the Yangtze River. The samples were selected from a continuous borehole in the Jiangnan Basin and analyzed for geochemical compositions. The  $\epsilon_{Nd}(0)$  values vary between -11.6 and -7.8, with an average of -9.6. Nd isotopic compositions cannot provide compelling evidence to prove whether the Pliocene sediments in the Jiangnan Basin were influenced by the source rocks in the Jinshajiang area characterized by extremely high  $\epsilon_{Nd}(0)$  values. While these source rocks made a great contribution to the Jiangnan Basin during the Quaternary. Less negative  $\epsilon_{Nd}(0)$  values reflect preferential erosion of source rocks in the Jinshajiang drainage. It reflected changes in erosion patterns during the Quaternary. The trace element compositions also revealed this important provenance change of the Jiangnan Basin sediments around the beginning of the Quaternary from more felsic provenances to more basic provenances. Input from the Emeishan LIP should account for this provenance change. Based on these geochemical data, we propose that the Yangtze River appears to develop into a large river similar as the modern Yangtze no later than the beginning of the Quaternary.

\*\*\*\*\*

### **Declining Sediment Yields in the Upper Yangtze: Dams, Degradation Control or Delivery?**

HIGGITT D.(1), ZHANG X.B.(2), HE X.B.(2)

*(1) National University of Singapore, SINGAPORE, SINGAPORE ; (2) Institute of Mountain Hazards and Environment, Chinese Academy of Sciences, CHENGDU, CHINA*

The global flux of sediment from continents to oceans has declined in recent decades as a result of major dam construction on some of the world's largest rivers. In China, for example, there has been a rapid and continuing expansion of hydro-electric power schemes which have drastically altered the hydrological regime. However, examination of time series of discharge and sediment yield suggest that in some areas the decline in sediment load measured at hydrographic stations is greater than can be attributed to sediment trapping by dams alone. Usually this additional reduction in sediment load has been attributed to the success of soil conservation measures. A case in point is the Jinsha River, the name given to the main branch of the Yangtze upstream of Yibin, Sichuan Province. The catchment area of the Jinsha at the gauging station near Yibin is about 450,000 km<sup>2</sup>. Following construction of the Ertan Dam on the Yalong River, a major tributary of the Jinsha, in 1998, the sediment load in the Jinsha has reduced dramatically. However, the reduction is far greater than the amount trapped by the Ertan Dam. A geomorphological survey of the river is investigating the likely causes of reduced sediment load. In addition to the impact of the dam and local conservation works, it is probable that a reduction in transport capacity during the monsoon period has influenced sediment delivery dynamics.

## Geomorphologic process of the first bend of the Yangtze River

YANG D.

*School of Geographic & Oceanographic Sciences, Nanjing University, NANJING, CHINA*

The Yangtze River (YR) suddenly changes its flow direction from SE to NE near Shigu at 2136km away from its source, forming a sharp turn with 280 degree named as "the first bending of the world".

Based on many field investigations during recent 18 years, it has been found that the fluvial landforms have a great change in the areas from Benzilan (around 17km long) to Fulong Bridge (45km), and then to Tuoding (15km), to Qizong (60km), and finally to Shigu (73km) reaching to the TLG. From Benzilan to Fulong Bridge, it is the wide valley with four rock-seated and one accumulational terrace. However, from Fulong bridge to Tuoding, the valley becomes sharp V-shape without any terrace and continued valley shoulder distributed, which should be the capturing river part. From Tuoding to Qizong, a distinct gorge presents with three terraces and 10-25m thick fluvial gravel deposits distribute. From Qizong to TLG, it is a strange drowned valley. The relict of the third and second terraces occasionally present along the two banks, and relatively large alluvial fans distribute in the mouth of many small tributaries overlying the floodplain of YR. Furthermore, 70m thick deposits accumulate at the valley bottom, covered by huge rocks sometimes. Several kilometer long river channel near Shigu flows along conjugate fractures with X shape.

According to these morphological characters, it could be concluded that the YR channel between Qizong and Shigu is an ancient tributary, named Shigu River. Its channel is controlled by the conjugate X shape fractures. This River incised deeply headward and captured the ancient YR to become the main channel of the new ancient YR during about 50-60 thousand years ago. The glacial developed and incised deeply in the valley after the formation of the second rock-seated terrace. Subsequently, large scale mass movements (e.g. landslides) happened and blocked the river, resulting of drowned characters in this reach.

\*\*\*\*\*

## Characteristics and self-adjusting behavior of anabranching channel patterns along the middle and lower reaches of the Yangtze River

YU G.A.(1), HUANG H.Q.(1), LIU X.F.(1), NANSON G.(2), FAN B.L.(3), LIU T.H.(3)

*(1) Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, BEIJING, CHINA ; (2) University of Wollongong, NEW SOUTH WALES, AUSTRALIA ; (3) Changjiang River Scientific Research Institute, WUHAN, CHINA*

Over a length of 1893 km along the middle and lower reaches of the Yangtze River numerous islands higher than bankfull exhibit in the middle of the river. In the upper part of the reaches there is normally one large island appearing in the river, while in the lower part the number of islands reaches up to 7. The planforms of these islands differ from one to another and the main channel and sub-channels alternate periodically. Previous studies on the behavior of these multi-channel river systems have been dominated with empirical analyses and there has been no consensus of opinions on how these river systems operate by themselves.

Under the encouragement of the success of the variational approach developed by Huang and Nanson (2000, 2002) for understanding the self-adjusting mechanism of straight alluvial channels, this study examines the applicability of the approach in multi-channel river systems. For the purpose a detailed investigation of the morphological forms of the islands exhibiting in the Yangtze River is made and several generalized types suitable for performing mathematical analysis are obtained. For a two-channel river system with the island in the middle of the river taking a triangular planform, a detailed mathematical analysis shows that the width and length of the island are determined by the proportion of water and sediment in two channels when the whole river system achieves equilibrium. Finally a comparison between the theoretical results and field observations is made and the cause for the resulted degree of consistency examined in detail.

### **Impacts of meander landforms evolution on hydrological functioning of a floodplain: the Loire Meander at Guilly (Central France)**

*RAMOND S.(1), ROBERT V.(2), GAUTIER E.(1), DEPRET T.(3), MARLIN C.(4), DURAND V.(4), MONVOISIN G.(4), NORET A.(4), MASSAULT M.(4)*

*(1) University of Paris 8 Vincennes - Saint-Denis, CNRS, UMR 8591, Laboratory of physical geography, MEUDON, FRANCE ; (2) CNRS, UMR 8591, Laboratory of physical geography, MEUDON, FRANCE ; (3) University of Paris 1 Pantheon-Sorbonne, CNRS, UMR 8591, Laboratory of physical geography, MEUDON, FRANCE ; (4) University of Paris-Sud 11, CNRS, UMR IDES, ORSAY, FRANCE*

The presentation focuses on a protected zone (meander of Guilly, 4.27 km<sup>2</sup>) along the Loire River where several actions of wetland preservation have been conducted. Most studies about the Guilly meander have concerned its geomorphologic evolutions. This meander is a part of a particular anthropogenic system which has been impacted by changes of land uses around in the areas close to the Loire River. More precisely, we relate these previous geomorphologic studies with the hydrological functioning of the alluvial plain, in order to demonstrate how and the morphological heritages may influence the present hydrology of the meander.

In the meander and in the alluvial plain, pressure sensors have been installed in several wells in the unconfined aquifers (time interval of ½ hour). The potentiometric data reflect the propagation of the hydrological signal from the Loire River towards the alluvial aquifer. In addition, water has been sampled monthly for both chemical and isotopic (<sup>18</sup>O, <sup>2</sup>H) analyses.

The comparison between the chemical and isotopic compositions of the groundwater from the shallow alluvial aquifer in the meander with that of the regional aquifer (Beauce formation), the rainfall and the Loire River allow to assess the contribution of each end-members. Furthermore, the water exchanges between the different water-bodies in the meander display an important temporal variability and an unequal response time. We observe important variations of water-table elevation according to the discharge of the Loire River; rapid supplies from the river towards the alluvial aquifer exist especially during flood periods.

These supplies show significant spatial variations characterized not only by the distance to the river, but also by morphological and sedimentary heritages. Amongst all the wells, the hydrogeological response of those located near or into a paleo-channel differs from the other ones.

\*\*\*\*\*

### **Predicting life span of restored secondary channels and backwaters (Rhône river, France)**

*RIQUIER J., PIÉGAY H.*

*Université de Lyon, CNRS-UMR5600 Environnement-Ville-Société, LYON, FRANCE*

During the last two centuries, human actions have deeply affected the physical and ecological integrity of the Rhône river-floodplain system. A large restoration project aiming to enhance aquatic habitat conditions within the Rhône corridor started in 1998. Twenty-five floodplain channels were dredged, either locally or over their entire lengths with or without upstream and/or downstream alluvial plug removal. The guiding principles were to optimize the ecological functioning and to maximise the diversity of habitat conditions within and between floodplain channels at the reach scale. One of the key questions of such actions was their sustainability. As stated by several researchers, acting on forms rather than on processes may be a short term strategy. From cutoff to final terrestrial stage, floodplain channels experienced various life spans ranging from a few decades to several centuries. The evolution of the water depth in cutoff channels is mainly controlled by overflow sedimentation rates related to suspended sediment concentrations and main channel geometry (i.e. bed degradation/aggradation, channel shifting, entrance geometry linking cutoff and main channel). However this topic has been barely explored in river restoration ecology. Understanding the temporal evolution of sedimentation rates and being able to predict life span of such restored channels are challenging issues in order to propose appropriate and suitable restorations. We used biennial bathymetric and sediment thickness surveys, repeated every two years for a decade, to characterize the temporal evolution of longitudinal sedimentation pattern in eighteen restored floodplain channels (5 secondary channels and 15 backwaters). We established statistical relationships allowing to predict life span of floodplain channels related to a set of geomorphic controls. The restoration procedures are then discussed with regard to the processes affecting the long term sustainability of these environments.

## **Severe monsoon floods and floodplain development in the lower reach of the Stung Sen River, Lower Mekong Basin**

NAGUMO N.(1), SUGAI T.(1), KUBO S.(2)

(1) Graduate School of Frontier Sciences, The University of Tokyo, CHIBA, JAPAN ; (2) Department of Geography, Waseda University, TOKYO, JAPAN

The Stung Sen River, the biggest influent tributary of the Lake Tonle Sap in Cambodia, is characterized by seasonal changes of water level and discharge under the Asian monsoon climate. Floodplain in the lower reach consists of two major geomorphic elements of back marsh and meander belt displaying a complicated pattern of abandoned channels and meander scrolls. During the decennial-scale severe floods in 2011, along with meander belt, back marsh was considerably submerged by surging in-channel floodwater overflow with heavy rainfall, and dense suspension was widely provided. This is consistent with the constant accumulation rate of back marsh during the Holocene reconstructed by AMS-<sup>14</sup>C dating of the back marsh sediments. However, during the usual monsoon season, monsoon floodwater rarely widely overflows and the accumulation of back marsh seems not to have been prominent. This suggests that the formation of back marsh is mainly promoted by the decennial-scale severe floods rather than annual floods. The accumulation processes of the Stung Sen River floodplain is probably controlled by the high-magnitude and less-frequent floods in comparison with those of humid temperate climate zone.

\*\*\*\*\*

## **Morphodynamics and stability of the amur riverbed**

KIM V., MAKHINOV A.

*Institute of Water and Ecology Problems FEB RUS, KHABAROVSK, RUSSIAN FEDERATION*

In the Amur lower reaches its riverbed undergoes extensive transformations. The river divides into numerous large and small sub-channels of different shape and size, thus forming an exceptionally complicated hydrographic system. Large sub-channels compose a time-stable river net carcass of a branching delta type. These sub-channels also divide and merge with dozens of small permanent or temporary streams. Most of them freely meander, but their curves are not sharp.

All along its lower reaches (from the Songhua mouth) the Amur shows the positive balance of discharged suspended solids, which determine most specifics of developing riverbed processes. The intensive accumulation of alluvial deposits in the riverbed and floodplain causes an extremely complicated river branching, a relatively not high floodplain and a very intensive horizontal deformations of main and secondary river channels.

River ice also plays a significant role in the transformation of the Amur banks, as it causes their mechanical destruction and the accumulation of ice-brought sediments in the riverbed and its floodplain.

In the recent 50-60 years human activities in the Amur Basin have noticeably affected the intensity of riverbed transformations and the amount of discharged suspended solids. Most significant Amur riverbed transformations take place in areas of intense anthropogenic impacts, in particular near population centers, hydropower facilities, dredging operations.

### **River bank erosion, shifting of off-take point: a case study of river Bhagirathi, West Bengal, India**

BHATTACHARJEE S.

*Jogesh Chandra Chaudhuri College, KOLKATA, INDIA*

River Ganges enters Maldah district of West Bengal after touching the outlier of Rajmahal Hills and swings across the deltaic plain. According to Rennell (16<sup>th</sup> century), Bhagirathi was connected with Ganga near Suti, Murshidabad district, West Bengal.

During 1801, Bhagirathi was connected in two places- Mohangung near Farakka and Suti (Colebrook, 1801). After that, Mohangung village was destroyed due to bank erosion of Ganges. During 1825 River Ganges captured some portion of Bhagirathi due to shifting of its course and a new off-take point was created in Chokha, 12 km away from the previous in south western direction.

In the year 1847 an artificial mouth was made in eastward direction, 3 km away from Suti. After a massive flood erosion and westward shifting of Ganges river course, a new off-take point was born in 1852. In 1871 further a new off-take point was found in Chaurashiya.

From the map of 1925 (Survey of India), it was found that river Bhagirathi was connected with Ganges in three different places, i.e. Nayansukh, Suti and Giria. From the present satellite images, it is found that the off-take of river Bhagirathi is connected with river Ganges near khejurgram of Mithipur, Murshidabad. During 1975-80 Giria was engulfed by Ganges due to severe soil erosion. In between 1974-1985, river Ganga eroded its right bank and shifted in westward direction. Due to severe bank erosion, many villages have been engulfed in the river Ganges. The present paper deals with the spatio-temporal shifting of the off-take point of River Bhagirathi, rate of its bank erosion and related consequences. The entire work is based on the field survey with modern techniques, GIS and RS.

\*\*\*\*\*

### **Morphological changes of the Lower Siret River from 1891 to 2010: the decisive impact of engineering works and water management strategy**

SALIT F.(1), ARNAUD-FASSETTA G.(1), ZAHARIA L.(2), MADELIN M.(1), BELTRANDO G.(1)

*(1) Universite Paris Diderot, PARIS, FRANCE ; (2) Faculty of Geography, BUCHAREST, ROMANIA*

This study provides an example of a river affected by water management strategy during the twentieth century and how the political-historical context had as much consequences as the hydrological events on spatial and temporal dynamics of the river. The work focuses on the Lower Siret River (100 km length) located east of the Carpathians. The Siret River is one of the last tributaries of the Danube River with a mean annual flow of 210 m<sup>3</sup>/s at the Lungoci station, situated 105 km upstream of the Danube confluence. Historic changes (1891-2010) in both channel planform and hydraulic dynamics of the Lower Siret River, especially in relation to river engineering measures (regularisation, channelisation, dams) from the 70's, were quantified. By using a GIS analysis, channel geometry was digitised between 1891 and 2010 and some semi-quantitative variables (active-channel width, sinuosity index and braided index) were calculated. Dykes and groynes network erected in order to protect arable land by regularising the channel and to decrease the harmful effects of the water in the 70's, led to river channelisation, with the narrowing of the channel planform of 46% on average in 60 years, and increased the impact of the floods in the floodplain as it the case during the historic flood event of July 2005. It is necessary to quantify and spatialise the channel changes imposed by the water management strategy during the Communist period to succeed the implementation of the EU Flood Directive.

### Short-term channel adjustments in an anthropized stretch of the Calore River (Southern Italy)

VALENTE A., MAGLIULO P.

University of Sannio, BENEVENTO, ITALY

The results of a study aimed at identifying and quantifying the geomorphological changes experienced by a strongly anthropized stretch of the Calore River (Southern Italy) between 1955 and 1998 are shown. This stretch is characterized by the presence of the town of Benevento and a high frequency of alluvial sediments extraction sites. The study was carried out by processing in GIS environment data derived from interpretation of orthophotos and maps, and from detailed field surveys. In Benevento, a large number of human infrastructures that, according to the existing literature, influence river dynamics, such as bridges and walls, are present. Moreover, in this stretch, all the extraction sites are currently active and sediments are withdrawn directly from the riverbed. The withdrawals started almost everywhere between 1955 and 1977.

The data showed that, in 1955, the morphology of the river was of transitional type. During the examined period, the Calore River underwent a narrowing of ~75%. Field evidence such as exhumation of bridges and walls foundations and terracing of the floodplain that was active in 1955 revealed a lowering of the riverbed, probably still ongoing. The amount of the lowering, not precisely quantifiable, could be of ~3-4 metres. It was also found a drastic reduction in the fluvial bars area, while their number increased significantly, except for point bars. Due to these adjustments, the river morphology changed from transitional to single-tread with alternate bars. This result is in agreement with literature data about most of the Italian rivers. Probably, the causes of the observed adjustments are connected to the drastic reduction of the liquid discharge, due to the Calore River spring exploitation since late 50's, and of the bedload transport induced by sediments extraction and, finally, to the effects of bridges and walls. However, our data do not allow excluding an active role played by climate and/or land use change at the basin scale.

\*\*\*\*\*

### Present changing in river system of the upper Po River Plain (Italy)

MARAGA F.(1), BELLARDONE G.(2), TURCONI L.(1)

(1) National Research Council (Cnr), Dept. of Earth and Environment, Institute for geo-hydrological protection (IRPI), branch of Turin, TURIN, ITALY ; (2) Regione Piemonte, TURIN, ITALY

It refers to the Po river changes in the upper Po plain, north western Italy. The changes implicate the river channel bed deepening and the river channel network contraction. Geomorphologic conditions are related to the active uplift of the landforms in Tertiary sedimentary substrate at the boundary of the fluvial plain having Holocene shallow fluvial deposits. The substrate is emerging in the river beds since few decades due to channel erosion processes.

The present Po river system morphological changes can be summarized as: (1) shortening river axis; (2) narrowing active channel width; (3) sediment erosion at the river channel bottom. The major flood of October 2000 recorded larger bank erosion than previously. Following floods occurred shorter and faster depending on the network changes versus a more steepening system. Bank erosion in the channel exceeded the flooding onto the plain. The Maximum of erosion was noticeable in the channel reaches where the substrate is exposed.

Latest morphological evidences of the river network steepening show meander cuts-off during the previous minor floods from 1949 to 1977. These evidences highlight the faster processes of the shortening changes in the study area by an average shortening of 4 km/year. Longitudinal topographic profiles are 1 m deepened at the channel medium bed level from 1999 to 2004.

The river network contraction involved faster flood propagation, decrease in sediment availability for the sediment transport in the channel bed and fluvial deposition. Instability effect are recognized on the fluvial public works due to damages in walls and bridges. Surface water table deepens in the plain as channel network is deepening and water losing involves water lack in river biomasses maintenance.

### **Sediment transport measurements providing insights on initiation of motion and high flow bedload transport at the Austrian Danube**

LIEDERMANN M., TRITTHART M., GMEINER P., HABERSACK H.  
*BOKU University, Vienna, VIENNA, AUSTRIA*

Within a large restoration project at the Danube River to the East of Vienna an ambitious sediment transport monitoring program using advanced measurement equipment was conducted. Among other methods, a basket sampler was used to quantify initiation of motion, bedload dynamics and annual bedload transport. Due to high flow velocities and water depth, the sampler had to be modified to suit the requirements of the Danube River in order to assure undisturbed sampling. Over four years, a total of 38 cross-sectional bed load transport measurements were conducted over the entire discharge spectrum, thereby covering low flows as well as several flood events up to a 15-year event.

Significant bedload transport was observed at low flow conditions, indicating that initiation of motion takes place at much lower discharges than predicted by commonly used uniform bedload transport formulae. Furthermore it was found that the bedload transport increases with discharge, but to a much lower extent around bankfull discharge. Results of a gravel tracer study performed within the same river reach and 3D sediment transport modelling affirmed these findings. Hence commonly used approaches underestimate bedload transport at the reach for low flow conditions and overestimate transport at high flows. Therefore new concepts had to be found for establishing a bedload transport-discharge rating curve. Amongst others, a sigma function was fitted to the data describing better the occurring transport situation.

The analysis of the data led to a substantial progress in describing sediment transport characteristics at a large gravel bed river, thus increasing process understanding and facilitating the evaluation of a restoration project.

\*\*\*\*\*

### **The evolution of the fluvial process in the lower Yellow River since 1960**

TIAN S.M., WANG W.H., LI Y., ZHANG X.H.  
*Institute of Hydraulic Research, YRCC, ZHENGZHOU CITY, HENAN PROVINCE, CHINA*

The Yellow River carries abundant water and excessive sediment and the channel bed and river bank are erodible. Since 1960, many large and middle reservoirs have been built in the Yellow River. The water and sediment conditions of the river have undergone great changes, especially after the operation and the practice of the water and sediment regulation of Xiaolangdi Reservoir. The incoming water and sediment in the lower Yellow River has changed greatly. The cross-sectional shape of the channel has adjusted a little. At the same time, the river training works have been improved since 1960. Under the actions of water-sediment conditions and river training works, the river regime of the lower Yellow River has experienced remarkable variations.

The paper analyzes the characteristics of the river regime and the mainstream lines of the wandering reach in the lower Yellow River since 1960. The results indicate that the bend coefficient shows an increase trend, the mainstream swing and width-depth ration shows a declined trend, which indicate that the wandering features of the river have been inhibited and the river regime has become regular. In addition, the river pattern is also discriminated by the river regime parameters and the fractal dimension method. The values of the discrimination indicators are getting closed to the braided river. In some years, the river pattern has exhibited the features of the braided river.

The changes of the river regime are first due to the water-sediment conditions. With the operation of the reservoirs, the annual water amount, the frequency and the peak of the flood have decreased. Then the flow dynamics and its action on the river channel reduce too. On the other hand, the river training works has limited the swing range of the mainstream. Both of them have affected the fluvial geomorphology of the lower Yellow River and lead to the stabilization of the river. So the river regime have transformed from the scattered to the normalized.

### Tracking the middle reach of the Yellow River running eastward across the Ordos Plateau and North China Plain

*HU Z., PAN B., GAO H., HU X.*

*Key Laboratory of Western China's Environmental Systems, Ministry of Education, Lanzhou University, LANZHOU, CHINA*

The middle reach of the Yellow River from the Chinese Loess Plateau downward to the North China Plain, runs through the uplifted Jinshan Gorge and subsiding Fenwei Basin, offers a favorable setting where the response of the fluvial landscape to the uplift and climatic change can be evaluated individually. In the northern Jinshaan Gorge, a continuous fluviolacustrine strata with a chronological framework of >8.3-3.7 Ma were accumulated in the Baode region, being correlated sediments of the Tangxian Planation Surface. The statistics of gravel fabric and lithology in these fluviolacustrine sediments reveals that a paleo-lake occupying the Baode area was fed by some local streams from surrounding uplifted regions. In the northern Jinshaan Gorge, two fluvial gravel layers covered by aeolian Red Clay were stacked on the Tangxian Planation Surface. Their formation times were dated prior to 4.9 Ma and 3.7 Ma respectively. The statistics of gravel fabric and lithology indicates that these gravel layers represent a northward flowing paleo-river, which is different from the southward flowing Yellow River. It linked the paleo-lake occupying the Baode region and the drainage in the Hetao Basin. A dramatic surface uplift initiating prior to 3.7 Ma not only interrupted the fluviolacustrine sedimentation, but also led to lifting of the Planation Surface. Owing to this drastic uplift, hypsographic relief was enlarged, and resulting in fluvial head erosion. In the northern Jinshaan Gorge, the northward flowing river linking the Baode paleo-lake and the drainage in the Hetao Basin was pirated by the river in the southern Loess Plateau, and the Yellow River appeared prior to 1.2 Ma. An episode of drastic uplift initiating at 1.2 Ma forced the Yellow River to continuously downcut along the Jinshaan Gorge, and developing a series of fluvial terraces. The modern spectacular down-cutting valley has been shaped gradually by the Yellow River since this uplift.

\*\*\*\*\*

### Geomorphic Changes in the Indian Sundarban between 1917-23 and 2012: Evidences from Maps, Images and Hydrography

*BANDYOPADHYAY S.(1), MUKHERJEE D.(2), KAR N.S.(1)*

*(1) University of Calcutta, KOLKATA, INDIA ; (2) University of Burdwan, BARDHAMAN, INDIA*

A high tidal range and tropical climate helped to form the world's largest patch of mangrove wetlands – Sundarban – at the mouths of the Ganga-Brahmaputra delta (India and Bangladesh). The area started to be reclaimed from early 14th Century. However, an active governmental effort for deforestation commenced from 1790s and by 1950s about 5,366 km<sup>2</sup> (56%) of mangroves were converted into farmlands in India. To form a holistic database on long-term changes in the Indian Sundarban, we compared five datasets: Survey of India maps of 1917-23, 1942 & 1968-69 and RS data of L3+Pan (2001) & L4 (2012) from IRS missions. All these materials were georeferenced, mosaiced and digitised.

The results show that all southern sea-facing islands of Indian Sundarban recorded progressive erosion – a trend that continued from 18th century. However, in the interior (often reclaimed) portions of Sundarban, inter-island creeks are being silted up, resulting in net accretion and reduction in number of islands. The progressive and irreversible transformation of intra-island creeks into stagnant water bodies and finally into plugged depressions is one of the most notable post-reclamation changes that largely took place during an approximate span of fifty years.

For maintenance of morphological steady state, length of the resonant macrotidal estuaries of Sundarban need to equal a quarter of the wavelength of the tide entering into them. The tidal wavelength, in turn, depends critically on the mean depth of the estuaries. Reclamation and construction of marginal embankments increase their mean depths and set up time-velocity asymmetry in tidal currents. This condition largely explains bank erosion and in-channel siltation seen in the interiors of Sundarban. The chief reasons for rapid erosion of its seaface include abandonment of sediment-replenishing western distributaries of the Ganga and off-shore interception of westward transportation of sediments by a submarine canyon.

## **Poster presentations:**

### **Neogene gravels and dammed-lake sediments newly discovered in Nujiang (Salween) River valleys, Yunnan**

ZHAO X.(1), WU Z.(2), YE P.(2), TONG Y.(2), HU D.(2)

(1) *Institute of Geology and Geophysics, Chinese Academy of Sciences, BEIJING, CHINA* ; (2) *Institute of Geomechanics, Chinese Academy of Geological Sciences, BEIJING, CHINA*

In Our field survey in the Daojie Basin through which the Nujiang (Salween) River passes, lower terraces below 150m above river level were re-identified and re-divided into eight level terraces ( $T_1 \sim T_8$ ). At the same time, there are four level higher terraces 180~380m above river level ( $T_{10} \sim T_{13}$ ) and a suit of dammed-lake sediments and their buried alluviums to be newly discovered. Lower terraces were dated by OSL, U-series and ESR methods, whereas the dammed-lake sediments were paleomagnetically analyzed. The results show that six levels of lower terraces are formed since the Middle Pleistocene, and that the upper part of the dammed-lake sediments is dominated by normal polarity but contains two short times of negative polarity, whereas the lower part is of negative polarity. According to correlation with the standard magnetic polarity time scale, the formation age of the dammed-lake sediments should be 4.2~2.6Ma, i. e. the Middle-Late Pliocene. Thus, the burial terrace below the dammed-lake sediments and the higher terraces should form in the early of Pliocene to the late of Miocene. On the basis of the results in the paper and our preliminary regional stratigraphic correlation, it can be believed that accompanied with intermittent uplift of the Tibetan Plateau since the middle and late of Miocene, the Nujiang River occurred and cut down and by the early of Pliocene cut down into below today's river beds.

\*\*\*\*\*

### **Hydromorphodynamic of Anavilhanas Fluvial Archipelago - Amazon- Brazil**

ALVES N.S.(1), RODRIGUES C.(2)

(1) *UNIVERSIDADE DO ESTADO DO AMAZONAS, MANAUS, BRAZIL* ; (2) *UNIVERSIDADE DE SÃO PAULO, SÃO PAULO, BRAZIL*

The Anavilhanas Fluvial Archipelago is situated in Lower Negro River, a tributary of Solimões River in Amazon Region that is characterized by a complex of islands, bars, lakes, "furos" and river channels is inside a region that combines humid tropical forest vegetation cover, mean annual rainfall of 2000 mm and mean annual temperatures about 27°C. This fluvial island complex, the largest in the world, appears to be a heritage of a sub-Recent anastomosing system whose actual islands are isolated by river channels with narrow margins and internal ocellar lakes. This research has characterized tree main different hydromorphodynamic environments that has identified from semi-detailed geomorphologic mapping, morphometric fieldwork and sedimentologic analyses: river channels, channel margins and internal lakes. The distinctive processes of those environments have seasonal variability that follows the dry season, the rise water level period and the wet season, all of them commanded by a bimodal annual variability of the water level of Solimões River, distant about 120 km. The wet season starts in October/November and its first peak of water level occurs in the beginning of the year that is followed by a maximum water level that occurs in June/July. The analysis of water levels data of Manaus (1902 to 2010) has revealed mean annual amplitude of 11 m. The same value and periods have observed in Anavilhanas region over the year of 2011. The major river channels revealed high rates of bedload transport over the wet season, low rates of dissolved and suspended load over the year and exposure of mega-dunes over the dry season. The channel margins appears to be stable in many places but can be eroded over the rise water level period. The lakes have river-lake seasonal dynamics that combines periods of decantation in a lacustrine and low energy environment and periods of rise of water levels that accompanies the growth of flow energy and connection to the river flows.

### **Fluvial competition exemplified by formation and evolution of the Fen River and Jinshan Yellow River, North China**

ZHANG K.

*Sun Yat-sen University, GUANGZHOU, CHINA*

Competition exists not only in organisms and human society, but in geomorphic open systems evolution of many landforms can be analogized to competition. The Fen and Jinshan Yellow Rivers (eastern-reach of the prominent square-shaped bend of the Yellow River) on E and W sides of the Lüliang Mountains, provide an example of fluvial competition. The Fen River is now a tributary of the Yellow River, the 2nd largest river in China. However, the depositional sequence and chronology (including magneto-loess stratigraphy and OSL dating) along the Jinshan Yellow River, indicates that before connection of the Hetao Basin (Hetao Great Lake, into which the upper reach of the Yellow River debouched) to the north, the Jinshan Yellow River shared similar features with the Fen River in terms of flow direction and length. Both rivers can be considered as “twins” originating from uplift of the Lüliang Mountains and both flowed from N to S on E and W sides of the mountains, respectively, into the Yuncheng Basin, the local base level. Following two stages of N2 broad valley and early to middle Qp deep gorge development, in late Qp, the Jinshan Yellow River eroded headward and cut into the Hetao Basin. An abrupt increase in the discharge and length of the Yellow River led to rapid down-cutting to “win” the competition with the Fen River, which was degraded to a tributary. A near 100-year debate on the formation age of the Jinshan Yellow River, i.e., N2, early Qp, late Qp, has centered on conglomerate along the broad valley, the highest strath terraces along the lower to middle reaches of the Jinshan Gorge, and the highest strath terraces along the upper reach of the gorge, respectively, representing three evolutionary stages. The various view points are not necessarily conflicting. A large river is not always the oldest one, and vice versa. Fluvial competition can cause one river to develop faster than another resulting in a complicated landform evolution.

\*\*\*\*\*

### **Permafrost-cored alluvial bedforms and related channel morphology of the Lena River, Central Yakutia**

TANANAEV N.

*P.I. Melnikov Permafrost Institute, Siberian Branch, Russian Academy of Science, YAKUTSK, RUSSIAN FEDERATION*

Major features of formation and development of the large cryogenic alluvial bedforms within the middle reach of the Lena River are reviewed. Under severe climatic conditions of Central Yakutia, permafrost is widely observed within the river channels. Frozen cores in large bedforms limit their mobility, leading to the enhanced bank erosion and channel degradation. It is shown that these bedforms control major river valley morphology features within the studied reach, from the channel topography structure to the formation of the channel pattern and the valley bottom. Development of the pseudomeanders within otherwise braided channel pattern is a distinct effect of these permafrost-cored bedforms. Qualitative model is offered to describe the cyclic development of these bedforms, emphasizing the role of the dominating channel pattern and ice jamming. This cyclic pattern is related to the large-scale water flux variations, which were correlated with Milankovitch-type oscillations via climatic modeling results.

## **Geomorphological and geocological mapping of river valleys, floodplains and channels**

CHERNOV A.

*Faculty of Geogbrahyy, Voscow State University, MOSCOW, RUSSIAN FEDERATION*

The paper deals with principles of small-scale mapping of floodplain-channel complexes. Mapping in small scale implies showing river channel and floodplain as a linear object – a multi-component strip over the river line on topographic map. It is a set of stacked over each other bands of successively decreasing width divided with bordering lines. Properties of channels and floodplains are shown by band width, color and hatching, and color of inter-band borders. The following information is shown: width and morphological type of channels and floodplains, channel dynamics (bank erosion rates, meander growth rates), sediment type, morphology and composition of banks, meander curvature, river behavior at confluence reaches, economic activities in channels and valleys influence on channel processes, etc.

Processes and phenomena on valley sides are depicted by symbols alongside river strips. External geographical and geological conditions are shown by colored and hatching background over the whole map.

Such approach was used to compile a set of maps showing river morphology and dynamics in the whole Russia and surrounding states, European part of Russia, selected regions as well as geocological state of floodplain-channel complexes and risk of channel processes in different Russian rivers. Geocological maps display environmental conditions governed, first, by dynamics of river channel itself, and, second, by economic activities at river banks. Risk maps show estimations of potential danger that is generated nearby rivers by natural channel migrations and by human impact.

\*\*\*\*\*

## **A study on phasic changes of sediment erosion and accumulation in the Inner Mongolian reach of the upper Yellow River and contributions of main factors**

SHI C., SHAO W., FAN X.

*Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, BEIJING, CHINA*

Using data of hydrological records, annual water and sediment diversion, and sediment retention and water regulation by dams, this study investigated the phasic changes in sediment erosion/deposition in the Inner Mongolian reach and in the series of water and sediment inputs to the reach. It is disclosed that there were two abrupt changes in the series of water and sediment inputs to the reach and the reach experienced a period of aggradation, a period of erosion, and then a period of aggradation again with the years 1962 and 1986 as the break points. For determining the causes for the conversions between aggradation and erosion, the contributions of main influencing factors were quantified. The results show that the variation of runoff due to climate change is the important cause for the conversions from aggradation in the first period to erosion in the second period and back to aggradation in the third period. Sediment retention behind the dams on the main stream is found to be the first factor resulting in the transition from aggradation in the first period to erosion in the second period, and reduction of sediment input from tributaries to be another factor making a certain contribution to it. Besides the runoff reduction associated with climate change, the rise of sediment input from tributaries, reduction of sediment retention behind dams, and increase of water diversion are revealed to be favorable to the transition from erosion in the second period to aggradation in the third period. The results also show that water diversion has played an important role in the long-term aggradation of the Inner Mongolian reach and the gradual rise of water diversion has enhanced the aggradation. It is suggested that the control of water use and reduction of sediment input from the tributaries should be an effective way to alleviate the aggradation in the Inner Mongolian reach.

*Keywords:* Alluvial river; Changes in water and sediment discharge; River channel aggradation.

## Evolution of River Systems in the Indian Part of Upper Ganga Delta: Evidences from Maps and Satellite Images

DAS S., BANDYOPADHYAY S.

*Department of Geography, University of Calcutta, KOLKATA, INDIA*

The western part of the Ganga-Brahmaputra delta, India and Bangladesh, is mostly contributed by the Ganga and its tributaries. The major distributaries and palaeodistributaries of the river that drain the Indian non-tidal part of the delta include the Bhagirathi, Gobra, Bhandardaha, Bhairab, Sialmari, Jalangi, Mathabhanga, Churni, Ichhamati, Jamuna and Anjana among others. Most of these distributaries are characterised by intense meandering and their channels have shifted frequently in the past. The off-takes of the major ones are periodically affected by the shifting of the main channel of the Ganga during the monsoons.

The database for this study consists of maps of James Rennell's *Bengal Atlas* (1:316,800;1767-74) *Atlas of India* (1:253,440;1848-56), Survey of India (1:63,360; 1916–1931) and selected satellite images from Corona (1967), IRS (LISS-3+PAN, LISS-4 Mono: 2001–2007) and Landsat (MSS, TM, ETM+: 1973–2011) missions. Available discharge and gauge height data of selected rivers for different years are collated with the investigation of maps and images. Field surveys are carried out at specific off-takes and confluences using Total Station, Echo-sounder and GPS to analyse the present scenario.

The results indicate marked degeneration of the distributaries especially at their headwaters where siltation is a common phenomenon. This can be linked to abandonment of the western part of the delta. In some instances (e.g., in Ichhamati and Jamuna) the oxbow lakes associated with certain rivers are seen to get smaller in width and depth with decreasing age indicating gradual deterioration of the river channel. This characteristic, however, is not seen in the non-degenerated or artificially resuscitated distributaries (e.g., in Bhagirathi) where the cross-sections of all the ox-bows as well as the active channel are similar. Decay of some of the rivers (e.g., Anjana) can also be related to anthropogenic activity like encroachment and drainage diversion.

\*\*\*\*\*

## Spatial organization of Pantanal lagoons in Matogrosso Do Sul, Brazil

FERNANDES E.(1), QUEIROZ NETO J.P.(2)

*(1) Universidade Federal do Rio Grande do Norte, NATAL, BRAZIL ; (2) Universidade de São Paulo, SÃO PAULO, BRAZIL*

Several studies have highlighted the interesting concentration of lagoons, where the great variability in the quality of their waters, characterized by saline lagoons with sodium and chlorinated, bicarbonate water, would be a peculiarity of the region. These lacustrine groupings occur in southern ledge of Taquari River alluvial macro and are part of the vast alluvial plain of the Pantanal, in the Upper Paraguay River Basin, including Brazil, Bolivia, Paraguay and Argentina. The aim of this study is to show that the lagoons are not randomly distributed in the region; instead, they have an organization or patterns in the spatial distribution, as well as a relationship between their distributions and their sizes that allows us to understand the dynamics and evolution of hydrological landscape. The study was conducted through the use of remote sensing techniques for classification of TM LANDSAT TM 5 (226/73) satellite images and integration of water quality data collected in the field. SPRING (INPE, Brazil) and ArcView GIS 3.2 (ESRI) programs were used for image classification, statistical treatments and correlation of themes. It was classified this universe of lagoons in 3 size classes and, based on these 3 classes, it was carried out the spatial density calculate for each theme. It was used an extension for the Arcview 3.2 program called "*FeatureDensity.avx*" whose algorithm calculated the ratio between the area of lagoons on the total area regional determining concentration of 5 classes of ponds by the method of natural breaks. The spatial organization of ponds has suggested that these have strong genetic influence of two current and past tenses processes, which has been operating in the morphological evolution of Taquari river alluvial fan: 1) morphostructural processes related to regional structural lineaments, 2) hydrodynamic processes of Taquari river alluvial fan.

### **Similarity analysis of scale effects of specific sediment yield in the Yangtze River basin, China**

YAN Y.

*Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Science, BEIJING, CHINA*

Scale effects of specific sediment yield are very important issues not only for the water and soil conservation, but for the constructions of different levels of dams. The Yangtze River basin is the largest river basin in China. Scale effects of specific sediment yield were studied on different tributaries or on the whole basin. Based on our study of the whole Yangtze River basin, there were three different kinds of relationships between specific sediment yield ( $Y_s$ ) and drainage area ( $A$ ), there are,  $Y_s$  increases with  $A$ ,  $Y_s$  decreases with  $A$ , and  $Y_s$  is indifferent to  $A$ . In this study, we tried to reveal the reasons to form the different kinds of relationships between  $Y_s$  and  $A$ . We focused on the study of similarities of scale effects among main channels and tributaries of the Yangtze River basin. All rivers with more than two hydrological stations were selected to. This study were carried out on two levels, firstly, study the similarity of scale effects of main channel of Yangtze River and of the tributaries which flow into the main channel; secondly, study the similarity of scale effects of large tributaries of the Yangtze River basin. On the first level, because of the large area which we studied, the influencing factors are very complex, scale effects between main channel and tributaries were much different. On the second level, thought there were several differences in a few large tributaries, in general, the scale effects in each large tributary are similar. While among different tributaries, there were different patterns of scale effects. Scale patterns for the tributaries on the left side of the main channels were much different from that of the right side. Meanwhile for the tributaries on the left side of the main channel, scale patterns were also changed from west to east. Tectonics, landform, geology, climate, as well as land-use and land-cover were used to explain the similarity of the scale effects.

\*\*\*\*\*

### **Fluvial patterns and its use for the assesment of amazonian geodiversity, discussion and application ont the Xingu River Basin**

SILVA J.(1), RODRIGUES C.(1), PEREIRA D.(2)

*(1) Department of Geography - University of Sao Paulo, SAO PAULO, BRAZIL ; (2) Geology Centre - University of Minho, BRAGA, PORTUGAL*

This research has intended to demonstrate and evaluate the potential use of fluvial geomorphological variables as geodiversity indicators. The aim of this work is the morphological characterization and analysis of fluvial patterns in the Xingu River Basin, in order to demonstrate the relevance of these parameters for the assessment of Amazonian geodiversity. Two different spatial scales were used for this research. On a more detailed scale(1:150,000), maps of fluvial morphology were made for 23 selected areas, which represented the diversity of fluvial patterns in the drainage basin. This characterization proved the great diversity of fluvial patterns in the study area, demonstrating the relevance of this parameter as an indicator of geodiversity. On a less detailed scale, a method to quantify the geodiversity was applied to the entire drainage basin, based on the measurement and integration of abiotic elements spatialized on thematic maps with scales ranging from 1:250,000 to 1:1,000,000. The index of geodiversity ranged from 4 to 32. The hot spot of geodiversity is at the boundary between Complexo do Xingu and the Amazonian Sedimentary Basin, close to "Volta Grande do Xingu", where there are different types of rocks, soils, reliefs and mineral resources, in addition to the fluvial patterns with the highest scientific and aesthetic value. Although still largely preserved by conservation units and indigenous lands, the Xingu Basin suffers severe anthropogenic pressures, mainly caused by the construction of Belo Monte Dam in the area of highest geodiversity, which presents no legal protection at all. The main contributions of this research are the enrichment of the knowledge basis about large Amazonian rivers, as well as the application of a method for mapping the geodiversity indexes, which can be useful as a tool for environmental planning, particularly in defining priority conservation areas.

## Developmental History of the World's Longest Rivers

YANG J.

*Ministry of Land and Resources ,China, BEIJING , CHINA*

For more than 50 years, the author has surveyed the courses (either entire or most) of the longest rivers of 6 continents and other rivers in the world >5000km. He also discovered key evidence of their geological history , such as the highest terraces (1250m above the current river bottom, in the Three Gorges of the Yangtze River), the largest number of terraces (>32 terraces, in the Longyangxia Gorges, Yellow River), the largest visible thickness of loess deposit (315m, in Lanzhou, Gansu, China), the most complete profile of river evolution for 2.5 Ma. (In Lanzhou), the longest sections of mountains with many terraces (5/7 of the Yangtze and 7/11 of the Yellow R.), the deepest vertical karst sinkholes (622m, in the Three Gorges of the Yangtze). In Mts Andes, on the west slope: the marine terrace is over 1000m a. s. l , on the east slope: the Amazon terrace has 8 more steps, etc. Based on these observations, the author proposed a framework for the developmental history of the world's rivers controlled by new tectonic movement ( China, the Andes, the Alps, New Zealand...) and climate change ( N. America, Siberia, Europe...) In this framework, we can confirm the detailed history of the world's rivers.

Except the tremendous social impact, this study can also provide a theoretical basis for water management. In China the predictions of this study were confirmed by the Yangtze flood in 1998. The study also points out the new channel that will be taken by the Yellow R. after 25 years. According to this study the original reason of the unprecedented depletion of lower Yangtze since the spring of 2011 etc was improper impoundment by the Three Gorges Reservoir. This study is also essential to the research of earthquakes induced by giant reservoirs (such as the Three Gorges and the Longyangxia Gorge reservoir). If these kinds of studies had been carried out prior to the Wenchuan Earthquake, 2008, the number of the deaths couldn't have been reached 87 000.

\*\*\*\*\*

## The lower Indus Basin: an anthropogenically modified hydrosystem under the influence of extreme events

ATIF S., ARNAUD-FASSETTA G., FORT M.

*Université Paris Diderot, UMR PRODIG, Sorbonne-Paris-Cité, PARIS, FRANCE*

The Indus basin is under a constant process of anthropogenic evolution since the earliest human civilizations of Moen-jo-Daro and Harrapa. Irrigation and water management practices have evolved to serve the purpose of its ever-dependent population. Large dams, barrage, link and irrigation canals stretch across the entire river basin. These form a set of anthropogenic controls, to which the river channel adjusts over time. But as large floods such as those in 2003, 2005 and 2010 flow down the lower Indus basin they modify the natural evolutionary behaviour of the stream. In a few places this can be channel migration far and off to highly inhibited land resulting in widespread devastation of property and loss of human lives. Similarly, as a result of anthropogenic controls in the north the river delta, which is an integral component of fluvial landscape and an indicator of the river's health, tends to deteriorate. This situation is further aggravated by coastal cyclones, which have gained momentum during the last decade. This study aims to use a nested reach style approach in an evaluation of the channel's plan form and its possible causes with particular focus on the effects of floods. An additional component is the study of the extent of seawater intrusion into the main river channel.

### **Simulation of floods in the Rhône valley from Lidar DEM: Assessing impacts of hydraulic structures on the floodplain dynamics faced new regulation of 2014**

HENAFF Q., BELTRANDO G., ARNAUD-FASSETTA G.  
Universite Paris Diderot - UMR 8586 (PRODIG) du CNRS, PARIS, FRANCE

The recent catastrophic floods (September and November 2002, December 2003) of the Rhône River highlighted the need for knowledge to understand the complexity of the hydrosystem functioning. The Rhône River that is termed as 'hydrologically controlled' by human society and managers, still maintains a paradoxical fluvial risk.

The hydroelectric development of the river changed both its structure and hydrosedimentary functioning. To minimize these environmental impacts, the Environmental Code (Article L.214-18) imposes an enhancement of streamflows for the Rhône River (15 projects required for 2014). The fluvial geomorphological dynamics will evolve in response to this new regulation, imposing to taking into account for the impacts of flood events in the highly urbanized floodplain.

Benefiting of a 1-meter resolution Lidar Digital Elevation Model (BDT Rhône - IGN), which integrates altitudes with a precision of less than 20cm, and with partnerships such as the French Water Data Center (EauFrance) and the Compagnie Nationale du Rhône for hydraulic structures data, one-dimensional steady and unsteady flow hydraulic modeling of the Rhône River was used to simulate floods in order to define a probabilistic scenarios grid of hydrological hazard. Satellite imagery of the 2002 flood event (International Charter on Space and Major Disasters) allowed us to calibrate the hydraulic model and to quantify the impacts of hydraulic structures for simulated floods.

This grid of flood scenarios should represent a useful geodatabase for modeling and mapping hydrological hazard in the Rhône valley considering impacts of hydraulic structures.

\*\*\*\*\*

### **A quantitative approach of the morphological changes in the Middle Garonne river (South-west France) during the last 300 years**

DAVID M.(1), CAROZZA J.M.(2), VALETTE P.(1)  
(1) GEODE UMR 5602 CNRS - University of Toulouse, TOULOUSE, FRANCE ; (2) University of Strasbourg, GEODE UMR 5602 CNRS, STRASBOURG, FRANCE

The Garonne river (South-west France) experiments a state of hydrogeomorphological crisis that results in : 1) lose of diversity in riparian environments, 2) decreased of the lateral mobility and 3) a general tendency to channel incision. According to previous studies, these phenomena are the result of human activity intensification in the watershed during the 20<sup>th</sup> century (reforestation on the slopes of the watershed), in the channel (industrial gravel extraction, sediment retention by hydro-electric dam construction) or on riverbanks (riverbanks stabilization for protection against flooding and for navigation). However, studies on this evolution are sparse and generally focus on short time evolution (< 50 yr). The aim of this study is to propose a periodization of morphological evolution of the river Garonne from the 18<sup>th</sup> century to present, on a reach of nearly 80 km between Toulouse and the Tarn tributary in order to test hypothesis about driven forces (*i.e.* climate vs anthropization).

This work is based on a qualitative and quantitative approach of historical dataset (textual sources, maps, engineering plans, etc.). 1) Fifteen maps covering the all study area allow high temporal resolution analysis of channel/floodplain evolution ; 2) Quantitative analysis of channel planar shape parameters (*i.e.* sinuosity, channel width, active band width, channel island number, braiding index, etc.) for each set maps allows to reconstitute the channel evolution trajectory.

The chronological framework of evolution is compared on the one hand with historical data and anthropic disturbance in the channel, riverbank stabilization, etc. and on the other hand to regional climatic and hydrological data (mainly flood) in order to test hypothesis on anthropic versus climatic driven evolution. These results could highlight management choices and fluvial restoration options in the context of climatic change.

**S19B - Small catchments (IAG-WG)**

Convenor: *Andrzej KOSTRZEWSKI*





## **Oral presentations:**

### **The monitoring of small rivers catchments in various climatic zones - assumptions of methodological and methodical studies**

KOSTRZEWSKI A.

*Adam Mickiewicz University, POZNAN, POLAND*

Contemporary shaping and relief changes of the Earth surface are the effects of the denudation system functioning, that zonal specificity is well presented by river catchments.

River and lake catchments are important landscape structures in all morphoclimatic zones. They reveal as research subjects of the specialized as well complex, interdisciplinary character. It can be accepted that river and lake catchments are landscape structures (geoecosystems), very useful to determine past and present changes of Earth surface. Small river and lake catchments are landscape structures especially sensitive in the scope of influences of both natural and man induced processes. External and internal impulses and their results are quickly registered in the memory of the river catchment system.

River catchment is treated as an open system - geoecosystem, where we would like to determine the energy circulation and matter transfer with the use of appropriate methods.

In such a presentation it is essential to standardize field measuring system, the elaboration of appropriate informatics system, the application of geoecological approach and correctly tested models.

Presented methodological and methodical requirements are realized within the Natural Environment Monitoring, treated as a research trend in environmental investigations.

The fundamental assumption of the program "Small catchment" is a realization of interdisciplinary research in river and lake catchments in different morphoclimatic zones, on the base of the organized multi-year stationary studies. The realization of the program intend the use of standardized research methods and gathering the results in thematically oriented data base, allowing comparative studies.

The identification, on the basis comparative studies of response of the fluvial systems to changes in land use, observed climatic changes is very important, in both theoretic and applied points of view.

\*\*\*\*\*

### **Geomorphological features of small watercourses in a context of river landscape sustainability in the Czech Republic**

JAKUBINSKY J.

*Global Change Research Centre AS CR, v.v.i., BRNO, CZECH REPUBLIC*

The paper presents results of research focused on the study of morphological values of the small watercourses in the Czech Republic and their environmental consequences. Particularly the issues of watercourse countersink, and differences between natural and artificially increase deepening of the river channel conditioned by anthropogenic activities are solved there. Presented are the results of research into the relationship between a number of hydromorphological parameters and intensity of human activities within the river landscape area. The river landscape is traditionally viewed as an ecosystem along watercourses, which functioning is directly conditioned by the presence of a river. Because this is a very attractive place for realization of the human needs, it can be seen a conflict between the activities of human society and effects of the natural processes associated with the presence of a dynamically evolving river networks.

Central question in the study of human impacts on the river landscape is primarily how to distinguish the natural evolution of riverbed morphology from man-conditioned disturbances. Secondary, the prediction of expected changes in watercourses ecosystem taking into account the specific impact of human activities is assess. Research procedures outlined above are implemented using the data acquired by a detailed field survey on several model sites, situated in different regions of the Czech Republic.

The essence of the research comes from the fact that any change in a single variable which affects morphology of the river environment may cause a series of channel pattern changes with the feedback in the form of further secondary channel parameters. A significant part of the solved issues is also a question of establishing the initial (more or less natural) state of the stream channel and inundation area from which it can be derived the procedure for expression the degree of fluvial ecosystem degradation.

### **Geochemical and physical loss from a small catchment area in the sub-humid 'tropics: contribution of gullies**

*AUGUSTIN C.(1), CRUZ L.(2), FABRIS J.(1), ROCHA L.(3)*

*(1) UNIVERSIDADE FEDERAL DE MINAS GERAIS, BELO HORIZONTE, MG, BRAZIL ; (2) Fundação Estadual de Meio Ambiente, BELO HORIZONTE, BRAZIL ; (3) Universidade Federal de São João Del Rey, SÃO JOÃO DEL REY, BRAZIL*

Gullies are common features in tropical areas although not restricted to this part of the globe. In tropical areas intense soil loss which constitutes one of the main characteristics of this type of concentrated erosion can sometimes intercept the ground water level resulting in superficial water flow inside the gullies during the entire year and loss of chemical elements that otherwise would remain in the system. In situations in which chemical loss constitutes one of the main processes of landscape denudation, the role of gullies can be significant. The aim of this research is to understand the contribution of chemical and physical losses from gullies and their role in the geomorphic dynamics in an area formed by a 3<sup>rd</sup> order drainage basin in a tropical area of southeast Brazil. Results show that the weathering stage has achieved total allitisation at the top and upper portion of the slopes where the gullies occur corresponding to an old erosion surface where an expressive amount of gibbsite and goethite as well as a ratio of  $\text{SiO}_2:\text{Al}_2\text{O}_3 < 2$  are found. Where intense physical erosion took place, the removal of the old weathered surface (lower slopes, gullies, etc) more likely leads to monosiallisation resulting in partial removal of  $\text{SiO}_2$  and neof ormation of kaolinite ( $\text{SiO}_2:\text{Al}_2\text{O}_3 = 2$ ). Data demonstrate also the overwhelming physical loss of sediments in the gullies creates conditions for a more extensive and quicker removal of sediments and chemical elements in solution. This contributes to enhance changes in the thick weathered mantle which tends to be stripped away generating the formation of new soil. This constitutes one of the main processes of landscape development in this relatively stable tectonic area. Gulling also influences chemical balance through the more rapid circulation of underground water leading to the occurrence of less saturated chemical solutions which tends to promote geochemical changes.

\*\*\*\*\*

### **Extreme land-forming processes development and distribution in the Ukrainian Carpathians under natural and man-made factors**

*MYKHNOVYCH A.(1), KOVALCHUK I.(2), KRAVCHUK Y.(1), PYLYPOVYCH O.(1), CHIKOVA I.(3)*

*(1) Ivan Franko National University of Lviv, LVIV, UKRAINE ; (2) National University of Nature Use and Life Sciences of Ukraine, KYIV, UKRAINE ; (3) Ukrainian Academy of Mining Sciences, Mining and chemical raw material department, LVIV, UKRAINE*

The Ukrainian Carpathians is the area of wide spectrum exogenous processes development. The paper deals with the analysis of the conditions, factors, regularities of extreme land-forming processes distribution and development intensity. Such analysis is based on the results of the long-term observations and investigations within the special representative areas (study sites) and fields of stationary and semi-stationary observations and measurements. These sites have been chosen due to the specific geological and geomorphologic conditions within the river basin systems of different order. By the combinations of natural conditions and regime of nature use and economical activity the Precarpathian decline with the southern-western margin of the Eastern-European platform, Carpathian mountains and Transcarpathian internal decline are defined.

Natural conditions (tectonic and geological structure, relief, precipitation) define the distribution of zones and periods of extreme activation of land-forming processes in the Ukrainian Carpathians. Most significant and temporary increasing factor of the geomorphologic processes extreme activation is economical activities in the river basins of the region. The third important factor of the activation is seismic activity in the region. Most active in this aspect is the Transcarpathian region where local earthquake epicenters are corresponded to the active tectonic breaks. The largest activation of the geomorphologic processes in the region has been observed in the period of extreme flood events caused by combination of extraordinary meteorological conditions, relief forms and man-made impacts.

### **Assessment of the relationships among morphometric parameters and hydrologic indices**

KARALIS S., KALOGEROPOULOS A., KARYMBALIS E., CHALKIAS C.  
HAROKOPIO UNIVERSITY, DEPT. OF GEOGRAPHY, ATHENS, GREECE

This paper seeks to investigate the role of morphometric characteristics of the drainage networks and basins in the physical mechanism of surface runoff. There are two main factors that affect the generation of surface runoff. These are the rainfall characteristics (spatiotemporal context) and the catchments characteristics (static context). Using as a starting point an extreme flash flood event in Xerias torrent which was described as a hundred years flood, an attempt was made to extend this flood throughout 41 small relatively mountainous catchments (ranging in area from 1.5 to 330.5 km<sup>2</sup>) located in North Peloponnese, Greece. A GIS-based spatially distributed unit hydrograph model is used in order to obtain the hydrologic indices (such as rising limb, peak discharge, falling limb, critical time etc). These indices are compared with the basic quantitative geomorphological characteristics of the drainage networks and associated basins (bifurcation ratio, basin circularity, Melton's ruggedness number, basin slope, asymmetry factor) of the study area in order to relate the basin character to the discharge produced. The basic idea is to quantify the relationships among the geomorphology (expressed through quantitative indices) and the hydrological characteristics, which are derivatives of a flood.

\*\*\*\*\*

### **Quantitative Morph metric Analysis of Machna River basin Management, M.P.(India)**

NAMDEO S.  
Motilal Vigyan Mahavidyalya, Bhopal, BHOPAL, INDIA

Flowing water (Geomorphological drainage) and associated mass gravity movement have been active over a long time span and are responsible for the development of present surface geometry. Quantitative analysis of geomorphological drainage is systematic description of the watershed and river channel system which measures the linear aspects of drainage network, aerial and relief aspects of channel network. In the present study, the quantitative analysis of drainage basin is based on methods given by Strahler (1953 and 1964), Chorely (1957), Shumm (1956), Miller (1945), Melton (1957), Smith (1950). The Machna river watershed (Lat. 22°00' to 22°25' N; long. 77°45' to 78°03' E; Narmada river basin) drains across different landscapes and it is an important source of sustainable water resources of the area. The study reveals the past climatic conditions, impact of present land use along with natural conditions in managing watershed. The bifurcation ratio indicates development of drainage due to underlying homogeneous parent material which is basalt and granitic gneisses. The mean bifurcation ratio indicates well developed surface drainage and permeable strata, a prerequisite for augmenting the ground water level. Parameters of aerial aspects indicate variations in discharge of rain water from different zones of watershed. However, bifurcation ratio suggests a moderate discharge from watershed. The stream frequency and filtration number along with overland flow to enhance understanding of watershed development and relief aspects of the analysis have been found to be useful in designing the various structures of the watershed. The study concludes that quantitative analysis of drainage morphometry is a desirable approach for understanding of the integrated watershed management.

## Variability of soil erosion in the last-glacial areas on the example of NE Poland

SMOLSKA E.

University of Warsaw, WARSAW, POLAND

The aim of the study was to recognize soil erosion in the last-glacial area on the example of NE Poland. Monitoring of soil erosion was conducted on selected slopes in the upper Szeszupa catchment in years: 1987-1989, 1998-1999 and 2007-2011, a total during 10 years. In 2007-2009 measurements were also performed within 3 runoff plots on sandy soils under differential land use: black fallow, grain crops and potatoes. Each plot was 22 m long and 2 m wide. During rainfalls of moderate intensity sheet wash caused erosion of the upper and the middle segments of hillslopes and deposition of eroded material in their concave (lower) segments. Rills formed locally due to rainfalls above 20 mm on sandy-loamy, sandy-silty and loamy-sandy slopes longer than 100 m. Only a limited amount of material was transported beyond slopes and accumulated at the footslopes. For the average intensity of rainfalls, annual soil erosion ranged from 0,05 to 7 t×ha<sup>-1</sup>. Due to heavy rainfalls the effectiveness of both processes: sheet and rill erosion was several times greater, up to 30-50 t×ha<sup>-1</sup> and locally even 80-90 t×ha<sup>-1</sup>. Intensive erosion, accompanied by soil loss up to 170 t×ha<sup>-1</sup>, lead to the formation of frequent rills, and locally, to the development of ephemeral gullies. Strong erosion occurred on hillslopes were several features facilitated the soil loss, most importantly: the type of crop and the early stage of its development, local lithology and morphology of the slope. The study area experiences heavy rainfalls (>30 mm and erosivity > 300 MJ×mm×ha<sup>-1</sup>×h<sup>-1</sup>) in May or June with frequency once every 7-10 years on average. It is estimated that 15% of the study catchment area is threatened by soil erosion.

\*\*\*\*\*

## Weather times and flood generation in the Araguás catchment (Central Spanish Pyrenees)

NADAL ROMERO E., CORTESI N., GONZÁLEZ HIDALGO C.

University of Zaragoza, ZARAGOZA, SPAIN

Flood generation and soil erosion is associated with specific weather conditions that can be described by weather Types (WT) approaches. The WT approach consists on classified atmospheric conditions. Previous climate researches in the Iberian Peninsula (IP) have analyzed the relationship between precipitations and specific WT, being the most prevalent to produce precipitation the Westerly, South-Westerly and Cyclonic WTs. These investigations have also demonstrated that specific WT are the main driven of precipitation accordingly different areas.

In this study, an analysis of WT and flood generation, storm-flow and soil erosion data during 7 hydrological years in the Pyrenees mountain area is presented. The analyses indicates that the Anti-cyclonic (A) type is the most frequent class (17.04%), but contribute with a rather small amount (5%) to total precipitation amount. On the other hand, the three wettest WTs, namely Cyclonic (C), Northwesterly (NW) and westerly (W) types, together representing only 20% of all days, account for 45% of the total precipitation.

Since October 2005, a total of 253 floods were identified in the study area. The most frequent WT generating floods were Cyclonic (19.4%), Northwesterly (NW) (15.4%) and Westerly (14.6%) types. The analysis of monitored storm-flow and sediment yield (SY) in relation to the WTs reveals a clear propensity for the south westerly (SW) weather pattern to dominate the maximum storm-flow generation and the maximum SY.

### **Typology of torrential systems prone to debris flows occurrence in the Hérens valley (Switzerland)**

MAILLARD B.(1), REYNARD E.(2), THELER D.(1)

(1) *ECOTEC Environnement SA, SIERRE, SWITZERLAND* ; (2) *Institute of geography and sustainability, University of Lausanne, LAUSANNE, SWITZERLAND*

Debris flows are one of the most active sediment transport vectors in the mountain regions. The objective of this study on debris flows in the Hérens Valley (Valais, Switzerland) is twofold: (1) to identify geomorphological contexts favourable to trigger debris flows and (2) to estimate the volumes potentially mobilized. The research, conducted by a combination of qualitative and quantitative methods, was divided into two stages. As a first step, we classified small torrential basins based on hydrogeomorphological and morphometric criteria and according to their morphodynamic activity. As a second step, the potentially mobilizable sediment volumes were calculated for several torrential systems particularly active or at risk for infrastructure, using a semi-quantitative geomorphological method. The results show that, because of the variety of factors responsible for the debris flow triggering, it is not possible to predict debris flow activity only from morphometrical analyses.

\*\*\*\*\*

### **Damming in semiarid, relation between landscape connectivity and effective catchment area on Saco creek watershed Brazilian semiarid**

SOUZA J., CORREA A.

*Federal University of Pernambuco, RECIFE, BRAZIL*

The water resources management in the semi-arid has a close linkage with the annual and inter-annual variability of precipitation, which induced the creation of a hydro infrastructure network based on construction of dams, in special at warm semiarid zones, to use supply and irrigation to population, being essential the management of these dams and of their contributions areas. This study tried to analyze the physical system of the Saco creek watershed, situated in Brazil semiarid, with emphasis on the fluvial system, and from this evaluate the issue of regional planning aimed at damming the semiarid zone. Having the landscape connectivity as a concern analyzing the process of conveyance and sedimentation in semi-arid environment. For this geomorphological and land use, mappings were analyzed, and also classifications of precipitation/runoff events, based on average monthly runoff, that will identify the effective events of the system. The impediments location/characteristic enables the understanding of the effective catchment area on the watershed to three different magnitudes of runoff events. In low magnitude scenario only 33.8%, of the watershed contributed effectively to drainage network, in moderate magnitude this value grew to 61.6%, this augment is a result of the impediments overcoming; reaching to 70.8% in high magnitude events, this little variation is controlled by the existence of dams which storage all sediment, including in high magnitude events, released only with dams disruption. Landscape connectivity analysis can subside the dam management on semiarid zones; with emphasis on capture of the sediments before they arrive in the dams, increasing its useful life.

## **Debris dams on the far eastern rivers and their impact on the dynamics of riverbed transformations**

MAKHINOVA A., KIM V.

*Institute of Water and Ecological Problems FEB RAS, Khabarovsk, Russian Federation*

Forest vegetation noticeably affects the formation of the riverbed relief and the intensity of riverbed processes. Big trees in water streams 8-10 meters wide significantly block the water flow and cause the formation of stable broads. Fallen trees often cause changes of riverbed morphology as alluvial material starts accumulating in front of them and broads of specific morphology are formed behind.

Big rivers up to 150 meters wide may also be blocked with debris dams. They may be the result of economic activities in river basins. Wood cutting and forest fires disturb river runoff causing active riverbed transformations and bank erosion. As the result more trees and debris fall into the river and dam the water flow. The last stage of this process is the formation of numerous small river branches, where erosion is significantly lower.

Fallen trees in rivers more than 150-200 meters wide do not noticeably affect the river flow. Such rivers easily carry even big trees, shallows being an exception. Trees in shallow places facilitate the accumulation of alluvial matter or the formation of localized deep pools.

\*\*\*\*\*

## **Investigating morphodynamics and sediment fluxes in a river reach impacted by a series of dams using landscape evolution modelling with CAESAR-Lisflood**

POEPPL R.E.(1), KEILER M.(2), COULTHARD T.(3)

*(1) Department of Geography and Regional Research, University of Vienna, Austria, VIENNA, AUSTRIA ; (2) Institute of Geography, University of Bern, Switzerland, BERN, SWITZERLAND ; (3) Department of Geography, Environment and Earth Sciences, University of Hull, United Kingdom, HULL, UNITED KINGDOM*

Dams are often considered to have the most significant impact on rivers and concerns about the effects of dam construction have recently increased with the rising number of dams. Dam construction generally reduces downstream sediment fluxes which involves geomorphic changes in the affected river reaches (i.e. upstream/reservoir aggradation, downstream degradation). With dam removal the opposite generally occurs, i.e. upstream degradation and aggradation in the downstream reaches. However, the situation can become more complex in river systems that are impacted by a series of dams due to emerging feedback processes between the river and the multiple dams. In the presented study we modelled different scenarios of dam construction and dam removal within a river reach impacted by a series of dams using the landscape evolution model CAESAR. The model was run with data from a small catchment located in Lower Austria. Modelled geomorphic changes and sediment fluxes were spatio-temporally analysed and interpreted in the context of dam construction/removal. Geomorphic changes were quantified using zonal statistics in ArcGIS, while calculated water and sediment fluxes were analysed according to their total sediment volume and grain size distribution. In order to validate the modelling results, sedimentological surveys were performed in the field. First analyses of the modelling results revealed the occurrence of negative feedback processes within a series of dams restricting dam-induced downstream erosion as well as upstream erosion after dam removal as a function of distance between dams.

## **Embedded Dam Technique on River Basins in Rehabilitation Studies: The Case of the Afyonkarahisar Dort River**

SELÇUK BIRİCİK A.(1), EKİNÇİ D.(2)

(1) MARMARA UNIVERSITY, ISTANBUL, TURKEY ; (2) ISTANBUL UNIVERSITY, ISTANBUL, TURKEY

Rivers possess a delicate environmentalism that depends on a regular cycle of disturbance within certain tolerances. The geomorphological processes, plant and animal communities that inhabit the river and river margins have evolved to adapt to their rivers own peculiar pattern of flood and drought, slow and fast current. However floods are the most common and widespread of all natural disasters and there are many disruptive effects of flooding on human settlements and economic activities. Dams are important in this case. There are several types of dams. One of them is embedded dam. They prevent flooding of small areas. The concept of embedded dam is combined with the old principle of stationary set balance to produce an alternative approach for obtaining the steady-state distribution of the level in a dam with general release rule. Embedded dam system shall be indicated and benefits will be determined. These are described in the case of Dort River dam in this study.

\*\*\*\*\*

## **Coarse sediment study in small mid-mountain catchments: a multidisciplinary attitude**

HARTVICH F., LANGHAMMER J., STYCH P.

Charles University in Prague, PRAGUE, CZECH REPUBLIC

Within the project "Impact of disturbances in montane landscape on the dynamics of runoff and fluvial processes", the distribution, analysis and monitoring of the fluvial sediment bodies were among the main objectives, as the dynamics of the fluvial systems is known to be a sensitive indicator of the environmental changes. The study areas are situated in the mid-mountains of the Šumava Mts., a region hit with severe landscape disturbances of both natural and human origin, namely windstorms Kyrill (2007) and Emma (2008), and following bark-beetle infestation and consequent forest management measures including vast logging. Recent development of technologies has enabled using new attitudes also in the fluvial geomorphology. Within this study, we have employed some of these innovative methods. Initially, mapping of the fluvial landforms was performed using a specially adapted form-based mapping method, which had two-fold advantage: it enabled even less-experienced field workers to achieve acceptable results, and allowed very easy processing and analysis of the data in GIS. The results were complemented with the analysis of the 1 m LiDAR DEM, thus bringing very accurate relief properties information. Geophysical profiling using the ERT method was applied across the studied valleys to observe the depth of the valley infill. Selected sedimentary accumulations were measured using a ground LiDAR laser scanner, creating extremely detailed surface model, to be used as a reference surface for future repeated measurements, thus calculating the sediment transport volumes. Finally, granulometric analysis using a photography-based software Sedimetrics was performed on suitable accumulations. Although the research has commenced only recently, we have already obtained a valuable data on the current distribution of the sedimentary bodies within the studied catchments as well as a base for future reference aiming to assess the current, disturbance-driven sediment dynamics.

## **Poster presentations:**

### **The magnitude and frequency of morphogenetic processes in small catchments (Western Tatra Mts., Poland)**

PLACZKOWSKA E.

*Institute of Geography and Spatial Management, Jagiellonian University, KRAKOW, POLAND*

Small catchments 1<sup>st</sup>-3<sup>rd</sup> order (according to Horton-Strahler's classification) are very important in the sediments and organic contents fluxes. They are a source of energy and matter for fluvial system. Thus they are transitional segments between slope and channel systems. The aim of the paper is to recognize the magnitude and frequency of morphogenetic processes (especially fluvial processes) in small catchments in Western Tatra Mts.

The study area is the Western Tatra Mountains within the Tatra National Park in Poland. There are three geocological zones in the study area – forest zone (to 1500 m a.s.l), subalpine zone (1500-1800 m a.s.l) and alpine zone (over 1800 m a.s.l). There is morphogenetic processes differentiation within these zones, especially above and below the timberline. The high-mountain areas are characterized by variable weather conditions. The annual precipitation is up to 2000 mm.

The study was carried out in seven chosen valleys in the Western Tatra Mountains using field experiment with marked debris. Three valleys are located in sub-alpine and alpine zones and four of them are located in forest zone. The study sites were installed in channels of different order, different structure and different hydrodynamics. Simultaneously the water level in streams and discharge were measured. The bedload movement in small channels from 1<sup>st</sup> to 3<sup>rd</sup> order is generally rare. It occurs once or twice a year but in the uppermost part of valley it is even less frequently occurring. Distances of bedload movement generally increase downstream and they are from less than one meter in upper stretch of 1<sup>st</sup> order channel to few meters in 2<sup>nd</sup> or 3<sup>rd</sup> order channels. In forest zone the distance of bedload movement can reach up to 60 meters. The occurrence of mineral and woody debris in channels is very important. They build traps for moving debris and reduce its removal from the catchment.

\*\*\*\*\*

### **The specificity of energy and matter circulation in the coastal, forested lake gardno catchment on Wolin Island (NW Poland)**

KOSTRZEWSKI A., TYLKOWSKI J.

*Adam Mickiewicz University, POZNAN, POLAND*

The operation of the morphogenetic system of lake catchments should be considered in spatial-temporal terms. In the contemporary denudation system of such catchments the physico-chemical transformation of precipitation plays a significant morphogenetic role. Of crucial importance for an insight into the operation of lake geoeosystems is to establish regularities underlying the transformation of the chemical composition of precipitation at the successive stages of the water cycle in a catchment, including throughfall, stemflow, groundwater, and surface water. Seasonal differences in the amount and chemical composition of precipitation determine annual variations of the load of chemical substances introduced into slope covers, and play an important role in net denudation in the catchment.

The full forested Lake Gardno catchment is situated on the Wolin End Moraine. It's neighbourhood of the cliff coast of Wolin Island and it has no surface outlet.

The base of the research was the AMU Environmental Monitoring Station at Biała Góra/Grodno and the period covered was 1997-2012.

The main objectives of the work in the Lake Gardno catchment are following:

- hydrochemical transformation of precipitation
- seasonal variations of water's hydrochemical properties
- marine aerosols influence on the chemical properties of water
- the role of the fog in the water and the elements circulation
- water and denudative balance
- model of the water cycle and the elements in the catchment.

The quantitative assessment of the energy and matter circulation in the Lake Gardno catchment is presented here in a model of the functioning of dissolved matter in a long-term and yearly cycle.

### Monitoring programme of sediment flux in small upland catchments, SE Poland

RODZIK J.(1), JANICKI G.(1), CHABUDZINSKI L.(1), FRAN CZAK L.(1), SILUCH M.(1), STEP NIEWSKI K.(1), DYER J.(2), KOLODZIEJ G.(1), MACIEJEWSKA E.(1)

(1) *Maria Curie-Skłodowska University, LUBLIN, POLAND* ; (2) *Mississippi State University, MEMPHIS, UNITED STATES*

The purpose of monitoring of small upland catchments, launched in 2011, is to determine differences in sediment and solute yields as well as in sources of material supply to the channels under conditions of land use changes in the eastern part of the Polish Uplands. Seven catchments with an area of 12-68 km<sup>2</sup> and varying land cover were identified, representing different lithological types of upland relief. Five subcatchments were identified within them to determine the impact of the catchment area on the unit size of transport.

Field and laboratory investigations include the following:

- automatic recording of water levels and measurements of flows once per month;
- pH and water temperature measurements once per month;
- quantitative analysis of sediments and solutes in water samples collected once per week;
- qualitative analysis of samples collected once per month;
- quantitative analysis of water samples collected daily during flood events.

The initial research results indicate that the areas built of Cretaceous carbonate-silicate rocks – gajzes and opokas – are characterized by the lowest rate of fluvial transport. The highest rates are found in loess areas incised by gullies. The unit rate of sediment transport clearly decreases with an increase in catchment area, while the rate of solute transport slightly increases.

The presented monitoring scheme is a part of the programme: “Rainstorm prediction and mathematic modelling of its environmental and social-economic effects”, financed from the resources of the Polish National Scientific Centre.

\*\*\*\*\*

### The effect of landuse changes on sediment transportation in a small catchment during last 60 years

KIM J.K.(1), NAHM W.H.(1), KIM M.S.(2), YANG D.Y.(1), JEONG G.S.(3)

(1) *Korea Institute of Geoscience & Mineral Resources (KIGAM), DAEJEON, SOUTH KOREA* ; (2) *Korean Association of Soil and Water Conservation, SEOUL, SOUTH KOREA* ; (3) *Chungnam National University, DAEJEON, SOUTH KOREA*

To investigate the effect of landuse changes on sediment transportation in a small catchment, a short core from reservoir was obtained. Reservoir sedimentation rate changes during last 60 years were reconstructed by radionuclides, exPb-210 and Cs-137, and landuse changes from 1960's to 2000's were estimated by analyzing aerial photographs. Reservoir sedimentation rate changes can be recognized in three periods. During first period (1940's ~ early in 1950's), reservoir sedimentation rate had increased since the construction of reservoir. During second period (early in 1950's ~ early in 1990's), reservoir sedimentation rates were stable relatively around 3 kg m<sup>-2</sup> a<sup>-1</sup>, however, two higher sedimentation peaks occurred. During last period (early in 1990's ~ 2003), reservoir sedimentation rate had increased sharply. Before 1990's, the sediment transportations from a catchment to reservoir had been changed little although the increase of forest and grassland areas and the readjustment of rice fields had been occurred repeatedly and those landuse changes might not affect considerably the sediment transportation. The increasing of field area and bare area due to the reduction of forest area since early in 1990's might be a dominant factor for the increasing the supply of sediment from a catchment, and gradually increasing rainfall amount in this study area since 1970's would also assist the rapid increasing of sedimentation rate. Therefore, these results implied that land use changes and increasing rainfall caused by climate changes could be result in huge sediment transportation in the future.

### **Changes of size distribution of the raindrops against rainfall intensity in Daejeon, Korea**

LIM Y.(1), KIM J.W.(1), KIM J.K.(2)

(1) Seoul National University, SEOUL, SOUTH KOREA ; (2) Korea Institute of Geoscience & Mineral Resources (KIGAM), DAEJEON, SOUTH KOREA

To evaluate the size distribution of the raindrops under various rainfall intensities, the terminal velocity and the size distribution of raindrops for 17 rainfall events were measured from January 2010 to August 2011 using laser-optical disdrometer in Daejeon, Korea. The predominant drop size and median drop size ( $D_{50}$ ) became larger with rainfall intensity increasing, although the value of  $D_{50}$  was stabilized for rainfall intensities over 70 mm/h. Compared to the number of raindrops estimated by Marshall and Palmer model, the observed number of raindrops less than 2 mm of the diameter overestimated. Gamma distribution was fitted to the number of raindrops with each raindrop size class, however, over 3 mm for the diameter, the estimated line using by gamma distribution enveloped the observed raindrop number. Therefore, we suggest that gamma distribution model and Marshall and Palmer model could be employed as an upper and a lower limit of the number of raindrops for each raindrop size class over 3 mm for raindrop diameter, respectively.

\*\*\*\*\*

### **The GPR (ground penetrating radar) use to estimate the annual rate of sediment delivery in small catchments from Obcinele Bucovinei (the Romanian Carpathians)**

LESENCIUC C.

UNIVERSITY "ALEXANDRU IOAN CUZA" IASI, IASI, ROMANIA

Among the geomorphological processes characteristic to the Romanian territory, landslides are specific to hilly and mountainous areas. These landslides cause serious changes to both the area where they take place and its surroundings, leading to the formation of natural-dam lakes. Lake lezer from Obcinele Bucovinei falls into this category, being considered, based on present information, the oldest natural-dam lake from Romania.

The lakes formed by landslides represent local pools for the river deposits. They are relevant to geomorphology but especially for hydrotechnics because anthropic lakes are far more younger than natural lakes and longer deposition times can give a better estimation of sediment delivery.

The lake and the upstream catchment area belong to the flysch area of the Romanian Carpathians, with strong folded sediment layers constituted from glauconitic slates, compacted clays, striped clays and clays with globular-siderite, rocks that are prone to trigger the landslides.

The studies focused on this area have begun in 2009 when the lake and its surrounding area were surveyed with a Leica TCR 1201 total station. Based on these surveys, an extremely-accurate digital elevation model (DEM) was created for the present topography and of the clogged valley-sector upstream of the lake. After this, the GPR surveys aimed to create a carbon-copy DEM of the initial valley, before the formation of Lake lezer. The overlying of the two DEMs enabled us to estimate the sediment volume deposited in the lake. By dividing the total sediment volume by the accumulation period (1100 years old) and the catchment area (3.71 km<sup>2</sup>), it resulted an annual upstream catchment sediment delivery rate (21m<sup>3</sup>/km<sup>2</sup>/year) that was smaller than the estimated rate for other flysch areas of the Romanian Carpathians.

### **Soil moisture dynamics of a Muhly grass hillslope seep system**

SLATTERY M., LLADO L.

*Texas Christian University, FORT WORTH, UNITED STATES*

Groundwater seeps are characteristic hydrological and ecological features of many landscapes. While they exist in a variety of environments, their extent and hydrologic characteristics are poorly understood. This study examines the hydrology of seeps dominated by Seep Muhly grass (*Muhlenbergia reverchonii*) in the Grand Prairie Ecoregion of Texas. The objective of the research is to document and quantify the soil moisture dynamics of a hillslope hollow seep system. We monitored soil water content and matric potential for 16 months along a slope transect within a headwater hillslope hollow containing an upslope Muhly seep. We captured seep dynamics across a wide moisture spectrum, including extreme drought, storms, and snowmelt. In all cases, the Muhly seep wetted first and remained at, or above, field capacity for at least three days following a precipitation event. This is the result of local pedologic/geologic controls: these seeps sit atop fractured limestone underlain by a subsurface clay layer, which results in water percolating to the clay, ponding, and then slowly moving downslope on top of what is, in effect, a mid-slope aquitard. The hydrologic functioning of these seeps has both practical and theoretical ramifications. From a practical standpoint, Muhly seep systems are being considered for delineation as possible wetlands; the timing and extent of saturation of these systems suggests they should be. From a theoretical perspective, the Variable Source Area (VSA) may not be adequate in capturing the full hydrologic complexity of seeps, especially if the seeps are geologically controlled and disconnected hydrologically from the rest of the hillslope.

\*\*\*\*\*

### **Physic Characterization of Watershed of Reibeirão do Feijão, in the counties of São Carlos, Itirapina and Analandia ' Sao Paulo, Brazil ' as Morphopedology Compartmentation subsidy**

CERMINARO A., OLIVEIRA D.D.

*UNIVERSIDADE DE SAO PAULO, SAO PAULO, BRAZIL*

This study has as aim to study the watershed of Ribeirão do Feijão, localized in east-center of Sao Paulo state where ranges the counties of Sao Carlos, Analândia and Itirapina. The main objective is cartographic and theoretical production to characterization of physical, geological, geomorphological and pedological, which structure the landscape of watershed. The products analyses were operationalized in ArcGis 9.2 software developed by ESRI, which were used cartographic bases extracted from the letter SF-23-Y-A-I of IBGE, Sao Carlos grid, scale 1:50000. It is aimed with this production such materials to generate of data and information which enable a morphopedological compartmentalization of this area.

Holistic perspective analyses of the surroundings are related to ecodynamics and ecogeography prepositions and morphopedological compartmentalization methods developed by TRICART e KILLIAN (1979), which were propagated by Castro & Salomão (2000). The interdisciplinary understanding of the factors involved in sculpturing the landscape attempts to uncover the relationship of matter and energy exchange between the different factors that contribute to and define the modeled landscape, which are representing through homogeneous units of their compartments. Therefore, the confection and description of the thematic maps are essential to the understanding of systemic watershed, and also based on the whole idea of environment system developed by Chistofoletti (1999).

Studies of pedo-geomorphological interactions, their dynamics and interpretations should be understood as preliminary studies fundamental to planning, because they may allow notes to land uses, supported by information of nature components seamlessly, synthetically processed and represented in areas homogeneous, allowing better definition of guidelines and actions to be implemented in physical space-territorial.

### **Holocene sediment dynamics for two small river catchments in Normandy (Western France)**

VIEL V., LESPEZ L., DELAHAYE D., LE GOUÉE P.  
*LETG - Caen - GEOPHEN, CAEN, FRANCE*

Geomorphological and palaeoenvironmental research on Holocene sedimentation in the valleys of Normandy provides evidence for long term fluvial system changes related to climate and human activities. In order to evaluate erosion rates evolution and subsequent sedimentation on slopes and the valley bottom, an Holocene sediment budget based on field data have been conducted for two small catchment localized on the sedimentary Paris Basin (NW France). An extensive geomorphological survey was carried out for the Thue (80 km<sup>2</sup>) and the Mue (100 km<sup>2</sup>) river catchments. Data from 41 cores and 11 hand auger cross-sections, regularly placed among the valley bottom were used to quantify the alluvial storage and identify the stratigraphy. 18 AMS radiocarbon dating on organic samples from core drilling were used to define the chronology of the alluvial filling. Slope erosion was determined using 230 soil profiles description from auger coring transects within a small sub-catchment (9 km<sup>2</sup>) and extrapolated to the entire river basin according to a soil erosion model. Results underline an important evolution of sedimentation into the valley bottom moving from tufa and organic remains to a widespread silty deposit (overbank and colluvial material). Quantification of alluvial and colluvial deposits indicate that 90% of eroded sediments are stored in the watershed, preferentially on dry valleys and as alluvial deposits. Available radiocarbon dating on the last organic deposit of the valley bottom dates the onset of silty deposits during the end of the Bronze Age and indicates an increase in sedimentation rate during the Gallo Roman period and Middle Age. Results are discussed in relation with the paleoenvironmental and archaeological data available at the local and regional scale which suggest an important complexity slope erosion processes and sediment redistribution into the catchment.

\*\*\*\*\*

### **The results of ravine erosion monitoring in the territory of Udmurt Republic**

RYSIN I.  
*Udmurt State University, IZHEVSK, RUSSIAN FEDERATION*

In order to study the ravine formation mechanism and receive some quantitative characteristics of their seasonal and annual increase some semystationary observations for the growth of more than 160 ravines at 28 key sections located in different landscape conditions are being conducted from 1978 year. The territory of Udmurt Republic is located in the east of the Russian Plain in the southern part of the Vyatka-Kama interstream area.

By using the method of bench marks, located along the drainage line it is possible to determine the rate of ravine growth. At the majority of the stationaries (93 ravines) observations are carried out once a year (usually July) and at 10 key places (46 ravines) measurements are taken twice a year (in spring and autumn). Since 1993 y. 10 ravines located in the environs of Izhevsk are additionally observed in summer after the heavy rainfalls.

The mean velocity of ravine growth ranges greatly. The maximum index is 123 m/year. The mean velocity of secondary ravine growth (1,4 m/year) exceeds that of the primary ravines (1,1 m/year). Bed ravines washing away loamy, sandy, alluvial and gully deposits have the greatest many-years velocity of growth (2,2 m/year).

In the context of many years about 80% of annual ravine increase is produced by spring water drainage. However during the years of extremely heavy rainfall 90-94% of annual ravine growth is noticed at some key-places. The growth of certain ravines may exceed annual norm in tens times.

Field stationary studies gave the opportunity to define the limit indexes of the 12 hour precipitation layer, at which various intensity ravine erosion takes place. When this layer is less than 25 mm there is no growth of ravines at all, when it is more than 55 mm the growth is considerable, but at 70 mm it becomes catastrophic. The intensity and time of heavy rainfall has a great importance at this.

### **Influence of soil and vegetal cover on hydrological behavior of a forested catchment in a mid mountain environment**

SERRANO MUELA P.(1), REGÜÉS D.(1), NADAL-ROMERO E.(2)

(1) Instituto Pirenaico de Ecología, ZARAGOZA, SPAIN ; (2) Universidad de Zaragoza, ZARAGOZA, SPAIN

The study is developed in the San Salvador forested catchment (0.92 km<sup>2</sup>). This work presents a summary of the analysis of the hydrological response and the main factors that favors the hydrological dynamics: soils, which favors infiltration processes and vegetal cover, which influences on interception rates and soil processes and the water table fluctuations (Serrano-Muela, 2012).

The hydrological response of the San Salvador catchment has been studied at annual, monthly and event scale. The most detailed study has demonstrated the influence of antecedent conditions, the characteristics of rainfall and the water table dynamics on the flood generation. At annual scale, three hydrological periods can be observed: humid period, in which most of the stormflow of the year is produced and the events are more significant; dry period, frequently without response; and finally, the transition periods showing important variability of responses.

The interception values observed in the basin are generally high. Throughfall values obtained in the three species confirm the influence of this process and its relation to the type of species and their phenological state.

With respect to the dynamics of groundwater levels, they are characterized by a marked seasonality, showing rapid oscillations, a fact very typical of forest areas. This temporal dynamics revealed an effect on the hydrological response.

The study of soils in the San Salvador catchment had revealed the enormous importance of certain soil properties such as structure, texture and organic matter content. These structures, for example, promote the infiltration of water and this circulation within the subsurface and the subsurface water movement.

Serrano-Muela, M.P. 2012. *Influencia de la cubierta vegetal y las propiedades del suelo en la respuesta hidrológica: generación de escorrentía en una cuenca forestal de la montaña media pirenaica*. Tesis Doctoral inédita. Universidad de Zaragoza. 317 pp. Zaragoza.

\*\*\*\*\*

### **Groundwater dynamics in a forests submediterranean environment**

SERRANO MUELA P.(1), REGÜÉS D.(2), NADAL-ROMERO E.(3), LANA-RENAULT N.(4)

(1) Instituto Pirenaico de Ecología, ZARAGOZA, SPAIN ; (2) Instituto Pirenaico de Ecología, ZARAGOZA, SPAIN ; (3) Universidad de Zaragoza, ZARAGOZA, SPAIN ; (4) Universidad de La Rioja, LOGROÑO, SPAIN

This work studies groundwater dynamics considering this variable as an indicator of the water content status of a catchment, relating this dynamic to the hydrological response, which allowed us to investigate about the identification of dominant hydrological processes in the forested San Salvador catchment.

The groundwater dynamic in this catchment is characterized by three facts:

i) The marked seasonality between the driest and wettest periods, a pattern also observed in other hydrological variables (rainfall, evaporation, storm-flow generation, interception), as a result of the Mediterranean climatic influence.

ii) The absence of moments in which the water table reaches the surface, indicating that during the study period there were no surface saturation situations. The associated stormflow response occurs without saturation, which is indicating the occurrence of subsurface runoff processes.

iii) The rapidly oscillating of water table levels, both rise and declining. This fact is largely influenced by precipitation events, especially by its magnitude. This difference in behavior is related to forest environments, depending on soil characteristics, which are very permeable due to its high porosity and high infiltration capacity, especially in the shady slope.

The water table dynamics is similar in other forest environments, even in different climatic contexts. This study demonstrates that the presence of vegetal cover is a key factor in the soil development and their hydric properties, even more decisive than other factors (climatic or topographic).

### Lahar initiation on small upstream catchments of Merapi volcano during 2012-2013 rainy season

WIBOWO S.B.(1), MAJOR J.J.(2), PIERSON T.C.(2), MOUROT P.(3), HADMOKO D.S.(4), LAVIGNE F.(5)

(1) Université Paris 1 Panthéon-Sorbonne, PARIS, FRANCE ; (2) Cascades Volcano Observatory, USGS, VANCOUVER, UNITED STATES ; (3) Myotis S.A.S, ECHIROLLES, FRANCE ; (4) Research Center for Disaster, YOGYAKARTA, INDONESIA ; (5) Laboratoire de Géographie Physique, MEUDON, FRANCE

Unconsolidated tephra resulted from 2010 centennial eruption of Merapi were deposited on the upstream flank of volcano. Although the materials are not very fresh anymore and vegetations (especially *Pennisetum purpureum* and *Acacia decurrens*) have grown fast, lahars still can be generated by rainfall events. The objectives of this study are to compare lahar initiation process on small volcanically disturbed and undisturbed basin. We use 4 – 5 rain gauges installed within the catchment areas. Three meters long weirs are installed at the mouth of each catchment to facilitate flow measurement using load cell and laser stage sensor. Soil moisture sensors are also used to measure the infiltration rate of the catchments. We also measure flow depths at the up and middle channel using pore pressure transducer. Until 10 January 2013, daily observation show that one landslide has occurred within the volcanically disturbed basin roughly 15 m before the weir. Flow magnitude and transported materials on disturbed basin channel are greater than on undisturbed basin channel. However, this would change since *Pennisetum purpureum* grows extremely fast during rainy season and may reduce surface runoff on disturbed basin.

Keywords: volcanically disturbed basin, lahar initiation, vegetation

\*\*\*\*\*

### Land use in floodplains: a study on the Riparian Buffer in Sub-basin river Ipiranga - River tributary guandu / Brazil

TESTA P.M.C., RODRIGUES BARBOSA D., VIEIRA DE MELLO E., GUNDIM SILVA F., MACEDO RODRIGUES N.

UGF, RIO DE JANEIRO, BRAZIL

According to Brazil (2007), generally, the problem of the flood risk areas in Brazil's cities can be summarized in the following items: economic and social crisis with a long-term solution; housing policy for low-income historically inefficient; ineffectiveness of control systems use and occupation of the soil, lack of legislation adequate for areas susceptible to the risks mentioned, lack of technical support for the populations; popular culture living in lowland areas.

For these reasons, the Riparian buffer demarcations (Based on the standards established by the n° 12.651/2012 federal law and by the n° 650/1983 state law) which are strips of land which coincide with the floodplains around the rivers, lakes, and lagoons fundamental to the ecological equilibrium, offering protection for the waters, lakes and dams and preventing the flow of pollutants into the water systems and avoiding losses of material goods, human casualties caused by floods, and others.

The current work seeks to classify the use of land and delimit the riparian buffer in the Ipiranga water basin, which drains a part of the municipality of Nova Iguaçu, located in the Metropolitan area of Rio de Janeiro. The intersection of the two maps will offer as a result, the spatial analysis of the existing conflicts between the practice of environmental laws and other uses of land identified in the floodplains.

The Ipiranga water basin has an area of 2220 Km<sup>2</sup> and it was verified that the Riparian Buffer determined by law is 30 meters (for rivers which are less than 10 meters wide) and 50 meters at the source (according to the forestall code). The uses of soil at the water basin were hierarchically organized as follows: pastures (31,63%), riparian vegetation (30,02%), marshes (17,80%), urban occupation (10,24%), agriculture (9,04%) and exposed soil (1,27%).

## **Determining catchment-scale connectivity using hysteresis analysis of discharge and suspended sediment**

MASSELINK R.(1), KEESSTRA S.(1), GIMÉNEZ R.(2), CASALÍ J.(2), SEEGER M.(3)

(1) Wageningen University, WAGENINGEN, NETHERLANDS ; (2) Public University of Navarra, PAMPLONA, SPAIN ; (3) University of Trier, TRIER, GERMANY

Recent developments in hydrology and geomorphology include the connectivity principle, which describes how different elements in a landscape are connected and how water and matter move between these elements. So far, studies on connectivity have been mainly of a conceptual nature, while studies that quantitatively establish relations in connectivity are rare. In this study we have used discharge/sediment concentration hysteresis analysis as a method to assess the connectivity in a catchment. The analyses were done on 17 years of high quality, high resolution discharge and sediment data from two catchments in Navarre, Spain. These catchments are assumed to have high and low connectivity respectively, enabling the test of hysteresis analysis as a methodology for connectivity assessment. The type of hysteresis was determined for all relevant precipitation events (N>150). In addition, the influence of soil moisture patterns and vegetation state on hysteresis types and therefore connectivity was assessed. Results of the analysis will be compared to several indices for connectivity and catchment complexity.

We hypothesise that for catchments with low connectivity a more clockwise hysteresis will be observed, this is, sediment sources distributed around the catchment will not contribute to the sediment loss. Highly connected catchments will display an anti-clockwise hysteresis, or no hysteresis (linear), which means that sediment sources with higher distance to the outflow may contribute also to the sediment losses of the catchment. We also hypothesize that the type of hysteresis is dependent on the time in the growing season and on soil moisture patterns. Variability in soil moisture and vegetation patterns either connect or disconnect water and sediment sources at different stages through time and therefore generate different hysteresis patterns.

\*\*\*\*\*

## **Contemporary functioning of peat catchments on a glaciofluvial fan. Case study: Orawska Basin, Polish Carpathians**

LAJCZAK A.

Jan Kochanowski University, Institute of Geography, KIELCE, POLAND

The paper analyzes selected aspects of the functioning of small autochthonous catchments featuring peat bogs found across the Czarny Dunajec glaciofluvial fan in the Orawska Basin, which is located across the northern Tatra Mountain foreland in the Western Carpathians in southern Poland. Consecutive changes in the abiotic environment are discussed relative to increasing human pressure, which has contributed to the gradual transition from meandering channels to braided channels: 1) changes in peat bog extent and volume, 2) changes in the quantity of water permanently stored in peat deposits, 3) changes in groundwater stream recharge, 4) changes in the surface stream network, 5) changes in stream channel morphology. The paper focuses on the last 160 years of catchment evolution. The development of meandering channels common in the study area is determined by the following factors: 1) physical ability to freely meander in an area with clayey parent material covered by peat deposits, 2) significant supply of groundwater to stabilize stream discharge, 3) small channel gradients, 4) large supply of fine sediments. The second factor is the most important of the four factors. The renaturalization of peat bogs started in the 1950s and accelerated in the 1990s and has contributed to an increase in stream sinuosity and a resulting increase in catchment water content. The paper is based on the analysis of maps from the last 230 years as well as aerial photographs, National Hydrological Survey data, extensive field research and laboratory research.



**S19C - Sediment fluxes and morphodynamics of stream channels**

Convenors: *Alain RECKING, John PITLICK, Mike CHURCH*  
& Nicola SURIAN





## **Oral presentations:**

### **Time scale analysis of bedload discharge over steep slopes: from intermittency to white noise**

*HEYMAN J.(1), METTRA F.(1), MA H.B.(2), ANCEY C.(1)*

*(1) EPFL - ENAC - LHE, LAUSANNE, SWITZERLAND ; (2) Departement of Hydraulic Engineering, Tsinghua University, BEIJING, CHINA*

Bedload transport remains largely unpredictable in steep slope rivers. Comparing experimental data obtained in a steep slope flume and a stochastic model, we show that bedload discharge statistics strongly depend on the measurement time and spatial scale. We base our talk on a flume experiment that resolved 7 orders of magnitude in time (from 10-2s to 105s) of solid discharge. Computing the variance of the mean solid discharge depending on the sampling time, we distinguished three successive time scales: (1) intermittent (2) correlated and (3) white noise limit. The intermittent time scale is the shortest and is characterized by long periods of time without any transport. Then, we observe a correlation time scale that spread over 3 order of magnitude in time. Correlation can result from various phenomena (bedform migration, collective motion...). The largest scale observed corresponds to the white noise limit, and occurred for time scales larger than 103s. To understand better the dynamics involved, we compare these results to a stochastic model that capture the basic dynamics of particles motion. Along a one-dimensional spatial grid, particles can erode, deposit, or be advected by the flow according to a Markov process. In the continuous limit, this process converges to a stochastic partial differential equation (SPDE) of advection-diffusion-reaction for the variable  $\rho(x,t)$ , the density of moving particles (or particle activity). We theoretically derived the first and second moments of the SPDE, together with the spatio-temporal correlation function. By integration of the later, we show that the three different scaling are well described by our model. We point out that depending on the chosen measurement technique to sample bedload, one can expect different statistical behaviors. Notably, we distinguish between "local" techniques that sample bedload at a given location through time, and "spatial" techniques that sample bedload also in the spatial dimension.

\*\*\*\*\*

### **From bedform evolution to channel slope fluctuations in steep-slope streams**

*METTRA F.(1), HEYMAN J.(1), MA H.(2), ANCEY C.(1)*

*(1) Ecole Polytechnique Fédérale de Lausanne, LAUSANNE, SWITZERLAND ; (2) State Key Laboratory of Hydrosience and Engineering, Tsinghua University, BEIJING, CHINA*

In mountain streams, bedload transport rates are prone to strong variability. Indeed an increasing number of laboratory and field studies in steep-slope conditions show fluctuations of bedload transport rate over several temporal and spatial scales. This behavior is even more pronounced for intermediate flow rates (i.e., small but frequent floods). Today, the characteristics and origins of these fluctuations are still poorly understood. One possible explanation of these fluctuations is that the formation and migration of bedforms greatly influence bedload transport.

To accurately investigate bedload transport rates simultaneously with channel bed evolution, we designed an idealized laboratory experiment. A 3-m long, 8-cm wide, transparent flume was used with well-sorted natural gravel ( $d_{50}=6.5$  mm). A technique using accelerometers has been developed to record the arrival time of every particle at the outlet of the flume. An analysis of bedload transport rates on a wide range of time scales is thus possible. In addition, bed elevation is monitored using cameras from the side of the channel.

First, we discuss the presence and the evolution of bedforms (antidunes in this study) for different sediment input rates, flume angles and flow rates. Particularly, in the stationary state, the larger the sediment input rate, the higher the mean migration velocity.

Secondly, keeping steady flow rate and constant sediment input discharge, we observe various migration velocities and fluctuations of global channel slope. This celerity is faster when the channel slope is close to a critical angle. When channel slope is slightly above the angle of no-erosion, the local morphologies evolve slower. This shows that the channel bed behaves like a metastable system and bedform migration seems to be the key mechanism of erosion at the channel scale (like avalanches on a sandpile).

**On grain blocking, step formation, sediment transport dynamics and self-organized criticality in steep streams**

MOLNAR P., SALETTI M.

*ETH Zurich, ZURICH, SWITZERLAND*

Steep mountain streams commonly develop a bed morphology which consists of boulders arranged into steps, i.e. channel width-spanning structures which are separated by plunging pools. The step-pool system is a self-organizing and self-sustaining structure. The temporary storage of sediment in steps and the release of that sediment in avalanche-like pulses when steps collapse, leads to a complex nonlinear threshold-driven dynamics in sediment transport. In this paper we explore the notion that the emergent properties of sediment transport and the transient state of the bed morphology in step-pool streams are closely linked, and that the state in which sediment transporting events due to the collapse and rebuilding of steps of all sizes occur is in some aspects analogous to a critical state in self-organized open dissipative dynamical systems. We illustrate these notions with cellular automaton based modeling of grain transport, blocking and release, using spectral analysis, power-law distributions and intermittency statistics of grain counts and sediment transport rates as indicator variables. We compare results of 1 and 2-d models with some data from flume experiments and field observatories. The paper will address the notions of stability and equilibrium, of the attribution of cause and effect, and of the timescales of process and form in step-pool systems.

\*\*\*\*\*

**Critical conditions for beginning of coarse sediment transport in headwater channels based in flysch rocks (Moravskoslezské Beskydy Mts., Western Carpathians)**

GALIA T., HRADECKÝ J.

*University of Ostrava, Department of Physical geography and geoecology, OSTRAVA, CZECH REPUBLIC*

Our contribution summarizes results of incipient of bedload transport research conducted in small headwater streams in region of Moravskoslezské Beskydy Mts. (flysch Western Carpathians). Two methods were applied: flood competence method and marked particle displacement method. The first one presented measuring of diameters of largest boulders (200-400 mm) stored in to fluvial accumulations during  $Q_{20-25}$  flood event (5/2010). By contrast, transport of marked cobbles (18-152 mm) was evaluated between 11/2010-7/2011, when some smaller events in local torrents occurred and maximal observed discharge was equal to bankfull stage ( $Q_1-Q_2$ ). Relationships between grain diameter and critical conditions (unit stream power, unit discharge and bed shear stress) for incipient of motion of bed coarse sediments were developed. Generally, lower critical values for moving of certain grain diameters were derived then they originated from other environments (e.g. Italian Alps or Ands). This may be caused by lower bed armouring or higher sediment supply of relatively smaller particles compared to magnitude of discharges in local evaluated headwater channels. Also there was observed some higher dynamics of sediment transport in pool then in step in step-pool morphology systems during bankfull flows, whereas during lower flows the opposite situation arose.

## Evaluating bedload transport in coarse alluvial streams with RFID and motion tracers

LINDSAY O., JOHNSON J.P.L.

*The University of Texas at Austin, AUSTIN, UNITED STATES*

Bedload monitoring efforts can be challenging because bedload transport only occurs during high flow conditions. We present bedload data that captures both Eulerian and Lagrangian transport perspectives based on techniques developed in Reynolds Creek, Idaho, a gauged coarse alluvial stream. To date, we deployed ~1150 Radio Frequency Identification (RFID) tracers and ~170 motion tracers. Our RFID tracers are natural or concrete clasts embedded with RFID tags. Motion tracers are cobbles with RFID tags as well as accelerometers that log  $\pm 3$  g accelerations along three orthogonal axes (x, y and z) every 10-15 min. Several tracers traveled over 6 km with the majority traveling over 2.5 km. Because a motion tracer provides additional during-flood bedload data, with changes in acceleration indicating movement since its last record, we use these times to constrain total time-in-motion as well as compare tracer movement histories. We gained transport distance information by relocating motion tracers after transport events. With displacement distances and motion timing records, we constrained bedload velocities over several transport events. During floods, we also collected spatial RFID and motion tracer data by installing several stationary RFID antennas that logged times and unique ID numbers as tracers passed. Peaks in tracers passing correspond well with hydrograph peaks and we are evaluating tracer movement relationships to rising and falling limbs of hydrographs. Unique field-based insights acquired from combining RFID and motion tracers with stationary antennas can advance the understanding of bedload transport in coarse alluvial streams environments.

\*\*\*\*\*

## Bedload transport monitoring in a small upland catchment

LIEBAULT F.(1), LARONNE J.B.(2), KLOTZ S.(1), JANTZI H.(1), RAVANAT X.(1), FAVARIO J.(1)

*(1) Irtsea Grenoble, SAINT-MARTIN-D'HERES, FRANCE ; (2) Ben Gurion University of the Negev, BEER SHEVA, ISRAEL*

An automatic Reid-type (or Birkbeck) bedload slot sampler was recently deployed in the Moulin catchment at Draix (ORE Draix-Bléone) to obtain a continuous record of bedload fluxes in extreme conditions of sediment transport. The Draix catchments in the Jurassic black marls of the Southern Prealps of Digne are recognized as very active eroding catchments. Total annual sediment yields measured since the early 1980s reach values of several thousands of t/km<sup>2</sup>/yr. Suspended sediment concentrations are also very high, reaching values of several hundreds of g/l during spring and summer convective storms. Bedload transport was routinely measured at catchment outlets by topographic surveying of sediment retention basins for almost 30 years. These data only give the total bedload yield integrated over the duration of the event. With the deployment of a bedload slot sampler in the Moulin catchment (drainage area: 9 ha), it is now possible to record bedload flux for a sampling time of 20s. First results obtained with this new equipment gave information about (i) instantaneous bedload fluxes, (ii) bedload responses to hydraulic conditions, (iii) grain size-distribution of bedload, and (iv) the regulation effect of the channel on the bedload response. Maximum recorded instantaneous bedload fluxes are amongst the highest ever reported in the literature. First observations also revealed fluctuating bedload responses to shear stress between seasons, under the effect of changing channel conditions (sediment texture and channel morphology) in the approach reach of the sampler.

### **Morphodynamic and bedload displacement on a meander loop (Cher River)**

DEPRET T.(1), GRANCHER D.(1), GAUTIER E.(2), HOOKE J.(3)

(1) Université Paris 1. LGP CNRS, MEUDON, FRANCE ; (2) Université Paris 8. LGP CNRS, MEUDON, FRANCE ; (3) Liverpool University, LIVERPOOL, UNITED KINGDOM

The aim of the present study is to evaluate precisely bedload displacements in a low-energy meandering river. The migration mechanisms of the Cher River (a Loire River tributary), have been highly constrained for decades because of bank protections.

The morphodynamic functioning of one loop was analysed during 2 years (2010-2011 and 2011-2012) using pit-Tags to measure the bedload displacements. Only the particles larger than  $D_{50}$  could be tagged. This method allows us i) to determine the frequency of the bedload mobilization, ii) to estimate the volume carried every year and iii) to reconstitute distances and trajectories of the bedload. Moreover, in order to estimate the efficient discharge during the last 25 years, we used bedload transport formulae (Recking, 2010). This also allowed us to extrapolate the type of transport (partial or total) for discharges higher than bankfull.

Despite of a high frequency of mobilization (between 29 and 87 days each year depending on the location on the loop), the transport is never (or almost never) total. The average and the median distances of transport for both the 2 study years and for the last 25 years can be considered very low because they are systematically lower than the distance between 2 contiguous geomorphological units. Moreover, during the last 25 years, the average and the median distances of transport of the upper half of the particle-size distribution are respectively of 0.35-2.4 km and 0.2-1 km.

Because of the weakness of the current processes, meander loops, and wavelength in particular, largely seem over-sized. The maintaining of these dimensions is interpreted as the direct consequence of bank protections: they have resulted somewhat in a fossilization of the planform pattern.

Bibliography: Recking, A., 2010. 'A comparison between flume and field bedload transport data and consequences for surface based bedload transport prediction', *Water Resources Research* 46, 1-16.

\*\*\*\*\*

### **Linking process and form using a field data set: issues, challenges and prospects**

MARQUIS G.A.(1), ROY A.G.(2)

(1) Université du Québec à Montréal, MONTRÉAL, CANADA ; (2) University of Waterloo, WATERLOO, CANADA

In order to understand landscape evolution and transformation, we need to measure and model the processes that move the material through the forms. However, transport laws that are currently available to predict accurately sediment fluxes are not satisfactory. This is particularly true for bedload sediment transport where multiple factors such as sediment supply or the structure of the particles on the river bed modulate the response. Despite its complexity, bedload transport is continuously investigated as a key process driving changes in river bed morphology. Most of the knowledge on bedload transport was acquired from flume experiments where factors can be controlled and therefore their respective roles determined. However, there are important limitations in the transfer of this knowledge to natural river channels where the interactions of factors may be at play and where unsteady driving forces promote non-linear responses of the system. Bedload sediment transport is difficult to measure *in situ*, especially in gravel-bed rivers where coarse particles interact and move intermittently. Therefore, only a few field studies have collected simultaneous bedload sediment transport and morphological changes over a sequence of several floods. Here, we present such a data set collected for 20 flood events in a small gravel-bed river, Béard Creek (Québec, Canada). The data set is used to explore various issues and challenges on linking process and form measurements obtained in the field: (1) the methods to analyze data collected without experimental control and in a context where contingent conditions may prevail and (2) the scale offset between bedload sediment transport and morphological changes at the scale of a flood event. A detailed analysis of the linkages between bedload fluxes and different aspects of river bed morphology leads us to revisit the conceptual models of gravel-bed river dynamics.

## **The impact of impoundment on sediment transport and channel bar dynamics on the Brazos River, Texas**

SLATTERY M., MELCHORS M.

*Texas Christian University, FORT WORTH, UNITED STATES*

Dams typically have significant geomorphic effects downstream, but impacts vary according to size of the river and dam, hydrologic regime, environmental setting, history, and channel morphology, as well as with the purpose and operation of the impoundment. This study examines sediment transport and channel bar response following closure of the De Cordova Bend Dam on the Brazos River near Glen Rose, Texas. We analysed aerial photography spanning two decades preceding and following dam construction, digitizing bar complexes along a reach 53 river kilometers downstream of the dam. We also monitored suspended sediment and bedload transport over a range of flow conditions, and conducted multiple channel bar surveys over one year in order to understand short-term changes within the system. Channel bars remained relatively stable during the two decades preceding impoundment (< 20% variation in bar area) but showed a ~ 40% reduction in area within the first six years following impoundment. Channel bars then recovered to their approximate pre-impoundment extent within 15 years of dam closure. We also observed significant variability over event-time scales, with channel bars losing ~ one-third of their area following large storm events. Mean annual sediment flux totaled 6.48 million tons per annum, with bedload accounting for 24.5% of the overall annual load. We suggest that this reach of the Brazos is in a steady-state with respect to sediment supply and transport capacity, but recognize this as just one of several possible reference states for the system.

\*\*\*\*\*

## **Morphodynamics of small wadis on the southern slopes of High Atlas Mountains (on the example of upper Dades catchment, Morocco)**

ROJAN E.(1), DLUZEWSKI M.(1), KRZEMIEN K.(2), BIEJAT K.(1)

*(1) Faculty of Geography and Regional Studies, University of Warsaw, WARSZAWA, POLAND ; (2) Jagiellonian University, Institute of Geography and Spatial Management, Department of Geomorphology, CRACOW, POLAND*

The research was carried out in the area of intensive morphodynamic processes caused by high rates of physical weathering and low vegetation density in high mountains of dry climatic zones. The aim of the study was to determine the morphodynamics of main rivers' episodic tributaries within the area of the southern slopes of the High Atlas Mountains. The field research was conducted in three tributary catchments in the lower, middle and upper parts of the upper Dades catchment. The impact of the morphological characteristics of the valleys on the amount of material supplied to the channels was analysed. The shapes of the channels, their erosional and accumulation landforms, the amount of the slope material supplied, were used to identify morphodynamic reaches. In the highest reaches, high amount of material received from the slopes and low river discharge had the biggest impact on morphodynamics, which resulted in low erosion value. Downstream from there, the increased amount of discharge was sufficient to manage with even higher amount of slope material, partly due to considerable channel gradients. These reaches were identified as transitional with erosion dominating over accumulation. The lowest reaches' functioning was typical for multichannel rivers with periodical changes of their shape. These reaches featured a balance of deposition and erosion. Their morphodynamics were driven much less by the supply of slope material than by their morphometry, especially the width and gradient. All three tributary basins included reaches of similar morphodynamic types, but in different proportions. These different compositions were found to have a crucial role in the differentiation of accumulation fans' development. This confirmed a hypothesis that the development of the main river valleys of the High Atlas Mts. was strictly dependent on the denudational and fluvial systems of the tributary catchments.

### Revisiting the river bar instability

*CHIODI F.(1), ANDREOTTI B.(2), CLAUDIN P.(3)*

*(1) CNRS - ESPCI - Uni. Paris Diderot, PARIS, FRANCE ; (2) Université Paris Diderot, PARIS, FRANCE ; (3) CNRS, PARIS, FRANCE*

The river bar instability is revisited, using a hydrodynamical model based on Reynolds averaged Navier-Stokes equations. The results are contrasted with the standard analysis based on shallow water Saint-Venant equations. We first show that the stability of both transverse modes (ripples) and of small wavelength inclined modes (bars) predicted by the Saint-Venant approach are artefacts of this hydrodynamical approximation. When using a more reliable hydrodynamical model, the dispersion relation does not present any maximum of the growth rate when the sediment transport is assumed to be locally saturated. The analysis therefore reveals the fundamental importance of the relaxation of sediment transport towards equilibrium as it is responsible for the stabilisation of small wavelength modes. This dynamical mechanism is characterised by the saturation number, defined as the ratio of the saturation length to the water depth  $L_{sat}/H$ . This dimensionless number controls the transition from ripples (transverse patterns) at small  $L_{sat}/H$ , to bars (inclined patterns) at large  $L_{sat}/H$ . At a given value of the saturation number, the instability presents a threshold and a convective-absolute transition, both controlled by the channel aspect ratio  $\beta$ . We have investigated the characteristics of the most unstable mode as a function of the main parameters,  $L_{sat}/H$ ,  $\beta$  and of a subdominant parameter controlling the relative influence of drag and gravity on sediment transport. As previously found, the transition from alternate bars to multiple bars is mostly controlled by the river aspect ratio. By contrast, in the alternate bar regime (large  $L_{sat}/H$ ), the selected wavelength does not depend much on  $\beta$  and approximately scales as  $H^{2/3} L_{sat}^{1/3}/C$ , where  $C$  is the Chezy number.

\*\*\*\*\*

### Combining Geotechnical and Hydro-Morphological Modelling to Investigate the Dynamics of Meandering Rivers

*ROUSSEAU Y.(1), VAN DE WIEL M.(1), BIRON P.(2)*

*(1) Western University of Canada, LONDON, CANADA ; (2) Concordia University, MONTRÉAL, CANADA*

Despite decades of research on the morphological evolution of rivers, the mechanisms by which meandering rivers form and evolve are not well understood. Nonetheless, a common feature of natural and experimental meandering channels is that they develop in vegetated, cohesive soils. Although the effects of cohesion on river bank stability have been assessed over relatively short reaches, it remains uncertain whether the repeated occurrence of smaller bank failures can lead to the formation of a fully-developed meandering planform. Recent improvements in computational power and in the efficiency of bank stability algorithms, combined with expanded knowledge on plant properties and improved access to morphodynamics modelling tools, unlocked the potential to undertake such investigation. This research simulates the development of a meandering river planform through the use of a computational fluid dynamics (CFD) model, namely TELEMAC-2D. The stability of river banks is assessed by a newly developed bank failure module that takes into account translational, rotational and Cantilever slope failure modes. This module is coupled with TELEMAC to simulate lateral channel adjustments along a 9 km reach (~40 channel widths) of a large river (the St. François River, tributary of the St. Lawrence River, Québec) and along a 1.5 km reach (~95 channel widths) of a small semi-alluvial stream (Medway Creek, Ontario). In both cases, detailed bathymetric survey datasets are available to calibrate and validate the model. The modelling results are analyzed in a simple GIS software tool developed for this project to statistically quantify the similarity in predicted flow properties and bathymetries between predicted and measured values. Furthermore, a sensitivity analysis is run to determine the impact of different combinations of river bank and bed properties on the resulting channel bathymetry.

### **An experimental study of the grain sorting effect on braided pattern**

LEDUC P., RECKING A., NAAIM M.  
*Irstea, SAINT MARTIN D'HERES, FRANCE*

Braided rivers are characterized by complex morphologies, with several channels and their dynamics is still poorly understood. A better understanding of braiding depending on the equilibrium state of the river (in equilibrium, erosion or aggradation) is essential for a sustainable river management. We conducted a series of laboratory experiments to study the influence of particle size sorting on braided river morphology.

Two series of experiments were carried out, the first with uniform sediments (0.5 to 1.5 mm with an average diameter of 0.7 mm), and the second with a bimodal distribution consisting of a mixture of coarse and fine sands, ranging from 1.5 mm to 3 mm with a mean diameter of 1.8 mm. Both sands have different color to facilitate visual observations of grain sorting and to measure the spatial distribution of different grain sizes. Hydro-sedimentary conditions were maintained constant in both cases throughout the experiment. Successive bed topographies were measured using the Moiré method. Both sets of experiments showed different mechanisms.

The experience using uniform sediments indicates that bar morphology is controlled by the continuous propagation of sedimentary lobes. The lobe deposit creates various morphological elements including "sedimentary" border and large scour areas. The experience using non-uniform sediments indicate that coarse deposits directly control the direction of flow by locally increasing the bed roughness. Paths taken by the coarse and fine grains are different and depend on the bed roughness. Selective depositions are frequently observed and give to the bed surface a heterogeneous composition. The geometry of the confluence of two active channels depends on the grain size range. Indeed, the depth of the confluence area seems smaller with heterogeneous sediment: coarse sediments are attracted in the pool, limiting thereby erosion. These observations give us keys for understanding fields morphologies and dynamics.

\*\*\*\*\*

### **Riparian vegetation as a primary control on channel width: results and insights from the laboratory to the field**

TAL M.(1), GRAN K.(2)  
*(1) Aix-Marseille Université, CEREGE UMR 7330, AIX-EN-PROVENCE CEDEX 04, FRANCE ; (2) University of Minnesota Duluth, DULUTH, MINNESOTA, UNITED STATES*

Braided rivers are characterized by highly mobile channels that migrate laterally across their braidplain. Riparian vegetation directly opposes this tendency by increasing bank strength and reducing flow velocities. This competition, which can be expressed as a ratio of a biotic timescale to a physical timescale, constitutes a fundamental control on the fraction of the riverbed that will ultimately remain active and the fraction that will become incorporated into the floodplain. From a management perspective, changes in precipitation, vegetation type, and flood control efforts are shifting the balance between lateral mobility and vegetation growth and stabilization on a number of rivers, with implications on a range of issues from sediment transport and flood capacity to the availability and quality of habitat for migratory waterfowl.

Laboratory experiments in which vegetation was added to a braided channel lead to the emergence of a steady-state single-thread channel. The timescale for vegetation to establish versus the timescale for channels to migrate the width of the braidplain was a key control on the bankfull channel width and the extent of vegetation encroachment. The eruption of Mount Pinatubo, Philippines in 1991 filled river valleys with sand and destroyed all vegetation, transforming the once single-thread gravel-bed rivers into braided. As sediment loading from eruptive deposits decreases, vegetation is able to establish in the braidplain and persist through the rainy season. Measurements of physical properties of the reemerging vegetation (root strength, stem diameter and density, etc.) are being combined with measurements of sediment transport, lateral mobility of channels, and aggradation rates in order quantify the competition between channel dynamics and vegetation and predict the future equilibrium form of these rivers.

### **Effects of bedload input on channel widening in a restored section of the Drau River, Austria**

KLOESCH M., TRITTHART M., BLAMAUER B., HABERSACK H.  
*University of Natural Resources and Life Sciences, Vienna, VIENNA, AUSTRIA*

Channel widening became a common measure in Austria for mitigating channel incision, improving ecological integrity and ensuring flood protection. Recent projects aimed to limit the restoration works to removal of bank protection, which enabled self-initiated widening through bank erosion. For now, the restored sections showed the anticipated response to the measures. However, continued construction of hydropower plants may further reduce the bedload input from upstream. This study now aims to test the effects of variations in reach-scale bedload transport on the widening of the restored sections.

In a side-channel of a restored section at the Drau River, widening showed to be associated with the emergence and accretion of bars. During a comprehensive monitoring program a mid-channel bar was observed to accrete during higher discharges and to narrow the branch along the bank, resulting in flow acceleration and subsequent bank erosion. Based on repeated topographic surveys, substrate sampling and measurements of flow velocities and water levels, a two-dimensional sediment transport model was calibrated. Basket sampler measurements conducted 20 km upstream of the restored site delivered a bedload rating curve and defined the bedload input at the upstream boundary of the model. Series of time-lapse images helped determining the onset of fluvial erosion along the bank toe and hydrodynamic-numerical modeling delivered the corresponding flow characteristics leading to bank erosion.

Modelled scenarios with varied bedload input revealed that bank erosion associated with mid-channel bars may be suppressed at reduced bedload input from upstream. Reach-scale bedload transport therefore showed to affect the morphodynamics of restored sections and finally their widening tendencies and overall functionality. Over short time-scale, bank erosion showed to additionally depend on the hydrograph characteristics following the flow events.

\*\*\*\*\*

### **Experimental sediment reintroduction into the Rhine River downstream the Kembs dam: feedbacks from repeated field measures and high resolution imagery**

ARNAUD F.(1), BÉAL D.(1), PIÉGAY H.(1), ROLLET A.J.(2), SCHMITT L.(3)  
*(1) CNRS UMR 5600 EVS, LYON, FRANCE ; (2) CNRS UMR 6554 GEOPHEN-LETG, CAEN, FRANCE ; (3) CNRS UMR 7362 LIVE, STRASBOURG, FRANCE*

The Upper Rhine River has undergone several anthropogenic modifications since the last two centuries for flood protection, navigation and hydropower generation. Channelization, groynes and damming heavily altered the 50 km-long "Old Rhine" by-passed section between Kembs and Breisach inducing channel pattern simplification, bed incision, armouring, ecological alterations. A sediment introduction experiment has been conducted in October 2010 within the framework of the INTERREG project "Redynamization of the Old Rhine". This project aimed at restoring sediment transport and recreating a variety of ecological habitats to improve the biodiversity of the river reach. For these purposes, 23000 m<sup>3</sup> of gravel have been injected into the channel forming a 620 m-long and 11 m-wide deposit. A monitoring program investigated the sediment dispersion processes and the improvements in channel morphology and grain size based on three complementary measures: 1) tracking the displacement of 1500 particles equipped with passive integrated transponders to provide knowledge on the mass dispersion and bedload transport rates, 2) surveying bathymetry and topography using DGPS/echosounding and very high spatial resolution imagery to detail changes in bed geometry and sediment wave propagation, 3) sampling the surface grain size of the aquatic channel and emerged gravel bars to characterize the size distribution of the injected sediments excavated from the floodplain and to learn about the sorting effect with the dispersion. Environmental benefits and potential risks for society were evaluated thanks to the four surveys characterized between 2009 and 2013 (initial, post-injection and post-floods approx. Q<sub>2</sub> occurred in December 2010 and June 2012). Feedbacks helped to define large scale and sustainable restoration scenarios in terms of modalities of sediment introduction (quantities, grain size distribution ...) and monitoring program to implement (suitable evaluation indicators).

**Relationships between bank protection and forced pool characteristics in a low gradient flood prone river, Central Norway**

VATNE G.

*Dept. of Geography, Norwegian University of Science and Technology, TRONDHEIM, NORWAY*

Forced pools are well-known natural phenomena in mountain streams, and are attributed to constrictions in the stream channel. However, they are not described from many other river environments. A recent detailed survey of the lower reaches (30 km) of the flood prone river Gaula, Central Norway, has revealed a highly variable bed profile, including many pools with residual depth exceeding 5 m. The river has originally a low gradient (0.001) meandering channel, but the channel is since the 1930's strongly controlled using bank protection schemes. The extensive bank protection is motivated from the many quick clay areas in the adjacent valley, and the many historical quick clay slides that have been triggered by channel migration. Parallel, extensive gravel mining took place from 1950 to 1990s (> 4 mill m<sup>3</sup>). This has drastically altered the sediment budget, and has on average lowered the stream bed by 2 m in the investigated reaches, exposing clay along the river bed and banks. Pool characteristics (downstream spacing, volume, exit slope, upstream gradient etc.) have been analysed to test two hypotheses; (1) spacing and location of pools are controlled by the location of bank protections, hence being forced pools, (2) controls of pool characteristics are similar to those found in mountain streams. The analysis shows the majority of the deep pools to be controlled by man-made channel constrictions, but also natural constrictions occur. There is no clear downstream trend in pool characteristics as pool volume is strongly influenced by local channel curvature. Patches of marine clays overlaid by coarse alluvial material is observed in pool beds, suggesting sediment starvation and active pool scouring to continue.

\*\*\*\*\*

**Spatial and temporal patterns of channel change and bedload transport of the Wood River, Upper Klamath Basin, USA: implications for assessing river management and restoration**

HUGHES M.

*Oregon Institute of Technology, KLAMATH FALLS, UNITED STATES*

The Wood River in the Upper Klamath Basin of southern Oregon is a spring-fed meandering channel that occupies a north-south sloping graben separating two major volcanic provinces, the Cascade Mountains to the west and the northern Great Basin to the east. Incision and downstream transport of volcaniclastic sediments in the upper watershed has graded the valley floor and emplaced an active meander belt lying approximately 1.0 - 1.5 meters below adjacent surfaces. In the lower valley, the river is channelized, leveed, and perched above lake-fringe wetland systems that were diked, drained, and cleared of native vegetation and converted to cattle pastures in the mid-20<sup>th</sup> century. River management and restoration projects since the mid-1990's have emphasized naturalization of meander patterns and floodplain reconstruction within the confines of levees that separate the river from the fluviodeltaic wetland systems. Future restoration plans call for reconnecting the river to these wetlands, however several challenges exist, including the relatively large difference in elevation between the channel bed and adjacent wetland floor environments, seasonal backwater effects from Agency Lake near the mouth of the river, and uncertainties regarding sediment transport that would modulate river-wetland reconnection. Early results of an ongoing bedload measurement campaign suggest that in the absence of backwater, the bed is continuously mobile in the lower valley, despite low stream power. Bedload rates range from approximately 0.07 to 0.5 tons per day and generally decrease downstream. Restoration of the lowermost reach appears to have rejuvenated bedload transport, filling a formerly channelized confluence with new bars and vegetated benches. Downstream of this area, diversion of the river into a formerly active deltaic wetland has restored shoal habitats that are now providing substrate for expansion of native vegetation and enhanced wildlife habitat.

### **Contemporary channel adjustments in a periurban catchment in the frame of a long-term sediment cascade history (Yzeron, City of Lyon, France)**

GROSPRETRE L.(1), SCHMITT L.(2), JACOB N.(3), DELILE H.(1), PRIVOLT G.(1), PREUSSER F.(4), COTTET M.(1)

(1) University of Lyon, UMR 5600 CNRS, LYON, FRANCE ; (2) University of Strasbourg, UMR 7362 CNRS, STRASBOURG, FRANCE ; (3) University of Lyon, UMR 5133 CNRS, LYON, FRANCE ; (4) Stockholm University, STOCKHOLM, SWEDEN

The initial goal of the study was to evaluate contemporary geomorphic effects of urbanization in the Yzeron catchment (147 km<sup>2</sup>). Many incisions were identified in headwater stream channels. Dendrochronological analyses of riparian trees show that most of incisions began between 1970 and 1990, during which urbanization has increased from 15 to 30%. Recentness of incisions is corroborated by stages of channel adjustments, but many of them have been observed in the rural as in the periurban part of the catchment. It led us to broaden our approach and seek further explanations in long-term land use changes. Finally, it appeared that current channels evolutions could not be understood without integrating the long-term sediment cascade history of the catchment. Extensive croplands have contributed to soil erosion and significant sedimentary fill of the headwater valley bottoms until the end of the 19<sup>th</sup> century, and likely since the end of the Middle Age. During the 20<sup>th</sup> century, croplands were mainly replaced by grasslands and forests. It reduced soil erosion, leading to a sediment deficit that disrupts channels stability, so that sediments accumulated during several centuries in headwater valley bottoms are now remobilized and transported downstream. In the periurban belt of Lyon City, grasslands were also replaced by impervious areas and storm sewers after 1950, resulting in greater frequency and intensity of floods. When urbanization extended in a headwater basin after long-term changes in agricultural land use, the latter two disturbances are cumulative and result in severe bed and bank erosion.

Although incisions extend only over a relatively small part of the hydrographic network (6%), channel enlargement ratios can reach 35 (11,7 on average) and eroded banks are mainly composed of sand (53% on average). Headwater channel incisions are therefore an important source of fine sediment to main channels, in which sand deposits are growing strongly.

\*\*\*\*\*

### **What Impact Does Urbanisation Have on the Depth of Bedload Sediment in Streams?**

ZORRIASATEYN N., STEWARDSON M., VIETZ G., RUTHERFORD I., FLETCHER T.  
The University of Melbourne, PARKVILLE, AUSTRALIA

Bedload sediment in streams provides a range of ecosystem services (e.g. instream habitat, nutrient exchange). Urbanisation of a catchment has a significant impact on bedload transport and can upset the balance for retention of bedload sediment. Urbanisation increases the frequency and magnitude of flows that transport coarse-grained bedload sediment, but also affects the sources and amount of sediment reaching streams. The resulting impact on sediment availability is not well understood. This paper examines the impact of urban stormwater flow regimes on the threshold of sediment-carrying capability and the impact this has on the depth of bedload sediment in stream channels. We compare sites across a gradient of urbanisation in the Melbourne region, Australia; a) reference b) peri-urban c) urban and d) urban with stormwater harvesting. For each site a one-dimensional hydraulic model is developed and depth of bedload is modelled as changes to the channel boundary using the deformable bed function and quasi-unsteady flow analysis. Bed level changes are determined for each section based on deformation of the bed boundary. For each flow scenario we demonstrate changes to the stream bed (erosion and deposition) and verify the results against field observations. This study demonstrates that increased urbanisation of a catchment increases sediment transport capacity and decreases bedload sediment depth by 87.4% and 58.6% relatively at the urban sites. Since sediment supply commonly decreases as urbanisation matures, the differences are expected to be even larger than demonstrated. Stormwater harvesting will help mitigate morphologic changes resulting from impervious runoff, however, the feasibility of restoring ecosystem services in urban streams with reduced sediment supply remains open and important question for urban stream management.

Keywords: Urbanisation, Modelling, Bedload depth, Stormwater

### **Stream incision and sediment wave consecutive to three centuries of timber floating in the Morvan Massif (Central France)**

GOB F.(1), JACOB-ROUSSEAU N.(2), LE DREZEN Y.(1), HOUBRECHTS G.(3)

(1) University Paris 1 - Pantheon-Sorbonne, PARIS, FRANCE ; (2) Université Lumière Lyon II, LYON, FRANCE ; (3) University of Liege, LIEGE, BELGIUM

The upper catchment of the Yonne River is nowadays usually considered as having been scarcely impacted by human activity. At the Seine basin scale, the gravel bed streams flowing down the small forested massif of the Morvan are even considered as of high ecological quality. However, this perception of the river changes completely once one looks back to the recent past. Indeed, these streams have been subject to intensive industrial activity for more than 300 years, between the 16<sup>th</sup> and early 20<sup>th</sup> centuries, as Paris' need for timber fuel amplified. The Yonne River and all of its tributaries were heavily modified to facilitate the transportation of timber logs towards Paris through floating on the Morvan's dense network of streams and the Yonne's and Seine's main channel. This activity has led to intense modifications of sediment flux still easily observable on the present river morphology, 90 years after the floating activity ended.

Every single stream of the upper Yonne catchment was equipped with small ponds allowing the generation of water releases, flushing the logs downstream. Historical archives allowed the discharges and the frequency of these flushes to be calculated. Artificial floods developing specific stream powers of over 250 W/m<sup>2</sup> were generated several times per week during wintertime in steep-sided streams that were 4 to 5 m wide. Such energy generated a drastic increase in sediment transport and led to erosion and massive incision of the beds. A few kilometers downstream, when the small tributaries joined the main valley, the Yonne River had a larger bed and gentler slope. Artificial floods were thus less powerful there and sediment transport conformed more to natural conditions. Considering the huge amount of sediment supply from upstream and the slowing down of the sediment flux, the Yonne river bed aggrades. A perched riverbed today lies up to 1.5m higher than the floodplain and may be seen on more than 25 km of the course.

\*\*\*\*\*

### **Recent morphological evolution of a headwater stream in agricultural context after channelization (Ligoire River, France)**

LANDEMAINE V.(1), GAY A.(2), CERDAN O.(2), SALVADOR-BLANES S.(3), RODRIGUES S.(3)

(1) Université de Rouen - BRGM, MONT SAINT AIGNAN, FRANCE ; (2) BRGM, ORLEANS, FRANCE ; (3) Laboratoire GéHCo, TOURS, FRANCE

In France, since the beginning of the 20<sup>th</sup> century, rural landscapes have been extensively modified by human activities. These practices have resulted in profound sedimentary and morphological alterations (channel bed incision, deposition of fine sediment, bank erosion, etc.), detrimental to the achievement of good status according to the EU Water Framework Directive.

The present study takes place in this context. The main channel (21 km) of the Ligoire small stream was studied. It drains a watershed of 82 km<sup>2</sup>, occupied by nearly 90 % of arable lands.

The objectives of the study were threefold: (1) to quantify the incision and deposition processes since the channelization of the stream (1970), (2) to quantify the deposition rates of fine sediments in the channel, and (3) to explain the spatial distribution of these deposits.

At first, compilation of historical documents allowed the stream original topography reconstruction just after channelization. Then, cross sections and sediment thickness were measured at the same locations.

The results show that over the 1970-2012 period: 60% of the stream was incised on average by -34 cm (- 0.8 cm.yr<sup>-1</sup>) and the total volume of exported sediment amounts to 16 300 m<sup>3</sup> (390 m<sup>3</sup>.yr<sup>-1</sup>); 40 % of the stream bed rose by +31 cm on average (+0.7 cm.yr<sup>-1</sup>), the volume of accumulated sediment amounts to 12 400 m<sup>3</sup> (300 m<sup>3</sup>.yr<sup>-1</sup>). These processes of respective incision and sedimentation can be related to the channel topographic evolution over the same period (longitudinal slope, width, etc.).

The volume of rather fine-grained sediments deposited on the bed of the stream channel, measured over the April-May 2012 period, amounted to 12 130 m<sup>3</sup>, with an average thickness of 19 cm. The distribution of these sediments is partly influenced by the presence of five water obstacles.

Finally, the methodology developed for this study allows the use of channelization historical documents to quantify stream sediment dynamic over several decades.

**The post-glacial evolution of Cordilleran rivers in southwestern British Columbia: timescales, texture and topography**

TUNNICLIFFE J.

*University of Auckland, School of Environment, AUCKLAND, NEW ZEALAND*

The rivers of British Columbia's major Cordilleran valleys have taken thousands of years to re-grade their profiles and adjust their sedimentary character following the close of Pleistocene glaciation. As the rivers incised their considerable glacial valley fills, a heterogeneous mix of material has been recruited to the sediment load, altering the resistance characteristics of the river beds and changing the slope and concavity of their long profiles. We use a 1-d model framework to study the co-evolution of the long profile and longitudinal grain size patterns in a generic river valley model, as well as simulating aspects of the dynamics of some classic paraglacial river valleys of British Columbia. Using reconstructed stratigraphic records of the original glacial valley fills, we employ a surface-based transport model, coupled with a large-scale sediment budget, to examine timescales of (i) bed degradation, (ii) reach storage and turnover, and (iii) development of the post-glacial grain-size fining profile. We further examine factors that influence the final river profile form, such as tributaries, lateral sediment inputs, and storage within sedimentary links. Finally, we evaluate the balance of errors introduced by hydro-climatic reconstructions (e.g. estimates of flood recurrence), channel configuration parameters (sinuosity, cross-section, characteristic planform) and process parameters (abrasion rates, transport formulation, active-layer configuration).

\*\*\*\*\*

**Aggradation and incision of the fluvial terraces in response to the change in the river regime and pattern during the Holocene in Gujarat Alluvial Plain, western India**

SRIDHAR A.

*Department of Geology, The M.S>University of Baroda, VADODARA, INDIA*

Aggradation and incision of the fluvial terraces in response to the change in the river regime during Holocene in Gujarat Alluvial Plains, western India

Alpa Sridhar

Department of Geology, Faculty of Science,  
M. S. University, Baroda, Vadodara

Fluvial valleys in western India have well-developed terrace systems and exposed sediment records from the upland to the lower reaches in the river basins have been studied in order to understand the process-response relationship of sediment erosion and accumulation to the climate and tectonic pulses. The regime based palaeohydrological and palaeocompetence analyses have been employed to estimate the flow energy and discharge conditions. Gravel terrace from the upland reach provides evidence of braided gravel-bed river that switched to a gravel bed wandering fluvial style during early Holocene; the mid-late Holocene channel form changed from wide, large-amplitude meanders to smaller meanders with decreased width/depth ratio, unit stream power and the bed shear stresses. The discharge estimates indicate similar values to the present day channel, albeit with a higher competence. The results suggest that discharge varied spatially and temporally during Holocene, the incision and aggradation of the sediments was controlled by fluctuations in sediment influx and the river responded to these changes by switching of stream patterns. Whereas the aggradation of the gravel terrace during the early Holocene was controlled by the tectonically induced large sediment influx, the incision that followed was in response to the increased discharge and competence. In the alluvial zone aggradation occurred due to the fluctuating discharge conditions during mid Holocene. The later phase of incision however was possibly independent of the discharge conditions.

## Quantifying the influence of landscape connectivity on alluvial sediment flux in the upper Yellow River

NICOLL T., BRIERLEY G.

*University of Auckland, AUCKLAND, NEW ZEALAND*

Landscape connectivity describes how water and sediment move through and between landscape compartments. The strength of these linkages is a critical determinant of sediment flux at the catchment scale. The upper Yellow River drains an area of approximately 130,000 km<sup>2</sup> within Qinghai province, western China. Within this area, the 235km<sup>2</sup> Garang tributary catchment is a typical example of the major excavation of basin fill sediments triggered by incision along the Yellow River. Landscapes and sediment dynamics vary dramatically within the Garang catchment, from highly disconnected depositional landscapes dominated by broad alluvial plains within the upper catchment (3500-3700m elevation) to the Danxia landscapes of the lower catchment (2200-2400m) that are characterised by high rates of erosion and strong linkages between hillslope sites of sediment generation and the channel network. Sediment volumes within these highly diverse landscapes have been quantified using a combination of field measurement and GIS modelling, creating a generalized field-based sediment budget. This field-based study of sediment dynamics within the Garang catchment is then used to complement and assess a GIS-based examination of landscape connectivity within the entire upper Yellow River basin. This large-scale examination of geomorphometric measures that estimates the degree of landscape connectivity within the upper Yellow River breaks the landscape down into regions by dominant geomorphic process type. The changing importance of various controls on sediment dynamics within these diverse landscapes are examined at the catchment and regional scale.

\*\*\*\*\*

## Trends in alluvial channel geometry: an indicator of decadal fluctuations in regional sediment supply and local flood risk

SLATER L.J., SINGER M.B.

*University of St Andrews, ST ANDREWS, FIFE, UNITED KINGDOM*

Adjustments in alluvial channel geometry over multi-decadal time periods indicate regional changes in sediment supply, but have not yet been investigated systematically over continental scales, for lack of adequate data. Using the recently-available public dataset of USGS stream channel measurements, we applied rigorous filters to evaluate significant trends ( $p < 0.05$ ) and variability in stream channel geometry as measured repeatedly in channel cross sections (area, width, and bed elevation), between 1950 and 2012, against land-cover characteristics (e.g., lithology, landcover) and trends ( $p < 0.05$ ) in annual streamflow percentiles at the same sites. From these, we identify regional patterns in channel erosion (widening, bed degradation, and area increase) and accretion (narrowing, aggradation and area decrease,) throughout the conterminous United States. We find that while short-term (year-to-year) streamflow sequences drive the magnitude of local changes in channel geometry, long-term trends (channel evolution trajectories) are indicative of regional changes in the sediment balance, which is affected by land use and urbanization. We find that erosional trends are dominant across the continental USA, compared to accretional trends. These decadal trends in channel geometry indicate long-term nonstationarity in basin sediment budgets, with dramatic implications for aquatic habitat and local flood risk, especially under the influence of a changing climate. This work highlights the importance of investigating channel boundaries in combination with trends in flood frequency to clarify the influences of changes in sediment supply and changes in hydrology in increasing/decreasing flood risk.

**A simple approach to understand the kinetics of the responses of the river beds to changes in the sediment supply and hydrological regimes at the watershed scale**

ALCAYAGA SALDIAS H.(1), BELLEUDY P.(2)

(1) Dept. Civil Engineering, University Diego Portales / UDP, SANTIAGO, CHILE ; (2) Université de Grenoble / Laboratoire d'études d'étude des Transferts en Hydrologie et Environnement, GRENOBLE, FRANCE

Our objective is the assessment of the morphological behaviour of the river network at basin scale in reaction to perturbations of the hydrological regime and of the sediment sources. For such an objective a detailed modelling is not appropriate. On the other hand conceptual models hardly take into account the superposition of effects and the connectivity of the branched system in the watershed.

A simplified model has been built which is based on the use of the flow duration curve and of its integration for the evaluation of the yearly transport capacity of each homogenous river reach. A calculation is made of the yearly transformation of the river characteristics and the consequent sediment volume is conveyed downstream as a consequence of the connectivity of the different reaches.

Under influence of permanent disturbances, the model simulations show that rapid response of the river-bed at the beginning of the relaxation period is followed by a much slower evolution towards a new dynamic equilibrium. This trend in the morphological behavior is coherent with the conceptual ideas and with field observations from the literature. The sensitivity of the dynamic responses to physical parameters included in the hydraulic and sediment transport equations is tested. The model allows also a characterization of the forming discharge for each of the river reaches.

This modelling has been applied for the simulation of the transformations of the Isère river system upstream of the city of Grenoble (drainage area 5700 km<sup>2</sup>), in response to successive and superposing perturbations of the river during the last 150 years: mainly the channelization of long river reaches, an intense gravel mining which is now stopped, and the development of HP equipment. The model is validated by comparison of its results with actual evolution of the river. It allows some assessment of the relative impacts of the impact of the large HP equipment of the basin compared to the other sources of perturbations.

\*\*\*\*\*

**Within-channel levees: a new-recognized fluvial form in the floodplain of a large river (Paraná River, South America)**

RAMONELL C.(1), MARCHETTI Z.(2), PEREIRA S.(2)

(1) Facultad de Ing. y Cs. Hídricas - Universidad Nacional del Litoral, SANTA FE, ARGENTINA ; (2) Facultad de Ing. y Cs. Hídricas - Universidad Nacional del Litoral, SANTA FE, ARGENTINA

Bars, islands and benches are the forms classically recognized of intra-channel sedimentation in rivers. We studied intra-channel forms in the Paraná River between the junction with the Paraguay River (27° 17' S) and its mouth (34° 26' S). The floodplain in this reach extends over 32,000 km<sup>2</sup>, and is modelled by the Paraná main channel, several major branches (ca. 200 to 500 m-width) and a lot of minor channels. Shifting rates from 1 m/year to 25 m/year were recorded in the branches, and up-to 200 m/year in tracts of the main channel. Bar and island formation, and enlargements and closures of channels are typical processes in the reach.

Inside of paleochannels or in channels with width-reduction tendencies, we found sets of parallel alluvial ridges like to natural levees, but lying below the bankfull levels. We propose the name of "within-channel levees" (WCL) for them, in consideration of their morphology and sedimentology. WCL could attain several km in length, and form ridge and trough reliefs of ca. 1 m, few meters-width. They are straights or curves in planview, sometimes like to scroll bars. Silty sediments are dominant in WCL, which are the prevailing sizes of the wash load in the river.

Inside the active channels the WCL are coupled to hydrophytes; rooted or floating vegetation in the secondary channels could cover significant lengths near the banks. Thus, the origin of the WCL could be related with the trap of suspended sediments by hydrophytes within the channels.

The WCL are conspicuous features in the Paraná River: they were mapped in detail downstream from 32° 04' S, where these forms extend over 3,000 km<sup>2</sup> forming more than 20 % of the fluvial geomorphic units of the area. On the other hand, the WCL are a form by means of river branches adjusts to diminished formative discharges, with siltation of fine sediments not restricted to overbank flows. The WCL recognition expands our interpretations in the analysis of the silty strata of the floodplain.

### **A comprehensive analysis of bedform evolution on the Rhône River, France**

PARROT E.(1), PIÉGAY H.(1), TAL M.(2)

(1) Université de Lyon, CNRS UMR 5600, Environnement Ville et Société (EVS), LYON, FRANCE ; (2) Aix-Marseille Université, CEREGE UMR 7330, AIX-EN-PROVENCE, FRANCE

Over the last 150 years the Rhône River has been heavily altered by human infrastructures along its 512 km length between Lake Geneva and the Mediterranean Sea. The first wave of channel modifications (1860 - 1930) consisted of dikes and groynes designed to narrow the channel and promote incision in order to facilitate navigation. A second period of modifications (1948 - 1986) consisted of construction of canals and dams for hydroelectricity production that bypass large reaches of the original river channel. The sum of these anthropogenic impacts has profoundly disturbed river bedforms and sediment transport conditions along its length.

This study examines the evolution of bedforms in response to these impacts through a comprehensive analysis of recent and historical bathymetric data. Specifically, our focus is on quantifying how mean channel elevation and the shape and frequency of pools and riffles have evolved. We segmented the present-day long profile into 55 homogenous reaches based on qualitative breaks, e.g. dams and tributaries, and quantitative breaks in slope detected statistically using the Hubert test. We then use principal component analysis and cluster analysis to identify groups of reaches with similar bedform properties. Finally, we attempt to explain this spatial organisation through analysis of bed evolution through time in the context of natural and anthropogenic influences. Grainsize and armour index collected along the entire length of the original river channel are used to further shed light on bedform evolution and longitudinal geomorphic pattern.

\*\*\*\*\*

### **Establishment of a sedimentation monitoring system of irrigation dams in Burkina Faso: The PADI project**

HALLOT E.(1), GUYON F.(2), ZANGRE A.(3), DABIRE F.(3), DE THYSEBAERT D.(4), PETIT F.(1)

(1) LHGF - University of Liege, LIEGE, BELGIUM ; (2) APEFE, OUAGADOUGOU, BURKINA FASO ; (3) DGADI - MAH, OUAGADOUGOU, BURKINA FASO ; (4) DCENN - SPW, NAMUR, BELGIUM

Sedimentation in irrigation dams is a natural process which is accelerated by (i) an increase in solid transport as a result of the soil degradation upstream due to poor agricultural practices and deforestation in the basins and (ii) the erosion of the banks aggravated by adverse anthropogenic uses (sand extraction, production of bricks...).

The progressive filling of dams has as effects (i) the decrease in water amounts available for irrigation and other uses of as fishing or livestock, and consequently an increase in conflicts of use, (ii) the degradation of the fragile ecosystems characterizing wetlands. All these effects can produce a negative impact on the living conditions of local populations.

Few studies on sedimentation of dams and streams in Burkina Faso have been conducted so far. However, national-level estimates give a loss of about 2% of their storage capacity each year or a total of at least 100 million cubic meters of water lost per year.

Three pilot small-basins were selected in 3 different areas of the Nakanbe River in order to involve and build up the capacity of a maximum of stakeholders from decentralized structures of the Ministry of Agriculture and Hydraulic.

Research and development activities has been designed to develop knowledge, tools and techniques in order to estimate (i) volumes of sediments deposited in impoundments by cores analysis, (ii) sediment supply from watershed by suspended and bed load sampling and (iii) by spatially distributed soil erosion and sediment delivery model.

Finally, we improve through this project a better planning of land development at local and watershed scale in order to significantly limit sedimentation in the infrastructure.

## **Evaluation of genetic structure of erosion intensity in river basins according to the analysis of river suspended sediment flux**

GUSAROV A.

*Kazan Federal University, Institute of Ecology and Geography, KAZAN, RUSSIAN FEDERATION*

This paper uses the results of river suspended sediment flux (SSF) analysis to propose a new hydrological method for quantitative estimation of the river bed and drainage basin (sheet erosion, rill and gully erosion) components of total erosion intensity in river basins. The suggested method is based on the establishment of the functional power connection between mean monthly water discharges (WD,  $Q(i)$ ) and suspended sediment fluxes ( $r(i)$ ) calculated for the low-water-discharge phases of a river's hydrological regime in various (on mean annual water discharges) years:  $r(i) = a \times [Q(i)^\mu]$  (where  $a$ ,  $\mu$  are some empirical coefficients), and further extrapolation of this connection for other phases of the hydrological regime. Thus, the extrapolation allows us to calculate (in a long-term annual SSF) the proportions of sediments originating in river beds and drainage basins. The proposed method is tested using a long-term (not less than 10 years) series of observations for WD and SSF of 124 chiefly small and midsize rivers of the East-European plain, the Urals, the Eastern Carpathians, the Ciscaucasia and the Caucasus, and Central Asian mountains, containing data on the mean monthly values of WD and SSF. The paper also compares the method with other methods for estimating the components of erosion intensity and SSF.

The preliminary estimation shows that along the whole array of the analyzed basins of plain and mountain rivers the share of river-bed erosion and SSF does not exceed, on average,  $8.8 \pm 1.6$  % with relative minimum of  $6.3 \pm 2.3$  % in the medium-altitude-mountain group of Central Asian basins and with relative maximum of  $11.8 \pm 3.9$  % in the plain river basins.

\*\*\*\*\*

## **Anomaly suspended sediment loads and channel morphology changes in a Mediterranean catchment: the effects of land cover and land use changes**

EGOZI R.

*Soil Erosion Research Station, EMEK HEFER, ISRAEL*

The relation between suspended sediment concentrations (SSC) and water discharge (Q) is fundamental in sediment transport studies characterizing the natural regime of sediment evacuation from the catchment. It is also known that semi-arid catchment produce relatively higher SSC compare to humid catchments, therefore, it was not surprising to find a good match in SSC-Q relation along Israel rainfall gradient. However, recent measurements of SSC in a Mediterranean catchment at the center of the coastal area of Israel show as high SSC (1,000-10,000 mg/L) as measured in semi-arid catchments with only half the mean annual rainfall amount (550 vs. 240 mm/yr, respectively). A morphological change in the channel network has been observed as well: while some channels have incised and become semi-alluvial channels, other sand-bed channels have been filled to the top with sediments. Land cover and land use changes analysis may provide some explanation to the rapid changes observed in the channel network morphology and sediment transport regime. The results of the study questioning the classic and well accepted channel pattern classifications.

**Sediment tracing in the upper Hunter catchment using elemental and mineralogical composition: Implications for catchment-scale suspended sediment (dis)connectivity and management**

*FRYIRS K., GORE D.*

*Macquarie University, NORTH RYDE, AUSTRALIA*

The (dis)connectivity of longitudinal, lateral and vertical linkages in catchments drives bio-geo-chemical fluxes. Of critical importance is the vertical exchange of water, sediment and nutrients between surface and groundwater systems in the hyporheic zone which is most effective in gravel bed rivers where subsurface flow pathways are created in interstitial space between clasts.

Human activities have impaired the function of this vertical exchange in river channels, but one concern is the influx of fine-grained sediment from upstream sources that clogs the interstices of gravel beds forming a colmation layer. One key aspect of treating this problem is to understand suspended sediment sources and the (dis)connectivity of the catchment sediment cascade. Only then can sources be treated using river rehabilitation techniques that either prevent erosion or promote sediment storage in catchments.

We use a case study from the upper Hunter catchment in Eastern Australia to show how release of alluvial suspended sediment from channel bank erosion sources since European settlement has resulted in the formation of a colmation layer along the upper Hunter River trunk stream at Muswellbrook. We use X-ray fluorescence (XRF) and X-ray diffractometry (XRD) technology to determine the elemental and mineralogical signature of floodplain sediment sources and the colmation layer across this 4200 km<sup>2</sup> catchment. This sediment tracing technique allows us to construct a picture of how suspended sediment flux operates in this system. We place this understanding in context of catchment-scale (dis)connectivity of the sediment cascade by examining the effective catchment area from which these sources are supplied and the effective timescales over which this dynamic is occurring. Understanding the spatial variability in sediment supply is critical for the development of catchment action plans that treat the causes of sediment source and delivery problems rather than just the symptoms.

\*\*\*\*\*

**Sediment budget modelling in the northern Great Barrier Reef, Australia; without empirical data ' don't bother!**

*BROOKS A., SPENCER J., OLLEY J., PIETSCH T., CURWEN G., BOROMBOVITS D., SHELLBERG J.*

*Griffith University, BRISBANE, AUSTRALIA*

The Great Barrier Reef (GBR) World Heritage Area is an international asset under threat from terrestrial runoff, and significant effort has been expended modelling sediment and nutrient export from reef catchments. In this study we test the sediment budget for the Normanby catchment Cape York, Australia; a catchment previous SedNet modelling (based on very few local empirical data) indicated is the 3rd largest contributor of sediment to the GBR. The modelling predicted that 89% of the ~ 1.1Mt annual average suspended sediment output was sourced from hillslope erosion, with 1% from bank erosion and 10% from Gully erosion. Following an extensive data collection program we have established that the upper catchment contributes on average ~1.4Mt/yr of fine sediment to the reef - a similar quantum to previous modelling, but from entirely different sources. The budget is instead dominated by bank erosion in minor alluvial channels (54%); alluvial gully erosion (24%); colluvial gully erosion (13%), primary channel bank erosion (8%) and hillslope erosion (~1%). Sediment storage accounts for ~55% of sediment input (1.27Mt/yr), of which 424Kt/yr is stored in in-channel benches. Sediment tracing using fallout radionuclides confirms the budget is dominated by sub-surface sources (>80%). Geochemical tracing to the receiving bay indicates 46% of benthic sedimentation has a terrestrial source, in contrast to previous estimates of 4%. Of the terrestrial sources, we found that only 18% of the fine sediment is sourced from the upper catchment (i.e. of the ~1.4Mt), with the bulk coming from erosion of the coastal plain/delta (representing an additional ≥ 4Mt/yr not previously considered). The study highlights that without the underpinning of empirical data similar to that used in this study (which we would regard as an absolute minimum), any attempt to model the system is at best, futile, and at worst likely to give completely misleading results and hence management actions.

## **Poster presentations:**

### **Mechanical and chemical erosion in three basins located in different geomorphologic provinces of Sao Paulo State, Brazil**

*SARDINHA D.S.(1), CONCEIÇÃO F.T.(2), GODOY L.H.(2)*

*(1) Alfenas Federal University/UNIFAL ? Science and Technology Institute/ICT, POÇOS DE CALDAS/MG, BRAZIL ; (2) Paulista State University/Unesp ? Geosciences and Exact Sciences Institute/IGCE, RIO CLARO/SP, BRAZIL*

The present study compared the mechanical and chemical erosion in the Meio Stream (252.0 km<sup>2</sup>), Alto Sorocaba (670.4 km<sup>2</sup>) and Jaú River (467.16 km<sup>2</sup>) basins located in the Geomorphologic Provinces of: "Depressão Periférica" in the Paraná Basin eastern border; Plateaus and sierras of the East-southeast Atlantic; and Paraná Basin Plateaus, respectively. Total suspended solids (TSS) and total dissolved solids (TDS) concentrations were analyzed by gravimetric method during the dry and rainy seasons over one hydrological year and the outflow calculated in each basin mouth multiplying the water flow velocity by the cross section area of the river channel. The mechanical and chemical annual erosions were calculated using the areas, average weighted concentrations and average outflow for the three basins. The results indicate that mechanical erosion rates were 3.25 t/km<sup>2</sup>/year to Meio Stream, 25.40 t/km<sup>2</sup>/year for Alto Sorocaba and 14.93 t/km<sup>2</sup>/year in Jaú River. The chemical erosion rates were 38.83 t/km<sup>2</sup>/year to Meio Stream, 62.55 t/km<sup>2</sup>/year for Alto Sorocaba and 21.57 t/km<sup>2</sup>/year in Jaú River. The total annual erosion was also calculated, i.e., 11 x 10<sup>3</sup>, 59 x 10<sup>3</sup> and 17x 10<sup>3</sup> t/year for the Meio Stream, Alto Sorocaba and Jaú River basins, with approximately 70% of total solids load transported during the rainy summer months. The largest erosion rate was obtained in Alto Sorocaba basin, due to the lithology (phyllites, metabasics and granites) and the greater altimetry variation. In Meio Stream (diabases, sandstones, siltstones and mudstones) and Jaú River (basalts and sedimentary covers), the differences can be explained by the lithology (highest rate of chemical erosion in Meio Stream) and altimetry variation (a higher rate of mechanical erosion in Jaú River). The interaction among rainwater, the atmosphere, rocks and declivity controls the evolution of ground surface and, consequently, the mechanical and chemical denudation velocity on the studied watersheds.

\*\*\*\*\*

### **Upper Drac River restoration project : restoration of a braided river bed incised in clay substratum through sediment reloading and bed widening**

*LAVAL F.(1), VENTO O.(1), ESCORIHUELA F.(1), JOUSSE C.(1), KOULINSKI V.(2), BREILH B.(3), MONTANE A.(1)*

*(1) Bureau d'Etudes BURGEAP, ST MARTIN D HERES, FRANCE ; (2) Bureau d'Etudes ETRM, SEEZ, FRANCE ; (3) Syndicat Mixte de la Communauté Locale de l'Eau du Drac amont (CLEDA), ST BONNET EN CHAMPSAUR, FRANCE*

The Drac River restoration project, covering a 3.5 km-long and 1%-sloped stream in the Champsaur valley (French Alps), is based on two geomorphological observations: 1) the whole river bed is subject to a major incision trend (up to 4 m) in clay substratum ; 2) its initial braided fluvial style tends now to a rectilinear one.

This situation is linked to upstream and downstream sediment extractions in the past decades. The last important floods (2006, 2008, 2011) sped up this incision issue: now the river flows directly above clay substratum, leading to a permanent and irreversible incision. The environmental impacts are major: groundwater drop (alluvial forest, wetlands habitat mortality) ; aquatic habitat degradation (coarse armoring, fine sealing, facies homogeneity, lack of spawning areas) ; increasing risks for land uses (treatment plant, diked lake, landslides). Without a remaining ancient upstream weir, the backwards erosion could even propagate upstream.

Beyond ending recent upstream extraction, the project aims at restoring the braided morphology through sediment reloading according to equilibrium profile, bed rewidening and compatible granulometry.

The pre-engineering study successively led to localize substratum altimetry, estimate the reload sediment volume according to objective profiles, analyze available coarse sediment from old terraces and external supply, and finally size the new bed geometry in reference to upper braided streams. The high objective profile, close to the 1913-reference and chosen to avoid substratum contacts, requires to raise a downstream weir, to restore a 80 to 200 m active bed width and to inject a 400 000 m<sup>3</sup> volume. The ecological impacts on forest and river habitats are minimized due to the current degraded situation ; however, ecological measures on protected habitats and species will help fast recovery.

The works are scheduled for the end of 2013 and appear as one of the most ambitious sediment reload projects ever done.

### **Combining field measurements and flume experiments for analysing fluvial bedload transport and morphodynamics in steep mountain streams**

BEYLICH A.A., LAUTE K.

*Geological Survey of Norway (NGU), TRONDHEIM, NORWAY*

Fluvial bedload transport, temporal storage and channel morphodynamics have high importance for sedimentary budgets of steep catchments and steep mountain streams. In addition, headwater catchments and steep mountain streams can be relevant sediment sources for lowland river systems. Since 2004 extended and interdisciplinary field investigations on fluvial bedload transport and channel morphodynamics using a range of different methods and techniques have been performed in a number of selected stream segments in supply-limited fluvial systems in the inner Nordfjord (Erdalen and Bødalen drainage basins) in western Norway. Field studies in the Erdalen drainage basin (79.5 km<sup>2</sup>) and the Bødalen drainage basin (60.1 km<sup>2</sup>) have included (i) continuous channel discharge monitoring, (ii) frequently repeated surveys of channel morphometry and granulometric analyses, (iii) different tracer techniques (painted stones, magnetic tracers), (iv) Helley-Smith and other basket measurements, (v) horizontally installed impact sensors, (vi) underwater video filming and (vii) extended biofilm analyses, including also controlled biofilm growing experiments with fixed baskets in selected channels. The field studies have been combined with flume experiments for calibration of field measurements, especially of the measurements that have been carried out with impact sensors. As a key achievement, the entire range of different bedload component grain sizes can be covered by the applied combination of techniques. The flux of bedload material can be quantified and is related to the spatio-temporal variability of sediment supply / availability within the drainage basins and to temporal sediment storage within the channel systems.

\*\*\*\*\*

### **Islands in a European mountain river: linkages with large wood deposition, flood flows and plant diversity**

WYZGA B.(1), MIKUS P.(1), KACZKA R.(2), WALUSIAK E.(1), ZAWIEJSKA J.(3)

*(1) Institute of Nature Conservation, Polish Academy of Sciences, KRAKOW, POLAND ; (2) Faculty of Earth Sciences, University of Silesia, SOSNOWIEC, POLAND ; (3) Institute of Geography, Pedagogical University, KRAKOW, POLAND*

Long-term observations and recent morphological and botanical surveys conducted in the gravel-bed Czarny Dunajec River, Polish Carpathians, were used to determine the processes and patterns governing initiation and development of vegetated islands and their floristic complexity. Moreover, dendrochronologically estimated years of island inception were compared with the timing and magnitude of flood flows in the period 1970-2011 to infer about controls on the formation and persistence of islands in the river. In the high-energy, braided river, islands originate as a result of deposition of large vegetative particles, mostly large wood, on gravel bars and the associated vegetative regeneration of living wood or the growth of seedlings and saplings in the shelter of wood accumulations. Tree-ring dating of the largest trees growing in particular island zones indicated a predominant upstream island growth in the river. It results from repeated accumulation and subsequent regeneration of living wood on the head of islands and contrasts with progressive downstream island growth in the rivers supplied with large, stable logs of the tree species without the capability to re-sprout. The lack of islands from the years 1982-1996 most likely reflects the removal of relatively young islands by two major floods in the 1990s. After 1997 the occurrence of low to moderate floods facilitated the formation and persistence of islands. The plant inventory demonstrated that species richness increased non-linearly with the increasing age, area and shoreline length of islands. Islands supported more plant species than the riparian forest and attained comparable species richness at an early stage of development. Fast developing, dynamic and supporting rich plant communities, islands contribute highly to the overall floristic complexity of the river corridor and their re-establishment should be viewed as an important factor in the restoration of hydromorphologically degraded mountain rivers.

## **Geomorphological changes associated with avulsion: a case study of the Feshie fan, SCOTLAND**

CLARKE L.(1), WERRITTY A.(2)

(1) University of Hull, HULL, UNITED KINGDOM ; (2) University of Dundee, DUNDEE, UNITED KINGDOM

In February 1990 a major flood caused an avulsion on the Feshie fan, resulting in the main channel switching position by 500 metres. The impact and response of fluvial systems to avulsions is a topic of ongoing debate in fluvial geomorphology, and the Feshie fan provides an ideal case study to enhance understanding of fluvial response to an avulsion.

The Feshie catchment drains from the Cairngorms Mountains in the Scottish Highlands yielding, at the confluence of the River Feshie with the River Spey, an active alluvial fan. Investigating contemporary fan processes and the stability of alluvial fans in the northern temperate zone is often hindered by excessively rapid adjustment or large scale engineering. Uniquely the Feshie fan escapes both constraints and, despite some flood control works and land management strategies influencing the vegetation in the area, the fan system is relatively undisturbed and has been designated as a geomorphological Site of Special Scientific Interest (SSSI).

The historical development of the active fan downstream of the current apex is recorded in a series of large-scale maps and aerial photographs, which have been analysed using digital photogrammetry to document the historical evolution of the fan over the last 100 years. These data have been combined with field data, both contemporary and collected immediately following the 1990 avulsion to determine how the morphology and flow conditions on the lower Feshie have responded in the thirty years since the avulsion event.

It was found that the Feshie fan is still active. Preliminary analysis has shown that the position of the main channel has altered continually over the observed period and channel switching and changes in morphology are a characteristic feature of this system. Through reconstruction of the morphology and flow conditions pre- and post-avulsion it is hoped that better understanding can be gained of the processes operating and driving avulsion.

\*\*\*\*\*

## **River Preservation Project : Evaluating the erosion surface rate of river banks using temporal and spatial analysis on 4 pilot sites of the Lanterne's Basin**

LAMBERET T.

BURGEAP, LYON, FRANCE

The analysis of geodynamic activities on the Lanterne river Basin is inscribed in a local will to restore and preserve rivers mobility and biodiversity. For the past five years, a restoration program has been implemented to recover ecological and morphological rivers functionalities, including removal of weirs and riprap (stone embankments) on 4 pilot sites, covering a 15.5 km-long stream in Lanterne Valley (French Vosges Range).

These rivers are characterized by a low slope (0,40 %), a meandering bed and agricultural pressure (pasture, cultivated area), which contributes to the rivers physical alteration (old water mill, stabilization weirs, bank protection). In this specific context, two scenarios of river management have been set: 1) the preservation of weirs and riprap 2) their removal. The aim of the study was to quantify and compare geodynamic, ecologic and hydraulic impacts between the two scenarios at different temporal scales (5, 10 and 20 years from now), and more specifically to estimate erosion rate (m<sup>2</sup>/year) due to lateral erosion.

The engineering study led to determine annual erosive coefficient of every site by combining different technical methods : diachronic analysis from historical aerial photographs (1949, 1998, 2003, 2008 and 2011), ground investigation (bank erodibility, stream diversity, riparian vegetation, river topography, grain size distribution, riprap deterioration rate), hydraulic modeling, calculation of hydromorphological variable (slope, tractive forces, specific power) and evaluation of mobility potential by construction of geodynamic index (potential sinuosity, meander evolution rate, river amplitude rate).

This exhaustive analysis enables to quantify land surface losses (in m<sup>2</sup>) and evaluate impacts of every scenario at several temporal scales on water levels and ecologic state.

The results provide an efficient decision support tool notably for land negotiation in order to ensure an effective area for river mobility.

### **Sediment transport in a small watershed by Agricultural activities in Sao Paulo State, Brazil**

SPATTI JR. E.(1), CONCEIÇÃO F.T.(2), PINTO S.D.A.F.(2), PEREIRA L.H.(2)

(1) Paulista State University/Unesp, RIO CLARO, BRAZIL; (2) Paulista State University/Unesp, RIO CLARO, BRAZIL

The growing demand for geographic space conditioning direct impact on the availability of natural resources, mainly in terms of quantity and quality of water. Thus, it is necessary to consider the processes linked to sediment transport, whose dynamics in a natural system is changed without planning for the occupation of slopes, due to agricultural activities. These anthropogenic influences promote the removal of vegetation and, consequently, increase of erosive processes, which lead to the loss of agricultural lands, reduced soil fertility and productivity, increasing the amount of sediments carried by rivers causing silting of water sources. To evaluate this process, it was performed a monitoring of sediment transport during the period of one year in a small watershed, i.e. Monjolo Grande Stream basin, with 30 km<sup>2</sup> of area and located in São Paulo State, Brazil. This watershed is composed of sandstones, with slopes ranging from 20 to 45% and its predominant land use is the sugar cane crops. The sediment transport total in this watershed was obtained through a simplified method of Colby, which is indicated to small watershed covered by sandstones and with small average depth during the dry season. During 2010, with an annual rainfall of about 1480 mm, it was obtained a total of 13,735x10<sup>3</sup> kg of sediment transported from the Monjolo Grande Stream basin. January, with a total rainfall of 520 mm, transported approximately 66% of total sediment carried out of this basin. If the total value obtained for the sediment transport is divided by the area of the basin, it is possible to estimate a specific sediment transport of 476x10<sup>3</sup> kg/km<sup>2</sup>/yr. The results show that the works related to sediment transport in small watershed can be important tools in the study of denudation relief.

\*\*\*\*\*

### **Experiments and modelling of size segregation in bedload transport**

BEL C., RORSMAN K., FREY P.

*Irstea, SAINT-MARTIN-D'HERES, FRANCE*

Bedload, the larger material that is transported in stream channels, has major consequences, for both environmental sustainability, and flood alleviation. Computing local and even bulk quantities such as the sediment flux in rivers is still challenging. One important reason pertains to the very wide range of grain size leading to size segregation and drastic morphological changes. When the coarser particles of the bed are moving, statistically dynamic void openings permit downward percolation of a large range of grain size, much more than by spontaneous percolation. This process named "kinetic sieving", has been studied in industrial contexts but rarely in natural sediment transport. We present an experimental study of two-size mixtures of coarse spherical glass beads entrained by a shallow turbulent and supercritical water flow down a steep channel. The particle diameters were 4 and 6mm, the channel width 6.5mm and the slope 10%. The water flow rate and the particle rate were kept constant at the upstream entrance. First only the coarser particle rate was input and adjusted to obtain bed load equilibrium, that is, neither bed degradation nor aggradation over a sufficiently long time. Then a very low rate of smaller particles was introduced to study the evolution of segregating smaller particles. Particle flows were filmed from the side by a high-speed camera. A quasi-continuous region of smaller beads developed under moving and above quasi-immobile coarser beads. The time evolution of segregating smaller beads will be assessed. Normal and streamwise particle velocity and concentration depth profiles will be presented. These experimental results will be compared to existing theoretical models (in particular Gray and Chugunov, 2006).

J.M.N.T. Gray and V.A. Chugunov. Particle-size segregation and diffusive remixing in shallow granular avalanches. *Journal of Fluid Mechanics*, 569:365–398, December 2006.

### Development of Basin-Scale Models to Estimate Bed Load Sediment Flux

*PITLICK J.(1), RECKING A.(2)*

*(1) C, C, UNITED STATES ; (2) Irstea, SAINT MARTIN D'HERES, FRANCE*

The movement and storage of bed load sediment is of first-order importance in determining the form and function of high-gradient rivers. Unfortunately, measurement programmes designed to sample bed load and quantify fluxes are becoming increasingly rare, thus different approaches are needed to estimate transport rates and annual sediment yields, particularly in areas with high sediment supply. In this talk we will present results from a year-long study to develop basin-scale estimates of bed load sediment fluxes in rivers draining the French western Alps. The study focuses on rivers draining the core of the Ecrins Massif where sediment supply appears to be relatively high. Measurements of channel and bed material properties taken within individual river reaches are being used with a transport relation to model bed load sediment fluxes at channel-forming discharges. An important component of the modeling effort is to evaluate thresholds for incipient motion of bed load in steep channels. Previous research indicates that thresholds for motion are influenced by several factors, including channel slope, relative roughness, and the supply of sand-sized sediment. Our preliminary analysis of data from gravel-bed rivers draining the Ecrins Massif suggests that, at channel-forming discharges, bankfull Shields numbers are much higher than would be predicted using the standard Shields criterion. Corrections for the effects of steep slopes and high relative roughness narrow the difference between bankfull and threshold Shields numbers to some extent, but in many of our study reaches, the shear stress at bankfull discharge is still more than 2 times the threshold for motion. Consequently, we estimate that, in many of our study reaches, width-integrated bed load transport rates at bankfull discharge exceed  $100 \text{ kg s}^{-1}$ , which is comparable to measured loads in other river systems with very high sediment supply.

\*\*\*\*\*

### Lateral channel migration and bank erosion along the Trotus River (Eastern Carpathians)

*DUMITRIU D.(1), NICULITA M.(1), OBREJA F.(2)*

*(1) Alexandru Ioan Cuza University of Iasi, IASI, ROMANIA ; (2) Stefan cel Mare University of Suceava, SUCEAVA, ROMANIA*

River bank erosion is a natural geomorphological process specific of river channels. In many countries, including Romania, there was little interest in quantitative measurements of river bank erosion, compared with other processes, although it is a major process responsible for direct feeding the river channels with materials.

This poster presents preliminary results from a larger study focused on river banks as one of the sources of sediments in the Trotus River drainage basin ( $4,500 \text{ km}^2$ ). A first step was to identify river reaches subject to bank erosion, which were then classified in two groups depending on prevailing processes that trigger lateral erosion (i.e hydraulic processes and mass movement).

In the second stage, grain size of the river bank materials was analysed as it is known that the effectiveness of erosion depends also on the degree of cohesiveness and particle size of the deposits. With data on the amount of the Trotus River bank erosion and bank material characteristics available, methods and quantification techniques were chosen. Assessment of the bank erosion was made by geomorphological survey, cartographic analysis of different map editions (1896-2010), indirect computing methods and, lately, by using Leica 3D laser scanning techniques for river bank monitoring (laser scanner started in August 2009).

They yielded bank erosion rates varying for different river sectors between 1 and 25 m/yr and bank accretion rates varying between 3 and 12.5 m/yr.

### **Asynchronicity in floodplain processes. An example from the Dijle catchment, Central Belgium**

BROOThAERTS N., NOTEBAERT B., VERSTRAETEN G.  
KU Leuven, LEUVEN, BELGIUM

Major changes in fluvial architectures appear in many Holocene floodplains of Western Europe, under influence of changing catchment properties. Typically, organic and peaty deposits – deposited in a marshy environment during the Early and Middle Holocene – are replaced by inorganic overbank deposits. This domination of inorganic deposits is attributed to an increase in soil erosion due to increasing human impact during the last few millennia. The onset of intense human land use changes is often determined based on a few or one single dating of this transition in fluvial architecture. In this study, the temporal and spatial variability of this transition was studied for two cross sections in the Dijle catchment, located in the Belgian loess belt.

Two study sites were selected: one in a small tributary (13 km<sup>2</sup> catchment area; floodplain width 90 m) and one in the main trunk valley (760 km<sup>2</sup>; floodplain width 1020 m), for which the top of the peat layer was dated at several points along a transect perpendicular to the valley axis. Datable material was handpicked for non-aquatic plant remains, and dated using AMS radiocarbon dating. Results for the small tributary show that the end of the peat accumulation is ranging between 376 ±61 and 620 ±40 cal BP (n=6). For the main trunk valley, the top of the peat layer is even more diachronic (ranging from 715 ±24 to 7415 ±56 cal BP; n=15). The results indicate that for the broad lower floodplain, sediment supply starts with low quantities only influencing peat accumulation near the channel, while only later on the distal parts of the floodplain are affected. For the smaller floodplains, the transitions in the floodplain are more abrupt, affecting the entire floodplain width. Overall, the observed asynchronicity in the floodplain transitions shows that the reliability of single-core dating results can be doubted.

\*\*\*\*\*

### **Sediment transport and morphodynamics of two highly modified rivers: valley management issues and keys for river stakeholders**

CHAPUIS M.(1), DUFOUR S.(2), MACVICAR B.(1), ROY A.(1), COUVERT B.(3)

(1) University of Waterloo, WATERLOO, CANADA ; (2) COSTEL, University of Rennes 2, RENNES, FRANCE ; (3) Artelia Group, MARSEILLE, FRANCE

A river system can be highly instable at different spatial and temporal scales. When this instability conflicts with human landscape use, sediment fluxes and morphodynamics issues can be a key factor of river management. We study two highly modified river systems: a large wandering gravel bed river located in the Southern French Alps (Durance River, drainage area 14,000km<sup>2</sup>) and a small gravel bed river located in the urbanized area of Toronto, Canada (Wilket Creek, drainage area 15km<sup>2</sup>).

Because of a growing human pressure on their valley, both rivers hydrology and morphodynamics has been highly modified in the last 50 years, with increase in flooding risk because of the high lateral and vertical mobility of rivers that conflict with human infrastructures. Despite the difference of scale between these two river systems, we developed a methodology to characterize river mobility in order to give management keys for river stakeholders.

The first step to lead to sustainable river management is to assess the mobility of the fluvial system. To do so, we set up a topographic survey of longitudinal profile and cross-sections. Then we link migration rates with hydrology for the studied periods.

The second step is to lead a diachronic study of migration rates of the river, based on the most relevant orthophotographs of the system. Then we try to link this 'long term' migration rate obtained to the previous 'short term' migration rate.

The third step of our approach is to assess the sediment fluxes that shape the river system. For gravel bed rivers, we monitor the coarse fraction of bed sediments using a RFID tracking of gravels. These surveys give us information concerning distance of transport and travel paths for individual particles for single events. But most of all, we highlight a link between sediment mobility, hydrology and bedforms.

The improved knowledge of river morphodynamics then enables us to give relevant management keys for river stakeholders.

### High frequency measurements of suspended sediment particles of the Rhone River, France

ANTONELLI C.(1), ZEBRACKI M.(1), SABATIER D.(2), GAIROARD S.(2), LAUNAY M.(3)

(1) IRSN, SAINT-PAUL-LEZ-DURANCE, FRANCE ; (2) CNRS - CEREGE, AIX-EN-PROVENCE, FRANCE ; (3) IRSTEA, LYON, FRANCE

On the lower Rhone River, suspended sediments are monitored with a high temporal resolution in an observatory largely devoted to contaminant survey. In order to precise contaminants affinities with particles and the role of flood in their transport, grain-size characteristics of the suspended load have to be determined. Recently, a LISST-Streamside has been installed to acquire grain-size distribution with a high temporal resolution. The first step of deployment was devoted to calibrate the apparatus. A LISST-portable and a Beckman Coulter LS 13 320 were used to compare standardized samples and Rhone River samples. During that time, the LISST-Streamside was also used to acquire grain-size analyses in the river.

First results of the inter-comparison tests indicate that:

- Calibration of the LISST-Streamside is coherent with the LISST-portable grain-size analyzer and with the Beckman Coulter used in the lab. Nevertheless, inter-comparison also demonstrate that the finest particles ( $< 3\mu\text{m}$ ) are overestimated. This overestimation is thought to be due to the limited number of canals of the LISST. Also the optical model of the LISSTs cannot be adapted to the sediment matrix which involves possible bias on the grain size characterization.
- For low level concentrations of suspended sediments, analyses are not well reproducible, that could presume future difficulties to measure particles under low-water conditions,

In the river, we observe that:

- the average median ( $d_{50}$ ) particle size over the studied period is about  $10\mu\text{m}$ ,
- the correlation between discharge and  $d_{50}$  confirm that largest particles are moved for higher discharges. During the only event recorded, sands represented for almost 17% of the total load in suspension,
- the evolution of grain-size distribution is variable at the hourly scale. The effects of flocculation of suspended sediment could explain this variability as demonstrated in the literature but further analyses have to be made to confirm this hypothesis.

\*\*\*\*\*

### Interpretation of the fluvial dynamic from Tucum stream/SP, Brazil: sedimentary load balance and transformations of the alluvial forms

VALEZIO É.V., PEREZ FILHO A.

UNICAMP, CAMPINAS, BRAZIL

The fluvial channels express in their typology the integrated dynamic of the physical elements constituents from the system. The relationship between the sedimentary load and its outspread in the fluvial channels configuration is extremely important to understand the processes that there are perpetuated, either for natural order reasons, or anthropogenic order. For analysis and interpretation of the dynamics involved and their answers to changes in relation to the use and occupation of land and in the lithological and pedological constitution of Tucum stream area, located in the city of São Pedro, in the Brazilian state of São Paulo, we used the dynamic equilibrium theory approach proposed by Hack (1960) and the general systems theory, systematized by Bertalanffy around 1930. The results analysis of the sedimentation processes and the increase of the alluvial banks along Tucum stream was performed by collecting water samples at high and low course, as a way of understanding the behavior of the suspended sedimentary load and its outspread in the reconfiguration of the fluvial channel forms. Longitudinal profiles from Tucum stream were also made, based on the topographic letter in scale 1:10.000 (1978) and elaborated *in situ* (2012) via GPS and altimeter. Analysis of the channel changes were performed using not orbital aerial photographs from periods of 1962 and 2000 in approximate scale 1:25.000, providing the interpretation of the processes incidents in it. The results point to increase and insertion of alluvial banks along the medium and low course expressed in the longitudinal profile, also allowing its correlation with the difference between the amount of suspended solids in the sampled areas.

### **The relationship between wind gaps and histosols in the Atlantic Plateau Paulista, Southeastern Brazil**

DE OLIVEIRA D.

*Universidade de São Paulo, SÃO PAULO, BRAZIL*

The Atlantic Plateau Paulista, in Brazil, is dominated by convex shapes, with deep valleys and high drainage density. The layout of the drainage network depends on several factors, including the geotectonic position of the state, extending over a Precambrian crystalline shield, bathed by the ocean and into the Paleozoic sedimentary basin of the Paraná and the climate factor. The products of erosion were accumulated negative element in the sedimentary basin. Thus, most of the rivers moved inward, to the Paraíba do Sul River or the Parana basin. The Serra da Mantiqueira Hills and Serra do Mar Escarpment led the formation of newer drainage on slopes steeper. Background levels closer and lower arisen due to the post-Cretaceous tectonism in southeastern Atlantic Plateau forced a progressive reversal of parts of the drainages that went into the interior through multiple river captures. In this case, river captures have a relationship with soils, especially Histosols inside the wind gaps. Histosols were found at least in four areas located in Serra do Mar Escarpment and reverse, they are: Paraíba do Sul basin's wind gap, Guaratuba basin's wind gap, Capivari basin's wind gap and Cotia basin's wind gap. In all these cases, Histosols have an important role in the development of drainage in cases of drainage anomalies and river captures in humid and forested tropical areas.

\*\*\*\*\*

### **The stream capture process between the rivers Tiete and Paraíba Do Sul in the Atlantic Plateau Paulista: The case of Guararema's Elbow**

PASA V., DE OLIVEIRA D.

*Universidade de São Paulo, SÃO PAULO, BRAZIL*

The Atlantic Ocean formation, as a result of the separation of African and South America continental margins, in the Southeastern region of Brazil, and especially, the Atlantic Plateau Paulista, suffered process of rifting. These formations occur in the margins of the Atlantic Ocean and the result is the intensification of denudational processes, reorganization of the drainage network and greater supply capacity of sediments, giving large sedimentary packages. On the ground, occur abasement and uplift of regional blocks with the formation of elongated and subsidence surfaces, as in the case of the Paraíba valley, between the Serra do Mar Escarpment and Mantiqueira Hills, and more elevated areas, such as the Tietê River. The area understood by these two important rivers is composed of ancient crystalline rocks the Brazilian Cycle, covered by Tertiary sediments, as the São Paulo and Taubaté Sedimentary Basins, of large regional expression, and source material Quaternary. In the region are found predominant faults of direction NE-SW and between the Mesozoic and the Cenozoic, some of these faults were reactivated. In the region of Guararema, the Paraíba do Sul River reversed its direction, as a result of stream capture, getting marked at relief the elbow of capture. Until this period, its drainages flowed its waters at the Tietê River. Are evidences of this connection, as the current structural alignment of drainages, of direction NE-SW, the wind gap and soil type. After the formation of drainage anomaly, one of its branches eroded the watershed and retreated its headwaters to the adjacent drainage, capturing a large part of its tributaries. The soil of the region is the type Histosol, commonly found in environments of paleodrainage, also observed in other anomalies of the Atlantic Plateau Paulista.

## Sediment Dynamics and catchment connectivity at the catchment

CROKE J.(1), THOMPSON C.(1), FRYIRS K.(2)

(1) Australian Rivers Institute, BRISBANE, AUSTRALIA ; (2) Macquarie University, SYDNEY, NSW 2109, AUSTRALIA

Although many types of connectivity are defined, overall, there is widespread recognition that the term connectivity in any 'geo-ecological' sense is useful in promoting the interconnection between the morphological components of the landscape and the material fluxes that move across, and through, the drainage basin (Bracken and Croke, 2008). All forms of connectivity are considered relevant to the storage, residency and delivery of sediments and pollutants within a drainage basin. Whilst recent studies have acknowledged the role of connectivity in catchment modelling and landuse management, the lack of field data which actually measures and quantifies it as a process in time and space hinders its widespread adoption as a practical tool in water quality protection and river management. This is especially the case in relation to sediment connectivity.

This paper investigates the dynamics and connectivity of sediment mobilised during an extreme flood event in southeast Queensland during the summer of 2011. The study avails of high-resolution, multi-temporal LiDAR to assess spatial and temporal patterns of sediment movement. Spatial changes in channel capacity exert a major control on downstream patterns of channel to floodplain connectivity. The presence of large macrochannels in particular mid-valley which contain the majority of flood flow for this extreme event limits lateral connectivity with the adjacent floodplain. The delivery of material downstream is not just a function of the spatial arrangement of alluvial landforms such as buffers and barriers, it is also a product of the temporal time frame such landforms are inundated. Some floodplains therefore act as blankets of buffers during frequent flood events whilst others remain redundant and act as barriers except during the most extreme or catastrophic flood events.

\*\*\*\*\*

## Intermittent suspension of sand from the bed in the Fraser River

MARQUIS G.A.(1), VENDITTI J.G.(2), CHURCH M.(3), KOSTASCHUK R.A.(2), ATTARD M.E.(2), RENNIE C.D.(4)

(1) Université du Québec à Montréal / Simon Fraser University, MONTRÉAL, CANADA ; (2) Simon Fraser University, BURNABY, CANADA ; (3) University of British Columbia, VANCOUVER, CANADA ; (4) University of Ottawa, OTTAWA, CANADA

In sand-bedded rivers dominated by dune bedforms, bed sediments are entrained into suspension by strong and recurrent vertical turbulent flow structures generated from the interaction between the flow and the dunes. Understanding how these coherent flow structures (CFS) suspend bed material sediment is critical to accurately estimate size-dependent sediment flux, yet most previous work on the link between CFS and suspension dynamics has been qualitative in nature. Here, we examine the linkage between sediment suspension and CFS using high frequency time-series collected in the thalweg of a 12 m deep sand-bedded section of Fraser River at Mission, British Columbia, Canada, during the rising limb of the 2010 freshet. A Laser In-Situ Scattering and Transmissometry (LISST-100) instrument was used to measure the concentration and grain-size distribution of suspended sediment particles 2.5 to 500 microns in diameter at a frequency of 1 Hz. An Acoustic Doppler Velocimeter (ADV) was mounted to the LISST in order to collect simultaneous 3D velocity at a frequency of 32 Hz. The instruments were deployed from an anchored boat to measure at-a-point velocity and sediment concentration over 20 minutes at 5 positions in the water column forming a vertical profile. Analysis reveals that a disproportionate amount of sediment is carried intermittently by CFS and that this effect is grain size dependent. For the smallest grain size, 60 % of the suspended bed material flux occurs during 50 % of the time-series and for the largest grain size, more than 90 % of the flux occurs during 50 % of the time. The increase in flux of the largest sizes is concomitant with slower than average streamwise velocity fluctuations associated with vertical upwelling more than 70 % of the time. These preliminary results quantify the role of CFS play in bed material suspension dynamics and will eventually lead to a more rational understanding of the sand-bedded river morphodynamics.

### **Effects of human action on the transportation of Tucum Stream Channel in Sao Pedro, Brazil**

PEREZ FILHO A.(1), VALEZIO E.V.(2), CARPI JUNIOR S.(2)

(1) Department of Geography, Geosciences Institute, State University of Campinas (Unicamp), CAMPINAS, BRAZIL ; (2) UNICAMP, CAMPINAS - SP, BRAZIL

River channels are essential part in understanding the dynamics of terrestrial relief sculpting, with its typology resulting directly from the processes present in the hydrographic basin. Such transformations occur along the time of nature through climatic and tectonic changes, and along the time of man by human activities. The dynamism observed by geomorphological processes in areas with hot and humid tropical climate has enhanced characteristics in soils that are susceptible to erosion. As these soils receive a considerable rain load, they present a series of erosive forms, such as ridges, ravines and gullies, especially when inappropriately used and occupied.

In the case of Tucum stream basin in São Pedro, Brazil, the anthropic variable appears as a catalyst of the linear erosion, which, despite having a natural genesis, has been intensified by badly implemented actions by the municipal administration. Taking into account the systemic approach to support discussions, we used aerial photographs, bibliographic and cartographic materials, field work to collect data and observations, as a way to analyze and interpret the changes occurred in the basin over the past 50 years. The significant variations in the longitudinal profile of Tucum stream in recent decades has demonstrated that it is finding a new phase of dynamic balance, mainly influenced by erosion processes located upstream.

\*\*\*\*\*

### **Event-scale sediment fluxes and morphodynamics of a semi-arid river: the influence of climate drivers and human actions in the Lower Santa Clara River, California, USA**

DOWNS P.(1), DUSTERHOFF S.(2)

(1) Plymouth University, PLYMOUTH, UNITED KINGDOM ; (2) Stillwater Sciences, BERKELEY, UNITED STATES

The present-day morphodynamics of the 4,200 km<sup>2</sup> lower Santa Clara River in southern California is influenced by very high rates of sediment supply from the Western Transverse Range mountains, highly episodic rainfall produced by an ENSO-influenced semi-arid climate, and various human activities over historical time. Available sediment gauging records and an unusual frequency of topographic survey over the last 80 years makes it possible to reconstruct channel morphology evolution over recent decades as a response to a number of discrete high flow events. Such reconstruction reinforces the importance in semi-arid environments of large flow events with return periods well in excess of bankfull recurrence interval and statistically in excess of the 3–8 year return frequency associated with ENSO. However, the high flow event-channel morphodynamic relationship is not simple and depends also upon other factors including human activities such as embankment construction, tributary dam building and instream aggregate mining, the relative magnitude of tributary discharges generated during individual storm events, and antecedent conditions wherein the greatest morphological impact generally occurs in response to two large flood events in a single winter, such as occurred in 1969 and 2005. Reach-scale sediment budgets of the observed fluxes and morphodynamic response are used to illustrate these various aspects, focussing attention on the challenges inherent to defining a distinct Anthropocene fluvial response under conditions of changing climate, and of planning sustainable management responses.

## The changes in riverbed plant cover in two rivers upstream the dam reservoir. A case study of the Czorsztyn Reservoir in southern Poland

LIRO M.

*Jagiellonian Univeristy in Krakow, KRAKOW, POLAND*

Riverbed vegetation plays a key role in the erosion and sedimentation processes in a river channel, as it modifies the direction of channel form development. To determine an effect of a dam reservoir backwater on vegetation on the channel form I used the GIS to analyse a set of aerial photographs taken in 2002 and 2009 year after construction of the Czorsztyn Reservoir (CR) in 1997 for two courses of the Dunajec and Białka rivers that flow into the reservoir. Dunajec is a sinuous, single channel river, while Białka has a braided channel. The maximum water stage variations in the CR reach 19.24m. During the highest water levels in the reservoir, the Dunajec and Białka riverbeds are flooded with reservoir water up to 1500m and 400m upstream of the reservoir. In this study the variations in plant cover within these reaches are compared with those of the control reaches remaining beyond the reservoir influences. In the period 2002-2009 the plant cover of the channel forms of Dunajec increased from 46% to 71% within the backwater zone and in both years was above two times larger than that of the control reach were was 20% and 31%, accordingly. In that period the vegetation expansion rate was 1.5 times higher within the backwater zone than that of the control. In that period the plant cover of the channel forms of Białka within the backwater zone remained almost unchanged and reached 14% and 16%, respectively. In the control reach the channel plant cover was also constant but was two times larger in the years under study and reached 30%. The higher rates of vegetation expansion on the Dunajec riverbed within the backwater zone was caused by deposition of fine-grained sediments and channel pattern and dynamics that promote plant development on the channel forms. Vegetation begins from the river mouth zone, where fine-grained sediments deposit most often and runs upstream. On the Białka riverbed such tendency is not observed because of different channel pattern and dynamics.

\*\*\*\*\*

## Analysis of the relationship between the dynamics of saturated areas and sediment transport in a basin in Southern Brazil

REDIN VESTENA L.(1), KOBİYAMA M.(2)

*(1) Universidade Estadual do Centro\_Oeste, GUARAPUAVA, BRAZIL ; (2) Universidade Federal de Santa Catarina, FLORIANÓPOLIS, BRAZIL*

The objective of the present work was to analyze the expansion and retraction dynamics of the saturated areas and the fluvial sediment transport in the Caeté River catchment in Alfredo Wagner city, Santa Catarina State, Brazil. The relation between the water discharge and the suspended sediment (SS) concentration were analyzed with the hourly hydrosedimentological data obtained at the automatic stations and by field measurements. By applying the TOPMODEL the sediment delivery ratio of the catchment was estimated and the fluvial solid discharge was related with the saturated areas. The mean values of the total solid discharge and the sediment delivery ratio (SDR), calculated from August 2004 to January of 2008 were 54,257.9 t/year and 4.23%, respectively, with significant annual variations. The months that presented larger SDR were not equal to those presented larger values of soil loss. In the Caeté River catchment, it was verified an intense hydrosedimentological dynamics characterized with a potentially fragile area to the action of the erosive processes, with high mobility of sediments, and with significant deposition amounts on the valleys bottoms and on the slopes ruptures. The TOPMODEL presented satisfactory performance of calibration and validation. The relationship between discharge and SS concentration has the behavior type "eight figure" where the SS concentration peak precedes the discharge peak with the presence of more than one peak for event. The simulated saturated-areas in relation to the total catchment area varied from 3.30% to 13.63%. The correlation of saturated areas with SS discharge and with total solid discharge is stronger than that with SS concentration. It is therefore conclude that the expansion and retraction dynamics of the saturated areas influences on the amount of transported sediment along the river, being constituted in important sediment-source area, because they are directly connected to the river course.

**Theoretical and methodical basis of study of granulometry as an indicator of formation conditions of modern and ancient alluvial deposits**

GILYAZOV A.

*KAZAN (VOLGA REGION) FEDERAL UNIVERSITY, KAZAN, RUSSIAN FEDERATION*

Modern geomorphology increasingly uses quantitative tools that allow making objective comparisons and conclusions. One group of such methods is associated with morphometric study of sediments. It includes granulometric, morphometric and textural analysis of the material in order to determination of its origins, the conditions of transport and accumulation, the intensity and direction of the various exogenous processes.

Granulometric analysis for determination of conditions of sediment formation (especially alluvial) is being developed for a relatively long time. But so far, there are only very general ideas that explain the variability in the size of transported and accumulated alluvial particles.

Granulometric features of alluvial deposits and river sediments are influenced by many factors. Importance of these factors varies: in different natural and anthropogenic conditions some of them are the leading factors that determine the appearance of the main features of granulometric of river sediments and alluvial deposits, and others create more subtle variations of these basic features. Investigations on similar subjects were only made at the local level. They considered only the individual factors affecting the granulometric of the alluvial material.

As part of this paper the posed problem is resolved on new level. Extensive quantitative data on granulometric of contemporary river sediments and ancient alluvial deposits in the former USSR have been summarized, mathematical-statistical model of size variability of river sediments and alluvial deposits as a function of landscape-climatic, lithological, orographic, and anthropogenic factors has been proposed.

The solution of this problem has palaeogeographical significance. Knowing the impact of various factors on the formation of granulometry of modern river sediments and floodplains, it is possible to reconstruct formation conditions of ancient alluvium.

\*\*\*\*\*

**The fluvial dynamic influences on evolution of the relief in the Pomba River Depression, Southeastern Brazil**

OLIVEIRA L., MAGALHÃES JÚNIOR A.

*Universidade Federal de Minas Gerais, BELO HORIZONTE, BRAZIL*

Located on the east region of Minas Gerais State, Southeastern Brazil, the upper Pomba River basin presents differences regarding the morphology, despite similar climate, lithology, and free of a recognized structural control. This suggests a decisive role of the fluvial processes on the genesis of two distinct morphological compartments: the Pomba River Depression and the Campos das Vertentes Plateau. Aiming to test this hypotheses, it was made the investigation, characterization, interpretation and dating by Optical Stimulated Luminescence (OSL) method of old fluvial sediments on the main valleys which drain both morphological compartments. The dating also showed that recently (less than 4,000 years), watercourses belonging to the Pomba River basin have captured channels situated at the Campos das Vertentes Plateau and belonging to the Doce River basin. These processes may be responsible for incorporation of Campos das Vertentes Plateau areas to the Pomba River basin, causing the retreat of the hydrographic divider, and contributing to retreat processes of the front escarpment. The recent incision of the upper watercourses suggests a continuing advancement of the Pomba River Depression on the Campos das Vertentes Plateau. Regionally, the fluvial geomorphology is marked by the occurrence of alluvial levels ~25 m above the present rivers on the valleys near the Serra da Mantiqueira scarp. It could be indicative that the depression expansion was refrained by the small rates of the front slope retreat, at least since the deposition of this fluvial level. The depression evolution towards the upper Pomba River basin may occur at bigger rates, what is suggested by the longitudinal profile of the main channel and by the propension of the upper basin to have its tributaries captured by the tributaries of the medium basin.

## **Geomorphological analysis of longitudinal profiles of the river valleys in the Northern Hemisphere**

SATDAROVA

*Kazan (Volga Region) Federal University, KAZAN, RUSSIAN FEDERATION*

The formation of the longitudinal profile of the river valley is an important issue of dynamic geomorphology. The longitudinal profile of the river is a very sensitive indicator of changes in the geographical environment. It is important to analyze the shape in various climatic and landscape conditions. Thus, the subject is to construct longitudinal profiles in different areas of the Northern Hemisphere and geomorphological analysis of their shape. Changes in the environment in the best way reflect the plain, zonal rivers of the middle length. Plotting of longitudinal profiles of the rivers is based on topographic maps, and digital elevation models.

Longitudinal profiles of the rivers can be classified according to various criteria. In our research the main criteria is a shape of longitudinal profile. Profiles are divided into 5 types: concave, convex, straight, stepped, complex (combination of different types).

Deformation of longitudinal profiles depends on many factors. These factors include: water flow, sediment flux, the rock composition, relief, tectonic movement, vegetation, and human activities. Best effect of these factors is shown in the lower reaches of the rivers. Statistical calculations make it possible to quantify the impact of given factors. The results of the research show that the greatest influence on the shape of the longitudinal profile and on its slopes have water flow and sediment flux, and the lowest – agricultural human activity.

Curvilinear correlation coefficient between water flow and the weight average of slope of the lower reaches of rivers is 0.73. The relationship between the sediment flux and the weight average of slope of the lower reaches of rivers is expressed quite clearly too. Curvilinear correlation coefficient is 0.60. Longitudinal profile changes slowly, and intensive human activities are not very affected its.

\*\*\*\*\*

## **Experimental assessment of the effectiveness of sediment transport estimates from morphological changes**

BERTOLDI W.(1), GARCIA LUGO G.A.(2)

*(1) University of Trento, TRENTO, ITALY ; (2) School of Geography, Queen Mary University of London, LONDON, UNITED KINGDOM*

We present preliminary results from a set of experiments conducted in the Hydraulic Laboratory, University of Trento. The experiments were aimed at modelling morphological dynamics and sediment transport processes in gravel-bed rivers characterised by different channel patterns. The investigation was carried out in a flume filled with uniform size sand (d<sub>50</sub> equal to 1 mm) scraped at a 1% longitudinal slope, where we changed the width of the channel (ranging from 0.15 to 1.5 m) and the water discharge (1.5 to 2.5 l/s). The set of runs covered different morphologies: narrow, flat bed channels, migrating alternate bars, transitional / wandering systems, and multichannel, braided networks. We monitored the experiments through continuous measurements of the sediment transport rate at the downstream end of the flume and with a high accuracy laser survey of the bed topography (on a point grid of 0.005 by 0.05 m). Two subsequent surveys were conducted for each experiment in order to estimate scour and deposition volume and spatial pattern.

The coupled measurements of bedload flux and morphological change allow the assessment of the effectiveness of sediment transport estimates from morphological budgeting, as well as the effect of different morphologies. In particular, the investigation will highlight the proportion of bed load flux not involved in morphological changes. Furthermore, the analysis will relate the spatial variability of scour/deposition sequences with the temporal fluctuations of the instantaneous transport rate.

### Hydrological impacts of floods in SE Spain, September 2012

KIRKBY M.(1), HOOKE J.(2), SMITH M.(1), BARBERA G.(3), GARCIA-PINTADO J.(4), BRACKEN L.(5)

(1) *University of Leeds, LEEDS, UNITED KINGDOM* ; (2) *University of Liverpool, LIVERPOOL, UNITED KINGDOM* ; (3) *CSIC-CEBAS, MURCIA, SPAIN* ; (4) *University of Reading, READING, UNITED KINGDOM* ; (5) *University of Durham, DURHAM, UNITED KINGDOM*

The recent floods in SE Spain have been the most severe since the well documented floods of 1973, associated with a daily rainfall in excess of 250mm. Detailed rainfall records in the Nogalte catchment from 1997-2007 showed a maximum daily rain of 120 mm, although this was not sufficient to cause widespread flow within the main river. Using rainfall radar, it has been possible to observe the pattern of storm movement and timing with much greater precision than in the past. Combining these data with detailed fieldwork on infiltration variability within the Nogalte, detailed modelling of overland flow dynamics, and a distributed post-flood survey to reconstruct peak flows across the catchment, it has been possible to identify the areas which produced the greatest runoff and hypothesise the timing of flood generation across the catchment. Results are compared to a analysis of small scale flooding that occurred in 1997. This allows us to evaluate the significance of remedial measures such as check dams, and changes in land use, notably an increasing area planted to almonds, on the generation of the flood, with implications for future practice.

\*\*\*\*\*

### Man activity affecting the river (dis)continuum system in the Moravskoslezské Beskydy Mts. and their forefield

SKARPICH V., HRADECKY J., DUSEK R.

*Department of Physical Geography and Geoecology, Faculty of Science, University of Ostrava, OSTRAVA, CZECH REPUBLIC*

Rivers draining the Czech part of the Flysch Carpathians have been deeply incised over the last 100 years. Regional geological settings predispose to large sediments supply in to the river systems. In case of the sediment deficit, river channels in the weak flysch bedrock are affected by high rates of incision. Focusing on the incision processes and causes affecting the sediment supply and transport through the river system, we studied the contemporary changes in the Morávka, Ostravice and Olše River basins. The highest rate of incision in the study area was recorded in the Morávka River basin – ca. 16 cm per year in the last 40-50 years. Mean value of incision in the Ostravice River basin is ca. 3.2 cm per year and ca. 1.2 cm per year in the Olše River basin. Main causes of the incision were identified as (i) decrease in sediment supply to the channels (related to the land use and land cover changes in the study area and to the man-made channel bank stabilizations, affecting the lateral connectivity in river system) and (ii) high number of barriers (dams or weirs), influencing the sediment transport through the river system in longitudinal direction. Present incision processes are accelerated by the synergy of the local geological conditions and increase in transport capacity of the rivers caused by channel narrowing and channelization.

### **Channel adjustments in a large gravel-bed river (Tagliamento River, Italy): what's the role of different sediment sources?**

SURIAN N., ZILIANI L.

*University of Padua, PADOVA, ITALY*

The general aim of this study is to explain channel adjustments and controlling factors in a large gravel-bed river. As for controlling factors, the aim is to assess the role of those acting at catchment and reach scales and then, more specifically, the role of upstream sediment sources (i.e. catchment area) versus local sediment sources (i.e. bank erosion). The Tagliamento River is large gravel-bed river in northeastern Italy; in the study reach, 49 km long, the morphology varies from braided to single-thread. Traditional methods for studying historical channel changes (i.e. use of aerial photos, topographic data, field surveys) were coupled with numerical modeling (use of CAESAR cellular model).

River channel underwent three main phases of adjustment over the last 200 years. The first two phases were characterized by narrowing (channel width decreased from 1250 to 540 m) and incision (about 1 m); the third phase, from the 1990s to present day, by widening (from 540 to 600 m) and slight aggradation (about 0.2 m). As for controlling factors, we argue that the long-term channel evolution of the Tagliamento River was driven primarily by human intervention at reach scale (i.e., sediment mining and channelization). Changes in sediment supply in the catchment area had no, or minor, effects in the study reach, though sediment connectivity is very high in this fluvial system. Sediment supply from bank erosion turned out to be a key factor of the most recent channel evolution. This case study shows that over relatively short time periods (i.e. decades) local sediment sources (i.e. bank erosion) can have a major role on channel processes, greater than upstream sediment sources. These conclusions are notable for making prediction on future channel evolution as well as for river management.

\*\*\*\*\*

### **Influence of bottom vegetation on sediment transport and morphodynamics**

LE BOUTEILLER C., VENDITTI J.

*Simon Fraser University, VANCOUVER, CANADA*

Vegetation growing on the bottom of a stream is a common feature in many rivers. It interacts both with the water flow and with sediment transport. As a result, local morphodynamics are modified.

In order to investigate the effect of bottom vegetation on sediment transport, we perform a series of experiments in a 12-meter long and 1-meter wide flume. Flexible vegetation, made of plastic blades, is attached on the bed over a 6-meter long section. The sediment used for the experiment is fine sand with a D50 of 0.15mm. Water and sediment are recirculated through the system. Low and high plant densities are used. For each flow, the experiment is run until a morphodynamic equilibrium can be defined.

Results show that the plant patch with a low density has little effect on the sediment transport. On the other hand, the sediment transport capacity is reduced in the high-density patch. This results first in deposition at the entrance of the plant patch. An equilibrium configuration allowing a uniform sediment flux in the flume is finally reached by an adjustment of the bed, with an increase of the bed slope in the plant patch.

We then partition the bottom shear stress in the vegetated section. The total stress is the sum of a form drag component, due to the bedforms and the vegetation, and of a skin friction component, which is the only component responsible for entraining sediment. As the vegetation density increases, the vegetation-induced form drag increases while the skin friction component decreases. That's why a higher slope is needed to accommodate a given sediment flux when vegetation is present.

Such findings indicate how morphodynamics react to changes in the vegetation coverage of a channel bottom. They will also be helpful to improve current 2D-morphodynamic models, which do not take into account properly the influence of bottom vegetation on sediment fluxes.

### **Sediment transfer assessment in Macaé River, Rio de Janeiro, Brazil**

AMADEU P., CABRAL J., LUCAS C., MÔNICA M.

*Universidade Federal do Rio de Janeiro, RIO DE JANEIRO, BRAZIL*

The knowledge of interaction of man within the landscape and the evolution of landscape has made increasingly part of the discussions in the environmental sciences, because of the growing concern over the conditions of natural environments, requiring further studies hydrosedimentological and on connectivity of landscapes. The research was done in the Macaé river, northern state of Rio de Janeiro, characterized by different fluvial environments but is largely rectified in the areas of lowland and in the higher parts there are strong influences of the activities of agriculture, industry and tourism. The aims to assessment transfer of fluvial sediments, in the longitudinal dimension of the channel. The methodology of the study was based on analysis of load and suspended sediments collected in field work between the 5-year (October 2007 to October 2012), with analysis in the laboratory to the load sediments and suspended sediment. The analysis of hydrological data of rainfall and fluvial discharge was sourced from the site HIDROWEB, ANA (National Water Agency). Furthermore, were used images of Google Earth (1:10.000) for the 2003, 2006 and 2010 years to the sectorization of fluvial environments. The Macaé river has four fluvial environments with distinct behaviors of sediments transfer and can be characterized as partially connected. The most sediment retention tends to concentrate in the medium course of the river, with presence of sandy depositional features (lateral, longitudinal, submerged) due geomorphological conditions of the area, as sinuosity, slope, providing small transport coarse sediment, except in extreme events. The understanding of the relationship between environments can be a indicator of possible imbalances in the internal system as well as the consequences of the changes introduced in the environmental system, are needed for studies involving better ways of planning and management for the watershed.

\*\*\*\*\*

### **Quantifying fluvial sediment transport in a mountain catchment in Upper Styria (Austria) using sediment impact sensors**

SASS O.(1), STANGL J.(2), SCHNEIDER J.(3), HARB G.(3)

*(1) Institut f\_r Geographie und Raumforschung, GRAZ, AUSTRIA ; (2) Institut f?r Geographie und Raumforschung, GRAZ, AUSTRIA ; (3) Institut fuer Wasserbau, GRAZ, AUSTRIA*

Sediment transport in river systems is a recurrent problem for geomorphological sediment budget studies, natural hazard assessment and river engineering. However, bedload measurements at alpine torrents are rare; in Styria, they are altogether missing. Due to a catastrophic flooding event in 2011, we chose the catchment of the Schöttlbach in the upper Mur river valley as our study area. In the framework of the ClimCatch project, we aim to develop a conceptual model of coupled and decoupled sediment routing to quantify the most prominent sediment fluxes and sediment sinks, combining geomorphological and river engineering techniques. Diachronous Airborne and Terrestrial Laser Scans provide an overview of mass fluxes on the slopes and in the channels while ground-penetrating radar and 2D-surveys aim at quantifying the volume of temporary sediment stores. The total output of the catchment is quantified by means of repeated surveys of a sediment retention basin at the outlet.

Besides sediment sinks and total sediment output, sediment transport in the torrents is of particular interest. We use sediment impact sensors (SIS) which were installed in several river sections in the main stretch of the Schöttlbach and in its tributaries. The SIS consist of an acceleration sensor installed underneath a steel plate mounted in the riverbed. The number of clast impacts is recorded in a nearby logger-case. Our measurements focus on the representative sub-catchments and deliver values on the in- and output of river sections. Tests and calibration have been carried out in an artificial channel at the Water Engineering laboratory of the TU Graz; the sensors are sensitive enough to record impacts of particles > 5 mm. The SIS were installed in winter 2012/13; further calibrations are currently carried out in the field using mobile basket samplers. First results allow us to derive the start of sediment transport in dependence of precipitation and runoff.

## **Dynamic of sediments monitoring by terrestrial laserscanner, application to quantify sediment yield of four torrents in French Alps**

BERTHET J., ASTRADE L., JAILLET S., PLOYON E.  
*Edytem, LE BOURGET DU LAC, FRANCE*

High resolution topography modeling by terrestrial laserscan (TLS) is becoming a commonly used tool in fluvial geomorphology. The main goal of this method is to make diachronic comparisons, then quantify accurately sediment dynamic or survey changing channel morphology of a delimited river section. The general aims of our research are to get thesediment budgets of four torrents in the French Alps (Creusaz and Arveyron d'Argentière, in Mont-Blanc massif, Glacière in Chartreuse massif and Lampe in Vercors massif), to attempt to extrapolate results to quantify sediment yield in order to have a better understanding of the coupling processes between channels and hillslopes. We have tried to acquire one or two topographic models foreach year. Reaches studied are between 150 and 400 meters long and 5 and 40 meters wide. Sediment transport can be proceeded by debris flows (Lampe and Glacière) or bedload (Creusaz and Arveyron). Torrents may also be held by dikes and checks dams or still be a natural stream. Thus, diversity of environmental requirement is an important parameter which will influence data quality.

Results differ depending on which torrent is studied. Concerning Lampe torrent, where the topographic follow up began in 2004, the diachronic comparison of models shows outstanding movement of debris flows. Sediment yield is relatively easy to understand. Concerning Mont-Blanc massif, the first TLS model is three years old. We have also included in our results other previous data as GPS or aerial LIDAR topographic models. On these latter torrents, channel changing is more complex and the interpretation of theresults has to involve the importance of sediment management. Almost each autumn, between 50cm to 1m of gravels is extracted on the downstream of the Creusaz reach. But as the floor level is the same at the beginning ofeach summer, before flood events, we can estimate and compare the volume of sediment deposits.

\*\*\*\*\*

## **Suspended Sediment Yield in a Subtropical Watershed**

OLIVEIRA F., HAAK L.  
*Federal University of Parana, CURITIBA, BRAZIL*

The study aimed to analyze the variation of suspended sediment yield at different points of the 88 km long Cubatão River and its main tributary, located in Santa Catarina State, southern Brazil. The 490 km<sup>2</sup> watershed is composed mainly by three different environments: the coastal plain, the scarps of the Serra do Mar mountain range and the Atlantic Plateau, with an altitude variation of 1,500 m. The diversity of structural and morphological features has strong influence in the rain distribution pattern, in the vegetation distribution and organization of the drainage network. Those conditions, on its turn, influence river dynamics which reflects on discharge and suspended sediment yield patterns. Discharge, turbidity and suspended sediment concentration were monitored monthly over a period of five years at three different points along the Cubatão River, located in the plateau (point 1), at base of the escarpments (point 2) and at the border of the coastal plain (point 3), as well as at one point in its main tributary located just before their confluence (point 4). Results indicate a clear distinct hydrological and hydrossedimentological behavior within the watershed, with substantially different suspended sediment yield patterns. Suspended sediment concentration may proportionally decrease or increase with discharge variation at the different monitoring points. On the other hand, general suspended sediment yield per unit area decreases from the plateau to the coastal plain despite the increase of drainage area and number of tributaries. Differences in suspended sediment concentrations at the monitoring points can be related not only to relief structure and pluviometric distribution, but also to land use characteristics.

### **Sediment transport by tidal river management**

KEESSTRA S.(1), VAN MINNEN J.(1), DE DIE L.(1), KHAN S.A.(2), WESTER F.(1)

(1) Wageningen University, WAGENINGEN, NETHERLANDS ; (2) Bangladesh University of Engineering and Technology, DAHKA, BANGLADESH

Bangladesh forms part of the largest fluvio-deltaic system in the world, the Ganges-Brahmaputra-Meghna delta. The delta receives sediment from both rivers draining the Himalayas and from the sea with tidal rivers as transporters. In this study we focused on the sediment dynamics by tidal river management in a tidal river in the south west delta between Khulna and Jessore.

In this complex system, the sediment dynamics are dependent on three major factors: (1) tidal range, (2) the area to which the water can flow to, and (3) the sediment load of the water. In addition there are factors changing over longer time spans that influence the sediment dynamics, the height of the low and high tide both at regular days and during spring and neap tide; and the strong seasonality in rainfall due to the monsoonal character of the climate. After the coastal embankment project which separated the river from the flood plains, the river channel silted up due to decreased flow velocity of the water. The river bed became higher than the elevation of the adjacent low-lying lands, locally called *beels*. This caused serious drainage problems in the area due to higher drainage basis of the rivers.

To create a higher flow velocity with the intention to erode the deposited material in the river channels, a group of farmers decided to cut the embankment and open one of the *beels* along the tidal river, thereby creating a so-called *tidal basin*. This paper analyses whether this works in terms of lowering the drainage basis and providing a better livelihood for the people living in the polders or surrounding the *beels*. We have looked at the sediment dynamics both in the tidal basin and the tidal river up and downstream of the tidal basin. In the tidal basin we assessed which parameters influence the sedimentation and how the sediment was distributed in the tidal basin; and how this variable sedimentation might influence the redevelopment of the area when the tidal basin will be silted up.

\*\*\*\*\*

### **Analysis of the flow of suspended sediments from the behavior of the variation of water stain in the region of the confluence of the Negro and Solimoes-Amazonas Rivers, Amazonia, Brazil**

PIMENTEL MARINHO T.(1), FILIZOLA N.(1), SANTOS A.L.(2), NASCIMENTO A.(1), JEAN-MICHEL M.(3), COCHNEAU G.(4)

(1) Universidade Federal do Amazonas, MANAUS-AM, BRAZIL ; (2) SERVIÇO GEOLÓGICO DO BRASIL/CPRM, MANAUS-AM, BRAZIL ; (3) INSTITUT DE RECHERCHE POUR LE DEVELOPPEMENT/IRD, TOULOUSE, FRANCE ; (4) INSTITUT DE RECHERCHE POUR LE DEVELOPPEMENT/IRD, BRASÍLIA-DF, BRAZIL

This work contributes to spatial hydrology studies and is presented here as an alternative to monitor the concentrations of suspended sediments in the Amazon Basin. The analyses focus on the study of the phenomenon of the confluence of the Negro River (black water) and the Solimões-Amazonas River (white water). For the analyses we used images from the Terra and Aqua satellites, MODIS sensor, which presents significant advantages in terms of temporal resolution in relation to other sensors used for studies of Amazonian rivers (NOVO et al, 2007; MARTINEZ et al 2009, ESPINOZA et al 2009). In the region of confluence, we observed the variability of the river's own section along the length (difference in length between the black and white water portions). This was done in a predetermined area in order to assess both the dimensions of the mixing zone and the variability of suspended sediment concentration. This assessment was conducted by studying an area at the end of the confluence near Itacoatiara town, where one of the clippings of the MODIS Project ORE-HYBAM is ([www.ore-hybam.org](http://www.ore-hybam.org)). This clipping contains a series of spatial data for the period 2000 to 2012. The section was divided into three masks representing black water, white water and the mixing zone. The images were treated and processed using specific software (GETMODIS and MOD3R), developed for the BRO-HYBAM Project. The initial results obtained from the correlation between the data of infrared reflectance of the two rivers and the given quota of the Manaus station show the existent relationships between a strong suspended sediment load from the Solimões-Amazonas River and the very low load of the Negro River. These relationships have very important annual variability that visually mark the hydraulic dam effect existent in this area. (MEADE et al., 1991 and STERNBERG, 1998).

**Geomorphic analysis of the ephemeral stream distributary systems of the Kobo basin (northern Ethiopia)***BILLI P.(1), CIAMPALINI R.(2)**(1) Dipartimento di Scienze della Terra, FERRARA, ITALY ; (2) INRA, US InfoSol, ORLEANS, FRANCE*

Drylands cover one-third of the Earth's surface (Zekai, 2008) and about half of the countries in the world must deal with arid and semi-arid conditions and water supply problems (UNESCO, 1977). Ephemeral streams are a distinctive feature of drylands and are distinguished by high flow variability, as they are dry for most of the year but subjected to sporadic and intense flash floods in response to localized, heavy rainstorms (Knighton and Nanson, 1997). These extreme hydrological conditions provide ephemeral streams with peculiar channel morphology, dynamics and sediment transport processes (Tooth, 2000).

This study deals with the geomorphic features of the ephemeral streams of the Kobo basin (Wollo, Ethiopia), that is a typical, recent structural basin associated with the development of the Danakil branch of the Ethiopian rift. All the ephemeral streams, but one, draining the basin margins end up in the basin floor where they form large distributary systems. Aim of this study is to investigate the control on the geomorphic parameters and geometry of these distributary systems by their catchment characteristics such as area, slope, drainage density, slope gradient and length, hierarchization and the channel feeder main characteristics such as width, gradient and streambed sediment. The results show that the coupling of the geomorphic features of the upstream portion of the river system and the geometry of the distributary system provides an efficient network for describing the development of ephemeral streams, their distributary systems and their channel dynamics. This study shed some light on poorly known geomorphic agents like ephemeral streams and gets an insight into crucial information for a more efficient land management and flash floods effects mitigation.

Finally, the geomorphic features of the distributary systems of the Kobo basin ephemeral streams are compared with those observed on Mars to test the hydrologic origin of the latter.

\*\*\*\*\*

**Reach-scale morphological changes of a braided river following a 15-year flood with multitemporal airborne LiDAR***LALLIAS-TACON S.(1), LIEBAULT F.(1), PIEGAY H.(2)**(1) Irstea, SAINT-MARTIN-D'HERES, FRANCE ; (2) University of Lyon, CNRS-UMR 5600, LYON, FRANCE*

In this study, multitemporal airborne LiDAR surveys were used to reconstruct reach-scale morphological changes of a gravel-bed braided river following a channel-forming flood event. LiDAR surveys covered a 7-km reach of the Bès River, a very active aggrading braided channel in the Southern French Prealps. The site was surveyed in October 2008 and April 2010. Between these two dates, a 15-year flood occurred in December 2009, with a peakflow discharge of 171 m<sup>3</sup> s<sup>-1</sup>.

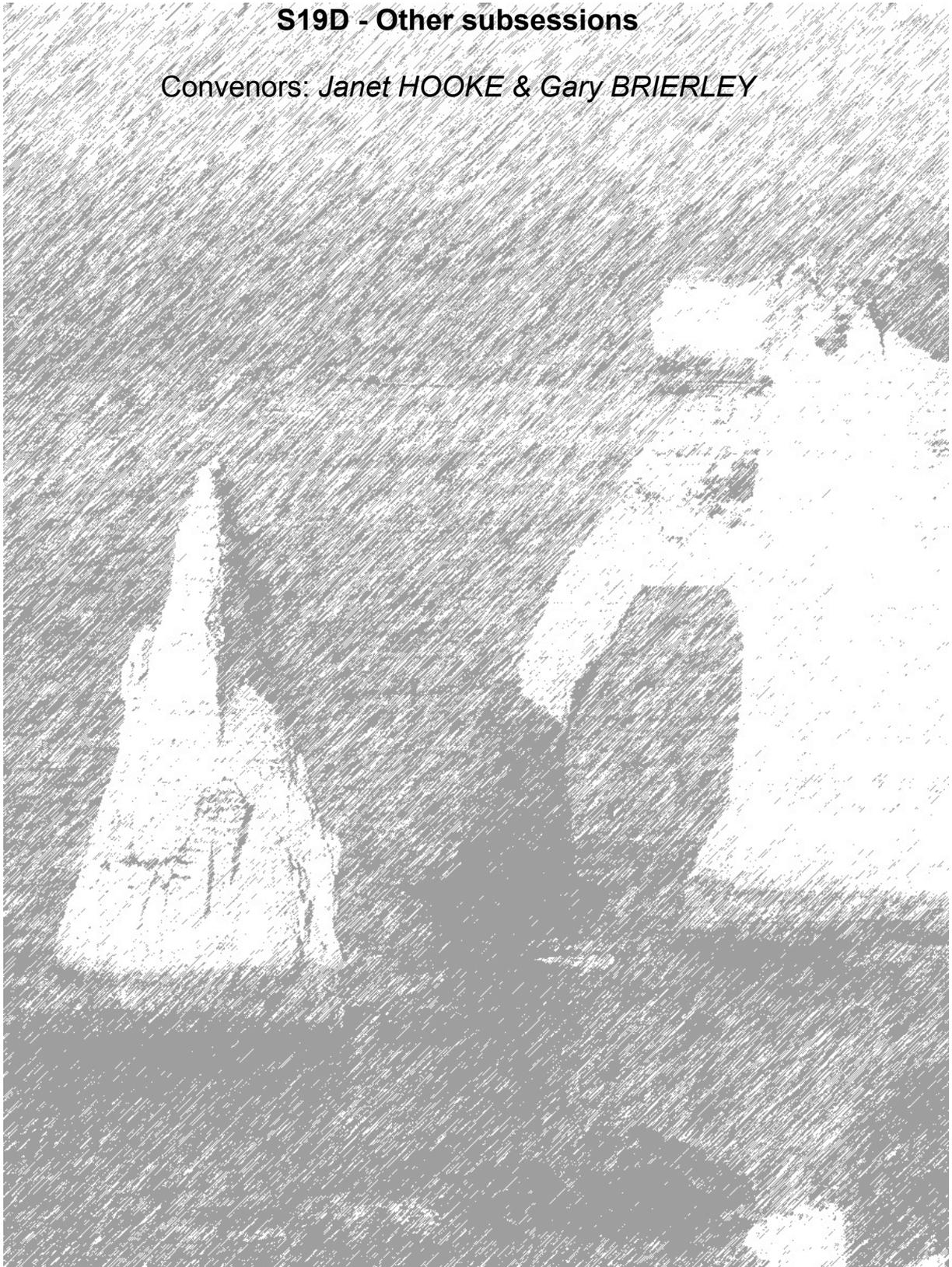
LiDAR data processing shows that the two LiDAR surveys were not correctly merged altimetrically and planimetrically. The re-alignment of the two LiDAR surveys was done by selecting stable surfaces. Spatially distributed error in DEM of difference was accounted with dGPS field measurements by sampling different types of terrains, i.e. road, fine and coarse exposed gravel bars, sparse and dense vegetated areas, and alluvial forest. Elevation comparison shows that LiDAR-derived elevations of 2010 overestimate systematically dGPS elevation measures of about 7 cm on the road. This systematic error as well as the standard deviation increase with surfaces complexity, i.e. increase of vegetation density and surface slope. For each combination of terrain, a critical threshold error of morphological change was calculated.

The scour and fill map provided by the calculation of the elevation differences done after correction between the two DEM shows that the Bès River underwent significant morphological changes during the December 2009 flood, e.g. bank erosion, channel scour and fill. Fill occurred on surfaces characterized by low relative elevations in 2008. Two types of scour are characterized: bank erosion and bar sculpting. Scour/fill sequences are clearly observable along the streamwise direction, showing a longitudinal periodic signal of sediment budget due to alternating sequences of erosion-deposition. A Fast Fourier Transform gives a period of 665 m, which represents 5 times the mean active channel width.



**S19D - Other subsessions**

Convenors: *Janet HOOKE & Gary BRIERLEY*





## **Oral presentations:**

### **A philosophy of rivers**

NANSON G.(1), HUANG H.Q.(2)

(1) *Univeristy of Wollongong, WOLLONGONG, AUSTRALIA* ; (2) *Cinese Academy of Sciences, BEIJING, CHINA*

Underlying the study of fluvial geomorphology has been the desire to understand the fundamental behaviour of rivers and hence predict their adjustment for purposes of management. Resolving the physical laws governing forces and motions has been prevented by a lack of mathematical closure, hence variational approaches have been adopted whereby assumptions are made regarding possible optimum operating states (extremal hypotheses). However, until recently there has been no logical basis to justify selecting any one of these. By a mathematical 'sleight of hand', the channel form ratio ( $w/d$ ) has reduced the number of variables and merged Newtonian and variational approaches, showing that rivers are controlled by the *least action principle*. Alluvial rivers evolve teleomatically and iteratively via various forms of *dynamic equilibrium* towards progressively more stable states, *stationary equilibrium* being the most stable and the ultimate attractor. In rivers this is 'survival of the most stable', comparable to biological evolution's 'survival of the fittest'. In clean water this ultimate state occurs at Froude No 1; in rivers transporting bedload it occurs at H No 0.3. Correcting earlier versions of the Meyer-Peter Müller bedload equation with the H number, and using field data from the Yangtze River, we show this large river adjusts its channel morphology to *maximum flow efficiency* (transporting its imposed bedload with the least amount of power). This approach greatly expands an understanding of the dynamics of rivers and shows them to be controlled by least action. This for the first time provides a simple means of quantitatively measuring and defining a river's equilibrium state. It opens the way for predicting channel adjustment and river management in different environmental settings and shows why rivers are rarely straight but adopt various dynamic forms from steep step-pools to gentle anastomosing systems.

\*\*\*\*\*

### **Bedload dynamics in gravel bed rivers**

PETIT F., HALLOT E., PEETERS A., LEVECQ Y., HOUBRECHTS G.

*University of Liege, LIEGE, BELGIUM*

The aim of this research was threefold: 1) to improve the values of bedload mobilisation discharge in gravel bed rivers, 2) to determine the bedload velocity over the short and long term and 3) to quantify bedload transport and to examine bedload discharge in relation to the stream power and to the excess stream power.

Since 2006, we used the PIT-tag technique in order to mark pebbles from Ardennian rivers. Ten rivers of different geomorphological properties were fitted out with PIT-tags (in 18 different sites) and 67 surveys were carried out after hydrological events.

These data allow a valuable relationship between the stream power during floods and the size of the biggest elements mobilised to be proposed. This relation is obtained for medium sized rivers (50-200 km<sup>2</sup>) with bed material composed of gravel ( $D_{50}$  between 2 and 10 cm).

Furthermore, we also obtained good relationships between the average transport distance and the excess of stream power reached during the hydrological events. In order to estimate the bedload virtual velocity over a longer time scale, we applied these relationships to the hydrological events recorded by gauging stations over more than 30 years. We obtained values of virtual velocity which are between 2 km/century for a low energy river with a sinuous bed and well developed riffle-pool sequences (Rulles River – 33 W/m<sup>2</sup> at  $Q_b$ ) and 11 km/century in a more powerful river with a straight channel (Aisne River – 81 W/m<sup>2</sup> at  $Q_b$ ) and a sub-flat bed. The propagation velocity of bedload is therefore influenced by the energy available. However, it is also necessary to take into account the river pattern, the characteristics of the armoured layer and the presence of potential trapping sites.

### **Measuring and modeling of basalt pebble abrasion in the Williams River, Australia**

SZABO T.(1), FITYUS S.(2), DOMOKOS G.(1)

(1) *Budapest University of Technology and Economics, BUDAPEST, HUNGARY* ; (2) *The University of Newcastle, NEWCASTLE, AUSTRALIA*

The phenomenon of downstream fining in gravel-bed rivers has been attributed to two main processes: size-selective transport and abrasion. In most of the studies, the latter process is considered to be inappropriate to explain the observed strong size reduction, because measurable laboratory abrasion rates are too small. However, a few researchers pointed out that abrasion-in-place processes as an additional abrasion mechanism may be dominant in a real river.

We collected basalt particles along a 100 km reach of the Williams River, New South Wales, Australia and measured the size and shape of them. Firstly, we show that abrasion is clearly important in our case because we found pebble shapes similar to ventifacts (sometimes called aquafacts) at the lower part of the river. These shapes are formed by the "sandblasting" effect of the over-passing suspended load. Secondly, we present statistical results on the downstream variation of grain shape and size along the river. Size variation follows an exponential decrease with a small diminution coefficient which also suggests that abrasion alone is capable to explain the observed size reduction.

Since most of the studies emphasize the role of size-selective transport in gravel-bed rivers, numerical models found in the literature only consider sorting as the fining mechanism. Therefore, based on the field observations, we present a new numerical abrasion model to reconstruct the downstream variation in grain size and shape in the Williams River. The model relies on a recent theoretical result describing the collective evolution of size and shape in large pebble collections as a Markov process, due to mutual abrasion and friction. Model results verify that abrasion is sufficient to produce the desirable exponential downstream fining, at least for small diminution coefficients. The new numerical model is expandable and transparent, so it is easily adaptable to other sedimentary environments as well.

\*\*\*\*\*

### **In-Channel Fine Sediment Retention and Dynamics: A Review**

STEWARTSON M., RUTHERFURD I.

*The University of Melbourne, MELBOURNE UNIVERSITY, AUSTRALIA*

Fine sediment dynamics in catchments has an important influence on river ecosystem and human health. Contaminants such as pathogens and micropollutants can be attached to fine sediments and their transport, fate and biogeochemical environment in which they might be transformed is dependent on fine sediment dynamics. Further, fine particulate organic matter transported through the river network can support riverine foodwebs through uptake by heterotrophic bacteria. For catchment-scale modeling of sediment budgets, it is commonly assumed that fine sediment delivered to a river network is transported directly to receiving waters or deposited on floodplains during overbank events. In reality, fine sediments can be stored within channels for example in slackwaters, artificial impoundments and the streambed. These fine sediment stores often have physical and chemical properties that support distinct biotic communities. Understanding fine sediment retention and its distribution at the reach and catchment and scales is important for managing riverine landscapes. This paper reviews the literature to establish the current knowledge of magnitude, residence time and longitudinal distribution of these storages within catchments. A conceptual model is presented as a basis for hypothesis development and testing.

### The impacts of climatically-driven hydrological change upon sediment flux in Alpine river basins

LANE S.N.(1), BALIN D.(2), LOVIS B.(2), MICHELETTI N.(2)

(1) IGD, Université de Lausanne, LAUSANNE, SWITZERLAND ; (2) IGD, Université de Lausanne, LAUSANNE, SWITZERLAND

Both future temperature and precipitation changes could have a dramatic impact upon the geomorphic response of high mountain river basins. The availability of historical climate records and aerial image archives since the 1940s now provides the opportunity to investigate over the recent past the forcing of geomorphic systems by rapid climate change, of importance because very few studies have disentangled the signature of such change in geomorphic records. Here we consider an Alpine river basin (altitude c. 1,200 m to 3,005 m), with very little direct human impact, but where there is excellent archival imagery. The imagery reveals three distinct phases of river basin change each period corresponding almost exactly to periods of known climatic warming/cooling in the last 5 decades of the 20<sup>th</sup> Century. To evaluate this climate forcing, we test a set of plausible hypotheses using mathematical modelling. To assess possible changes in sediment production activity, we apply the 1D heat diffusion equation to the basin scale, driven using historical temperature records. This shows that one plausible explanation remains decreases/increases in the percentage of the sediment supply zone that is frozen during warming/cooling periods. To assess changes in sediment transport capacity, we apply a multi-fraction sediment transport model to the predictions from a reconstruction of basin hydrological response that begins in 1940. This reveals systematic changes in hydrological response which, notably because of non-linearities in the transport equations, translates into dramatic changes in sediment transport capacity that mirror those of possible temperature driven changes in sediment production. Thus, both of these hypotheses remain plausible and it is possible that they act synergistically to cause rapid and dramatic changes in basin sediment state. Thus, understanding climate impacts on geomorphic response requires coupled temperature-precipitation effects to be considered.

\*\*\*\*\*

### Quantifying spatial and temporal variations of specific event sediment yields in different climatic zones

GAO P.(1), NEARING M.(2), HICKS M.(3)

(1) Syracuse University, SYRACUSE, NEW YORK, UNITED STATES ; (2) USDA-ARS Southwest Watershed Research Center, TUCSON, AZ, 85719, UNITED STATES ; (3) NIWA, Box 8602, CHRISTCHURCH 8440, NEW ZEALAND

The spatial and temporal variations of suspended sediment (SS) in areas of different climates have been widely studied in term of the relationship between specific sediment yields (SSY) and watershed areas (A). However, such relationship changes as watersheds change from one climatic to another zone, which leads to both uncertainty and difficulty in quantifying the SSY-A relationship. This study introduces an alternative approach to quantifying the distinct characteristics of SS transport among different climatic zones. First, we show that in many arid and semi-arid regions of the world, SS transport in watersheds with various sizes can be generally quantified by a simple proportional relationship between event specific sediment yield ( $SSY_e$ , t/km<sup>2</sup>) and runoff depth ( $h$ , mm). The constant,  $m$  (kg/m<sup>3</sup>) is physically equivalent to the discharge-weighted event mean sediment concentration. For 15 watersheds from semi-arid American southwest, southern Italy, and Algeria with areas approximately ranging from 0.01 to 500 km<sup>2</sup>, values of  $m$  range from 11 to 34 with the average of 19 kg/m<sup>3</sup> suggesting that  $m$  remains roughly constant across all watersheds and hence reflects the common nature of SS transport in these semi-arid areas. Second, we show that the range of  $m$  values in these watersheds is significantly lower than that (around 700 kg/m<sup>3</sup>) of watersheds in the loess area of China where SS is transported through hyperconcentrated flows suggesting the powerful role of  $m$  in distinguishing different processes of SS transport. Third, we further demonstrate that the proportional relationship also sustains in 9 watersheds of humid regions with variable areas from 1 to 600 km<sup>2</sup> and the values of  $m$  are limited in the lower range between 0.1 and 5. These results clearly reveal that the proportional relationship and the associated constant  $m$  can be used to distinguish different patterns of SS transport in different climatic zones.

**Modern depositional processes in a confined, flood prone setting: benches of the Shoalhaven River, NSW, Australia**

KERMODE S.J.(1), COHEN T.J.(2), REINFELDS I.V.(3), NANSON G.C.(2), JONES B.G.(2)

(1) University of Wollongong, Australian Nuclear Science and Technology Organisation, WOLLONGONG, AUSTRALIA ; (2) University of Wollongong, WOLLONGONG, AUSTRALIA ; (3) NSW Office of Water, WOLLONGONG, AUSTRALIA

The lower Shoalhaven River provides an opportunity to examine bench processes in a confined setting. Stratigraphic analysis of trenches and auger holes, ground penetrating radar, Hec-RAS modelling and geochronological techniques combine to identify that benches of multiple levels along Bull Reach are composed of coarse material and have been extensively eroded and reworked by modern events. Kermode et al. (2012) established the long-term polycyclical nature of the higher alluvial surfaces (up to 193 ka in age), and this is contrasted with the youth of the lower inset alluvial surfaces, which are shown to be less than 270 years in age.

This study evaluates the relative significance of both flood regime and effects of European settlement on the geomorphic effectiveness of high magnitude events and investigates the characteristics of bench formation in this confined setting. It characterises the nature of depositional events and the relationship between facies at an event scale. Using Hec-RAS modelling, events of different recurrence intervals are compared to explore the relative impact of varying flood magnitudes. The results bring into question the theory that inundation frequencies of these surfaces are constant, or associated with formative processes.

\*\*\*\*\*

**Valley floor changes along and adjacent to the Baviaanskloof River, Eastern Cape Province, South Africa: Testing confinement**

SMITH-ADAO L.(1), ROWNTREE K.(2), NEL J.(1)

(1) CSIR, NRE, CAPE TOWN, SOUTH AFRICA ; (2) Rhodes University, Geography Department, GRAHAMSTOWN, SOUTH AFRICA

Dryland environments describe the world's hyper-arid, arid, semi-arid and dry-subhumid regions. These regions are seldom seen as priorities for research because of their harsh climates, widespread distribution and limited resources. They are generally poorly understood. Local knowledge of physical processes operating in South African dryland fluvial systems is fragmentary and matches these global trends. River system function and structure are strongly linked to the catchment of which they are a part of. Catchment and channel variables are important in controlling the biophysical characteristics of the valley floor within a spatiotemporal context. The former determine the runoff and sediment regime of the river while the latter control the stability of the channel. The degree of valley confinement in particular devises process-form connections along rivers. A pilot study in the Baviaanskloof revealed the interdependence of river valley morphology, surface-groundwater interactions and vegetation in narrow and wide valley sections. Testing this relationship further on the Baviaanskloof River proved to be suitable as alternating confined, semi-confined and unconfined reaches allow for expression of a wide range of physical forces and biological outcomes. The overall aim of the study was to examine the relationship between fluvial styles, valley floor morphology and vegetation distribution patterns in the semi-arid Baviaanskloof River catchment, South Africa. This study will contribute towards catchment rehabilitation and a long-term monitoring programme. Fieldwork commenced systematically down the valley at 14 study sites during a winter sampling programme, 2009 to 2010. Data collected across the valley floor included cross-sectional surveys, vegetation distribution, sedimentary characteristics (texture and chemistry) and groundwater levels. The methods and procedures that were used to collate the data are briefly discussed, together with detailed interpreted results.

### **Is braided river index only related to discharge and geomorphic activity? Feedbacks from thermal infrared remote sensing**

WAWRZY尼亚K V.(1), PIÉGAY H.(1), ALLEMAND P.(2), VAUDOR L.(1), GRANDJEAN P.(2)

(1) *Université de Lyon - CNRS UMR 5600 EVS, LYON, FRANCE* ; (2) *Université de Lyon - CNRS UMR 5276 LGL-TPE, LYON, FRANCE*

The study of braided rivers often referred to braided index as an indicator of the intensity of the braided activity. Historical geomorphology often used such index to explore how braided activity increased or decreased through time. More recently, some authors clearly related the braided index to the discharge from experimental approaches.

Nevertheless, neither the discharge nor the braided activity sometimes explain intense braided index at low flow. Some of the rivers can have a very dense braided pattern whereas others are limited to fast flowing channels. Braided patterns can be explained by different connections with groundwater. Herein in order to evaluate groundwater-fed channels, we used thermal infrared images because groundwater exhibits a different thermal signature from surface water. Acquisitions were performed during summer in 9 braided reaches located in the French Alps. We reported two types of thermal patterns. The first type showed very low thermal variability throughout the day. This low variability was linked to the little diversity found in the aquatic habitat, notably due to the proglacial regimes with high summer flows which homogenize water temperature. The second type exhibited a higher thermal variability with changes during the day. The temperature of flowing channels changed during the daytime according to the air temperature. In contrast, the temperature of channels only downstream connected to the main network exhibited smaller changes which created thermal variability over space and time associated with hyporheic or phreatic flows. These findings allow for a prediction of temperature heterogeneity based on time and the aquatic habitat diversity, notably the proportion of ponds, alluvial and groundwater channels. These results should have potential consequences for the implementation of the EU Water Framework Directive for targeting reaches for restoration and conservation.

\*\*\*\*\*

### **Experimental investigation into the impact of vegetation on fan morphology and flow**

CLARKE L., MCLELLAND S., COULTHARD T.

*University of Hull, HULL, UNITED KINGDOM*

Riparian vegetation can significantly influence the geomorphology of fluvial systems, however, there is still limited understanding of the role vegetation plays in the development of alluvial fans, despite the large number of vegetated fans in temperate and humid climates. An understanding of the feedback loops between water flow, sediment dynamics and vegetation is key to understanding the geomorphological response of alluvial fans. But it is difficult to investigate these relationships in the natural world due to the complexity of the geomorphic and biological processes and timescales involved.

To examine the effects of vegetation on channel form, flow dynamics and morphology during fan evolution a series of experiments were conducted using the Total Environment Simulator at the University of Hull. The experiments followed a 'similarity of processes' approach and not scaled to a specific field prototype. Live vegetation (alfalfa) was used to simulate the influence of vegetation on the fan development. Numerous plots were run using the same initial conditions and constant water discharge and sediment feed rates, but the vegetation density and amount of geomorphic time (times of active fan development) between seeding / vegetation growth varied between plots.

The fan morphology was recorded at regular intervals using a laser scanner and overhead photography to gain near-continuous data quantifying fan topography, flow patterns, channel migration and avulsion frequency. The use of these techniques allowed collection of high resolution spatial and temporal data on fan development with minimal disruption to the experiments.

The results of the preliminary experiments showed that vegetation did influence the morphology and flow conditions during fan evolution. Vegetation reduced the number of active channels, and increasing the vegetation density also led to lower lateral migration rates, the formation of narrower and deeper channels and an increase in fan slope.

### **The Fluvial Critical Zone ' the co-evolution of a geomorphic-vegetation-soil system**

BÄTZ N.(1), LANE S.(1), VERRECCHIA E.(2)

(1) *Institute of Geography and Sustainability - University of Lausanne, LAUSANNE, SWITZERLAND* ; (2) *Biogeosciences Laboratory - Institute of Earth Sciences - University of Lausanne, LAUSANNE, SWITZERLAND*

Traditionally, braided river research has considered flow and sediment transport processes and their linkages to river morphology. In the last two decades, research has been extended to the vegetation of the fluvial geomorphological system, recognising that vegetation dynamics can be as important as sediment dynamics in controlling braided river forms and processes. However, the role of soil has largely been overlooked. Research in more stable fluvial settings has described and quantified the nature of soils (e.g. terraces), but what is the role of soil in the transformation from an actively braiding river through stabilisation during vegetation development to a terrace system? Is soil simply passive and a consequence of vegetation development on a stabilising braid bar deposit, or is it actively involved in changing the timescales of system transformation? We present and test a conceptual model for the role of river-vegetation-soil interactions over timescales of decades rather than years. We studied the braided Allondon River, a protected nature reserve in the west of Canton Geneva, Switzerland, which comprises a braided river – terrace system, including active braiding processes, rapid vegetation colonisation, stabilisation of braid bar deposits, but also developing soil profiles. Whilst sediment stratification and topography modulate initial habitat properties and initial vegetation colonisation, soil forming processes, notably tied to organic matter accumulation, influence the succession speed and pathways. When combined with disturbance processes, this drives the spatial differentiation of the river-floodplain ecosystem. Overall, we can imagine this system as a 'fluvial critical zone' in which geomorphology, vegetation and soil co-evolve to create a diverse fluvial ecosystem. Given the importance of pedogenesis as a control on the rate of ecosystem change, it is critical to factor soil into questions regarding braided river management.

\*\*\*\*\*

### **Identifying channel incision and its hydraulic importance: examples from Polish Carpathian rivers**

WYZGA B.(1), ZAWIEJSKA J.(2), RADECKI-PAWLIK A.(3)

(1) *Institute of Nature Conservation, Polish Academy of Sciences, KRAKOW, POLAND* ; (2) *Institute of Geography, Pedagogical University, KRAKOW, POLAND* ; (3) *Department of Hydraulic Engineering and Geotechnique, Agricultural University, KRAKOW, POLAND*

Channel deepening may result from either channel incision or river metamorphosis changing a wide and shallow channel to the narrow and deep one. Only that first type of channel change leads to increased flow capacity of the channel. Therefore, a lowering of water stage associated with a given discharge rather than a lowering of river bed should be used to identify channel incision. A lowering of minimum annual stage at gauging stations is normally used to assess the relative importance of channel incision along a river or within a particular region. Rivers of the Polish Carpathians incised by 0.5-3.8 m over the 20th century, with greater incision in their middle and lower courses than in the upper ones. Variability in the hydraulic importance of channel incision with increasing river size was analysed by comparing changes in the frequency of valley floor inundation at gauging stations located along the 7th-order Dunajec River. Despite a lower nominal amount of channel incision in the upper river course, here incision has increased channel conveyance and reduced the frequency of valley floor inundation considerably more than in the lower course. Hydraulic effects of channel incision depend also on lateral stability of an incising river. Low-energy rivers from the eastern part of the Polish Carpathians remained laterally stable during channel incision. As a result, stages for low flood discharges have lowered substantially and less so for high-magnitude floods; and velocity of the flows conveyed over the highly elevated floodplains has become considerably lower. In high-energy rivers of the western part of the Polish Carpathians, incised meander belts were formed due to the alternation of incision and lateral channel migration. This has resulted in substantially lowered stages for all flood discharges and increased velocity of the flows conveyed over the newly-formed, low-lying floodplains.

**Anthropogenic intervention into the river pattern as a cause of the Ol'e River floodplain development change (with the use of magnetic susceptibility for the sedimentary record interpretation)**

CHUDANICOVA M., HRADECKY J., PANEK T.

*Department of Physical Geography and Geoecology, University of Ostrava, OSTRAVA, CZECH REPUBLIC*

Sedimentary records of the total six cores and two bank exposures were investigated in the Olše River floodplain. Set of laboratory analyses (magnetic susceptibility measurement, loss on ignition, grain-size analysis) were supported by study of the old maps, historical aerial photos and archive river management and flood records. From the historical records it is obvious that even at the beginning of the 20th century the river in the study area had braiding pattern with 100 to 300 m wide gravel streambed. In 1930s the natural stream was replaced by 28 m wide straightened artificial channel with vegetation enforcements and side channels were enclosed. After these modifications fine sediments were probably deposited on gravel bars of the former wide gravel streambed. Magnetic susceptibility (MS) measurements of upper fines of all investigated cores showed that these are very young because they were completely magnetically enhanced. MS is very sensitive to secondary ferrimagnetic iron oxides or ferromagnetic particles released into the environment especially during high-temperature combustion of fossil fuels, from road traffic or various waste-water outlets. Even several pieces of man made products like plasters and film plastic were found in fine sediments just above gravels. In 1962 flood defences were built at both sides of the channel which probably influenced sedimentation rates of the floodplain. Upper fine sediments of the investigated cores behind flood defences was up to 40 cm thick while the thickness of the inside flood defences fines was around 100 cm.

Further sedimentary record interpretation was based on the assumption that MS peak determines the 1980s, the time of the coal extraction, attached steel production and concentration of fly ashes culmination. This assumption was supported by <sup>137</sup>Cs dating of bank exposures. MS values were up to eight times higher than values from other localities in Czech Republic.

\*\*\*\*\*

**Changes of channel planform within anastomosing river system transformed by hydro technical works (the Odra River, W Poland)**

SLOWIK M.

*Adam Mickiewicz University, Department of Geographic and Geologic Sciences, POZNAN, POLAND*

The Odra River is one of the largest lowland rivers situated in W Poland. Its river bed was subjected to intensive hydro technical works. Three artificial canals were constructed in the middle course of the valley in the 19<sup>th</sup> century. Before that time, the Odra valley had been an enormous wetland. Historical maps indicate that various river planforms (multi-channel, meandering and "disappearing in wetlands") had been active here before the anthropogenic intervention.

GPR (ground penetrating radar) surveys ground-truthed by core data and analyses of satellite and aerial images were conducted to retrace the natural course of the river. The field works were carried out in four detailed study sites representing remains of former river patterns. The retraced channels indicate many features of an anastomosing pattern: low valley gradient, remains of floodbasins and high contents of muds and silts in the valley floor. Particular anabranches of the river were characterized by different patterns (meandering and multi-channel) depending on changes of the valley gradient and geology of particular sections of the valley. Moreover, traces of the river bed incision and transformation from meandering to multi-channel planform were found in W part of the valley, close to a canalized bifurcation to the Odra River. The transition and forming the bifurcation might have been caused by an intensive flood event. Its traces, marked by a distinct erosional surface, were discovered in the floodplain architecture.

The research provided a basis for river restoration projects that may be conducted in this area in the future. The results also show that anastomosing rivers had been active in Central Europe before they were transformed by hydro technical works. It is also indicated that relatively small anastomosing systems are easier to study than large rivers characterized by such planforms. They provide a great potential to study processes forming this unique type of river pattern.

### **Spatial and temporal variability of braided river bio-geomorphic patterns at the regional scale, the case of the French Rhône basin**

BELLETTI B.(1), DUFOUR S.(2), PIÉGAY H.(3)

(1) University of Florence, FLORENCE, ITALY ; (2) COSTEL CNRS UMR6554-LETG University of Rennes 2, RENNES, FRANCE ; (3) CNRS UMR5600-EVS University of Lyon, LYON, FRANCE

The French Rhône basin is characterised by several braided reaches, preserved from the widespread disappearing occurred in the XX century. Given the complexity of these river systems, an interdisciplinary project has been conducted to better understand their functioning and to support their management, according to the WFD. In that context, this work focussed on the characterisation of the braided reaches, in terms of aquatic habitat and riverscape patterns. We selected 53 braided reaches located in several geographical contexts and performed a comparison of their contemporary pattern and their evolution since the 1950s. The study is based on aerial photos from the French National Geographical Institute and applies remote-sensing techniques.

We observe that contemporary aquatic habitats and braiding pattern are controlled not only by the water discharge but also by the groundwater position and the connectivity to sediment sources.

From the 1950s to the 2000s, the overall pattern is evolving through a river narrowing but some reaches are still active and widened. The causes seem to be related to: (1) high magnitude and low frequency floods, (2) sediment regime, (3) geographical position in the catchment and (4) colonisation conditions for pioneer species.

We then focussed on 12 reaches, distributed into 4 main hydro-geographical regions, to better understand the role of major floods in the braided river evolution. We analysed the braiding width and the vegetation pattern evolution between five observation dates (1950 to 2000). We found that several evolution patterns exist, depending on (1) the combined effect of the floods (magnitude and duration), (2) the position of a reach in its temporal trajectory, and (3) the river catchment characteristics (i.e. sediment and hydro-climatic regimes).

Finally we make some considerations in terms of braided reach management (i.e. conservation, restoration) in the Rhône catchment, in terms of habitats and braided reach riverscape.

\*\*\*\*\*

### **Recent channel adjustments of major rivers in southern Apennines (Italy): a contribution to the understanding of fluvial response to human impact and climate change**

SCORPIO V.(1), AUCELLI P.(2), GIANO I.(3), PISANO L.(1), ROBUSTELLI G.(4), ROSSKOPF C.(1), SCHIATTARELLA M.(3)

(1) Università degli Studi del Molise, PESCHE, ISERNIA, ITALY ; (2) Università degli Studi di Napoli "Parthenope, NAPOLI, ITALY ; (3) Università degli Studi della Basilicata, POTENZA, ITALY ; (4) Università della Calabria, COSENZA, ITALY

As highlighted by several studies, many Italian rivers have been affected at least since the mid-1950s by relevant channel adjustments, mainly consisting in pattern changes, channel narrowing and lowering, which are largely thought to be controlled by human interventions on the catchments and/or directly on the river systems. This is true also for major rivers of southern Italy, but the case studies are still limited especially when compared to those available for central and northern Italy. Our contribution deals with the analysis of channel adjustments that have affected some of the major Southern Apennines rivers: the rivers Biferno, Trigno and Volturno (Molise), Calore (Campania), Fortore and Ofanto (Puglia), Sinni (Basilicata) and, finally, Crati and Savuto (Calabria) which during the last decades, have all been undergone some type of human intervention such as the construction of dams, in-channel mining, etc. Our reconstruction of channel adjustments is based on a multi-temporal analysis in a GIS environment of topographic maps, aerial photos and orthophotos carried out on selected river reaches, and on the assessment of their actual morphological setting and dynamics by means of field surveys and DGPS topographic measurements. The comparison of obtained results highlight a common evolutive trend consisting in pattern changes from braided to wandering or sinuous, a strong channel narrowing, mostly exceeding 80%, and a moderate to very high channel incision, while, concerning the last 10 years only, some of the investigated rivers, the Savuto and Crati rivers, appear to be affected by an inversion of this trend, consisting in channel enlargement and the increase of fluvial bars. In order to investigate on the possible influence of anthropic and natural factors, the relationships between the reconstructed channel modifications and the main interventions on single river systems at the channel scale and rainfall trends are analysed.

### **Morphological degradation and restoration of the Ahr river (Italian Alps) and their effect on riparian vegetation**

CAMPANA D., COMITI F., GIAMMARCHI F., TONON G.

*Free University of Bozen, BOLZANO, ITALY*

Over the last two centuries, the vast majority of rivers in the European Alps have undergone significant hydromorphological modifications due to land reclamation, flood mitigation, hydropower production and gravel mining. However, only few investigations have quantified such changes addressing also their impact on riparian vegetation growth.

The Ahr river (Eastern Italian Alps, drainage area 630 km<sup>2</sup>, 25 km<sup>2</sup> covered by glaciers) featured an anabranching pattern with the presence of large riparian areas during the 19<sup>th</sup> century, until the first half of the 20<sup>th</sup> century. Since the 1960s, the channel underwent intense variations as a result of gravel mining and sediment retention due to a hydropower dam and several check-dams along its tributaries. Bed incision followed by bank stabilization works led to a hydrological and morphological disconnection of the floodplain from the channel. Moreover, cross-section narrowing and deepening of the riverbed brought about bed armouring and reduction of morphological diversity, until several reaches of the river were restored by widening and raising the bed in the period 2003-2011.

Planimetric changes occurred in the Ahr were determined by the interpretation of 10 maps and aerial photos covering the period 1820-2011. Cross-sections derived from topographic surveys and from Lidar-DTM led to estimate the elevation of the different surfaces presents in the river corridor and thus to estimate the extent of vertical changes during the degradation phase. The effect of morphological degradation and restoration on the growth of the adjacent riparian forest is being monitored since spring 2011 through dendrochronological analysis of 3 tree species. Preliminary results indicate a different response to bed incision by the different species in terms of radial growth, whereas no effects are evident after the restoration works. However, these have increased the morphological diversity in terms of morphological units such bars and islands.

\*\*\*\*\*

### **Historical river channel change and stability in Irish catchments: implications for river management under the EU Water Framework Directive**

TURNER J.N., JONES A.F., HARVEY E.

*University College Dublin, DUBLIN, IRELAND*

An understanding of longer-term processes operating in river channels is necessary for effective river management and to assess potential response to environmental change. Evaluation of types and rates of lateral channel movement over historical timescales using temporal sequences of map and aerial photographic data has been undertaken in catchments worldwide. In Ireland such data are widely available but there have hitherto been few attempts to assess rates and patterns of historical river channel change, particularly at the catchment scale. This is in spite of the acknowledged differences between Irish rivers and those in other nearby regions, such as Britain, and a long history of intensive land use and channel engineering. This study aims to quantify historical lateral channel change in two major Irish river catchments, the Boyne and the Suir, to evaluate downstream variations in channel change in relation to controlling factors and to assess the impact of anthropogenic activity on channel position. Channel margins and islands have been digitized from historical maps and aerial photography to identify areas of erosion, deposition, artificially cut channel reaches and reaches abandoned during engineered realignment. Results are presented for 500 m reaches of the main rivers in each of the two catchments and are compared with channel sinuosity and gradient. Comparisons between individual sub-catchments and between the Boyne and the Suir show variation in the type and rates of channel change recorded, and in the degree and extent of anthropogenic modifications to the river channel. The implications of the history of channel change in Irish rivers are discussed in the context of contemporary typological characterisation and management objectives under the EU Water Framework Directive (2000/60EC).

**Detecting the Fluvial Channel Mobility and the Erosion Process Development for a Sustainable Management of the Mayo Tsanaga (North Cameroon)**

TEOUGAM N.(1), TCHAWA P.(2), TCHINDJANG M.(2)

(1) University of Maroua, MAROUA, CAMEROON ; (2) University of Yaoundé I, YAOUNDE, CAMEROON

Severe drought episodes, capricious rainfall and vegetation degradation have been identified as the main environmental problems facing the ecologically fragile Far-northern region of Cameroon. But a refined assessment of these problems has brought into light the issue of soil erosion along thirteen rivers and stream flowing from the foothills of the Mandara Mountains to the neighboring plains. The prominent and longest of these rivers is the Mayo Tsanaga, which constitutes an ideal laboratory for understanding how the geomorphic processes of fluvial erosion impacted the sustainable development of the bank land assets buffering in it mid-section 120 km. This major environmental problem compromises the sustainable development of the Maroua and its surrounding cities of Gazawa and Bogo. Field raw measurements performed in this research and analysis of data from different sources (aerial photographs, topographic maps, Google Earth images) show that the width of some channel sections has grown from less than 10 to more than 100 meters over a 50-years period. The result is the increase in the valley width combined to the unpredictable trend of channel migration also providing striking footprints of erosion patterns along the river banks. Also, land uses on the channel buffers and river banks show evident signs of multiple infrastructural degradations, such as soil degradation of farm lands, local disruptions of water pipes and electric cable systems, collapse or severe damaging of many residential properties, and degradation of terrestrial communication infrastructures (roads and bridges) crossing the Mayo Tsanaga river. Consequently, fluvial dynamics has increased as bank erosion and accumulation profiles have gained length. Overall, the last 50 years meander divagation of the Mayo Tsanaga river indicates an increasing mobility if its channel and the degradation of its banks due to erosion.

\*\*\*\*\*

**Catchment-scale versus site-scale controls on flood impact: Flooding in northern Victoria, Australia in 2010 to 2012**

MARREN P.(1), ZOLJAN S.(1), SMITH H.(2), TEO E.(1)

(1) University of Melbourne, PARKVILLE, AUSTRALIA ; (2) University of Plymouth, PLYMOUTH, UNITED KINGDOM

After a decade of drought, repeated extreme rainfall events occurred over northern Victoria, Australia in September, October and December 2010, January 2011 and March 2012. These floods caused widespread erosion and channel change, although the impact of the floods was variable, both within and between catchments. This study examines the relative role of catchment-scale processes such as downstream stream power changes, and site-scale controls such as riparian vegetation and channel management history in determining the nature and extent of erosion following these floods. We also examined the roles of event duration and event ordering in controlling flood impact.

A combination of pre-flood survey data, aerial photography and LiDAR data, and post-flood surveys and aerial photography allowed us to map the extent of erosion in the King River and Corryong Creek, tributaries of the Murray River located in northeast Victoria. Erosion was correlated with stream power, vegetation and site-specific factors. We found that there was a general correspondence between stream power and erosion intensity at the catchment scale, but at the reach scale, there was a poor correlation between erosion and stream power. Sites with intermediate unit stream powers ( $300-600 \text{ Wm}^{-2}$ ) only had extensive erosion when floods persisted for more than 36 hours. Vegetation played a major role in site-scale variation in erosion. Generally, vegetated sites had less erosion than unvegetated sites, and vegetation became more effective downstream. Reaches with extensive invasive willows often had minimal erosion, but triggered local avulsions as flows bypassed the willowed reach. Where avulsions did not occur flow began to erode behind individual willows in later floods causing rapid local widening of the channel in response to relatively modest flows. Vegetation plays an important role in moderating flood impact, but in high stream power reaches riparian widths one to two trees wide are ineffective.

## **Geomorphological impact and feedback effects of occurrence and sequences of flood events of differing characteristics**

HOOKE J.

*University of Liverpool, LIVERPOOL, UNITED KINGDOM*

Flood events have morphological and sedimentological effects on channels and floodplains and also associated social, economic and ecological impacts. Prediction of impacts is very important for flood management and for long-term interpretation of the role and frequency of floods. It is often assumed, particularly in sedimentological analyses, that the amount of sedimentation and size of material is proportionate to the magnitude of the peak flow. Here, evidence is examined of erosion and deposition in relation to series of events in two contrasting environments. Geomorphological impacts are found to vary in relation to magnitude, duration, season and sequence of conditions.

On ephemeral channels in SE Spain the effects of differing flows over nearly two decades have been measured, including a major flood in 1997, a series of more minor events and a very large event in October 2012, interspersed with drought periods. Thresholds for impacts are identified and feedback effects of changes in morphology are calculated, together with effects of vegetation. On active meandering channels in NW England the effects of peak flows over a 30 year period are evaluated. Bank erosion rates are closely related to winter peak flow. Evidence is provided that sedimentation varies markedly between winter floods and short duration summer peak flows of comparable magnitude. This has important implications for interpretation of flood magnitude and frequency from the sediment record. In both environments the presence and state of vegetation is found to have a large effect. The evidence from a range of events of varying magnitude enables testing and validation of models of flood impacts and demonstrates the need for a nuanced approach incorporating various characteristics of flood events.

\*\*\*\*\*

## **Flooding from extreme rainfall: Geomorphological effectiveness as a vehicle for flood risk management and whole river restoration**

SEAR D.(1), DEARING J.(1), WHEATON J.(2), BATES P.(3), NEAL J.(3)

*(1) University of Southampton, SOUTHAMPTON, UNITED KINGDOM ; (2) Utah State University, LOGAN, UNITED STATES ; (3) Bristol University, BRISTOL, UNITED KINGDOM*

Recent attention on the human impacts of extreme rainfall events are understandable and the immediate emphasis on urban flooding justifiable. However, the focus on urban flooding and the decisions taken at a time of crisis may obscure the longer term benefits of extreme events in effecting large scale restoration of hydromorphology, and in some cases, the delivery of flood risk benefits. In this paper, we use the example of a rare (1:1000yr rainfall, 1:600 yr flood), geomorphologically effective flood to explore the case for a re-evaluation of such events. Using a combination of morphological sediment budgeting, flood modeling and long term flood reconstruction we explore the role of a rare events in provisioning longer term ecosystem services such as flood risk reduction, and the restoration of physical habitats. We demonstrate first, that human modification to the floodplain resulted in an increase in flood risk; secondly, that the morphological effects of the flood resulted in a post-event channel that delivered a reduction in the depth and extent of flood risk. Thirdly, we demonstrate that the morphological changes resulting from the flood event delivered a more diverse physical habitat template that might have formed an opportunity to provision other ecosystem services. Finally we highlight the rarity of such events and argue that rather than seeing them only in terms of their immediate human impact, resource managers need to consider their wider, longer term benefits. To achieve this, demands equally rapid inclusion of geomorphological data capture and analysis combined with ecological and hydrological science.

**Physical controls of vegetation recruitment patterns on the Drôme River (SE France): An analysis based on a chronosequence of high resolution aerial imagery**

*RÄPPLÉ B.(1), PIÉGAY H.(1), MUTZ M.(2), STELLA J.C.(3), TRÉMÉLO M.L.(1), WILCOX A.(4)*

*(1) CNRS UMR 5600 EVS / Site ENS de Lyon, University of Lyon, LYON, FRANCE ; (2) Department of Freshwater Conservation, Brandenburg University of Technology Cottbus, COTTBUS, GERMANY ; (3) Department of Forest and Natural Resources Management, State University of New York College of Environmental Science and Forestry, SYRACUSE, NEW YORK, UNITED STATES ; (4) Department of Geosciences, University of Montana, MISSOULA, MONTANA, UNITED STATES*

Along with the recent recognition of the role of vegetation in influencing channel hydraulics, and thus fluvial morphology, comes the need for scientific research on vegetation recruitment and its control factors. Flood disturbance is known to create a suitable physical template for the establishment of woody pioneers. Sapling recruitment patterns and underlying physical controls were investigated on a 5 km braided reach of the Drôme River in South-eastern France, following the 2003 50-year flood event. The approach was based on the analysis of a chronosequence of high resolution aerial images acquired annually between 2005 and 2011, complemented by airborne LiDAR data and field observations. The study highlights how physical complexity induced by natural variations in hydro-climatic and consequently hydro-geomorphic conditions facilitates variable patterns of recruitment. The initial post-flood vegetative cover, which made up 10% of the total active channel area in 2005, was seen to double within six years. This expansion could be attributed primarily to recruitment, to a lesser extent also to the net growth of older vegetation patches. The variability of hydro-climatic conditions was reflected in the temporal and spatial patterns of recruitment, with a pronounced peak of vegetation expansion in 2007 and a decreasing trend over the following years. Recruitment was further seen to be sustained in a variety of geomorphic units, which showed different probabilities and patterns of recruitment. Active channels were the prominent geomorphic unit in terms of total biomass development, while woody debris units showed the highest probability for recruitment. An understanding of vegetation recruitment is becoming crucial for predicting fluvial system evolution in different hydro-climatic contexts. Applied, these findings should contribute to improve efforts made in the field of flood risk management, as well as restoration planning.

\*\*\*\*\*

**Assessment of the annual dynamics of large woods along a 60 km semi-alluvial river section of the Gaspé Peninsula, Quebec, Canada, feedbacks from 3 year field surveys combined with airborne and ground images**

*BOIVIN M.(1), BUFFIN-BELANGER T.(2), PIEGAY H.(3)*

*(1) Université du Québec à Rimouski/ UMR5600 ENS-Lyon/ Centre d'étude Nordique (CEN), RIMOUSKI/LYON, CANADA ; (2) Université du Québec à Rimouski / CEN, RIMOUSKI, CANADA ; (3) UMR5600/ENS-Lyon, LYON, FRANCE*

The semi-alluvial rivers of the Gaspé Peninsula, Québec, are prone to introduce and transport large quantities of in-channel wood because of channel shifting due to high energy flows and uncohesive banks. These large quantities of wood influence significantly the river dynamics. The delta of the Saint Jean river encompasses large wood jams (LWJ) building up since 1960, measuring more than 3 km in length and creating frequent avulsions. These jams provide a unique opportunity to quantify a wood budget through time and to better understand the controlling factors. The wood budget includes the evaluation of wood volumes produced by bank erosion (input), still in transit in the river corridor (deposited on bars or channel edges) and accumulated in the delta (output). An annual survey was carried out from 2010 to 2012 to locate and describe more than 300 jams and 600 individual woods along a 60 km long river section. The repeated surveys allowed defining the morphological characteristics as well as the jam configuration that promote wood mobility and deposit. The repeated surveys also allowed examining the transport rates from one year to another for specific river sections. The results indicate that the volumes of woods deposited along the 60 km section are 4 times higher in 2011 and 2012 than in 2010. Increase in wood amount occurs mainly in upper alluvial sections of the rivers whereas decrease is observed in the semi-alluvial middle sections. Airborne and ground photo / video images are used to evaluate the volume introduced yearly by erosion and determine the transport rates. The analytical model developed from the wood budget and the understanding of wood dynamics can assist river managers in their decision making to determine possible solutions that include the production, transport and accumulation of large wood in river.

### **Necessity of linking paleontological and contemporary approaches for understanding river dynamics**

CORENBLIT D.(1), BORNETTE G.(2), STEIGER J.(1), DAVIES N.(3)

(1) Clermont University, CNRS, UMR 6042, GEOLAB - Laboratoire de géographie physique et environnementale, 63057, CLERMONT-FERRAND, FRANCE ; (2) CNRS, UMR 5023, LEHNA - Laboratoire d'Ecologie des Hydrosystèmes Naturels et Anthropisés, 69622, VILLEURBANNE, FRANCE ; (3) Gent University, Department of Geology and soil science, Krijgslaan 281 S8, GENT, BELGIUM

It is well established now that riparian plants within river corridors modulate both the longitudinal and transversal hydrogeomorphic gradients and associated fluvial landforms. By trapping sediment, nutrients and organic matter, plants control the spatio-temporal organisation of ecological processes and related habitats during the fluvial biogeomorphological succession. This control defines the biogeomorphic equilibrium conditions related to the resistance and resilience of the ecosystem structure to flood disturbances. Plants respond to river dynamics at ecological (contemporary) timescales, but have started to respond to river dynamics since they began to colonize terrestrial environments on the continents. These responses are related to physiological, morphological, biomechanical and life-history adaptations to regular submersions and mechanical constraints caused by flood flow. It was recently demonstrated that, at evolutionary timescales, plant adaptations led to the emergence of a variety of contrasted fluvial biogeomorphic types. Each of these types shows characteristic ecogeomorphological structures and dynamics. We suggest that within biogeomorphic type specific kinds of eco-evolutionary dynamics may occur with strong ecological and evolutionary feedbacks between biotic and abiotic components. The future challenge will be to establish a clear link between geomorphic, ecological and evolutionary processes and feedbacks to validate the hypothesis of an eco-evolutionary dynamics within river corridors.

\*\*\*\*\*

### **Downstream channel changes of a tropical alluvial river due to construction of a dam: The example of the Subansiri in Assam, India**

GOSWAMI U., ACHARJEE S.

*Dibrugarh University, DIBRUGARH, INDIA*

Channel shifting, bankline migration, bank erosion and fill, and varied type of other channel changes are frequently observed in the river channel of the Subansiri since periods of available records. The catastrophic flood event associated with the 1950 Assam earthquake is reported to be one of the main causes behind the gradual change of channel pattern of the river from meandering to braided. The ongoing construction of a mega dam at Gerukamukh since 2006, initiating far reaching changes in channel form and process, has marked the end of the natural fluvial regime of the Subansiri solely responsible for the earlier downstream river channel changes. Notable channel changes as a result of anthropogenic influence are now beginning to appear in the downstream reaches.

A study on the river channel changes of the Subansiri for the period 1990-2010 using remote sensing and GIS reveals noteworthy changes of varied types, during the period 1990-2000, resulting entirely due to its natural fluvial regime. But during the subsequent periods of 2000-2007 and 2007-2010, channel changes bearing signatures of anthropogenic influence are emerging gradually. During the twenty year period from 1999-2010 the river has gained in width, shortened channel length, steepened channel slope and has been actively migrating towards west. The annual rate of erosion has decreased from 7.031 km<sup>2</sup> in 1990-2000 to 5.640 km<sup>2</sup> in 2000-2007, whereas the annual rate of fill during the same period has increased by 3.80 times from 2.415 km<sup>2</sup> to 9.224 km<sup>2</sup>. As a result there has been an increase in braiding intensity as compared to a decrease in sinuosity index. Thus, while the braided pattern persists during the study period, the river has changed channel pattern from sinuous to straight. Moreover, the characteristic anabranching pattern of the Subansiri, associated with the river since 1920, has now totally disappeared.

Key words: Bankline migration, channel pattern, Subansiri, sinuosity, braiding index.

## **Geomorphic changes of a dry-temperate meandering river highly disturbed by a large dam, Sauce Grande River, Argentina**

CASADO A.(1), PEIRY J.L.(1), CAMPO A.M.(2)

(1) Clermont Université, Université Blaise Pascal, GEOLAB - CNRS, UMR 6042, GEOLAB, CLERMONT-FERRAND, FRANCE ; (2) Departamento de Geografía y Turismo, Universidad Nacional del Sur - CONICET, BAHÍA BLANCA, ARGENTINA

Flow regulation by dams may modify the morphology of the river downstream by altering the equilibrium between the flow transport capacity and the sediment load available to transport. This study focuses on the Sauce Grande River, an ungauged dry temperate basin of about 4000 km<sup>2</sup> located in central-eastern Argentina. The Paso de las Piedras Dam has impounded the middle river section since 1978 for water supply to Bahía Blanca (400 000 inhab.); despite the large capacity of the impoundment, the effects of the dam on the river environment remain poorly evaluated. This study quantifies the geomorphic response of the river downstream to major decrease in discharge and sediment inputs, and compares the direction of geomorphic changes to qualitative models of channel adjustment.

River channel changes were inspected based on (i) field surveys of the present river channel state, and (ii) historical aerial photographs and imagery of pre-dam (1961) and post-dam (1981; 2004) channel states for two river segments of 40 km-length above and below the dam. Methods used GIS-based measures of channel narrowing (widening), lateral migration and vegetation growth between consecutive time steps, and field-based morphologic descriptions of sample reaches along the river segments.

Results showed that geomorphic changes within the river below the dam were related to human intervention (e.g. bed digging, artificial meander cut-off and levees building) more than to natural adjustments to reduced flow discharge and sediment load (e.g. incision and narrowing). In contrast to the river upstream, which exhibited high lateral mobility, there was no clear evidence of channel activity since dam closure; bank profiles showed high stability and progressive vegetation growth. These findings suggest that the dam has induced stable (moribund) river channel conditions downstream. Results are discussed relative to predictive models of channel metamorphosis below dams available in literature.

\*\*\*\*\*

## **Geomorphic Impacts of Riparian (Dis)Connectivity: Dams and Dam Removals as 'Natural' Geomorphic Experiments**

MAGILLIGAN F.(1), NISLOW K.(2), RENSHAW C.(1), GARTNER J.(1)

(1) Dartmouth College, LEBANON, UNITED STATES ; (2) USDA-Forest Service, NORTHAMPTON, MA, UNITED STATES

Dams, and their subsequent removals, have profound impacts on geomorphic processes and ecologically functioning. Dams can thus be considered natural experiments where the disturbance is fixed in time and space, allowing the ability to test the geomorphic and hydraulic responses to a perturbation (or its removal) and to follow these adjustments spatially and temporally. This presentation covers the type, magnitude, and spatial variability of geomorphic responses to dams and dam removal throughout the Connecticut River watershed. To represent the effects of flow regulation, we analyzed tributary confluences on the regulated West River, VT, where 2 flood control dams exist. We document the time series of post-regulation channel narrowing and associated bar growth due to the influx of tributary sediment and also identify the critical covariate response to simultaneous changes in channel properties and flow competency. To capture the effects of dam removal, we analyzed the recent removal of 2 run-of-river structures. Our detailed pre- and post-removal field and lidar-based results for the Homestead Dam, NH reveal that in contrast to predictions from a widely applied conceptual model, the greatest geomorphic change did not occur adjacent to and immediately after the dam removal. Nor did knickpoint migration, rapid incision, or extensive channel widening in reservoir sediment occur. With thousands of dams likely to be considered for removal/repair in the coming decades, this study helps to advance predictions of the geomorphic response to dam removal and to elucidate the style and timing of fluvial responses to disturbances.

### **Geomorphological response to weir removal: the River Twymyn, mid Wales, UK**

WHITFIELD G.(1), WHITFIELD E.(2)

(1) Environment Agency, WARRINGTON, UNITED KINGDOM ; (2) Liverpool John Moores University, LIVERPOOL, UNITED KINGDOM

Weirs are a common anthropogenic obstruction in British river systems. Historically, these physical barriers were built in an attempt to control river flow for various purposes including navigation, managing flood risk, and abstraction of water to operate industrial machinery. With the move towards catchment-scale restoration of river systems, largely driven by the EU Water Framework Directive, there is a shift in thinking towards considering removal of weirs in an attempt to restore more 'natural' processes to rivers whose hydrological and sedimentological regime are fundamentally influenced by such anthropogenic disturbances. In addition to removing the impounding effects of weirs, weir removal also increases coarse sediment connectivity between the upstream and downstream reaches that may have been largely disconnected following construction. Restoring more natural flow and sediment transfer patterns can lead to significant improvements for the ecological and biological status of rivers, helping to deliver the objectives of the Water Framework Directive. However, the sudden change of base-level that accompanies weir removal can lead to significant morphological adjustment, both laterally and vertically, as the river adjusts to a new longitudinal profile. In this paper we examine the potential geomorphological consequences of weir removal on the River Twymyn, a principal tributary of the River Dyfi in mid-Wales. We demonstrate the value that geomorphologists can bring to the assessment of weir removal projects for identifying risks and opportunities which need to be considered alongside the implications for in-stream ecology and fauna.

\*\*\*\*\*

### **Geomorphological monitoring after dam removal**

IBISATE A.(1), ACÍN V.(2), BALLARIN D.(3), DIAZ E.(1), GRANADO D.(2), MORA D.(3), OLLERO A.(4)

(1) Dpt. Geography, Prehistory and Archaeology, University of the Basque Country, UPV/EHU, VITORIA-GASTEIZ, SPAIN ; (2) ECOTER, S.C. Ecology and Land, ZARAGOZA, SPAIN ; (3) MASTERGEO, ZARAGOZA, SPAIN ; (4) Dpt. of Geography and Land Management, University of Zaragoza, ZARAGOZA, SPAIN

A geomorphological monitoring tool was implemented following several dam removals in different case studies in northern Spain. Hereby the example of Mendaraz dam in Urumea River is presented. Dam removal is one of the most frequent and effective fluvial restoration actions. Nevertheless only in few occasions geomorphological processes have been monitored. This monitoring included channel cross-sections, longitudinal profiles, lateral and vertical dynamics of river banks measurements from fix points and marked trees, sediment grain size, mobility and transport assessment and river bed morphologies. Geomorphological variables and field measurements have to be adapted to the local characteristics of the channel and the channel affected by the adjustment defined in each site. In the case study the river channel has been gradually adjusted after the dam removal and several changes have been identified after an extraordinary flood occurred in November 2011. The monitoring methodology was effective and could be applied to other cases.

**Hydromorphological adjustments and re-adjustments of low energy rivers in a sub-urban catchment following historical engineering and recent urbanization**

JUGIE M.(1), GOB F.(1), SLAWSON D.(2), LECOEUR C.(1)  
(1) LGP UMR 8591, MEUDON, FRANCE ; (2) IRSTEA, ANTONY, FRANCE

According to the EU Water Framework Directive (WFD, October 2000), European rivers and streams have to attain "good ecological status" through the preservation and restoration of aquatic environments by 2015. Member States of the European Union will have to ensure environmental continuity through "the adequate distribution of fish species and transport of sediments" that is undermined, longitudinally, by the impacts of transverse structures, such as weirs and dams, or laterally by structures such as levees, dikes and bank protection.

In France, more than 60,000 transverse structures have been identified on rivers as being obstacles to ecological and sedimentary continuity. Because of their historical occupation by societies, rivers flowing in the Paris area have long been anthropized and artificialized. River courses, channel shape, sediment transport and hydrological regime modifications have tremendously transformed the hydrosystems surrounding the city of Paris.

In addition to these ancient pressures a rapid and massive urbanization of the suburban areas around Paris has applied a new type of constraint to the hydrosystems in recent decades. This undermines the balance that was established following ancient engineering and disturbs the current functioning of the majority of valleys. These new types of land occupation have significantly altered the ecological conditions and transformed the hydrological responses of rivers.

In this study, we therefore seek to understand these processes of successive adjustments (ancient and recent) of small rivers from the urban margins of the Orge watershed (to the south of Paris). We use a multi-scalar spatial and temporal approach, and employ multi-disciplinary techniques based on local and global scales, geography, history, ecology and hydrology. Our goal is to provide a set of results to several disciplines through a transversal approach in order to assist decision makers in restoration planning.

\*\*\*\*\*

**Long term impacts of flow abstraction upon basin scale sedimentation processes in an Alpine valley system**

REGAMEY B., LANE S.N., MICHELETTI N.  
IGD, Université de Lausanne, LAUSANNE, SWITZERLAND

Flow abstraction and diversion to water storage systems is a common element of Alpine hydro-electric power schemes. However, such systems are commonly associated with exceptionally high sediment production rates, necessitating very particular approaches to sediment management. Commonly, whilst water is abstracted, sediment (both coarse and fine fractions) is left behind. In order to avoid infrastructure failure, the latter is commonly designed to allow sediment to pass in short duration high magnitude sedimentary floods. The importance of such schemes aside, there has been relatively little investigation of the geomorphic impacts of such sediment management systems. In this paper, we present results from two spatio-temporal scales of analysis in order to establish these impacts. The first applies image processing to archival aerial photography to document the long-term impacts of flow abstraction and sedimentary floods in the Val d'Héréns, Switzerland. Results show that flow abstraction significantly reduces the time when the river was competent to transport sediment, and hence the total sediment transport capacity. The result has been a temporary disconnection of sediment flux through the system, and reflected in significantly reduced rates of sediment delivery to Lac Léman downstream. However, the image analysis also shows that whilst sedimentation was initially restricted to close to the abstraction sites, this sediment has been progressively reworked through a succession of sedimentary floods, causing deposition sites to move progressively further downstream. These deposition sites are themselves constrained by geomorphic forcing, centred on reaches of lower river bed slope and with sufficient lateral accommodation space. The implication of these observations is that the sediment flux will eventually reconnect with the main valley stems further downstream. The second scale sought to quantify this response in more detail by laser scanning on a 400 m river reach.

### On the use of floodplain landforms to generate flood risk maps

DEMERS S.(1), OLSEN T.(1), BUFFIN-BÉLANGER T.(1), BIRON P.(2)

(1) *Université du Québec à Rimouski, RIMOUSKI, CANADA* ; (2) *Concordia University, MONTREAL, CANADA*

Flood hazard maps are often produced by hydraulic simulations that predict water levels at discharges of given frequencies. The hydraulic approach presents the conditions at one given time in the life of the river and thus marginalizes the effect of time trajectories in both hydrological and morphological conditions. In contrast, hydrogeomorphology (HGM) conceives the floodplain as a physical object resulting from ongoing long-term river processes and represents the extent where flood hazards should be expected. In Quebec (Canada), HGM understanding of river processes and landforms has yet to be considered for flood risk maps and implemented in floodplain regulations. This stems in part from a lack of appropriate HGM mapping guidelines specifically aimed towards risk management. We propose a typology for mapping floodplain forms based on prior HGM practices in order to adapt mapping guidelines to various floodplain styles. This typology is applied to three rivers located in southern Quebec (Canada): the Matane (50 km), Yamaska Sud-Est (3 km) and De La Roche (3 km). These rivers present contrasted floodplain styles of different flow energies and landform arrangements. For the Matane River, increased discharges due to climate change as well as in-channel sedimentation in the most heavily populated zones of the floodplain yields high uncertainty - or low life expectancy - of risk maps produced from hydraulic simulations. A quantification of flood processes using 1D simulation (HEC-RAS) gives a detailed understanding of flood hazards on the three floodplains. Our analysis shows how specific floodplain landforms are related with flood hydrodynamics and how they can be used to infer flood hazards. This leads to general guidelines for the appropriate integration of HGM landforms along with hydraulic simulations in flood risk management which are considered based on Quebec regulations.

\*\*\*\*\*

### Inherited rivers. Anthropogenic changes in the low energy rivers in W France from 1500 BC and implications for their current management

LESPEZ L.(1), VIEL V.(1), GERMAIN-VALLÉE C.(2), ROLLET A.J.(1), GERMAINE M.A.(3), CADOR J.M.(1), DELAHAYE D.(1)

(1) *Geophen-LETG Caen-UMR 6554 CNRS, UCBN, CAEN, FRANCE* ; (2) *Service Archéologique du Conseil Général du Calvados, CAEN, FRANCE* ; (3) *LAVUE-UMR CNRS 7218, UNIVERSITÉ PARIS OUEST-NANTERRE-LA DÉFENSE, FRANCE, FRANCE*

European WFD promotes restoration of ecological continuity of aquatic environments and of hydromorphological conditions. In this paper, we propose to put it into perspective by determining the role of heritages in modern systems. In western France, the small rivers constitute mainly inactive rivers of low energy circulating within cohesive alluvial plains. Geomorphological, research conducted in Normandy proposes a model of their long-term evolution. The Time of Nature is characterized by multichannel anabranching rivers in wetland environment. From the 2<sup>nd</sup> mil. BC, sedimentary archives show increasing overbank silty deposition while the fluvial systems become meandering. This change is the result of the erosion of soils due to increase in cultivated area and connectivity within the catchments. From the Antiquity, the time of hydraulic control is characterized by the creation of drainage ditches, leats, mills that had the consequence of controlling the channel. In the 18th c., a mill could be found every 1.3km along a river. Thus, repercussions of exploitation of the catchments, followed by hydraulic control complete the metamorphosis by creating societal/environmental system of substitution whose equilibrium has been maintained by societies for more than a millennium. So, the temptation of nature that has taken hold of some experts needs to be forgiving because we will never restore the river as they were before. Having assimilated the issues of biodiversity loss, we have to manage inherited channels. From a practical viewpoint, we need investigations integrating sedimentary heritage to assess the equilibrium state of the current rivers. Furthermore, reflexion on the reference model should be open and take into account the relationship with the floodplain while the restoration works conducted are more often focused on the channel. To conclude, we promote the use of a holistic approach of these ordinary waterways including long-term dynamics.

**Landscape Connectivity in Hilly Catchments on Middle Paraiba do Sul River Valley, Southeastern Brazilian Plateau**

PEIXOTO M., DEL POZO I.F.

*Federal University of Rio de Janeiro, RIO DE JANEIRO, BRAZIL*

In hilly catchments of Middle Paraiba do Sul River Valley, Southeastern Brazil, different types of erosion processes and mass movements are associated to regional reorganization of drainage systems along the Holocene. This study presents river and connectivity analysis done on 4<sup>th</sup> order river basins representative of regional quaternary evolution patterns identified by previous stratigraphic and geomorphologic work developed at Southeastern Brazilian Atlantic Plateau, aiming to contribute to river and basin management. Methods adopted comprised: a) mapping quaternary depositional features on valley flats and drainage headwaters concave-plane hollows, accomplished with a semi automatic procedure adapted from Correa (2008), using a 10m resolution DEM generated with 1:5,000 topographic charts of Volta Redonda Municipality; b) land cover and land use mapping using Ikonos satellite images (2009), provided by Geoeye; c) erosion and river geomorphic features mapping, based on Castro et al. (2002) and Peixoto et al. (2010). The maps generated on 1:25,000 scale allowed the recognition of buffers and barriers (according Fryrs et al., 2007) related to different geomorphic features, their spatial distribution and permanence, which are associated to Quaternary landscape evolution, determining the significance of connectivity maps generated. Erosive and mass movement processes connect slopes, valley flats and drowned headwaters to main streams, but also create new features of disconnectivity, like swamps and "empty" valleys, which hydrologic function and potential for river rehabilitation have been investigated.

\*\*\*\*\*

**Sediment connectivity in the upper Thina River, Eastern Cape, South Africa**

VAN DER WAAL B., ROWNTREE K.

*Rhodes University, GRAHAMSTOWN, SOUTH AFRICA*

Landscape connectivity has been transformed in catchments worldwide, which has implications for the spatial transfer of sediment. In the Thina River catchment, Eastern Cape, South Africa, an important high rainfall water resource, subsistence farming on communal land led to overgrazing, which increased soil erosion and led to the formation of extensive gulley networks. This increased the slope-channel connectivity and increased the runoff of the system, cutting into valley fills and reducing the chances of channel-floodplain connectivity. Sediment is thus efficiently exported from the system and has effects on the sustainability of downstream water resources. Work is in progress to investigate historical changes to slope-channel and channel-floodplain connectivity in relation to land use and climate changes. The research approach will be outlined and preliminary findings presented. Anticipated results will include mapping of slope-channel connectivity over the last 50 years and dating (OSL and Pb-137) of floodplain sediments, paleochannels and selected terraces.

## Characterising Urban Rivers to support their Sustainable Management

GURNELL A.

*Queen Mary, University of London, LONDON, UNITED KINGDOM*

In order to improve understanding of associations among fluvial processes, vegetation, engineering modification and the form and dynamics of urban rivers, survey and assessment methodologies are needed. Such methodologies need to record information on the detailed physical properties of urban rivers and their margins in a consistent way that is susceptible to statistical analysis. A number of surveys have been developed to characterise rivers and their corridors but few have been developed specifically for application to urban water courses. The Urban River Survey is one such survey.

This paper describes the URS, the indicators that are derived from it and the web tool that handles the data. Results from its application in the UK will be reported. In particular, analysis of URS data reveals the degree to which river engineering constrains the morphological characteristics of urban rivers and their dynamics, and it also provides a way of tracking trajectories of river adjustment in response to changed engineering or rehabilitation activities. These results provide a framework within which management approaches can be designed and their success documented.

\*\*\*\*\*

## Geomorphological assessment of urban river reaches: results and discussion of five case studies (North Italy)

GUSMAROLI G.(1), CEDDIA M.(2), SOGNI D.(2), MANNUCCI G.(3), DOTTI N.(3), PARINI M.(4)

*(1) Studio Ecoingegno, VENICE, ITALY ; (2) Progepiter srl, MILANO, ITALY ; (3) ARPA Lombardia, MILANO, ITALY ; (4) Regione Lombardia, MILANO, ITALY*

Urban river restoration is worldwide recognized as a current issue both for river basin management and for urban planning strategies. Typically urban waterfronts constitute unnatural borders for river channels and correlated in-stream infrastructures interrupt the longitudinal river continuum, thus making towns to be actual bottlenecks for fluvial eco-dynamics and increasing natural risk conditions (undesired floods and morphological un-stabilities) both locally and up/downstream.

In order to effectively support river management, it is commonly known that a comprehension of fluvial geomorphic processes (past trends and future trajectories) could properly underpin decision making processes. This assumption finds a challenging field of application within urban reaches of watercourses, where giving room to river dynamics (or being subjected to the effects of such a strategy adopted up/downstream) represents a tough socio-economic tangle.

This paper presents the outcomes of the hydro-geomorphologic assessment campaign led on five rivers in the North of Italy (Lambro, Seveso, Olona, Mella, Staffora, with an investigated total length of about 500 kilometres), all of them identified as Po river tributaries flowing within Lombardia administrative territory and characterized by an high degree of urbanization along respective corridors. The study is part of a broader ongoing project ("Progetto Fiumi", promoted and funded by Lombardia Region and implemented by Lombardia Environmental Protection Agency), aimed at assessing ecological conditions of the watercourses above mentioned and supporting catchment scale planning in order to accomplish WFD requirements. The assessment methodology adopted is the one finalized to obtain the Morphological Quality Index (Rinaldi et al., 2012) for each investigated reach. Final discussion concerns the meaningfulness of the information obtained and its possible usefulness for management purposes.

## Reach-Scale Index for Sand-Bed Channels

COTTON G.

*GK Cotton Consulting, GREENWOOD VILLAGE, UNITED STATES*

The development of a reach-scale index for sand-bed channels is presented. The index provides a quantitative means of scaling a prototype reference reach to other reaches within a watershed. The index is shown to be insensitive to a wide range of commonly used sediment transport equations that have been developed independently for sand-bed channels. The index can be applied to the assessment and design of stream restoration projects, where the physical processes of water and sediment transport play a dominant role in the form of the stream channel. The scaling of sand-bed morphology is compared to scaling relationships for cobble and gravel bed streams. Stream data from four independent studies of sediment transport for 91 streams in the western United States was used to compare scaling relationships. These data suggest that channels near threshold conditions (i.e. cobble bed channels) have width and depth that are largely independent of sediment transport, while channels with higher sediment transport (i.e. sand-bed channels) must include sediment transport in the scaling of channel width and depth. A computational method is demonstrated for the application of the index method.

\*\*\*\*\*

## Reflections on the application of the 'Freedom space' river management approach to help mitigate climate change impacts on three rivers of southern Québec, Canada

BUFFIN-BELANGER T.(1), BIRON P.(2), LAROCQUE M.(3)

*(1) Université du Québec à Rimouski, RIMOUSKI, CANADA ; (2) Concordia University, MONTREAL, CANADA ; (3) Université du Québec à Montréal, MONTREAL, CANADA*

Projected climate change involves modification of the hydrological regime that will in turn affect river dynamics: longer periods of low flow, increased risk of flooding as well changes in bank erosion patterns are likely to occur. In Quebec, the current river management policy does not allow for the consideration of such changes. The development of management tools adapted to climate change is thus needed to ensure sustainable management of rivers. In this paper, we present the results from the application of a "Freedom space" approach on three contrasted rivers of southern Québec: De la Roche, Yamaska Sud-Est and Matane. This approach seeks to strengthen the resilience of river systems by leaving a space of freedom to rivers rather than forcing them to move inside a buffer strip of fixed width. The approach is based on the hydro-geomorphology of rivers and it combines three distinct spaces to maintain natural river dynamics : flooding, mobility and integrity, the latter including wetlands. The methodological tools to determine the minimum space required for ecological integrity that also minimizes the risks associated with bank erosion and flooding in the current and future climate are described for a range of geomorphological contexts. Dynamics and connectivity between wetlands and rivers within the freedom space are also examined for the river De la Roche and Matane. Finally, a cost-benefit analysis compares the current management of rivers based on frequent interventions (eg bank stabilization) with the space of freedom.

## **Fluvial Geomorphology in Practice: Lessons learnt in the development and application of the River Styles framework**

*BRIERLEY G.(1), FRYIRS K.(2), TADAKI M.(1)*

*(1) The University of Auckland, AUCKLAND, NEW ZEALAND ; (2) Macquarie University, NORTH RYDE, SYDNEY, AUSTRALIA*

Everything is contextual! The primacy of place-based understandings with which to inform landscape interpretations and management applications is increasingly recognized. Rather than relying unduly on conceptual or theoretical representations of landscapes that suggest how the world 'should' ideally look and behave, appropriately contextualized, place-based understandings enable us to detect where local differences matter. This provides a critical basis to assess the representativeness of sample or reference sites and the transferability of insights between different locations. Many challenges must be addressed in dealing with inherent complexities of landscape understandings and their applications. The River Styles framework was developed as a generic toolkit to support river management applications. Inevitably, it bears the imprint of its co-developers. In this paper we report on experiences gained in the development of this framework and associated professional short courses, highlighting how they fashioned the (re)framing of this pedagogic toolkit. In this 'learning' approach to river science and management, procedures are open-ended and flexible, enabling them to be adapted to any given situation in an uncertainty-embracing form of science-management interactions. This presents a notable contrast to more prescriptive (cookbook) applications. Significant implications of this work include the development of skill sets with which to apply these principles and steps taken to establish and maintain appropriate information bases. This paper takes up the recent challenges made within physical geography to think more broadly about the work of our science, and steps taken to action it into relevance.

\*\*\*\*\*

## **A methodological framework for hydromorphological analysis of Italian streams (IDRAIM) aimed to an integrated management of fluvial hazard and river restoration**

*RINALDI M.(1), SURIAN N.(2), COMITI F.(3), BUSSETTINI M.(4)*

*(1) Dipartimento di Scienze della Terra, FIRENZE, ITALY ; (2) Dipartimento di Geoscienze, PADOVA, ITALY ; (3) Facoltà di Scienze e Tecnologie, BOLZANO, ITALY ; (4) ISPRA, ROMA, ITALY*

Development of integrative approaches for river management is increasingly needed by public agencies across Europe, where recent directives are aimed to conflicting objectives, while scientific frameworks designed for a single objective are in most cases doomed to failure.

In Italy, given the high level of urbanization, flood safety is the main priority in river management, although there is an increasing effort towards river restoration driven by the implementation of the Water Framework Directive. Consequently, the Italian National Institute for Environmental Protection and Research (ISPRA) has promoted a research program with the objective of developing a comprehensive methodological framework (named IDRAIM) to support management of river processes, integrating the objectives of the Water Framework and Flood Directive. The framework stems from existing experiences of geomorphological approaches developed in other countries (e.g. the River Styles Framework), but it accounts for the specific Italian context in terms of channel adjustments and human pressures, and includes the fluvial dynamics component. Some key characteristics are the following: (1) the method builds on a catchment-wide spatially hierarchical framework; (2) the temporal component of the analysis is explicitly accounted; (3) channel dynamics and its implications in terms of fluvial hazards are explicitly accounted for.

The general structure includes the following four stages: (1) catchment-wide characterization of the river system, including an initial setting and segmentation of the river system; (2) analysis of past channel evolution, leading to an assessment of present morphological quality and channel dynamics; (3) evaluation of potential future trajectories of channel morphology; (4) integrated management aimed to improvement of river morphological quality and mitigation of channel dynamics hazards.

### **Making space for geomorphic processes: the example of buffers for rivers**

RUTHERFURD I.

*The University of Melbourne, MELBOURNE, AUSTRALIA*

The theme of this conference is geomorphology and sustainability. A key to managing geomorphic processes sustainably is to give those processes room to operate. Buffers along streams both protect the river system from human impacts, but also protect humans from bank erosion, deposition, and flooding. The majority of literature on buffers relates to protecting stream water quality. In this talk I will review situations where buffers can be successfully used around rivers – in particular for meander migration, avulsions, and anabranch development – and review approaches to predicting the width of the buffers required. I also demonstrate how the width of the buffers can potentially be reduced by revegetating stream banks with dense native vegetation. Such buffers have been used with success in several areas of the world, but there are also examples where such buffers have been counterproductive. I explore the planning and policy challenges of implementing such buffers in practice.

\*\*\*\*\*

### **Potential and actual geomorphic complexity of restored streams in headwater streams of northern Sweden**

POLVILEE, NILSSON C.

*Umeå University, UMEÅ, SWEDEN*

Ecological theory suggests that habitat heterogeneity and species richness are positively correlated; therefore stream restoration often relies on increasing geomorphic complexity to promote biodiversity. However, to enable sustainability the restored channel complexity should be based on the potential complexity for a given site, as a function of valley and catchment characteristics. Our objectives are to evaluate stream restoration effects after timber floating, by: (1) quantifying post-restoration changes in geomorphic complexity in four geomorphic aspects: longitudinal, cross-sectional, planform, and sediment texture; (2) constructing pre- and post-restoration geomorphic complexity gradients, and (3) determining trajectories of potential complexity. We focus on tributary channels in boreal forests of northern Sweden, where stream modifications associated with log-floating from the 1850s-1960s created highly simplified channels. Driven by concerns for fish, restoration began in the 1970s, with the return of large cobbles and boulders from the channel edge, and evolved into 'demonstration restoration,' placing very large boulders and trees into the channel, reopening side channels, and constructing fish spawning areas. We evaluate 22 reaches along tributaries of the Vindel River in northern Sweden, with four levels of restoration status: channelized, restored, demonstration restoration, and unimpacted. Detailed morphologic, sediment, and instream wood data allow calculation of 5-15 metrics of fluvial complexity for each geomorphic aspect. We compare the complexity metrics by restoration status using ANOVAs and use multivariate ordination to create a complexity gradient. We use these comparisons and characterizations of valley and catchment characteristics to evaluate if trajectories of change in morphology due to reach-scale restoration efforts track with potential reach complexity.

## The effects of river restoration on flood risk and flood hydrology

DIXON S.(1), SEAR D.(1), ODoni N.(2)

(1) University of Southampton, SOUTHAMPTON, UNITED KINGDOM ; (2) University of Bristol, BRISTOL, UNITED KINGDOM

The addition of large wood to river channels during river restoration projects is a popular method of attempting to improve physical and biological conditions in degraded river systems. Projects utilising large wood can involve the installation of engineered logjams (ELJs), the planting and enhancement of riparian forests or a combination of both. The success of such restoration projects in improving biotic and geomorphic conditions has been documented; however one aspect which has hitherto received very limited attention in the literature is the effect on catchment flood hydrology.

Altering the wood loading of a channel through installation of ELJs and increasing floodplain surface complexity through encouraging mature woodland could be expected to increase the local hydraulic resistance, increasing the timing and duration of overbank events locally and increasing the travel time of a flood wave through a reach. This reach-scale effect has been documented in models and the field. The impacts of these local changes at a catchment scale remains to be explored. Catchment scale effects are particularly important where headwater stream restoration is upstream of vulnerable urban locations.

We present results of a numerical modelling study based on a 98km<sup>2</sup> catchment using OVERFLOW; a simplified hydrological model. We investigate the effects on catchment scale flood hydrology of implementing three restoration scenarios (using ELJs alone, using riparian forest restoration and a combination of riparian forest and ELJ installation) at scales from reach to sub-catchment.

We demonstrate that changes to catchment flood hydrology are highly location dependant and downstream flood peaks can increase with synchronisation of sub-catchment flood waves. We constrain magnitude estimates for increases and decreases in flood peaks for modelled restoration scenarios and scales. Finally we analyse the potential for using river restoration as part of an integrated flood risk management strategy.

\*\*\*\*\*

## The role of geomorphic processes in the sustainability of large wood loads in rivers: A Bayesian approach

STOUT J., RUTHERFURD I., WEBB A.

University of Melbourne, PARKVILLE, AUSTRALIA

A growing worldwide literature is demonstrating the geomorphic and ecologic roles played by wood in streams. After a century of removing wood from streams in many parts of the world, many restoration projects now include extremely expensive reintroduction of wood. Managers are also revegetating cleared stream banks. In large lowland rivers, bank erosion is often the most important mechanism delivering wood to streams. For planning of stream management works, the important question is how long it will take (decades to millennia) for streams to recover an adequate wood load, with and without interventions? We report on a study into rates of wood accession and depletion in Victoria, Australia. The study is based on possibly the world's largest survey of in-channel wood, in which large wood has been mapped by high-resolution aerial photography in over 27,000 km of Victoria's largest streams. This data-set can be combined with LiDAR data, and field-truthed measures of reference sites, providing a cumulative estimate of the effects of the processes driving the mass balance of wood to these systems. Further field work and data mining will be done to populate the parameter spatial distributions of delivery and removal of wood from the river channel.

Over large stream networks, and centuries of time, the gains and losses of wood can be considered in probabilistic terms. A Bayesian statistical approach allows us to model latent (i.e. unknown) parameters as random variables that describe the physical processes driving the addition and loss of wood within reaches across the large network. The model can be used to probabilistically predict future wood loads, addressing the rates of recovery from anthropogenic disturbances, with and without different interventions. An important feedback element of the model is the effect of in-stream wood on bank erosion rates, and bed sediment transport rates. I report on methods used to develop and apply the model to Australian rivers.

## Assessing the success of river restoration projects through Geomorphology

*PEETERS A.(1), VERNIERS G.(2), DE LE COURT B.(3), HALLOT E.(1), HOUBRECHTS G.(1), PETIT F.(1)*  
(1) University of Liege, LHGF, LIEGE, BELGIUM ; (2) University of Namur, URBE, NAMUR, BELGIUM ; (3) Service Publique de Wallonie, DECNN, NAMUR, BELGIUM

In the context of the Water Framework Directive's goal of attaining "good ecological status", a LIFE+ project (called Walphy), co-funded by the European Union and the Service Public de Wallonie, was launched in 2009. It aims to undertake experimental river restoration projects and to assess their success on the basis of ecological and geomorphological monitoring.

Geomorphological monitoring differs depending on the type of restoration project: improvement of longitudinal continuity or transversal continuity.

Restoration projects involving longitudinal continuity concern courses where obstacles impede the free movement of fish and sediment. In the Bocq basin, many of these obstacles (old weirs between 1 and 3 m high) have been removed. The release of sediment was studied using traced pebbles (PIT tags), which enable the recovery of bedload transport to be highlighted. Additional monitoring is based on the comparison of topographic surveys and cross-sections carried out pre- and post-removal. This can show a recovery of the natural transport of sediment when stream bed aggradation is observed downstream from the removed dam.

Restoration projects involving transversal continuity concern straightened courses with artificial banks and therefore poor stream-floodplain connectivity. These works consist of enhancing river channels and restoring meanders or banks. Geomorphological monitoring is also based on surveys conducted pre- and post-restoration work. Some reaches have been improved by the reintroduction of spawning gravel. Several methods were used to characterize the clogging of this gravel reintroduction (hydraulic conductivity, wooden stakes). In addition, the mobility of this gravel was monitored using traced pebbles (PIT tags).

Finally, restoration works and their stability and resistance to erosion are considered in relation to flood characteristics (discharge, recurrence, specific stream power and shear stress).

\*\*\*\*\*

## Morphological descriptors and typologies of French rivers as tools for managing river restoration

*THOMMERET N.(1), BILODEAU C.(2), GOB F.(1), BAUDOIN J.M.(3), ALBERT M.B.(4), BELLIARD J.(4)*  
(1) Laboratoire de Géographie Physique UMR 8591 CNRS-Université Paris 1 Panthéon-Sorbonne, MEUDON, FRANCE ; (2) LADYSS Université Diderot Paris 7, PARIS, FRANCE ; (3) ONEMA, AIX EN PROVENCE, FRANCE ; (4) Irstea, ANTONY, FRANCE

The European Water Framework Directive (WFD) requires that the hydromorphological conditions of water courses meet good ecological status. In this context, managers of water bodies need morphological descriptors and typology in order to evaluate and quantify the impact of hydromorphological alterations on biocenoses. The application of the WFD thus requires that "reference" characteristics should be determined. The scientific community has agreed, however, that the definition of natural conditions is not meaningful as hydrosystems constantly evolve through time and space.

This study aims to define hydromorphological descriptors from "reference" models and typologies integrating the complexity of the processes at play and the diversity of the various situations. These models are based on well-known theories that link river morphology and basin characteristics (catchment size, geology, land cover, etc.) and build on a large set of reaches considered as relatively poorly impacted by human pressures and statistically coherent on a regional basis.

Our data set results from a collection of about 1000 measurements of French river reaches. They have been collected on the field at station scale following the same protocol, over the last three years and include: topographical descriptions (width, depth, slope, etc.) of the reaches at bankfull stage, discharge measurements, sediment size and riverine vegetation descriptions. They are gathered in the CARHYCE (river hydromorphological characterization) data set managed by the French National Agency for Water and Aquatic Environments (ONEMA).

Our models allow the quantification of the reaches morphological alteration. They provide tools to manage and better understand key parameters controlling hydromorphological pressure on biocenoses. The objective of these "reference" models is to achieve a more natural functioning of the hydrosystem through performing restoration operations.

### Investigating the potential of seed banks as a regeneration niche in riparian systems: Implications for vegetation-based river rehabilitation

*O'DONNELL J., FRYIRS K., LEISHMAN M.R.*  
*Macquarie University, SYDNEY, AUSTRALIA*

River systems present unique riparian environments for the study of seed banks – accumulations of viable seeds and propagules stored within sediment. Seed banks provide multiple opportunities for plants to establish in a range of environmental conditions and can facilitate the rapid recolonisation of vegetation after disturbance. As such, they are recognised as an important *regeneration niche* and there is a strong drive to increase their utilisation in the rehabilitation of degraded rivers and streams. We present findings of current seed bank research conducted within the Lower Hunter River catchment in New South Wales, Australia. For two sand bed streams we compared the vertical stratification of seed banks between geomorphic units that are characterised by different inundation and reworking frequencies: bars, benches and floodplain. Contrary to our hypothesis that bars would house few seeds as a result of continual disturbance, we found both very high and low seed numbers could be present. Bench and floodplain seed banks were more consistently abundant and species-rich. In terms of seed stratification, benches were highly variable with depth to 30 cm reflecting recurrent reworking and deposition, whereas floodplain seed bank abundance and richness declined with depth, consistent with seed banks formed under low disturbance and sedimentation rates. We are also investigating controlling factors on the formation of seed banks in different geomorphic structures, such as inundation frequencies and unit exposure times, propagule inputs from local vegetation and hydrochory (the transport and deposition of propagules by water). We present implications for the succession of riparian vegetation in relation to both the influence of hydrology and vegetative controls on stream geomorphology. Understanding seedbank dynamics is being incorporated into river rehabilitation activities that focus on riparian re-vegetation.

\*\*\*\*\*

### Hydromorphological impacts of hydrosedimentary and ecological continuity's restoration. Example of the Yerres RIV., seine catchment, France

*MELUN G.(1), ARNAUD-FASSETTA G.(1), FORT M.(1), CHALAUX E.(2), LUCAS E.(2), FOUREL S.(2), GUESDON L.(2)*

*(1) Université Paris Diderot, PARIS, FRANCE ; (2) SyAGE (Syndicat mixte pour l'Assainissement et la Gestion des Eaux du bassin versant de l'Yerres), MONTGERON, FRANCE*

The European Water Framework Directive (WFD) aims to achieve “a good ecological and chemical status” by 2015. Hydromorphology influences ecological status in three ways: (i) hydrological regime (flow and groundwater), (ii) morphological conditions, and (iii) longitudinal and transverse continuity of rivers. Physical and ecological impacts of those structures upon hydrosystems are known, but removal's impacts are misunderstood due to lack of scientific feedbacks. According to particular methodology, based on field measurements and modelling, we aim at characterizing and quantifying hydromorphological impacts of dam removals on riverbed and bank structures. This study is applied to the Yerres watershed particularly significant due to its anthropic pressure conditions. We study limnimetric adjustments, stream power variations, transport capacity variations and riverbanks dynamics in no-dam context, at the reach scale. Our results show that there is a clear morphological adjustment of the riverbed and bank structures, even though locally those possibilities are constrained by anthropogenic facilities. Run-of-the-river dam removals result in: (i) systematic lowering of water level, (ii) shrinkage of the cross-section, (iii) increase of stream-power and transport capacity, proportional to uncompartimentalised context (calculated values are locally greater than 35 W/m<sup>2</sup>, hence suggesting that flow would have theoretical capacity to modify the channel geometry notably in sections without protection); (iv) clear recovery of bank erosion processes during flood events. Finally, our study demonstrates that the Yerres River can be hydromorphologically restored; yet higher hydrodynamic conditions in no-dam context involve new issues particularly in relation with the human occupation of the Yerres's valley (wetlands and channels disconnection, patrimonial buildings destabilization, impacts on recreational uses), that river managers have to consider.

## **Poster presentations:**

### **Measurement of Hydraulic Head Distribution below River Bed at around Alluvial Fan End: Case Study in the Inukami River, Central Japan**

KURASHIGE Y.

*The University of Shiga Prefecture, HIKONE, JAPAN*

Hydraulic head distribution below river bed was measured at around alluvial fan end of the Inukami River, Central Japan. Ten measurement sites were set at 2 m intervals in a flow direction. At each measurement site, piezometers were set at two different depths. Water level in the piezometer was measured with a digital caliper. A digital caliper was attached with a hand-made connector, and this connector can easily set at the top of each piezometer. The caliper was set on each piezometer using this connector at each measuring time. Accuracy of the water depth measurement in the piezometer was 0.14 mm. The measurement revealed that local water circulation appears in the longitudinal cross section during normal condition and just after a rainfall event. In contrast, several days after a rainfall event, upwelling of groundwater occurs at almost all sites.

\*\*\*\*\*

### **Restoration of Dynamic Processes - Hydro-geomorphological Research in the Riparian Forest between Neuburg and Ingolstadt**

CYFFKA B., FISCHER P., HAAS F.

*Catholic University Eichstaett-Ingolstadt, EICHSTAETT, GERMANY*

Within the framework of a restoration project eight working groups of different scientific disciplines have been operating since 2009. Major objective of this interdisciplinary project is to foster the dynamic processes on the floodplain. Further object is the identification and analyses of hydro-geomorphological processes and their impact on for vegetation and fauna.

Several measures are being taken to achieve these objectives. First there is a permanent bypass river going round the dam of a hydro power station with a discharge of up to 5 m<sup>3</sup>/s. Furthermore, ecological floodings are conducted and a groundwater drawdown is in action. These dynamic features shall create habitats with different ecological conditions. Oscillation of water level is one of the most important preconditions for a sound riparian ecosystem. Therefore the evoked hydro-geomorphological processes are being monitored.

River morphology is controlled by terrestrial laser scanning and large scale mapping by a drone. After analysing the results of this surveillance it will be possible to determine erosion and aggradation rates at selected undercut slopes and point bars. First dislocations of the river course have already been detected and flooding areas were identified. Further methods such as measurement of bed and suspended load, cross profiles and mapping of the river bed are complementary research work.

To understand the effects of the controlled discharge on river morphology is an exciting field experiment with nature-like circumstances. The aim is to detect the interaction of the permanent bypass and the ecological floodings with the biotic nature by applying the mentioned mixture of methods because the interdependencies have not fully been understood so far.

At the end recommendations shall be given in order to control discharge and floodings which will be important for a sustainable development of sensitive riparian ecosystems.

### Spatial distribution of cutoffs on the Peixe River, Brazil

MORAIS E.(1), HOOKE J.(2), ROCHA P.(1)

(1) São Paulo State University, PRESIDENTE PRUDENTE, BRAZIL ; (2) University of Liverpool, LIVERPOOL, UNITED KINGDOM

The aim of this study is to investigate the spatial distribution of meander cutoffs on the Peixe River, São Paulo State, Brazil. The river is a tributary of the Parana River and exhibits a meandering pattern with a remarkable alluvial valley which possesses features such as oxbow lakes and paleochannels. Landsat 5/TM images have been analysed between 1985 and 2010 at intervals of five years for a 60 km reach of the Peixe River. Images were geometrically corrected and the fluvial channel was digitized. The results have shown 21 cutoffs along the reach and a trend of cutoffs has propagated upstream. There is a concentration of cutoffs (60%) related to the formation of a secondary channel resulting from an avulsion process (~12 Km). This concentration of cutoffs is intensified upstream after 1995. In 1998 with the construction of a dam at the Parana River, a 4 km segment of the Peixe River confluence was transformed into a reservoir. Cutoff processes have been approached in a multitude of different ways, however an examination of the influence of base level change on the spatial distribution of cutoffs should be considered.

\*\*\*\*\*

### Determining soil flux from small riparian areas colonised by the invasive plant, *Impatiens glandulifera* on a small watercourse in northwest Switzerland

GREENWOOD P., KUHN N.

University of Basel, BASEL, SWITZERLAND

*Impatiens glandulifera* (common English name: Himalayan Balsam) was introduced into Europe in the mid-19<sup>th</sup> century. Its invasive tendency has facilitated its expansion throughout mainland Europe due to certain lifecycle traits which have allowed it to become rapidly established and out-compete most native floral species. Its favoured habitat includes damp, nutrient-rich soils which experience frequent natural disturbance, such as riparian zones. Once present, watercourses then inadvertently act as conduits that facilitate the downstream movement of seeds into un-contaminated parts of the catchment. They then form into discrete mono-cultural stands that typically range in area from a few m<sup>-2</sup> to >150 m<sup>-2</sup>. *Impatiens glandulifera* is cold-intolerant and experiences rapid 'die-back' in temperate countries during the first frosts. This can increase the susceptibility of riparian areas previously occupied by *I. glandulifera* to soil detachment and erosion by impacting raindrops and surface runoff. This communication reports the preliminary findings from on-going work conducted in a contaminated sub-catchment of the Birs River, northwest Switzerland. The investigation sought to quantify soil flux from a number of discrete riparian areas occupied by *I. glandulifera* before, during and after the die-back period. A technique using erosion pins and an erosion bridge was employed to micro-profile the soil surface, as this caused the least disturbance when measuring through vegetation. Initial soil surface profiles were established at predetermined locations within five contaminated sites before die-back occurred, and at five nearby uncontaminated reference sites. Soil surface profiles at all 10 sites were then re-measured each week. The average change in the soil surface profile (mm week<sup>-1</sup>) was quantified for each site, converted to an equivalent soil flux value (kg m<sup>-2</sup> week<sup>-1</sup>) and the results were compared for both groups.

### **River channel recent dynamics in relation to floods in the Curvature Carpathians (Romania)**

GRECU F., IOANA-TOROIMAC G., DOBRE R., ZAHARIA L.

*University of Bucharest, Faculty of Geography, BUCHAREST, ROMANIA*

Our previous studies showed that rivers coming down the Curvature Carpathians' region (including mountainous and subcarpathians areas, and the adjacent plain) cross a channel narrowing stage. This process is due to several factors: on a geological timescale, it is the consequence of neotectonics (Carpathians' uplifting and an active subsidence in the plain) and channel incision; on a historical timescale, it is the consequence of human interventions (dams, dykes...) and sediment load decrease. In this general context, we intend to continue analysing these evolutionary aspects by focusing on the relation between channel's dynamics and floods, especially because since 2005 important floods impacted on these hydrosystems. How these floods modified channel's morphology? Erosion and lateral reactivation, incision or aggradation? Which is the impact on the transport capacity of the channel and, consequently, on future inundations? In order to understand this relation, our study takes into account: aerial photos from 2005 and 2009; cross profiles before and after the floods; water discharges and suspended sediment loads. The comparison between the aerial photos shows the 2D evolution; the comparison between the cross profiles completes the analysis by a 3D image of the channel dynamics; the water discharges and suspended sediment loads allow us to characterise the floods. The preliminary results show that: 1) in the case of Buzau River and Teleajen River, the most affected reaches, near bridges, suffered from an incision process during these floods and, consequently, they were anthropically adjusted in order to diminish water's velocity; 2) in the case of Prahova River, the narrowing process continued despite the floods of 2005 and 2007.

\*\*\*\*\*

### **Flow variability in large tropical river systems in the Amazon**

MANYARI W.

*University of Brasilia, BRASILIA, BRAZIL*

Growing use of water resources, especially for generating power, has been observed across the globe. Scientific knowledge concerning the dynamics of flow – covering factors such as magnitude, frequency and duration – is scarce in relation to large tropical river systems. The role sediment load plays in preserving the ecological integrity of ecosystems along the banks and in the estuaries of alluvial rivers should not be ignored. Besides examining several features of the extremely complex, dynamic behavior of rivers in the Amazon on the basis of statistical surveys, the present study thus aims to serve as a starting point for formulating management strategies that take due account of the need to preserve the connection between the surrounding plain and the river channel, which is interrupted by a reduction in the frequency and extent of floods and an almost complete suppression of sediment load. Attempts to offset the impacts the installation of dozens of hydroelectric schemes is expected to produce as a result of the new economic cycle under way in the Amazon region should therefore reach beyond the fragmentary approach to flow variability, in which only the minimum flow levels are computed when it comes to defining a so-called ecological flow. The present study analyses the components of the flow regimen for three major rivers in the Amazon Basin (Xingu, Tocantins and Madeira) in stretches immediately downstream from locations where damming is either planned or has already been undertaken for power generation purposes. This introductory analysis seeks to describe the heterogeneous space-time pattern as a key strategy for maintaining ecological integrity with ecotone statistics typical of riverside environments in the Amazon.

### **Comparison between bedload transport rates estimated with tracer-clasts and results given by theoretical equations in an atlantic mountain stream (Pigüeña rivers, NW Spain)**

VÁQUEZ-TARRÍO D., ROSANA M.D.

INDUROT (Universidad de Oviedo), MIERES, SPAIN

High-order reaches placed in mountain basins show an important decrease in slope when compared with the immediate upstream low-order channels and this occur very close to the sediment producing areas. Consequently, coarse sediment deposits develop into these reaches. Then, channel bed sediment typically falls in coarse ranges of grain sizes, being bedload transport sporadic and occurring with flow conditions close to the threshold ones.

Rivers from NW Spain are defined by this situation, dropping by 2,000 m in a short path (50 km). Thus, drainage networks with relatively steep slopes and where channel bed sediment is typically coarse make appearance.

We selected Pigüeña river basin and we used tagged stones (painted and with inserted magnets) to trace bed sediment movement during flood events. By this way, we could estimate bedload transport rates between 1.1 to 4.0 kg/s for three flood episodes. After doing that, we decided to apply nine different transport equations in order to compare the output values given by these formulas with the bedload rates estimated previously with the tracers.

None of the chosen equations performed adequately: all of them tend to overestimate when compared with the tracer results, being the Wilcock-Crowe (2003) equation the only exception to that. For us, the main reason explaining this general overprediction is related with bed structures and textures. These equations assume how the channel will carry the entire load which is able to transport, without taking into account potential limitations in the sediment supply.

But in these rivers, armouring is ubiquitous, and together with structural arrangements could increase the resistance to transport entrainment, inducing a competent-limited situation and reducing the supply of sediment coming from bed surface. Wilcock-Crowe introduces complex corrections into the "hiding function" and considers the effect of sand content on entrainment; this could explain why it performs better.

\*\*\*\*\*

### **A multi-scale framework for assessing processes and forms within European Rivers**

GURNELL A.

Queen Mary, University of London, LONDON, UNITED KINGDOM

This poster is presented on behalf of the WP2 team of the REFORM programme.

The REFORM (REstoring rivers FOR effective catchment Management) research programme is an EU FP7 funded collaborative project involving 25 partners drawn from 15 European countries. The team working on work package 2 (WP2) are devising a multi-scale framework for assessing the hydrogeomorphological functioning of European rivers to underpin the hydromorphological and ecological objectives of the Water Framework Directive.

This poster will present the approach being adopted. This includes the definition, delineation, and characterization of a nested hierarchy of spatial units from catchment to geomorphic unit scales. It also includes the indicators that are being considered to support understanding of current river geomorphic functioning and its historical dynamics and to provide a context for assessing sensitivity to future changes in environmental conditions or management prescriptions.

## Time-history of the gravel sheet in Ardennian rivers over the last 100,000 years

*HOU BRECHTS G., DENIS A.C., JUVIGNÉ E., PETIT F.*  
*University of Liège - Department of Geography, LIEGE, BELGIUM*

It is generally held that, in north-western Europe, the main part of the gravel sheets under river beds were deposited during the Weichselian period in a periglacial environment. However, other parameters such as propagation of knickpoints in fluvial networks may also influence incision or aggradation. However, only few studies have dated the periods of formation of the gravel sheets and have described their properties.

The first aim of this research was to determine the thickness of the gravel sheets still remaining under the river beds and to estimate the potential incision of these rivers before reaching the bedrock. Then we tried to answer a number of other questions: When did these thick gravel deposits fill the valley bottom? When were the lowest terraces abandoned? When did the rivers incise the bedrock? What is the morphology of the bedrock under the gravel layer?

Numerous boreholes were made by percussion drilling in different floodplains of the Ardenne Massif and core samples were taken, down to the bedrock. Afterwards, different volcanic tephra from the Late Pleistocene were used as stratigraphic markers to date the relative periods of terrace formation and to reconstruct the past evolution of the gravel sheets. Pollen and metallurgic slag were also used to date the periods of bed level evolution.

In the Ardennian massif, the thickness of the gravel sheet beneath the river beds is very variable (from 10 m in the downstream part of the Ourthe River to less than 1 m in the upper catchments). In some valleys, weathered bedrock has been observed under the gravel sheet to a thickness of several meters.

Different phases of accumulation and incision over the last 100,000 years have been dated. Some evolutions can be clearly linked to climate changes but some modifications of bed levels also occurred during the Weichselian period and could be a response to the propagation of knickpoints in the fluvial networks.

\*\*\*\*\*

## Lithotopo units as ecoregions of fluvial systems: methodology and application

*HORACIO J.(1), PÉREZ-ALBERTI A.(2), OLLERO A.(3), CANOSA J.F.(4)*  
*(1) Dept. of Geography, University of Santiago de Compostela, SANTIAGO DE COMPOSTELA, SPAIN ; (2) Environmental Technology Laboratory. Technology Research Institute. University of Santiago de Compostela, SANTIAGO DE COMPOSTELA, SPAIN ; (3) Dept. of Geography and Land Management, University of Zaragoza, ZARAGOZA, SPAIN ; (4) Dept. of Geology, University of Oviedo, OVIEDO, SPAIN*

A lithotopo unit (LU) is an area with the same lithology and topography, where fluvial-ecological processes respond to similar behaviors. Our research proposes a method for identifying each unit type and analyzes its prevailing morphometric, energetic, sedimentary and hydraulic features. An LU perfectly fits the definition of ecoregion used by the Water Framework Directive (WFD) to classify surface water bodies, hence the importance of designing methodologies that generate distinct and internally homogeneous LUs.

Our method classifies the lithology according to the content of SiO<sub>2</sub> (silica) and by its mechanical behavior against erosion (isotropic and anisotropic rocks). The topographic descriptors that we used were slope, elevation and roughness. All individual variables were assembled into homogeneous groups through multivariate classification techniques. The LU testing took place in Galicia (29.562 km<sup>2</sup>, NW of Spain), and yielded a total of eight types. The behavior of the variables was checked at 29 points of the Cabe River basin (732 km<sup>2</sup>), which includes up to four different LU types. The morphometric variables that we analyzed were the drainage density, the frequency index and the torrentiality coefficient. As for the hydraulic geometry, we studied, at bankfull level, the hydraulic radius, the width / depth ratio and the average depth. The specific stream power and the average size of the sediment were also estimated.

Our results concern three points: i) for each LU, the WFD's System B geomorphological descriptors and those used by us, move in a range of very stable values; ii) the watershed / subwatershed provides a logical scale for resource management, but the LU sets a protocol of action, as river forms and processes are linked to each LU; iii) LU mapping helps organize the geomorphological and ecological compression of river systems, and facilitates their application and comparison with other areas.

### **Effects of a major flood on a mountain river on physical habitat conditions for river biota, channel morphology and valley-floor infrastructure**

HAJDUKIEWICZ H.(1), WYZGA B.(1), MIKUS P.(1), ZAWIEJSKA J.(2), RADECKI-PAWLIK A.(3)

(1) *Institute of Nature Conservation, Polish Academy of Sciences, KRAKOW, POLAND* ; (2) *Institute of Geography, Pedagogical University, KRAKOW, POLAND* ; (3) *Department of Hydraulic Engineering and Geotechnique, Agricultural University, KRAKOW, POLAND*

To restore the gravel-bed Biała River, Polish Carpathians, establishing erodible corridor was proposed in two reaches located in its mountain and foothill course. In these reaches, longer, unmanaged channel sections alternate with short, channelized sections and that pattern of channel types is associated with a general tendency towards increasing channel narrowing and incision in the downstream direction. In June 2010 a flood with a recurrence interval of at least tens of years occurred on the river and this study aims at determining its effects on physical habitat conditions for river biota, channel morphology and valley-floor infrastructure. Surveys of 10 pairs of closely located unmanaged and channelized cross-sections, performed in 2009 and the late summer of 2010, allowed to assess the flood-induced changes to physical habitat conditions. Before the flood, unmanaged cross-sections were typified by a significantly greater number of low-flow channels, finer bed material and greater lateral variability in depth-averaged and near-bed flow velocity than channelized cross-sections. The flood seems to have equalized habitat conditions in both types of river cross-sections, obliterating differences in particular physical habitat parameters between channelized and unmanaged channel sections. A comparison of channel planform from 2009 and 2012 indicated that greater channel incision typical of more downstream sections was reflected in a lower degree of the river widening by the flood. Bankfull channel width increased by half in the surveyed unmanaged cross-sections and by one third in the channelized cross-sections. However, damage to the valley-floor infrastructure was practically limited to the channelized river sections, indicating incompetent management of riparian areas rather than the degree of river widening as a principal reason for the economic losses during the flood.

\*\*\*\*\*

### **Sediment yield prediction in river basins by means of geomorphic parameters and regression- ANN relationships**

KHANCHOUL K.(1), TOURKI M.(1), LE BISSONNAIS Y.(2)

(1) *Badji Mokhtar University-Annaba, ANNABA, ALGERIA* ; (2) *LISAH, SUPAGRO, MONTPELLIER, FRANCE*

Knowledge of sediment yield and the factors controlling it provides useful information for estimating erosion intensities within river basins. Probst and Amiotte-Suchet (1992), in their review of suspended sediment transported by wadis in the Maghreb, have underlined the lack of available data for such river types. Nevertheless, further study of the quantification of sediment transport in these regions and its variability is clearly required. The objective of this study is to build a model from which suspended sediment yield can be estimated from ungauged rivers using computed suspended sediment yield and physical factors. In this work, regression relationships are built between suspended sediment yield that is computed from rating curves established from long-term measurement series at gauging stations in Algerian drainage basins and corresponding basic physiographic parameters (precipitation, runoff, coefficient of torrentiality, basin area, orographic coefficient, lithology index). Moreover, the basic neural network is employed in this study. This used stochastic process possesses a three-layer learning network consisting of the input layer, the hidden layer, and the output layer. The proposed Levenberg–Marquardt algorithm to train the neural networks of the current research study is based on the feedforward backpropagation method. Different combinations of several internal parameters, i.e., data partitioning approach, number of neurons in each hidden layer, transfer function, error goal, are tried. The regression performance ( $r$ ) and the computation of the efficiency factor (EF) have provided information about the predictive capabilities of the two types of models. Single plot displays of network outputs with respect to targets for training, validation, and test sets have indicated that ANNs are a promising method for predicting suspended sediment yield ( $r = 0.997$  and  $EF = 0.99$ ), as they have performed better than the conventional multiple regression model.

**Longitudinal and temporal variation of bed-material grain size in a mountain river disturbed by gravel extraction and channelization, the Czarny Dunajec, Polish Carpathians**

ZAWIEJSKA J.(1), HAJDUKIEWICZ H.(2), WYZGA B.(2), RADECKI-PAWLIK A.(3), MIKUS P.(2)

(1) *Institute of Geography, Pedagogical University of Cracow, KRAKOW, POLAND* ; (2) *Institute of Nature Conservation, Polish Academy of Sciences, KRAKOW, POLAND* ; (3) *Department of Hydraulics Engineering and Geotechnique, Agricultural University, KRAKOW, POLAND*

The impact of human disturbances on the conditions of channel sedimentation in the Czarny Dunajec River, Polish Carpathians, was investigated by reconstructing longitudinal and temporal changes in the grain size of bar sediments. We determined surface bed-material grain size on 47 gravel bars along an 18 km long river reach without tributaries in which some sections were modified by gravel extraction and the resultant channel incision, or channelization over the past few decades. A downstream fining trend of bar sediments was established based on the sites with average river width and a vertically stable channel, and used as reference for the other samples. In the deeply incised, upper part of the reach, bar gravels are markedly coarser than the reference grain size. Here, sieving analysis of channel sediments formed at different periods showed coarsening of the bed material over the second half of the 20th century. With larger particles extracted from the channel in the past decades, fine grains must have been flushed out, whereas the concentration of flood flows in the deeper, narrower channel has increased their competence, enabling a delivery of the coarse particles from the upstream reach. In the narrow, regulated channel section in the middle part of the reach, bar sediments exhibit better-than-average sorting and change from coarser to graded similarly to the reference grain size along the section. In a wide, multi-thread channel in the lower part of the reach, bar gravels are distinctly finer than the reference grain size. The middle section has been channelized to prevent sediment delivery to a downstream-located dam reservoir. However, it actually efficiently transfers the bed material evacuated from the upstream, incising river section. As low unit stream power and high channel-form roughness facilitate sediment deposition in the unmanaged, lower part of the reach, it functions as a sediment sink, reducing bed material delivery to the dam reservoir.

\*\*\*\*\*

**The Interannual regime of rivers: a comparison between peixe (western Sao Paulo State, Brazil) and dee river (UK) and the sea index influences**

ROCHA P.(1), HOOKE J.M.(2)

(1) *UNESP / BRAZIL, PRESIDENTE PRUDENTE-SP, BRAZIL* ; (2) *University of Liverpool, LIVERPOOL, UNITED KINGDOM*

Oceans are the lower boundary condition most important for climate and have leading a role in interdecadal climate variability. Many researchers have shown the importance of the Ocean Indices in the river regime and hydrology of catchments, by direct or indirect methods. This paper discusses the hydrological behaviour of the Peixe River in Brazil and Dee River in UK, and its relationship with the main climatic Oceans Index. The rivers drain catchments of different global and regional climate zones. The Peixe River basin drains a 2.910 km<sup>2</sup> area. The Dee River drains a 1.013,2 km<sup>2</sup> catchments area. Both rivers are in the Cf areas of Climatic Classification of Köppen. The data series of the gauging stations was obtained from official sites in Brazil (National Water Agency) and United Kingdom (National Water Archive). The Tropical South Atlantic Index (TSA) data, the Pacific Decadal Oscillation (PDO) Index; the North Atlantic Oscillation Index (NAO) were made from literature and complemented by National Oceanic and Atmospheric Administration -Physical Science Division (NOOA-PSD). To compare the hydrological regime of the rivers were used the inter-annual mean deviation of the 1948-2007 series for the Peixe River and 1938-2010 series for the Dee River and its correlations among PDO, TSA and NAO Indices. The results indicate that there was significant variability in the hydrologic regime of Peixe River throughout the evaluated series, with three well-defined periods; the most significant changes happened after the 1970's, associated with the warm period of the PDO Index. Both PDO and TSA Index had a positive relationship with the Mean Deviation of Peixe River, indicating an influence on the river's flow regime. For the Dee River, three periods were also identified and a positive relationship with the NAO Index. Despite of the positive relationship among rivers and Ocean Indices, they were with low r<sup>2</sup>.

### **Morphological changes along alpine river reaches affected by natural et human impact: examples on river pellice and chisone (NW Italy)**

AUDISIO C.(1), TURCONI L.(2)

(1) University of Chieti - Pescara, MURELLO (CN), ITALY ; (2) CNR-IRPI, TORINO, ITALY

The causes of modification along rivers are either natural or human.

If the morphological variations in the past were mainly determined by the severe and extreme floods which periodically affected the rivers, since 1940s, as a lot of works and researches demonstrated, the natural impact cannot be separated by the human impact. The presence of dams, the channelization works, the channel modification and river diversion, the bridge crossing, the sediment removal and mining are part of the anthropic causes which have influenced the river adjustments.

The present work illustrates a summary of the studies and researches done on channel adjustment and evolutionary trend of two rivers flowing in the North Western sector of Italy. The used methodology is based on the reconstruction of spatial *variation* in channel *morphology* and sediment dynamics using historical maps and aerial photos in the medium and short-term period. Contemporary, the principal natural and human interventions on the river have been investigated. All data are inserted in a GIS for the uniformity of the coordinate system. Based on the availability of documentary sources, cartographical, photographic and ortho-photographical data, the method allows a reconstruction of the history of the river. Then, the modification of the channel and the active bankfull were related to the natural and human impacts trying to investigate which is the preponderant cause of variation and how floods and human intervention influence each other. The modification of some index over time, as the width, is a useful tool for interpreting the evolutionary trend of the river and tries also to predict its future evolution.

The studied rivers are: River Pellice (35 km – from Luserna San Giovanni to Po confluence), and River Chisone (12 km – from Pinerolo to Pellice confluence).

\*\*\*\*\*

### **Annual landform changes and their effects on pioneer species in the active braided gravel-bed river in the upper reaches of the Azusa River, central Japan**

SHIMAZU H.

Rissho University, KUMAGAYA, JAPAN

The upper reaches of the Azusa River, central Japan, a braided gravel-bed river, is characterized by a pioneer species, *Salix arbutifolia*, occurring as patches of various age classes and old isolated trees in the active riverbed. This is a rare species which has a limited geographic distribution in the Japanese Islands. This is one of the important riverine landscapes in Japan. This study aims to clarify formative process of the landscape from the geomorphological viewpoint. The geomorphological maps of the observation site, which were made in every summer from 1994 to 2012, and which recorded annual landform changes of the riverbed and images of the riverbed taken by interval shooting cameras recorded flood conditions in the summer and autumn season in 2011 and after late spring in 2012 revealed geomorphological processes. Sediment transport and/or landform changes occurred every year in severe heavy rain events more than 100 millimeters per day during the snowmelt flooding season in April and May and/or the rainy season in June and July. There were some stable spots in bars and/or islands in the active riverbed for several years where pioneer plants, especially *Salix arbutifolia*, germinated and grew to young pioneer patches. Generally lateral erosion gives serious disturbance for young pioneer patches. Because most channel migrations were not caused by lateral shifting with lateral erosion but by channel burying and new channel excavation, they could survive after channel migration event. Sometimes slight lateral erosion occurred and it caused destruction and/or size reduction of the patches. If a seedling patch remains not to be destroyed for several years, it becomes a grown patch, finally old isolated trees. Because the germination year was different each patch, the patches are in various age classes. These geomorphic processes provide peculiar riverine landscape in the upper reaches of the Azusa River.

**Towards understanding spatial and temporal variations in landscape response to climate change at an upland Karoo site, South Africa.**

OLDKNOW C., HOOKE J., LANG A., MAUZ B.  
*University of Liverpool, LIVERPOOL, UNITED KINGDOM*

The semi-arid landscapes of the Karoo, South Africa are highly susceptible to land degradation. Recent studies have shown that erosion has increased tenfold in the past 200 years since the onset of European colonisation expressed through gullying and badlands. Yet these rapidly eroding areas occur in striking juxtaposition with areas of apparent stability, where dolerite dykes intrude into softer Karoo Supergroup mudstones and shales.

Within the Karoo landscape lies the Ganora catchment (31° 51'34.45"S, 24° 37'48.95E), which is a tributary system of the southward flowing Sundays River which drains the Great Escarpment. Patterns of contemporary erosion appear to be superimposed on a longer term record of cut and fill that predates European occupation. Other work nearby suggests that alluvial fills are much older than previously thought (> 100 ka), and could be diachronous due to effects of sediment disconnectivity. Major research questions are herein addressed concerning: i) the timing of past cut and fill episodes and whether these can be explained in terms of autogenic fluvial sedimentation dynamics or climate, ii) Evaluation of intra-catchment scale changes in landscape sensitivity and response through time. The combined results of soil magnetic analyses and OSL dating of alluvial sediments are presented in order to explore spatial variations in landscape response, and whether apparent signals of change are relatable to (non)autogenic factors. Initial magnetic susceptibility determinations provide clear discrimination between different sediment generating zones, and have thus enabled alluvial fill sediments to be fingerprinted.

The preliminary data presented signify a key step towards the creation of a landscape response model that incorporates the influence of buffers and barriers to sediment movement, the dynamics of sediment connectivity through time with associated mechanisms and feedbacks in upland Karoo catchments.

\*\*\*\*\*

**Regional scenario of Quaternary climatic oscillations: low river terraces and flood plains in the current context of Depressão Periférica Paulista**

STORANI D.L., PEREZ FILHO A.  
*UNICAMP, CAMPINAS, BRAZIL*

The topography of São Paulo State, in the southeast region of Brazil, is divided into geomorphological provinces analyzed from its structure, formation and lithologic basis. Depressão Periférica Paulista (Paulista Peripheral Depression) corresponds to one of these provinces, with a hilly topography, and is a zone of occurrence of Paleozoic and Mesozoic sedimentary sequences in São Paulo State, also including discontinuous areas of intrusive bodies. Small areas of Precambrian rocks are also incorporated in this province. Its origin, according with Ab'Saber (1969), is predominantly denudacional.

The proposed study aims to identify and interpret the levels of low Quaternary river terraces and floodplains using the OSL (Optically Stimulated Luminescence) technique in different surface formations located on the terraces and recent alluvium in the selected rivers of the studied geomorphological province. The results obtained will allow to trace the relationship between the genesis of such forms, and possible preterit environmental conditions, in an attempt to identify and explain possible alternations of semi-arid periods and the subsequent carving of the river canal in hot and humid conditions.

The results obtained by the datation method will build a regionalized set for climate oscillations, mainly from the Quaternary (Pleistocene and Holocene). It will also be taken into account the influence of neotectonic activities in the shaping of such forms of topography, allowing the analysis of a regional correspondence between ages and levels of river terraces of the same geomorphological province.

### **Quaternary Basin of the Pantanal Mato-Grossense, Brazil: fluvial Megafans**

*FACINCANI E.M., BACANI V.M., SANTOS R.M., PEREIRA W.*  
*Universidade Federal de Mato Grosso do Sul-CPaq, AQUIDAUANA, BRAZIL*

The Pantanal is a tectonically active sedimentary basin marked by several fluvial fans, which represent the main feature to determine the characteristics of the Pantanal landscape. This work presents the concepts involved in the formation of the fluvial megafans that, in the Pantanal, involves climatic, hydrological, sedimentological and Neotectonics aspects. The fluvial fans of Pantanal are depositional systems shaped as an open fan or a cone segment, characterized by distributary channels of great lateral mobility, due to unconfined flow from the highlands surrounding the Pantanal Basin. So it is important to understand the formation of mega-fans fluvial systems, because its mechanism is the key to the understanding of the filling of the sedimentary basin of Pantanal. The megafans of Pantanal Basin are positioned mainly at the left margin of Paraguay River, (Corixo-Grande Paraguay, São Lourenço, Taquari, Negro, Taboco, Cuiabá and Aquidauana-Miranda) surrounded by the highlands of Maracaju-Campo Grande, Taquari-Itiquira, Guimarães e Parecis.

\*\*\*\*\*

### **Negro River: fluvial megafan. Southeastern border of the Pantanal Basin, Brazil**

*FACINCANI E.M.(1), BACANI V.M.(1), SANTOS R.M.(1), QUIRINO P.B.(1), CORDEIRO B.M.(2), PEREIRA W.(1)*

*(1) Universidade Federal de Mato Grosso do Sul-CPaq, AQUIDAUANA, BRAZIL ; (2) Universidade de São Paulo, SÃO PAULO, BRAZIL*

The Negro fluvial megafan is a depositional system located on the southeastern border of the Pantanal wetland and has been evolving since the Pleistocene. Its surface exhibits modern and relict geomorphological features, such as channels and paleochannels. The Negro River flows westward and belongs to the Upper Paraguay drainage basin. Theater-headed valleys characterize the catchment area on the Maracaju-Campo Grande Plateau, where the Negro River shows an obsequent behavior in relation to Paleozoic and Mesozoic sedimentary strata of Paraná basin. A conspicuous NNE escarpment is the natural limit between the source area on the plateau and the depositional setting on the Pantanal wetland. The geomorphological zonation allowed to establish an evolution started in the late Pleistocene when unconfined flows given rise to formation of a proximal lobe. During a period dominated by erosion an incised valley has cut older deposits on the upper fan. Sedimentation during Holocene times has been taken place on the modern distal distributary fan lobe and on the meander belt that aggraded the incised valley.

**Evaluating a functional hydromorphological restoration of a lateral channel of the Upper Rhine (France): first results and implications of the temporal trajectory to restoration sustainability**

*LEJEUNE Q., SCHMITT L., ZIMMERMANN A., ESCHBACH D.*  
*University of Strasbourg, ERL 7230, STRASBOURG, FRANCE*

The Upper Rhine hydrosystem exhibits a high biodiversity. Since mid-19<sup>th</sup> century, several engineering projects developed for flood control, agriculture, navigation and hydropower, have drastically impacted aquatic and riparian habitats. In this context, the specific alluvial species of the Rohrschollen natural reserve is declining. Its main watercourse, the Bauerngrundwasser, an anastomosing channel of the Rhine, has now a constant and low discharge (under 0.1m<sup>3</sup>/s), inducing a high rate of fine sediment deposition. During periods of high flow, the site is flooded but water has no energy due to a dam's backwater effect.

The LIFE+ project "Restauration de la dynamique des habitats alluviaux rhénans sur l'île du Rohrschollen", managed by the City of Strasbourg, plans to restore the hydromorphological and ecological functionality of the hydrosystem: bedload dynamics, channel mobility, surface water-groundwater exchanges, renewal of pioneer ecosystems. Thus, the Bauerngrundwasser will be reconnected to the Rhine by building a new upstream connection channel. Water input will attain 80m<sup>3</sup>/s, leading to dynamic floods and making of this project one of the most ambitious for the French side.

To assess the efficiency of this restoration project, a hydromorphological monitoring (included in an interdisciplinary project) is carried out and is based on the comparison of pre- and post-restoration dynamics. It includes in particular a topographic (LiDAR, theodolite), a cartographic (aerial photo), a sediment transport (sampling, PIT tag, erosion chain), a hydrological (water level sensors, gauging) and a hydrogeological (piezometer) studies. This paper will give the first results, as well as the implications of the temporal trajectory of the system (historical study based on old maps, aerial photos and sedimentological investigations), which have notably been got in order to give some prospective guidelines concerning the efficiency and sustainability of the restoration.

\*\*\*\*\*

**Fluvial geomorphological adjustments to global change in Iberian Rivers**

*BESN P., IBISATE A.*  
*University of the Basque Country - Department of Geography, Prehistory and Archaeology, VITORIA-GASTEIZ, SPAIN*

Global change, not only climatologic conditions but also and especially human impacts have long affected fluvial dynamics, and geomorphic processes and forms in Iberian Rivers due to their particular Mediterranean climatic conditions and the heavy pressure on water resources.

Based on aerial photographs and cartography changes in channel dimensions, planform and vertical adjustments have been analysed in several reaches of 4 river basins representing different environmental conditions: Ebro, Llobregat, Júcar and Guadalquivir. The variations in active channel and riparian surfaces were studied by comparing aerial photographs and ortophoto maps using GIS tools (ArcGis 10). The aerial photographs were firstly georeferenced and geometrically corrected, and the different surfaces digitalized (water surface, unvegetated sediment bars, pioneer vegetation, riparian forest, forest plantations, crops and artificial surfaces). Finally changes of the different surfaces along all the studied years have been measured and quantified. Besides that vertical adjustments were analysed comparing cartography from different dates.

These changes have been related with changes on the river basin and river course (land uses, precipitation, reservoirs, water abstractions, bank protections, etc.) as well as hydrological conditions, mainly floods.

Overall all the reaches present a reduction of their fluvial surface, principally active channel, a channel narrowing and a lost of diversity. Differences have been detected depending on the basin characteristics and climatic conditions of each river reach.

### Elucidating the level of influence of key factors on the spatial distribution of overbank deposition

GAMBOA-ROCHA A., STEWARDSON M., RUTHERFURD I., FINLAYSON B.

Melbourne University, MELBOURNE, AUSTRALIA

Floodplains evolve from sediment transport, erosion and deposition processes. As these floodplain-building processes determine floodplain evolution in alluvial systems, it is important to understand the mechanisms and factors that influence the spatial distribution of overbank sediment deposition.

This investigation uses a novel modeling approach combined with Cs<sup>137</sup> dating techniques to assess the key factors producing spatial patterns of overbank sediment deposition.

Individual floodplain units were strategically selected using LIDAR imagery. These were classified by their hydraulic connectivity and used to locate sites for sediment core collection and radionuclide analysis. A process based conceptual model was developed from an analysis of existing models as reported in the literature. A numerical model was constructed from a refined analysis of the interactions among the key factors that determine overbank sediment transport and deposition. This model therefore incorporates the relationship that exists among the key factors influencing overbank deposition amounts and patterns and also includes an improved relationship between the spatial variability of suspended sediment concentration and sediment travel time. A sensitivity analysis was designed to identify the factors that exerted the greatest influence on the spatial variability of overbank sediment deposition.

Results of the sensitivity analysis suggest that key influencing factors controlling the spatial distribution of overbank sedimentation are variation in (i) the duration of flood inundation and (ii) the flow path and consequent travel times from the channel. The model accuracy was evaluated against field-estimates of overbank sediment deposition. We also found that there is generally good correspondence between model predictions and the measured deposition rates. Our results provide a refined conceptualisation of floodplain sedimentation processes as a basis for further research.

\*\*\*\*\*

### Variation trend of the sedimentation rate in the Yinchuan Plain of the upper Yellow River since 0.7 Ma B.P. and its main influencing factors

WANG S., YAN Y., HE L., YAN M.

Institute of Geographic Sciences and Natural Resources Research; Chinese Academy of Sciences, BEIJING, CHINA

As an alluvial plain of the upper Yellow River, the Yinchuan Plain has a Quaternary stratum is closed to 1 km. In order to reveal the historical variation trend of the sedimentation rate in the Yinchuan Plain and analyze its influencing factors, this work mainly based on the dating data of a bore columnar section (thickness 189.6 m) in the plain to estimate the sedimentation rate change since 0.7Ma, and to couple it with the variation of the channel downcutting rate at the Heishanxia gorge (upwards the Yinchuan Plain). The results indicate that an allometric function ( $R^2=0.977$ ) could be used to fit the historical variation trend of the sedimentation rate with time in the Yinchuan plain. The mean sedimentation rate is 0.115 mm/a in the period from 0.7 Ma B.P. to 112.35 ka B.P. while a distinct increase trend (mean value is 1.962 mm/a) since 112.35 ka B.P. The relationship between time and the channel downcutting rate could also be fitted by a similar allometric function ( $R^2=0.967$ ). To reveal the potential relation between the sedimentation rate and the channel downcutting rate we calculated the sedimentation rate and the channel downcutting rate in an interval of 10 ka according to the relevant fitted functions, respectively, and a linear relationship ( $R^2=0.995$ ) between the sedimentation rate and the channel downcutting rate was fitted. It means that the change of the sedimentation rate in the Yinchuan Plain was mainly influenced by the tectonic rise in the upstream basin. The climate of the upper Yellow River basin has changed to more arid since 120 ka B.P. and has induced decrease of the annual precipitation which could induce the decrease of the vegetation cover and enhanced rainstorm which could induce more strong erosion in the upriver Yellow River basin. The increase of the tectonic rise and the climate change to aridity were the main influencing factor on the increase of sedimentation rate in the Yinchuan plain since 112.35 ka B.P.

### **Velocity distribution of turbulent open-channel flow over permeable rough bed**

CHEN X., LIN M., LIN B.

*Fujian Normal University, FUZHOU, CHINA*

Fluvial river bed usually consists of sands. When the diameter of the sands is large enough, such as gravel bed, the effects of bed permeability on the main stream flow can not be neglected and the flow characteristics are different from that of impermeable bed, which is still need to be well studied. A laboratory experimental research is reported in the paper which considered such effect on the velocity distribution of turbulent open-channel flow. The experiment was conducted in a glass-sided flume that is 20m long, 0.8m wide and 0.6m deep. The bed of flume was glued a layer of uniform marbles with a diameter of 1 cm. Located at a distance 10m from the upstream end of the flume is a rectangular recess that is 1.65m long and 0.7m wide. The permeable bed is simulated in the recess where is well packed with twelve layers of the same marbles. The velocity measurements were carried out using a laser Doppler velocimeter (LDV, DANTEC) and the probe of the LDV was installed at a high resolution traversing system. The measurements were conducted for three flow conditions. Velocity distribution at 2 locations for impermeable bed and 3 for permeable bed were measured. The results show that the velocity distribution for impermeable bed follows the law of the wall when the reference level is lowered to 0.25-diameter of the marble top. For permeable bed, no-slip condition at bed surface is no longer available and the velocity distribution is the same as that of impermeable bed when a slip velocity was used to modify, and the values of shear velocity are found to increase. How the slip velocity and shear velocity varies are still need to further investigated.

\*\*\*\*\*

### **Knickpoint initiation and migration rate of bedrock rivers dissecting the Middle to Late Pleistocene marine terraces at North Sanriku coast, NE Japan**

OGAMI T.

*Chuo University, TOKYO, JAPAN*

River knickpoints are detected from longitudinal profiles of rivers at North Sanriku coast, NE Japan. Three bedrock rivers with knickpoints are investigated. Length and catchment areas of the rivers varies 23.5 to 30.1 km and 54.6 to 92.1 km<sup>2</sup>, respectively. The rivers are cross cutting the Middle to Late Pleistocene marine terraces. The initiations of the river knickpoints are estimated based on geomorphic features of marine terraces and shoreline angles.

In study area, the Middle to Late Pleistocene marine terraces are developing, which indicate broad tectonic uplifting at North Sanriku coast. Formation ages of the terraces are determined by tephro-chronology. There are at least 8 marine terraces developed during interglacial high-stand periods (MIS 19, 17, 15, 13, 11, 9, 7 and 5e). Altitude of surface of the terraces vary 270 m to 30 m above sea level. Former shorelines dividing the marine terraces are traced approximately parallel each other along present coast.

The river knickpoint of each river is formed at 4.5 km, 5.0 km and 17 km path length from river mouth. They should have been migrating upstream as a result of bedrock erosion since their initiation. Assuming that the knickpoints were formed at the edge of marine terraces, initiating places of the knickpoints are confined within specific area. The place of the initial knickpoints should be located at seaward and higher altitude than present position of knickpoints.

At one of the rivers, the initial knickpoint is estimated to be formed at edge of MIS 13 marine terrace, which formed as sea-cliff during MIS 11 high-stand. At another river, the initial knickpoint is estimated at edge of either MIS 15 or 13 marine terraces, which formed as MIS 13 or 11 sea-cliff. As a result, averaged migration rate of knickpoints are 7.5 m/ka (in 400 ka) and 11–7.2 m/ka (in 400–480 ka). Based on the knickpoint migration rates, incision rate of bedrock rivers are discussed.

### **Late Quaternary evolution of the lower reaches of Ziliana stream in south Mt. Olympus (Greece)**

*BATHRELLOS G., SKILODIMOU H., MAROUKIAN H., GAKI-PAPANASTASSIOU K.*

*National & Kapodistrian University of Athens, Faculty of Geology & Geoenvironment, Department of Geography & Climatology, ZOGRAFOS, ATHENS, GREECE*

Active tectonism influences the evolution of hydrographic networks. The uplift and the faults of Mount Olympus directly control the development of its major drainage networks. The study area is located at the southwestern edge of the eastern piedmont of Olympus in east Central Greece. The piedmont is composed of three extensive east looking alluvial fans of Quaternary age and a thickness of 1,100m that are inactive and eroding today. The southern alluvial fan of the Olympus piedmont is located in the study area.

This study examines the paleogeographic evolution of the lower reaches of Lazi Griva, Ziliana and Vathyrema streams having a total drainage area of 141Km<sup>2</sup>. For this purpose, detailed field work, large scale geomorphological mapping, sedimentological analysis and geoarcheological investigations were performed. A spatial database was created, and ArcGIS 10 software was used to process the collected data.

The uplift of Mount Olympus has led to active downcutting in the upper reaches of the three streams and enhanced sedimentation rates and occasional heavy floods in the lower reaches. The reactivation of a major normal fault zone running N-S along the eastern front of Mount Olympus has created a temporary local base level (knick-point) at the exit of the three streams from the mountain. At this location, due to the fault zone, the three streams join and reach the sea in a single main channel of Ziliana. At their confluence, on a terrace, there is the Middle Geometric settlement of Livithra (the burial place of mythic musician Orpheus) which is believed to have been destroyed by an earthquake and/or a heavy flood. Consequently, the Quaternary active tectonism is the main geomorphic factor influencing the evolution of the lower reaches of Ziliana stream.

\*\*\*\*\*

### **Spatial and temporal variability in cut-off sedimentation**

*HOOKE J.*

*University of Liverpool, LIVERPOOL, UNITED KINGDOM*

Formation of cut-offs in meandering rivers is a major part of floodplain construction and is very important in providing varied habitats as well as the remnants of old channels leaving topographic and compositional signals in the floodplain. Some research has demonstrated the effects of orientation and morphology of cut-off on sedimentation rates but limited data are available on initial patterns and rates of infill. The occurrence of several cut-offs at various dates over the past 30 years on one active meandering river reach with pre-existing morphological data enables the spatial and temporal distributions of sedimentation to be examined. These have all experienced a common hydrological, sediment and land use regime. Data on rates and patterns of sedimentation are presented. The evidence is that rapid, coarse sedimentation occurs initially in the upstream cut-off entrance then finer sedimentation to half bankfull level within a few years. Infill of the downstream exit is much slower and comprises much finer sediment. The amount of infill and presence of water bodies within the old channel is influenced by the pre-existing morphology of pools, riffles and bars. This is closely related to the morphology of the bend and its stage of meander development in the commonly occurring evolutionary sequence. Compound bends at time of cut-off are common and thus a shallowing occurs in the apex, influencing depth of sedimentation and formation of an ox-bow lake. These results have important implications for inferences made from sediment cores in palaeochannels if position of the cores in relation to the meander morphology is not taken into account adequately. The data on variability of habitats created in cut-offs and likely timescales of infill are valuable for geomorphological and ecological management.

## **The decay and related environment problems of the deltaic rivers in West Bengal, India**

**BERA B.**

*Rabindra Bharati University, KOLKATA, INDIA*

We live in a land of million rivers. Each of these rivers and their tributaries play an important role in our social, cultural and economic lives. But, at present the rivers of deltaic Bengal are in the state of decay. The river Sialmari, Bhairab, Chota Bhairab, Bhandardaha nala are the main tributaries of river Jalangi, and river Jalangi is also the tributary of Bhagirathi-Hugli and distributary of Padma. Though river Bhagirathi-Hugli is the most important river, during 16<sup>th</sup> century River Jalangi was most important river in West Bengal than river Bhagirathi. Another river Mathabhanga is bifurcated into two branches at Majdia as Churni and Ichamati, also the distributaries of river Padma. It is evident from Rennel's Map, several other rivers were also flowing on the vast tract of Murshidabad and Nadia districts of West Bengal during 16<sup>th</sup> century. Due to shift of river course of Ganga-Padma and gradual siltation at the off-take point of Nadia rivers, many rivers are gradually decayed, somewhere are converted into palaeo channels, otherwise they are entirely disappeared.

Several culverts, bridges and concrete embankments, brick fields have been constructed across the deltaic rivers simultaneously. As a result upland discharge and capability of the rivers are decreasing day by day and various environmental hazards and disasters (flood, river bank erosion, soil erosion) are also occurred in the consecutive years. For unscientific human interference the micro geomorphological features have been modified. Many important rivers are already choked out.

\*\*\*\*\*

## **Quaternary Paleolandforms at Sanaga-Mbam confluence between geography and historical palaeoenvironmental approach**

**EKASSI ONDOUA L.(1), TCHINDJANG M.(1), WAKPONOU A.(2)**

*(1) University of Yaoundé I, YAOUNDE, CAMEROON ; (2) University of Ngaoundéré, NGAOUNDERE, CAMEROON*

The Bafia penneplains known as Gulf of Bafia situated at the river Mbam and Sanaga confluence is an area which fairly recorded environmental changes (past and present) recognized by the markers such as the terraces observed on the major rivers. However, apart from a few sources for the period before the Quaternary, information on geomorphological landscapes are mentioned only by regional maps.

This study therefore aims to overcome this lack of information by proceeding to paleoenvironmental studies. In addition to documentary sources that highlight old depletion of Plio-Quaternary climate, this work is based on field studies and observations throughout this Bafia penneplain to reflect the relationships between the different geomorphic units. Superficial deposits samples collected on five pits for this purpose have been submitted to sedimentological analysis in the laboratory.

The results have clarified the various stages of the implementation of paleolandforms (palaeosurfaces, palaeotopographies and terraces), inheritance of Quaternary climatic episodes. Deduction of it paleoclimatic significance and the approximate reconstruction rhythms that marked the geomorphological landscape allow us to understand the current evolution of the environment at the Mbam- Sanaga confluence.

### **Current development of the bed and major Chari river bank at N'Djamena since Holocene**

DOUDJE K.(1), TCHINDJANG M.(2), MOUPENG B.(1)

(1) *University of N'Djamena, N'DJAMENA, CHAD* ; (2) *University of Yaoundé I, YAOUNDE, CAMEROON*

River bed provides a lot of information on the evolution of palaeoclimate. But it also help to build an example of models to illustrate some dynamic climatic conditions and geological data. These considerations lead us to study the erosion on the Chari river banks from the Holocene to the present day in N'Djamena. Chari river is an endorheic watercourse who dug his bed in tertiary and quaternary sediments. This river belongs to a tropical system across two types of climate: tropical wet and tropical dry season contrasts. To realize this study, we carried out observations and samples collecting across the Chari banks.

Samplings were made on river sections occupied by banks and quarries; these samples were examined with a microscope and a laboratory tests have been made. The data collection data are supplemented by aerial photographs and satellite images which were used to assess Chari bank erosion. Samples from open cuts by sediments banks showed that it come from fluvio-lacustrine origin deposited during the palaeo-Holocene climatic change. They are mainly sandy clay materials inconsistent silt, therefore less resistant to fluvial erosion. The lateral erosion affects those banks that recede. This phenomenon, its scale, concerned municipal authorities of the city.

Seasonal fluctuations of the Chari regime, seem to be the main factor of sedimentation of fine materials to medium cuts observed on levees which form the floodplain. The heterogeneity in the diversity of materials and layering can be explained by an irregular river dynamic and changing over time.

In addition, during the dry season, Chari river at N'Djamena, seems to suffer from wind influence. The presence of eolised sand as well as the lower level of the Holocene banks dune accumulations occurring in the dry season, now show that throughout the ages, the action of the trade winds has been ongoing on regular basis. This implies that conditions have changed since a few thousand years.

\*\*\*\*\*

### **Development of the Chari river bank from Mandjaffa to Milezi (1970 - 2008) at N'Djamena (Tchad)**

DOUDJE K.(1), TCHINDJANG M.(2), MOUPENG B.(1)

(1) *University of N'Djamena, N'DJAMENA, CHAD* ; (2) *University of Yaoundé I, YAOUNDE, CAMEROON*

The Chari River banks at N'Djamena lay on the land sandy - clay of Holocene. It presents from upstream and downstream of Milezi alluvial plain oversized (500 - 1500 m wide) in which the Chari current develops an unsuited system of mobile meandering.

This paper focuses on the geomorphic adjustments of this river banks system belonging to a low energy environment. It is seen as a response of the stream to the spatio - temporal variations of water and sediment discharges and / or a significant change in a component of its internal geometry. The changes in these independent and dependent variables of the riverbed are induced by intrinsic factors (evolutionary process inherent in water) and / or extrinsic (climate change, anthropogenic interventions direct and indirect).

Before understanding the modes and rates of change in these banks, we firstly try to clarify the influence of the geomorphological framework and liquid flow rates on the physical structure and the functioning of this fluvial hydrosystem. Thereafter, one will considered geomorphological changes in three aspects: the shaping of the Chari bed, the morpho - sedimentary dynamics related to seasonal variations in flows, and, finally, the effects of human activities on the evolution of the Chari banks.

The study of Holocene fluvial dynamics shows that the morphological structure of the current floodplain was definitively acquired in the Quaternary with the establishment of a coating sandy clay with an average of 1.5 to 2 m thick. A diachronic analysis of the horizontal alignment reveals a high mobility of the riverbed.

Geomorphological modifications induced by flows characteristics are associated with important solid sediment transportation on the river bed. These results are complementary to the previous work extended to the entire Chad basin.

**Linking land use, riparian vegetation and channel changes in two catchments in the Upper Olifants River, Mpumalanga Province, South Africa**

PETERSEN C., JOVANOVIĆ N.  
CSIR, CAPE TOWN, SOUTH AFRICA

The Upper Olifants catchment is located in the Mpumalanga Province, South Africa. It is of economic significance with the main activities being mining, agriculture and power generation. Much of these activities are dependent on goods and services derived from aquatic ecosystems and have had a detrimental impact on these ecosystems. The overall research focus is on the fluvial environment and how this understanding can provide insight into the dynamics of pollution such as eutrophication and sedimentation. The aim was determining links between the land use, riparian vegetation and channel form. Geomorphological monitoring in the catchment focussed on two tributaries. The study sites occur in two geomorphological zones and vegetation biomes resulting in different channel impacts and geomorphological processes with agriculture as a common land use. Cross-sections were used for channel form and change. Bank and in-stream sediment and vegetation were sampled and the vegetation composition and distribution was used to assess the effectiveness of the riparian zone in stabilising the banks relative to bank sediments. Discharge data were also related to channel and riparian vegetation changes. In-channel discharge changes have an influence on river morphology, aquatic habitat change and influence the distribution of riparian plant communities. Preliminary results showed that the Wilge River remained relatively stable with little or no change in the channel geometry. The Koffiespruit was dynamic, showing evidence of bed and bank erosion, channel widening and narrowing and in-channel deposition. The riparian zone at the Wilge River adds to the stability of the banks whereas the absence of a riparian zone at the Koffiespruit influences the rivers' dynamic nature. Higher botanical diversities of plant species occurred at the Wilge as compared to the grassland setting of the Koffiespruit.

\*\*\*\*\*

**Morphological effects of a large flood: the case study of the Magra River (Italy)**

RINALDI M., NARDI L.  
Dipartimento di Ingegneria Civile e Ambientale, FIRENZE, ITALY

Understanding patterns and processes of channel response to a large flood and their relations with the evolutionary morphological trajectory is important in order to predict future changes, assess channel dynamics hazards, and identify possible management options.

This study aims to document channel changes occurred during a large flood and analyze them in the context of the longer term (last 150 years) evolutionary trajectory.

The Magra River catchment experienced an extreme flood event (return periods ranging from about 100-200 years along the Magra, and to 500 years along some tributaries) in October 2011 which resulted in morphological changes, flooding, damage and loss of human lives.

Analysis of past channel changes are based on multi-temporal series of aerial photos, cross-sections, longitudinal profiles, and field surveys. Morphological changes consequent to the flood event were investigated by: (1) field survey, including a reconstruction of the peak stage profile; (2) analysis of aerial photos and LiDAR before and after the event; (3) topographic survey of cross-sections.

Results of the evolutionary trends show a recent phase (last 10-15 years) of dominant aggradation and widening, following previous phases (last 100-150 years) of progressive narrowing and incision. The October 2011 produced a complex pattern of changes, but with prevailing aggradation of the channel bed alternated to erosion. Comparison of aerial photos before and after the flood event clearly shows an important channel widening, related to two different processes: (1) bank retreat; (2) overbank sedimentation of bedload. Comparison with the longer term evolutionary trajectory shows that the channel width is still in the range of variations occurred during the last 50-60 years.

Changes in channel width occurred along a series of partly-confined tributaries are more impressive, with frequent avulsions and, in some cases, a complete aggradation of the available alluvial plain.

### **Abandoned borrow pits from Buzau River's floodplain (Romania) - evolution and management**

IOANA-TOROIMAC G., GRECU F.

*University of Bucharest, Faculty of Geography, BUCHAREST, ROMANIA*

Gravel and sand extraction from dry bars leaves borrow pits – negative landforms. They are an issue of river management, with consequences on river dynamics and ecological functions. Within this general framework, we analysed the example of Buzau River (watershed area: 5264 km<sup>2</sup>; mean annual discharge: 29 m<sup>3</sup>/s), which is coming down Romanian Curvature Carpathians; our analysis focused on a braided reach of Buzau River, located in a plain region, between Scurtesti and Stancesti villages. We analysed borrow pits of its floodplain to assess their diachronic evolution and to diagnose their management strategy. Therefore, firstly, we investigated their evolution using, both, topographic maps and aerial photos from the last three decades, and particle size measurements. Secondly, we assessed their management by interviewing quarries' owners, local authorities and managers (Romanian Waters National Administration and National Forests Service). Our analysis showed that gravel and sand extraction continues to take place in the abandoned active channel of the river. The resulting borrow pits function independently from the main channel, because Buzau River migrates slowly and it overflows rarely; marshes occur by water table rising. Regarding their management, they are abandoned after exploitation. Furthermore, they are in the middle of a conflict of goals – mining activity vs. habitats' conservation in a Site for Community Importance of Natura 2000 network. We concluded that abandoned borrow pits' management lacks of strategy. Furthermore, because of the uncertain reactivation of Buzau's abandoned active channel, a policy reassessment must be undertaken.

\*\*\*\*\*

### **Evaluation of morphometric and morphological variables: analyses of topographic, geological and partitioning maps of Guaratuba basin ' Boraceia ' São Paulo ' Brasil**

NUNES PATUCCI N., OLIVEIRA D.

*UNIVERSIDADE DE SÃO PAULO, SÃO PAULO, BRAZIL*

This current research is about the continuation of studies, in Guaratuba basin, started by ROSSI (1999) and OLIVEIRA (2003), however with emphasis on the morphometric and morphological processes. The Guaratuba basin is located in different geomorphological partitioning in Serra do Mar (plateau, sierra and coastal plain), measuring 113, 5 Km<sup>2</sup> in area, and located approximately in 45°56' and 45°52' of west longitude and 23°38' and 23°42' of south latitude. Were analyzed spatial and linear parameters to understand the relation between infiltration, runoff and terrain modeling, in order to develop a prognosis for the evolution of the area.

In an attempt to mediate these processes, first it was held the partitioning of topography, characterizing and describing the importance of each compartment, in the second stage it was obtained information regarding the surface structure of the landscape, such as geological and hydrological characterization and in the third moment, the realization of morphometric studies to the understanding of the physical environment of the area.

By the end, it was made the tabulation of the data and preparation of cartographic materials (slope, altimetry, partitioning, geological and drainage maps) using Geographic Information Systems (GIS), in order to provide explanations about the relation draining-sculpturing of the modeled.

To the preparation of the slope map, it was used the EMBRAPA slope classification, where the reliefs range from plan to heavily-mountainous, and to the execution of the altimetry map, it was used a scale that ranged between 80 to 970m.

The following spatial parameters were analyzed: density of rivers, drainage density, area, perimeter of basin, circularity index, maintenance coefficient, and shape index; the linear parameters verified were: the study and quantification of the hierarchy drain, the ratio between the mean lengths of the channels of each order and the extension of the superficial course.

**Morphodynamic and morphologic changes analysis in rivers of the Sierra de Comechingones piedmont, Cordoba province, Argentina, during the Late Holocene-present. Environmental implications**

DEGIOVANNI S., ANDREAZZINI J.

*Universidad Nacional de Rio Cuarto, RIO CUARTO, ARGENTINA*

Since Late Holocene, regional drainage networks have started an important incision process, related to tectonic, climatic and anthropogenic causes, that still continues and has generated notorious changes. The Eastern piedmont of Comechingones mountain is part of a Cenozoic bajada (currently inactive) formed by alluvial, colluvial and aeolian sediments, and dissected by fluvial systems. This work discusses the morphological and morphodynamic modifications in piedmont fluvial reaches in the main tributaries of Cuarto River, and their incidence in environmental risks. Geological-geomorphological detail surveys were carried out, and variations in morphological and morphometric indicators for valley and channel were measured, as width, sinuosity index (S) and width/depth ratio (w/d). The oldest fluvial belt, 1000 to 1500 m wide, was developed by meandering rivers, and presents two levels of Holocene accumulation terraces. The channels have a variable width, 80 - 130 m, w/d ratio of 100-150, S in the order of 1,5 - 2,2 and meanders of variable geometry. Although lateral erosion (local rates of up to 100 m/30-40 years) and, subordinately, aggradation processes are important, these channels also respond to the regional incision process. Pleistocene cemented sequences or crystalline rocks were reached in many of the sections as a result of channels downcutting (up to 12 m), generating semi-confined channels, with more straight patterns, narrower fluvial belt (100-200 m), and minor width (lower than 50 m), w/d ratio (30-40) and S (minimum values of 1,03-1,05). The transport and incision process are dominant in these reaches, while the aggradation and banks erosion processes are minimal. In semi-confined channels fluvial erosion hazard, mainly banks erosion, decreased significantly, and flooding hazard was ended, while the speed, height of water in flood events, and the transport capacity were increased, augmenting the downstream threat.

\*\*\*\*\*

**The effect of input load on large wood dynamics in braided streams: preliminary results from physical modelling**

BERTOLDI W.(1), MAO L.(2), COMITI F.(3), GURNELL A.(4), MCLELLAND S.(5), RAVAZZOLO D.(6), TAL M.(7), WELBER M.(1), ZANELLA S.(1)

*(1) University of Trento, TRENTO, ITALY ; (2) Departamento de Ecosistemas y Medio Ambiente, Pontificia Universidad Católica de Chile, SANTIAGO, CHILE ; (3) Faculty of Science and Technology, Free University of Bolzano, BOLZANO, ITALY ; (4) School of Geography, Queen Mary University of London, LONDON, UNITED KINGDOM ; (5) Department of Geography, University of Hull, HULL, UNITED KINGDOM ; (6) Dipartimento Territorio e Sistemi Agro-forestali, University of Padova, PADOVA, ITALY ; (7) Aix-Marseille Université, CEREGE UMR 7330, AIX-EN-PROVENCE, FRANCE*

We present preliminary results from a set of experiments conducted in the Total Environment Simulator flume at the University of Hull (funded as an Access Project in Hydralab IV, EC Contract Number 265120). The experiments were designed to reproduce a large gravel-bed braided river, self formed in a well-sorted sand bed (0.725 mm) subject to a constant discharge (1.25 l/s). Three parallel flume experiments were used to investigate the dynamics of large wood - modelled using coloured-coded dowels 80 mm long and 2.6 mm in diameter – at different input rates (ranging from 40 to 180 logs/hour). The three channels were surveyed by a vertical, movable camera with a temporal step of 1 hour. All deposited logs were then manually mapped to describe the position, grouping style, mobility, and persistence of each log.

The results showed that log deposition and re-mobilization was largely controlled by the morphology of the channel network, particularly by the occurrence of sediment bars and flow bifurcations. The rapid morphological changes and bank erosion along the main anabranch were the main cause of wood re-mobilisation. Up to 40% of logs moved after 1 hour, and less than 20% stayed at the same place after 5 hours. As a result of the high mobility of the logs, only about 15% of new logs deposited each hour against an existing jam, resulting in a configuration with small jams and up to 40% of the logs being deposited as single logs. For high log input rates (more than 120 logs/hour), we observed the occurrence of larger jams comprising up to 50 logs. The analysis highlighted that these large log accumulations caused a change in the wood deposition mechanism and decreased the mobility of individual elements within these large log jams.

The results give us an improved understanding of the wood supply / accumulation dynamics in complex river systems which are essential to better understand the interactions among river flow dynamics, sediment transport and large wood.

## Fluviomorphological hazards in roads crossing ephemeral channels on the South East coast of Spain

CONESA-GARCÍA C.(1), GARCÍA-LORENZO R.(2)

(1) Departamento de Geografía Física, Universidad de Murcia, MURCIA, SPAIN ; (2) Servicio de Integración e Información Ambiental, Comunidad Autónoma de la Región de Murcia, MURCIA, SPAIN

Most road-stream crossings over ephemeral channels are vulnerable to extreme hydrologic events. Flash flood waters can significantly overflow the channel banks and may change course, defying the ability of drainage work to perform its intended function. Bridges and culverts are usually built when traffic or the road network's importance justifies the cost, while fords are a more common crossing method on local roads. This paper is aimed to analyze the main fluvimorphological hazards (FH), affecting road-stream crossings over dry streams in South East Spain. FH study provides two different approaches depending on the type of crossing they are applied to:  $FH_B$  for bridge crossings and  $FH_{CF}$  for road-crossing drainage culverts and fords. These approaches are focused on estimating the predictable morphological effects for discharges at bankfull and flood-prone stages. The parameters included in  $FH_B$  are granular bed susceptibility to incision, associated with the bed armouring rate, critical velocity ( $V_c$ ) and general transitory scouring (GTS). In particular,  $V_c$  and GTS directly affect the stability of pier footings and bridge foundations, and can be appropriate indicators for assessing fluvimorphological hazards at these crossings. In contrast, for  $FH_{CF}$  factors such as bed instability, bed load transport and channel roughness were considered due to their influence on the obstruction of drains, culverts and fords. The study was carried out on the Mediterranean coast in the Region of Murcia (Spain), where there are numerous examples of road-stream crossings with insufficient drainage over ephemeral channels. These crossings are exposed to high transport rates and erosion during flooding, causing highly dangerous situations for road traffic. In order to test the applied methods, the results were compared with real geomorphological impacts produced by recent floods.

Key words : Fluvimorphological hazards, road-stream crossings, ephemeral channels, South East coast of Spain.

\*\*\*\*\*

## Geospatial Mapping Ancient Phad Irrigation System in Mousam Basin, Maharashtra (INDIA): A GIS Approach

THAKRE D.

L.V.H.COLLEGE, NASHIK, INDIA

Traditional water-harvesting systems have existed in India since time immemorial, successfully satisfying the needs of civilizations in their quest for the 'elixir of life'. Maharashtra has a unique traditional water-harvesting technique, known as the 'Phad' system, whose roots can be traced back over 300 years. The Mousam River, located in northwestern part of Nasik District of Maharashtra State is a unique example of Phad irrigation system. The community managed Phad irrigation system is prevalent in northwest. Each system consists of one diversion weir, canals, distributaries, field channels, and the command area. The command area is divided in to four parts. Each part is called as Phad. Size of the Phad is 10 to 200 ha. Te average size is 100-125 ha. The capital costs for construction of weirs were supported by King or Ruler. River Mousam drains the upper part of Western Ghats rain shadow zone of Tapti River system. The natural slope of the basin converging from side slopes, rolling topography, structural terraces in middle part of the basin, and smooth undulating pediment surfaces in the lower reaches are some of the significant geomorphological characteristics, that are supportive to this irrigation system..Present paper attempts to study old Phad irrigation system in GIS environment. By using GIS techniques and tools, Phad canals, distributaries, and command area of each phad zone will be mapped to get the area under each zone. The main trunk Stream of Mousam River and all its major tributaries/distributaries under this system will be mapped to obtain all its geomorphometric data. The results obtained will then tested whether this system can be applicable to the river basin having similar geoenvironmental conditions.

### **Contribution of geomatic for multiscale characterisation of river systems: application to the Rhone basin**

WIEDERKEHR E.(1), DUFOUR S.(2), PIÉGAY H.(3)

(1) CNRS UMR 5600 Environnement, Ville, Soci\_t\_ - ENS de Lyon, LYON CEDEX 07, FRANCE ; (2) CNRS UMR 6554 - Université Rennes 2, RENNES, FRANCE ; (3) CNRS UMR 5600 Environnement, Ville, Soci?t? - ENS de Lyon, LYON CEDEX 07, FRANCE

To achieve the good ecological status of aquatic environments stated by the WFD, an assessment of the physical condition of the hydrographic network appears as an essential step for targeting actions, yet this issue still requires research of a fundamental nature. Such assessment in the basin of the Rhône generates a number of scientific questions to be answered before considering practical applications. Focusing geomorphic understanding at a regional scale is a new approach which has methodological constraints linked in particular to the great heterogeneity of environments.

We developed a semi-automatic method to provide indicators of physical quality within the Rhone river network. We implemented geomatic tools which have been tested and applied to evaluate their effectiveness and to provide reliable evidence for the characterization of large-scale physical conditions.

We extracted every 100m, the widths of the active channel and the valley bottom. From these data, we created geomorphological homogeneous reaches (GHR). Each GHR have been characterized by a set of metrics such as sinuosity, channel confinement in the floodplain, relative frequency of water channel in the active channel, channel slope, channel active width and inner GHR variability of width. From a statistical analysis performed on this set of metrics, we identified 18 channel pattern types. This database has been then used to perform queries to identify reaches of high natural unheritage value or identify reaches with a high potential in lateral shifting.

This procedure applied systematically at the regional network scale is more powerful than a sampling procedure because it allows identifying longitudinal thresholds and potentially relates them with their drivers. Moreover, the semi-automatically method can be applied on the other basins and the database can be completed by new metrics if no data are available so that the method is reproducible and can be implemented within an adaptive strategy.

\*\*\*\*\*

### **Hypsometric Analysis for Prioritization and Conservation Planning of Sub Watersheds; a Case study of Arjunsagar Lake Catchment, North Maharashtra, India**

NIKAM S.

S.P.H.College, MALEGAON, INDIA

Hypsometric integrals and hypsometric curve are important indicators of stages of watershed development i.e. stabilized, mature and young. In the present study attempt has been made to suggest the prioritization of sub watersheds of study area for water and soil conservation planning based on Hypsometric integrals values. Study area selected for the present investigation is Arjunsagar lake catchment.

Administratively Arjunsagar lake catchment situated in Satana tahsil of Nashik district, Maharashtra state, India and extends between geocoordinates of 20°38'08.34"N to 20°43'34.73"N latitude and 73°54'22.50"E to 73°58'59.02"E longitude. Total geographical area of study area is 56.36 Km<sup>2</sup> including 02 Km<sup>2</sup> water body. Arjunsagar dam were constructed on *Aram* river flowing from north to south east.

Total 08 sub watersheds from the study area delineated using Survey of India Topographical map 46H/14 on 1:50,000 scale. Elevation of the basin ranges between 703m to 1543m. Area has been calculated for every 20m contour interval of all the sub watersheds. Entire watersheds exhibit high potential of surface runoff and soil loss and no efforts have been taken to properly undertake such kind of assessment. Thematic map of HI values and descriptive statistics of watersheds calculated using GIS techniques. According to generated results hypsometric integral values of watersheds are ranges between 0.21 to 0.52. Low hypsometric values indicate old and more eroded areas on the other hand high hypsometric integral values indicated less erosion. In the area hypsometric curve observed in S shaped and concave shaped. Convex shaped hypsometric curve characterize watershed in young stage, S shape curves indicate the basins in maturity stage and concave hypsometric curve characterize basins in old stage. Watershed prioritization has been done based on HI values.

**Examination of the morphological characteristics of alluvial fans modified by interactions with rivers in broad axial valleys in Yukon Territory, Canada, and Alaska, U.S.A.**

GILES P.(1), WHITEHOUSE B.(1), KARYMBALIS E.(2)

(1) Saint Mary's University, HALIFAX, NOVA SCOTIA, CANADA ; (2) Harokopio University, ATHENS, GREECE

Although the predominant planform morphology of an alluvial fan is a roughly symmetrical pattern radiating outwards from the apex, fans in broad axial valleys in Yukon Territory, Canada, and Alaska, U.S.A., commonly exhibit planform asymmetry. Planform asymmetry is defined as inequality in the lengths of longitudinal profiles from the apex to points around the lower boundary. This study investigates interactions between fans and axial rivers that result in the observed asymmetrical morphologies, as well as deflection of axial rivers across their valleys. In narrow valleys, lateral migration of axial rivers is restricted which leads to fan toes being trimmed straight across, or to damming of the valley if fan sedimentation rate overwhelms the river's transport capacity. In broader valleys, episodic erosion caused by lateral migration of axial river channels has been described as an important process that trims fan toes and limits progradation of fans, at least temporarily. In the broad glacial valleys examined in Yukon and Alaska, axial river channels occupy only a portion of the valley width and the rivers tend to be deflected by the fan mass. Therefore, toe erosion and limited progradation cause longitudinal profiles on the axial valley upstream sides of fans to be shorter than the downstream sides which leads to the asymmetry in fan planform morphologies. Scarped faces are frequently observed at the lower ends of shorter profiles, whereas profiles on the longer sides of fans run out gradually. Measurements of fan morphologies were made to describe asymmetry quantitatively and to demonstrate that there is a statistically significant relationship between asymmetrical tendency and direction of axial river flow. However, a related hypothesis stating that unequal longitudinal profile lengths on an asymmetrical fan would cause fan surface gradients to differ, which would consequently influence the spatial distribution of streams on the fan surface, was not supported.

\*\*\*\*\*

**Small catchment river styles® in Brazilian dryland, saco creek watershed**

SOUZA J., BARROS A.C.M., CORREA A.C.B.

Federal University of Pernambuco, RECIFE, BRAZIL

The growth of the environmental worry has increased the necessity to adopt policies to the hydric resources management. An appropriate management is essential to understand the behavior of fluvial environments, especially in drylands that are primordially instable places. To this, arises the River Styles® Framework that can be used to describe the characteristics and behavior of fluvial environments. Thus, the main concern of this research is to identify and describe the River Styles® of Saco Creek watershed, in semiarid Northeast of Brazil, as well as understand the behavior of each River Style®. To do this, it was used ASTER GDEM data, QUICKBIRD images, air photograph, and field data, in order to identify the elements and characteristics of River Styles®. In the Saco Creek watershed it was identified four different compartments; the headwaters, wetland zone, fault scarp and the pediment zone; that will control the type of River Style®, in addition to the strong anthropogenic influences. It was identified and described seven River Styles; Headwaters and Gullies in the headwaters zone, the gullies will be developed on quaternary colluviums; Floodout, Intact Valley Fill and Discontinuous Sand Bed in wetland zone; Discontinuous Floodplain Bedrock-controlled and Gorges in the fault scarp zone; and Intact Valley Fill, Discontinuous Sand Bed and Discontinuous Floodplain Bedrock-controlled in pediment zone. In the pediment zone the presence of several dams, in special the Saco Dam, which control the evolution of the River Styles® changing the cut-fill channel processes. From the identification and analysis of the River Styles® in each reach, the adoption of policies to hydric management becomes more adequated.

### **Analysis of relationships among alluvial fans and source basins in Lake Trichonis (Western Greece)**

KARYMBALIS E.(1), GILES P.(2), PAPANASTASSIOU D.(3), FERENTINO M.(1), GAKI-PAPANASTASSIOU K.(4)

(1) Department of Geography, Harokopio University, ATHENS, GREECE ; (2) Department of Geography, Saint Mary's University, HALIFAX, NOVA SCOTIA, CANADA ; (3) Institute of Geodynamics, National Observatory of Athens, ATHENS, GREECE ; (4) Department of Geography-Climatology, Faculty of Geology & Geoenvironment, National Kapodistrian University of Athens, ATHENS, GREECE

In this study 17 morphometric variables describing 23 alluvial fans and their contributing drainage basins in the tectonically active area of Lake Trichonis (Western Greece) are examined. The main objective of this study is to classify the fans according to the primary depositional processes (fluvial and/or debris flow) controlling their formation. Another purpose of this study is to present fan-basin morphometric relationships for the fans, and to investigate the possible relationship between the geographic distribution of the fans and basins with the local tectonic patterns.

The Trichonis graben is a 10km width Quaternary structure that strikes WNW-ESE for a distance of 32km and cuts across the early Tertiary NW-SE fold and thrust structures of the Pindos Mountains. The depression at north and south flanks is bounded by E-W and NW-SE trending faults. The alluvial fans of the study area are developed on the hanging wall of these neotectonic normal faults. The morphology of the fans is strongly affected by the accommodation space created by subsidence.

Selected morphometric parameters of the basins were measured using topographic maps at 1:50000 scale with 20 m contour lines, while parameters of the fans were derived from topographic diagrams at 1:5000 scale with 2m contour lines. Self Organizing Maps (SOM) were used in order to investigate clustering tendency of alluvial fans according to both qualitative data and morphometric variables.

The coupling of quantitative morphometry and the artificial intelligence method (SOM) led to the classification of the fans into two main types with distinct morphological characteristics. Large, less rugged basins have produced at the eastern side 18 relatively extensive, gently sloping fans dominated by fluvial processes. In contrast, at the western part of the graben 5 of the fans are steeper formed by a combination of fluvial and debris-flow deposition processes supplied by smaller, more rugged basins located.

\*\*\*\*\*

### **Integrating river geomorphic processes into optimal planning of reservoir operations**

DINH Q.(1), BIZZI S.(1), BERNARDI D.(2), PAVAN S.(2), CASTELLETTI A.(1), SCHIPPA L.(2), SONCINI-SESSA R.(1)

(1) Department of Electronics and Information, Politecnico di Milano, MILAN, ITALY ; (2) Department of Engineering, University of Ferrara, FERRARA, ITALY

Water management through dams and reservoirs is worldwide necessary to support key human-related activities ranging from hydropower production to water allocation, and flood risk mitigation. Reservoir operations are commonly planned in order to maximize these objectives. However reservoirs strongly influence river geomorphic processes causing sediment deficit downstream, altering the flow regime, leading often to process of river bed incision. Multi-objectives (MO) optimization techniques used to identify optimal regulation policies require elevate computing power and then the modelling of fluvial processes is commonly neglected. This is a significant limitation since the river geomorphic processes deeply affect water management: for instance the variations of river cross sections over few years can notably affect flood mitigation and water supply strategies. Moreover geomorphological and ecological processes are deeply inter-correlated.

We present a case study in Italy on the Po River where alternatives release policies of Isola Serafini dam have been analysed in terms of their effects on hydropower production and river bed incision. A 1-d hydro-dynamic model with mobile boundaries has been used to simulate the river bed evolution on a ten year horizon. The response surface methodology (RSM) has been applied to embed the understanding of the river geomorphic processes into optimal control of water management. The main idea of RSM is to use a sequence of designed experiments to obtain an optimal response surface. The application of such technique allowed us to assess the trade-off between hydropower production and river bed incision of optimal release policies. This is a novel and promising attempt to start integrating the understanding of fluvial geomorphic processes into optimal planning of reservoir operations.

### **Sedge as an influence on channel form: case study of *Carex nudata* in gravel-bedded John Day River, Oregon, USA**

MCDOWELL P.

University of Oregon, EUGENE, UNITED STATES

New models of interactions between vegetation and hydrogeomorphic processes suggest that vegetation may exert a major influence on channel form. While this principle is well established for woody vegetation, particularly woody debris, there is less understanding of how herbaceous vegetation influences channel form. In the upper John Day River, a montane, cobble- to gravel-bedded river in the intermountain West, a native sedge, *Carex nudata*, forms tussocks on the active channel bed, at and within the low flow water level. These tussocks are highly resistant to erosion due to a dense root network. *C. nudata* was highly suppressed by cattle grazing until it was ended in 2000, and *C. nudata* populations increased dramatically thereafter. This paper uses historical and modern field data to address questions about the expansion, and geomorphic and ecologic impacts of *C. nudata*. Today the tussocks occur in several distinctive biogeomorphic structures, including bar-fringing tussock rows, tussock rows at the base of banks, and mid-channel clusters and individual tussocks. The tussocks behave as boulder-sized resistance elements. The bar fringing rows stabilize active gravel bars, while the bank-base rows appear to be associated with bank erosion and channel widening. The mid-channel tussocks occur on pool tails and riffle crests. They result in bed scour and, in some cases, channel widening.

From a habitat perspective, *C. nudata* has increased fish cover, as well as the complexity of bed morphology and hydraulic diversity. The flood of record in May 2011 produced only limited erosion of *C. nudata* tussocks. Comparison of pre and post-flood channel cross-sections shows both the stabilizing and erosive effects of *C. nudata*. These changes suggest that *C. nudata* is setting a new trajectory of channel adjustment toward narrower, rougher, more stable, and reduced sediment transport conditions.

\*\*\*\*\*

### **Diversion of running water discharge from par river to girna river valley**

NIKAM C.

M.S.G.COLLEGE, MALEGAON, INDIA

Water is the fundamental need for the Socio-economic development of any region. In recent years, Maharashtra State (India) is facing the problem of regional disparity because of spatial and temporal variability in rainfall and lack of proper utilization of running water slope of Western part of the Sahyadri is very steep, receives excess amount of rainfall and adds wasteful into Arabian Sea. Par River (2000 to 3000 mm Avg. Annual Rainfall) originates from Kame hills of Sahyadri ranges. The river flows further west towards Gujarat State (India) and adds wasteful water into Arabian Sea. Par river basin experience water scarcity in summer in contrast overflow discharge in rainy season. The undulating topography limits the local irrigation.

In contrast, eastern part of the Sahyadri (Girna river valley) is the rainshadow zone receiving very low rainfall (1500-2000 mm Avg. Annual Rainfall). This region therefore always experience water scarcity.

Circulation of water is possible at two levels for sustainable development of any region. In intra-basin circulation of running water, circulation is possible within a basin itself (Punad Project). Whereas, in inter-basin circulation of running water, circulation is possible from one basin to another. Proper utilization of water is possible in the study area by inter-basin circulation of water from Par to Girna basin.

**Historical planform adjustments of rivers from the Eastern part of Pannonian Basin, as indicators of neotectonic features**

PERȘOIU I., ROBU D.

*Ștefan cel Mare University, SUCEAVA, ROMANIA*

Someș River, one of the main rivers draining the NW part of Romania, features abrupt changes between meandering, straight and anabranching channel reaches (on both alluvial and mixed channel types). Its longitudinal profile variability, as shown by the planform and vertical morphological and morphometrical characteristics (*i.e.*, sinuosity, channel width, channel slope, river bank heights), reflects both regional geological setting (*e.g.*, different rates of tectonical uplifts and subsidences, structural controls) and, for the last decades, human induced channel straightening.

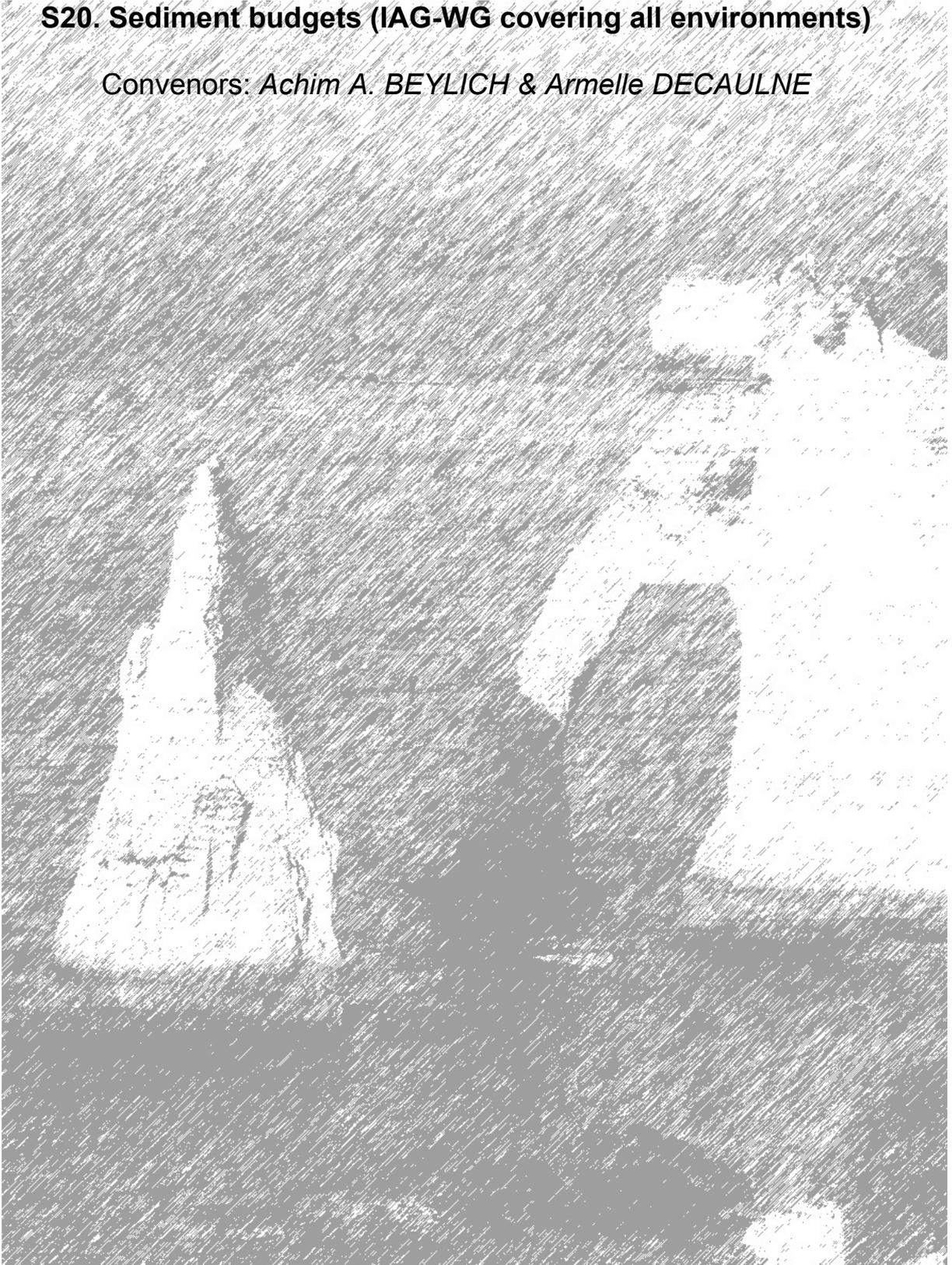
In this study, we analyze, based on successive topographic maps (covering ~150 years), the historical behavior of the lower reach of Someș River, in order to identify local scale neotectonic elements in the subsidence area (-1 mm/yrs) of the eastern Pannonian Basin. The area of investigation has a particular scientific importance, as covering the contact between Romanian Carpathians and the eastern edge of Pannonian Basin, a region with a strong neotectonic activity.

Based on river channel behavior over the past century and half, we have identified a series of local subsidence basins and local active faults, which, superimposed on the geological map of the area allowed us to propose a detailed neotectonic map of the region.

\*\*\*\*\*

**S20. Sediment budgets (IAG-WG covering all environments)**

Convenors: *Achim A. BEYLICH & Armelle DECAULNE*





## **Oral presentations:**

### **Development and application of a fingerprinting technique for quantitative source ascription of fine sediment in a large dynamic fluvial environment: Manawatu, New Zealand**

VALE S.

*Massey University, PALMERSTON NORTH, NEW ZEALAND*

Research into the quantification and modelling of sediment movement through a wide range of Earth's surface processes has increased substantially in recent decades. However, catchment scale identification of erosion processes and geomorphically active areas contributing to sediment yield have often been poorly understood and quantified. This lack of understanding is a limitation to identifying critical source areas and appropriate mitigation techniques for governing bodies. Traditional field-based techniques for sediment source identification are typically qualitative, time consuming and difficult to apply to larger catchment scales. Sediment fingerprinting provides an alternative approach to quantifying sediment sources. The Manawatu River catchment provides an appropriate location to test the effectiveness of this technique in a large dynamic catchment subject to significant anthropogenic influences.

In this research 'sediment fingerprinting' techniques were applied to identify the sources of fine sediment throughout the Manawatu catchment, a range of tracer (e.g. elemental, radionuclide, isotopic) analysis's were applied (e.g. XRF, ICP-MS). Initial sampling was undertaken at key confluence sites to explore and test the geochemical techniques as well as guide the concept of design for the full scale study. This focused on what sort of variability was occurring within the study environment, selection of sample locations, and what method of sample preparation and analysis was both resource efficient and provided source discrimination. Source ascription is achieved from the approach of a spatial distribution of sub catchments and the geological source as well as what geomorphic processes are responsible for sediment production. This research demonstrates the use of sediment fingerprinting in a rapid and efficient approach for identifying principal sources of sediment, sediment associated nutrients and contaminants which crucially aid erosion management strategies

\*\*\*\*\*

### **The sediment budget: a tool to evaluate scale effect on sediment dynamics into a catchment**

VIEL V., DELAHAYE D., ROLLET A.J., LESPEZ L., REULIER R., CADOR J.M., DAVIDSON R.

*LETG - Caen - GEOPHEN, CAEN, FRANCE*

The quantification and characterisation of hydrological and sedimentary transfers are now major challenges to preserving and restoring European soils and water resources (Law on Water; Water Framework Directive, WFD). To provide better watercourse and watershed managements, many studies attempted to evaluate soil and bank erosion at local scale in the hydrosystem. However, sediment dynamics into the catchment remain difficult to analyze from local to global scale because of intermediary traps. Therefore, to improve the knowledge of these systems and to go beyond the "black box" study of the way of the catchment works, it is essential (1) to localise the origin of sediments into the watershed and (2) to identify the role of interlocking scales on the spatial and temporal dynamics of sediment transfers. In order to evaluate sediment dynamics variability at different scales, 5 nested sediment budgets quantifying soil and bank contribution, and sediment exports or storages were realized in a same catchment for a three years period. This study specifically focused in the Seules watershed (430 km<sup>2</sup>), a typical and poorly documented feature for low-energy water system (<20 W/m<sup>2</sup>) located in the northern-western part of France, in Europe. To evaluate slope contribution, soil erosion and runoff connectivity were studied for two representative sub-catchments (15 km<sup>2</sup>). Bank erosion was estimated by field investigation from 5 reference sites. Results were then extrapolated at the catchment scale using a modeling approach. In the same time, 4 high frequency monitoring stations were used to control suspended sediment export at different scales into the catchment. Results underline the role of the initiation of the drainage networks into sub-catchments while bank contribution becomes predominant in the downstream part of the watershed.

**Application of the physically based model, power spectral analyses and cross correlation analyses to estimate the sediment budget and the delay time for an impacted stream: case study of Italy**

*PELACANI S.(1), MAERKER M.(1), SCHMITT F.G.(2)*

*(1) University of Florence, FLORENCE, ITALY ; (2) Université des Lille, CNRS Laboratory of Oceanology and Geosciences, WIMEREUX, FRANCE*

In this study we compare the results of a soil erosion model applied at watershed scale to the suspended sediment measured in the stream network. A sediment delivery model is applied at watershed scale; the evaluation of sediment delivery is related to a connectivity fluxes index that describes the internal linkages between runoff and sediment sources in upper parts of catchments and the receiving sinks. An analysis of the fine suspended sediment transport and storage was conducted for an human impacted catchments draining into a reservoir, Florence, Italy. The time scales of catchment hydrologic response was evaluated using spectral analysis. By comparing the spectral power of the input sediment source and output stations each wavelength determines how strongly the catchment attenuates hydrologic and chemical signals on each timescale. The delay time distribution of the turbidity dataset, and hence of suspended sediment, were calculated using the cross correlation function. Results show that the time of particle transit ranging between 190 days to one year. The turbidity dataset at the output station has consistently lower power spectrum than the inlet station along the range of the studied wavelengths. On the other hand, the output station shows a scaling exponent higher than the inlet station. Implying a higher persistence of the turbidity. The fractal analysis points out that the system is not in equilibrium. The present work has demonstrated that by comparing the spectral power of the input and output stations at each wavelength for the turbidity dataset, it is possible to explain the behavior of a basin subject to anthropogenic disturbances. When the results obtained from field data are compared with those from the RUSLE model, the SDR values indicate that there was sediment storage on the channel bed of the non-impacted stream, more than of the impacted one. This discrepancy may be due to an underestimation of hillslope deposition by the RUSLE model.

\*\*\*\*\*

**Modeling of rainfall-runoff and soil erosion processes in various scales and using various DEM - assessment of effects**

*DEVATY J., DOSTAL T., KRASA J.*

*Dept. of Irrigation, Drainage and Landscape Engineering, Faculty of Civil Engineering, CTU in Prague, PRAGUE, CZECH REPUBLIC*

Rainfall-runoff, erosion and transport processes are of high importance within an area of interest and are often modeled by computer tools of different mathematical approach and precision. Each model requires different set of input data and provides different possibilities to simulate surface runoff pattern complexity. In case of distributed rainfall-runoff models digital elevation model is the essential input. This paper presents results of sensitivity study on DEM's source and resolution for two fully distributed model tools. The simulations were carried out using empirically based continuous model WATEM/SEDEM and physically based event model Erosion 3D. The elevation data used were: (i) 10x10 m resolution DEM GEODIS (professionally treated commercially available raster DEM), (ii) 5x5 m resolution DEM derived from contour-lines in original scale 1:10000 with equidistance 2 m and (iii) 3x3 m resolution DEM derived from laser-scan elevation LiDAR 5G data. The goal of the modeling was to assess potentials and limits of the DEMs and model tools for description of surface runoff, erosion and sediment transport processes, concerning runoff pattern generation. Set of scenarios was modeled to evaluate variations in soil loss and its spatial distribution in scales of single field plot to small watershed. Different approaches to simulate control measures design and their effects were tested in the small scale using Erosion 3D model and using WATEM/SEDEM or simple USLE/GIS approach in medium to large areas.

This paper was supported by projects:

NAZV č. QI91C008 „TPEO“

NAZV č. QJ1230056 „KLIMA“

BV č. VG 2012 2015 092

## **Geological and geomorphological controls of suspended sediment fluxes in periglacial environments of Russian Arctic**

TANANAEV N.

*P.I. Melnikov Permafrost Institute, Siberian Branch, Russian Academy of Science, YAKUTSK, RUSSIAN FEDERATION*

It is widely assumed that suspended sediment flux is a product of geomorphic processes, spatially distributed within the river catchment. Periglacial conditions normally restrict the activity of these processes, along with increased volumes of temporary sediment storage. Thus in our study we hypothesize that in the Russian Arctic suspended load tends to originate within the river valleys, due to better source-to-stream connectivity and enhanced sediment availability. Understanding of interconnections between sediment fluxes and its geomorphic controls requires the correct quantification of the former. Contemporary sediment flux calculations were carried out for 22 gauging stations on 13 large rivers of Russian Arctic. Results show that increased sediment yield is observed in geologically 'young' and dynamic areas of Verkhoyansk Range and Arctic Lowlands, in contrast with relatively stable Neogene planation surface of Central Yakutia. Within the Arctic Lowlands, intensively eroded river banks act as a primary sediment source. Bank retreat rates reach 40-50 m at meander heads, bank material is represented by alluvial deposits with high ice content, heavily affected by cryogenic weathering. In alpine environment of Verkhoyansk Range, lacking well-developed Quaternary deposit cover, valley slope failure may supply significant amounts of sediment to the streams. This material generally originates from Sartang (MIS2) moraine complex and glacial till, and is subject to both cryogenic and chemical weathering in river channels, generating suspended load. Periglacial conditions of the studied region thus appear to limit sediment generation and transport on the planation surfaces, while enhancing sediment supply of glacially disrupted material (in Verkhoyansk Mountains) and cryodisturbed alluvial deposits via bank erosion (in Arctic Lowlands).

\*\*\*\*\*

## **Spatial patterns and timescales of fine sediment redistribution in river basins: application of a sediment budget model with fallout radionuclide tracers**

SMITH H. BLAKE W.

*University of Plymouth, PLYMOUTH, UNITED KINGDOM*

Understanding the redistribution of fine sediment within river basins requires information on the rates and timescale of sediment supply and transfer across various landscape compartments. Sediment budgets provide an effective tool for examining these patterns. Such information is typically available from small intensively monitored research catchments, while examination of larger scale patterns of sediment transfer often requires the use of modelling-based approaches. Furthermore, knowledge of timescales of fine sediment transfer in river basins is limited. Few studies link sediment budgets with explicit information on the residence or travel times of fine sediment. This information is essential for understanding contemporary patterns of river basin sediment redistribution, and has implications for predicting possible recovery times of rivers affected by contaminated sediment from historic or recent pollution. Against this background, we aim to quantify the spatial patterns and timescales of suspended sediment transfer through a river basin (917 km<sup>2</sup>) situated in south-west England. We apply a spatially-distributed sediment budget model (SedNet) in conjunction with high-resolution spatial data and long-term rainfall and river flow measurements. Model outputs provide an indication of mean annual patterns of sediment redistribution and yields, which were computed for three land cover surveys (1990, 2000, 2007). This modelling was coupled with methods for estimating fine sediment residence times based on Be-7/excess Pb-210 ratios and a two-compartment radionuclide mass balance model comprising slow and rapid transport components. Findings from this study demonstrate the need for more integrated approaches to better understand spatial patterns and timescales of sediment redistribution in river basins.

### **Sediment Budgets in data poor environments: Case of the Kambaniru Catchment, Indonesia**

HOBGEN S.(1), WASSON R.(2), MYERS B.(1), FISHER R.(1)

(1) Charles Darwin University, DARWIN, AUSTRALIA ; (2) National University of Singapore, SINGAPORE, SINGAPORE

The islands of the East Nusa Tenggara province are some of the driest in Indonesia, with a long dry season, short wet season (3-5 months) and variable low annual rainfall. Food security is an increasing challenge with a growing population and greater variability in rainfall projected under climate change scenarios. Weirs have been constructed to provide reliable agricultural water supplies, however the landscape is highly erodible and weir pools are rapidly filling with sediment. Understanding of sediment sources is needed to design and implement effective measures to reduce sedimentation.

This study of sedimentation in the Kambaniru catchment in eastern Indonesia has developed sediment source mapping and a rudimentary sediment budget. The relative contribution of topsoil and subsoil to sedimentation was determined using radionuclide tracers  $^{137}\text{Cs}$ ,  $^{210}\text{Pb}_{(\text{excess})}$  and  $^{239+240}\text{Pu}$ . This analysis highlighted the importance of subsoil sediment sources, previously largely ignored in Indonesian government catchment management policies. Mapping of sediment sources used remote sensing, field measurements and local knowledge. Mapping of 'high risk' areas for topsoil erosion was undertaken based on the RUSLE equation and highlighted breaks in connectivity in the upper catchment due to the presence of dambo like structures acting as sediment sinks. Free software and imagery (SAGA GIS and Landsat, SPOT5, ASTER DEM and imagery on Google Earth) were purposely used to design methods for a low resource context. Gully erosion and channel change (subsoil sources) were found to be locally significant, although topsoil contributions are considerably higher than other reported values for the region. This research provides opportunities for improving the local capacity to understand sedimentation processes as a basis for developing appropriate catchment management.

\*\*\*\*\*

### **Contributions of on-land sediment sources and transfer to the overall Loire river basin sediment budget**

GAY A.(1), CERDAN O.(2), DELMAS M.(3), DESMET M.(4), DEGAN F.(4)

(1) French Geological Survey (BRGM), ORLEANS, FRANCE ; (2) French Geological Survey (BRGM), ORLEANS, FRANCE ; (3) INRA Infosol, ORLEANS, FRANCE ; (4) GéHCo, TOURS, FRANCE

Sediment fluxes within continental areas play a major role in the global biogeochemical cycles and are often at the source of soil surface degradation as well as water and ecosystems pollution. In a context of significant land use and climate change, it appears important to be able to carry out sediment budgets to assess potential future impacts induced by such changes. The purpose of this study is to examine the source-to-sink dynamic of the sediment cycle for 123 small to medium catchments (10 to  $10^4$  km<sup>2</sup>) distributed over the Loire River basin (France). To this aim, three different steps will be carried out. First, estimations of mean annual specific sediment load for the 123 catchments are estimated from suspended sediment concentration and water discharge measurements at basin outlets over the past four decades. Secondly, catchment global parameters (topography, landuse, drainage density...) and simple indices, combining these parameters, will be calculated to study the relationship between hillslope production and sediment load at basins outlet. Finally, we will focus on the development of a distributed modelling approach of on-land sediment transfer processes. Special attention will be given to hillslope runoff and sediment connectivity by taking into account landscape spatial organisation and linear pathways as determinant features for sediment transport. The results from the first step on mean annual specific sediment loads, show that catchments contribute from 30 to  $4 \cdot 10^5$  t.yr<sup>-1</sup> to the overall Loire river sediment exports (which equals  $10^{11}$  t.yr<sup>-1</sup>). Investigations on catchments global characteristics should then allow the identification of dominant processes in sediment redistribution, help to draw local and then regional distributed sediment budgets and bridge the gap between the different spatial scales. Contribution of hillslopes to the overall catchment budget should finally help to assess in-stream contributions and redistribution processes.

### Using suspended sediment records and lake deposits to reconstruct current and past sediment dynamics in a small agricultural catchment

FOUCHER A.(1), DESMET M.(1), SALVADOR-BLANES S.(1), CERDAN O.(2), EVRARD O.(3), LEFEVRE I.(3)  
 (1) Université de Tours, Laboratoire GehCo, TOURS, FRANCE ; (2) BRGM, ORLÉANS, FRANCE ; (3) Laboratoire des Sciences du Climat et de l'Environnement (LSCE/IPSL), GIF-SUR-YVETTE, FRANCE

Sediments budget affords an effective conceptual framework for quantifying sediment mobilization, transport, deposition and storage within, and sediment output from, a drainage basin. Our study aims at assessing the effect of long-term land use changes on suspended sediment fluxes and lake in fillings through the analysis of current and past transfers in a small catchment.

The Experimental Louroux Lake Catchment (24 km<sup>2</sup>) is a small agricultural basin located in the south-western of the Parisian Basin (France). Since 60 years, this catchment has largely been affected by land use changes. The catchment has been submitted to an intensification of agricultural practices, reflected by land consolidation, and subsurface drainage (more than 220 drain tile outlets, more than 90 % of the catchment drained).

Past transfers are traced through the analysis of four sediment cores taken from the Louroux Lake. The sediment deposits yield valuable informations relating to both the magnitude of sediment yield in the local area and the impact of postwar land use change. Since 1000 AD lake bed sedimentation rates have varied, but a pronounced acceleration since the postwar periods has been recorded. Indeed, since 1945, suspended sediment yields have represented 4 cm/year and seismic data indicate that from 2003 to 2011 sediments in the lake accrued by 55 cm in all lake areas.

Three stream monitoring stations are located at the outlets of the main lake tributaries and two at upstream sub-catchments. Three outlets of subsurface tile drain systems are also continuously monitored in different parts of the catchment. Representative samples of suspended sediment are collected to encompass the variability in suspended sediment sources during the study year.

Finally, the fingerprinting method has been performed over the dated cores, suspended sediments and various supposed sources to explore the relative contribution of those sources on the sediment delivery in the lake.

\*\*\*\*\*

### A spatially-distributed sediment budget for a regulated catchment in coastal California, USA

DOWNS P.(1), DUSTERHOFF S.(2), LEVERICH G.(2)  
 (1) Plymouth University, PLYMOUTH, UNITED KINGDOM ; (2) Stillwater Sciences, BERKELEY, UNITED STATES

A distributed sediment budget (1983–2008) is constructed for the non-impounded area of regulated Lagunitas Creek, California (*i.e.*, 64km<sup>2</sup> of 213km<sup>2</sup>). The budget uses a combination of extensive field surveys, historical data and topographic surveys, numerical modelling, and a representative-area extrapolation method to generate spatially-explicit sediment delivery estimates for contemporary processes. All major processes are represented and compared to sediment output estimated from gauging station records to avoid issues related to unmeasured residuals. Further independent corroboration is developed using reservoir bathymetric survey and literature-reported sedimentation values from the local area. Error estimates are propagated from measurements associated with field surveys and sediment gauging, while sensitivity analyses provide an indication of uncertainty related to data assumptions and models. An estimated yield of approximately 20,000 t a<sup>-1</sup> implies an average unit yield of ~300 t km<sup>-2</sup> a<sup>-1</sup> from the undammed, sediment-contributing area. This rate is comparable with reported maximum yields of sediment derived during land surface disturbances associated with initial Euro-American settlement in the catchment and occurs because nearly 60% of the effective sediment production is now derived from channel erosion sources (due largely due to flow regulation). Further, catchment sediment yields are maximised because the incising mainstem channel creates a highly efficient routing conduit to the catchment mouth. Together, these attributes illustrate the importance of quantifying channel-derived sediment in estimating contemporary human impacts on fluvial systems, especially those subjected to regulation, urbanisation, channelisation and field drainage as a consequence of population growth in the recent Anthropocene period.

### **Quantification of the fluvial sediment budget and associated particle-bound pollutant redistribution in an agriculture-dominated river basin of the European Russia: the problem of upscaling**

*BELYAEV V.(1), EVRARD O.(2), MARKELOV M.(1), SHAMSHURINA E.(1), IVANOVA N.(1), GOLOSOV V.(1), PARAMONOVA T.(3), OTTLE C.(2), LEFEVRE I.(2), BONTE P.(2)*

*(1) Laboratory of soil erosion and fluvial processes, Faculty of Geography, Lomonosov Moscow State University, MOSCOW, RUSSIAN FEDERATION ; (2) Laboratoire des Sciences du Climat et de l'Environnement (LSCE/IPSL), Unité Mixte de Recherche 8212 (CEA/CNRS/UVSQ), Centre de Recherche du CNRS, GIF-SUR-YVETTE, FRANCE ; (3) Department of Radioecology and Ecotoxicology, Faculty of Soil Science, Lomonosov Moscow State University, MOSCOW, RUSSIAN FEDERATION*

Quantitative assessment of a fluvial sediment budget is the key approach in fluvial geomorphology and hydrology, and also an essential tool for investigating the redistribution of particle-bound contaminants. Here we present an application of several independent approaches for quantifying the post-fallout particle-bound redistribution of the Chernobyl-derived <sup>137</sup>Cs and the basin-scale sediment budget for the River Plava basin situated in the Central European Russia. First stage of the study included creation of the digital elevation model and land use map for the entire River Plava basin and morphometric analysis of the cultivated slope morphology and fluvial network characteristics. Basing on that, several representative small catchments were selected as key study sites where detailed investigations of local-scale sediment redistribution and delivery have been undertaken at the second stage of the work. Methods used at the key catchments included <sup>137</sup>Cs-based sediment tracing, two soil erosion models and the analysis of soil profile morphological structure. At the third stage results obtained for the key catchments have been upscaled in order to reconstruct the entire River Plava sediment budget. The upscaling was based on statistical analysis of cultivated hillslope morphology, sediment delivery ratios for valleys of different Hortonian order and the analyzed spatial patterns of the fluvial network. The results showed that most of the sediment originating from soil erosion on cultivated slopes is redeposited on the uncultivated lower parts of the slopes or in the bottoms of infilled gullies, hollows and 1-3rd order valleys. The River Plava valley itself represents a system dominated by efficient transport, with very limited floodplain sediment storage. Sediment interception by the existing local dams and reservoirs have also been taken into account. It has been estimated that only about 1-2% of the basin-scale sediment volume reaches the River Plava basin outlet.

\*\*\*\*\*

### **Role of landslides in sedimentary fluxes in tropical mountain regions**

*GUNS M.(1), VANACKER V.(1), DEMOULIN A.(2)*

*(1) Université catholique de Louvain, George Lemaître Centre for Earth and Climate Research, Earth and Life Institute, 1348, BELGIUM ; (2) Université de Liège, Dept of Physical Geography and Quaternary, 1348, BELGIUM*

Landslides are known to be recurrent phenomena in active mountain belts, but the contribution of landslides to the overall sedimentary fluxes is not yet well known. In this work, we provide new data on landslide-derived sediment production and its contribution to sediment fluxes for a tropical Andean catchment. The Rio Pangor catchment (Ecuadorian Cordillera Occidental, 280km<sup>2</sup>) is particularly interesting for this study, as it has a wide range of landslide types with varying depths, surface area, and different topographic settings.

Landslide inventories were established based on sequential aerial photographs (1963, 1977 and 1989) and a very high resolution WorldView2 image (2010). Aerial photographs were ortho-rectified, and coregistered with the WorldView2 satellite image. Field campaigns were realised to collect field-based data on landslide types, their depths, widths and lengths. This allowed us to establish an empirical relationship between landslide area and volume, which was then applied to the landslide inventories to estimate landslide-related sediment production rates. The contribution of landslides to the overall sediment flux of the Pangor catchment was then estimated by comparing the landslide-related sediment production to (i) the suspended sediment loads at the outlet of the catchment and to (ii) 10-Be derived denudation rates.

The empirical landslide area-volume relationship established here for the Ecuadorian Andes has a sigma equals to 1.42, which is typical for landslides involving bedrock failure (Larsen et al., 2010), and an exponent alpha equal to 0.18. With our empirical equation, the volume estimation is similar (+10%) to the one obtained using the equation proposed by Larsen et al. (2010) for the Himalayas.

Landslide-derived sediment production is estimated at 250 – 1200 mm/kyr, and is within the range of the 10Be-derived denudation rates. This suggests that landslides are the main source of sediment in this tropical mountainous catchment.

### **Sediment budget of two glacial rivers in Iceland**

JENSEN E.

*Icelandic Meteorological Office, REYKJAVIK, ICELAND*

Recent analyses on sediment budget in two glacial rivers in Iceland are presented here. These river catchments are very dynamic and hydro power plants have been planned in both of them. Þjórsá river is the largest river in Iceland and hydro power is already being harnessed in the upper reaches. Skaftá river has very complicated hydrology with frequent glacial outbursts (jökulhlaups). Here the total sediment, suspended sediments and bedload budget is summarised for both rivers. The large river Þjórsá has total budget of 1.64 million tonnes per year whereas the Skaftá river has total sediment budget of 5.5 million tonnes per year. The glacial outbursts occurring in Skaftá were calculated separately and show values between two to over three million tonnes per event. The years 2002 and 2003 had both two jökulhlaup events (glacial outbursts) and as a consequence the annual budget of those two years was almost doubled. This information is very important to future planning of hydro power harvesting. The data includes other interesting information pointing to climate change effects as well as recently confirmed ashfall effects on glacial melt.

\*\*\*\*\*

### **Geocological functions of polar river systems**

ZWOLINSKI Z.

*Institute of Geocology and Geoinformation, Adam Mickiewicz University in Poznan, POZNAŃ, POLAND*

This paper outlines general functions with which to interpret river evolution, behaviour and character in polar systems. On the basis of different river schemes presented by various authors hierarchical, functional and systematic divisions of river patterns are analysed within drainage basin. Drainage basin or river catchment as holistic system is fundamental assumption of this undertaken analysis. The fluvial system presented by Schumm (1977) is an input to this analysis. Next several river schemes which have various analytical assumptions: geological, geomorphic, morphometric, hydrological, denudational, glaciological, sedimentological, ecological, botanical etc are adjusted. After examination of these different visions useful features of each scheme are adopted to a model of polar river system. Adopted analysis is based on four steps of reading the landscape (Fryirs and Brierley 2012) in this case of fluvial and slope landscapes in glacial, proglacial, periglacial and paraglacial terms. As an effect of analysis geocological functions for river systems on polar areas are presented. These functions are divided for glaciated and unglaciated catchments. Distinguished functions described successive geocological zones in polar catchments.

Fryirs K.A. & Brierley G.J., 2012. *Geomorphic Analysis of River Systems: An Approach to Reading the Landscape*. John Wiley & Sons, Chichester.

Schumm S.A., 1977. *The fluvial system*. John Wiley & Sons, Chichester and New York.

## **Response of Landslide Sediment Dynamics to Forest Clearing in Coastal British Columbia, Canada**

BRARDINONI F.(1), MAYNARD D.(2), ROLLERSON T.(3)

(1) *University of Milano-Bicocca, MILANO, ITALY* ; (2) *Maynard & Assoc., NORTH VANCOUVER, CANADA* ; (3) *Golder Associates Ltd., GABRIOLA ISLAND, CANADA*

We compile and examine a landslide historical inventory in northeastern Vancouver Island, Canada. The study area is underlain by extrusive (upper Triassic Karmutsen Formation) and intrusive rocks (Jurassic Island Intrusions). The dataset, compiled via interpretation of sequential aerial photosets, helicopter traverses, and extensive fieldwork, comprises a total of 1961 sediment sources, including 798 field-measured events. Field- and photo-based data cover a time window of approximately 70 years. The effects of forest management on landslide activity are assessed in terms of landslide density, sediment production, landslide geometry, landslide magnitude-frequency relations, topographic conditions of landslide initiation and deposition, and sediment redistribution across landscape components.

Results indicate that forest management alters natural landslide dynamics in many respects. Logging-related debris avalanches are typically smaller, consequently the magnitude-frequency relation in logged terrain occupies the small-to-medium magnitude spectrum (< 6000 m<sup>3</sup>), with frequencies increasing by over an order of magnitude. Lithologic effects on sediment production appear amplified in that terrain underlain by extrusive rocks become increasingly more unstable than intrusive ones. Analysis of landslide initiation and deposition zones reveals that forest management accelerates sediment aggradation on mid and lower hillslopes and along the gully network. This pattern, which accelerates sediment recharge of gully systems, has the potential of increasing the frequency of channelized debris-flows, hence cause an extended period of disturbance, before sediment dynamics recover to pre-logging conditions. The effects of forest clearing on hillslope-channel coupling are composite: in cutblocks the percentage of sediment delivered to streams is reduced by 20-60% whereas road-related landslides are associated with highest connectivity to streams.

\*\*\*\*\*

## **Controls of snow avalanche distribution and geomorphic avalanche activity at hillslopes in steep mountain valleys in western Norway**

LAUTE K., BEYLICH A.A.

*Geological Survey of Norway (NGU), TRONDHEIM, NORWAY*

Snow avalanches are common phenomena in Norway. Research on snow avalanches provides insights into possible effects of predicted climate change on avalanche activity and connected sediment transport in mountain areas. This study focuses on (i) controlling factors of avalanche distribution and activity, and on (ii) their relative importance regarding mass transfers in two steep, parabolic-shaped and glacier-connected tributary valleys (Erdalen and Bødalen) in western Norway. Mapping of distribution, extension and run-out distances of avalanches is combined with spatial data analysis of morphometric controls. Based on correlation of climate data with monitored avalanche events the timing and frequency of avalanches is explored and debris mass transfer on hillslopes caused by avalanches is estimated. The denudative effect of snow avalanches occurs in two steps: firstly throughout erosion directly on the surface of the rockwall and secondly due to their transport ability which causes significant remobilization and transport of available debris further downslope. The distribution of snow avalanches depends on the valley orientation, slope aspects and rockwall morphometry. Especially distinct "bowl" shaped leeside upper rockwall areas allow a high accumulation rate of snow during winter which is then released as avalanches during spring. The timing and frequency of avalanches in both valleys depend mainly on snowfall intensity, periods with strong winds combined with a stable wind direction or sudden air temperature changes. As snow avalanches represent one of the dominant denudational processes they have a high relative importance regarding mass transfer within the sedimentary budgets of the entire valleys.

### **The Temporal and Spatial Quantification of Holocene Sediment Dynamics in a meso-scale catchment in northern Bavaria / Germany**

FUCHS M., WILL M.

*University of Giessen, GIESSEN, GERMANY*

The Aufsess River catchment (97 km<sup>2</sup>) in northern Bavaria, Germany, is studied to establish a Holocene sediment budget and to investigate the sediment dynamics since the early times of farming in the 3<sup>rd</sup> millennium BCE. The temporal characterization of the sediment dynamics is based on an intensive dating program with 73 OSL and 14 <sup>14</sup>C ages. To estimate soil erosion and deposition, colluvial and alluvial archives are investigated in the field by piling and trenching, supported by laboratory analyses. The sediment budget shows that 58% of these sediments are stored as colluvium in on- and foot-slope positions, 9% are stored as alluvium in the floodplains and 33% are exported from the Aufsess River catchment. Colluviation starts in the End-Neolithic (ca. 3100 BCE), while first indicators of soil erosion derived alluviation is recorded ca. 2-3 ka later. The pattern of sedimentation rates also displays differences between the colluvial and alluvial system, with a distinct increase in the Middle Ages (ca. 1000 CE) for the alluvial system, while the colluvial system records low sedimentation rates for this period. A contrast is also observed since Modern Times (ca. 1500 CE), with increasing sedimentation rates for the colluvial system, whereas the alluvial system records decreasing rates. The different behavior of the colluvial and alluvial system clearly shows the non-linear behavior of the catchment's fluvial system. The results further suggest that human impact is most probably the dominant factor influencing the sediment dynamics of the catchment since the introduction of farming.

\*\*\*\*\*

### **Regionalization of geomorphic processes in the proglacial area of Gepatsch and Weißsee glaciers, Ötztal Alps, Austria**

HILGER L., HECKMANN T., HAAS F., BECHT M.

*Catholic University of Eichstaett-Ingolstadt, EICHSTAETT, GERMANY*

Geomorphic processes in proglacial areas show intensities significantly higher than in lowlands. This fact can partially be explained by accelerated geomorphic reworking of comparatively recently exposed sediments and increased rockfall activity, both reflecting a transition to non-glacial conditions. Present day degradation of permafrost in elevation zones above the glacier tongues further contributes to high morphodynamics in such areas. A regionalization of geomorphic process domains and rates is a prerequisite to arrive at process-differentiated and total sediment budgets, not only in high mountain areas.

This paper focuses on the preliminary results of a regionalization of geomorphic processes within the proglacial areas and the sediment contributing slopes of two glaciers in the Ötztal Alps, Austria. The presented work is part of the interdisciplinary joint project PROSA (High-resolution measurements of morphodynamics in rapidly changing **PRO**glacial **S**ystems of the **A**lps) investigating the relative importance of glacial and non-glacial geomorphic processes for a recent process-differentiated sediment budget.

While multi-epoch terrestrial laser scanning data (TLS) of test sites at rockwall-talus systems and heavily gullied lateral moraines made it possible to determine process areas and rates on the local scale, high-density airborne LiDAR (ALS) data was available for all of the ~62 km<sup>2</sup> study area. DEMs of difference (DoDs) were generated from both ALS and TLS data wherein DEM quality adapted limits of change detection (LoDs) were applied. The obtained rates were regionalized by applying both probability based process models and a detailed geomorphic map prepared from high resolution DEMs (and derivatives) and high-resolution orthophotos.

An investigation of process connectivity is under way. A graph-theoretical approach has been proposed for an analysis of the linkages of process domains to the proglacial zone and between different subsystems of the catchment.

### **Sediment transfer and geomorphic work on a periglacial mountain slope**

MUELLER J.(1), GAERTNER-ROER I.(1), KENNER R.(2), MORCHE D.(3)

(1) Department of Geography, University of Zurich, ZURICH, SWITZERLAND ; (2) WSL Institute for Snow and Avalanche Research SLF, DAVOS, SWITZERLAND ; (3) Department of Geoscience and Geography, University of Halle-Wittenberg, HALLE, GERMANY

Mountain geosystems are characterized by an extensive transfer of mass and energy, reflected in its geomorphological processes shaping the landscape. Changes in the temperature regime lead to corresponding changes in geomorphological processes and are manifested in characteristic landforms. Thus, distinct changes are expected in the periglacial belt, which is most sensitive to temperature changes, especially at its boundaries. So far, few attempts have been undertaken to quantify the transfer of sediment or energy in this environment.

A periglacial mountain slope near the lower permafrost boundary was investigated in Eastern Switzerland (Corvatsch). The slope is characterized by a typical coarse debris process chain: rock wall --> rock fall --> talus slope --> permafrost creep --> rockglacier. Rockglaciers are considered to be sediment traps for the coarse debris system, reflecting the erosion history of the corresponding catchment. Headwall recession, creep processes and energy transfer (geomorphic work) of the talus slopes and rockglaciers are quantified using a multi-method-approach combining remote sensing and terrestrial methods. Multitemporal DTMs developed during the last two decades allow the quantification of sediment transfer of the slow moving landforms (frozen talus slopes and rockglaciers). Sediment input from the rock wall is quantified by repeated laser scanning over the last 4 years. The multitemporal high resolution topographic information is used to compute the geomorphic work within this period.

The purpose of the study is to describe sediment and energy transfer on a periglacial mountain slope and to assess the relevance of permafrost occurrence for sediment budgets in a changing climate. The geomorphic work approach allows the characterisation and quantification of the slope's sediment dynamics on the basis of energy transfer and creates process-related and scale independent comparability.

\*\*\*\*\*

### **Sediment sources, yield and connectivity in a low relief alpine catchment, Snowy Mountains, New South Wales, Australia**

STROMSOE N.(1), CALLOW N.(2), MCGOWAN H.(1), MARX S.(3)

(1) University of Queensland, BRISBANE, AUSTRALIA ; (2) University of Western Australia, PERTH, AUSTRALIA ; (3) University of Wollongong, WOLLONGONG, AUSTRALIA

The Snowy Mountains are a unique alpine region from which to investigate the relative significance of fluvial and atmospheric sediment input as well as the yield and transmission of sediment through different components of the landscape. The Snowy Mountains are relatively geologically old, of moderate relief (<2,500m asl) and have a well-developed soil mantle protected by a dense cover of vegetation at even the highest elevations. Some previous research has shown transport rates are generally low for an alpine region (<20t/km<sup>2</sup>/yr).

Using uranium isotopes, <sup>14</sup>C, <sup>210</sup>Pb and <sup>137</sup>Cs and ICP-MS analysis of sediment geochemistry, we investigated sediment transport and residence times in the Snowy Mountains over timescales of decades to several thousand years and for multiple depositional landscape features (e.g. tarns, bogs and reservoirs). Results to date suggest highly spatially variable sediment yields between 6 t/km<sup>2</sup>/yr (high elevation reservoir) to 230 t/km<sup>2</sup>/yr (tarn). Bog environments show almost entirely atmospheric input of sediments, though tarns are dominated by localised fluvial inputs. The modest sized (90 km<sup>2</sup>) catchment above the reservoir is moderately disturbed by post-European cattle grazing and recent severe bushfires and has a relatively connected catchment (60% effective catchment area). Yet the low reservoir sediment yield indicates that sediment transmission is reduced by micro-scale patterns of sediment disconnectivity which are observed occur across individual hillslopes. Bog environments proximal to streams are also likely to act as efficient filters, with distal bog environments showing limited or no evidence of sediment transmission and redistribution via fluvial processes. Ongoing work at the hillslope-scale will further quantify erosion rates by investigating soil development and residence times to provide a more complete understanding sedimentation in sediment stores.

## **Poster presentations:**

### **Estimate of Reservoirs Storage Capacity and Total Sediment Trapped in China**

LU X., YANG X., RAN L.

*Department of Geography, National University of Singapore, SINGAPORE, SINGAPORE*

Chinese rivers have been experiencing a drastic decline in sediment loads in recent decades. This is mainly due to massive reservoirs constructions, although other factors like rainfall reduction, water withdrawals, sand mining, and vegetation recovery also play an important role in the sediment loads decline. By use of remote sensing images in conjunction with Google Earth and field check, the spatial distribution of constructed reservoirs in the large Chinese river basins was delineated and their storage volumes were estimated. The number of the extracted reservoirs (>0.0036 km<sup>2</sup>) is close to 90,000, almost half of the extracted lakes (over 180,000). The extracted reservoirs have much higher capacity (780 km<sup>3</sup>) than the extracted lakes (260 km<sup>3</sup>). The total amount of sediment trapped behind these dams will be estimated. The ultimate goal is to evaluate their cumulative impacts on sediment supply to coastal areas.

\*\*\*\*\*

### **The I.A.G./A.I.G. SEDIBUD (Sediment Budgets in Cold Environments) Programme: Scientific key issues and future tasks**

BEYLICH A.A.(1), LAMOUREUX S.F.(2), DECAULNE A.(3)

*(1) Geological Survey of Norway (NGU), TRONDHEIM, NORWAY ; (2) Queen`s University, Department of Geography, KINGSTON, CANADA ; (3) CNRS UMR6042 Laboratory of Physical and Environmental Geography GEOLAB, University of Clermont-Ferrand, CLERMONT-FERRAND, FRANCE*

Projected climate change will undoubtedly change surface environments in cold regions and alter the fluxes of sediments, nutrients and solutes, but the absence of quantitative data and coordinated process monitoring and analysis to understand the sensitivity of the Earth surface environment is acute in cold climate environments. The I.A.G. / A.I.G. SEDIBUD (Sediment Budgets in Cold Environments) Programme, building on the ESF SEDIFLUX Network (started in 2004), was formed in 2005 to address this existing key knowledge gap. The central research question of this global group of scientists is to "Assess and model the contemporary sedimentary fluxes in cold climates, with emphasis on both particulate and dissolved components". SEDIBUD has developed manuals and protocols (SEDIFLUX Manual) with a key set of primary surface process monitoring and research data requirements to incorporate results from diverse field-based projects and allow coordinated quantitative analysis across the programme. About 50 defined SEDIBUD key test sites worldwide provide data on climate conditions, discharge and particulate and dissolved fluxes as well as information on other relevant surface processes. Defined SEDIBUD key tasks include (i) The ongoing and continued generation and compilation of comparable longer-term datasets on contemporary sedimentary and solute fluxes and yields from SEDIBUD key test sites worldwide, (ii) The continued extension of the SEDIBUD metadata database with these datasets, (iii) The testing of defined SEDIBUD hypotheses by using the datasets compiled in the SEDIBUD metadata database. Detailed information on SEDIBUD is found at the SEDIBUD website <http://www.geomorph.org/wg/wqsb.html>.

## Holocene human impacts on fluvial sedimentary budgets in Malta, Central Mediterranean

SULTANA D.

University of Malta, MSIDA, MALTA

The Maltese Islands occupy a pivotal area in the Central Mediterranean, despite the latter, there have been relatively few studies regarding Holocene sedimentary processes. Research addresses these lacunae and adds to our ability to understand the role the first Maltese inhabitants had in altering sedimentary budgets.

Sedimentological and palynological studies were carried out on core and outcrop data from Marsa with the aim of appraising Maltese middle Holocene (6000 cal. BP) sedimentary depositional environments and processes.

Studies indicate that tectonic and climatic environments within the Islands did not substantially change during the middle Holocene. Despite the uniformity of these parameters, sedimentary studies of fluvial sequences showed exceptionally high rates of accretion during the middle Holocene epoch. Sedimentary accumulation rates as high as 5 meter per 500 years were measured. Palynological studies within the same epoch also indicate a shift in pollen species with a dramatic decrease in woodland pollen and a simultaneous increase in agricultural associated pollen.

High fluvial sedimentation rates during the middle Holocene were not found to coincide with variations in climatic and tectonic environments and were thus not thought to be the cause. The increase in fluvial sediment budget is proposed to be the result of intense soil erosion in upland sediment source catchment areas. The authors propose that high erosion rates were the consequence of deforestation (as early as 7300 cal. BP), brought about by early human agricultural practices. Eroded sediments were transported via fluvial systems and deposited at sea-level forcing rapid delta progradation despite a transgressive marine environment. The study thus gives evidence to the impacts early human activities had on Maltese ecosystems and fluvial sediment budgets.

\*\*\*\*\*

## The main snow-avalanche winters of the last 100 years documented by dendrogeomorphology in the Bødalen and Erdalen valleys, inner Nordfjord, western Norway

DECAULNE A.(1), EGGERTSSON Ó.(2), LAUTE K.(3), BEYLICH A.A.(3)

(1) CNRS - Geolab, CLERMONT-FERRAND, FRANCE ; (2) Iceland Forest Service, Research Branch, Mogilsa, REYKJAVIK, ICELAND ; (3) Geological Survey of Norway (NGU), TRONDHEIM, NORWAY

The Bødalen and Erdalen valleys present a high relief and a U-shaped system in the innermost part of the Nordfjord area in western Norway. Elevation varies from 520 to 2082 m a.s.l.

The lower parts of the cones are covered with downy birch (*Betula pubescens* Ehrh.) and grey alder (*Alnus incana* (L.) Moench) shrubs; tress in the runout zone are heavily damaged up to the opposite slope, crossing the sub-horizontal valley floor.

The forest-covered valley floor offers a great opportunity for snow-avalanche reconstruction using tree rings.

The methods used in this study include field survey, tree sampling, sample analyses and construction of a snow-avalanche chronology. Field survey locates the obvious impacts of snow avalanches in the distal runout zone, such as mineral debris deposits and damage on trees. Tree sampling of up to 91 trees, alive and dead, include cores and disks, selected randomly and along transects within the runout zones. The construction of the snow-avalanche chronology is based on the eccentricity signal of the impacted trees, dead of trees and dating of scars; the calculation of the avalanche activity index is derived for each year, according to the number of signals registered by trees related to the number of trees alive at this time.

The age structure of the stands reveals rather young trees, ranging from 20 to over 100 years.

The snow-avalanche chronology reveals numerous winters over the last 100 years with a representation over 10% and more than two trees responding during the same growth season. Four main winters are highlighted, 1940-1950, 1975-1976, 1996-1997 and 2006-2007. All of them have extreme runout distances, reaching 350 to 430 m from the toe of the cone.

Dendrogeomorphology is an efficient tool to unravel snow-avalanche chronology in the valley during the last 100 years. The snow-avalanche calendar is very reliable since the 1950s.

### **A sediment budget of an intensively cultivated downslope area of the Seine River: The Pays de Caux loess plateaux**

*LANDEMAINE V.(1), CERDAN O.(2), LAIGNEL B.(3)*

*(1) Université de Rouen - BRGM, MONT SAINT AIGNAN, FRANCE ; (2) BRGM, ORLEANS, FRANCE ; (3) Université de Rouen, MONT SAINT AIGNAN, FRANCE*

In many cultivated areas of the loess belt in Northern Europe, loamy soils are particularly sensitive to runoff and erosion. The different erosion processes may not be continuous within a catchment, and runoff and erosion responses to rainfall events differ in function of the spatial scale of observation. Many of the underlying mechanisms of this scale effect are still unknown and/or not well described. In addition to spatial heterogeneities, erosion processes are also varying depending on the temporal resolution of measurements from the effect of the temporal dynamic of successive rainfall events to more seasonal variations either influenced by climate or anthropogenic land use changes. The objective of this paper is to identify and quantify the scale effects on runoff and erosion, from the field scale to the regional scale. The first part of this study will consider the effect of the spatial organisation of the landscape, both in terms of connectivity and patchiness. The second part will investigate the relative importance of the different processes that emerge as we move from one scale to another. More specifically we will quantify the different form of sediment transfer from local hillslope laminar flow, to concentrated flows to karst areas or to the river systems and, finally, to regional river export to the sea. These different quantifications will be extrapolated at the regional scale, taking into account of the landscape spatial organisation, to establish a regional sediment budget.

\*\*\*\*\*

### **Relationship between Norway spruce (*Picea abies* (L.) Karst.) growth anomalies and sedimentation rates in the sulphur mining area of Calimani Massif, Romania**

*ANGHEL T.(1), STOFFEL M.(2), POP O.(1), BUIMGA-IARINCA S.(1), IRIMUS I.A.(1)*

*(1) Babes-Bolyai University, Faculty of Geography, CLUJ-NAPOCA, ROMANIA ; (2) University of Bern, Institute for Geological Sciences, Laboratory of Dendrogeomorphology & University of Geneva, Institute for Environmental Sciences, Carouge-Geneva, BERN & GENEVA, SWITZERLAND*

Geomorphic processes (e.g., flows, slides) occurring in the poorly consolidated waste dump deposits of the sulphur mines represent a serious threat for the environment and people living downstream of abandoned sites. The Negoiu Românesc volcanic cone (Calimani Massif, Romania, 1895 m a.s.l.) is such a case, and toxic debris flows and landslides have recently started to affect a Norway spruce (*Picea abies* (L.) Karst.) forest located between 1700 and 1320 m a.s.l. In addition, at the lateral boundaries of the Dumitreleu retention basin, constructed to retain the waste, *P. Abies* trees are covered with up to 160 cm of toxic, sulphur-rich sediments originating from the waste dump deposits. This study aims at using dendrochronological methods to (i) analyze reactions of trees to sedimentation/burial by toxic debris and (ii) to determine the span time and burial depth tree can support in such an environment. The determination of tree locations was performed by topographical measurements using a Leica 407 total station. The dendrochronological study was performed with 22 buried *P. abies* trees. To analyze height, extent and intensity of anatomical changes in tree-ring records, a set of samples was extracted every 10 cm on the trunk of each tree, providing 450 increment cores and 57 stem discs. Another 20, non-affected *P. abies* trees were sampled (40 increment cores) to obtain undisturbed reference tree growth at the site and to compare with growth anomalies (i.e. residuals) in affected trees. The results show that trees severely react producing tangential rows of traumatic resin ducts (TRD) and growth suppression sequences (GS) during or following years with sedimentation events. The samples from affected trees show this type of reaction up to 110 cm under the sediment surface level reached in 2007, but also until 50 cm up on the trunks from this reference level. A high concentration of the TRD and GS is observed between 30 cm underground and 30 cm above to the reference level. These results could improve sampling strategies for the similar future studies in the mountain areas affected by mining activities.

**Spatio-temporal variation of snow avalanche activity in Piatra Craiului Mountains (Romanian Carpathians) assessed by dendrogeomorphological methods**

POP O.(1), MUNTEANU A.(2), GAVRILA I.(1), ANGHEL T.(1), PETREA D.(1)

(1) Babes-Bolyai University, Faculty of Geography, CLUJ-NAPOCA, ROMANIA ; (2) University of Bucarest, Faculty of Geography, BUCAREST, ROMANIA

Dendrogeomorphological methods were used here to analyze the reaction of trees to snow avalanche impact and to assess the time and spatial distribution of this geomorphic process in four different avalanche paths of Piatra Craiului Mountains. The dendrogeomorphological study was performed with 166 *Picea abies* (L.) Karst.) trees. Another 27, non-affected *P. abies* trees were sampled to obtain undisturbed reference tree growth at the site and to compare it with growth anomalies (i.e. residuals) in affected trees. The tree-rings showing growth anomalies (e.g. tangential rows of traumatic resin ducts, compression wood, callus tissue, growth suppression and growth release) were used to reconstruct a minimum frequency of avalanche activity for each of the four avalanche path site. The results show the affected trees reacted severely during or following years with snow avalanche events. In addition, data shows that the intensity of growth reactions in trees is positively correlated with position of trees on the avalanche couloir.

\*\*\*\*\*

**The experimental Louroux lake catchment: continuous records of discharge and suspended sediment flux in a small agricultural catchment**

FOUCHER A.(1), SALVADOR-BLANES S.(1), DESMET M.(1), CERDAN O.(2), EVRARD O.(3), LEFEVRE I.(3)

(1) Université François Rabelais de Tours, Laboratoire GeHCo, TOURS, FRANCE ; (2) BRGM, ORLÉANS, FRANCE ; (3) Laboratoire des Sciences du Climat et de l'Environnement (LSCE/IPSL), GIF-SUR-YVETTE, FRANCE

The experimental Louroux lake catchment is a small agricultural headwater catchment (24 km<sup>2</sup>) of the Indre River which drains into the Loire River (France). This small catchment has been equipped with an experimental setup monitoring suspended sediment fluxes since 2012.

This catchment is characterised by lowland topography with gentle slopes (0.44 %). Most of the catchment (95 %) is cultivated and there are only a few fields occupied by long term pasture. Since the last Second World War, an intensive farming has been established. The catchment has been extensively submitted to subsurface drainage using drain tile. There are at least 220 drain tile outlets in the catchment and it is estimated that 90 % of the catchment is drained, 20 km of stream have been created and the lands reallocated.

A 55 ha lake dating back from the Middle Ages is present at the catchment outlet: this lake intercepts the suspended sediment flow of the catchment. Since 1000 AD, lake bed sedimentation rates have varied, with a pronounced acceleration since the early 1940s with lower quality of lake and rivers waters (N and P pollutions). The increase in suspended sediment yields and water degradation during the postwar periods is attributed to an increase of intensive farming in the catchment.

Eight continuous monitoring stations and one weather station have been positioned over the catchment. Continuous records of discharge and suspended sediment concentration are available from each of monitoring stations using V-notch and turbidity sensors. Three stream monitoring stations are located at the outlets of the main lake tributaries and two at upstream sub-catchments. The outlets of three subsurface drain tile systems draining arable fields are also monitored at different parts of the catchment.

This monitoring should allow a better understanding of the origin and dynamics of sediment transport within small intensively cultivated plain catchments.

### Lateglacial to Holocene sediment budget of a small subAlpine river catchment: using 3D palaeotopographic reconstructions for volume quantification

GUI TER F.(1), BRISSET E.(2), MIRAMONT C.(1), ANTHONY E.(3), BRUNETON H.(3)

(1) IMBE Aix-Marseille University, AIX EN PROVENCE, FRANCE ; (2) CEREGE/IMBE - Aix Marseille University, AIX EN PROVENCE, FRANCE ; (3) CEREGE - Aix-Marseille University, AIX EN PROVENCE, FRANCE

We present GIS-based quantification of stream catchment sediment budgets in a high-energy subAlpine setting in south-eastern France characterized by markedly different phases of deposition, stream incision, erosion and downstream sediment export. GPS-assisted field investigations were conducted in order to map accurately the geomorphology of the Charanc catchment at 3 key-dates of the morphogenetic evolution corresponding to (1) the abandonment surface of periglacial accumulation glacis at ca. 20,000 cal. BP; (2) the state of the catchment before dismantling of the periglacial slopes at ca.14,500 cal. BP and; (3) the “Main Postglacial Infilling” (MPI) abandonment surface prior to

Between 20,000 and 14,500 cal. BP, 36 million m<sup>3</sup> of sediments were eroded from the hillslopes. This eroded material was totally exported out of the catchment without intermediate storage. This sediment load did not accumulate in the Drouzet downstream of the Charanc. This entire volume of sediment was exported much further downstream to the trunk valleys of the Petit Buëch and Durance Rivers. Between 14,500 cal. BP and the present, 14 million m<sup>3</sup> of sediment were eroded at the expense of the periglacial glacis remnants and the marly substrate. 73 % (i.e., 10 millions of m<sup>3</sup>) of the eroded material was stored in fan-shaped MPI deposits. At the present time, 6 million m<sup>3</sup> of MPI deposits (46 % of the eroded volume) are still stored in the catchment.

We analyse the spatio-temporal variability of these results in the light of the regional palaeo-environmental and climatic framework of the Lateglacial to Holocene periods, and compare specific erosion rates to present-day rates obtained from instrument-based measurements in such highly erodible environments.

\*\*\*\*\*

### Sediment Fluxes in Karkevagge, Swedish Lapland: A compilation of Previous Studies

DIXON J.

University of Arkansas, FAYETTEVILLE, UNITED STATES

Kärkevagge is a 5km long glaciated valley located in northern Swedish Lapland at approximately 68° 26' N latitude and 18° 18'E longitude. The 30yr Mean annual air temperature from the nearby Katterjåkk climate station is -1.7°C and mean annual precipitation is 844mm. Mean total sediment output from the catchment is in the vicinity of 0.2-1.2 tkm<sup>2</sup>d<sup>-1</sup> (Rehn et al. 1982). There is however considerable spatial variability in sediment transfer within the valley. In addition, flood and slush events contribute substantially greater amounts of suspended sediment up to as much as 3.4 tkm<sup>2</sup>d<sup>-1</sup>. In addition there is considerable variability in suspended sediment transport within the valley channel systems

Considerable variability in solute flux is observed within the valley. Total solute flux is greatest in the vicinity of the valley outlet, but within the valley solute flux is greatest at the base of the dam impounding Lake Rissajaure.

Solifluction movements are on average 4cm per year but display considerable spatial variability depending on available moisture. Mean mass transfer is in the vicinity of 20,000 mt/yr (Ridefelt et al., 2009). Slush avalanches and slush torrents represent significant contributors to sediment transport in the valley. Slush avalanches display considerable temporal variability in their magnitude varying from as little as 0.5m<sup>3</sup> to >300m<sup>3</sup> Rapp (1960). Slush torrents may contribute between 10,000 and 20,000 m<sup>3</sup> of mass flow (Gude et al., 2000). ey.

Sediment fluxes within Kärkevagge are strongly variable both spatially and temporally. There is some suggestion that while some processes appear to have changed little since Rapp's 1960 study other processes have increased measurably in magnitude.

### How Far was this Sediment Origin? A Granulometry May Tell

MERCIER J.

*Universit\_ de Strasbourg, STRASBOURG, FRANCE*

On hillslope, using the continuity and flow equations, the altitude of a square meter result's from the local mass balance by unit volume.

This sediment budget obey different geomorphological processes including: production, mobilization, transit, deposition. Some of the processes involved: distance to the source, time travel, residence time, can be inferred from the development of sediment particle analysis. In this text, applying geomorphology, physics and distributions, we use a model that gives a numerical value to characterize sand distribution and a possible explanation of the physical parameters involved.

The samples are originating from the Vosges Mountains were slopes processes, water balance, microclimatic studies have been performed for several decades in the Ringelbach watershed.

\*\*\*\*\*

### Morphodynamics of reservoir banks in the Kama River: "accessory" geomorphic processes

NAZAROV N.N., FROLOVA I.V.

*Perm State University National Research, PERM, RUSSIAN FEDERATION*

At the Kama River reservoir banks (57 N, 55 E) poorly studied are hydration and physical weathering, suffusion, piping (tunnel erosion) and wind erosion.

Hydration weathering together with physical weathering and phytogenic destruction promotes removal of mineral and organic matter independent of any denudation agents. Geomorphic effects of this action are evident from bared roots of trees and stumps.

Frost weathering produces up to 40-cm deep cracks on sandbanks. Later on frost cracks may widen and obtain some intricate configurations under action of wind and surf flows.

Location of suffusion sinkholes is predetermined by rock fissuring. They are mostly abundant at edges of river terraces. Collapses of high banks are being prepared by piping. This process is active inside block slides, scree and landslide bodies that rest against steep banks. Subsurface erosion tunnels reach 1.5 m in diameter and 3-4 m in length.

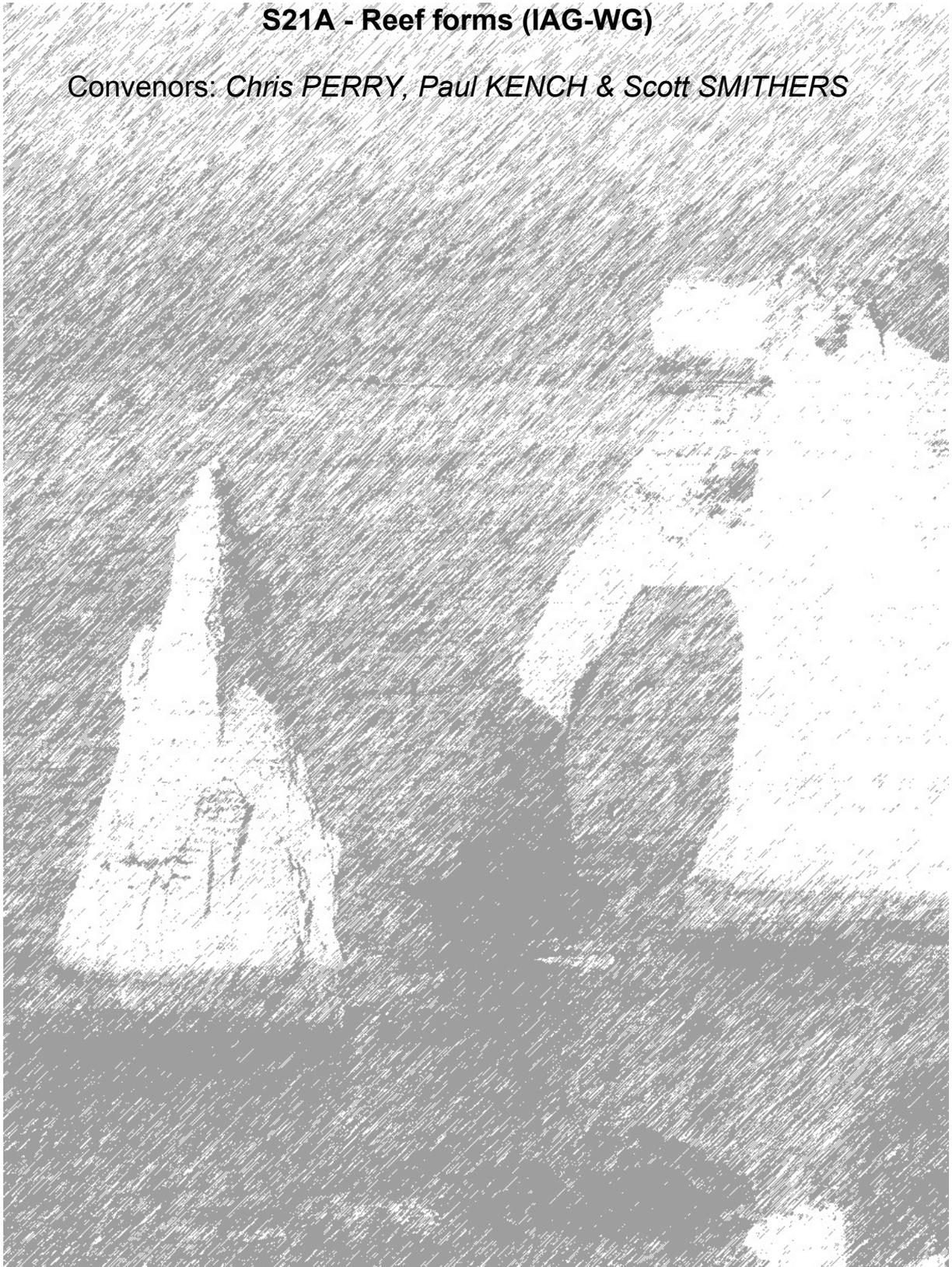
Wind erosion acts on river terraces composed of fine and medium sands. If prevailing wind directions are normal to bank, sand is being thrown from slopes to terrace surfaces and is transported inside by tens of meters from terrace edge. Observations show that under dry windy weather sand layer removed from terrace slope may reach 5-7 cm in a 3 day period.

Aeolian microforms or sand cover formed during the spring-summer season on terrace surfaces at a 30-m distance from the terrace edge are usually 3-5 cm thick (up to 15-25 cm in some years). Traces of redeposited sand are often found as far as 120-150 m from terrace edges.

\*\*\*\*\*

**S21A - Reef forms (IAG-WG)**

Convenors: *Chris PERRY, Paul KENCH & Scott SMITHERS*





## **Oral presentations:**

### **Biotic dynamics as a driver of coral reef geomorphology**

*RIEGL B.(1), PERRY C.(2), SMITHERS S.(3), KENCH P.(4)*

*(1) Nova Southeastern University, DANIA BEACH, UNITED STATES ; (2) University of Exeter, EXETER, UNITED KINGDOM ; (3) James Cook University, TOWNSVILLE, AUSTRALIA ; (4) University of Auckland, AUCKLAND, NEW ZEALAND*

Reef-building is a major geomorphic process accomplished by mostly biological processes. It is therefore not surprising that interference with life-processes of reef-builders should result in visible alterations or even total switch-off of the framework-building processes. Corals have been key geomorphic agents throughout earth history, as can be seen from their contribution to frammstones, rubble ridges, and unconsolidated sediments in general. Life-processes of branching corals are generally understood and can be, in combination with findings from taphonomy and geomorphology, be used to hindcast past dynamics on which forecasts to future dynamics can be predicated. We use findings from settings under very different environmental control, from typically reef-building (Great Barrier Reef) to non-reefal (Persian/Arabian Gulf) coral-dominated systems to illustrate how the generation of morphological structure is controlled by life processes such as reproduction, growth, and predation. Present-day climate change is poised to disadvantage corals by increasing disturbance frequency, causing increased rarity of corals or, at the very least, changes in community structure. This has the potential of changing their sedimentological and geomorphological signature. Changes in the contribution of different growthforms will influence the structure of frameworks, depressed coral populations may even result in a transition from frameworks to coral rudstones to floatstones and the morphology of the sedimentary body may in the end no longer be biotically controlled. Models and field-results are used to illustrate trajectories.

\*\*\*\*\*

### **Holocene growth of King Reef - the largest mainland fringing reef on Great Barrier Reef, Australia**

*SMITHERS S.(1), PERRY C.(2), ROCHE R.(3)*

*(1) James Cook University, TOWNSVILLE, AUSTRALIA ; (2) College of Life and Environmental Sciences University of Exeter, EXETER, UNITED KINGDOM ; (3) School of Ocean Sciences, Bangor University, BANGOR, UNITED KINGDOM*

The Great Barrier Reef is the world's largest reef system, containing more than 2900 named reefs, approximately one third of which are classified as fringing reefs (incipient and proper). The great majority of these fringing reefs are attached to high islands located in the GBR lagoon, with relatively few adjoining the mainland coast. Sediment and freshwater discharge from coastal catchments have been implicated as factors responsible for this paucity, impeding coral and fringing reef growth along large sections of the coast, including a stretch extending over almost 300 km between the northern Whitsundays and King Reef (17°46'50"S; 146°07'43"E) where fringing reefs are absent. Limited availability of hard rocky headlands to provide appropriate substrate for coral recruitment has also been suggested as a major constraint, with mainland fringing reefs most common on the Whitsunday coast between Cape Conway and Gloucester Island, where strong geological control has produced deep embayments confined by steep headlands. Covering an area of 8 km<sup>2</sup>, King Reef is the largest mainland attached reef on the GBR. It is located adjacent to the Wet Tropics where proximal rivers seasonally deliver significant quantities of sediment and water to the coast. Here we report on research aimed at establishing the Holocene evolution of King Reef based on 14 cores from 2 transects and involving 26 AMS radiocarbon dates. Chrono-stratigraphic investigations indicate that King Reef initiated in shallow water over a surprising variety of substrates between 5800 and 5400 cal years BP and was substantially in place by around 400 cal years BP. Although a reasonably healthy reef community exists at the seaward fringe of King Reef today, reef structure has essentially ceased to increase in size over the past few thousand years. In this paper we discuss how the initiation substrates, age and structure of King Reef may challenge common views of reef distribution and growth.

### **Discovery of submerged karst terrain in modern reef area by broadband multibeam bathymetric survey in the southern Ryukyu Islands, Japan**

KAN H.(1), URATA K.(2), NAGAO M.(3), HORI N.(4), OHASHI T.(1), NAKASHIMA Y.(5), GOTO K.(6), YOKOYAMA Y.(7), SUZUKI A.(3)

(1) Okayama University, OKAYAMA, JAPAN ; (2) Osaka University of Economics and Law, OSAKA, JAPAN ; (3) National Institute of Advanced Industrial Science and Technology (AIST), TSUKUBA, JAPAN ; (4) Nara University, NARA, JAPAN ; (5) Ariake National College of Technology, Omuta, JAPAN ; (6) Tohoku University, SENDAI, JAPAN ; (7) University of Tokyo (AORI), KASHIWA, JAPAN

The extensive development of various types of karst was founded under the modern reef environment in the southern Ryukyu Islands. We conducted a broadband multibeam survey at the central area of Nagura Bay, Ishigaki Island in August 2011. The minimum/maximum depth was 1.6/58.5m in the measured area of 1.85 x 2.7 km. The sounding results were visualized at a lateral grid resolution of 1m.

The observed submarine topography showed the numerous closed contours which is recognized as karst, the topography formed by groundwater flow. The following five karst types were recognized in the surveyed area: 1) doline karst, 2) compound doline (uvala) or mega-doline, 3) cockpit karst, 4) polygonal karst, 5) fluviokarst. These types may reflect the difference of karstification process and stage. SCUBA diving observations suggested the Holocene reef and reef sediments are accumulated on the submerged karst to form "cover karst" in Nagura Bay. The small-scale karst landform such as karren may be buried during the reef sedimentation.

By comparing with the sounding results observed from other reef areas around Ishigaki Island, the shape and size of topographic relief was different between submerged karst and coral reef. The reef environment established on the submerged karst was also unique from other fringing reefs and a barrier reef around Ishigaki Island because of the difference in topographic relief, water movement, sedimentary condition and presumably freshwater influence.

\*\*\*\*\*

### **Calcium carbonate budget of a Maldivian reef platform**

MORGAN K., KENCH P.

The University of Auckland, AUCKLAND, NEW ZEALAND

Coral reefs represent the end product of a suite of constructive and destructive ecological processes. Such processes occur at an individual organism scale; however, the collective balance between them dictates the abundance and distribution of reef organisms, net rates of reef accretion and the generation of detrital sediments for entire reef systems. A calcium carbonate budget provides a conceptual framework for quantifying the contribution of different calcareous organisms in the reef-building potential of an individual reef. This study uses a census-based method to estimate rates of gross carbonate production and biological erosion for Vabbinfaru reef platform, North Malè Atoll, Maldives. The study aims to generate new field-based datasets for the central Indian Ocean region and to extend the geographic range of existing budget studies. Gross carbonate production of primary (hermatypic corals) and secondary (encrusting organisms) producers were determined by estimating the benthic cover and abundance of reef organisms, coupled with *in situ* rates of skeletal calcification. Site-specific rates at which organisms (parrotfish, urchins and boring organisms) erode the reef framework were then quantified and subtracted from gross production values to generate an annual rate of net carbonate production ( $\text{kg m}^{-2} \text{y}^{-1}$ ). Results from Vabbinfaru are compared to existing budget studies for other reef-building provinces and the implications of the findings are discussed in relation to the ecological state and the geomorphic development of the reef.

## Hydrodynamic process controls on reef platform sedimentation and island formation

MANDLIER P., KENCH P.

*The University of Auckland, AUCKLAND, NEW ZEALAND*

Coral reef islands are accumulations of unconsolidated sand and gravel deposited on reef platform surfaces by ocean waves and currents. The morphological characteristics and stability of islands is controlled by hydrodynamic processes operating on reef surfaces which in turn are largely defined by the interactions of waves with the underlying platform structure. Reef shape and orientation to incident waves are crucial parameters controlling refraction and convergence processes and hence the potential for sediment accumulation and island formation. Platform geometries which promote marked wave refraction and centripetal wave motion are likely to retain sediment on the reef surface and accumulate a sandy cay. In contrast, reef configurations which impede wave convergence exhibit a higher potential for the off-reef evacuation of reef flat sediments and the formation of subtidal leeward sand aprons. This study presents results of wave measurements, bathymetric surveys and analysis of sediments collected from multiple lagoonal patch reefs in the Maldives which corroborate such projections and provide field evidence for a geomorphic model of reef sedimentation and island formation. Analysis of wave and current data demonstrates that platforms exhibit distinctive hydrodynamic process signatures, related to reef configuration, which control the dispersal and characteristics of sediment on the reef flat. Sediment collected from windward interference zones of elliptical reefs exhibit a coarser texture and faster settling properties than surface samples obtained from leeward reef regions and island beaches. Such spatial variations in sediment texture are attributed to across reef wave energy gradients which control the potential to entrain and transfer material of different size and shape. Results validate theoretical projections of hydrodynamic process controls on platform sedimentation and have significant implications for the morphological development of reef flat deposits.

\*\*\*\*\*

## Infill of Faro Lagoons: Size Thresholds and Controls on Island Formation in the Maldives

KENCH P.(1), PERRY C.(2), SMITHERS S.(3), YAMANO H.(4), O'LEARY M.(5)

*(1) The University of Auckland, AUCKLAND, NEW ZEALAND ; (2) University of Exeter, EXETER, UNITED KINGDOM ; (3) James Cook University, TOWNSVILLE, AUSTRALIA ; (4) National Institute for Environmental Studies, TSUKUBA, JAPAN ; (5) Curtin University, PERTH, AUSTRALIA*

Faro are annular-shaped reefs that impound lagoons, located within the larger lagoon basin of atolls and are conspicuous yet enigmatic features of Maldivian reef systems. While more than 1,000 faro occur in the Maldives, in varying stages of infill with some remaining largely empty while others are completely filled and capped by islands, the formation and Holocene development of these features remain unresolved. However, faro infill in the late Holocene has been implicated as critical for development of islands within atoll lagoons in the Maldives. Little is known of the rates of infill and timing of infill of faro that may support island formation. Clearly resolution of the timing of faro infill and onset of island building is critical for an improved understanding of the controls on island development and future island building potential. We present a dataset of the latter stages of faro infill and island formation from 7 lagoonal reef platforms in South Maalhosmadulu atoll, Maldives, based on morphostratigraphic analysis of 45 cores. A chronological framework of faro infill and island development is constructed from 90 radiometric dates. Results show a consistent multi-phase sedimentary infill sequence in each faro that terminates in *Halimeda*-rich sediments. Results also identify three apparent size thresholds of morphological development of faro, which have distinct chronological signatures and are related to island building potential. First, platforms <0.5 km<sup>2</sup> are typically filled by 5,500 years BP and have supported island accumulation between 5,000 and 3,500 years BP. Second, platforms 0.5-1.25 km<sup>2</sup> are in the final stages of infill and have ephemeral unvegetated sand cays. These platforms may provide opportunities for further island accumulation under suitable sediment supply regimes. Third, platforms >1.25 km<sup>2</sup> have not filled and given the dimensions of these faro, they are unlikely to fill over the next millennia.

### **Morphological response of reef island on rocas atoll (South Atlantic Ocean) to Seasonal energetic wave conditions**

COSTA M.(1), MACEDO E.(2), SIEGLE E.(1)

(1) Universidade de Sao Paulo, SAO PAULO, BRAZIL ; (2) Instituto Chico Mendes de Conservação da Biodiversidade, FERNANDO DE NORONHA, BRAZIL

Reef islands on Rocas Atoll, the only atoll in the South Atlantic Ocean, are located at its leeward side, being protected from waves most part of the year but subjected to the impact of energetic swells from the north from November to February. With the aim of assessing the morphological evolution related to the incoming waves, in situ measurements were conducted in November 2012, covering a series of energetic wave conditions. Waves were measured by an ADCP (Nortek Aquadopp profiler) deployed at 1.2 km distance from the reef island and 0.9 km from the reef rim during 28 days. Simultaneously, the morphology of the entire reef island was surveyed with the use of a Differential Global Positioning System (DGPS). High energy waves with peak periods of about 13 s and significant wave heights of 2 m presented a weekly recurrence followed by a gradual decay. Morphological surveys show that the northwestern side of the island, which has been historically eroded, undergoes larger morphological changes. However, in contrast, there was an increase in volume on the beach island. The tridimensional terrain elevation models clearly show the removal of submerged banks dispersed on the reef rim and their deposition over the beach. This is thought to be due to the intense wave set-up generated by waves breaking on the leeward reef edge, moving the sediments in the opposite direction to that of the overall gravity-driven outflow. The results suggest that the sediment redistribution by seasonal northern swells contribute to sediment accretion on the reef island, thereby reducing the long-term erosion of this portion of the island.

\*\*\*\*\*

### **A sediment budget for Lizard Island, northern Great Barrier Reef**

JAVIER L.(1), WOODROFFE C.(2), PHINN S.(1), HAMYLTON S.(2)

(1) The University of Queensland, ST. LUCIA, AUSTRALIA ; (2) The University of Wollongong, WOLLONGONG, AUSTRALIA

The gloomy long-term prospect for coral reefs and associated landforms could be attributed to the fact that many of these reef systems, particularly fringing reefs, have experienced little to no growth since the early Holocene and now face multiple and interacting pressures arising from the 'super wicked problem' of global climate change. However, current understanding of the feedbacks between ecosystems and landform evolution in a changing climate context is very limited. The study of sediment generation and transport within reef systems is fundamental for understanding processes acting upon reef systems at temporal scales ranging from ecological processes to the evolution of associated landforms. However, there are significant gaps in the scientific understanding of sediment dynamics within coral reef systems. The calculation of a sediment budget by determining volumetric rates of sediment generation, transport and loss is an approach that may enable some reconciliation of the behaviour of a coral reef system at different time scales. In this paper we apply this approach to Lizard Island, a small fringing reef system in the northern Great Barrier Reef (GBR). Lizard Island is unique in the GBR as siliciclastic and carbonate sediments are being co-deposited in close proximity. In addition, the reef system has been isolated from large-scale human activities, providing a great opportunity to investigate sediment dynamics. The aim of this study is to compare the historical and contemporary sediment budgets of the mixed siliciclastic-carbonate coastal system in Lizard Island. The catchment evolution model SIBERIA was used to calculate the rate of sediment production on the island. Carbonate production was upscaled using benthic cover maps and published production rates. The resultant sediment budget was used to better understand the processes driving the geomorphic evolution of this system and provided insights into potential changes under future climate scenarios.

## **Atoll Island Geomorphology and Stability: Nukulaelae Atoll, Tuvalu, Central Pacific**

MCLEAN R.

*University of New South Wales-Canberra, CANBERRA ACT, AUSTRALIA*

Nukulaelae is an elongate oval shaped atoll aligned NW-SE, 11 km and 3.3 km wide at it narrowest. It is the smallest atoll in Tuvalu. Nukulaelae has a continuous rim with no passages from ocean to lagoon; the reef rim is typically 400 m wide along the eastern and western sides and 600 m at the northern and southern ends. Twenty separate islets occupy a total of 18% of the reef flat rim (1190 ha). On the eastern side are two narrow islets both about 5 km long and 150 m wide. The remaining islets on the north and south are compact, of various shapes, sizes, are oriented orthogonal to the reef and are located on lagoon side of the reef flat. There are no islets on the western side of the atoll.

Twelve cross-islet profiles were surveyed on the five largest islets. Four main landform units were distinguished: (1) ocean-side ridge complex comprising the highest ridge (s) commonly of coral rubble; (2) lagoon-side berm complex is lower, backslope gentler and sediment sand-sized with foraminifera an important component; (3) central depression occupies the low area between ocean ridge(s) and lagoon berm (s); and, (4) pulaka pit-spoil bank complex comprises excavated depressions (pits) and surrounding ridges (spoil banks). These anthropogenic landforms have the highest relative relief on Nukulaelae.

Around the islets shorelines consist of reef derived sand and gravel and consolidated rock platforms. Unconsolidated shores display erosional features and accretional deposits. Minimal changes in islet shorelines have occurred during the last 30 years. All islands present in 1976 exist today. The plan outline and surface topography of the mainislet, Fangaua, in the northwest, is similar to that surveyed in 1897, during the Royal Society's Expedition to Funafuti atoll, 130 km north of Nukulaelae. The location of islands and their plan form and morphology are described and long-term stability discussed.

\*\*\*\*\*

## **Poster presentations:**

### **Quantifying the impacts of regional scale reef ecosystem decline on the geomorphic performance and growth potential of Caribbean coral reefs**

PERRY C.(1), MURPHY G.(1), KENCH P.(2), SMITHERS S.(3), EDINGER E.(4), STENECK R.(5), MUMBY P.(6)

*(1) University of Exeter, EXETER, UNITED KINGDOM ; (2) Univeristy of Auckland, AUCKLAND, NEW ZEALAND ; (3) James Cook University, TOWNSVILLE, AUSTRALIA ; (4) Memorial University, ST JOHNS, CANADA ; (5) University of Maine, MAINE, UNITED STATES ; (6) University of Queensland, BRISBANE, AUSTRALIA*

Global-scale deteriorations in coral reef health have caused major shifts in species composition and are likely to be exacerbated by climate change. It has been suggested that one effect of these observed and projected ecological changes will be lower carbonate production rates on coral reefs, which will impair reef growth potential, compromise their ecosystem functions, and ultimately lead to states of net reef erosion. However, quantitative data to support such assertions are limited, and linkages between the ecological state of reefs and their past and present geomorphic performance (in other words their growth potential) are unresolved. Here we show that ecological change across the Caribbean has suppressed carbonate production rates and significantly slowed coral reef accretion. Using measures of gross and net carbonate production and erosion from 19 Caribbean reefs, we show that contemporary carbonate production rates are now substantially below those calculated for pre-disturbance and 'healthy' Caribbean reefs. On average, current production rates are less than 50% of pre-disturbance rates, and 37% of surveyed sites were net erosional. Calculated accretion rates ( $\text{mm yr}^{-1}$ ) are also an order of magnitude lower within shallow water habitats compared to Holocene averages. A live coral cover threshold of around 10% is identified that is critical to maintaining positive production states. Below this ecological threshold many carbonate budgets become net negative and reef accretion stalls. Collectively, these data suggest that recent ecological declines are now propagating through the system to impact on the geomorphic performance of Caribbean reefs and will impair their future growth potential. Caribbean reefs thus have vastly reduced capacity to keep up with rising sea levels, and those ecosystem functions most dependent on reef structures are imminently threatened.

**Precise timing and elevation of the mid-Holocene highstand at Belitung Island, Indonesia, on the Sunda Shelf, from coral microatolls**

SWITZER A.(1), MELTZNER A.J.(1), WU C.C.(2), CHIANG H.W.(1), SHEN C.C.(2), GONG S.Y.(3), SUWARGADI B.W.(4), NATAWIDJAJA D.H.(4), HORTON B.P.(5)

(1) Earth Observatory of Singapore, SINGAPORE, SINGAPORE ; (2) Department of Geosciences, National Taiwan University, TAIPEI, TAIWAN ; (3) Department of Geology, National Museum of Natural Science, TAICHUNG, TAIWAN ; (4) Research Center for Geotechnology, Indonesian Institute of Sciences, BANDUNG, INDONESIA ; (5) Department of Earth and Environmental Science, University of Pennsylvania, PHILADELPHIA, UNITED STATES

The largest relative sea-level (RSL) signal is found in once glaciated (near-field) regions where ice loading produced considerable deformation of the Earth. At increasing distance from the centers of major glaciation, the ice-induced component of the signal diminishes and the eustatic (or meltwater) signal becomes dominant. At tectonically stable far-field locations, such as the Sunda Shelf, the RSL signal is commonly characterized by a mid-Holocene sea-level maximum, or highstand, at the time meltwater production decreased. The fall in RSL from this time to the present is a result of ongoing glacial isostatic adjustment (GIA) processes, including hydroisostatic loading (continental levering). Despite advances in understanding sea-level history in the far field, research near the Sunda Shelf has lagged, and the magnitude and timing of the mid-Holocene highstand in this region remain unresolved.

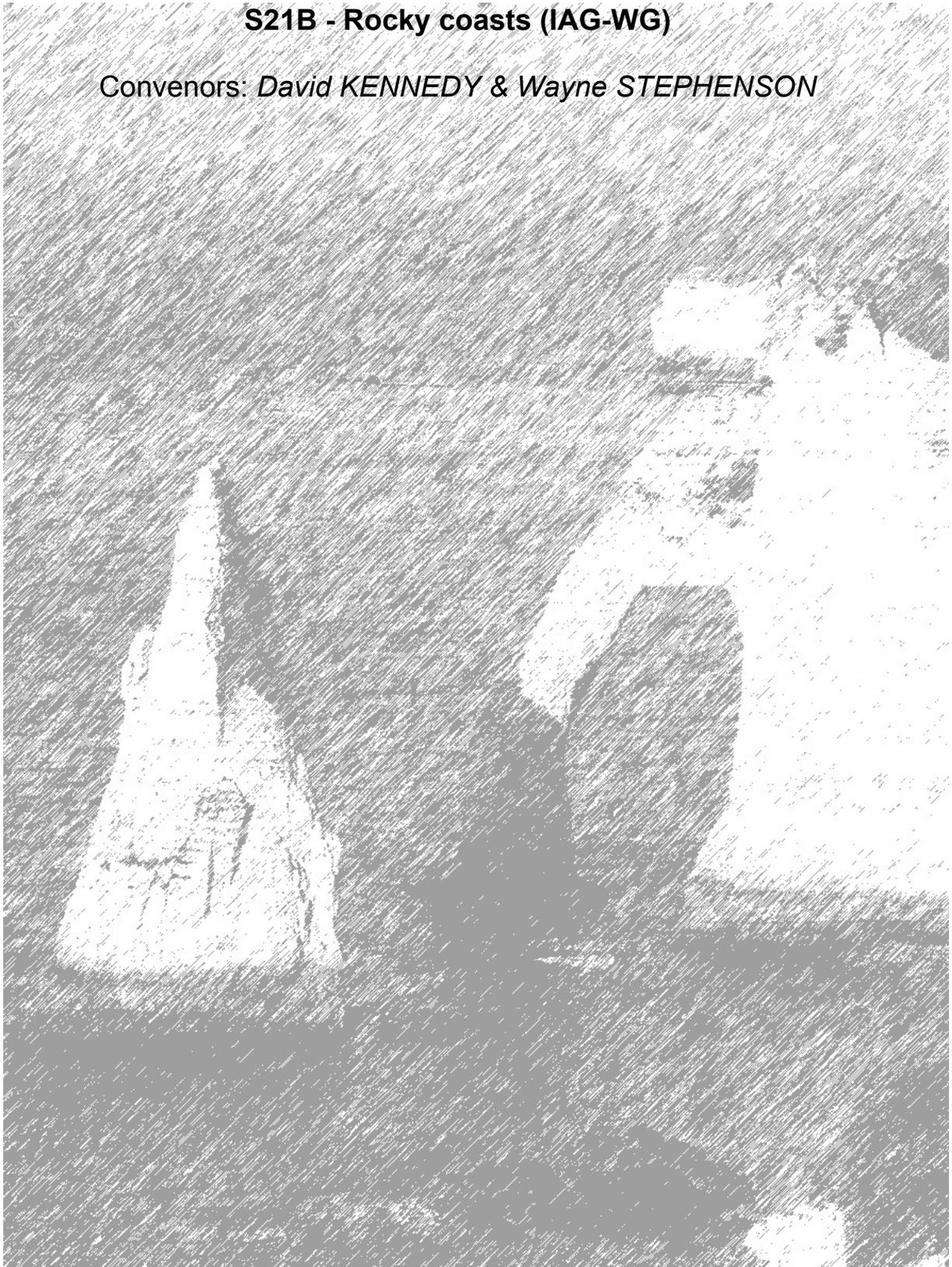
We present a preliminary mid-Holocene sea-level record from Belitung Island, Indonesia, on the Sunda Shelf, based primarily on coral microatolls. Microatolls' upward growth is limited by aerial exposure and hence they track low water to within a few cm, providing a high resolution record of former sea level. We slabbed 16 microatolls (each yielding a series of sea-level index points) and slabbed or cored 14 additional coral heads (each yielding a minimum sea-level marker). Preliminary U-Th and 14C dates suggest sea level rose rapidly to a highstand of +1.8 m at ~6.9 ka and then fell more gradually; we are working to determine appropriate initial  $^{230}\text{Th}/^{232}\text{Th}$  ratios for the U-Th age calculation and appropriate  $\Delta R$  corrections for 14C dating.

Although the basic form of our sea-level record is comparable to state-of-the-art GIA models, important differences emerge regarding both the timing and amplitude of the mid-Holocene highstand and the fall in RSL to present. Our data will be critical to calibrating GIA models and will allow for an improved understanding of eustatic history.

\*\*\*\*\*

**S21B - Rocky coasts (IAG-WG)**

Convenors: *David KENNEDY & Wayne STEPHENSON*





## **Oral presentations:**

### **The influence of inter-tidal shore platforms on soft cliff recession rates and headland formation on the southwest coast of the Isle of Wight**

*STUIVER C., NICHOLLS R.J., RICHARDS D., BARTON M.*  
*University of Southampton, SOUTHAMPTON, UNITED KINGDOM*

Management of soft cliff recession is one of the major global challenges of the 21st Century. Due to the high cost of coastal defences and the conservation and amenity value placed on natural coastlines, managed retreat is expected to become increasingly common in the future. To accurately predict future rates and patterns of erosion required for managed retreat it is important to understand the factors controlling recession.

On the open coast it is the exposure of the cliff toe combined with its strength that is critical in controlling recession rates. Exposure of the cliff toe is in turn controlled by the presence and character of a beach and/or shore platform. Variations in the exposure of the cliff toe alongshore can result in the formation of subtle headlands. This study on the southwest coast of the Isle of Wight considers the geological and geotechnical properties of the cliff and platform, the beach morphology and sediment budget and the refraction of wave energy along the coast, as controls on headland formation. The shallow dip of the geology and stratigraphic variation means that the lithology of the cliff is not always reflected in the platform. This shows platform lithology is the dominant control over headland formation and evolution. Characterisation of the platform lithology and geotechnical strength is a major focus of this study; to determine the factors which lead to the creation and maintenance of an intertidal platform in one lithology but not another.

This study highlights the importance of considering the detailed variations in geology when investigating cliff recession on sediment starved coastlines. For example one headland within the study area owes its existence to a shore platform created by two beds no more than 1m thick. Furthermore, changes in geological exposure with continued retreat or changes in the lithology outcropping in the intertidal zone with sea level rise can influence the subsequent coastal evolution.

\*\*\*\*\*

### **Alongshore variations in hard rock coastal cliff erosion**

*NORMAN E., ROSSER N., BRAIN M., PETLEY D., WAUGH S.*  
*Durham University, DURHAM, UNITED KINGDOM*

Characterising the degree to which the platform geometry of hard rock coastlines reflects the distribution and variability of erosive intensity is key for understanding likely future coastline change. However, understanding of the controls and patterns of erosion along rocky coastlines is limited as few studies have focussed on hard rock cliffs. Apparently slow responses to environmental forcing, difficulties in capturing the rate of erosion and the multitude of forcing variables over a variety of spatial and temporal scales have limited the characterisation of cliff change and the dominant controls at the kilometre scale. Terrestrial laser scanning (TLS) has overcome many of these limitations, and is used here to enable continuous monitoring coverage at a high spatial resolution along 3 km of crenulous coastline.

We use TLS to explore the spatial development of cliff face erosion along a 3 km stretch of near vertical rock cliffs along the North York Moors National Park coast, UK. The cliffs are approximately 70 m high, consisting of near-horizontally bedded layers of Jurassic mudstones (at the cliff toe), shales, siltstones and sandstones. Data is presented from one year captured at monthly intervals, from which erosion is compared to the platform geometry of the coast obtained from airborne LiDAR. We explore variability in erosion depths, rockfall magnitudes and frequencies, and the vertical distribution of rockfall up-cliff. We test the effects of varying cliff-line concavity, convexity and aspect with respect to incoming marine and subaerial processes and rock mass structure. In future this data will be used to inform a model of coastline retreat that includes a platform component.

## **Pluri-decadal evolution of cretaceous coastal cliffs along the eastern English Channel in Upper-Normandy (NW France), as evidenced by aerial photographs and Lidar**

ELINEAU S.(1), DUPERRET A.(2), MERRIEN-SOUKATCHOFF V.(3)

(1) UMR 6294 CNRS LOMC, Université du Havre, Laboratoire Ondes et Milieux Complexes, 53 rue de Prony BP540, LE HAVRE, FRANCE ; (2) UMR 6538 CNRS Domaines Océaniques, Institut Universitaire Européen de la Mer, place Nicolas Copernic, PLOUZANE, FRANCE ; (3) UMR Géoressource, Ecole des Mines de Nancy, Université de Lorraine, Parc de Saurupt, CS 14234, NANCY, FRANCE

The Upper-Normandy coastline is made of high (95m) coastal cliffs cut in sedimentary rocks. Successive, transverse-oriented to the coast, topographic cross-sections spaced 500 m apart were extracted from high-resolution LiDAR aerial surveys performed in 2006, 2008 and 2011 north of Le Havre town, between the La Hève and Antifer capes. They show three main slope breaks, that have been mapped, using georeferenced aerial photographs (taken in 1939 and 1985) and orthophotographs (2008 and 2011).

Mapping shows that the cliff toe has a general accretion with a progressive increase to the north. Four spatial sectors can be defined from the La Hève Cape to the north with respective accretions (1) up to 0.50 m/year on a distance of 1 km, (2) a mean of 0.40 m/year on 2 km, (3) 1 m/year on 5 km and (4) 2 m/year on 3.5 km with local peaks at 2.7 m/year.

In parallel, the mid-slope break and the top cliff show deformations associated with a rotational sliding of the entire cliff. Such gravitational deformation has been confirmed by 2D Finite Elements models of the cliff. Nevertheless, the cliff toe evolution is four times more important than the mid-slope break and the cliff top evolutions. This could be related to the Antifer harbor amenities built in 1973 at north of the studied area which favors sedimentary accumulation guided by a littoral drift.

The total volume of the slope wedge is around 38 millions of m<sup>3</sup> on 16.5 km of coastline length. Some sedimentary lobes of the slope wedge, reaching the actual sea level (corresponding to 5% of the study coastline length), are eroded by the sea during high spring tides.

We have tested the potential effect of a sea-level rise on the coastal slope instability. A potential surge of 2 m is already observed at Le Havre. If the surge (due to a tempest) is concomitant with a spring high tide, this may amplify the erosion of the wedge toe and extends the contact between the sea and the land from 5% to 65% of the studied coastline.

\*\*\*\*\*

## **Fall of coastal chalk cliffs in Upper Normandy: Towards the determination of triggering factors**

LETORTU P.(1), COSTA S.(1), CADOR J.M.(1), CANTAT O.(1), MAQUAIRE O.(1), BONNET E.(2)

(1) UMR LETG-Caen GEOPHEN, CAEN, FRANCE ; (2) UMR IDEES-Caen, CAEN, FRANCE

Coastal chalk cliffs in Upper Normandy have often been studied in terms of retreat rate. However, few studies have been done on factors and processes leading to fall. It is admitted that coastal cliffs are sensitive to sub-aerial weathering factors (rainfall, temperatures) and to sea action that may be summed up to the evacuation of fallen debris leading to a new instability.

The aim of this work is to attempt to make a distinction between sub-aerial weathering and marine agents in the trigger of fall from these coastal cliffs with shore platform, composed of Upper Cretaceous chalk.

A weekly inventory of 331 falls (from 1 m<sup>3</sup> to 238 000 m<sup>3</sup>) that occurred along a 37.5 km long coast (between Veules-les-Roses and Le Tréport) during the 2002-2009 period was analyzed. Statistical analyses were used in order to attempt to relate these fallen debris to meteorological and marine parameters that could be potentially responsible for the trigger of fall.

Our results highlighted:

- 1) A spatial polarization of scree phenomena or mass movements at Cap d'Ailly (favorable lithostratigraphic context),
- 2) Falls occurred all year long with a predominance during winter for massive falls (followed by autumn, spring and summer),
- 3) Most massive falls seemed preferentially triggered by heavy rainfall, and freeze/thaw cycles seemed responsible for scree production phenomena (individual particles),
- 4) Marine factors were not negligible but their influence is always difficult to quantify as falls of small volumes may quickly be removed during a turbulent period,
- 5) The fitting of falls samples to power law provided frequencies and return periods of events, useful for predictive purposes. A strong spatial variability due to lithological characteristics of chalk outcrops was noticed.

Despite this important inventory, some difficulties remained in quantifying the proportion of marine and sub-aerial weathering processes (problems of combination or relay of processes and probably hysteresis phenomena).

### **Analyzing the spatial structure of sea cliff instabilities through repeated high resolution terrestrial laser scanning surveys and point processes statistics**

ROHMER J., DEWEZ T.

*BRGM, ORLEANS, FRANCE*

On rocky coasts, slope failures are spatially discontinuous and temporally intermittent. Many studies have addressed frequency-size statistics by means of collapse scar inventories, but only a few have addressed their spatial distribution. Yet, spatial patterns carry information about the external processes and the predisposing factors underlying sea-cliff retreat.

Over the last decade, terrestrial laser scanning (TLS) has enabled high accuracy surveys of collapse sizes and locations, which opens the way for addressing sea-cliff instabilities within the theoretical statistical background of "spatial point process".

We use an inventory of >8500 sea cliff failures collated from 6 repeated TLS surveys over 2.5yr along a coastal chalk cliff in Normandy (France). We first show, through the analysis of residuals, that the spatial process underlying the occurrence of instabilities is inhomogeneous, which means that the spatial density (number of events per unit area) spatially varies along the coastline and along the cliff height.

Based on the computation of the inhomogeneous second-order spatial characteristics (e.g., Ripley's K- function) and Monte-Carlo tests, we highlight several trends:

1. Small instabilities (volume  $<10^{-2} \text{ m}^3$ ) cluster in patches over a spatial radius of less than 5-10m, and disperse above this distance;
2. Larger instabilities present a regular spatial pattern whatever the distance between events;
3. Assuming that a unique process both generates small and large instabilities, we show that the probability of occurrence of a given event, whether "small" or "large", is not influenced by its neighbourhoods;
4. Conversely, assuming that two distinct processes generate small and large events, we show that they are not independent (for a given epoch);
5. The occurrence of small instabilities seems not to be influenced by past events, but a temporal dependence may exist for larger instabilities.

\*\*\*\*\*

### **A new approach to coastal cliff landslide hazard assessment**

DICKSON M.

*University of Auckland, AUCKLAND, NEW ZEALAND*

Worldwide coastal cliff-top land is highly prized for residential building sites. However, cliff erosion rates are accelerating under sea level rise and arresting erosion is both extremely expensive and temporary. In Auckland, New Zealand, urban development has proceeded at a rate nearly double the national average, and much of this has occurred atop cliffs made of weak sedimentary rock. Hazard planning in New Zealand has historically used heuristic models that yield a setback zone of restricted development. Such models have little predictive power and do not account for spatial variability in erosion rates. However, spatial variability is important: many sedimentary cliffs have slow 'background' erosion rates, whereas sudden episodic failure can remove several metres of cliff top in a single event. In this paper we take a different approach to the coastal landsliding problem. The first phase of work involved extensive mapping (field, air photos and LiDAR) along 45 km of coast. Landslide locations were identified and failure characteristics and geological attributes of the cliff were mapped. In tandem, mapping was also conducted on a regular grid at locations without failure, resulting in a large database of failed and unfailed sites, fault locations and other environment characteristics. A machine-learning method was used to identify the key characteristics of sites that had experienced landsliding over the period covered in our database. Three predictors were found to account for more than 80% of the relative influence. A resampling method was used to build probabilistic estimates of landslide likelihood at each sample point, which were then interpolated to produce region-wide maps showing landsliding susceptibility as well as the uncertainty in estimates at each location. The approach was cost-effective compared to previous hazard zone work, and provides a basis for a different type of hazard zonation on cliffed coasts subject to episodic failure.

## **Application of GNU Octave tools to analyse the shape of a rocky shoreline - an example from Hornsund area (SW Spitsbergen, Svalbard)**

SWIRAD Z.(1), REES W.G.(2)

(1) University of Wrocław, WROCLAW, POLAND ; (2) Scott Polar Research Institute, CAMBRIDGE, UNITED KINGDOM

In order to assess spatial differentiation in the shape of a shoreline objectively, it is crucial to accurately measure geomorphometric parameters of the coastline. GNU Octave free software can be helpful in geometrical calculations of the shoreline.

The shoreline is presented as a set of vectorized points along its course. Vectorization was performed on the orthophotomap. The length of the shoreline is the sum of sections between all the points. Having divided the result by the number of points, the average distance between two points is returned and reasonable distance for interpolation may be chosen. The shoreline is consequently divided into equal sections.

Headlands are defined as the points at which the angle between two consecutive vectors is bigger than at next four points on either side of them. After headlands are defined, orientation, width, depth and mean depth of embayments (areas between each pair of headlands) may be calculated.

The method has been applied to the 17 km long stretch of coastline of Hornsund, south-west Spitsbergen, located on the border of the fiord and open sea. The fragment of the coast is composed by metamorphic rocks: amphibolites, quartzites, schists, marbles and paragneisses.

GNU Octave proposed 16 headlands which were the basis of the analysis focused on intervening embayments. The analysis shows that the deepest embayments face west and south-west (towards open sea), but they also occur in places where structure and lithology are complex. Paragneisses support wide but shallow embayments, whereas most headlands are formed of quartzites. Further within the fiord embayments are carved in the series of schists and marbles and these are deep but narrow.

Since it is reasonable to assume that the shape of an embayment reflects both wave energy and structural control, further analysis will be aimed at identification of controlling factors and their relative influence on the shape of the north Hornsund coastline.

\*\*\*\*\*

## **A feedback model relates rocky coast erosion to percolation theory, a new perspective on the statistics of erosion events**

SAPOVAL B.(1), BALDASSARRI A.(2)

(1) Ecole Polytechnique-CNRS, PALAISEAU, FRANCE ; (2) Institute for Complex Systems-La Sapienza, ROMA, ITALY

Rocky coasts represents around 75% of the world's shorelines (R. A. Davis, Jr, D. M. Fitzgerald, *Beaches and Coasts*, Blackwell, Oxford 2004) and their dynamics is erratic, featuring numerous small and sometimes dramatic events. We discuss various situations where the coast shape can possibly be attributed to the feedback of the coast morphology on the erosive power. As erosion can spontaneously create irregular seashores, the geometrical irregularity in turn participates to the damping of sea-waves, decreasing the average erosive power. There may then exist a self-stabilization of the coast morphology.

A simple numerical implementation of such stabilization leads, through a complex avalanche dynamics, to the appearance of an irregular sea-shore. The coast shape depends on the coupling between morphology and damping and on spatial correlations in the rocks lithologic properties. When the distributions of the lithologies exhibit long range spatial correlations, a variety of morphologies are obtained mimicking observed coastline complexity. When rock lithologies are uncorrelated and for weak coupling, the process builds fractal sea-coasts with a dimension equal to  $4/3$ , characteristic of percolation interfaces (B. Sapoval, A. Baldassarri, A. Gabrielli, *Self-stabilized Fractality of Sea-coasts through Erosion*, *Phys. Rev. Lett.* 93, 098501 (2004)).

On the other hand, the statistics of erosion events display long tail distributions that does not enter the category of Gaussian process, but rather that of critical systems. Our model provides a natural frame to explain these statistics. From a practical point of view, the analogy with percolation interfaces means that the coast constitutes a strong, but simultaneously locally fragile barrier. Accordingly, natural or human degradation of the rocks properties can trigger random and large erosion events, difficult to predict and control. In that sense, natural coasts should be "preserved" and managed with care.

### **Set up and evolution of cliff-top storm deposits on the western coast of Banneg island in the Molène archipelago, Brittany, France**

FICHAUT B., SUANEZ S.

*Université de Bretagne Occidentale, PLOUZANÉ, FRANCE*

More than 1000 m<sup>3</sup> of loose blocks quarried from the cliff face and top lie at the rear of the top of the western cliffs of Banneg island. These cliff-top storm deposits can locally form a spread of isolated blocks, however they more often form clusters or ridges at altitudes between 7 and 14 m above sea level and up to 75 m from the edge of the cliff. Locally these ridges are deposited in several parallel lines, up to three in the central part of the island. In the past twenty years these deposits have been drastically re-worked and new blocks have been quarried from the cliffs during two storms in december 1989 and march 2008. Four methods were used to analyze the changes that occurred during these events. Analysis of the hydrodynamic conditions and of the extreme water levels, census of the fresh sockets of quarrying in the bedrock, measurement of blocks displacement and time-series analysis of ground photographs were conducted. They enabled to determine that most of the clasts come from the cliff-top and the wave scoured platform immediately on the rear. They also show that where parallel ridges exist, the ones standing right next to the cliff edge have been hardly reworked whereas on the ones lying inland considerable changes occurred. Therefore it is possible to propose a spatio-temporal model of clusters formation and to explain the occurring of parallel ridges. The most seaward ridges are erected first. Concomitant erosion and lowering of the cliff-top enable waves to become airborne and to throw clasts above the front ridge, eventually without reworking it. These blocks form a second ridge inland and eventually a third one possibly linked to the rebound of the mass of water coming from the largest waves.

\*\*\*\*\*

### **Geomorphic hazard along southern Abruzzo coast (central Italy)**

MARINO A., CIUCCI M.

*INAIL/DIPIA, ROMA, ITALY*

The area object of this research is the coastal are between Ortona and Vasto (southern Abruzzo) where are located several coastal cliffs. The main reason for this choice is constituted by the significant typological variability of existing processes. The most part of the coast is actually affected by landslides not necessarily coincident with active cliffs.

The results obtained from stability analysis and the assessment of retrogradation rates allowed to underline same basic features in morpho-evolutive process of cliffs in the studied area.

In studied cliffs kinematics resulted significant following factors:

Morpho-evolutive stage: in active cliffs erosive processes at the bottom imply steep slopes where instability events mostly develop as toppling or translational slipping along new sub-vertical surfaces; affected volumes are relatively small but the event can be in principle characterised by high frequency.

Waves: further than directly induced erosive processes, results to be significant the wave pressure on cliffs; this tends to modify failure kinematics, causing translational slipping on sub-vertical surfaces, and reducing, at the same time available strength.

Litho-structural features: the kind of kinematics at failure result to be strictly depending both on directly interested by waves lithotype, and on stratigraphic position of different lithotypes related to sea level. Indeed translational plane kinematics appear to be prevailing when stronger lithologies are affected. Whereas rotational kinematics characterise cliffs where clay outcrops at, or just beneath, sea level. In these conditions unstable volumes are larger and the average retrogradation rates are higher; anyway it must be considered that if the frequency of these instabilities does not allow the displacement of landslide mass by marine action the cliff became inactive and the instabilities should be located in stronger materials.

## **Geomorphological evidence of extreme wave events in the Maltese Islands**

MOTTERSHEAD D., BRAY M., FARRIS P., SOAR P.  
*University of Portsmouth, PORTSMOUTH, UNITED KINGDOM*

The Maltese islands occupy a pivotal site in the central Mediterranean Sea, around the margins of which are abundant examples of extreme wave deposits, and thus offer a unique location for testing extreme wave effects in an open sea location. Malta is situated in a moderate sea wave environment in an historic tsunamigenic region. Unlike the Caribbean and Pacific, the Mediterranean does not suffer the confounding factors of tropical cyclones nor, unlike the Atlantic Ocean, storm waves of oceanic magnitude.

Maltese coastlines present topographies ranging from high cliffs, through coastal bedrock slopes and platforms to small coastal valleys, offering a range of potential responses to extreme wave attack. We present an extensive range of both erosional and depositional evidence of extreme wave activity and, in particular, a sensitive relationship between relief and the elevation and distribution of the evidence recorded.

The coasts bearing extreme wave evidence face NE, which is not the aspect of maximum fetch or wind velocities. This aspect is also consistent with the orientation of imbricated boulders. Boulder deposits extend up to >22 m asl, with many boulders exceeding the capacity of current storm waves to move them (Nott 2003). Shell encrusted boulders, derived from below sea level are found up to 6 m asl, apparently consistent with tsunamigenic deposits.

Lithological and morphological evidence show that bedrock erosion has occurred at elevations as high as 7-12 m asl, and we report a range of erosional forms which we believe may be previously unreported in Mediterranean contexts.

Some of the evidence may be explained by extreme storms, but a significant proportion appears to require the higher energies of tsunamigenic sources, of which there is other evidence in the region.

The postulation of tsunami waves reaching elevations of up to 22 m has significant implications for public safety and coastal management in Malta.

\*\*\*\*\*

## **Evidence of storm wave induced shore platform boulder dynamics at Timaru, New Zealand**

ABAZOVIC A., STEPHENSON W.J.  
*Department of Geography, University of Otago, DUNEDIN, NEW ZEALAND*

Boulder accumulations on intertidal shore platforms on the east coast of the South Island of New Zealand present an opportunity to examine boulder mobility, transport modes and energy regimes needed for transport. This study is currently monitoring boulder transport through tagging, repeated photographing and surveying. In addition, self-contained accelerometers are being used to investigate the mode of boulder transport during storm events. Initial assessment of boulder sedimentology suggests that storm activity is responsible for boulder movement but transport by tsunami cannot be ruled out at this setting.

Preliminary observations, made in June and October 2012, revealed that the fine boulders located at mid-platform have the highest probability of being moved by storm waves, particularly during south-east swell conditions and minimum wave heights of 4 m. Namely, the smallest two tagged boulders, located in the close proximity of one another, were both tilted over the longest axis between the two observations made. During that period, the most energetic two events had predicted minimum wave heights of 3 m and predicted maximum wave heights of 6 m. These wave heights apparently do not suffice for movement of coarser boulders as no mobility of medium or coarse boulders in close proximity was recorded during the same period. Thus especially the largest boulders, located on the southern end of the platform, very likely require intense storm conditions or possibly a tsunami wave for their movement to occur.

### Microseismic observations of coastal ground motion and geomorphic implications

YOUNG A.(1), GUZA R.(2), DICKSON M.(3), FLICK R.(2), WILLIAM O.(2)

(1) Scripps Institution of Oceanography, UCSD, LA JOLLA, CALIFORNIA, UNITED STATES ; (2) Scripps Institution of Oceanography, UCSD, LA JOLLA, CALIFORNIA, UNITED STATES ; (3) University of Auckland, AUCKLAND, NEW ZEALAND

Ground motions driven by local swell and infragravity ocean waves were observed at seven unique worldwide coastal settings including rocky, cliffed, and sandy coasts. Coastal ground motions were generated by low frequency gravitational ocean wave loading and attraction, and high frequency shaking caused by breaking ocean waves and wave-cliff impacts. Ground motions consistently increased with incident wave energy and were tidally modulated at various frequencies. However, tidal modulation differs between sites with dissimilar shore platforms, suggesting that platform elevation and geometry influences ocean-energy delivery to cliffs. High frequency response varied between sites, with elevated response at certain frequencies possibly related to local site geometry, ground material properties, and resonance affects. Similar high frequency ground motion observed at cliff and non-cliff sites suggests difficulties using seismic observations as a proxy for wave-cliff interaction in geomorphic studies. Low frequency cliff ground motion decays rapidly with inland distance from the cliff edge, causing continuous cyclic internal cliff strain. Although the observed strain values are several orders of magnitude lower than typical ultimate strain values for rock, the wave loading applies a large number of cycles and could potentially cause weakening through fatigue processes.

\*\*\*\*\*

### Towards an improved understanding of tidal notch development: ten years of micro-erosion meter rates, Phang Nga Bay, Thailand

MOSES C., ROBINSON D., WILLIAMS R.

University of Sussex, BRIGHTON, UNITED KINGDOM

Tidal notches, recesses extending along marine cliffs, develop because of higher weathering and erosion rates in the intertidal zone compared to the supratidal or subtidal zone. They are particularly well developed on Mediterranean and tropical rock coasts but also occur on rock coasts in higher latitudes. They develop in a range of rock types, including basalt and sandstone, but are arguably best developed, and certainly most intensively studied, on limestone. Tidal notches are commonly used as geomorphological indicators of sea level change and tectonic movement, with their horizontal depth often being used to estimate the duration of stillstands. Key models of cliff retreat are predicated on cliff undercutting and notch development.

Despite their importance in geomorphology and quaternary research, understanding of tidal notch erosion dynamics and modelling of their evolution remains limited. There are relatively few studies that directly measure rates of notch development and most have been short-term (2 – 3 years duration) and carried out on relatively soft, young rocks that yield quick results. Models of notch development are predominantly based on morphological studies and therefore give no indication of rates of development.

As part of an on-going, long-term study on Permian limestone at Phang Nga Bay, southern Thailand, we are addressing some of these issues through the collection and analysis of MEM measured rock surface recession data recorded both within notches and on the platforms that sometimes front them. Implications of the results to date, for models of notch development and rock coast erosion under tropical climates will be outlined.

### **Shore Platform and Cliff Notch Transitions along the La Paz Peninsula, Southern Baja, Mexico**

TRENHAILE A., PRESTANSKI K., PORTER N., GAGNON J.

*University of Windsor, Windsor, CANADA*

Increasing exposure to wave action produces a northerly transition from various types of high tidal notches to narrow shore platforms in the andesitic lahar deposits of the La Paz Peninsula, in southern Baja, Mexico. Notches were surveyed in 18 areas and wear pins were cemented into the apex of each notch. The platforms were also surveyed in three areas and 36 transverse micro-erosion meter (TMEM) stations were installed in them. Laboratory experiments, using fresh and salt water, and geochemical analysis of rock samples taken from the notches and surrounding areas, were used to supplement the field data and to determine rates of notch erosion. Field measurements were made at the beginning and end of a 2.5 year period and the experiments were run for 17 months. There was insufficient erosion in the notches to determine rates of downwearing from the wear pins, but rates in the laboratory experiments were about  $1.80 \text{ mm yr}^{-1}$  in salt water and  $0.39 \text{ mm yr}^{-1}$  in fresh water. The shore platforms were narrower (few tens of metres) and steeper ( $1^\circ$ ) than most platforms in similar microtidal environments, reflecting a weak wave environment and resistant rocks. Mean TMEM downwearing rates on the three platforms ranged from 0.14 to  $0.42 \text{ mm yr}^{-1}$ . There was a good relationship between notch height and the degree of exposure to wave action, but notch depth is time-dependent and the relationship with exposure was not statistically significant. Notch height was also related to the orientation and wave fetch of the site. The experiments and field evidence suggested that the notches were probably produced by salt weathering resulting from high tidal immersion near the cliff foot and from splash and spray at higher elevations. Contemporary erosion rates compensate for tectonic uplift rates of about  $0.12$  to  $0.15 \text{ mm yr}^{-1}$ , and coastal morphology is well adjusted to the present level of the sea.

\*\*\*\*\*

### **Rocky coast dynamics - comparison between shore platform and adjacent sandy beach**

GABRIEL S., OLIVEIRA S., HORTA J., MOURA D.

*Algarve University, FARO, PORTUGAL*

The balance between erosional and depositional processes depends on nearshore wave propagation as determined by wave climate, bottom slope, relative water depth and the structure connecting cliff and sea floor: shore platform or sandy beach. This work is developed in the aim of the ongoing research project named "*Erosion of Rocky Shores-differences in protection promoted by sandy beaches and shore platforms (EROS)*". Here we compare the wave propagation upon a shore platform and the adjacent sandy beach in a very crenulated rocky coast at Algarve, southern coast of Portugal. For this purpose two study sites differently exposed to the incident waves are considered. Six monitoring campaigns were performed always during spring tides in order to achieve the maximum intertidal exposed area. The nearshore wave characteristics were measured simultaneously in shore platform and sandy beach by four pressure transducers, programmed to acquire at 2 Hz frequency during one tidal cycle. The sensors were placed along transects perpendicular to shoreline, two at low spring water level and the other two near cliff bottom. The complete wave spectra was post-processed through spectral analysis in order to extract several parameters such as, significant wave height ( $H_s$ ) and period ( $T_s$ ), wave energy and power. The offshore wave climate conditions were obtained in the Hydrographic Institute(IH) Faro buoy. Bottom slope was gathered throughout topographic surveys performed both in platform and sandy beach, by using a Differential Global Position System (DGPS). The sandy beach grain size variation was also characterized. The results obtained stressed the dependency of the relationship between the coastline orientation and the offshore wave direction both for wave transformation, beach morphology and sediment granulometry. A more effective dissipation in wave energy was observed for higher  $H_s$  measured in seaward sensors, both in shore platform and in sandy beach.

## Using beach and sea cliff dynamics to understand rocky coastline morphology, sea stacks, and headland amplitude

LIMBER P.(1), MURRAY A.B.(1), ADAMS P.(2), GOLDSTEIN E.(1)

(1) Duke University, DURHAM, UNITED STATES ; (2) University of Florida, GAINESVILLE, UNITED STATES

On rocky coastlines, interactions between beaches and sea cliffs can explain a wide variety of morphological features and processes, including sea stacks, headland prevalence, cross-shore headland amplitude, and approach to a steady state. The key feedback is that sea cliffs, as they erode and retreat, can produce beach sediment that controls future cliff retreat rates. In small amounts, sediment can accelerate sea cliff retreat by acting as an abrasive tool, and in large amounts it can hinder cliff retreat by dissipating wave energy seaward of the cliff toe. Because wave-driven sediment transport actively distributes beach sediment alongshore, these feedbacks vary spatially. As a result, interesting morphological features can develop, ranging in scale from hundreds of meters to tens of kilometers.

At the largest scale (tens of kilometers), beach and sea cliff dynamics (coupled with alongshore sediment transport) offer a simple understanding of why some rocky coastlines exhibit alternating sequences of rocky headlands and isolated pocket beaches, while others feature wide, continuous beaches backed by stable sea cliffs. An answer can be found using a balance of beach sediment gains and losses, such that alongshore headland prevalence decreases as sediment gains increase, or as sea cliff retreat rates and heights increase. Zooming in and focusing on individual headlands and pocket beaches, the same beach and sea cliff dynamics can explain sea stack formation and prevalence, as well as cross-shore headland amplitude. Numerical and analytical model results suggest that certain combinations of wave climate, sea cliff characteristics, and initial headland shapes can encourage stack formation. When sea stacks do not form, results suggest that equilibrium cross-shore rocky headland amplitude (relative to neighboring embayments) is controlled by alongshore headland spacing, as well as the retreat rates and properties of the headland and embayment sea cliffs.

\*\*\*\*\*

## Beach nourishment impact in receding soft rock coastal cliffs using remote sensing techniques (Forte Novo, south Portugal)

NUNES M.(1), FERREIRA Ó.(1), BAILY B.(2), CALVÃO J.(3)

(1) University of Algarve, FARO, PORTUGAL ; (2) University of Portsmouth, PORTSMOUTH, UNITED KINGDOM ; (3) Universidade de Lisboa, LISBOA, PORTUGAL

Beach nourishment is considered to protect rock coastal cliffs from marine erosion, reducing significantly the cliff failures stimulated by wave action. By avoiding a direct marine action beach nourishment enables the analysis of sub-aerial erosion significance in coastal cliffs. The main goal of this study is to compare the role of marine and sub-aerial erosion at a cliff system, before and after beach nourishment.

The coastal cliffs at Forte Novo (Southern Portugal) are composed of Plio-Pleistocene poorly consolidated sandstones, a low resistant cliff material that registered high erosion rates since the construction of hard engineering structures updrift of the study area in the 70's. Beach nourishment in June 2010 added up to 4 m of sediment at the cliff base and 3 m over the berm.

The cliffs were monitored with 11 surveys from November 2009 until May 2012. Data collection initiated with an airborne LIDAR survey. The subsequent surveys were performed using a reflectorless total station or a terrestrial laser scanning to measure the cliff, and a RTK-DGPS to monitor the adjacent fronting beach. Hydrodynamic (wave and tide) and meteorological (rainfall) conditions are combined with cliff loss volume to analyse the forcing factors in cliff retreat before and after nourishment. The different impacts of marine and sub-aerial erosion were evaluated by comparing cliff loss volume during the monitoring period. The retreat of the cliff top line recorded a maximum of circa 7 m previously to the beach nourishment, and a maximum of circa 1 m after beach nourishment. Significant cliff failures occurred before beach nourishment. With a narrow beach the cliff base was frequently reached by waves in high tide and eroded during storms. Marine action was also responsible for the quick (days) erosion or removal of collapsed material. After beach nourishment the cliff became protected from wave attack with a wide beach and only exposed to slower sub-aerial erosion processes.

## **Boulder mobility and shore platform erosion in southern Galicia, Northwestern Spain**

PEREZ-ALBERTI A.

*Universidad de Santiago de Compostela, SANTIAGO DE COMPOSTELA, SPAIN*

Boulder accumulations, consisting of clasts of up to 2 m in diameter, are common on the granitic rocky coasts of the northwestern Iberian Peninsula. Broken storm waves move these clasts over boulder-strewn shore platforms and within boulder beaches. To determine the mobility of these boulders, and consequently their abrasional or protectional role in the evolution of this rocky coast, a study was undertaken on a boulder beach at Laxe Brava, between the rias of Arosa and Muros and Noia. Several techniques and data sources were used to track boulder movement in this area, including painting the boulders, GPS profiling with centimeter accuracy, airborne LiDAR survey (with an accuracy of 10 cm in 2008 and 30 cm in 2010), and aerial photography with a 4 cm resolution from a remotely controlled helicopter in 2012; these aerial data were used to produce orthophotos for 2008, 2010, and 2012. Boulder mobility, in the vertical and horizontal planes, was recorded and quantified in this area by integrating data layers in a GIS. A second study is being conducted to determine the abrasional affect of loose material, ranging from sand to boulders, in a small bay in southern Galicia. About 40 transverse micro-erosion meter stations were installed in summer 2012, at sites where abrasion is active and, for comparative purposes, in other places where surface downwearing is only by weathering. Photogrammetric techniques, with similar resolution as in the first study, will be used to record boulder movement and the dislodgement of joint blocks and other large rock fragments by wave quarrying.

\*\*\*\*\*

## **The role of biota in the weathering of microtidal shore platforms: first results from a new approach through case studies along the coast of NW Italy**

PAPPALARDO M.(1), CHELLI A.(2), PANNACCIULLI F.G.(3)

*(1) Dipartimento di Scienze della Terra, Pisa University, PISA, ITALY ; (2) Dipartimento di Fisica e Scienze della Terra M. Melloni, Parma University, PARMA, ITALY ; (3) ENEA - Centro Ricerche Ambiente Marino - S. Teresa, LA SPEZIA, ITALY*

This work was aimed to test if bioerosion and bioprotection can be considered effective morphological processes in the current shaping of small shore platforms in the microtidal environment of the Ligurian Sea (NW Mediterranean). At the study sites the biota colonising the rock surface of the intertidal and lower supralittoral zone displays the following zonation pattern: from sea-level going upwards we can find macroalgae, a fringe with grazing gastropods, echinoids and mussels, a well defined barnacle belt (mostly *Chthamalus* spp.) topped by cyanophytes and lichens (*Verrucaria adriatica*) spreading in the supralittoral zone. Their relative contribution to the overall platform erosion deserves to be tested.

We focussed on the bioerosive/bioprotective role of chthamalid barnacles and lichens on shore platforms surface. We randomly selected 10x10 cm quadrats where we measured organisms percentage cover and rock hardness using a Schmidt hammer test. This analytical method was applied to a number of tracts of the platforms displaying different organisms cover. Results from a number of study sites located in the Gulf of La Spezia on a carbonatic bedrock, demonstrate that only those parts of the rock covered by chthamalid barnacles display a reduction of rock hardness of the order of 10% compared to uncovered rock at the same elevation a.s.l.. Differences in rock hardness between covered and uncovered rock quadrats proved to be statistically significant. If we consider that in the uncovered part of the platforms at intertidal-lower supralittoral rock hardness is reduced by 50% with respect to fresh rock, bioerosion impact proves to be of a much lower magnitude than that of physical weathering. Data from further test sites, shaped in sandstones, and obtained with a different experimental design are presented in order to test our first results against further evidence. Different interpretative hypotheses are discussed to explain the highlighted weathering pattern.

### Wave transformations across a macro-tidal shore platform

STEPHENSON W.(1), NAYLOR L.(2), CHEN B.(1)

(1) University of Otago, DUNEDIN, NEW ZEALAND ; (2) University of Exeter, PENRYN, UNITED KINGDOM

How swell and wind waves are transformed across shore platforms has become a central question in rock coast studies with only a limited number of field studies recently reported in the literature. Critical questions include; how much energy relative to deep water is delivered to the platform cliff junction (where platform extension occurs), how much energy is transformed to infragravity frequencies and does energy in the infragravity band have any geomorphic consequence for rock coasts? Previous investigations of wave transformations across shore platforms have mostly occurred in micro-tidal environments where water depth and platform width are limiting factors on wave energy arriving at the cliff platform junction. Only one previous study has occurred in a macro-tidal setting, where the erosive potential of waves was assessed. Here we report on the results of the deployment of three wave recorders across a shore platform in a macro-tidal setting, on the Glamorgan coast of South Wales, United Kingdom. The pressure transducers were deployed across a platform for four days recording 2048 samples at 4 Hz, in burst at 10 minute intervals over eight high tides (489 bursts). At the outer edge of the platform water depths at high tide were 8 m meaning that waves crossed the platform without breaking. Maximum wave height at the top of the platform was 2.4 m and Hsig never exceeded 1.34 m. Water depth at the cliff platform junction at high tide were 1.4 m and limited wave heights by forcing breaking. Only a small amount of energy were observed at infragravity frequencies at the top of the platform. Analysis shows that less than 8% of the total energy is contained within infragravity frequencies; swell, wind and capillary waves dominate containing 92% of the total energy. On this platform it is unlikely that infragravity energy has any geomorphic function other than to remove a small amount of energy from the gravity wave frequencies.

\*\*\*\*\*

### Comparative rates of surface erosion of coastal engineering materials and of chalk and sandstone platforms, East Sussex, southeast England

ROBINSON D., MOSES C.

University of Sussex, BRIGHTON, UNITED KINGDOM

Understanding shore platform erosion dynamics is important in the context of coastal management, because platform erosion is considered to be linked to cliff retreat and, because coastal defence structures are often built directly into the platform at the cliff toe. The effective life span of defence structures is affected both by downwearing of the platforms on which they are built and by the resistance of the engineering materials to weathering and erosion.

The Cretaceous Chalk coasts of northwest Europe, and particularly those of southeast England, are among the most dynamic and most intensively studied rock coasts in the world. Perceptible changes to platforms, measured on monthly, seasonal, annual and decadal time scales provide a discontinuous database of erosion rates of Sussex platforms spanning over twenty years. The cliffs and platforms composed of Cretaceous sandstone, that occur also in southeast England, have been much less intensively studied. Much of the coast is urbanised and long stretches have been protected by various combinations of groynes and sea walls, some built of concrete, incorporating local flint, others comprised entirely of imported rock-blocks. The erosion rates and therefore potential life span of these engineering structures are essentially unknown.

Complementing and extending the existing dataset on the Chalk platforms, we provide some additional data on erosion rates, collected using Micro-Erosion Metres, of chalk and sandstone platforms, concrete walls and groynes, and imported rock-blocks, all collected over the same time period, for a range of sites along the southeast coast of England.

The implications of the results for coastal erosion rates and the lifespan and effectiveness of the coastal defence structures will be discussed.

## Rocky shore platform's evolution in the North-West Coast of Egypt

SALEEM A.(1), MAHMOUD A.M.(2)

(1) Ain Shams University, CAIRO, EGYPT ; (2) Ain Shams University, CAIRO, EGYPT

Both recent and old shore platforms are the most common element of the Egyptian Mediterranean rocky coast. Topographic and geological characteristics of the shore platforms have been identified in the field: platforms are situated at different altitudes in relation to mean sea level and they are formed in different carbonate formations from Miocene to Pleistocene ages. We measured many aspects of platform's rock discontinuities such as joints, bedding and minor faulting.

Absolute dating of the old platforms is not possible due to the lack of datable and precise biological sea level indicators. This study seeks to examine relative ages of shore platforms.

Many features testify to inheritance of the platforms such as:

- The occurrence of well developed benches and tidal notches above current MSL.
- Residual pools isolated by platforms down wearing.

We examined the long term evolution of shore platforms applying two field methods:

- Schmidt hammer test was used to quantitatively measure what degree, the platforms are weathered. Field measurements denote that subaerial weathering weakens rock strength by 50% and 40% for Miocene and Pleistocene limestone respectively
- Studying platform derived boulders: angular clasts of different size " pebbles to very coarse boulders" were moved by wave quarrying process. Firstly we defined platform derived boulders based on field measurements and notes and laboratory petrographic test then mathematical modeling, data of extreme waves "instrumental and or historical " were used to asses wave quarrying process on the platforms. It was found that regular winter storms are reshaping platforms every season however paleo extremity "storms and or tsunamis" had played a fundamental role in removing the largest blocks over long time scale.

\*\*\*\*\*

## 260 km of snorkel-geomorphological surveying along the Istrian rocky coast (Croatia, Slovenia, Italy): results from the 'Geoswim project'

FURLANI S., CUCCHI F.

Dept. of Mathematics and Geosciences, University of Trieste, TRIESTE, ITALY

The northeastern Adriatic coast is dominated by limestone plunging cliffs or near-vertical slopes. Although the present-day notch is completely lacking, the occurrence of a well-carved submerged notch have been observed by several Authors. It has been used, together with archaeological markers, to evaluate the tectonic subsidence of the area. In order to map in detail the submerged notch and to evaluate the factors driving its development, an ongoing snorkel geomorphological and hydrological survey has been carried out along the Istrian coast.

The survey was carried out during July 2012 through a 260 km snorkel-surveying, from Luka Budava to Trieste by S. Furlani. Moreover, two limited coastal sectors were selected to test the method. The route was covered by swimming in 28 days. A small boat with surveying instruments (two underwater 3D cameras, a CTD diver, GPS, invar rods, a roughness meter, an ultrasonic depth meter, etc) was pushed during the survey.

Data collected show that the submerged notch occurs only in the northern part of the Gulf of Trieste and the central part of the Istrian peninsula, along plunging cliffs, are even if the studied coast is carved on the same Mesozoic limestone. The coastal sectors where the submarine notch occur are bordered by high vertical limestone plunging cliffs. Moreover, the sites are interested by the occurrence of submarine springs which provide large amount of freshwaters, even during periods marked by very low rainfalls.

Although data collected are not sufficient to distinguish between bioweathering rates and chemical solution related to freshwaters, a strong positive correlation between coastal morphology, the occurrence of submarine springs and the submerged notch can be observed.

Data collected suggest (1) the effectiveness of the snorkel surveying on long sectors of rocky coasts in geomorphological studies and (2) to reconsider the role of submarine freshwater in the notch genesis and evolution.

## **Poster presentations:**

### **Photogrammetric evaluation of rocky coasts using UAV mapping system**

*PEREZ-ALBERTI A.(1), PIRES A.(2), LÓPEZ-SÁNCHEZ M.(3)*

*(1) Universidad de Santiago de Compostela, SANTIAGO DE COMPOSTELA, SPAIN ; (2) Universidade do Porto, PORTO, PORTUGAL ; (3) Cartogalicia, AMES, TEO (A CORUÑA), SPAIN*

In small scale areas (limited extent) unmanned aerial vehicles (UAVs) are an effective alternative to integrate with GIS mapping and applied cartography. UAVs are becoming the basis for photogrammetric projects and GIS platforms. These systems can be cost effective and have reasonable prices consequently they are applied in research projects with low budgets. UAVs reached a level of accuracy and expertise which allow the use of these systems as GIS mapping platforms. Over recent years UAV-platforms turn out to be very relevant for applications in precision farming, infrastructure maintenance, like road maintenance and dam surveillance. Likewise, UAVs can be applied to cadastral laws, generation of elevation models in small-scale areas such as gravel pits or even to other measurement technologies. Apart from all these applications this research gives an overview about the workflow of UAVs systems and their application for photogrammetric assessment of Galician rocky coasts (NW Spain).

The research presents the suitability of UAVs for GIS mapping applications; two examples for coastal cartography will be given in this work. Based on the general overview of UAV mapping and the two examples presented here, in future coastal projects it can be predicted using UAVs for most purposes which involve high resolution and accuracy. The boulders/clasts movements, coastline changes and shore monitoring are important data which depend on a quick and low cost system development to collect near real time spatial information. Such a prompt information collection skill has become a developing trend in the technology of remote sensing and GIS mapping. In this study, a UAV based spatial platform is proposed coupling GIS methodologies. Shoreline monitoring and boulder mobility analysis are important for integrated coastal zone management/planning. The current investigation is still in development to provide more detailed information.

\*\*\*\*\*

### **Cliff erosion in a monochromatic wave flume: analysis of cliff recession and collapse events**

*CAPLAIN B.(1), REGARD V.(2), ASTRUC D.(1)*

*(1) Institut de Mécanique des Fluides de Toulouse, TOULOUSE, FRANCE ; (2) Géosciences Environnement Toulouse, TOULOUSE, FRANCE*

Rocky coast erosion could be divided into cycles, each one corresponding to three successive phases: (i) the notch creation at the cliff toe by mechanical action of waves, (ii) the cliff fracturation leading to a collapse event (Young and Ashford, 2008) and (iii) the fallen cliff debris progressively evacuated by waves and currents modifying the bottom morphology. This study is devoted to the experimental analysis of the cliff recession rate, as a function of the wave climate, the grain size of sediment and the cliff height.

We performed the experiments in a wave flume of about 5 m long. A wetted sandy cliff is build with a height from water free surface of 8 cm. Three types of sand were used ( $D_{50} = 0.28-0.41-0.48$  mm). In order to detect the free surface and the sand surface, we set up two cameras, one on the side of the flume and the other above the flume. The wave climate is estimated by capacitive probes and is characterized by the surf similarity parameter  $\xi$  and the incident wave energy flux  $F$ .

At the beginning of the experiments, cliff retreat is very important and collapsed sediment quickly creates a sandy platform on the 10% slope, then the recession rate tends to 0. We showed that the cliff recession rate are proportional with  $F$  and are not monotonic with  $\xi$  which controls the bottom morphology. We deduced the volume of each collapse event and so we estimated the material cohesion. We observed that the cliff recession is more important for finer sand while the cliff is more cohesive. The volume of cliff collapse events increases with the cliff height  $h_c$  and the cliff recession decreases with  $h_c$ , actually the total volume of eroded sediment is independent with the cliff height.

Young, A. and Ashford, S. (2008). Instability investigation of cantilevered seacliffs. *Earth Surface Processes and Landforms*, 33:1661–1677.

### **Late Holocene sea-cliff retreat recorded by $^{10}\text{Be}$ profiles across a coastal platform: Theory and examples from the English Channel and Korea**

*REGARD V.(1), DEWEZ T.J.(2), BOURLÈS D.L.(3), ANDERSON R.S.(4), DUPERRET A.(5), COSTA S.(6), LEANNI L.(3), KEVIN P.(7), MAILLET G.M.(8)*

*(1) GET, Université de Toulouse/UPS/CNRS/IRD, TOULOUSE, FRANCE ; (2) BRGM; Risques Naturels, ORLÉANS, FRANCE ; (3) Aix-Marseille University, CEREGE, CNRS/IRD UM 34, AIX-EN-PROVENCE, FRANCE ; (4) University of Colorado, Dep. of Geological Sciences / INSTAAR, BOULDER, UNITED STATES ; (5) UMR CNRS 6538 Domaines océaniques, IUEM, PLOUZANÉ, FRANCE ; (6) Geophen, Université Caen Basse Normandie, CAEN, FRANCE ; (7) M2C, Université de Caen/CNRS, CAEN, FRANCE ; (8) LUNAM Université, CNRS UMR 6112 LPGN-BIAF, ANGERS, FRANCE*

A new method for documenting the long term retreat rate of sea cliffs based on measurements and modeling of  $^{10}\text{Be}$  concentration transects across present-day shore platforms is presented. The proposed numerical model relies on a scenario in which sea level rises since the last deglaciation, and predicts the shape of  $^{10}\text{Be}$  concentration transects as a function of prescribed cliff recession and vertical coastal platform downwearing rates. Two independent transect features allow fitting the long-term recession rate model to field observations: a sharp  $^{10}\text{Be}$  concentration drop predicted at the former stationary location of the cliff during the last glacial period ~100 ka ago, and a characteristic dome shape whose magnitude is directly related to the recession rate of the cliff.

A retreating chalk cliff site from the English Channel coast of France, at Mesnil Val, where the 7 m tidal range broadly exposes the shore platform, was selected to test the proposed method. Although retreat rates were too high to pinpoint the predicted  $^{10}\text{Be}$  concentration drop at the last glacial cliff position, the  $^{10}\text{Be}$  concentration of the flints sampled across the shore platform are consistent with the expected dome shape. When modeled using the proper tidal range and proposed Holocene sea level rise history, the  $^{10}\text{Be}$  data yield a cliff retreat rate since the mid-Holocene of 11-13 cm/yr. This is consistent with a 30-year-long measurement record, strongly supporting the validity of the  $^{10}\text{Be}$  method.

Using the data recently published by Choi et al. 2012, a second site, in Anmyeon island, western Korea, was tested. A significantly lower retreat rate, less than 1cm/yr, was then deduced.

Reference: Choi, K.H., Seong, Y.B., Jung, P.M., and Lee, S.Y., 2012, Using Cosmogenic  $^{10}\text{Be}$  Dating to Unravel the Antiquity of a Rocky Shore Platform on the West Coast of Korea: *Journal of Coastal Research*, v. 282, p. 641–657, doi: 10.2112/JCOASTRES-D-11-00087.1.

\*\*\*\*\*

### **Identification and quantification of rates of surface erosion on shore platforms in Malta and their relationship to environmental change**

*GAUCI R.(1), INKPEN R.(2), SCHEMBRI J.A.(3), FURLANI S.(4)*

*(1) University of Malta, PEMBROKE, MALTA ; (2) University of Portsmouth, PORTSMOUTH, UNITED KINGDOM ; (3) University of Malta, PEMBROKE, MALTA ; (4) University of Trieste, TRIESTE, ITALY*

This study examines the erosion processes operating on horizontal and sloping limestone shore platforms in five sites of the Maltese Islands. Nineteen transverse micro-erosion meter (TMEM) stations have been set along the north-eastern, north-western and south-eastern coastline of Malta. All the TMEM stations were placed in belt transect positions across the width of the shore platforms. Schmidt Hammer tests were undertaken to determine variations in the rock hardness along the established transects. This study forms part of a five-year research project aimed to establish a network of erosion monitoring sites that will provide a baseline of shore platform erosion rates and against which to assess future rates of change. The methodology and results obtained during the first year of the project will be presented and discussed in this presentation. Understanding the erosion patterns of Maltese shore platforms has important implications on the functioning of the wider coastal system. The selected shore platforms all form part of a headland system and are situated either at the tip of a headland or flank the side of a headland. On a larger scale these platforms are planar but at a finer scale they are mostly rough and rugged, with frequent discontinuities. The sites chosen are all backed by soft limestone sea cliffs. Thus, these platforms also act as regulators of wave energy impinging on cliff toes and govern the rates of sea cliff recession over time. The initial data collected suggests that surface erosion rates on the selected Maltese shore platforms integrate primarily processes of wave erosion and subaerial weathering (such as wetting and drying cycles); and these, in turn, are influenced mainly by the geology, coastal exposure and elevation-efficacy characteristics.

Key words: shore platform, transverse micro-erosion meter, surface erosion rates, Malta.

## Rock resistance variability across High Arctic rocky coastal zones - case studies from sheltered fjords of Svalbard and tsunami-affected coasts of Western Greenland

STRZELECKI M.

1. Department of Geography, Durham University, UK; 2. Department of Geology, UNIS, Norway; 3. Department of Cryospheric Research, AMU Poznan, Poland, DURHAM, UNITED KINGDOM

Recent decade has seen the major advance in cold region coastal geomorphology due to research progress along ice-rich permafrost coastlines of Siberia and Alaska.

On the contrary little attention was paid to Arctic rocky coastlines and their response to the reduction of sea ice cover and increased number of storms reaching Arctic region.

A significant limit to current understanding of cold coast evolution is the paucity of field observations regarding rock resistance of different polar coastlines and, in particular, the controls of different environmental variables on spatial patterns of shoreline morphology.

Results are presented from a pilot survey of rock resistance using N-type Schmidt Hammer Rock Tests across rocky cliffs and shore platforms developed in:

- sheltered bays of Billefjorden, Svalbard characterized by prolonged sea-ice conditions and very limited operation of wave and tidal action
- Vaigat Strait and Isfjorden in W Greenland influenced by landslide-triggered tsunamis and waves induced by ice-berg roll events.

The aim of a pilot study was to test the hypothesized coastal impact on the rate of rock weathering in high latitude regions. To do so I characterize the changes in rock resistance on the following coastal landforms:

- modern and uplifted wave-washed abrasion platforms– looking for relation between degree of rock surface weathering and distance from the shoreline as well as thickness of sediment cover on platform surface
- modern and uplifted rocky cliffs - looking for relation between degree of rock surface weathering and distance from the shoreline as well as difference in height above the sea level and relation to rock lithology

The results present another line of argument supporting intensification of weathering processes in cold region coastal settings.

\*\*\*\*\*

## Geo-engineering mapping of Aguiño groyne (Galicia, NW Spain): a rocky platform as a foundation?

PIRES A.(1), PÉREZ-ALBERTI A.(2), CHAMINÉ H.(1)

(1) Laboratory of Cartography and Applied Geology, School of Engineering (ISEP), Polytechnic of Porto; and Centre GeoBioTec\UA, PORTO, PORTUGAL ; (2) Laboratory of Environmental Technology (Geomorphology Area), Institute of Technological Research, University of Santiago de Compostela, GALICIA, SPAIN

It is well known that the wave climate of the Galician coast (NW Spain, Iberian Peninsula) is very energetic. The coastline is strongly diversified and characterised by mixed marine environments. The Aguiño site is located in Ribeira coastal area (NW Galicia) and comprises a very particular geomorphological setting. The studied site presents a rocky platform which is used mainly as a foundation for the maritime work and narrow sandy areas along the shore. The mixture of environments and the hydraulic conditions severity in Aguiño area made an unique research site. Several interdisciplinary studies were carried out to assess the coastal system considering the geomorphology, geotectonics, morphodynamic processes, forcing conditions, geomechanics of materials, geo-engineering methodologies and GIS mapping. The Aguiño maritime structure uses the rocky platform as a foundation so, this type of coastal protection solution offers numerous features that matters to be analysed and characterised. There is an intrinsic relationship between the artificial maritime design/construction and the natural rocky coast. The detailed cartography allowed reaching interesting results and encompasses geomorphologic, geo-engineering and coastal dynamic data. In addition, were performed in-situ strength tests to determine the hardness/rebound and durability of the rock material, not only on the rocky platform and boulders, but as well as on the armourstone placed along the groyne's armour layer. That holistic approach allowed the study of coastal geomorphology and geo-engineering along Aguiño site. The thematic maps will be very useful in the future to determine vulnerability zones to coastal erosion, hydraulic structure silting up, 3D modelling, geo-hazards and regional/local assessment for coastal management. The study presents also recommendations related to coastal zone management and planning in Aguiño area.

### Highly-resolution quantitative reconstruction of detritic quaternary cliffs retreat based on anatomical changes in exposed roots (Porquerolles island, France)

ROVERA G.(1), LOPEZ SAEZ J.(2), CORONA C.(3), STOFFEL M.(4)

(1) University J. Fourier, laboratory PACTE UMR5194 CNRS, GRENOBLE, FRANCE ; (2) IRSTEA UR EMGR, laboratory PACTE UMR5194 CNRS, GRENOBLE SAINT MARTIN D'HERES, FRANCE ; (3) Laboratory GEOLAB UMR6042 CNRS, CLERMONT-FERRAND, FRANCE ; (4) Laboratory of Dendrogeomorphology, University of Berne, BERNE, SWITZERLAND

The coasts of the western Mediterranean basin are interesting to quantify global warming effects as marine level rising or storms actions. Three types of coasts can be distinguished: cliffs, sandy beaches and rocky coasts with alternatively capes and pocket beaches. These pocket beaches are often associated with small detritic cliffs (<10 m) shaped by sea in quaternary slope sediments. The study concerns these small cliffs in Porquerolles (France), a forested island weakly impacted by coastal development and sedimentary inputs. In this context, the recent retreat of these cliffs, revealed by the increasing of numerous exposed roots and border pines falls for two decades, could be related to more frequent strong storms and sea level rising.

The first aim of this study is to quantify the contribution of the cliffs in the sedimentary balance of pocket beaches, which are isolated geomorphic units. The second is methodological: we use a dendrogeomorphic approach based on exposed roots of *Pinus halepensis* to quantify cliff retreat. A total of 58 exposed root sections were sampled and anatomical variations in annual growth rings resulting from denudation have been analyzed.

On average, the roots were 25 years old and have been exposed since 15 years. At the plot scale, average medium-term erosion rates range between 4.5 and 34.5 mm yr<sup>-1</sup> (average: 20 mm yr<sup>-1</sup>). The dropped debris volumes vary between 10 and 50 m<sup>3</sup> yr<sup>-1</sup>. These values are significantly lower than those obtained for the Mediterranean beaches (60 cm yr<sup>-1</sup>, 200 m<sup>3</sup> yr<sup>-1</sup>), but higher than cliff erosion rates. This contribution demonstrates that dendrogeomorphic analyses of roots have a significant potential for the quantification of cliff retreat and beach reloading in areas where past measurements are lacking. Detritic cliffs closed to pocket beaches seem sensitive spots to record strong storms effects and marine level rising, if the increase of these phenomena continues.

\*\*\*\*\*

### S. Paio (Labruge, Vila do Conde, Northern Portugal). A protected area and its geomorphologic value

ARAÚJO M., GOMES A.

FLUP-CEGOT-Universidade do Porto, PORTO, PORTUGAL

Northern Portuguese coast has a general trend of NNW-SSE from Bayonne till Espinho. This is a generally low coastline. Sandy beaches and dunes often cover Precambrian/Paleozoic bedrock. However, in some rare points, we have rocky cliffs. S. Paio is one of the highest points in this coastline.

An Iron Age settlement was discovered in the top of a 14 m amsl platform. Archaeologist calls it a "castro". At Galicia (northern Spain), this "castros" appear by the sea. But in Portugal this is the only one upon the coastline, and it was judged as quite unique by archaeologists. In the eighties this place had a difficult road access. The road improvement brought many visitors seduced by the scenic beauty of the place and also the danger of destructing archeological remains. Fortunately the city council decided to excavate the site and to protect it. It was important to make the city council archaeology cabinet understand that the scenic interest of the area was a consequence of geological and geomorphologic singularities and that all this valences together should be an important asset to local people economic sustainability and welfare:

- 1 – Imposing, rectilinear cliffs, all in NNE-SSW direction.
- 2 – Preserved rocky benches bearing marine deposits at several altitudes.
- 3 – A spectacular notch carved in fresh granite hanging over a vertical cliff, 9m amsl.
- 4 – A sequence of deposits (marine, probably Eemien, solifluidal, aeolian – TL dated 84k years).

The singularity of this staircase like topography, with hanging benches, deposits and notches suggests a recent uplift. A thrust fault affecting a quaternary deposit is found at a small distance (5km). This suggests that neotectonics are a possibility, improving the scientific value of the site.

The centre is now ready for visitors and it shows geologic, geomorphologic, archaeological, ethnographic and biologic information in a simple and interactive way.

### Investigating the interrelationship between boulder beach dynamics and storm events

BRAYNE R.(1), NAYLOR L.(2), REINHARDT L.(1), LORANG M.(3)

(1) University of Exeter, PENRYN, UNITED KINGDOM ; (2) University of Glasgow, GLASGOW, UNITED KINGDOM ; (3) University of Montana, FLAT HEAD LAKE, UNITED STATES

Clastic assemblages composed of pebble to boulder-sized material (Blair & McPherson, 1999) are a common feature of rocky coastlines globally. Such features effectively defend coasts against wave action and potential erosion. However, the limited number of field studies that address the dynamics of pebble-boulder beaches are rather qualitative or incomprehensive in their experimental approach. Consequently, our quantitative understanding of the dynamics of pebble/boulder beaches lags that of their sandy counterparts. We have developed a quantitative relationship between the rate of longshore transport and the local wave conditions by surveying the daily position of ~200 traced clasts whilst obtaining concurrent, detailed wave measurements from the adjacent shore platform over a number of field visits. The surveys were conducted within a ~300m stretch of Abbotsham beach, Bideford Bay, North Devon, which is a pathway of coarse clastic material to the ridge which protects Westward Ho! from inundation and erosion. The dynamics of clasts at Abbotsham therefore has a direct effect on the quantity of clastic material nourishing the valuable ridge. Field surveys, conducted during calm, moderate and stormy sea conditions, have enabled conclusions to be drawn about the relationship between the rate of longshore transport and the local wave characteristics. Our results show net longshore transport of clastic material towards the NNE during all observed wave conditions. The rate of longshore transport appears to be strongly related to the local wave conditions with individual clasts migrating up to 70m in one day during a storm. The forecasted change in the storminess of the north-east Atlantic and accelerated sea level rise is likely to have an impact the dynamics of coastal sedimentary systems. It is therefore important to develop a quantitative understanding of systems such as that in Bideford Bay to help predict their response to the forecasted change in wave climate.

\*\*\*\*\*

### Lithological control on coastal rock cliffs erosion of Safi, Morocco

RAGARU E.(1), MERCIER D.(1), CHAIBI M.(2), MAANAN M.(1)

(1) LETG-Nantes, Géolittomer, UMR 6554, Université de Nantes, NANTES, FRANCE ; (2) ELMar, équipe GEGEL, Faculté Polydisciplinaire de Safi, Université Cadi Ayyad de Marrakech, SAFI, MOROCCO

The coastline of the Safi region, between the Beddouza Cape (32°54'N - 09°28'W) and Jorf Lihoudi (32°18'N - 09°26'W), is characterised by different forms of coastal cliffs ranging from 5m to 153m high. Three different lithological units have been defined from the bottom to the top: 1) Plio-Quaternary aeolianites and coquina, 2) Cretaceous clays and sandstones, "Clay of Safi" 3) "Limestone of Dridrat" and 4) Jurassic limestones with clay, gypsum and sandstone.

The aim of this study is to identify 1/ the spatial and temporal distribution of coastal instabilities with a catalog events developed from aerial photographs using the GIS (1954-2011) and 2/ the lithological controlling factor, with a special focus on Clay of Safi, using a ratio : clay layer thickness/ cliff height × 100.

A conceptual model is used to define the processes acting on Safi coastal cliffs. Lithological, geomorphic, climate and anthropic parameters of 15 representative cliff sites are listed in a database.

The results of aerial photographs analysis revealed a low number (10 significant erosion hotspots) of events (collapse, rock fall and landslide) that have affected cliffs during the last 60 years. Historical erosion rates range from 7 to 13 cm/yr, where they are subject to erosion.

In Safi, the cliff retreat may be controlled by the proportion of clays whereby lower cliff angles are more clay-dominated. Cliffs, with a clay ratio upper than 60%, are more prone to mass movement than the others. This reflects the efficiency of continental processes. However, cliffs with less than 30% of clays ratio have no mass movement and are more subject to marine erosion. Laboratory analysis will be performed to confirm this hypothesis.



**S21C - Other subsessions**

Convenors: *Edward ANTHONY & Julian ORFORD*





## Oral presentations:

### **What is the contribution of abrasion to the sediment budget of a mixed sand and gravel beach?**

*CHEN B.(1), STEPHENSON W.(1), HEMMINGSEN M.(2)*

*(1) University of Otago, DUNEDIN, NEW ZEALAND ; (2) University of Canterbury, CHRISTCHURCH, NEW ZEALAND*

This project focuses on the identification and quantification of the abrasion of gravels on mixed sand and gravel beach using both the laboratory and field based experiments. Abrasion is the reduction in weight of gravels as they collide with each other in the swash zone following the impact of waves. The resulting fine sediment abraded from stones, is thought to cause significant sediment loss from mixed sand and gravel beaches. However, it is unclear just how much fine sediment produced by abrasion is lost from mixed beaches. There are a very few reported rates of abrasion based on field experiments. Using RFID technology and a VHF tracking system, abrasion of single gravel and groups of gravels were measured in the field. Field experiments not only measure in-situ abrasion rates, but also allow the abrasion rates to be linked to wave conditions during a range of energy levels including storms and calm conditions. Initial abrasion rates from early two experiments, when significant wave heights were 1.6m and 2.1m respectively, are reported as 0.043% and 0.120%, based on the average rate of abrasion of thirty tagged gravels during two days on the study beach. In addition five abrasion bins were deployed across the surf zone at 6m intervals from the top of the high tide to almost the low tide zone. The abrasion rates from top to bottom were 0.014%, 0.017%, 0.413%, 0.326%, and 0.178%, for those bins that remained stable in the swash zone over two days.

\*\*\*\*\*

### **Microtidal sandy beaches erosion: Diagnosis by DGPS measurements. Case study of the algiers west coast region- Algeria**

*BOUAKLINE S., BOUTBA M., GUETTOUCHE M.S.*

*University of Sciences and Technology Houari Boumediene (USTHB), Faculty of Earth Sciences, Geography and Spatial Planning, Laboratory of Geography and Spatial Planning, BEB EZZOUAR - ALGIERS, ALGERIA*

The coastal erosion is a reality that has been almost everywhere; it is the main problem that affects a majority of coasts all around the world. This natural scourge, driven by natural and human factors, as among them: (1) rising sea level, (2) large storms attacks, (3) decreasing sediments quantities feeding the beaches and (4) human anarchic actions... that may induce beaches desperation and unpredictable disasters.

As everywhere in the world, the Algerian coast suffers from this phenomenon too. Erosion's abundance and absence of scientific detailed mapping approach suggest proposing, in this study, a spatial model. We have considered Algiers's west coast, located between the peninsula of Sidi Fredj and the mouth of the Wadi El Agar (Zeralda), as the test site. The model was performed by a diagnosis based on field observations and erosion assessment through rigorous and repeated DGPS measurements of beach profiles and frequent shoreline monitoring.

Multi-date GPS shoreline data (2008, 2010 and 2011) have been superimposed and compared with other shorelines extracted from aerial photographs (1959, 1972 and 1980). The present study indicates that erosion during the period from **1959 to 2011** was predominant. A net rate of evolution has been estimated and is of the order of **-0.12 m / year**. This study indicates also that the sediment budget obtained from topographic measurements along beach profiles for the time period from **2008 to 2011** presents clearly a deficit estimated to **-13622m<sup>3</sup>**.

The two approaches used in this study show many similarities in spatial organization of the erosion processes but also a similar sediment transport direction along the test site area. Erosion will become increasingly important from southwest to northeast while the sedimentary transit is reversely organized. At the same time however, there is an important cross-shore movement of the sediment going offshore.

Key Words: coastal erosion, beach profiles, shoreline, sediment budget, DGPS.

### **Coastal monitoring and medium-term shoreline dynamics in Brittany (France)**

SUANEZ S.(1), STÉPHAN P.(2), FICHAUT B.(1), CUQ V.(1), BLAISE E.(1), CARIOLET J.M.(3), CANCOUËT R.(1), DELACOURT C.(1)

(1) *Université de Bretagne Occidentale, PLOUZANE, FRANCE* ; (2) *LGP UMR 8591 CNRS, MEUDON, FRANCE* ; (3) *University of Leicester, LEICESTER, UNITED KINGDOM*

This study is based on morphosedimentary monitoring of several sandy dune-beach systems and/or gravel beaches and barriers, located all around the Brittany coast (departements of Finistère and Côtes d'Armor). This monitoring was started in the early 2000s as part of the "Observatoire du Domaine Côtier (ODC) de l'Institut Universitaire Européen de la Mer". Depending on the site, the survey consists of (i) shoreline change measurements, and/or (ii) beach profile measurements including dune and tertidal beach, and/or (iii) 3D surface topography survey including aerial dune/beach system and offshore beach. From all these data, we propose a morphosedimentary budget of shoreline dynamics of Brittany beaches for the last decade. Between winter 2002-2003 and winter 2005-2006, sandy beaches were mainly suppled and gravel spits experienced lack of rollover and crestal overtopping. When beaches were in erosion, shoreline retreat was very low during this period where shoreline was less eroded. This first phase contrasted with the previous period, especially between 1999 and 2002 where erosion was predominant due to the impact of several storm events. During the winters 2006-2007 and 2007-2008, erosion was acting inducing sediment loss of all beaches (sandy beaches and gravel barriers). When beaches where already eroding, shoreline retreat was higher (e.g. storm event of 10 March 2008). Since the spring of 2008 (2008-2012), new phase of beaches recovery was observed due to the low morphogenetic activity (no impact Klauss in 2009, Xynthia in 2010 and Joachim in 2011, storm events). Analysis of hydrodynamic meteomarine consditions can offer a global schema of the morphodynamic fonctionning. The conjunction of storms, including SW direction, with high spring tides seems to play a much more important role in shoreline dynamics.

\*\*\*\*\*

### **Long-, mid- and short-term morphological behaviours of gravel barriers: illustrations from the coast of Brittany (France)**

STEPHAN P.(1), SUANEZ S.(2), FICHAUT B.(2)

(1) *Laboratoire de Géographie Physique (UMR8591 CNRS), MEUDON, FRANCE* ; (2) *Laboratoire Géomer LETG (UMR 6554 CNRS), PLOUZANÉ, FRANCE*

This study is asynthesis of 10 years of research on long-, mid- and short-term morphological behaviours of gravel barriers located on Brittany coastlines in the western part of France. At the long time-scale ( $10^3$  yr), the lithostratigraphy and biostratigraphy (foraminifera) of several back-barrier sediment sequences are examined to determine thephases of construction and breakdown of gravel barriers. These phasesare correlatedwith rates of sea-level rise, variations of sediment supply and wave-climate changes. Three major phases of barrier breakdown are identified around 800BC, 0-200 AD and 1070-1170 AD. This phases could be related to periods of major climatic changes and storminess, known as the Bond Cold events. At the mid time-scale ( $10^2$  yr),the recent mobility of 30 gravel barriers has been studied.The quantification of the recent mobility of the spits was performed using more than 200 aerial photographs taken between 1930 and 2011. Results show a sediment budget deficit at regional scale revealed by cannibalization, landward retreat by rollover and, in places, complete destruction of the gravel-dominated spits. Anthropogenic forcing partially explains the erosion of a minority of gravel spits studied. Analysis of climatic forcing, based on the reconstruction of high water levels, show that the rate of landward retreat by rollover is controlled by the frequency and the intensity of overwash events, the barrier alignment, the sediment budget and the accomodation space. On an annual timescale, morphological evolution of five gravel barriers affected by erosion was studied by a DGPS survey undertaken between 2002 to 2012. The role played by overwash dynamic was also studied by analysing oceanographic data set. Results show different pluri-annual phases of morphogenetic activity on the gravel barriers and highlight the high variable degree ofresilience of the barriers to extreme storm events.

### **Potential and limitations of Bayesian networks for understanding shoreline mobility: an example in La Réunion island**

*BULTEAU T.(1), BAILLS A.(1), PETITJEAN L.(2), GARCIN M.(1), DE LA TORRE Y.(3), PALANISAMY H.(4), LE COZANNET G.(1)*

*(1) BRGM, ORLÉANS, FRANCE ; (2) Laboratoire de météorologie dynamique - Université Pierre et Marie Curie, PARIS, FRANCE ; (3) BRGM, MONTPELLIER, FRANCE ; (4) LEGOS - Observatoire Midi-Pyrénées, TOULOUSE, FRANCE*

Coastal erosion is a global growing threat as more and more human activities and settlements concentrate on the coastal fringe. Today's climate change and induced sea level rise also contribute to change the risk of erosion. Understanding the current shoreline evolution is a necessary step to predict future changes and better manage this risk.

The shoreline mobility results from numerous factors and complex mechanisms acting at different spatial and temporal scales. Here, a data mining approach based on a Bayesian network (BN) is tested enabling one to use readily available data to analyse some causes of decadal-scale shoreline evolution in La Réunion (a volcanic tropical island in the Indian Ocean) and to reproduce the observed evolution trends. The BN is built to define causal relationships between 5 variables describing the state of a given coastal segment: geomorphic settings, exposure to energetic waves, presence of an estuary (importance of continental sediment loads), presence of human works in the vicinity of the segment and current shoreline mobility (accretion, stability or erosion, representative of about 30 years).

The retrospective predictions are correct in 79% of the cases. Evaluation of the model performance using log likelihood ratio scores indicates that the BN provides shoreline mobility predictions that are better than the prior probability. By evaluating the model behaviour using from one to four variables, the geomorphic settings are identified as the most important model parameter determining coastal evolution trends. Incorrect predictions of the BN are analysed in details and experts' know-how is used to assess the local causes of the observed mobility and to point out limits of the BN. Among the multiple causes of mis-prediction, the lack of sediment budget information (alongshore transport and interactions between adjacent coastal segments) is the most common.

\*\*\*\*\*

### **High resolution coastal evolution: dynamic profiles and geomorphological resilience beach index (GRBI)**

*MORISSETTE A.(1), JOYAL G.(2)*

*(1) Université du Québec, RIMOUSKI, CANADA ; (2) Université Laval, QUÉBEC, CANADA*

The morphological evolution of a spit, the Pointe a Emile, on the North Shore of the St.Lawrence estuary, Quebec, was investigated by photointerpretation from 1931 to 2011. The results suggest that the displacement of the neutral point of the spit is associated with an increase of erosion profiles at the expense of accumulation profiles. Photointerpretation, however, does not allow quantifying the monthly evolution models. To examine the micro fluctuations (horizontal and vertical) of the coastal morphology, 27 beach profiles at very high spatial (<2 cm) and temporal (monthly) resolution were collected using a DGPS from May 2011 to December 2011. The monthly profiles allow also evaluating the resilience processes and the level of coast resilience. The analysis of monthly evolution models reveal the existence of five dynamic profiles with morphological response directly related to hydrodynamic conditions. The geomorphological resilience beach index (GRBI) developed in this study is a way of clustering semi-quantitative data in order to express the level of resilience of beach profiles. The fluctuations of the GRBI represent monthly the level of beach profiles resilience and the rate of monthly morphological adaptation. The data show that the resilience of profiles without coastal protection is significantly different to that of profiles where rock armor has been used. The rate of monthly morphological adaptation of natural profiles (A, B, C and D) suggests that they can adapt morphologically to coastal hazards, while the sensitivity of the profiles with coastal protection tends to reduce the geomorphological resilience of the spit. This contributing to the emergence of a distal profile of submersion (D) and decreasing bluffs resilience in adjacent profiles (B). This represent another effect of coastal protection on reducing beach resilience.

### **Longshore variation of overwash occurrence in a barrier island (Portugal)**

MATIAS A.(1), CARRASCO A.R.(1), PACHECO A.(1), LOUREIRO C.(1), NUNES M.(1), FERREIRA Ó.(1), ARMAROLI C.(2), MASSELINK G.(3)

(1) CIMA - Universidade do Algarve, FARO, PORTUGAL ; (2) Università di Ferrara, FERRARA, ITALY ; (3) University of Plymouth, PLYMOUTH, UNITED KINGDOM

The occurrence and intensity of overwash depends on a number of factors that include hydrodynamic conditions, nearshore and foreshore topography, dune morphology, engineering structures, location and orientation of footpaths and roads, and buildings on the shorefront.

To study longshore variations in overwash, 24 cross-shore topo-bathymetric profiles were set on Barreta Island (Ria Formosa barrier island system, Portugal), from the nearshore (depth =12 m, below mean sea level, MSL) until the lagoon level on the island backbarrier. Pre- and post-overwash surveys were made between August 31, 2012 and December 28, 2012. During this period, overwash occurred both under storm conditions (maximum significant wave height of 3.5 m, in November) and non-storm conditions (maximum significant wave height of 1.5 m, in October). Barrier crest elevation was 3.6-4.6 m, and after November overwash the crest lowered up to 0.2 m. Overwash water intrusion distance across the barrier varied significantly alongshore between 0 m (at West) and 70 m (reaching the lagoon water). Differences in overwash intensity along the barrier are probably associated to nearshore and offshore bathymetric features. At West no overwash occurred because the swash bars that form part of the ebb delta of Ancão Inlet provide protection to the barrier dunes, as wave energy is dissipated further offshore. Towards East, overwash intrusion, barrier crest elevation and orientation are variable and so is the nearshore, with alongshore sand bars particularly until the depth of 6 m, where the beach profile is more active. Sand bars are probably related to sediments transported by littoral drift from Ancão Inlet delta or are remnants of ebb delta sediments from previous Ancão Inlet positions. Moreover, in 1996 the entire study area was westwards of Ancão Inlet and its migration changed the nearshore morphology, which currently influences the wave propagation and thus overwash occurrence on Barreta Island.

\*\*\*\*\*

### **Longshore cell development in a boulder beach, Mission Rocks, South Africa**

GREEN A.N., COOPER J.A.G., SMITH A.M., SALZMANN L.

*Geological Sciences, School of Agriculture, Earth and Environmental Sciences, University of KwaZulu-Natal, DURBAN, SOUTH AFRICA*

Mission Rocks is a rocky coastline with a well-developed shore-platform fronting a coastal dune cordon. The shore-platform slopes seaward and is overlain by a storm beach comprising slab-like boulders. Distinct imbrication patterns and boulder groupings are present within this beach. Boulders are separated into cells by coast-normal imbrication chains or by shallow, boulder-free "channels". The boulders, piled against the dune and between the channels show a coast-parallel, northerly-directed imbrication with a spread in orientation of the long axes. Each cell forms crude bedforms with a lee face sloping in the direction of longshore transport. These boulder-rich bedforms and the orientation of the boulders themselves are a product of storm-wave induced superimposition of swash to the shore platform and the development of longshore cells in the storm surge littoral zone.

### **Geomorphological development and sedimentary architecture and of two barrier islands (Sylt and Amrum/ German North Sea): Insights from ground-penetrating radar surveys and sedimentological data**

*TILLMANN T.(1), WUNDERLICH J.(2)*

*(1) Goethe-University Frankfurt a. M., Department of Physical Geography, FRANKFURT A. M., GERMANY ; (2) Goethe-University Frankfurt a. M., Department of Physical Geography, FRANKFURT A. M., GERMANY*

Barriers comprise approximately 15 % of the world's coastlines and are formed due to the combined action of wind, waves, and longshore currents. Barrier islands and barrier spits are geological young, highly dynamic and represent a complex coastal system that includes a number of different but closely related sedimentary depositional environments and geomorphologic elements of varying origin, genesis and evolution.

In this study ground-penetrating radar data of different antenna frequencies and sedimentological data were combined to reveal the sedimentary structure and architecture of two adjacent barrier island spits. Radiocarbon datings and amino acid racemisation datings (AAR) of shells help to define a chronological order and allow setting up a barrier island stratigraphy.

Based on these data, different geomorphological models of barrier spit development have been generated which describes the inter-action between extreme events, coastal processes and sedimentary development and contains the major episodes of island evolution.

The first model is concerned with the spit add-on zone where the southern barrier spit of Sylt is attached to the central island moraine core and shows a landward migration through barrier rollover affected by an interplay of barrier retreat and washover flooding associated with accumulation of sediment in a backbarrier environment as a result of several storm surges. The second model demonstrates a barrier spit accretion through southerly directed progradation. Eroded sediment was transported along the west coast of Sylt by longshore drift and was added to the southern spit-end. Progradation and barrier spit accretion were interrupted by severe storm surges. Storm surge generated erosion unconformities in a foreshore to shoreface environment redraw old spit-end positions that represent stages of barrier spit progradation. The third model describes the spit enlargement of Northern Amrum that was strongly influenced by overwash processes.

\*\*\*\*\*

### **Ecomorphodynamic Feedbacks Determine Barrier Island Response to Climate Change**

*MOORE L.(1), DURAN O.(1), WALTERS D.(1), YOUNG D.(2), FAGHERAZZI S.(3), MARIOTTI G.(3)*

*(1) University of North Carolina Chapel Hill, CHAPEL HILL, UNITED STATES ; (2) Virginia Commonwealth University, RICHMOND, VA, UNITED STATES ; (3) Boston University, BOSTON, UNITED STATES*

As low-lying coastal landforms, barrier islands are especially sensitive to changing environmental conditions. Ecomorphodynamic (i.e., combined biological and physical) interactions and feedbacks play a critical role in determining how these landscapes will evolve in the future as sea level rises, storm intensity increases and plant species composition changes. Barrier islands tend to exist in one of two primary states: Low and High. Low islands have little relief above sea level and are dominated by external processes, responding quickly on short time scales to changes in forcing (e.g., storms, sea level rise, etc.), migrating rapidly, and being low in ecological diversity. In contrast, High islands are less vulnerable to storms, tend to be dominated by internal processes (e.g., sand trapping by vegetation), require long time periods to respond to changes in forcing, migrate slowly (if at all) and host a range of plant species and morphological environments. The continued existence of barrier islands will depend on the degree to which islands can maintain elevation above sea level while responding to changes in forcing by migrating landward.

A long-term morphological-behavior model representing coupled barrier-marsh evolution (for the first time) and a new ecomorphodynamic model exploring the formation/recovery of dunes as a function of storms, shed light on the role of ecomorphodynamic interactions in determining barrier island response to climate change. Results suggest that connections between the marsh and barrier realms, which are mediated by biological processes in the marsh environment, are highly sensitive to factors such as sea level rise rate, antecedent morphology and marsh composition. Results also indicate that ecomorphodynamic feedbacks, such as those involved in dune-building processes, may cause gradual changes in biological and physical forcing to result in abrupt, non-linear transitions from the High to Low island state in the future.

## Projected Changes in Barrier-Island Wetland Distribution Caused by Sea-Level Rise

GIBEAUT J.

*Harte Research Institute, Texas A&M University - Corpus Christi, CORPUS CHRISTI, TEXAS, UNITED STATES*

Projecting future trends in wetland distribution is important for developing adaptation strategies for sea-level rise. The style of transition of estuarine wetlands during rising sea level depends largely on the slope of the upland and sediment supply. Fringing wetlands on Texas' barrier islands exist within an elevation range of 30 to 50 cm. On the bay sides of these islands, this amount of topographic change occurs in complicated patterns across relict geomorphic features, such as storm-surge channels, washover and flood-tidal delta deposits, and beach ridges and swales.

Using lidar digital elevation models and detailed wetlands mapping, we developed an inundation model that projects future wetland distribution caused by sea-level rise. Vertical accretion, edge erosion, and land-subsidence components are also included in the model. The model was applied to the barrier islands of the Galveston Bay System in Texas using the annual record of ocean level recorded for 90+ years by a nearby tide gauge. Results show the interplay of decadal-scale water-level variation and topography in determining wetland distribution.

The wetlands model was run 90 years into the future and shows wetlands migrating up the back barriers in a pattern dictated by geomorphology but disappearing on the bayward side owing to inundation and shoreline retreat. At the end of 90 years, upward migration allows for no net change in the total area of wetland environments. However, the ecologically important low marsh environment decreases by 15% while high marsh increases by 35%. The geomorphic stage of evolution of the barrier islands, transgressive versus regressive, also causes along-the-coast differences in how wetlands are expected to be impacted by sea-level rise.

\*\*\*\*\*

## Morphodynamics of barrier island evolution off SW Taiwan: An example from Wan-tzu-liao barrier, Tainan

LIN T.Y.(1), LOU J.Y.(2), LIOU J.Y.(3), HWUNG H.H.(4)

*(1) Department of Geography, National Taiwan Normal University, TAIPEI, TAIWAN ; (2) Department of Marine Science, Naval Academy, KAOHSIUNG, TAIWAN ; (3) Tainan Hydraulics Laboratory, National Cheng Kung University, TAINAN, TAIWAN ; (4) Department of Hydraulics and Ocean Engineering, National Cheng Kung University, TAINAN, TAIWAN*

A series of barrier islands are situated along the Tainan coast, in southwestern Taiwan, to form a barrier-lagoon system that plays an important role in coastal protection. Most of the sand barriers have become attached to the coastline during the last century due to human reclamation of the lagoon area, which has become used as breeding and fishing ponds. The Wan-tzu-liao barrier is the only island left that has retained its more natural state and could adjust itself to the changes created by coastal processes. In this paper, an extensive collection of vibration cores from different sedimentary environments of the Wan-tzu-liao barrier island is used to identify the sedimentary characteristics for each depositional unit. At the same time, the facies changes in the vertical stratigraphic sequences are used to speculate the possible environmental changes and explain the morphological evolution of the barrier island.

Based on preliminary analyses of the sedimentary sequences, the major processes that control the morphological changes of the barrier island may include : 1) the onshore-offshore sand movement facilitated by waves; 2) the prevailing longshore drift southward; 3) the strong wind transport southward during the winter; and 4) the overwash process that moves sand landward during a storm or typhoon. A transgressive model may be suitable for this barrier system. With the island migrating landward in response to the global trend of rising sea levels, this morphodynamic model predicts that the Wan-tsu-liao barrier's landward movement may accelerate and finally become attached to the continent coastline that is currently fixed at its position by a sea wall. Once the sand barrier is attached to the sea wall, it will become a sand beach at the toe of the sea wall, and, with rising sea levels, this sand beach would ultimately become submerged into the sea.

### **Linking nearshore and coastal changes in the southwestern North Sea and Dover Strait: the role of tidal sand banks on coastline evolution**

*HEQUETTE A.(1), RUZ M.H.(1), ANTHONY E.J.(2), MARIN D.(1)*

*(1) Université du Littoral Côte d'Opale, DUNKERQUE, FRANCE ; (2) Université Aix-Marseille, AIX-EN-PROVENCE, FRANCE*

Tidal sand banks occur extensively near the coast of the eastern English Channel and southern North Sea where they form linear shore-parallel, or slightly oblique, shallow sand bodies that affect the propagation of incident waves. Because they can play an important role in the dissipation and distribution of wave energy along the coast, they may have important effects on coastal morphodynamics and shoreline evolution. The coast of northern France largely consists of wide macrotidal sand beaches and coastal dunes that experienced contrasting evolutions during the last decades as revealed by aerial photographs. Hydrographic field sheets and historical bathymetry maps were used for mapping nearshore bathymetry changes since the 19<sup>th</sup> century. The spectral wave model SWAN was used for simulating wave propagation over different bathymetries in order to evaluate the effects of changing seabed morphology on wave refraction and on the pattern of wave energy distribution at the coast. Our results show variable nearshore sand bank evolutions that are associated with different shoreline changes along the coast. Sand banks commonly migrate alongshore at rates of several tens of m/yr due to strong alongshore-directed tidal currents that can be reinforced by wind forcing. Nearshore banks may also move onshore, but at slower rates, this landward movement being attributed to the action of storm waves. Onshore-migrating sand banks may eventually weld to the shore, supplying sand to the adjacent beaches, which can result in significant shoreline progradation. When sand banks are not attached to the shore, they are separated from the coast by a relatively deep channel that limits onshore sediment transport, favoring sediment deficit that may lead to shoreline retreat. Our results point to a strong relationship between changes in nearshore bathymetry and shoreline evolution, sand banks having different effects, however, depending on their depth, orientation and distance to the coast.

\*\*\*\*\*

### **Study of strandplain evolution along the Iranian coast of Makran (north western Indian Ocean) with application of ground penetrating radar**

*SHAH-HOSSEINI M.(1), MORHANGE C.(1), NADERI BENI A.(2), ANTHONY E.(1)*

*(1) CEREGE, AIX EN PROVENCE, FRANCE ; (2) Iranian National institute for Oceanography, TEHRAN, IRAN*

Omega shaped bays protected by rocky headlands are prominent morphological features in tectonically uplifting coast of Makran. In these bays the coastline is prograding and stranded coastal deposits are present to about 6 km from the modern coastline. Geomorphic landforms on these strandplains comprises of beach ridges, inter-ridge swales, sand dunes and fluvial deposits. The beach ridges are made of marine sand and shells trend parallel or nearly parallel to the modern shore. Strandplains of Chabahar bay studied along three shore-normal transects. Detailed mapping of geomorphic features took place based on SPOT5 satellite and radar imageries. Internal structure of the beach ridges imaged to a depth of 10 m at a resolution of 0.2 m using ground penetrating radar (GPR) with unshielded 100 MHz transmitter. Subsurface imaging complimented by direct observation of sedimentary sequences in vibratory cores and trenches. The chronology of the strandplain relies on the radiocarbon dating of fourteen minimum reworked marine shells collected from the beach ridges. Beach ridges are found to distance of more than 5 km from the coast and elevation of 12 m above the present sea level. GPR images reveal seaward dipping reflectors representing shoreface deposits which are capped by parallel or wavy foredune deposits. The contact between aeolian sand and underlying shoreface facies used as past sea level indicator. Dating on the marine shells from the swash zone deposits yields ages from 4800 to 270 years BP at the respective distances of 5 km to 500 m from the modern shore. Resulted profiles demonstrate up to 10m fall in local sea level during the last ~4800 years. The rates of changes in sea level vary in shore-normal and shore-parallel directions; this implies the controlling role of geological structures related to tectonic uplift in the formation of strandplains.

### **Anegada Island, British Virgin Islands: a case study of beach ridges**

GESCON A.L., COOPER J.A.G., JACKSON D.W.T.  
University of Ulster, COLERAINE, UNITED KINGDOM

Beach ridges occur worldwide in a variety of environmental settings. Their definition and formative processes, however, are still under debate. Of particular interest is their relationship to periods of storminess since in many cases they have been used as palaeostorm archives.

Anegada Island, located in the British Virgin Islands (Caribbean Sea), contains a 6 km<sup>2</sup> beach ridge plain with north and south-facing components. The northern (Atlantic-facing) plain has around 25 ridges while the southern plain has about 15 ridges. The origin of the beach sediments is the fringing coral reef that surrounds the island. The isolated site position is an opportunity to study the beach ridge formation without influence from other sediment sources.

Basing ourselves on six sets of historical aerial photos between 1953 and 2002 we have examined the beach ridge plain geometry and the temporal evolution of the shoreline. The southern beach ridge plain is more complex than the northern one and historical analysis shows that the south shore was reworked many times between 1953 and 2002. Accretion of around 80 metres has occurred at some locations along the north coast of Anegada Island within the same period.

On Anegada island west side we also examined a number of wave scenarios using a shallow water wave modeling (SWAN) to investigate the degree of forcing required to emplace the beach ridges.

Aerial imagery and wave modeling observations cast some light on the origin of beach ridges. Since 1953 several high magnitude storms were recorded in this area. For example Hurricane Donna in 1960 was at Category 4 when it passed over Anegada. This relationship between storm frequency and beach ridge genesis will be also discussed.

\*\*\*\*\*

### **Geomorphology and Internal Sedimentary Structure of Holocene Coastal Sandy Barriers along Rio de Janeiro Coast, Brazil**

FERNANDEZ G.(1), BAPTISTA DA ROCHA T.(2), RODRIGUES A.(3)

(1) Laboratory of Physical Geography (LAGEF). Univ. Federal Fluminense., NITEROI, BRAZIL ; (2) NEQUAT. UNIVE. FERDERAL FLUMINENSE, RIO DE JANEIRO, BRAZIL ; (3) LAGEMAR. UNIVERS. FEDERAL FLUMINENSE, NITEROI, BRAZIL

The coastline of Rio de Janeiro is a mosaic of environments, where we observed dunes, estuaries, rocky coasts, lagoons, deltas and mainly coastal sandy barriers (CSB). The morphology of CSB included different environments that extend from the backshore to the beach and shoreface. Several works development in USA, Europe, Australia and more recently in Brazil provides a well documented examples of morphological types that these features assume, specially related to the main process that controlled the Holocene evolution of CSB. These processes include sea level behavior, wave and tides regime, substrate morphology and gradient and sediment supply. The recent advances in high accurate morphological data by using Differential Global Positioning Systems (DGPS), airborne and terrestrial laser scanning create new possibilities for the study of CSB. If these studies include, for example, ground-penetrating radar (GPR) profiles, to show the internal sedimentary structure provides even better results. In this case the main objective of this work is describe the with high resolution data the different types of the geomorphology of the CSB observed along Rio de Janeiro coast. Associated with high resolution morphology, several GPR profiles were made to identify the subsurface structure. The results showed a coexistence of different morphological types of CSB, i.e. we identify regressive, transgressive and agradational barriers, distributed along the Rio de Janeiro coast. The regressive barriers were associated with the major rivers, suggesting the direct contribution of fluvial sediments. The internal structure observed by radar units shows a beach ridge pattern. The agradational barriers, marked by incorporation of aeolian sediments from the beach, by onshore winds, forming foredunes/blowouts, observed by high resolution data. Transgressive barriers forming by barrier-lagoon morphology, presents in the sedimentary structure facies derived from overwash above lagoon spits.

### Post-Little Ice Age evolution of High Arctic paraglacial coasts in Svalbard

ZAGÓRSKI P.(1), STRZELECKI M.(2), SUPERSON J.(1)

(1) *Maria Curie-Skłodowska University, Faculty of Earth Sciences and Spatial Management, LUBLIN, POLAND ;*  
 (2) *University Centre in Svalbard, Department of Arctic Geology, LONGYEARBYEN, NORWAY*

Since the end of the Little Ice Age (LIA) Svalbard landscape has been undergoing rapid environmental change and experiencing paraglacial readjustment transforming formerly glacial environments into non-glacial systems. In recent years the geomorphological research on Svalbard has focused on the paraglacial processes operating in proglacial zones and valley slopes of freshly deglaciated areas. On the contrary, relatively little is known regarding the potential impacts of paraglacial landscape transformation on the evolution of High Arctic coasts.

Here we analyse the mechanisms of adjustment of Svalbard coastal zone to paraglacial conditions associated with abrupt climate warming following the end of the LIA at the beginning of the 20th century. The results of the post-LIA observations document dramatic changes in sediment flux and coastal response under an intervals characterised by a warming climate, retreating local ice masses, a shortened winter sea-ice season and melting permafrost.

The attention is paid on the similarities and differences in the cascade of geomorphological processes which operate along the coastal zones in two following regions:

1) Recherchefjorden located in NW Spitsbergen – with coastal zone development influenced by storms developing in Greenland Sea

2) Northern Billefjorden located in central Spitsbergen – with coastal zone development constrained sheltered location, limited wave and prolonged sea-ice conditions.

The attention is paid on the similarities and differences in the cascade of geomorphological processes which operate along the coasts in two selected regions that differ in the intensity and frequency of storm events, climatic conditions and bedrock topography.

This study highlight the need for greater understanding of present-day geomorphological processes operating on High Arctic coasts, in the context global warming and accelerated rate of glacier retreat, future High Arctic landscape evolution is to be predicted.

\*\*\*\*\*

### Morphogenesis of Phra Thong's beach-ridge plain (Thailand) ' the contribution of gradual processes and episodic events

BRILL D.(1), BRUECKNER H.(1), JANKAEW K.(2), KELLETAT D.(1), SCHEFFERS A.(3)

(1) *University of Cologne, COLOGNE, GERMANY ;* (2) *Chulalongkorn University Bangkok, BANGKOK, THAILAND ;* (3) *Southern Cross University, LISMORE, AUSTRALIA*

Koh Phra Thong is located on the Andaman Sea coast of southwest Thailand, separated from the mainland only by tidal channels. The topography of the island is dominated by series of approximately shore-parallel beach ridges and swales, which reach heights of 2-5 m above mean sea level. While these morphologic features are predominantly covered by dense vegetation in the east of Phra Thong, they build up to an open beach-ridge plain in the 3 km wide western part of the island. Dating with optically stimulated luminescence (OSL) revealed an age of more than 100 ka for the eastern part of Phra Thong, thus suggesting a formation during the last interglacial period, while the western section accumulated during the last 6000 years. In general, the evolution of this beach-ridge plain was controlled by the littoral process responsible for the formation of single ridges and ridge sequences. While the ridges are formed by the longshore current together with the swash of waves in the stormy season, the periodic process of ridge-sequence formation was probably controlled by a combination of sediment supply and small-scale variations of the relative sea level due to tectonic uplift and subsidence at the Sunda Arc subduction zone. Variations in granulometry between different sections of the island, erosive discordances within the beach-ridge plain, and temporal changes of progradation rates between 30 and 250 m per century, point to repeated changes of these processes during the formation of the island. Another aspect is the episodic impact of tsunamis that inundated the island every 500-600 years, which may have contributed to the shape of the beach-ridge plain as well.

### **Middle to late holocene storminess record in western britany**

VAN VLIET-LANOE B.(1), HENAFF A.(2), DELACOURT C.(3), FERNANE A.(3), GOSLIN J.(2), HALLEGOUËT B.(2), PENAUD A.(3)

(1) UMR 6538 Domaines Océaniques, PLOUZANI, FRANCE ; (2) UMR 6554 CNRS LETG-Geomer, PLOUZANÉ, FRANCE ; (3) UMR 6538 Domaines Oc?aniques, PLOUZAN?, FRANCE

In order to have a better insight into the recurrence conditions for large storm event to assess coastal flooding risk, the record of storminess has been analysed on the southern coast of Audierne's Bay and in other sites of western Brittany. This work belongs to the COCORISCO project. Drilling transects, stratigraphic works and dating have been performed to constrain the chronology, the strength and if possible the wind direction of the main events. New dating, with recalibration of older one in a specific stratigraphic context, at Audierne and along the coasts of Brittany allow to define the conditions of occurrence of at least centennial events. A renewed relative eustatic curve has been constructed for the region on SLIP methodology (see Goslin et al.). Most events seem linked with cooling episodes, a negative winter NAO and a relative sea level close to the present one. A series of millennial storms occurred immediately prior to the Middle Age thermal Optimum. Other storms are clearly responsible for breaching, sand drift and dune building or remobilization. A direct consequence of it is the building of the recent coastal dunes from 1100 AD. Even storms exist at least since the Subboreal cooling, the storm frequency and intensity rose by steps during the Late Holocene. The maximum efficiency is reached during the Little Ice Age, during and after the Maunder solar minimum, with clustered events and duration of several days. This increase in storminess during the late Holocene is in agreement with the orbital forcing and the Holocene glacial history.

\*\*\*\*\*

### **Geomorphology, sedimentology and geochronology of cyclone-generated landforms and washover deposits along the coasts of NW Australia**

MAY S.M.(1), ENGEL M.(1), BRÜCKNER H.(1), PINT A.(1), KELLETAT D.(1), SCHEFFERS A.(2), SQUIRE P.(2)

(1) Institute of Geography, University of Cologne, COLOGNE, GERMANY ; (2) Southern Cross GeoScience, Southern Cross University, LISMORE, NSW, AUSTRALIA

Palaeotempestological research uses sedimentary evidence to enlarge the temporal frame of storm occurrence patterns given by historical records. Different sedimentary archives storing traces of tropical cyclone impact (washover fans, back-barrier mud flats, beach ridge systems) were investigated along the coasts of the Exmouth Gulf (W Australia) in order to evaluate their use for palaeotempestological research. (1) Washover sediments W of Onslow indicate several depositional units of mainly well-stratified sand with distinct heavy mineral laminae of varying concentrations, similar to modern storm and tsunami deposits documented in comparable settings. Different depositional events (cyclone and/or tsunami) can be inferred according to bioturbation horizons. (2) Along the W coast of the Exmouth Gulf, distinct lobate washover fans exhibit washover terraces, channel systems and delta-type sedimentation patterns. Their stratigraphy consists of shell debris layers, sand, coarse coral fragments and entire shells. Multiple reactivation of the washover fans is inferred from their complex pattern of accumulation and incision and a minimum of three palaeosols, each of them indicating one depositional event and a subsequent period of geomorphologic stability. (3) In Giralia Bay, S Exmouth Gulf, sandy chenier-like beach ridges characterize the landward boundary of extensive mud flats. Their geomorphology and stratigraphical architecture reflect the influence of intermittent/sporadic phases of morphodynamic activity due to littoral-type processes and are assumed to record recurring cyclone impact. Our preliminary findings suggest that the investigated sedimentary archives have a high potential for improving extreme wave histories (tsunamis, cyclone landfalls) of W Australia. Main challenges include dating ( $^{14}\text{C}$ , OSL, U/Th,  $^{210}\text{Pb}$ ) and distinguishing (a) between event and non-event processes, and (b) between event types, based on sedimentology, microfauna, and shell taphonomy.

## Storm Regime and Morphological Changes at Different Time Scales on the Romanian Black Sea Coast

VESPREMEANU-STROE A., TATUI F., CONSTANTINESCU S., PREOTEASA L., ZAINESCU F.

University of Bucharest, BUCHAREST, ROMANIA

An expected consequence of global climate change that will potentially impact the coastal landscape in the 21st century include an increase in storminess, which could result in an intensification of coastal erosion and more frequent flooding of low-lying coasts. Storminess can vary as a function of the local climatic variability, ultimately controlling the intensity of the coastal dynamics.

Hourly wind speed and direction data registered between 1960 and 2012 at five meteorological stations placed on the Romanian Black Sea coast were used to analyse the coastal storm ( $v \geq 10$  m/s,  $T \geq 24$  h) regime: mean wind speed, total duration, resultant wind direction, storm severity index – SSI and storm impact factor - SIF.

The coastal storms temporal variability shows three active intervals (1961-1973, 1975-1978, 1995-1998), with high intensities of both the erosional and accretional coastal processes, and two calm periods (1989-1994, 2005-2012), with a decrease of 50-70% of the shoreline migration rates. The last interval (2005-2012) is an exceptional negative anomaly, the storm frequency being half of the multi-decadal average. All intervals are strongly negatively correlated with the North Atlantic Oscillation ( $r = -0.76$ ), which demonstrates the control of climate variability systems on the frequency and intensity of winter storms on the Romanian Black Sea coast.

This coast is subject to intense geomorphological processes with a net domination of erosion (70% of total shoreline length). The strongest coastal processes are recorded during winter, due to high storms frequency and magnitude. The storm activity is responsible for 62% of the total longshore sediment transport (LST); moreover, the high prevalence of northern storms (89% from all storms) imposes an unidirectional development for many coastal processes at different time scales: LST, aeolian sediment transport, sand wave migration and deltaic lobes lop-sided development.

\*\*\*\*\*

## Coastal Foredune Evolution Under Extreme Events: Superstorm Sandy

PSUTY N.(1), SCHMELZ W.(1), SPAHN A.(1), CHRISTIANO M.(2)

(1) Rutgers University, HIGHLANDS, NEW JERSEY, UNITED STATES ; (2) National Park Service, NEW YORK, UNITED STATES

The impacts of superstorm Sandy produced major changes to the geomorphological features of the Fire Island (USA) barrier island, a coastal barrier consisting of a National Seashore, a State Park, a County Park, and seventeen private communities. The changes may represent a step-wise displacement in the evolution of the barrier island and an episodic response to the effects of sea-level rise and negative sediment budget. The changes produced in this latest major hurricane have resulted in numerous instances of barrier washover, foredune erosion, inlet creation, and shoreline migration. Long-term monitoring (since 1976) of the foredune system on portions of the barrier island helps to provide perspective to these latest changes. They can be indicative of the nature and dimension of foredune erosion, recovery, and spatial displacement. The present dimensional analysis combines the products of previous monitoring results with extensive LiDAR data sets to provide a unique insight to the barrier's morphological response and evolution associated with extreme events. Further, responses are analyzed across the several types of land ownership and land use that incorporate differing coastal beach and foredune management strategies in the public and private sectors of the barrier island.

**New understanding and prediction of storm impacts on gravel beaches (NUPSIG project): roles of geomorphological investigation and numerical modelling**

MASSELINK G.

*Plymouth University, PLYMOUTH, UNITED KINGDOM*

Gravel beaches protect low-lying back-barrier regions from flooding during storm events and their importance to society is widely acknowledged. Unfortunately, breaching and extensive storm damage has occurred at many gravel sites and this is likely to increase as a result of sea-level rise and enhanced storminess due to climate change. Limited scientific guidance is currently available to provide beach managers with operational management tools to predict the response of gravel beaches to storms. The New Understanding and Prediction of Storm Impacts on Gravel beaches (NUPSIG) project aims to improve our understanding of storm impacts on gravel coastal environments and to develop a predictive capability by modelling these impacts.

The NUPSIG project uses a 5-pronged approach to address its aim: (1) analyse hydrodynamic data collected during a proto-type laboratory experiment on a gravel beach; (2) collect hydrodynamic field data on a gravel beach under a range of conditions, including storm waves with wave heights up to 3 m; (3) measure swash dynamics and beach response on c. 6 gravel beaches during extreme wave conditions with wave heights in excess of 3 m; (4) use the data collected under 1-3 to develop and validate a numerical model to model hydrodynamics and morphological response of gravel beaches under storm conditions; and (5) develop a tool for end-users, based on the model formulated under (4), for predicting storm response of gravel beaches and barriers.

Results of the NUPSIG project will be presented and it will be argued that both geomorphological investigation and numerical modelling are required to significantly enhance understanding of gravel beach response under extreme conditions. It will also be argued that for the new understanding to have a significant impact on sustainable coastal management, end users need to be involved from the outset of the project, during the design of research approach and deliverables, and not added as an afterthought.

\*\*\*\*\*

**The impact of extreme and above average processes on morphodynamics of cliff slumps (Wolin Island - NW Poland)**

WINOWSKI M.

*Adam Mickiewicz University, POZNAN, POLAND*

Extreme processes undoubtedly have a major impact on the functioning of the Polish coast. These processes are the most common factor initiating the development of the coast. Increased activity of the sea and weather factors often results in the intensification of slope processes on sea cliffs. The result is the forming of new slumps and activate existing ones.

Based on the correlation of hydro-meteorological conditions prevailing over the last four decades, the date of initiation of slumps and field observations was recognized the origin of slumps and partial course of slumps development. To recognize slumps age, the dendrological method was used and the analysis of documentary material collected in the Department of Geoecology of the Adam Mickiewicz University in Poznan since 1981.

In total, over the last four decades (1973-2009) six episodes that have had a significant impact on the development of landslides within the cliffs of the island of Wolin were documented. Analysis of these episodes has allowed to determine the thresholds of slumps creation. On the base of the proposed thresholds, a catalog of extreme hydro-meteorological events (1973-2009) was presented. The analysis of presented events showed that in past 37 years extreme hydrometeorological phenomena occur on average every 2 years and 4 months and the frequency at this time grew three times.

## **New insights on morphological and sedimentary evidences of high energy marine flooding along the Moroccan Atlantic coast**

EL TALIBI H.(1), ZAGHLOUL M.N.(1), ABOUMARIA K.(1), WASSMER P.(2), MERCIER J.L.(3)

(1) Department of Earth Sciences, University Abdelmalek Essaadi, Faculty of Science and Technology, TANGIER, MOROCCO ; (2) Laboratoire de Géographie Physique, UMR 8591, Université Paris 1 Panthéon-Sorbonne, MEUDON, FRANCE ; (3) Faculté de Géographie et d'Aménagement, Université de Strasbourg, STRASBOURG, FRANCE

Despite a position along the passive margin of Africa, the Moroccan Atlantic coast is under the influence of the earthquake generation zone related to the collision between African and European plates along a W-E fault line crossing Gibraltar strait. The 1755 Lisbon quake, with an epicenter located 200 km WSW Cape St. Vincent, triggered a tsunami that struck the shores of Portugal 20 minutes after the earth tremor. Southward, the Moroccan coastline was affected by tsunami waves reaching 2 to 15 m in depth as documented in western historic archives for the cities of Tangier, Asilah, Sale and Mazagao. Investigations along the Moroccan coastline based on sedimentary proxies, in the framework of the MAREMOTTI project, led to propose a lowering of these values. Recently, we re-investigated the Moroccan Atlantic coast and found out morphologies and sedimentary deposits evidencing a strong energy flooding event. This event we attribute to the 1755 tsunami leaves noticeable traces on a hilly dissected topography. In the proximal domain, no deposits were emplaced. The strong turbulence of the flow allows a complete erosion of the soil. Landward, the decreasing of the energy induced a strong depositional process. The thick brownish sandy layer deposited contains at the base large angular rip-up clasts of dark soil. Marine origin of the deposits is attested by the presence of benthic and planctonic foraminiferas (*Ammonia tepida*, *Globigerinoides sphaeroidinellopsis*; *Bulimina sp...*). In the distal domain, the sudden loss of energy due to a reverse slope results of an accumulation of a huge amount of unsorted marine bioclasts, remains of microlithic industry, rounded pebbles, sub-angular beach rock clasts and fragments of pottery displaying blunt breaks. Beyond an undulating line, the energy was insufficient to erode the soil which remained unaffected. These new insights plead for a high energy flooding that might be consistent with the waves depth provided by the 1755 archives.

\*\*\*\*\*

## **Coastal multi-hazard cascades: how 12 seconds can reset baselines & trigger decades of coastal system adjustment**

HART D.E.

University of Canterbury - Geography, CHRISTCHURCH, NEW ZEALAND

Coastal environments are characterised by complex processes which interact with each other and respond to antecedent conditions. Such geomorphic dynamism, combined with the current global population 'rush to the sea', makes coastal hazard management a challenging problem. This presentation uses the example of earthquakes in an urban coastal setting to show how one type of geomorphic trigger can induce a cascade of changes that alter numerous coastal hazards risks.

From 2010 to 2011 Christchurch, New Zealand, experienced a shallow earthquake sequence, including a devastating 5 km deep, 6.2  $M_M$  quake with peak ground accelerations of 2.2 g. The seismic shocks radiated through the Holocene progradational plain occupied by the city, triggering extreme liquefaction; flooding; subaerial and submarine ground deformation; riverbank rafting and channel shrinkage; fine sediment pulses in tributaries, streams, estuaries and beaches; pollutant leakage into waterways; and widespread failures of coastal and riverside lifelines networks.

Instantaneous coastal consequences included relative sea level and horizontal shoreline changes of up to 1 m; marine cliff collapses; loss of tidal prism capacity and estuary surface area; isolation of harbour and bay suburbs; and prolonged closure or total loss of many coastal and river recreation amenities. Ongoing responses include unprecedented fining of beach deposits; low recruitment of marine and estuary biota; shoreline shifts; and changes to sediment budgets, mudflat profiles, and storm, tsunami and sea level rise risks.

Most of the earthquake effects can be explained by seismic interactions with coastal and river environments, past, present and future. As such, the Christchurch experience graphically illustrates why local awareness of the potential for coastal hazard cascades is essential for planning responses to coastal events that avoid exacerbating existing and future coastal hazards.

### **Extreme sea-level rise and adaptation options for coastal resort cities**

LEMCKERT C.(1), COOPER A.(2)

(1) Griffith School of Engineering, SOUTHPORT, AUSTRALIA ; (2) University of Ulster, COLERAINE, UNITED KINGDOM

The Gold Coast, Queensland, Australia, like many other localities around the world, is a coastal resort city whose urban environment has evolved through a series of human interventions on the natural shoreline and backshore zone. Such cities rely on a perceived high quality environment to attract tourists, which in turn results in them being reliant on continued maintenance operations. Any sea-level rise, for whatever reason, is likely to result in increased inundation frequency and shoreline erosion episodes. In this presentation we consider adaptation options and possible strategies for the city under various future high-end sea-level rise (SLR) scenarios of 1 m, 2 m and 5 m. We assume the beach and waterways must be preserved to enable the city to continue to exist as a resort environment. It is concluded that pre-planned adaptation would probably enable the city to survive SLR of 1 m. For a 2 m SLR we postulate that even with an adaptation plan in place, the scale of measures required would severely stretch the city's resources. Under a 5 m SLR we do not believe that any amount of planning would enable the city to survive as a coastal resort due to excessive cost. Such outcomes are expected to have international applicability.

\*\*\*\*\*

### **Holocene sedimentary processes in the West Bengal Sundarbans: facies dynamics in a peri-marine environment**

FLOOD R.(1), ORFORD J.(1), TURNER J.(2)

(1) Queen's University Belfast, BELFAST, UNITED KINGDOM ; (2) University College Dublin, DUBLIN, IRELAND

The Bengal Sundarbans is one of the largest tidal halophytic mangrove forests in the world stretching across the India-Bangladesh border. Situated between the river Hoogli in the west and the Ganges-Brahmaputra delta to the east, the Sundarbans was declared a UNESCO World Heritage Site in 1987 and serves as the primary habitat for endangered flora/faunal species. The relevance of this research is to identify the sources and fate of sediments in the Indian (West Bengal) Sundarbans tidal islands on the contemporary inactive deltaic system to the west of the present day Ganges-Brahmaputra, dominated by river estuary and cyclone activity. Through the application of geochemical and sedimentological facies analysis, an enhanced understanding of the Sundarbans sedimentary dynamics can be discerned. Geochemical and textural analyses have been completed on three cores from uninhabited intertidal islands (c 9m max depth) with high resolution geochemical (X-ray fluorescence (XRF)) and x-radiography carried out using ITRAX<sup>TM</sup> core scanning. Speculation regarding the sedimentary provenance in the Sundarbans has been viewed as being primarily marine-derived from the currently active delta front of the Ganges-Brahmaputra to the east of the Bengal Basin (Battacharrya et al., in press). The results obtained in this project, question such claims of provenance and processes with sedimentary pathways being more complex. Sediments appear to be the outcome of reworking within the deltaic-estuarine system with siliclastic and possible terrigenous loads dominating the sedimentary facies. Tidal geomorphological processes represent the dominant controls over sediment re-distribution within the Sundarbans, with possible high-energy depositional events characterising stochastic variation. The Sundarbans inter-tidal sedimentary environment is not completely understood, yet is central to the future of ca. 4 million inhabitants in a changing peri-marine environment.

### **The Influence of Tide for Suspended Sediment Transport in Barito River Delta, Southern Kalimantan, Indonesia**

ARISANTY d., SARTOHADI J., MARFAI M., SRI HADMOKO D.  
Gadjah Mada University, YOGYAKARTA, INDONESIA

Delta is an accumulation of sediment that influences of river and marine. Marine agent has a function to redistribute sediment in delta, such as tide. Intensively, tide influenced Barito Delta development. Barito River Delta was one of delta in Kalimantan, Indonesia. This delta was flat topography which southern part and central part of Barito Delta elevation were about 0-2 m above mean sea level, then rising to 3-4 m to the northern of Barito Delta.

Survey method was used in this research. Tidal measurement location consisted of 4 location, i.e. Tamban channel, Trisakti harbor, and Kapuas (lower part of delta) and Belawang (upper part of delta). Tide was measured in dry season and wet season for one day with 1 hour interval. Suspended sediment was taken on the highest and lowest tide level during 24 hour.

The research showed that tide in wet season was higher than in dry season due to rain water. Both in wet season and dry season were no significant differences of the height of tide between spring tide and neap tide. In wet season and dry season, low tide transported suspended sediment more intensively than high tide in spring tide and in neap tide. The velocity of tide current was higher in the low tide than high tide hence the sediment was transported was higher in low tide than high tide. The influence of tide to sediment transport decreased in upper part of delta (Belawang).

Keywords: Barito River Delta, Tide, Suspended sediment

\*\*\*\*\*

### **Altération of delta morphology by channel abandonment processes at Mahakam delta, east Kalimantan, Indonesia**

HUSEIN S.  
Department of Geological Engineering, UGM, YOGYAKARTA, INDONESIA

The modern Mahakam Delta, East Kalimantan, Indonesia, has been acknowledged as a typical example of a tropical mixed fluvial and tide-dominated delta (e.g. Galloway, 1975). Its subaerial delta plain has a fan-shaped morphology and is dissected by numerous distributary and estuary channels. As distributaries branch seaward out from the delta apex, they can be grouped into the northern and southern areas, while the central area is only occupied by estuaries.

This study investigates the distributary abandonment processes in the northern area which has 3 distributaries and 3 estuaries, by using echo-sounding profiles, grab sediment samples and hydrodynamics measurement. Distributaries exhibit relatively straight channels with flaring mouths while estuaries are more sinuous and have deeper and smaller mouths. Sand is more distributed in the bottom of the active distributaries than in the abandoned distributaries and gradually fines seaward but does not extend to the channel mouths while mud dominates the estuaries and the distal reaches of the distributaries. Hydrodynamic data indicates that the interaction of fluvial and tidal processes is dynamically active along the entire length of the distributaries. Fluvial processes dominate the sandy reaches of the distributaries, while tides are the most important process in the lower reaches of active distributaries, the inactive distributaries and estuaries.

This study suggests that the channel abandonment processes in the Mahakam Delta is sequential. As the tidal processes become more dominant, fluvially-supplied sand is being stored onshore in the distributaries and tidal processes are modifying distributary morphology and dominating sedimentary facies progressively further landward. As a whole, the present-day deltaic lobate morphology reflects a relic geometry of a former fluvial-dominated delta.

## Formation and evolution of the abandoned Yellow River delta

ZHANG Y.

*School of Geographic & Oceanographic Sciences, Nanjing University, NANJING, CHINA*

A large scale delta, called the Abandoned Yellow River delta (AYRD), was built at the middle of Jiangsu coast while the Yellow River entered into the Yellow Sea during 1128-1855AD. It formed a promontory in the Jiangsu coast, and the Jiangsu coast changed into the tide dominated tidal flat coast from the wave dominated sandy barrier bar – lagoon coast.

Since 1855AD when the Yellow River returned back to enter into the Bohai Sea, lost the huge sediment supply suddenly, the coastline of AYRD began to retreat rapidly suffering from the coastal erosion. In the early stage, the coastline retreated 400m/a at the cape part, and more than 23km withdrew so far. Furthermore, the erosion coast extended southwards. -5 m and -10 m isobaths regressed landwards. The offshore slope changed from convex shape into concave shape, and then retreated paralleled. The abandoned river mouth became a small estuary, formed chenier in the middle of 20<sup>th</sup>. After the high dikes and groins were constructed later of 20<sup>th</sup>, the regressive progress of the coastline was stopped. The abandoned river mouth turned into a small artificial bay, and the silty sand beach formed inside with remnant silty deposits. Obviously, wave dynamics is becoming active again along the coast. Meanwhile, the offshore slope is increasing, and -15m isobaths is moving landwards rapidly while part of the erosional materials are deposited in certain offshore area. Consequently, -10m~-15m deep tidal channels have been formed in the offshore area along the both sides of the AYRD. The surface sediment of the sea bottom is getting coarser, fine sand distribution area is extending landwards. The underwater part of the AYRD is still adjusting controlled by the wave and tide dynamics.

\*\*\*\*\*

## Longshore drift and sand sequestering in river deltas

ANTHONY E.

*Aix Marseille Universite, Institut Universitaire de France, CEREGE UMR CNRS 7330, AIX-EN-PROVENCE, FRANCE*

The retention of river-borne sediments essential to delta growth under a stable sea level depends on the receiving basin characteristics and on the relative influence of river, waves and tides, the three cornerstones of delta morphological classification. The wave factor primarily concerns longshore transport of river-supplied bedload. Strong unidirectional longshore drift can prevent delta development, or lead to strongly longshore-skewed deltas that eventually cease to prograde, with sand totally evacuated downdrift, giving a simple equilibrium drift-aligned delta shoreline, as in the textbook example of the Senegal delta. Even where wave influence is strong, large-scale delta morphodynamic adjustments can command the longshore drift cell structure, preventing sand leakage from the system. Wave-angle control has been advocated as a cause of drift reversal downdrift of wave-influenced delta mouths<sup>1</sup>. Similar drift reversal also occurs well downdrift of delta mouths where shoreline orientation changes rapidly due to more pronounced progradation in the mouth(s) sector where the 'hydraulic groyne' effect of river (+ tidal) discharge refracts waves, resulting in conservation of a large share of the bedload for progradation. The downdrift delta termini are commonly prominent sand spits. Examples occur on many deltas, including the Rhône and Ebro. Where several distributary mouths occur, multiplying the hydraulic groyne effect, pronounced longshore variability in wave-induced sand transport ensues, resulting in multiple drift cells that assure sand retention, as in the Mekong and Niger deltas. By affecting the way waves redistribute delta sediments, these controls express fluvial (+ tidal) determinants on delta development even when the ambient wave influence is strong, as shown by the wave-formed beach-ridge sets common in these deltas.

<sup>1</sup>Ashton, A. D., L. Giosan (2011), Wave-angle control of delta evolution, *Geophys. Res. Lett.*, 38, L13405, doi:10.1029/2011GL047630.

### **Temporal and spatial variability of coastal change on deltaic coast of Tabasco, Mexico**

MAGDIEL LYDIA B.R., ORTIZ PEREZ M.A.  
UNAM, Instituto de Geografía, MEXICO, MEXICO

The coastal plain more extensive and one of the most important in the southern Gulf of Mexico, is the coastal plain in the state of Tabasco in Mexico, associated with recent geological sedimentation processes of the central basin of the hydrological system the rivers Usumacinta-Mezcalapa. Even though predominant a plain fluvio-deltaic.

The coast of Tabasco presents remarkable changes in the advance and retreat of the relative position of the shoreline, which is attributed to the nature of the system changes in fluvial-deltaic and morphological adjustment to the front beach hydrodynamic conditions, which is uneven from one sector of the coast to another sector.

The dynamics of coastal environments exposed to the sea, like inlets and barrier islands, the dispersion control removal and deposition of sediments transported streams or channels adjacent to the margins of the inlets and barriers, which cause deposition or erosion on shoreface.

The morphodynamic coastal is the result of the interaction of variables that play a role in changing the relative position of the coastline, such as:

- a) Changes in the hydrodynamic conditions of the coast, mainly the relative rise in sea level by the inverse barometer effect, which is the response of the ocean surface to changes in atmospheric pressure.
- b) The variations in the circulation of winds and ocean currents, which are translated into a greater intensity of tropical cyclones, hurricanes, storm surges and tickets, "North" significantly affecting the coast of Tabasco.
- c) Changes in sediment dynamics, affected mainly by longshore transport of littoral drift along the coast.
- d) The redistribution of sedimentary deposits, generated mainly by diffraction and refraction of waves and local currents, near the margins of the barrier islands and their mouths.

\*\*\*\*\*

### **Geomorphology and evolution of the Save River Delta plain, South-Centre Mozambique**

MASSUANGANHE E.(1), WESTERBERG L.O.(1), ACHIMO M.(2)  
(1) Department of Physical Geography and Quaternary Geology, Stockholm University, STOCKHOLM, SWEDEN  
; (2) Department of Geology - Eduardo Mondlane University, MAPUTO, MOZAMBIQUE

Located in South-central Mozambique, the Save River delta is one of the larger deltas in Southern Africa and records its evolution by the geomorphologic features and sediments. In this study we used satellite images (Spot 5) and aerial photos to interpret and map the geomorphologic units of the delta aiming to assess the evolution of the delta plain. The map was integrated with field observations and sedimentary logs from exposed sections along the main river channel and cores. Additional analysis for grain size and radiocarbon dating was also performed. The results of this study show that the delta plain is composed by mangrove wetlands lying in intertidal flats characterized by a sequence of 1 to 2 meters of clay with organic matter intercalated with fine sand layers and overlapping medium to coarser beach sand. The mangrove wetland is crossed by beach ridges and dunes lying parallel to the present coastline, and coastal dunes forming a barrier to the open sea overlapping the wetland. Alluvial terraces, located topographically higher, stand morphologically elongated seawards at the center of the delta plain. Stratigraphically this unit is characterized by cyclic sequences of alluvial sand intercalated with bioturbated clay (at the bottom), peat layers (in the middle) and paleo-topsoil (in the top) for at least 4.5 meters of thickness. Incisive paleo-channels in the upper layers filled by very fine sand record the late distributary pattern of the river during the depositional process of the terrace. In overall, the geomorphologic and sedimentologic features of the Save River delta have evolved strongly controlled by the river in a progradation system covering the intertidal deposits. Ongoing dating will provide time sequence for these processes.

### **A renewed Holocene relative sea-level envelope for Western Brittany (France): Global signal and local artefacts**

GOSLIN J.(1), VAN-VLIET LANOË B.(2), HENAFF A.(1), DELACOURT C.(2), FERNANE A.(2), HALLEGOUET B.(1), PENAUD A.(2), SUANEZ S.(1)

(1) GEOMER, CNRS UMR 6554, IUEM, UBO, PLOUZANÉ, FRANCE ; (2) Domaines Oceaniques CNRS UMR 6538, IUEM, UBO, PLOUZANÉ, FRANCE

Along the last fifty years, researches made on Holocene sea-level reconstruction led to demonstrate that no real consensus exists on the Holocene eustatic curve at a worldwide scale (Fairbridge, 1961, Jelgersma, 1979, Gehrels, 1999, Vella & Provansal, 2000, Laprida, 2007). Then, many studies put in light that even sea-level reconstructions constructed from regions of a same oceanic facade could led to different results (e.g. for the French Atlantic coast, Morzadec-Kerfourn 1974, Ters, 1986, Lambeck, 1997, Stephan, 2011, Goslin et al., submitted). In particular, it has been continuously discussed whether sea-level rose under a continuous trend until present-day level or followed an oscillating pattern with negative variations superimposed on this global rise-tendency.

In Brittany region, a need for a renewed sea-level curve was felt in the framework of the COCORISCO research project on coastal risk assessment. New data were obtained all around the Finistère peninsula by performing a total of 25 new percussion cores and drillings. Particular attention was paid to the diversity of the studied sites, in terms of morphological site configurations, size, and storm swells exposition, in order to have the best insight of possibly recorded relative sea-level variations.

Thanks to more than 60 new C14 datings, this work represents a major advance in the knowledge of Brittany Holocene relative sea-level history. Results we obtained put in light the complex connections that exist between global sea-level signal and local sites sedimentary records. If correlations with global Holocene climatic cycles could be observed, it appears that negative sea-level signals observed in some sites could not be supported when confronted to other records. New information obtained on two sites by bathymetric and seismic campaigns will help to form hypothesis on specific local morphological evolutions and on the possible behavior of Brittany sedimentary stocks to Holocene sea-level rise.

\*\*\*\*\*

### **Incipient foredune development along macrotidal beaches, Northern France**

RUZ M.H.

*Université du Littoral Côte d'Opale, DUNKERQUE, FRANCE*

Incipient foredunes are new or developing foredunes forming by aeolian sand deposition within pioneer plant communities on the backshore of beaches. They represent the initial stage of foredune formation and are usually found along stable to prograding coastlines. Most studies on incipient foredune formation and evolution were carried out along micro to mesotidal coastlines while incipient foredune development on macrotidal coasts received little attention. The aim of this study is to describe incipient foredune development along macrotidal sandy beaches of northern France. In this area, where mean tidal range varies from 8 to 4 m, the beaches are 400 to 700 m wide at low tide and are characterized by a bar-through topography. Along stable to slowly prograding beaches, characterised by a narrow (< 30 m wide) upper beach, "classical" incipient foredunes are found. They develop from pioneer plant seedling in the wrack line seaward of the foredune stoss slope. In areas of sufficient sediment supply they rapidly coalesce, eventually forming a continuous dune ridge that develops into a new foredune. Along rapidly advancing shoreline sectors, specific incipient foredunes develop. Near Calais, onshore bank welding in the recent past has created a large sand flat up to 1000 m wide at low tide, offering a very important fetch and serving as a substrate for significant embryo dune development. At the landward margin of this sand flat, discrete hemispheric low elevated convex mounds (coppice dunes), surrounded by water during spring tides developed. They evolved *in situ*, growing in height over time, forming "mega" nekha, more than 3 m high. They are aligned parallel to the shoreline and still separated from the established foredune by a swale reached by uppermost water levels. Ultimately they could form a new foredune ridge. Along this macrotidal coast, the width of the upper beaches appears as a major factor controlling incipient foredune development.

## Morphological types of foredunes in Poland as an indicator of coast trend changes

LABUZ T.

*University of Szczecin, Faculty of Geosciences, SZCZECIN, POLAND*

The Polish coastal zone localized on south Baltic coast is 500 km long and mainly exposed on N direction. It is aligned and built by loose material (sand, till or peat, mainly). Almost 85% is built by sandy aeolian deposits creating different dune types. Among them typical coastal dune ridges are covering sand spits, barriers or lowlands on which they are developed. Only 15% of coastal dunes are in accretion phase. Foredunes - called incipient dunes - are an indicators of accumulative character of the coast. This work is a part of project called FoMoBi ([www.fomobi.pl](http://www.fomobi.pl)) – that is aimed to recognition of morphology and biodiversity of accumulative dune sections of Polish coast. Project is financed by Polish National Centre for Research and Development (NCBiR).

Work presents issues of foredunes morphodynamics classification that is created due to conducted field works and laboratory analyses. Methods of the field research are: i) field leveling as profiles across coastal forms, ii) surface measurements in plots 5x5 m of the embryo dunes on the upper beach and on larger areas 200 m along foredune ridge as 3D leveling using GPS RTK base and in future iii) ground laser scanning as a innovative tool.

There are used some indicators of relief changes as: foredune base and ridge or edge movements, foredune height and dune base width, beach width and height, height and dynamics of embryo dunes on the beach.

Foredunes are very variable in time and space where their surface changes is effect of several factors irregularly affecting through year. On the Polish coast there are few dynamics types of foredunes: A - coast of fast progradation with several small sandy dykes, B - one high still grooving dyke on stable coast, C - more or less stable dune occasionally eroded and restored, D – accumulative coast with withdrawing ridge due several erosion phenomena.

\*\*\*\*\*

## Decrease of the supply of wind-blown sands in front of artificial pine forest in coastal dunes

CHOI K.H., KIM Y.M., JUNG P.M.

*National Institute of Environmental Research, INCHEON, SOUTH KOREA*

Forestation on the coastal dunes has been thought to stabilize the dune landscapes and protect the residential area from strong winds, blown sands, and salt spray. Planting pines for dune stabilization was very common in the past and has still been performed by local governments in South Korea. However, it could cause coastal landscape less dynamic and deprive of its natural ability to recover, which in turn, results in a retreat of coastline. In this study, we compared topographic changes in the front side of artificial pine forest and the grass-covered area, for the purpose of the effectiveness of planting trees on dunes. We constructed two monitoring plots featured by AWS (automatic weather stations), erosion-deposition pins, and vegetation quadrats at each site, and have collected wind data and vegetation change as well as the information on the pattern and rate of wind-blown deposition of sandy materials since February 2011. Sand dunes on both sites grew from late winter to spring, when the strong northwesterly wind is dominant. From March to April, thick deposition was observed on the front side of the grass-covered dune: the sand dune piled up to ca. 30 cm vertically and advanced ca. 25 m landward from the high tide line. On the other hand, it affected only ca. 10 m landward in front of the forested area, with newly deposited materials less than ca. 12 cm. This small accretion might be related with the frequency of the effective wind. Compared with the grass-covered area, the mean wind velocity in artificial pine forest area decreased by up to 50%. Especially, the velocity of the strong winds faster than 4.5 m/s diminished to 25% of the control sites, resulting in decreased blown sand supply. Planting pines seems to be ineffective in protecting pines, but rather it lead negative impact on coastal dunes. It may result in a retreat of coastline, loss of land, and devastation of dune ecosystems.

### **Dune fences efficiency assessment on northern beaches of Portugal**

*PINHO J.(1), GRANJA H.(2), ALMEIDA E.(3), HENRIQUE A.(4), TEIXEIRA A.(3), VIEIRA S.(3)*

*(1) C-TAC/ Department of Civil Engineering, University of Minho, BRAGA, PORTUGAL ; (2) CIIMAR/ Department of Earth Sciences, University of Minho, BRAGA, PORTUGAL ; (3) University of Minho, BRAGA, PORTUGAL ; (4) Biological Park of Gaia, VILA NOVA DE GAIA, PORTUGAL*

The coastal zone of the northern region of Portugal has experienced a continued erosion process whose mitigation has passed, at an early stage, by the construction of coastal defense structures (mainly groins and revetments) that, given the acquired experience and current economic context, has revealed to be a solution whose efficiency and effectiveness are questionable.

Finding low cost alternatives to increase the resilience of coastal systems based on natural processes dynamics is an important area of applied research, allowing alternative sound responses in a context of progressive erosion of coastal systems beaches and dunes.

In this work we present results obtained for coastal segments of Vila Nova de Gaia municipality, Portugal, where a considerable investment on dune fences installation was done in an attempt to increase and recover the back dunes and their ecosystems through the trap and effective accumulation of sand moved by local winds.

Observation methodology is based on two different approaches: (i) coastal digital elevation models where derived recurring to aerial photogrammetric techniques (November 2008, April 2009, November 2009, May 2010); (ii) local measurements where conducted during the year 2012 in a set of dune fences. Obtained field data was processed through geographic information systems (GIS) tools.

During the observation period, the sediment budget was predominantly stable, although for some locations a positive trend was clearly observed. In some cases, the dune fences infilling was completed in a year. Obtained aeolian fluxes are presented as well as correlation results for wind and precipitation patterns.

\*\*\*\*\*

### **The role of the inter-bar depressions in hydrodynamic and sediment transport processes of sandy macrotidal beaches**

*CARTIER A.(1), HÉQUETTE A.(1), LARROUDE P.(2)*

*(1) Laboratoire d'Océanologie et de Géosciences UMR CNRS 8187, Université du Littoral Côte d'Opale, DUNKERQUE, FRANCE ; (2) LEGI-UMR 5519 UJF, Université de Grenoble, GRENOBLE, FRANCE*

Macrotidal beaches are generally characterized by a bar-trough topography consisting in an alternation of intertidal sand bars and depressions, intersected by shore-normal channels. Several studies have pointed out that sediment transport rates in these depressions can be important, notably during runnel drainage. Often described as a significant recycling mechanism of sediment in intertidal bar systems, currents and rates of sediment transport in inter-bar depressions have never been precisely studied or measured on macrotidal beaches however. The exact role of trough and channel topography on beach hydrodynamics and sediment transport processes are therefore not well known. Hydrodynamics measurements have been undertaken at Wissant Bay on the shore of the Dover Strait, Northern France, where 4 hydrographical instruments were deployed. An Acoustic Doppler Current Profiler (ADCP) coupled with an Acoustic Doppler Velocimeter measured the current and wave parameters in a well-defined trough while an electro-magnetic current meter and another ADCP have been deployed on the stoss side of the bars encompassing the trough. Sediment transport rates were calculated using the Van Rijn's (1993) formula which is integrated in a 2DH-model. Results show that during the falling or the rising tide, the trough experiences a strong increase of the current speed from the moment when the bar located seaward of the trough begin to emerge or be submerged, leading to a channelization of the flow. Current direction during such event is not controlled by wave or tidal conditions but by the topography itself. This increase of the mean flow results in an upper flow regime which is responsible of bedforms destruction associated with high sediment transports rates. This mechanism contributes to the stability of the barred morphology of these macrotidal beaches by inducing a residual circulation of wave-driven onshore transport sands from the upper to the lower beach during the falling tide.

## Dune Vulnerability and Management Strategy: A Case Study of West Bengal and Orissa Coasts, Bay of Bengal, India

DAS MAJUMDAR D.(1), PURKAIT B.(2), PAUL A.K.(3)

(1) Department of Remote Sensing & GIS, Vidyasagar University, MIDNAPORE, INDIA ; (2) Department of Geology, University of Calcutta, KOLKATA, INDIA ; (3) Department of Geography & Environment Management, Vidyasagar University, MIDNAPORE, INDIA

Vulnerability assessment of coastal sand dunes is necessary to evaluate the conservation status as well as to find out the most relevant disturbance events along the coastline. A critical study on the coastal dune vulnerability & management has been undertaken along the coastal tract of West Bengal and Orissa, Bay of Bengal, India. A total of 37 coastal dune sites have been surveyed and analyzed on the basis of structured rating scheme to assess the in situ geo-environmental condition and range of protection measures. Parameters like geomorphological condition (GC), marine influence (MI), aeolian influence (AI), vegetation condition (VC) and anthropogenic effects (AE) have been considered for vulnerability analysis. The percentages of the maximum possible rating for each category of information have been calculated and summation of the above information provides a Vulnerability Index (VI) which ranges from 42% to 65.9%. The Protection Measure (PM) as defined by the defence strategies has been undertaken for managing the dune vulnerability. The PM value ranges from 18.2% to 86.4% for the entire coastal stretch. Finally, based on VI/PM ratio a descriptive categorization of the vulnerability and protection measures of coastal dune at each site has been derived. The Euclidean distance in cluster analysis is used as the measure of association which enables to group the dune sites into five major classes according to their vulnerability levels. Wilks' Lamda test signifies the dimensionality of group discrimination at the 0.05 level of significance. Mapping of all the calculated parameters regarding dune vulnerability and protection provides spatial interpretation about the sensitivity of the dune system along the study area. The data-base thus generated on different aspects of dune system might be helpful for delineating the dune vulnerability and suggesting proper strategic measures.

\*\*\*\*\*

## Interactions between waves, sediments and pioneer plants in tidal marshes: Results from a full scale flume experiment

SILINSKI A.(1), HEUNER M.(2), DAUWE S.(1), PUIJALON S.(3), TROCH P.(4), BOUMA T.J.(5), VAN BELZEN J.(5), SCHÖDER U.(2), FUCHS E.(2), MEIRE P.(1), TEMMERMAN S.(1)

(1) Universiteit Antwerpen, WILRIJK (ANTWERPEN), BELGIUM ; (2) Federal Institute of Hydrology, KOBLENZ, GERMANY ; (3) Université Lyon 1, VILLEURBANNE CEDEX, FRANCE ; (4) Ghent University, ZWIJNAARDE, BELGIUM ; (5) Netherlands Institute for Sea Research, YERSEKE, NETHERLANDS

In theory, seaward expansion of tidal marsh shorelines can take place through establishment of pioneer plants on intertidal flats through *i*) clonal expansion, *ii*) rhizomes, or *iii*) seeds. In the Scheldt estuary (SW Netherlands), seedlings only occur occasionally, and the survival of transplanted plants on the mudflat has proved to be very limited. This arouses the question which factors limit plant establishment and survival. We studied in a wave flume the impact of short and long waves at several water levels on the tiredness of plants, drag forces on plants, and sediment scouring around adult shoots and seedlings of *Scirpus maritimus*.

The Wave Flume of the Department of Civil Engineering at the University Ghent has a length of 30 m, width of 1 m and height of 1.2 m. A natural sand slope was imitated on a length of 7 m. Waves with a height of 17 cm at the wave paddle and with 2 s and 10 s wave period were generated at three different water levels (5 cm, 20 cm and 35 cm). Individual seedlings and adult shoots of *Scirpus maritimus* were transplanted into the sediment bed with 10 replicates. Each test consisted of 200 waves sent onto the plants.

Under equal hydrodynamic conditions, adult plants and seedlings showed different responses. There was no clear tendency regarding the tiredness of seedlings. The adult shoots, however, showed a gradient of increasing tiredness with rising water level and higher wave period. Drag force was equally low on the seedlings for all conditions (< 0.25 N), whereas adult plants experienced higher drag forces (up to 3 N) from higher water levels and longer periods. The volume of the sediment scouring depended mainly on the hydrodynamic conditions and on the stem diameter. Analysis on shoot tensile strength and stiffness showed a clear difference in behaviour between adult plants and seedlings, potentially explaining the differences in drag force and in tiredness.

**Biogeomorphic succession of mangroves: Basic knowledge to improve restoration and management of tropical mangrove coasts**

BALKE T.(1), JEUKEN M.C.J.L.(1), HERMAN P.M.J.(2), BOUMA T.J.(2)

(1) Deltares, DELFT, NETHERLANDS ; (2) Royal Netherlands Institute for Sea Research, YERSEKE, NETHERLANDS

Mangroves are closely linked to their physical environment e.g. with the colonization of mudflats by seedlings or the trapping of sediments and elevation change to keep up with sea-level rise. Recent advances in biogeomorphology of tidal wetlands have improved our understanding of how these threatened and valuable ecosystems are interlinked with coastal sediment dynamics. Mangroves follow a biogeomorphic succession from a physical phase where physical disturbance forms a bottleneck to seedling establishment, through a biogeomorphic phase where feedbacks due to the vegetation cover alter sediment dynamics towards a partial disconnection from external forcing. We show with a series of flume and mesocosm experiments how colonization of mudflats is limited by coastal hydrodynamics and sediment dynamics. Moreover we analyzed spatial pattern of accretion/erosion processes in mangrove forests. Finally we present a conceptual framework for the biogeomorphic succession of mangroves. On the basis of this fundamental knowledge of mangrove dynamics we suggest measures to improve sustainable mangrove restoration and management. The close linkage of physical processes with mangrove functioning has long been marginalized and has only recently started to be considered when planning restoration projects. Present study quantifies a series of processes along the biogeomorphic succession by experimental work and field surveys with direct implication for applications.

\*\*\*\*\*

**Mangrove evolution and morphodynamic processes in Mayotte Island (Indian Ocean)**

JEANSON M.(1), DOLIQUE F.(2), ANTHONY E.(3)

(1) EPHE - Laboratoire de Geomorphologie et Environnement Littoral, DINARD, FRANCE ; (2) Université des Antilles et de la Guyane, UMR 228 ESPACE-DEV, SCHOELCHER, MARTINIQUE ; (3) Aix Marseille Université, Institut Universitaire de France CEREGE, UMR CNRS 6635, AIX EN PROVENCE, FRANCE

Mayotte Island, located in the Mozambique Channel, western Indian Ocean, is characterised by a vast, highly diversified reef-lagoon complex comprising significant mangrove development. The mangroves were mapped from 1949 to 2008 using digitised aerial photographs and a GIS was used to determine the evolution and rates of mangrove growth and loss. The results highlight a remarkably variable mangrove system subject to progression or stability on the north and east shores of the island, but exhibiting a clearly regressive pattern along the southern and western shores. On these latter coasts, hydrodynamic measurements and topographic surveys were conducted in several mangrove forests in order to gain a better understanding of this evolution. Results show that the decline of mangrove systems leads to a reorganisation of the sediment stocks previously fixed by the tree roots and the emergence of new shoreline morphodynamic patterns resulting from modifications in the hydrodynamic processes. Field observations also show longshore intertidal bar-trough systems fringing the southern and western mangrove forests. The surveys reveal that these bar-trough systems can affect the dynamics of mangrove forests by enhancing either erosion or accretion.

### **A risky retreat: Fine-tuning projections of salt marsh development in managed realignment projects**

*WHITE A., HANLEY M.E., MASSELINK G., BLAKE W.H., HOGGART S.P.G.  
Plymouth University, PLYMOUTH, UNITED KINGDOM*

In many coastal regions the restoration of salt marshes following managed realignment is recognised as a cost-effective and sustainable alternative to the construction of traditional 'hard' coastal defences. However, successful transition to salt marsh on actively managed sites is unpredictable and dependent on a host of local chemical, geomorphological and biological factors.

We monitored the response of low-lying grazing marsh to flooding at a site in Devon, UK after a self-regulating tidal gate (SRT) was installed in June 2011, applying an integrated, biogeomorphological approach (involving monitoring vegetation alongside changes in marsh morphology, inundation regime and sedimentation) in order to assess development of the site into a fully functioning salt marsh.

Four months following realignment, vegetation die-back was extensive in areas subjected to tidal inundation and freshwater marsh species remained as dominant. However, limited halophytic vegetation had emerged in the restored area within 12 months. A pressure transducer on the restored side of the SRT revealed that water levels were below 1.0 ODN for 90% of the time. Given the elevation of the marsh (0.9-1.0m ODN), the frequency, depth and spatial extent of inundation were less than projected. As a consequence, sediment deposition was negligible and suspended sediment concentrations measured at the SRT were similarly low. Predictions of potential sedimentation rates show that even if water levels on the restored marsh were increased to 1.2m ODN, a vertical accretion rate of only 0.9mm yr<sup>-1</sup> could be expected.

These results indicate that increasing water levels on managed sites still may not encourage salt marsh development if sedimentation rates are inhibited by the breach design. This highlights the necessity of monitoring and facilitating a variety of factors simultaneously in order to assess the development and future success of managed realignment schemes.

\*\*\*\*\*

### **Geomorphological responses of tidal islands and estuary channels to embankments: a paradox of sustainability and protection in the West Bengal Sundarbans**

*ORFORD J.D.(1), PETHICK J.(2), KUMAR S.(1)  
(1) Queen's University, BELFAST, UNITED KINGDOM ; (2) Independent Consultant, BEVERLY, UNITED KINGDOM*

The Indian (West Bengal) Sundarbans is composed of tidal islands superimposed on the palaeo-delta facies at the western edge of the contemporary Ganges delta (Bay of Bengal). The tidal islands define a series of blind rivers, which originally were part of the anastomosing proto-Ganges. They are now tidally dominated estuaries with channel-side morphological changes that are adjusting to varying time-scales of environmental change related to tidal prism, sea level change and sediment supply. For several centuries there has been in-migration to the Sundarbans by landless poor, who have now developed a sophisticated, but subsistence, monsoon-dominated rice economy. In West Bengal there are c. 4million inhabitants over 3500 km<sup>2</sup> protected from estuary water-sediment activity, cyclone surges and the threat of rising sea level, by hand-built embankments (dating back to the 19<sup>th</sup> century). The impact on the geomorphological system of the tidal islands (both inhabited and uninhabited) by the mode of embankment building (eg use of channel muds), the placement and presence of embankments (eg controls on island sedimentation; channel dynamics) is considered in terms of the implications for 21<sup>st</sup> century living under scenarios of change related to island subsidence; rising rates of extreme sea-level; sedimentation scarcity and positive feedback of tidal regime changes. The problem of how these communities can survive sustainably with local geomorphological condition, when the embankments are themselves contributing to the context of change is considered. The paradox is that upgrading embankment protection is an evidently popular (if not demanded option), but offers only short-term protection gain, compared to the rising embankments further distortion (positive feedback) of the estuary forcing conditions that will overcome the embankment protection in the longer-term. Consideration is made of potential island upwarping as a potential survival strategy for some of the population.

### **Evolution of the coastline of anthropised islands off Galicia and Brittany: Ons and Ushant**

REGNAULD H.(1), DAIRE M.Y.(2), LOPEZ ROMERO E.(3)

(1) Rennes 2, RENNES, FRANCE ; (2) Rennes 1Archeosciences, RENNES, FRANCE ; (3) Cesic, SANTIAGO, SPAIN

Remote islands have been anthropised from the late neolithic but to a lesser extent than the neighbouring continental areas. For this reason the impact of anthropisation on the "natural" behaviour of the coast is supposed to be far less important than on the main land. Studies on island of Ons, off Galicia and of Ushant off Brittany (within the frame work of the GALA project –Géographie et Archéologie du Littoral Atlantique) have shown that this statement may be strongly criticised. Even if the population is less abundant and if the occupation is discontinuous in time the local sensitivity of the coast makes it far more vulnerable than the main land coastline. The study of coastal exposures (with <sup>14</sup>C datations) together with the study of archaeological remains allows to reconstruct the interfingering between coastal accumulation/erosion and human activities. Surprisingly enough human impact was more efficient at times, and on some precise sites, during the middle ages than today. At that time, small coves and pocket beaches were intensively used for fishing and boating. Today these sites are too shallow for present boats and are not used any more for fish trapping. Most often they are included into protected zones. They presently behave as natural places even if they still bear the traces of their former state of semi artificialised coastlines.

\*\*\*\*\*

### **Shoreline evolution of Capo Peloro, the northernmost point of Sicily(Italy) : causes and temporary management**

RANDAZZO G., LANZA S.

University of Messina - Department of Physics and Earth Sciences, MESSINA, ITALY

Sicily, the largest island in the Mediterranean Sea, is separated from the Italian Peninsula by the 3.6-km-long Strait of Messina, extending along the homonymous town. The northernmost point of the Island and the one closest to the continent is Capo Peloro, a characteristic round beach which gives rise to the saddle separating the Tyrrhenian from the Ionian Sea. Along the beach, in the summertime, there are several lidos attracting daily thousand people from the town of Messina and its cosmopolitan area. In the recent past the shoreline of the Capo Peloro beach has undergone continuous evolution, monitored since Smith's survey in 1883 to the most recent aerial photographs and the field surveys. During autumn 2011 – winter 2012 the beach completely disappeared and the waves washed the local Coastguard Station. In this case, it is difficult to cite anthropogenic impact as being responsible for the abrupt shoreline change because coastal structures have not been built in the last years. In the area, dominant and regnant prevailing winds are general affecting the coastline from W – NW winds which are strongly screened because of the presence of the Eolian Archipelago. During the period of October 2011 – April 2012 several violent storms approached from the N – NNW sector from which the coastline has not any natural protection. Sedimentological and topographic surveys of the beach, performed in early spring, showed a surface-area loss of about 12,000 m<sup>2</sup> along about 1 km of coastline. In this situation, because of the particular context of the area, it was unadvisable to propose any hard structures for protecting the shoreline.

For that reason, an auto-transplantation of compatible (granulometrically and compositionally) coarse sand sediment was proposed. The whole amount of sediment (dredged material) was available, at a distance of about 500 m, accumulated along a short artificial channel. Unluckily bureaucracy has stopped this possible soft solution.

### **Anthropic interference versus littoral dynamics: Aguda (Northern Portugal) breakwater, Holocene evolution and recent coastal erosion**

*ARAÚJO M.(1), MONGE SOARES A.(2), CUNHA P.P.(3), GOMES A.(1), VIEIRA M.(4)*

*(1) CEGOT-FLUP, Universidade do Porto, PORTO, PORTUGAL ; (2) IST/ITN, Instituto Superior Técnico, Universidade de Lisboa, SACAVÉM, PORTUGAL ; (3) Faculdade de Ciências e Tecnologia-Dep. Ciências da Terra, COIMBRA, PORTUGAL ; (4) Ichron, MANCHESTER, UNITED KINGDOM*

Northern Portuguese coast has a general trend of NNW-SSE from Silleiro Cape, in Galicia, till Espinho (ca 124km). This coastline has a Precambrian/Paleozoic bedrock, generally covered by modern sandy beaches and aeolian dunes. In some places, beach erosion allows us to see ancient marine and lagoon deposits (from last interglacial until the Holocene) upon the bedrock.

Aguda beach is located near Porto, 11km south of Douro river mouth, close to Espinho (southern part of the Iberian Massif littoral outcrop).

The construction of a detached breakwater, accomplished in Spring 2002 in order to help the artisanal fishing activity had several consequences:

1 – Accumulation of sand in the North of the breakwater and severe erosion to the South affecting "aristocratic" Granja beach.

2 – This erosion revealed interesting sedimentary sequences and archaeological remains.

3 - Authorities began to transport sand accumulated by the breakwater to feed the Granja beach. This transport was made over the beach sands and underlying sediments by 50 tones trucks, destroying the sedimentary and archaeological evidences.

Fortunately some stratigraphic/sedimentologic work had already been done. However, the scarcity and discontinuity of the deposits, together with man made disturbance made sediment correlation more difficult.

We had an initial TL dating 8.7 ka BP in a black lagoon sediment, ca 3-4 m above mean sea level. However a more recent C14 data indicates a younger age for the sediment: 2950-3460 cal BP. A piece of *Salix* collected from that sediment was dated 2960-3214 cal BP and pollen analysis suggests a fresh-water environment.

These data indicates the existence of a lagoon with no-direct influence from the sea until a very recent time and may be a key to understand relative sea level during Holocene.

As a general conclusion we would like to underline the consequences of man interventions in the coastline: revealing old deposits, and, in the other hand, destroying them.

\*\*\*\*\*

### **The relief cartography in coastal areas: a contribution to the environmental planning of Bertioga, Sao Paulo State, Southeastern Brazil**

*TRAVALINI V.(1), CUNHA C.M.L.D.(2)*

*(1) UNESP Rio Claro, S\_O PAULO, BRAZIL ; (2) UNESP Rio Claro, S?O PAULO, BRAZIL*

The coastal environmental systems are areas of high complexity, due to material and energy exchanges existing in the interaction processes between the sea and the continent. These areas play an important role in territorial dynamics of a considerable group of countries, which shows intense human activities in coastal environments. The city of Bertioga, located in the coast of São Paulo state, southeastern of Brazil, it is in this context and shows a recent urban expansion, mainly related to the touristic activities. This phenomenon brought changes to the coastal environmental systems of Bertioga, pointing out the importance of an appropriated environmental planning of the area. In this context, this research aimed to analyze the relief morphometry of Bertioga, quantifying the attributes of the relief to understand the morphological structure and the fragilities of the area. The analysis was made elaborating three morphometric maps: Slope, Vertical and Horizontal Dissection and Geomorphology. Bertioga is comprised by three geomorphological compartments: Atlantic Plateau, Serra do Mar and Coastal Plain. In the Atlantic Plateau region the relief forms have a large variation, requiring a complex management of the land use. The Serra do Mar region is a mountain range with an abrupt relief with high slope values. This area is protected by a state park and the urban activities are not allowed. The Coastal Plain is a flat surface formed by sea and continent sediments. In this area the flat relief contributes to the urban occupation, but the environmental characteristics are not appropriated to the intense activity, because the soil sediments are not consolidated and there are mangroves and sandbanks remaining. Finally, this research contributed to increase the understanding of the land use dynamics and the fragilities of environmental system in Bertioga, and can be combined with other environmental studies to contribute to the environmental planning of the coastal regions.

### **Coastline vulnerability in the Kerkennah archipelago between 1963 and 2010**

*ETIENNE L.(1), BOUAZIZ R.(2), DAHECH S.(3), DAOUD A.(4), BELTRANDO G.(1)*

*(1) Université Diderot Sorbonne Paris Cité, UMR PRODIG, PARIS, FRANCE ; (2) Faculté des sciences humaines et sociales de Tunis, Laboratoire CGMEG, SFAX, TUNISIA ; (3) Faculté des lettres et sciences humaines, département de géographie, Université de Sfax, Laboratoire SYFACTE, SFAX, TUNISIA ; (4) Faculté des lettres et sciences humaines, département de géographie, Université de Sfax, Laboratoire EEE, SFAX, TUNISIA*

Sea level rise is a well-known factor of vulnerability in coastal areas. Indeed, it can lead to a retreat of the coastline that will itself cause a degradation of coastal habitats and economic activities. The Kerkennah archipelago, located in the Gabes Gulf in Tunisia, displays several archeological, geomorphological and botanical signs that suggest a retreat of the coastline; and dykes, walls and other structures have been recently built to protect the population on the seaboard. In this context, we attempt to understand and quantify the evolution of the coastline and to evaluate its vulnerability using the Coastal Vulnerability Index (CVI).

For that purpose, we analysed a Spot 5 image from 2010 and aerial photographs from 1963 which have been georeferenced and compared in a GIS. Using the Digital Shoreline Analysis System from Arc Gis, we evaluate the coastal evolution between these dates and show that the Kerkennah coastlines are mostly retreating (with a maximum of 100m). Additionally, data gathered during a field study indicate that those retreats depend on the orientation of the coast and to a greater extent, on the type of coast and on recent anthropic developments. The calculation of the CVI, adapted for this study, shows that coastal vulnerability is variable in the archipelago.

Finally we discuss the temporal and spatial scales chosen for this study. Indeed, most of the anthropic activities of the coast were installed after the 80's and therefore their impact must be recent. Also, the direction of the strongest winds, that generate the larger and most damaging waves have changed since the 70's. Our understanding of the cinematic of coastal evolution could therefore be significantly improved by the comparison with high resolution images from these two periods. Additionally, larger spatial scales should also be taken into account, since regional scale elements such as climatic change and subsidence might explain some of the local changes we observed.

\*\*\*\*\*

### **Toward a prevention of coastal erosion in the Magdalen Islands, Quebec, Canada**

*DREJZA S., BERNATCHEZ P., DUGAS S.*

*Université du Quebec a Rimouski, RIMOUSKI, CANADA*

The Magdalen Islands are situated in the Gulf of St. Lawrence (eastern Canada) and are composed of six rocky islands (28 % of the coastline) that are linked together by double sandy barrier systems (40 %). Coastal erosion is a serious concern in the archipelago because 68 % of the coastline undergoes erosion and since the 1950's the relative sea level rose by 3.5 mm/year. For these reasons, the Government of Quebec designated the archipelago for a priority study to better understand the entire coastal system and help manage erosion.

Regarding the coastal type, the processes, the hydrosedimentary cells and the strength of historical and recent erosion rates, we defined 251 homogeneous units over the entire coastal system (235 km). For each of them, we determined the most likely scenario of coastal evolution for the next 50 years, by taking into account the coastal processes, the past climate and the projections of future climate. This region is subsiding and will be particularly sensitive to the sea level rise. The reduction of more than 50 % of the ice cover will also lead to an increase in the number of storm events affecting the coast. The results show that the coastal system will undergo a sedimentary deficit, with projections of 81 % of coastline under erosion (35 % with a rate of more than 1 m/year) and only 14 % of the coastline under accumulation. Furthermore, the historical migration mean rate of -0.24 m/year is likely to triple to up to -0.66 m/year.

Afterward, we developed coastal erosion security setbacks for each of the homogeneous units of the archipelago, based on the following formula: setback distance = {yearly erosion rate following the most likely scenario X management horizon} + {maximum erosion retreat measured during one single event}. For the areas lacking data, based on a precautionary principle, a minimum setback was established for each type of coast. These setbacks will easily be applicable by managers to feed local land use policies.

## Geomorphic Changes at a Bay of Fundy Salt Marsh Restoration in New Brunswick, Canada

OLLERHEAD J.

*Mount Allison University, SACKVILLE, NEW BRUNSWICK, CANADA*

The purpose of this presentation is to report on geomorphic changes at a salt marsh restoration at a site near Aulac, NB in the Cumberland Basin of the Bay of Fundy. The Basin is a 118 km<sup>2</sup> turbid estuary with a semi-diurnal tidal range of 10 to 13 m. The fetch ranges from 5 to 20 km and the water has a high suspended sediment concentration (mean > 300 mg/L).

The project was designed and implemented in 2010. Three openings were cut in an existing dyke at the site in October 2010. As a result of this action, two different agricultural fields are now being regularly flooded with salt water from the Bay of Fundy. Field data were collected prior to construction for a number of environmental variables (e.g., topography, vegetation) and marker horizons installed.

Since the openings were constructed, they have been mapped three times using ground-based (2010, 2011) and aerial LiDAR (2010, 2012). Flows through one of the openings have been measured using an acoustic Doppler current profiler (ADCP) and water levels both inside and outside of the restoration cells have been measured for several months. Surface elevation change has been measured using cryogenic coring, DGPS, and aerial LiDAR.

Water flows through the openings remain mostly as modeled/expected. Erosion of the openings has been largely as expected (mostly of the channel banks). In the first year, up to 50 cm of sediment deposition per m<sup>2</sup> was measured, with mean deposition ranging from 9 cm per m<sup>2</sup> at the west end of the site to 22 cm per m<sup>2</sup> at the east end of the site. Sediment deposition now exceeds 70 cm per m<sup>2</sup> in some locations. The presentation concludes with an assessment of the initial success of the project.

\*\*\*\*\*

## Science in Support of Coastal Management: Developing Louisiana's 2012 Coastal Master Plan

REED D.

*The Water Institute of the Gulf, BATON ROUGE, UNITED STATES*

The purpose of the 2012 Louisiana Coastal Master Plan is to identify projects that will make a difference for the coast and communities of south Louisiana. Models were developed to estimate the effects of hundreds of projects that have the potential to make a difference to the coastal landscape and/or its communities and industries. While the most obvious symptoms of coastal degradation are land loss and increased damage from coastal storms, it was necessary to consider an array of consequences associated with actions geared towards either building land or protecting communities from flooding.

Results from eco-hydrology, wetland morphology and barrier morphology models were used to identify the effects of projects on the extent of coastal land, while vegetation, upper trophic level and ecosystem service models provided additional insight on how the resulting changes in estuarine gradient and landscape would affect a number of ecosystem metrics. Predicting change over time for a 50 year period allowed the consideration of tradeoffs among restoration approaches which either build land quickly that is then subject to decay and those which build land gradually over time. Storm surge/wave models were run across the 50 year future without action landscape and its expected vegetative cover. The resultant damages to coastal assets were calculated and both 'structural' and 'non-structural' risk reduction projects were selected on the basis of their cost, ability to meet desired levels of risk reduction, and overall reduction in expected annual damages.

A list of restoration and protection projects was thus identified with an expected cost of \$50 billion. Further modeling is being conducted to explore interactions among projects and the effect of different implementation sequences. The results of these analyses allow the State of Louisiana to move forward with implementation of the Master Plan knowing not only what it wants to do but what it expects to achieve.

**Influence of sediment recycling-recharging on mixed beach behaviour: a case study at Cayeux-sur-Mer, north France**

*CUROY J., MOSES C., ROBINSON D.*

*University of Sussex, FALMER, UNITED KINGDOM*

Gravel and mixed sediment beaches are widely distributed around the world and are increasingly important as a coastal defence.

Cayeux-sur-Mer has a mixed sediment beach located at the downdrift end of a 146 km long sedimentary cell that stretches from the Seine to the Somme estuary in N. France. The updrift stretch of the beach is managed by groynes together with sediment recycling and recharging combined. Immediately downdrift of the last of these groynes, the ungroyned beach is managed solely by recycling-recharging events. The recycle-recharge sediment, comprising 80% gravel and 20% sand, is deposited at the top of the beach along a 450 m stretch and modelled into a steep-walled compact ridge, ~4 m high and ~15 m wide. The impact of this ridge of sediment on the profile shape and surface grain size distribution of the beach face has been monitored along two cross-shore profiles, one directly in front of the ridge and the other 1 km downdrift from it. Measurements were made on each tide of a semi-lunar cycle between 28/10 and 11/11/2005, immediately following a recycling-recharging event.

Recycling-recharging had a significant impact on the beach profile in front of the ridge. First, the beach gradient steepened due to the incorporation of some of the recycled-recharged material. Second, the proportion of fines in the surface material across the beach increased compared to that recorded on the downdrift profile. Steepening will render the beach more reflective whilst the addition of sand will reduce the hydraulic conductivity of the beach face. Consequently wave energy will not be dissipated as efficiently as on a pure gravel beach and such coastal management could in fact result in more sediment transport than anticipated, hence eventually having a less beneficial effect than expected for the site.

\*\*\*\*\*

**Coastal squeeze: its assessment and integration within regional- and municipal-level planning tools**

*JOLICOEUR S.(1), BÉRUBÉ D.(2), DESROSIERS M.(2), O'CARROLL S.(1)*

*(1) Université de Moncton, MONCTON, CANADA ; (2) Ministère des ressources naturelles, BATHURST, CANADA*

In the context of climate change, long-term planning is a requirement for sustainable development of the coastal zone. With sea-level rise (SLR) driving an accelerated mobility of the coastline and a migration of coastal habitats, and socio-economic factors driving a densification of development at the coast, documenting and predicting the response of coastal systems to SLR is paramount to the achievement of conservation and urban planning goals. Natural Resources Canada and the provincial departments of Natural Resources and of the Environment have carried out an assessment of past coastal squeeze (CS) on the coast of New Brunswick. Quantitative estimates of past (1940s-) and future (2100) losses due to CS were obtained for selected habitats (based on sensitivity to CS, role in resilience of communities and presence of species of special status). Two scenarios of SLR, climate change-induced sediment budget modification, and socio-economic development in the coastal zone were applied. These results will help decision makers prioritize actions at the provincial level. However, municipal authorities also have an urgent need for specific tools in order to develop regulations to warrant the continuing integrity of coastal habitats in the future, to move away from short-term management of the coastal zone, and to prevent degradation or destruction of ecologically, culturally and economically valuable habitats. Such decision-aid tools have been prepared for a small rural community of Southeastern New Brunswick. GIS-derived erosion rates and a DTM have been used to estimate the position of the coastline and inner limits of coastal habitats in 2025 and 2055. These limits have been superimposed on cadastral information and (a) sectors sensitive to CS and (b) accommodation space necessary to allow migration of coastal habitats have been assessed. Methods and deliverables from both approaches will be presented.

### **Embayed configuration and geological control on beach morphodynamics and management: an overview of contrasting responses in embayed beaches of southwestern Portugal**

LOUREIRO C.(1), FERREIRA Ó.(1), COOPER A.(2)

(1) CIMA - Universidade do Algarve, FARO, PORTUGAL ; (2) CCMR - University of Ulster, COLERAINE, UNITED KINGDOM

Morphological change in embayed beaches is generally assumed to be influenced by embayment configuration and is consequently dependent on the planform, indentation and exposure to incident waves. In addition, in such bedrock-framed beach systems, geological control has been found to exert a substantial influence on beach morphodynamics, by modulating beach shape and segmentation, influencing sediment size and availability, causing alongshore variations in the wave field and inducing topographically-controlled nearshore circulation. Aiming to evaluate drivers of morphological variability and characterize morphodynamic behaviour of embayed beaches exposed to contrasting environmental conditions, a monitoring program was established in six embayments along the coastline of southwestern Portugal. Embayed beach morphological and sedimentary change was surveyed regularly over two years. Datasets were explored using statistical (e.g. empirical orthogonal functions) and probabilistic (e.g. Bayesian networks) analysis and related to forcing parameters obtained from time-series of observed and modelled hydrodynamic parameters.

While the dominant pattern of variability in all embayments was related to wave energy, as indicated by highly significant statistical correlations with the normalized wave power, secondary patterns of embayment morphological change were related to embayment specific responses, particularly beach rotation and rip circulation. The results of this study also confirmed earlier suggestions that geologically constrained beaches represent a distinct type of beach environment with particular modes of behaviour during and after storms. This new understanding has the potential to benefit management approaches within the constrained sedimentary setting of embayed beaches. Improved understanding of embayment morphodynamics will not only enable natural changes to be understood but will also contribute to maintenance of, or improvements in, beach use and safety.

\*\*\*\*\*

### **Development of an Integrated Geomorphic Model of Soft Cliff Retreat: Investigating the effects of varying lithology in the vertical**

CARPENTER N.(1), NICHOLLS R.J.(1), DICKSON M.E.(2)

(1) University of Southampton, SOUTHAMPTON, UNITED KINGDOM ; (2) University of Auckland, AUCKLAND, NEW ZEALAND

Geomorphic modelling of soft rock cliffs is an important method to understand future rates of retreat as it enables the consideration of a range of process interactions and can simulate changing environmental and climatic conditions. However, owing to the complexity of the cliff system and the need to understand mesoscale (10-100year) responses, modelling inherently involves simplification of the system under question. Therefore, one key issue concerns the treatment of variable lithology on geomorphic processes and shore retreat both in the alongshore and vertical.

A number of previous models have considered the impacts of alongshore variations but such studies have emphasised the role of a significant fronting beach. Considering sediment poor environments and the impact of coastal engineering structures on reducing downdrift beach volumes it is important that the impacts of variable lithology and interactions with sea-level rise are further understood. Moreover, it is important to understand the possible effects of vertical heterogeneity, as most cliffs are composed of interbedded stratigraphy of varying strength and composition.

This paper presents modifications to the reduced complexity, 2D SCAPE (Soft Cliff and Platform Erosion) model to consider the influence of horizontal layers of variable material strength in the vertical. Using the revised model we address some key geomorphic questions considering its impact on shore profile morphology, rates of cliff toe retreat and interactions with sea-level rise. We then apply the model to a study frontage of complex varied geology (demonstrated by the presence of a series of discrete headlands and bays) on the south west coast of the Isle of Wight (UK). Using the study frontage the model has been validated and used to consider the future implications of climate change on long term rates of retreat along the frontage.

**Cliff-top large boulders emplacement along the Southern coast of Menorca (Balearic Islands, Western Mediterranean): addressing the role of storm or tsunami wave processes in rock coast deposits**

GOMEZ-PUJOL L.(1), ROIG-MUNAR F.X.(2)

(1) SOCIB, Balearic Islands Coastal Observing and Forecasting System, PALMA, SPAIN ; (2) Departament Ciències de la Terra, Universitat de les Illes Balears, PALMA, SPAIN

The presence of large boulders along the cliff-top line of rocky coasts induces a debate on the occurrence and nature of past storms and/or tsunamis. Boulders of probable tsunami or storm wave origin have been reported throughout the world. Nevertheless there exists a controversial discussion about the origin of such deposits because sedimentary differences between those deposits have been poorly understood. In the Mediterranean different authors have interpreted the presence of boulders weighing over 20 t as moved by tsunamis whereas others recognise the role of storm. In southern and southeastern Menorca, the rock coast is characterized by anomalous deposits of calcareous boulders along terraces or platform surfaces 2–10 m above present sea level. This study investigates the size, shape, position and long-axis orientation of 73 boulders resting on two different locations, Punta des Pinar and ets Enderrossalls. Most of these boulders are rectangular, with sharp, broken edges. They are calcarenite fragments from 0.25 to 27 t in mass without evidences to have been submerged. Based on geomorphological evidence, we infer that the majority of boulders encountered were from a joint-bound pre-transport setting. The assessment of such cliff-top accumulations allow the depositing wave/s to be characterized in terms of necessary breaking wave height through the use of linear hydrodynamic equations. Additionally the use the significant wave height and period of maximum observed storms during the last 44 years, we have estimated the conditions that would have lead to their deposition, discerning between stormy deposition or tsunami evidences. Results show that 10 years return period storm waves could be enough to detach and explain the placement of many of the boulders, but there are some of them that do not fit with this pattern. Also, the placement of the boulders suggests the control of fractures and joints orientation as a control on boulder location.

\*\*\*\*\*

**Beach development on microtidal shore platforms**

KENNEDY D.

The University of Melbourne, PARKVILLE, AUSTRALIA

The rocky shore is often considered to be an inhospitable environment for beach development; however, sandy beaches are found at the rear of shore platforms around the globe from mid oceanic islands such as Niue, the continental microtidal margins of southern Australia, the macrotidal Bay of Fundy as well as the storm-dominated shores of England. Mathematical modelling of macro and mesotidal shorelines suggests beach accumulation is primarily controlled by the relationship between the gradient of the platform and the beach and the amount of available sediment. This research investigates the morphological parameters that influence beach accumulation on microtidal subhorizontal shore platforms. The sandstone-dominated parts of Victoria, Australia, are used as a field site where beaches over 1 m thick are found on the platform rear. These beaches are composed of well-sorted medium grained sand which slope seaward at between 3 – 5°. All the beaches are fronted by subhorizontal platforms at least 30 m wide and sit on top of abrasion ramps which, on average, have a slope 1° less than the overlying beach. The evolution of ramps and beaches appear related; ramps do not occur in locations where sediment cannot accumulate. At all the sites ample sediment occurs on the seabed which is available for transport onto the platforms. Little relation appears to occur between platform width and beach accumulation. The elevation of the platform immediately in front of the beach toe appears to be a critical factor in controlling whether sediment can accumulate with beaches only being present when the platform occurs below mean high water spring elevations.

## **Erosion, progradation and sediment transport between beach-dune systems and adjacent beaches on shore platforms**

BLANCO-CHAO R., FEAL-PEREZ A., DUARTE-CAMPOS A.

Universidad de Santiago de Compostela, SANTIAGO DE COMPOSTELA, SPAIN

We studied a process of erosion in beaches on shore platforms related with dune progradation and stabilization in NW Spain. The coast is composed of two beach-dune systems of 0.8 and 2 km in length, enclosed at the north and south ends by rocky sectors with sand beaches. Two proxies were used to study the erosion-accretion trends: the seaward limit of vegetated dunes in the beach-dune systems and the seaward edge of sand in the beaches on shore platforms. The proxies were digitized from digital aerial photographs from 1956 to 2010 and the changes in both proxies were calculated using the DSAS software (Thieler et al, 2005). Results confirm a process of dune progradation and stabilization in the beach-dune systems that occurs at the same time that the erosion of the beaches on the shore platforms. To investigate changes in wave and meteorological regime we analyzed the main wave parameters (from current and hindcast models), rain and wind parameters from meteorological stations and sea-level changes from tide gauges. No significative tendencies were found in any of the parameters but a trend to decrease in wave energy can be detected in the periods 1958-1971 and 2000-2010.

Results suggest that sediment is transported from the beach-dune systems to the beaches on the rocky sectors. As the beach-dune systems became progressively stabilized, the sand transport was reduced resulting in the erosion of the beaches on the shore platforms. The rates of change calculated for each period show a high correlation ( $r=0.96$ ) between the dune progradation and the erosion of the beaches on shore platforms. The highest rates of progradation and erosion were recorded in the north dunes and in the north rocky sector, due to the prevailing northward drift.

Thieler, E.R., Himmelstoss, E.A., Zichichi, J.L., Miller, T.L., 2005. *Digital Shoreline Analysis System (DSAS) version 3.0: An ArcGIS extension for calculating shoreline change*. U.S. Geological Survey Open-File Report 2005-1304.

\*\*\*\*\*

## **Poster presentations:**

### **Analysis of the relief of the city of Ilha Comprida, south coast of São Paulo, Brazil**

SOUZA T.A., OLIVEIRA R.C.

Universidade Estadual de Campinas, CAMPINAS, BRAZIL

The city of Ilha Comprida is located in the South Coast of the State of São Paulo (Brazil). It is characterized as a barrier-island, isolated from the continent by estuarine channels of the "Mar Pequeno" (or "Mar de Iguape") and the "Mar de Cananéia" (or "Mar de Fora"); and is part of the coastal plains of Cananéia-Iguape, the best developed coastal plain in the Paulista coastline. Ilha Comprida is considered the last episode responsible for the configuration of the coastline of the State of São Paulo. Its differential is been a product of sea level modifications throughout the Quaternary, which enables the affirmation that its geological evolution is quite recent, with its formation beginning around 5100 years B.P. (Before the Present), with the exception for the Morrete, a Pre-Cambrian alkaline intrusion with a 42-meter elevation, where Ilha Comprida's formation probably began, working as a "lashing points" for sediment deposits. The island presents well reserved relief formations due to the low population density, which enabled the geomorphological mapping with great precision. Facing these considerations, the objective of this study is to analyze the relief cartography of the city of Ilha Comprida made in the scale 1:10.000, contemplating the geomorphological compartmentalization and the relief formations present in each of these compartments, from stereoscopic pairs of aerial photographs from the year 1962.

## **The White Sea Coasts' response to the extreme storm of 15-16 November 2011. Coastal Development Forecast**

REPKINA T.

*Faculty of Geography at Lomonosov Moscow State University, MOSCOW, RUSSIAN FEDERATION*

During a storm the sea levels rose to levels above observed 50-year maximum (1.5-2m above the mean water level at high tide). Evaluation of the coastal response of various morphogenetic types of coast to the extreme storm serves to validate our forecast for the coast development using field data.

About 300 km of the coastline Dvina and Onega bays were explored. To evaluate the coastal dynamics repeat instrumentation measurements, geomorphological and landscape features and survey data obtained from local residents were used.

The abrasion coasts undergone a widespread intensification of erosion. Major mechanisms and magnitude of destruction were defined by lithology of cliffs and orientation of the coast relative to prevailing directions of extreme storm waves. Large quantities of coastal retreat (1-3m, and up to 7m), were observed at the erosion coasts developed in sandy sediments.

The most dramatic changes occurred at accumulative beaches composed of sands. The coastline retreated by 1-7m here. Front-dunes were damaged or completely washed away. Beaches were flattened. The beach sand moved to the tidal flats. Sand bars and shafts of the tidal flats were completely transformed. Residual value of deformation of the tidal flats reached up to 0.5 - 0.7m. This type of coasts are among the most densely populated, and most commonly used for recreational purposes. The private construction here occurs without consideration given to extreme natural phenomena. Therefore, the damage caused by the storm was the greatest here.

Accumulative littoral shores were flooded during the storm (by 0.2-1 km). Traces of erosion were not found.

Field data confirms the tendency of the coastline of the Dvina and Onega bays to retreat. This was revealed by examination of aerial photographs and topographical maps of various periods of time.

The research has been conducted as part of the Project "Natural Disaster Risk Evaluation in Coastal Areas".

The Project Leader is K.P. Koltermann.

\*\*\*\*\*

## **Evidences of sea-level oscillations on the coasts of Vistula and Curonian Spits (SE of Baltic Sea)**

BADYUKOVA E., ZHINDAREV L., LUKYANOVA S., SOLOVIEVA G.

*Moscow State University, MOSCOW, RUSSIAN FEDERATION*

The geomorphologic structure of the accumulative barrier forms bordering significant parts of sea coasts does not leave doubts in close connection of the reasons and stages of their formation with changes of a sea level. Such dependence is traced and in the structure of sandy barriers of southeast Baltic - Curonian and Vistula Spits. The most part of their surface is consist of the aeolian sand, marine genesis has a modern sea beach, and marine-lagoon genesis have a beach and low terraces in the Curonian and Vistula gulfs. Terraces fragmentary frames the lagoon coasts of both the spits and have height not more than 1.5 m.

On sea coast of the Vistula spit there are the layers of pebbles in the bottoms of some blow-outs. These layers can serve as age analogue of lagoon terrace. The present pebble layers position exceeds a modern sea level on 1.5 - 2 m. The pebble is also found out by a borehole on seaside of the Curonian spit, behind the foredune at absolute height of 1.5 m. Thus, along Vistula and Curonian Spits sea coast the ancient coastline corresponding to one of the last sea-level rise is traced. This rise not exceed, apparently, 0.5 m above its contemporary position. On the erosion sites the coastal bar fixing high position of a sea-level, exposes in the cliff bottom. On the accumulative coasts accompanying with the development modern and ancient aeolian forms of a relief, marine deposits substantially buried under aeolian sand. On the basis of radiocarbon dating <sup>14</sup>C of the mollusk shells from marine sediments absolute age 1270±60 cal BP (LU-6129) has been received. According to opinion of a lot of researchers, by this time one of last peaks of Limnea transgression exceeded. Sea level was on 0.5 m higher than contemporary one.

### **Detecting rapid changes in the hardness of engineering materials in the coastal built environment using the Equotip durometer**

COOMBES M.(1), FEAL-PÉREZ A.(2), NAYLOR L.(3)

(1) *University of Oxford, OXFORD, UNITED KINGDOM* ; (2) *Universidade de Santiago de Compostela, SANTIAGO DE COMPOSTELA, SPAIN* ; (3) *University of Exeter, PENRYN (CORNWALL), UNITED KINGDOM*

Engineering materials used in the coastal built environment (e.g. rock and concrete) are exposed to the same agents of weathering and erosion as natural rocky outcrops (e.g. waves, water, wind, salts, insolation, ice, abrasives and biota). These agents act to modify hard substrata in ways that are relevant to engineering durability and performance, and the conservation and aesthetics of structures of heritage and social value. Non-destructive tools able to provide comparable and easily obtainable information of material properties, and that can detect changes through time, are therefore of considerable value for material selection and monitoring during service life.

The equotip (Proceq) hardness tester was applied to rock and concrete exposed in the intertidal zone for three different time periods (0, 8 and 20 months). Limestone showed significant and progressive loss of hardness, while concrete increased in hardness. Granite showed no significant change. The observations are related to micro-scale (< mm) changes occurring at the material surface primarily via chemical and biological means. The equotip device is sensitive enough to detect changes in the hardness of engineering materials over relatively short periods of time.

\*\*\*\*\*

### **River channels as conduits for high energy coastal events**

KAIN C.(1), GOMEZ C.(1), HART D.(1), WASSMER P.(2), STARHEIM C.(1)

(1) *University of Canterbury, CHRISTCHURCH, NEW ZEALAND* ; (2) *Université de Strasbourg, STRASBOURG, FRANCE*

Coastal overwash events such as tsunamis and storms transport large amounts of sediment and leave important signatures in the landscape. The configuration of the coastline and topography has a significant impact on the depositional process and form of preserved features, and inundation distances and patterns are affected by surface roughness and elevation. Consequently, inundation may occur from directions other than shore-normal, significantly affecting deposition patterns. This research investigates the role of river channels as conduits for sediment transport during washover events, by virtue of their comparatively lower elevation and low friction of the water surface. A suite of sandy deposits on an embayed coastal plain in Canterbury, New Zealand was examined with the aim of determining their mechanism and direction of deposition. Analyses were undertaken on seven transects across an area of 2 km<sup>2</sup>, following the boundary of the river and beginning 1 km inland from the coast. Methods include stratigraphic logging, grain size analysis and Anisotropy of Magnetic Susceptibility (AMS) to determine spatial trends in deposit character and direction of deposition. AMS results confirm a deposition direction that is sub-parallel to the coast, i.e. from the river. This is confirmed by sedimentology results, which show deposits thin and fine inland. Mineralogy and microfossil content confirmed a marine origin for the sediment, suggestive of a high-energy coastal event. This has important implications for the reconstruction of high energy paleo-events from their deposits, and the use of the AMS technique to constrain flow direction improves the accuracy of modelling for such events.

**Current and wind-wave interactions with a low shoot-density *Zostera noltii* meadow in a fetch-limited micro-tidal setting, Berre Lagoon, Mediterranean France**

PAQUIER A., MEULÉ S., ANTHONY E.

*Aix-Marseille Université, CEREGE, AIX EN PROVENCE, FRANCE*

Berre Lagoon is a fetch-limited, micro-tidal brackish lagoon on the Mediterranean coast of France occupied by *Zostera noltii* meadows that significantly regressed in the early 20th century. It is inferred that sediment transport processes act as limiting factors through enhanced turbidity and meadow burial or erosion. The meadow shoot density is likely to create variations in sediment transport potential as shown in previous studies. The aim of this study is to elucidate the interactions between the Berre Lagoon low shoot-density meadow and currents and wind waves.

Winds, currents and waves were surveyed within a meadow thriving in very shallow water. Different wind orientations were monitored, notably during the Mistral, a strong and frequent NNW wind affecting French mediterranean sea, and which has the largest fetch over Berre Lagoon. Our initial hypothesis was, therefore, that the Mistral generated the highest waves, the strongest currents and thus induced efficient resuspension events within the meadow. However, the Mistral generated relatively weak currents, a feature we attribute to the morphology of the lagoon. In contrast, equivalent wave heights were observed with lighter winds having lower directional occurrences than the Mistral. These winds also induced stronger lagoon currents, and are thus likely to have a greater impact on the meadow by controlling sediment transport. A typical velocity profile that did not depend on wind direction was observed with flow reduction in the lower denser part of the canopy, and high turbulence and a stronger velocity gradient at the top of the canopy, in agreement with the literature. Despite meadow growth during spring, the boundary layer thickness did not increase significantly. We assume that this is due to flexibility of the *Z. noltii* canopy under the current flow effect.

\*\*\*\*\*

**Beach morphodynamics under rock-armour breakwater protection in a microtidal, storm-dominated Mediterranean setting**

GIAIME M.(1), ANTHONY E.(2), DUSSOUILLEZ P.(2)

*(1) Aix Marseille Université, AIX-EN-PROVENCE, FRANCE ; (2) Aix Marseille Université, AIX-EN-PROVENCE, FRANCE*

Four rock-armoured breakwaters were installed in 1989 on the eroding southern extremity of the embayed and highly touristic microtidal beach of St. Raphaël Bay on the Mediterranean coast of France, forming one of the rare breakwater fields in France. A nourishment of 200,000 m<sup>3</sup> of sand accompanied the project, resulting in an expanded beach area of nearly 36,000 m<sup>2</sup>. Between 1989, following this nourishment, and 2011, the breakwater-protected beach has remained quite stable, characterized by salients that developed in the lee of each breakwater. Six digital elevation models of the beach behind one of the breakwaters obtained between December 2011 and October 2012 show the construction of prominent low-energy berms that are partially destroyed by storms within this relatively stable budget context. Wave height measurements from pressure sensors deployed in various sectors of the pocket beach behind the breakwater display clear gradients in attenuation. The success of the breakwaters is related to the initial complementary nourishment that significantly enlarged the beach and its buffer capacity, and the optimal breakwater dimensions in terms of breakwater distance to the beach (X), breakwater length (B), and gap between breakwaters (G), which, for the study area, yield an index of  $X/(2B + G) = 0.08$ , well below the critical breakwater efficiency threshold of ~1 proposed in the literature. A third factor of stability, suggested by the wave height gradients, may reside in breakwater-induced sand exchange between the open stable beach to the north, which has not required protection, and the hitherto eroding but now breakwater-stabilized beach sector.

### **Consequences of the coastal geomorphologic system to the tsunami deposits generated by 1883 Krakatau eruption in Ujung Kulon Peninsula, Indonesia**

*ISKANDARSYAH T.(1), WASSMER P.(2), SCHWARTZ D.(2)*

*(1) Universitas Padjadjaran, JATINANGOR, INDONESIA ; (2) Université de Strasbourg, STRASBOURG, FRANCE*

Ujung Kulon is a peninsula at the west end of Java Island, close to the Krakatau volcanic complex. In 1883 Mount Krakatau erupted and generated a mega-tsunami, which had destroyed the neighboring coastal areas. The effects of Krakatau mega-tsunami reached Ujung Kulon up to the coastal of Indian Ocean. The tsunami deposits in the coastal plain of Ujung Kulon are assessed using textural and compositional analysis based on drilling and trenching data. In general, the tsunami deposits consist of a sandy layer with abundant reworked shell and other carbonate fragments, these coarse materials could be derived from the seabed until 40 meters depth. An important diagnostic criterion for these Krakatau tsunami deposits are the presence of pyroclastic materials of the 1883 Krakatau eruption. The pyroclastic materials associated with the tsunami deposits are volcanic ash and pumice, as product of pyroclastic flow which entering the sea. In the western part of Ujung Kulon National Park, the tsunami deposits have a thickness between 30 – 50 cm and locally more than 50 cm. On the contrary, along the coastal plain of the eastern part of Ujung Kulon National Park (Gunung Honje), the tsunami deposits are relatively thin but well-preserved (less than 15 cm). The thickest tsunami deposit was found in the middle part of Ujung Kulon (could be more than 1 meter), and it was presumably caused by its coastal geomorphological condition which was a narrow peneplain between Sunda Strait and Indian Ocean and situated on a V-shaped bay. When the great tsunami wave coming from the northern part, this area might be a wave trapped and the tsunami longer inundated with low accumulation rates. It could be the reason also for the presence of bioturbation in the pyroclastic layer at the upper part of tsunami deposit package. Moreover, the various tsunami deposits formed under the influence of different types of flow both from the Sunda Strait and the Indian Ocean.

\*\*\*\*\*

### **DGPS and high resolution SAR satellite data integration for coastline extraction and monitoring coastal assessment**

*BALDASSARRE M., BELLOTTI P., DAVOLI L.*

*Sapienza - University of Rome, ROME, ITALY*

The application of high resolution methods for shoreline mapping and shoreline map detection is expanding its importance for safe navigation, coastal resource management, coastal environmental protection, and sustainable coastal development and planning.

Remote sensing is providing useful tools for coastal monitoring and mapping not only based on optical sensors but also on SAR, because these last ones are increasing their performance both spatial and in time resolution.

The Italian COSMO-SkyMed mission offers a great opportunity to obtain radar images, useful for mapping, being characterized by high revisit time, thanks to its four-satellites constellation, and high spatial resolution (1x1 meter in SpotLight mode). Moreover SAR being spaceborne active sensor has the uncontested advantage to extracting information during the night and to penetrate atmosphere virtually in every weather conditions. From COSMO-SkyMed data, different typologies of information can be obtained, characterizing a coastal system and providing a reliable monitoring device.

Aimed at investigate the capability of shoreline extract from high resolution SAR images, the results have been compared to manually digitized shorelines data and to high precision Differential Global Positioning Systems (DGPS) data. Three different images, captured between October 2008 and December 2009, have been analyzed for the present work. They recorded marked seasonal coastline variations.

The study has been carried out along the northern coastal stretch of Sant'Eufemia Gulf (Tyrrhenian coast of Calabria, Southern Italy). This area is affected by high dynamism, with abundant transport of material. Moreover the area has high potential touristic attraction such a great environmental importance and, since 1995 it has been included in the European Conservation Program (LIFE Nature Project).

## Restoration of the coastal geo-environment along Tottori Sand Dunes

KODAMA Y.(1), WATAKABE T.(2)

(1) *Fac. Regional Sciences, Tottori-Univ., TOTTORI, JAPAN* ; (2) *Grad. School Regional Sciences, Tottori-Univ., TOTTORI, JAPAN*

Along the coast of Tottori Sand Dunes, western Japan, dimensions of offshore bars were illustrated from air photos taken in 1968-2008 at 5 year intervals and grain size distributions at berm crests on the beach have been investigated over a half century since 1955. The results show that beach environments have been restoring naturally after damages induced by human activities, such as sand and gravel harvesting in the Sendai River during 1960-1975, which had caused diminishing of offshore bars, coastal erosions and beach sediment coarsening (>1.0 mm) at 1980's and finally vegetation covering of the Tottori Sand Dunes. After stopping sand and gravel harvesting, large floods occurred in 1998 and 2004. These floods transported lots of sediment from upper parts of the drainage area to the main Sendai River. Around 2000, offshore bars along the coast became larger and grain sizes on the beach changes finer (<0.4mm) after 2011. These grain size values are similar to those in 1955. We are expecting that weeds on the Tottori Sand Dunes will relief naturally by activating blown sand. These phenomena become a good story to get visitors notice well-coordinated natural systems as a geo-park site in the San'in-kaigan Global Geo Park.

\*\*\*\*\*

## Coastal Dynamics in western Sicily

LIGUORI V.(1), MANNO G.(1), AGATE F.(2)

(1) *DICAM - Universite degli Studi di Palermo, PALERMO, ITALY* ; (2) *Enviromental Engineering, PALERMO, ITALY*

The study of the evolution of the beaches plays a fundamental role in every territorial politics regarding the coastal band. More than half the world population lives in coastal regions which support a florid touristic activity in many countries. The beach constitutes, in terms of economic value, the most important element of the coastal system, but also the more fragile and morphologically variable. Thus, studying its evolutions is fundamental in order to adopt the best management of this complex, densely populated and economically interesting zone. In this regard, the western coast of Sicily (Italy) is an effective example. It took its origin from variation of the sea middle level (Quaternary), with the consequent formation of marine terraces. Morphologically, the shore is made up by low and rock coast alternating beaches. The historical evolution of the coast has been performed through the use of aerial images identifying, despite several uncertainties, the position of the shoreline. Indeed the shoreline position extracted from an aerial image is a wet/dry line that describes the instantaneous land-water boundary at the time of imaging rather than a "normal" or "average" condition. Each wave instantaneously influences the shoreline position and hence, to take into account shoreline oscillations due to wave motion. Even if from a conceptual point of view the shore line is defined as a border between the emerged earth and the sea, its perennial variability makes it difficult to determine.

In order to start a correct management, a cognitive geomorphological study has been carried on, as well as a study of high strategic value and environmental sustainability. It was based on a continuous decisional process based on objectives defined by the UE, in order to classify the beaches and to define the characteristic which are necessary for a correct coastal management.

### **Spatial Variation of Grain-Size Composition of Artificial Beach at the Novosibirsk Reservoir**

FEDOROVA E.

*Institute for Water and Environmental Problems of SB of RAS, BARNAIL, RUSSIAN FEDERATION*

The largest artificial beach of the Novosibirsk reservoir is located in its northern part. In 1959-1962, to protect the railway, the beach was nourished, and in 1987 it was replenished. Currently, the research on the necessity of second replenishment is needed.

Grain-size is one of the determinants of sediment migration and accumulation. Grain-size composition is a stable parameter which keeps the information about previous and modern processes forming morphodynamics of coastal accretive forms.

The study of the beach's grain-size composition was made by IWEP SB RAS in 2010 and 2012. Based on the results of field studies on spatial and temporal variability of sediment grain size in the area under study, the authors analyzed current lithodynamic and hydrological processes. Ground samples were taken from the most characteristic morphological parts of the coast, namely in the berm, foreshore and underwater beach profiles. The samples were dried, weighed and sieved. Fractions >10; 10-5; 5-2; 2-1; 1-0.5; 0.5-0.25; 0.25-0.1; 0.1-0.05 mm were selected.

The constructed graphs of the mean grain size distribution within the profile clearly demonstrate the level regime change in the reservoir. The largest material ( $d_{50} = 0.42$  mm) is observed at normal water level of 113.5 m, then, down the profile, mean particle size decreases up to 0.26 mm. At low water level (111.2 m) mean size of the material increases to 0.31 mm, while down the profile it decreases again. The amount of fractions (less than 0.25 mm) increases in number in the sea direction. For beach nourishment sand size smaller than 0.25 mm is not suitable, because during storms and strong winds such particles are carried away from the land into the water and never come back to the land again. The sediments larger than 2 mm in size are absent in the underwater beach profile. The largest particles (5-10 mm) are concentrated in the center of the beach, out of reach of strong autumn storms when the reservoir level becomes low.

\*\*\*\*\*

### **Study of annual equilibrium beach evolution at coastal of man-made lake**

KHOMCHANOVSKII A., KHABIDOV A.

*Institute for Water and Environmental Problems of SB of RAS, BARNAIL, RUSSIAN FEDERATION*

The goal of the study was to investigate the influence of seasonal variation of wave action and water level on the beach profile changes.

The investigation has been done by numerical simulation and by field observations. An artificial sand beach located at Novosibirsk reservoir was chosen as an object of the study. This beach was constructed in 1959-1962, and it was replenished 25 years later. The long-term observations have demonstrated that the beach profile is in equilibrium.

The reservoir's water level varies seasonally. It rises up to the normal value in May – June, stays at this mark in July – August and slowly drops down to the minimal value in fall and winter.

Time series of wind data of from the nearest weather station were used to reproduce typical wave action during the ice-free period.

The numerical simulation of the beach profile changes has been done by SBEACH software.

The following main conclusions can be drawn from the results of numerical simulation and field observations conducted:

- 1). The most significant changes of the beach profile occur in autumn as a result of just a few south-west storms;
- 2). The reservoir's water level variations have a substantial influence on the annual beach profile evolution. For example, in September 2010 the bar that had been formed by the strong storm was moved towards the shore line due to lowering the water level.

### **Analyses of coastal geomorphology change in a macrotidal setting, west coast of Korea**

PARK S., LEE G.E.

*Chungnam National University, DAEJEON, SOUTH KOREA*

The Asan Bay in the western coast of Korea (eastern Yellow Sea) is a well-known macrotidal embayment with tidal ranges of up to 8 m. Strong tidal action caused by high tidal ranges in this area significantly increases the potential for erosional/depositional processes within the embayment. Furthermore, there has been active development such as the construction of seawalls, industrial complex, and harbor in the Asan Bay since the 1970's. This development changed the physical characteristics of the seawater including tidal current velocity and sediment flux, which caused changes in the coastal morphology. In this study, we studied the morphology change of the bay over the past 30 years both qualitatively and quantitatively, using a GIS's overlay analysis with data collected in 1976, 1985, 1996, and 2006.

We found that the Asan Bay became shallower for over the last 30 years; a shallowing tendency is distinctively observed around the large sand bank (Jungangcheontoe) and in tidal channels. The sand bank moved toward the northeast until 1996 and toward the south since 1996. The size of the sand bank was enlarged toward the southwest by profile section. We also observed that in profile of tidal channels, the southern channel became shallower than the northern channel. The sedimentation rate of the southern channel has been approximately five times higher than that of the northern channel. We conclude that the construction of artificial structures in the Asan Bay changed the tidal current velocity which changed the sedimentation and erosion rates, and caused changes in the coastal morphology.

\*\*\*\*\*

### **Field observations of morphological change on contrasting beaches: An investigation at two sites on the North Atlantic coast of Morocco**

TAAOUATI M.(1), ANTHONY E.J.(2), EL MRINI A.(3), NACHITE D.(1)

*(1) Department of Geology, Faculty of Sciences, TETOUAN, MOROCCO ; (2) Aix-Marseille University, Institut Universitaire de France, CEREGE, UMR CNRS 7330, Europôle Méditerranéen de l'Arbois, AIX-EN-PROVENCE, FRANCE ; (3) Géolittomer, LETG UMR 6554 CNRS, Faculté Lettres et Sciences Humaines, NANTES, FRANCE*

This work presents research, conducted for the first time, on beaches on the Tangiers Peninsula, North Atlantic coast of Morocco. The main aim was to investigate seasonal beach change under variations in wave climate. The field observations consisted of high-resolution topographic surveys of two selected beaches, Charf el Akab in the North and Asilah in the South, from 2005 to 2007 using a total station. The study area is a mesotidal environment subject to strong Atlantic swells, and the beaches are primarily composed of fine to medium sand and exhibit a gentle slope with a mean intertidal gradient of 0.02 and 0.04 at Charf el Akab and Asilah, respectively. The beaches show seasonal morphodynamic behavior, the rhythmic nature of which is governed by the swell and wind regime. Accretion episodes generally observed during the relatively low-energy summer season, are characterized by classic swash bar formation, whereas bars are flattened by winter storms. These changes, driven by wave energy, are typical of switches between the dissipative (winter) and intermediate (summer) domains. The volume changes further show the dominance of cross-shore variability at Charf el Akab beach, thus highlighting a strong relationship between morpho-sedimentary adjustments and wave energy flux; whereas longitudinal changes are more important at Asilah beach, where longshore drift prevails. The study shows thus the co-existence of a swash- and drift-aligned beach on a straight exposed coastline. Normalized beach volumes of  $-0.01$  and  $+0.04$   $m^3/m^2$  for Charf el Akab and Asilah, respectively, are within the volume error margin ( $\pm 0.05$  m) and thus reflect sediment budget stability over the two-year survey period. The short-term sediment budgets and longer-term remote-sensing evidence suggest that the beaches are attuned to these two different sand transport contexts. The local environmental conditions, including longshore drift continuity for Asilah beach, explain this difference.

### Monitoring of the sandy shoreline changes on the Pays de Monts coast from the 1920s to 2010

*JUIGNER M.(1), ROBIN M.(1), FATTAL P.(1), MAANAN M.(1), DEBAINE F.(1), BAUDOIN V.(2), LE GUERN C.(2), GOUGUET L.(3)*

*(1) IGARUN / UMR 6554 LETG - Geolittomer, NANTES, FRANCE ; (2) BRGM, NANTES, FRANCE ; (3) ONF, NANTES, FRANCE*

This presentation points out the multi-temporal shoreline change over a 90 year period (1920-2010) along the sandy coast of Pays de Monts (W France).

The aims of this study are to improve the shoreline change trends detection and the processes at the origin of these movements. Moreover, this is also to develop a repeatable method to quantify the coastline mobility on the sandy coast. Both GPS cross-shore and foredune topographic surveys (conducted at April 2010, 2011, 2012) and eight aerial photograph coverage are used to describe the coastline.

The coastline is based upon identification of morphological and botanical features characterizing beach-dune contact. The coastlines were digitized on each aerial photograph. The Digital Shoreline Analysis System (DSAS) enables calculation of rate of change statistics from multiple shoreline positions was used in combination with ArcGIS to calculate coastline change between consecutive aerial photographs. The change rates are computed with two statistic methods offered by the DSAS -WLR and EPR.

The long-term results indicates that the coastline in accretion is predominant with 37,4 % whereas erosion affects 26,4 % of the coastline with a maximum rate of -0,63 m/an. The periodic results show that intensity of erosion seems to be increasing since few years. It may be correlated with the marine and climatic setting (conjunction of tide, wind, swell, atmospheric pressure, leading to surges). Moreover, this study highlights the morphological impacts of the Xynthia storm and the foredune resilience over a short term. Finally, this study points out a smoothing method which allows digitizing accurate shorelines. This allows too segmenting the shoreline in order to analyse and classify the periodic results.

\*\*\*\*\*

### Multi-temporal scale development of embryo dunes on an accreting macrotidal beach: North Lincolnshire, UK

*MONTREUIL A., BULLARD J., CHANDLER J.*

*Loughborough university, LOUGHBOROUGH, UNITED KINGDOM*

Embryo dunes are important precursors to the development of established dunes in coastal and desert dunefields but are rarely the focus of research efforts. Topographic surveys of the embryo dunes located on the upper (>MHWs) section of an accreting macrotidal beach on the north Lincolnshire coast (UK) were carried out seasonally over a period of 16 months (July 2009–October 2010) using high resolution terrestrial laser scanning. This made it possible to quantify morphological changes and sand budget variability, as well as patterns and potential processes involved in sand input and output to the embryo dune field. The relationships among wind regime, storm surges and dune geomorphology were also explored. The volume of sand within the embryo dune field ranged from a minimum of 12,622.54 m<sup>3</sup> in January 2010 to a maximum of 13,263.17 m<sup>3</sup> in June 2010. The majority of volume gain was a result of seaward accretion in response to onshore aeolian sediment supply as opposed to either a gain in height or an expansion of the dune field in an alongshore direction. Sediment volume was reduced in the embryo dune field as a result of two severe storm surge events that occurred during the winter months. The storm surges caused erosion of corridors between dunes. Between October 2009 and January 2010 the embryo dunes lost c.315.49 m<sup>3</sup> of sand corresponding to a volumetric ratio of sand thickness of -0.026 m month<sup>-1</sup>. However, subsequent surveys show that the dunes then progressively recovered. In addition, the annual morphological development of the embryo dunes was explored between 2001 and 2011. After ten years, the patch of embryo dunes is still expanding but the influence of oblique onshore and alongshore winds has caused it to become elongated and also possibly prevented the dunes from merging with more established foredunes to landward.

## **Predicting storm erosion impacts on exposed beaches**

*TRINDADE J., RAMOS-PEREIRA A.*

*Centre of Geographical Studies of the University of Lisbon, LISBOA, PORTUGAL*

High energetic events and their impact on coastal zones are of fundamental importance when extreme system responses, maximum system resilience or susceptibility mapping are considered and studied. In beach systems, the magnitude of this dynamic behavior is highly dependent on wave height, period and direction, tide amplitude, sediment size and pre-existent morphology. The main objective is to present the results of predicted high magnitude storm impacts on beach profile erosion. These results are based on beach profile systematic monitoring data and correspondent empirical morphodynamic modeling, using SBEACH model, applied to three beach systems in the exposed and rocky coast near Lisbon (Portugal).

Measured profiles show considerable differences in the morphodynamic behavior of the three beach systems, considering their proximity and similar exposure to NW dominant wave direction. Planimetric behavior and sediment budgets differentiation are shown and measured storm impacts are analyzed and considered for profile extreme erosion prediction.

Predicted behavior of the beach profiles in the three beach systems is based on a 100year wave height return period using SBEACH morphodynamic model. The empirical nature of this beach profile behavior model allows the calibration using local hydrodynamic, sedimentological and morphodynamic parametrization. Results of the model calibration and validation processes are discussed.

Maximum profile recession due to extreme storm impact is finally mapped in the three systems and major systems predicted modifications are discussed in the management framework.

\*\*\*\*\*

## **Influence of coastal geomorphology on boulder transport by ice in the St. Lawrence estuary (Quebec, Canada)**

*MARIE G.(1), NEUMEIER U.(2), LE ROUX A.(3)*

*(1) Université du Québec à Rimouski, RIMOUSKI, CANADA ; (2) ISMER - Université du Québec à Rimouski, RIMOUSKI, CANADA ; (3) Université de Bretagne Occidentale, BREST, FRANCE*

Sea ice, which is present 3-4 months each winter in the St. Lawrence estuary, is a significant sediment transport agent. It erodes, pushes and carries sediments of all sizes in the intertidal and nearshore areas.

We studied the movements of large boulders (1-5 m) at two macrotidal locations on the south shore of the lower St. Lawrence Estuary: (1) Pointe-aux-Épinettes in the Bic Provincial Parc, a sand flat and salt marsh that is partially sheltered in a large embayment, and (2) East of Sainte-Luce-sur-Mer, a straight exposed coast with an irregular rocky platform. At the two locations, 200 and 100 boulders, respectively, were tagged with an electronic chip (PIT tag) to identify them unambiguously. Their position was surveyed using a differential GPS with a 15 mm accuracy during the ice-free season. Long-term movements were also estimated between Rimouski and Saint-Ulric from georeferenced historical aerial photographs (1963 and 2009).

Boulders are either pushed or rafted by ice-floes. Boulder transport appears relatively unpredictable with an interannual variability and a great spatial variability that depend on the coastal morphology (exposure to wave and tidal current, profile, roughness and lithology of the intertidal zone, position and burial of the boulder) and the conditions during ice break-up (ice abundance, wind, waves and currents).

Displacements are important on flat muddy and rocky coastal zones. They appear random in protected areas, with higher boulder mobility near the mean water line. On the cobble pavement covering the lower part of many rocky platforms, boulder movements are limited except at its margin.

Blocks pushed on short distance by ice-floes are quite frequent when the boulder is not too buried in mud or blocked by cobbles. Long distance movements of blocks by ice-rafting are less frequent, but they are probably responsible for a large amount of small-size sediment transport.

### **Changing Water Resources of West Bengal, India: A Micro level Study**

BISWAS B.

*The University of Burdwan, WEST BENGAL, BURDWAN, INDIA*

There may be no definite change in temporal pattern of water cycle of India but some parts including West Bengal is showing declining precipitation. So, the availability of water is decreasing. The situation is aggravated with the polluted surface water and contamination of the ground water by arsenic, fluoride etc. The increasing agricultural activities and urbanization also requires more water and land. The impact is felt on the decreasing surface water bodies, declining ground water resources.

India receives highly uneven 3816 TMC of precipitation. With the available management practices, presently West Bengal is having 13.02 Mham water requirement (82% of the total available water), while in 2025 the demand for water may be about 105%! This is observed even in the smaller villages also.

The ground water table has gone down at least 10 meter in several places in West Bengal in last 10 years and using Markov Random Field/Chain it has also been calculated the surface water bodies are also reducing its number and size at an alarming rate.

In West Bengal, 85% of water is withdrawn from ground water while 92% of it is used for irrigation. The meandering streams and rivers and other water bodies cover at least 5% of its area. Calculation has been done, using RS-GIS that they can hold excess rain water throughout the year and may also be used for domestic and other uses with proper care and management.

\*\*\*\*\*

### **Complex rotation of an embayed beach, Essaouira, Morocco**

ELMIMOUNI A.(1), ANTHONY E.(2), DAOUDI L.(2)

*(1) University Cadi Ayyad, MARRAKECH, MOROCCO ; (2) Institut Universitaire de France, Aix-Marseille Université, AIX-MARSEILLE, FRANCE*

This study concerns a relatively complex beach sediment circulation system in an embayment exposed to Atlantic waves, high-energy flash floods from a nearby wadi and intense aeolian activity. Essaouira bay beach, a famous resort on the Atlantic coast of Morocco, is enclosed to the north by a rock headland comprising a sheltered harbour and to the south by the mouth of a wadi, the River Ksob, which drains a steep catchment of 1480 km<sup>2</sup>. The mouth of the wadi is characterized by a large spit platform recurved to the north, and is connected to a 7 km-wide dune barrier. The beach is separated from this barrier by the city of Essaouira. The sand mobility on this beach implies a 'rotation' process between the two ends of the embayment the rock headland to the north and the broad wadi-mouth sandy spit platform to the south - that is not just under the command of waves, as is commonly reported for beach rotation in the literature. The rotation process also involves active aeolian mobility of sand towards the wadi mouth under the influence of constant winds from the north. The gradual accretion and build-up of the wadi mouth, notably via spit platform growth from both aeolian inputs and fresh sand supply by the Ksob, is periodically interrupted by high-energy flash floods that redistribute sand offshore. Sand is further abstracted from the spit platform and transported by wind and longshore drift towards the open beach south of Essaouira bay. The recovery of Essaouira beach occurs via wave-induced onshore transport, with redistribution towards the lower-energy northern sector of the beach through longshore drift induced by wave refraction and wave energy gradients in the bay. This beach rotation mode is original inasmuch as winds and flash floods are actors in the process. A planned resort in the Ksob estuary as well as the projected new Zerrar dam 30 km upstream of the bay could result in serious disequilibrium of the fragile sedimentary system of Essaouira beach.

## **Holocene evolution of coastal formations in the estuaries of the Guadalquivir and Tinto-Odiel (Gulf of Cadiz, SW Spain)**

CLEMENTE SALAS L.(1), MENANTEAU L.(2), RODRÍGUEZ-RAMIREZ A.(3)

(1) Instituto de Recursos Naturales y Agrobiología de Sevilla (IRNAS, CSIC), SEVILLA, SPAIN ; (2) LETG-Nantes GEOLITTOMER UMR 6554 CNRS and University of Nantes, NANTES, FRANCE ; (3) Departamento de Geodinámica y Paleontología, Universidad de Huelva, HUELVA, SPAIN

The paper summarises the dynamics of the Atlantic coast between the mouths of the rivers Tinto and Odiel and the Guadalquivir in the Holocene. The changes begin at Flandrian Transgression maxima (circa 6500 BP) with the stabilisation of sea level. This marks the beginning of coastal progradation, as seen in the formation of peat deposits in coastal lagoons dating from 4500 BP due to the development of sandy spits which tend to close the mouths of minor rivers. Successive spits have been dated at the mouth of the main rivers. In the Tinto and Odiel, we note the Punta Umbría spit (West), the Punta Arenilla reverse spit (East) and the hook complex of Isla Saltés. The evolutionary sequence has been established through study and dating. The current position of, for example, the watch towers built under Philip II is proof that progradation continues to this day.

In the Guadalquivir estuary, the progression of the Doñana and Algaida spits encouraged the development of the wetlands or Marismas. In these spits we distinguish active dune successions as well as a series of ridges built over several progradation phases: the first between 4200 and 2300 years BP, the second between 2000 and 1300 BP, and a third between 1000 BP and the present. These phases also underwent erosion between 4.500-4.000 years BP, 2.500-2.000 BP and 1300-1000 BP, as seen in the Carrizosa and Vetalengua ridges. They correspond to periods of greater marine influence in the estuary, giving rise to a series of ridges which constitute the chenier plain of Marilópez-Las Nuevas. The ridges of La Marismilla are formed in the final progradation stages of the Doñana spit. In all, there are 21 crests, each of which was formed over a period of 50-60 years, and they have been dated from 1800 BP to the present.

\*\*\*\*\*

## **Morondava, town in danger**

RAZAFIMBELO M.R.(1), RATIARISON A.(2)

(1) University of Antananarivo - Department of Sciences of Earth, ANTANANARIVO, MADAGASCAR ; (2) University of Antananarivo - Department of Physic, ANTANANARIVO, MADAGASCAR

Built on the delta of the River Morondava, between the two major distributary of the River, the city of Morondava which took the name of the River is, since 1914, prey to intense coastal erosion. The period from 1974 to 1997 is characterized by cyclic periods of erosion and sedimentation. A decrease of 100 metres was found in 1979.

The fight began in the years 1950-1960, with the construction of groyne along the waterfront of the city, the most affected part of the coastline. Areas (port, Hellot channel, dam of Dabara) during the colonial period, have caused significant destabilization almost irreversible, represented by spectacular erosion. The construction of the Spurs slowed the process of erosion for a few years but had not arrested him. It is from 1924 that is found the first effects of erosion at the end of the Hellot channel (Betania bay): when the flow of the North arm is low, the channel is subject to infilling and silt, the sea then tackles the marine shoreline from the mouth of the Hellot channel. When the flow is important, there is an important burial and sea fattens then this part of the shore. Then, there is the need to build a maritime boulevard to protect the city against tidal wave whose frequency is estimated at five to eight years. In 2010, work has been made to protect the coastline and rehabilitation of port access road. This work involved a linear 170 m on the side of Morondava. Despite this, the city continues to see its coastline gradually eaten away by the sea.

The use of satellite photos has highlighted the decline in shoreline and littoral drift evolution. Currently, the city is faced with the choice of an appropriate method in the design of coastal areas.

Keywords: Erosion, Littoral, layout, Morondava, Madagascar.

### Morphological changes and dynamics of comet-tails in the Molène archipelago (Brittany, France)

SUANEZ S.(1), FICHAUT B.(1), COSTA S.(2), DAVIDSON R.(2), ARDHUIN F.(3)

(1) Université de Bretagne Occidentale, PLOUZANE, FRANCE ; (2) Université de Caen - Basse Normandie, CAEN, FRANCE ; (3) LOS - IFREMER, PLOUZANÉ, FRANCE

From 2002 to 2012, a morphosedimentary survey of trailing accumulations that form comet tails was conducted on Trielen and Lez ar Chrzienn Islands in the Molène archipelago (Brittany, France). In addition, the local hydrodynamics, based on tidal measurement, and wave data obtained from modelling and field measurements, and local tide current measurements, was analysed. These comet tails are no longer supplied with active sediments from the nearshore platform. Therefore, the morphosedimentary evolution of these depositional forms involved reworking the current [*in situ*] stock and primarily depends on hydrodynamic conditions. When storm waves are coupled with high spring tides, sediment are transported from east to west. This orientation results from offshore waves that refract when passing Ouessant Island and thereby take on a northerly direction and attack the north-eastern tip of the comet tails. Sediment transport in the direction of western incident waves only occurred during periods of low morphogenetic conditions. From 2002 to 2012, for both studied comet tails, the net longshore sediment transport occurred in a direction opposite of the transport direction that prevailed during the construction of these accumulations. These morphosedimentary dynamics involve a process of "cannibalization" that is shared by all trailing accumulations that are no longer supplied with sediments. It is due to the depletion of Pleistocene stocks sedimentary stored on continental shelf platform. The analysis of hydrodynamic conditions shows no apparent relationship between the morphosedimentary changes and the North Atlantic Oscillation. The conjunction of storms with high spring tides seems to play a much more important role in the evolution of comet-tails.

\*\*\*\*\*

### Quantifying disturbances of lake terraces at two lakes on the NE Tibetan Plateau

LOCKOT G.(1), HARTMANN K.(1), WUENNEMANN B.(2)

(1) Freie Universitaet Berlin, BERLIN, GERMANY ; (2) Nanjing University, NANJING, CHINA

Investigation of palaeoshorelines is a common used method to illustrate lake level changes and palaeoclimatic conditions since almost 150 years. Abandoned beach ridges and terraces reshape the form of ancient lakes conserving information about extend of former water bodies. But many preserved palaeoshorelines do not mirror the original height of the past lake levels. They can be altered e.g. by deposition, erosion, tectonics or permafrost. Most studies omit these modifications in feature height. With help of two exemplary lakes from the NE Tibetan Plateau we present first ideas how to quantify uncertainties. Both lakes are located in the monsoonal area of the Tibetan Plateau thus receiving varying amounts of precipitation over the Holocene causing lake levels in different heights.

Lake Donggi Cona (35°18'N, 98°32'E) is situated in an active pull apart basin of the Kunlun Fault, one of the main fault systems in China. Hence it must be assumed that the development of lake terraces was influenced by tectonic, too. Broad dGPS surveying yield to the identification of four terrace generations, averaging at 3.5m, 6.1m, 10.1m and 16.7m above the recent lake level (4090m a.s.l.). Each generation varied within a certain range, suggesting a stronger (tectonic-driven) disturbance the more heterogeneous the generation appears. One-Way ANOVA enables grouping of every level into several subgenerations. Comparing these subgenerations with the known fault pattern the amount of tectonic alteration could be evaluated.

In contrast the terraces of Lake Heihai (36°N, 93°15'E) are disturbed by massive permafrost uplift. Here ancient lake sediments interfinger with segregation ice, building up a terrace complex 8m above the actual lake level (4500m a.s.l.). These uplifted sediments blocked one of the main inflows and changed the whole hydrology of the catchment. Hotspot analysis of a DEM revealed the spatial influence of the permafrost and made it extractable from the modern terraces.

### **Morphological evolution of the Sillon de Talbert gravel barrier spit (Brittany, France) since the 17e century: a challenge for coastal management?**

STEPHAN P.(1), FICHAUT B.(2), SUANEZ S.(2)

(1) *Laboratoire de Géographie Physique (UMR8591 CNRS), MEUDON, FRANCE* ; (2) *Laboratoire Géométrie LETG (UMR 6554 CNRS), PLOUZANÉ, FRANCE*

The Sillon de Talbert is one of the most larger gravel barrier spit of the English Channel and forms a swash-aligned formation. It partially protects the islands of the Bréhat Archipelago against coastal erosion and marine flooding of low-lying land. The main morphological changes to the Sillon de Talbert have been studied since the 17th century, and were accurately quantified between 1930 and 2012, based on early marine maps, aerial photographs and topographic surveys recently conducted by DGPS. The examination of early maps shows that this barrier was attached to the Olone Islands until the end of the 17th century. Towards the mid-18th century, a breach that had formed in the north of the barrier resulted in its transformation into a trailing spit. A slow cannibalisation processes began, dividing the spit into a source area at the proximal section, a transit zone in the median section and an accumulation zone at the distal section of the spit. Long-term analysis of shoreline changes over the past decades highlights the mobility of the Sillon de Talbert, which is characterized by rapid landward retreat by rollover. The results obtained show that for the entire period, the mean migration rate was 1.1 m/yr. This trend has led, over time, to the idea that action must be taken to stabilise and/or protect it by hard structures of coastal defense, especially from the 1960s as the lowland areas behind the spit were beginning to be urbanised. Since the 2000s, the national organization in charge of the acquisition of coastal land for its preservation has been implementing an acquisition policy geared towards urbanized areas sensitive to coastal erosion and marine flooding in the back-barrier area of the Sillon de Talbert. This policy enables the organization of strategic withdrawal and leaves natural processes to gradually take their course. DGPS survey show the resilience of the barrier to extreme storm events is better since the hard structures were destroyed.

\*\*\*\*\*

### **Nearshore Sandbars Behavior on Danube Delta Coast**

TATUI F., VESPREMEANU-STROE A.

*University of Bucharest, BUCHAREST, ROMANIA*

Two-dimensional alongshore sandbars are uniform, straight bars oriented parallel to the shoreline and are typical features on non- to meso-tidal, wave-dominated coasts.

Their dynamics is analyzed along the Romanian Danube Delta (Black Sea coast) virtually tideless beaches. We used statistical methods (complex empirical orthogonal functions and cluster analysis) applied on 10 years of seasonal bathymetric surveys (2003-2013), carried on cross-shore profiles, in order to investigate the differences and similarities in spatial and temporal sandbar characteristics with a series of geometric, morphometric and morphodynamic parameters.

The seasonal behavior of nearshore sandbars clearly indicates a pronounced offshore movement during winter (due to intense storm activity) and a slow onshore movement in the summer. At the multiannual scale, they migrate net offshore in a cyclic manner, in close relationship with the overall shoreline mobility patterns.

The analysis points to significant inter-site differences in spatial and temporal sandbar behavior along the different coastal sectors as a result of the medium and long-term evolution of the coast, via the nearshore slope, wave climate and sediment availability for each sector. There are substantially different sandbars number, morphology and behavior on the sediment-rich accretional sectors than on the erosional ones.

Besides inter-site variations, nearshore sandbars exhibit considerable intra-site variability in their long-term behavior. This variability is related to a grouping of bar migration patterns linked with the differences in geometric and morphometric bar parameters (bar zone width, bar volume) between different sub-sectors of the same coastal area. This is the result of the specific coastal processes and environmental characteristics: nearshore slope; submersed morphology, expressed by the presence of arm mouths; alongshore distribution of wave patterns, longshore and cross-shore currents and sediment budgets.

### Prototype of the information system for coastal zone monitoring

LYGIN A., MARUSIN K., LYGIN A., KHABIDOV A.

*Institute for Water and Environmental Problems, SB RAS (IWEP SB RAS), BARNAUL, RUSSIAN FEDERATION*

Prototype of the Information System for Coastal Zone Monitoring (IS) was designed to store and process data on coastal zone dynamics obtained from various sources such as "Mobile System for Coastal Zone Monitoring", developed in the framework of the federal program, or State Observation network stations.

Data Access Layer (DAL) uses a relational model (connected and disconnected levels) and Entity Data Model (EDM). DAL is packaged in dynamic link libraries for using with web-services and local desktop applications.

Providing information services are launched on the Microsoft® Internet Information Services (IIS) version 7.0. Communication via TCP and HTTP is feasible.

The IS includes seven software components for solving some engineering problems based on the data obtained:

- program for calculating wind wave parameters outside the coastal zone;
- program for calculating wave shoaling and refraction;
- program for calculating equilibrium beach profile and nourishment volume;
- program for calculating net annual alongshore transport;
- program for modeling storm-induced sand beach profile changes;
- program for modeling erosion of the clay coastal profile;
- program for modeling shoreline changes.

The components have options for export data to XML and flat text files. The work was supported by RFBR (project 11-05-10046-к) and federal target program "Research and development on priority directions of scientific-technological complex of Russia in 2007-2013" (project 16.515.11.5075).

\*\*\*\*\*

### Water level modeling on micro-tidal beach, application of several wave breaking approaches

NICOLAE LERMA A.(1), THOMAS Y.F.(2), ANDRADE C.A.(3)

*(1) BRGM, Risques Côtiers et Changement Climatique, 3 AVENUE CLAUDE-GUILLEMIN - BP 36009 - 45060 ORLÉANS, FRANCE ; (2) Laboratoire de Géographie Physique, 1 PLACE ARISTIDE BRIAND, 92195 MEUDON, FRANCE ; (3) Escuela Naval ?Almirante Padilla?, CARTAGENA DE INDIAS, COLOMBIA*

Beaches of Bocagrande peninsula, in the South-West of the Colombian old bastioned town of Cartagena de Indias are of great interest for coastal floods studies. The urban and touristic activities of the district suffer regularly substantial floods, due to the very low-lying topography of the whole sandy bar. In today's sea level rise context, concerns about flood's extents and frequencies are locally growing. The site benefits from high precision topographic data (LIDAR), a  $\Delta$ GPS topo-bathymetric evolution monitoring and a video observation system (HORUS) used to detect high water level during storms and strong swell events.

Those assets make Bocagrande an appropriate site to realize a crossed study of several wave breaking models and compare the different simulated water levels with observations. From nested-scale simulations of wave propagation with WW3 and SWAN models, several methods aiming at reproducing the wave breaking phenomenon are tested. Parametric formula (Stockdon/ Holman), boussinesq model (pCOULWAVE), Non-Linear Shallow Water model (SWASH) and Smooth Particule Hydrodynamics approach (SPhysics) are applied on Bocagrande's beaches' characteristics to derive water levels at the coast.

The comparison between observations and simulations shows variable results. While the most accurate simulations have a vertical precision of 0,10 to 0,20 m, others shows a link between beach steepness and the increase in error values. Moreover the water levels calculations underline the importance of beach profile morphology on the highest reached levels and on floods' extents.

### **Geomorphological Evolution of the coastline in Baie d'Audierne (Western Brittany, France) and relation with changes in the land use**

RUAULT R.(1), REGNAULD H.(2), TIERCELIN J.J.(3), PROUST J.N.(3), MOTTE E.(2)

(1) *Université Rennes II, RENNES, FRANCE* ; (2) *Université Rennes II, UMR 6554, RENNES, FRANCE* ; (3) *Université Rennes 1, OSUR Géosciences, RENNES, FRANCE*

This study deals with the evolution of one part of the coast line (Baie d'Audierne, western coast of Brittany) since WW2. At this moment, the Baie d'Audierne was exploited for military protection work (extraction of one million tons of pebbles). As a consequence the gravel ridge was unable to cope with storms and the fresh water lagoons (Trunvel and Kergalan) were very often flooded by marine waters. The ecological behavior of the entire sites was deeply changed. The local communities decided to take control of these lagoons: close the outlet in order to raise the level of fresh water within the lagoon or contrarily artificially open the gap to empty the lagoon and use the new dry land for agriculture. There is a changing and complicated relation between political decisions and the ecological state of the study sites. With the help of air photographs, local archives and field work in sedimentology, land use changes map were drawn and dune building was reconstructed since gravel extraction has ceased. We try to see if there is a present reconstitution of new natural environment that could work without artificialisation (or human control) of the gaps and outlet.

\*\*\*\*\*

### **Geological Exploration in the Coastal Zone of Bangladesh**

ALAM A.K.M., TALUKDAR A., AHSAN A.

*Geological Survey of Bangladesh, DHAKA, BANGLADESH*

Systematic geological and geomorphological mapping covering the entire coastal zone of Bangladesh has been done under a project funded by the government. Main objectives of the work were to determine the geomorphological and geological characteristics, to delineate spatial distribution of each unit, and to understand the coastal dynamic processes. Moreover, identification of the natural hazard prone areas along the coastal zone has been made.

Different multitemporal and multispectral remote sensing data (SPOT Panchromatic, IRS LISS, Landsat and aerial photographs), topographic maps have been used for mapping and change detection. Extensive fieldwork has been carried out for checking the interpretation, and collecting samples and other relevant data. Besides the surficial mapping subsurface samples have been collected from bore holes with depth ranging from 20m to 260m. Geophysical logging in the bore holes and survey using seismic refraction method have also been carried. The collected samples have been analyzed for mineralogy, chemistry, palynology, micropaleontology and age dating.

Geomorphologically, the coastal zone of Bangladesh has been divided into 3 each having different geological characteristics. Bank erosion, flash flood, cyclone, landslide, water logging, salinity increase and arsenic contamination in groundwater are the major natural hazards identified in the coastal area. A geoscientific database has been created which can be used for hazard mitigation or loss reduction, landuse planning, urban planning, formulating strategy for combating and /or adaptation to climate change effects etc. i.e. for sustainable development planning

### **Evolution of quaternary coastal landscape in the Giglio Island (Tuscany, Italy)**

*CIAMPALINI A.(1), FIDOLINI F.(1), ANDREETTA A.(2), CONSOLONI I.(3), MORETTI S.(1)*

*(1) Earth Sciences Department, University of Firenze, FIRENZE, ITALY ; (2) Dipartimento di Scienze delle Produzioni Vegetali, del Suolo e dell'Ambiente Agro Forestale, Università di Firenze, FIRENZE, ITALY ; (3) Earth Sciences Department, University of Pisa, PISA, ITALY*

Eolianite deposits represent important relict coastal landforms on many mid-latitude continents and islands. These kind of sediments are very useful in paleoclimatic reconstruction because their deposition occurred usually during the interglacial and some interstadial sea-level highstand especially in the Quaternary.

On the other hand, several studies suggest that other eolianite deposits can be formed during glacial periods, during a low sea-level stand. These deposits are eolian-reworked relict shelf or coastal sediments, or remnants of former highly mobile coastal dunes. The study of the sedimentary characteristics, the isotopic composition and the use of an suitable dating method can help to understand when and under which climatic conditions, a considered eolianite deposit was formed.

Along the northern coast of the Giglio island (Tuscany, Italy) a small outcrop of eolianite deposits has been recognized. These deposits are placed at the top of a sedimentary sequence formed by continental deposits. The investigated sequence is placed along the coast about 1 m a.s.l. Facies analysis suggests that the sequence evolved from fluvial to eolian environment.

Fluvial sediments consist of sandy channel deposits cutting alluvial plain deposits, showing a well developed paleosol lying on a granitic bedrock.

A sample from the upper, strictly aeolian part of the sequence and one from the channel deposits were subjected to OSL (Optically Stimulated Luminescence) dating.

The succession has been sampled for oxygen isotopic analysis, collecting pedogenic carbonate concretions (ryzoliths) and continental mollusks.

This work contributes to the increase of the number of Quaternary eolianite deposits accounted for in literature and it helps to outline climatic and environmental boundary conditions for the formation of this type of deposit.

\*\*\*\*\*

### **Survey and analysis of coastal geomorphology using Terrestrial LIDAR in Kosrae, Federated States of Micronesia**

*PARK H.S.(1), KWON M.S.(1), JEON C.K.(2)*

*(1) KIOST, ANSAN, SOUTH KOREA ; (2) KESTI, SEOUL, SOUTH KOREA*

Coastal areas in the equatorial Pacific island nations are being threatened by coastal erosion and flooding caused by the global climate change and sea level rise. Actually, 80% Coastal regions of Kosrae, Federated States of Micronesia have high exposure to the effect of coastal erosion. Survey on coastal geomorphology is important because it can serve as a direct indicator for sea level rise and be used in the basic data for coastal vulnerability analysis. In this study, the precise 3D topography using terrestrial LIDAR and total station was surveyed in Kosrae, Federated States of Micronesia, and vulnerable areas to floods were also analyzed by 3D terrain analysis. As a result, an average elevation of the intertidal zones, dykes, roads and residential areas were -0.2m, 2.4m, 2.6m and 1.9~2.4m above sea level, respectively. The elevation of the north and south coastal road was about 2.7m, while coastal road in central area located at estuary of the river was about 2.2m, and represented in the lowest elevation. An average elevation of central area in dyke was also 2.1m, and represented the lowest. The central area was analyzed as being high vulnerability to floods, given that the tide range of this area was 1.8m. Especially, flooding comes first in inland area located at estuary when assumed a simple sea level rise. It is due to low elevation, 1.4m. The elevation of the intertidal zone raised toward the south (average 0.5m) from the north (average -0.4m) high, while the width of the south intertidal zone was more narrow than north. In other words, the waves break near the dyke due to the narrow width of the south intertidal zone area. There is a high possibility that the wave energy may is a risk factor causing the dyke erosion as a result. In actual fieldwork and data provided from the local government of Kosrae, it can verify that active erosion had been found around the south coastal road.

## **Morphological Evolution along the North Part of Paraíba do Sul River Delta, Rio de Janeiro Brazil**

FERNANDEZ G.

Laboratory of Physical Geography (LAGEF). Univ. Federal Fluminense., NITERÓI, BRAZIL

The morphological evolution of Deltas is determined by fluvial input and the hydraulic process (waves, tides and currents), reworking the sediments, forming a complex of different environments. The Paraíba do Sul Delta represents an example of wave dominated delta, where sequences of beach/foredunes ridges can be observed and describes different phases of deltaic sedimentation along the late Quaternary. In early studies, most of the authors focus in the Holocene evolution, which describes that the main process for the coastal evolution was linking by regressive trend of sea level, during mid-late Holocene, after maximum occurred in 5.300 B.P. Instead this previous works suggest that the inappropriate use of term Delta, because the role of fluvial input was not detected, in recent investigations proved that the sediment supply is the main source for the deltaic sedimentation. In this case the main objective of this work is understanding the mechanism for the formation and evolution of the beach/foredunes ridges, in the north part of Paraíba do Sul Delta, and the internal sedimentary structure. To reach these objectives we survey the submarine morphology along the delta front and the prodelta, using 10 bathymetric profiles across the coastline. We choose 3 bathymetric profiles and prolonged to the beach, to describe the topographic evolution connecting the beach and the shoreface. The internal structure was made by Ground Penetrating Radar profiles. The bathymetric profiles showed that, along of the delta front and the prodelta, sequences of submarine bars were gradually organized as one, by incident waves. The emergence bar migrates towards to the beach, identified by topographical surveys, by overwash process. Finally the emergence bar is connecting to the coast, and promotes the shoreline progradation by incorporation sequences of the ridges. The internal sedimentary structure, determined by GPR profiles, showed radarfacies associated of beach and shoreface patterns.

\*\*\*\*\*

## **Geomorphic evolution of the Pinios River delta, in Central Greece, in the Late Holocene**

KARYMBALIS E.(1), KOUGEMITROU E.(1), GAKI-PAPANASTASSIOU K.(2), TSANAKAS K.(2), DRINIA H.(3), ANTONARAKOU A.(3), STATHOPOULOS V.(4)

(1) Department of Geography, Harokopio University, ATHENS, GREECE ; (2) Department of Geography-Climatology, Faculty of Geology & Geoenvironment, National Kapodistrian University of Athens, ATHENS, GREECE ; (3) Department of Historical Geology and palaeontology, Faculty of Geology & Geoenvironment, National Kapodistrian University of Athens, ATHENS, GREECE ; (4) Technological Educational Institution of Halkida, PSACHNA, EVIA ISLAND, GREECE

This study deals with the geomorphic evolution of the Pinios river delta, which is a late Holocene arcuate type delta, located in the southern Thermaikos Gulf (Central Greece).

This work has combined field geomorphological mapping with the study of the stratigraphy of Late Holocene deltaic sediments. A detailed geomorphic map at the scale of 1:5,000 has been prepared showing both the deltaic plain and the coastal zone features using GIS techniques. Comparative interpretation of aerial photographs taken in different dates and reliable maps of the last two centuries along with field observations depict recent changes of the delta morphology. Three boreholes reaching the depth of 4.5m were drilled with a portable drilling set. The stratigraphy of the late Holocene sediments was studied in detail and 40 sediment samples, collected from selected sedimentary layers, were analyzed using micropaleontological and granulometric methods while mollusc samples were dated using AMS radiocarbon method. The study of the stratigraphy of the Holocene deltaic sediments showed that during this period the sea invaded the area of the southern delta and created a shallow open marine environment which at times was disturbed by multiple terrestrial inputs induced by fluvial discharge and longshore drift.

Geomorphological mapping showed that among the most important factors for the recent development of the delta are fluvial sedimentation, wave activity and longshore currents. The dominant landforms in the deltaic plain is the numerous abandoned meandering channels and four generations of beach ridges through which the coastline has advanced during the late Holocene. Today the delta shoreline is generally retreating due to marine processes especially where former river mouths occur where retreat rates reach up to 4m/yr for the last 60 years.

## Conceptual Models for Natural Mechanisms of Sediment Bypassing at the Tidal Inlets along the Konkan Coast of Maharashtra, India

DHORDE A.(1), DHORDE A.(2)

(1) Department of Geography, Nowrosjee Wadia College, Pune, PUNE, INDIA ; (2) Department of Geography, University of Pune., PUNE, INDIA

Inlet sediment bypassing is the process by which sediment moves from the up drift to the down drift side of the inlet, involving the inlet channel and ebb tidal delta (FitzGerald et al, 2000). Sediment movement onshore typically takes place in the form of large landward migrating swash bars which may vary in size. Part of the sediment moving along the down drift beach may be recirculated back towards the inlet or even get transferred further down the bar. In either case sediment movement will be totally determined by the morphology of ebb tidal delta and the wave approach. These general patterns of sand transport result in sediment bypassing at the inlet. This paper attempts at demonstrating mechanisms by which sand is transferred to the down ward shoreline at the tidal inlet along the *Konkan* coast.

Four conceptual models are presented based on the pioneering work of Brunn and Gerritsen (1959), Brunn (1966) and FitzGerald (1982). In all the models only natural, unstructured inlets are considered. The first model proposes the mechanism of spit elongation, ebb channel extension & elongation and natural reclamation of the bay area. The attributing factors being sea level regression and excessive sedimentation based on past processes. The second model tries to stress mechanism behind the spit extension and inlet migration in the near past. The third model is related to the ongoing processes and proposes the mechanism of ebb tidal delta breaching and ebb channel shifts. The last model relates to flood delta formation and bay filling.

Bruun, P. (1966). Tidal inlets and littoral drift: Vol. 2, Universitetsforlaget, Oslo.

Bruun, P.,and Gerritsen,F.(1959) Natural bypassing of sand at coastal inlets,*Jour. Waterways and Harbors Div.*, 85, 401-412

FitzGerald,D.M.(1982). Sediment bypassing at mixed energy tidal inlets,*Proc. 18<sup>th</sup> Coastal Engg. Conf.*, ASCE, 1094-1118.

FitzGerald,D.M.,Kraus,N.C,Hands,E.B.(2000):Natural Mechanisms of Sediment Bypassing at Tidal Inlets, CHETN-IV-30,US

\*\*\*\*\*

## A quantitative comparison of seasonal, annual, and decadal changes in coastal geomorphology in the southern Outer Hebrides, Scotland

YOUNG E.(1), DAWSON S.(1), MCKENZIE B.(2)

(1) University of Dundee, DUNDEE, UNITED KINGDOM ; (2) The James Hutton Institute, INVERGOWRIE, UNITED KINGDOM

In January 2005 a severe storm caused extensive coastal erosion along the western coast of South Uist. A combination of extremely low atmospheric pressure (953 mb<sup>1</sup>) and high wind speeds coincided with high tide, leading to widespread wave undercutting of the dune toe and machair front, with up to 10 m of coastal retreat reported<sup>2</sup> along particularly exposed areas. Large areas of the coastal machair grasslands were flooded, or covered with storm debris, and roads and buildings were damaged. The physical effects of the storm were perceived to be so severe that coastal defence works were erected in five locations to protect infrastructure and agricultural land.

However, it has been suggested that the coastal retreat associated with the January 2005 storm may not be significantly greater than that which would be expected to occur over a typical winter storm season<sup>2</sup>. It is the aim of this research to provide a better context for interpreting the effects of extreme events such as the January 2005 storm by quantifying the cyclical changes that occur on the western coast of South Uist over tidal, seasonal, and annual timescales. Repeat RTK-dGPS surveys and a 2005 LiDAR dataset (© SNH) covering the coastal zone at three sites are used to assess planimetric and volumetric changes. Additionally, historic aerial photography and maps are used to establish the rate and nature of longer term coastal trends in this area. Initial results and interpretations indicate a long term trend of coastal retreat, with highest rates of retreat occurring at exposed sandy headlands, and significant seasonal variability in the beach profile.

<sup>1</sup>Dawson, A., Dawson, S., Ritchie, W. 2007. *Scott. Geogr. J.* 123(2): 135-149.

<sup>2</sup>Angus, S., Rennie, A., 2008. SNH Commissioned Report, Inverness.

### **Reconstruction of coastal evolution and Holocene sea-level history from surface morphology and lagoon sediments of a regressive, micro-tidal environment**

SANDER L.(1), MORIGI C.(2), FRUERGAARD M.(1), JOHANNESSEN P.N.(2), NIELSEN L.H.(2), PEJRUP M.(1)

(1) University of Copenhagen, Department of Geosciences and Natural Resource Management, COPENHAGEN, DENMARK ; (2) Geological Survey of Denmark and Greenland, COPENHAGEN, DENMARK

The island of Samsø is located in the southern Kattegat Sea, Denmark. The area experienced a period of rapid transgression during the early Atlantic, reaching its maximum approx. 7,600 yr BP. Since then, isostatic uplift gradually caused relative sea-level to drop. Ephemeral shallow-water lagoons and associated barrier systems evolved in topographic depressions along the shores of Samsø. Most of these filled in and became inactive until today.

In the scope of this project we study the evolution of the coastal landscape from the mid-Holocene to present day. Methodologically, we combine the interpretation of the surface morphology with the investigation of stratigraphical variations in the sedimentary deposits, based on core samples.

We use a high-resolution digital elevation model (DEM) and GPS-supported field survey data to “read out” the geomorphological record as well as to deduce a first estimate on timing and accretion rates of beach ridge and spit development. The sedimentological analysis of core samples taken along transects in the fine-grained lagoonal deposits allows us to single out varying energy levels and sediment influx from surrounding sources and thus gives us valuable insight into the evolution and the forming processes of these lagoons and their associated landforms. Age control is established by optically stimulated luminescence dating on sandy samples as well as by radiocarbon dating where applicable.

We further explore the use of benthic (intertidal) foraminifera as an interpretative tool for paleoelevation and correlation of core samples as well as to assess palaeoenvironmental changes (e.g. tides, salinity) in the lagoon.

The aim of this study is to facilitate a three-dimensional description and interpretation of Holocene deposits, landforms and their relation to sea-level.

\*\*\*\*\*

### **Landslide hazard zoning at large scale along Lower Normandy coast affected by slow-moving landslides (France)**

MAQUAIRE O.(1), LISSAK C.(2), COSTA S.(2), THIERY Y.(3), FRESSARD M.(2), DAVIDSON R.(2)

(1) LETG-Caen GEOPHEN, UMR 6554 CNRS Universit<sub>é</sub> de Caen Basse-Normandie, CAEN, FRANCE ; (2) LETG-Caen GEOPHEN, UMR 6554 CNRS Universit<sub>é</sub> de Caen Basse-Normandie, CAEN, FRANCE ; (3) EURO-ENGINEERING, PAU, FRANCE

In Normandy (North-West France), landslides occurring along the coasts are large, deep in marly, sandy and chalky formations. All are characterized by a seasonal activity (1-10 cm.y<sup>-1</sup>) and regularly affected by brutal accelerations inducing pluri-decimetres to pluri-meters horizontal/vertical displacements and the main scarp recession to upstream. These landslides are located along a very touristic coastal area where an increasing land pressure is observed. The landslides have induced direct damages to infrastructures (roads, buildings) and indirect damages to the economical activity.

In a context of land use planning help, this study focused on the landslide hazard zoning at the local scale and on the potential landslide extension based on the integration of multi approach and multi-source data.

First, a geomorphological diagnostic based on several complementary methods to provide direct, indirect and spatially-distributed information of the slope morphology and the internal structure. The results have highlighted the landslides composition into several compartments related to the existence of nested chalk panels and blocks. Secondly, the historical landslide dynamic reconstruction has been lead to define the potential evolution of the major scarp position based on the interpretation and comparison of historical data (aerial photographs, topographic maps...).

In a prospective way, and mainly based on morphological criteria, three degrees of hazard have been determinate (high, moderate, low) according to two scenarios based on knowledge of the morphostructure.

### Development of a Coastal Sensitivity Index for Elafonissos Island, Peloponnese

MAGKLARA M., KARYMBALIS E.

HAROKOPIO UNIVERSITY OF ATHENS, DEPARTMENT OF GEOGRAPHY, ATHENS, GREECE

Many of the world's coasts appear sensitive to the impacts of climate change and particularly sea-level rise. Approximately half the EU population lives 50 km or less from the coast; with 19% of the EU population living within a 10 km coastal strip. In this study, the effects of an anticipated sea-level rise by the year 2100 for the small island of Elafonissos located in southern Peloponnese are estimated. For this purpose a Coastal Sensitivity Index (CSI) similar to the formula proposed for the US and Canada coasts is applied, modified for the Mediterranean environment. CSI calculation involves the relation of the following physical variables, to be related in a quantifiable manner that expresses the relative sensitivity of the coast to physical changes due to future sea-level rise: geomorphology, coastal slope, relative sea-level rise rate, shoreline erosion or accretion rate, mean tidal range and mean wave height. Every section of the coastline is assigned a risk ranking based on each variable, and the CSI is calculated as the square root of the product of the ranked parameters divided by the total number of variables. Rocky and cliffed sections as well as beaches backed by dunes are less sensitive whereas sandy beaches backed by low plains record the highest sensitivity. The results of this study provide a framework for coastal managers and planners to prioritize efforts to enhance the resilience or consider adaptation measures in the coastal zone within the study region.

\*\*\*\*\*

### Verification of dean's equilibrium beach profile formula for large man-made lakes

LYGIN A., LYGIN A., KHABIDOV A.

Institute for Water and Environmental Problems, SB RAS (IWEPS SB RAS), BARNAUL, RUSSIAN FEDERATION

The Dean's equilibrium beach profile formula describes the shape of dynamic equilibrium sandy profile:

$$h(x) = Ax^{2/3}, \quad (1)$$

where  $h$  - a water depth ranging from 0 to  $D_c$ .

$D_c$  - a closure depth, the maximum depth up to which the movement of sediment and, consequently, the current fluctuations in the profile form occur.

$A$  - a steepness parameter profile that depends on the grain size of the material ( $d$ ).

Ease of Dean's function use is in its simple analytical expression that allows to avoid time-consuming numerical simulations under the equilibrium profile construction. It is known that the Dean's equilibrium model holds for the seashore. But we can prove empirically that it is also valid for large man-made lakes.

In fact, the formula of Dean (1) is a special case of a power regression of the form

$$h(x) = A_1 x^n, \quad (2)$$

except for the Dean's coefficient  $n$  fixed at  $2/3$ , and the parameter  $A$ , independent of the actual configuration of the profile for which an equilibrium is built, but depended equilibrium just of the average median grain size of the material  $d$ , which has developed this profile.

Suppose that the shape of the dynamic equilibrium profile has a form of a power function, then for each coastal profile a unique profile of equilibrium expressed by (2), with their unique coefficients  $A$  and  $n$  depending solely on the actual profile configuration exists. Coefficients  $A$  and  $n$  can be calculated by the least-squares method (LSM) widely used in regression analysis.

If Dean's coefficients  $A=A(d)$  and  $n=2/3$  are close to coefficients  $A_1$  and  $n$  obtained by LSM, and the mean relative error of approximation is within the tolerance range, the Dean's model is adequate for this profile.

Successful validation of Dean's formula was done for sandy profiles of the Novosibirsk reservoir, which are in equilibrium in the last tens years.

### **Rip channel patterns on the beach near the mouth of Sele River (southern Italy)**

VALENTE A.(1), PENNETTA M.(2), SICA M.(3)

(1) University of Sannio, BENEVENTO, ITALY ; (2) University of Napoli "Federico II, NAPOLI, ITALY ; (3) Autorità di Bacino Interregionale del F.Sele, NAPOLI, ITALY

The analysis of long-term measurements carried out on the coast of Sele River, located on the western margin of southern Italy, showed a rather articulated morphology of the submerged beach. Along it several channels perpendicular to the shoreline were found, which affecting the original bars parallel to the shore, thus they have shrunk dramatically. These channels are developed mainly between 0 and 5 meters deep and, according to the sedimentological characters, play a significant role in the seaward transport of sediments removed from the bottom. More specifically, the bars are constituted by fine and relatively unsorted sands, while the channels are characterized by the presence of sandy and sorted sediments. The increased size of the sediment in the channels as well as its better selection correlates well to the high hydrodynamic energy of flowing water in the channels probably modeled by rip currents. The presence of these currents has been confirmed by some bathymetric surveys.

The rip currents are also responsible for the morphological changes of the emerged beach and of the typical rhythmic shoreline, with alternating embayments separated by cusps. The embayments are located in correspondence of the head of rip channels, while the cusps laid out at the bars edges, on which the incident waves break. The rip currents erosion on the seabed extended over the inner portion of the emerged beach, causing erosion processes on the dune and discontinuity in the dune system. Such discontinuities promote the genesis of blowouts and parabolic dunes on the beach, that can be the first sign of severe erosion of the coastal system, which is already quite evident in the investigated coastline.

\*\*\*\*\*

### **Vulnerability assessment of Al Hoceima bay (Moroccan Mediterranean coast): a coastal management tool to reduce potential impacts of sea-level rise and storm surges**

KHOUAKHI A.(1), SNOUSSI M.(2)

(1) University Mohammed V, Faculty of science -Agdal , RABAT, MOROCCO ; (2) University Mohammed V, Faculty of science -Agdal, RABAT, MOROCCO

Projected increases in sea level rise (SLR) and in the magnitude and frequency of extreme weather events pose a major challenge for the management of low-lying coastal ecosystems and human settlements in the context of climate change. The bay of Al Hoceima is one of the least studied and largest low-lying coastal areas of the Moroccan Mediterranean coast, and is highly exposed to the effects of SLR and storms. The coast is also a touristic area and one of the most important economic assets in the region of Al Hoceima. Physical coastal vulnerability assessments are one of the principal tools for developing coastal management plans. Here we assess the vulnerability of the coastline to sea level rise and extreme weather events through a standard index methodology based on physical and geomorphological indices a) litho-morphology, b) Beach width c) Coastal slope d) Width of forest behind the beach e) Exposure of the coast, based on the orientation of the coast relative to wave direction and finally f) the Width of vegetation behind the beach. Subsequently a socio-economic valuation of potential impacts in the area was carried out. Using a combination of high resolution maps and remotely-sensed data, we selected the five most relevant physical parameters for local-scale vulnerability analysis, based on 50m/50m cells along the coastline. A total of 822 cells were identified and evaluated, with individual parameter scores ranging from 1 to 4 and calculated total scores from 10 to 20. We found that 28% of the studied coastline is highly vulnerable to the effects of SLR and extreme weather events. These findings will have direct repercussions for coastal development programs over both the short and long terms.

## Definition of geomorphologic coastal systems at the Sao Paulo's coast - a taxonomic proposal

MATOS FIERZ M.

UNIVERSITY OF SAO PAULO, SAO PAULO, BRAZIL

The geomorphological researches of the coastal area are generally focused on understanding which preterit processes that resulted current forms. Thus, propose a taxonomic order to the coastal geomorphology which consists of an adequate systematization of representations of relief in the evolution context of these processes and forms that borders and contributes to the dynamic and maintenance of the coastal plains. The taxonomy can be directed to the geomorphological characteristics represented by the molded recesses shapes and sustained on materials of Crystalline Basement and filled by the Quaternary sediments sourced from the continent or the continental shelf. Therefore, the contribution occurs in the sense of defining a subdivision in taxonomic levels for the researches in coastal geomorphology. To define the different geomorphological systems in the fieldwork, we used the following instruments: the penetrometer to measure the strength of materials and GPR (Ground Penetrating Radar) to differentiate the materials which forms the layers of Quaternary deposits with different levels of resistance in coastal plain. The proposed taxonomy of coastal relief presents the main morfostructures and morfesculptures (Mecerjakov, 1968) and its characteristics depending on the bedrock and soil, resulting in the genesis of active coastal processes. The macrocompartments or geomorphological systems and subsystems are represented on the geomorphological mapping. Thus, it was defined the genetic characteristics of morfostructures of the Crystalline Basement (first taxon), Quaternary deposits (second taxon) and Coastal Plain (third taxon), which is part of the morfoesculptures of fourth taxon or geomorphological subsystems, namely: beach, plain fluvial, fluvial terrace, plain intertidal, marine terrace, plain fluvial-marine, marine terrace covered with dunes and sandy ridges, hills and coastal hills of the southern coast of the state of São Paulo.

\*\*\*\*\*

## The Ubatuba Beachrock (State of São Paulo, Brazil): A New Evidence of a Mid-Holocene Negative Sea-Level

DE GOUVEIA SOUZA C.

Geological Institute, SAO PAULO, BRAZIL

There has been recent debate on whether there has been a negative oscillating of the Holocene sea-level in Brazil. This paper presents a new evidence of a negative sea-level in the mid-Holocene, based on a beachrock found on the Tenório Beach, at Ubatuba County (State of São Paulo, Brazil). Beachrocks refer to the calcium carbonate-cemented sediments that result from lithification in the intertidal zones of tropical coasts, and are considered incontestable evidence of sea-level oscillations. In Brazil, they are common features outcropping along the whole Northeast and East coasts, but they are rare at the Southeast (Rio de Janeiro and São Paulo states), where the most southward remains are referred for the Cabo Frio region (Rio de Janeiro). The Ubatuba beachrock became exposed in 2010 after several storm surges. Its surface lies ca. 0,4m below the current mean sea-level, and exhibits ca. 600 m<sup>2</sup> in area and 0,4m of maximum height. Although internal sedimentary structures are difficult to be identified, its surface shows morphology from upper foreshore and backshore zones relief. The beachrock is composed by very coarse sands rich in shell fragments, what suggest different morphodynamic conditions from the present beach (fine sands). The cement is mainly formed by calcite. Some penetrative fractures crossing the main body are also filled by calcite cement. Both cements have been dated by the AMS method and showed ages from 4820-4400 yr cal BP (4400 ± 30 yr BP) to 3950-3630 yr cal BP (3830 ± 30 yr BP), respectively. The whole surface of the beachrock is marked by dozens of palaeo-urchin burrows, indicating that it has been submerged after the cementation. Considering that some authors have found evidences indicating that the Holocene transgression maximum began about 5000 yr BP for the study area, then the Ubatuba beachrock seems to prove that after this maximum there was a rapid negative sea-level oscillating down to ca. -0,4 m, followed by a new sea-level rising.

### **Geoindicators and beach classification for coastal management in Arraial do Cabo, Rio de Janeiro, Brazil**

PEDROSA F., NASCIMENTO F.

*Federal University of Fluminense, RIO DE JANEIRO, BRAZIL*

The research of geomorphology can be useful for many different studies. On the coastal management, it also has an important role. The evaluation of different geomorphologic components of a beach and shoreline can help classify the current state of a beach; and therefore determine the best kind of management for the area. The study of the geoindicators on the shoreline was the method chosen to classify the urban beaches in Arraial do Cabo, RJ, Brazil. To study and classify the urban beaches, was made a visual observation of some geoindicators that could show the state of the beach: erosive, stable or accreting. This method is very simple to observe, and it can diminish the time spent in field researchers with the same purposes, just as it reduces the cost of the same researches. It was observed the following geoindicators: the length of the beach; the presence or absence of vegetation, frontal dunes and cliffs; the energy of the waves; if the beach is protected or exposed to open sea; the presence or absence of deteriorated beach vegetation; the granulometry of the sand; the presence or absence of heavy minerals; the presence or absence of engineering intervention; and the presence or absence of urbanization (residential, commercial or touristic purposes) and its position related to the beach. With all these geoindicators observed, it can be determined if the beach researched is more or less exposed to coastal erosion. The principal results are: Praia Grande was classified as a beach with stabilizing tendency. Prainha has erosive tendencies. Praia do Forno indicates a prior state of stability, but a erosive tendency. And Praia dos Anjos, the same as Praia do Forno. Thus, is possible to say that three of the four beaches has an urgent need of coastal management, with suggestions of ways to prevent the total erosion. The geoindicators can also be used as an instrument by the Brazilian coastal legislation, to cover the necessity of coastal monitoring and management.

\*\*\*\*\*

### **Chronology of coastal progradation rates along the Santa Catarina litoral, Brazil**

GONZALEZ-VILA F.

*IRNAS-CSIC, SEVILLE, SPAIN*

The study was done along a 3 km trench profile, perpendicular to the shore line in Volta Velha and at the front of prograding Holocene barriers. Inorganic, and organic elemental analyses, extractable lipid fraction (GC-MS), analytical pyrolysis (Py-GC/MS) and  $^{13}\text{C}$  nuclear magnetic resonance (NMR) were used for the characterisation of organic matter, which was dated by  $^{14}\text{C}$  AMS. In the samples, quartz grains are weakly cemented by a mixture of sesquioxides (2-4%) and humic material with elemental C content between 1 and 3%.

Most of the intensity in the solid-state  $^{13}\text{C}$  NMR spectrum of both VV1 and VV2 samples, differing in age by ca 4 kyr, is in the alkyl C region (45 - 0 ppm) assigned to methylene groups i.e. in fatty or amino acids but also in paraffinic structures. Comparable high intensity is seen in the Carboxyl/carbonyl C region, which is also assignable to amide C.

The signal at 75 ppm in the region of O-alkyl C (110 to 60 ppm) originates most likely from carbohydrates. The low relative contribution of this signal indicates a high humification degree in the older sample VV1. Comparing samples VV1 and VV2, clear time dependent decrease in the carbohydrates is observed, probably reflecting the time of exposure of organic matter to weathering.

In terms of chronology of the accretionary process, the results of 6 AMS  $^{14}\text{C}$  dating performed on samples from the soil B horizon (80 cm depth), plotted against the distance from the active shore, fitted almost perfectly the polynomial, uniformly accelerating trend line.

The starting point of the sequence corresponds to the period antecedent to the mid-Holocene highstand (5800-5000 Cal BP). The first period of coastal accretion (7-3 kyr cal BP) corresponds to a slower (0.2 m/yr) progradation. After 3000 cal BP the accretion is faster (0.61 m/yr); the lowering of the RSL permitted the formation of broad prograding barriers. These data further corroborate the model of Angulo et al. (2006) for the regional coastal barriers.

### **Environmental Problems in coastal margins of Nile delta**

SAYED M.(1), SHAABAN A.B.(1), REGNAULD H.(2), ABDEL HAMID A.(1)

(1) Cairo university, CAIRO, EGYPT ; (2) Rennes 2 University, RENNES, FRANCE

During the last five decades the coastal strips of the Nile delta had been changed dramatically and affected by various land use changes. The environmental system consists principally of lagoons, sand bars, spits, vegetated dunes, river estuaries and wetlands. With the overpopulation change of Nile delta, human-induced changes have covered many aspects like land-reclamation, fish-farming, urban expansion, and international & regional highways. The current study detects extends and limits of these changes since the oldest map available (1818) till 2010 satellite images. Sequence of field surveys through 2008-2012 have assured the results and sustain the data check techniques. This paper will focus on three examples of the land-cover changes: (1) the Rosetta promontory retreatment; (2) coastal dunes destruction in north-western parts of the delta; and (3) the Urban geomorphology of salt weathering in south-eastern margins where the delta conjunct with Suez Canal region.

\*\*\*\*\*

### **Quaternary environmental evolution recorded by littoral deposits in China's southeast coast**

ZHIZHONG L., JIANHUI J., XIULING C., FANGEN H., XIANLI W., JIN X.

College of Geographical Sciences, Fujian Normal University, Fuzhou Fujian Province, FUZHOU FUJIAN, CHINA

Two littoral sediment profiles, Liushui and Keren, on the southeast coast of China provide clear environmental evolution history since 1.80Ma. Two transformation events of neotectonics- climate changes, their boundaries between Calabrian Stage and Ionian Stage (C/I, or Q1/Q2) and between Ionian Stage and Upper (I/U, or Q2/Q3), had caused two obvious depositional hiatuses in Liushui Profile . The age of C/I hiatus (115.2-75.2 Ma, ESR ages) agrees well with the boundary age between Brunhes Epoch and Matuyama Epoch (B/M) of palaeomagnetism. The depositional hiatus of I/U characterized by a suddenly changing grain-size parameters of "old red sand". These hiatuses reflects the influence of coupled the neotectonics-climate (global sea level) changes on the region depositional environment. According to these hiatuses, environmental change history of the area can be divided into two stages. The stratum of lower stage consists of two marine facies layers and a littoral "old red sand" layer. The grain size and magnetic susceptibility of lower stage sediments characterized by the influence of high frequency and small amplitude global sea-level oscillation. The upper stage sediments is made dominantly of littoral "old red sand" depositing since Ionian Stage(or Q2, about 0.78Ma,ESR ages), including coarse reticulate "old red sand" developed in Ionian Stage( Q2), and fine reticulate "old red sand" in early Upper (Q13) . There is an obvious OSL age gap and a suddenly changing sedimentary facies from 100-80Ka at the depth of 12-11m in Keren Profile. They are evidence that reflect the transitional change of last interglacial period (MIS5e) to last glacial period (MIS4). Due to fine reticulate "old red sand" of early Upper (Q13) widely distributed in northeast coast of China' south subtropics, the warm-wet climate similar to that of north margin of tropical climate today would appeared in northeast China's south subtropics areas in early Upper(or last interglacial period, MIS5e).

Key Words: littoral deposits; neotectonics; climate change; sea-level change; ESR and OSL dating; southeast coast of China.

**Ecological and Geomorphic Controls on Spatial Variation of Crab Burrows: A Case Study in Bakkhali Beach Area, West Bengal, India**

CHAUDHURI S.

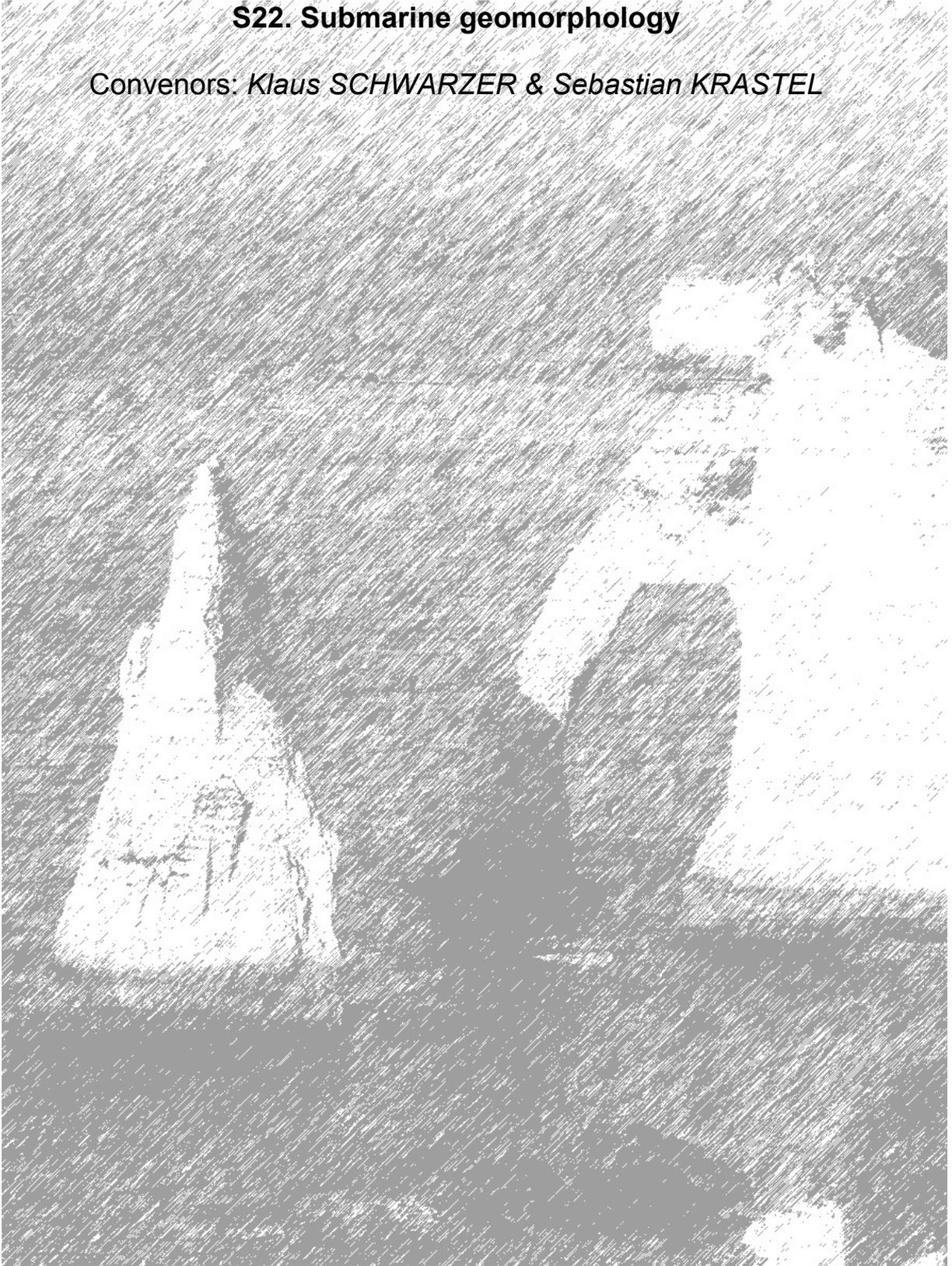
*West Bengal State Univeristy, KOLKATA, INDIA*

Observations on crab burrows in the beach environment of Bakkhali helps to decipher the spatial differentiation of crab behavioural responses with the changing ecological and geomorphic parameters. The present paper deals with crab dwelling structures and this exhibit maximum variation in their characteristics near the spring high tide line and also between the mean and spring high tide line. Near the low tide line the crab burrows are less diversified with other associated species. Random and zone-wise data on bioturbation parameters (viz. average burrow diameter, burrow orientations and burrow density) indicate dominant control of elevation or inundation on crab ichnofabric. Larger burrows show a landward increasing burrow density and dispersions in their burrow orientations suggesting that these were constrained with elevation/inundation. Apparent correlation of bioturbation parameters with sedimentation parameters was also noted, for these post-event burrows. Indirect control of energy fluctuations appears to be more relevant in this context that determines the direct control of varied nutrient supply in the beach area. Plaster casts of crab burrows indicate that the deepest and widest burrows are present near the high tide line, which are often attached with a terminal chamber at the end of the burrow. The shape of the burrows vary from the typical 'J' shape to more complex 'Y' and 'U' shapes. Detailed investigation of the burrow shapes and dimensions show some correlation with beach elevation and tidal inundation zones, which may throw some light on the ecological behaviour of the crab species.

\*\*\*\*\*

## **S22. Submarine geomorphology**

Convenors: *Klaus SCHWARZER & Sebastian KRASTEL*





## Oral presentations:

### **Deriving long-term (multi-century) quantitative measures of marine geomorphological change using qualitative records**

BURNINGHAM H., FRENCH J.  
UCL, LONDON, UNITED KINGDOM

Hydrographic charts are widely used for the assessment of submarine geomorphology and short- to medium-term (years - decades, possibly centuries) seabed morphodynamics. Advances in GIS have facilitated a revival of these cartographic archives through enhanced methods of georeferencing, digitisation and spatial analysis, to produce detailed insights into seabed evolution. The time frame associated with geospatially-accurate hydrographic charts is primarily the 1900s to the present, and in some locations, charts from the mid to late 1800s might also be available. The temporal perspective is often compromised in favour of spatial precision, which usually limits the historical scope to 100-150 years. The period of exploration and discovery (late 1500s to early 1800s), however, delivered a number of resources that, although unsuitable for geospatial analyses, can still be used to reconstruct a multi-century scale history of submarine geomorphological change. In this paper, we use a landform unit scale (feature-focused) approach to describe and analyse an extended history of change in inner shelf geomorphology, using examples from southeast England and the southern North Sea. Banks, shoals and cross-bank channels are assessed in terms of their minimum depths and between-bank channels in terms of their maximum depths. Using more than 200 atlases, navigation pilots and seabed maps and charts, a 300-400 year history of change is achievable. The measures enable the identification of accretion (vertical growth of banks), breakdown (vertical denudation of banks), shoaling (of channels), entrenching (vertical accretion of banks and deepening of between-bank channels) and evolution of feature shape (change in major and minor axis lengths). Examples presented include evidence of: a) the demise or appearance of seabed forms, b) features that exhibit contrasting pre- to post-19th century behaviour and c) significant reshaping of seabed forms.

\*\*\*\*\*

### **Submarine geomorphology and the geomorphometric approach - Recent developments**

MICALLEF A.  
University of Malta, MSIDA, MALTA

Whereas geomorphometric techniques have become a standard tool in the investigation of terrestrial and planetary landscapes, their application in the study of submarine environments has been more infrequent. Advances in seafloor data acquisition systems made in the last two decades, however, have generated a renewed interest in employing geomorphometric techniques and geomorphologic concepts to investigate submarine landscapes.

In this presentation I will provide an overview of techniques that I developed for the geomorphometric analyses of multibeam echosounder data, and demonstrate how their application has enhanced our understanding of three aspects of shallow and deep marine geological phenomena:

- (i) **Mass movements** - by improving the mapping of slope failures across the Norwegian continental slope, identifying their triggering mechanisms and modes of failure, and demonstrating scale invariance in terms of statistics and morphology.
- (ii) **Canyons** - by comparing the morphology of submarine canyons in four continental margins (Catalan, Hikurangi, Argentinian, Maltese) and characterising the differences in canyon processes and evolution between active and passive margins.
- (iii) **Submerged landscapes** - by reconstructing the evolution of the submerged terrestrial paleolandscape of the Maltese Islands during the last glacial cycle and relating this to key stages in Quaternary environmental change.

## **Geomorphological expression of shallow water carbonate buildings in the Mediterranean Sea**

BRACCHI V., SAVINI A., MARCHESE F., CORSELLI C.

Dept. of Earth and Environmental Sciences, Milano-Bicocca University, MILANO, ITALY

Coralligenous habitat consists of autochthonous carbonate build-ups, which produce frameworks with three-dimensional structure that serve as shelter and provide storm protection by buffering wave action along coastlines. So it plays a primary role in the geomorphological development of continental shelf. It is further on considered a high spot of biodiversity and recognized as a protected habitat in the EC Regulation No. 1967/2006 concerning management measures for the sustainable exploitation of fishery resources in the Mediterranean Sea. Different actions were indeed promoted to collect new more detailed data on its range of distribution and extent in the Mediterranean and European seas.

In the framework of BIOMAP project (P.O FESR 2007/2013), promoted by Puglia Region, Italy, two oceanographic cruises were carried out along the Apulian continental shelf (central Mediterranean sea) to collect acoustic data (through MultiBeam Echosounder Systems (MBES) and high-frequency Side Scan Sonar (SSS)) and video inspections, to identify and locate coralligenous habitats, between 10 and 100 m of water depth. The whole data set was processed and analysed through proper GIS-based tools, to investigate the variety of morphologies that coralligenous habitat developed at the explored locations. Detailed Digital Terrain Models (DTMs) have been provided through MBES data-processing and merged with SSS backscattering. The obtained *morpho-acoustic facies* were quantitatively characterized (through morphometric and textural analysis of their acoustic properties) and associated to the collected ground-truthing information (i.e. video inspections).

Different geomorphological expressions of coralligenous habitat have been thus identified. The role of some main environmental parameters (i.e. water depth and current exposure) in determining such different morphologies of coralligenous habitat was investigated.

\*\*\*\*\*

## **Characterization of current sediment dynamics, obtained from the distribution and movement of underwater dunes: the example of the English Channel**

GARLAN T.

SHOM, BREST, FRANCE

During the bathymetric surveys achieved by the French Hydrographic Office (SHOM), submarine dunes were detected in the shallow water zone, at the end of the nineteenth century. He nevertheless had to wait until the late twentieth century, with the arrival of multibeam echo sounder and GPS, to have an accurate characterization of the morphology and location of these dunes. It has thus become possible over the past fifteen years to precisely quantify the speed of dunes and follow their morphological evolution over time. According to sediments and hydrodynamics involved, these rates vary from a few meters to tens of meters per year. The synthesis of Wever (2004), gives all the values of dunes displacements reported in the scientific literature. These studies are unfortunately limited to depths less than 40m. SHOM has done campaigns for several years devoted to the study of the dynamics of dunes of the North Sea, the English Channel and the Celtic Sea, ie the border of Belgium to the continental slope of the Atlantic. The most recent hydrographic surveys conducted in the north and west of Britain, at depths of 70 to 200m, delineated two very large dune fields, that until now had been described only by a few old profiles. More than two thousand dunes were identified during surveys of 2011 and 2012. These one have been added to the GIS dedicated to banks and dunes of the French continental shelf. These surveys have highlighted the boundaries of these two dune fields, and have highlighted the existence of fields of barchan, giant dunes and very large variations in the orientation of the dunes, characterizing the complexity of these environments. After describing the dune fields, we establish a classification of dunes based on their shape, their dynamics and their environment in order to achieve a synthesis of the sedimentary dynamics of the Channel and the Celtic Sea.

### **Submarine geomorphology of a tropical shelf: examples from the Rio Grande Do Norte Shelf, NE Brazil**

VITAL H., GOMES M., NOGUEIRA M., PIERRI G., LIRA H., SILVA J.P., ALMEIDA N.  
Universidade Federal do Rio Grande do Norte, NATAL, BRAZIL

This study focuses on the submarine geomorphology of the Brazilian continental shelf adjacent to the Rio Grande do Norte State, NE Brazil. This tropical shelf represents a modern, highly dynamic mixed carbonate-siliciclastic system characterized by reduced width and shallow depths as compared with other parts of the Brazilian shelf. It has an average width of 40 km, the shelf-break lying at a depth of ~ 60 m and comprises two different sectors separated by the Touros structural high: an eastern and a northern. The study area was investigated by single and multibeam bathymetry, associated with high resolution seismic, remote sensing, sample collection, and scuba dive. The analysis of this data-set revealed an expressive submarine geomorphology represented by very large dune-fields (dune heights reach up to 6 m, and dune widths vary from 400 m to more than 900 m), both longitudinal and transverse to the coast, and small wave- and current generated dunes. Corals knolls and patch reefs are present in the middle to outer shelf in the northern sector, while the most visible are on the inner shelf along the eastern sector, especially around the Touros High. The most important traces of continental terraces are the Natal plateau and marginal Rio Grande do Norte plateau. Channel structures originating at the mouths of the main rivers and extending to the shelf edge can be regarded as incised valleys which cut into the shelf deposits during sea level lowstands. Submerged sand banks are common along this shelf. They are observed at different depths (of 10, 20, 40 and 60 m), the most continuous and prominent structure being found on the 20-25 m isobaths and extending from eastern to northern sector. Samples taken by diving, revealed laminated sandstone cemented by carbonates, similar to the beachrocks commonly exposed along the coast and could be related to ancient coastlines.

\*\*\*\*\*

### **Geomorphological response to North Atlantic Deep Water circulation: Examples from high-energy current environments at the Faroe and Greenland margins and abyssal southwestern North Atlantic**

NIELSEN T., KUIJPERS A.  
Geological Survey of Denmark and Greenland, COPENHAGEN, DENMARK

North Atlantic deep convection in the Greenland Sea region and Labrador - Irminger Sea basins leads to strong bottom current activity associated with Greenland-Scotland Ridge (GSR) overflow and deep western boundary current circulation. We will present examples of seismic records and other evidence (e.g. side scan sonar) documenting strong bottom current action on the seabed along the Nordic Seas overflow pathway from the Faroe-Shetland gateway via the Southeast Greenland margin and thereafter northward along the Southwest Greenland margin towards Davis Strait. In addition, seabed evidence from the Greater Antilles Outer Ridge north of Puerto Rico demonstrates persistent strong boundary current activity also at western North Atlantic lower latitudes. Geomorphological response to this high-energy bottom current regime is expressed in a variety of dynamical bedforms ranging from mega-scale contourites via well-defined sediment waves, sand ribbons and erosional furrows to small-scale ripple marks. Boundary current activity may interact with other seabed shaping processes. For instance, on the Southeast Greenland slope and rise complex interaction between downslope (turbidity flow) sediment transport processes and strong bottom current activity has resulted in the formation of large, well-developed transverse ridges separated by turbidity flow channels. Using known relationships between various bedform types and bottom water dynamics, an estimate of maximum (near)bottom flow speed can be made. Applying this information to actual results from bottom water current measurements, indications for fluctuating maximum bottom water speed have been found, demonstrating important variations in the NADW flow pattern through time.

**Sea floor morphology of north-western Gulf of Corinth (Greece): combined impacts of Late Quaternary eustatism and active tectonics**

*BECKERS A.(1), BECK C.(2), HUBERT-FERRARI A.(1), TRIPSANAS E.(3), SAKELLARIOU D.(3), DE BATIST M.(4), DE RYCKER K.(4), BASCOU P.(2)*

*(1) University of Liège, LIÈGE, BELGIUM ; (2) University of Savoie, LE BOURGET DU LAC, FRANCE ; (3) Hellenic Center of Marine Research, ANAVYSSOS, GREECE ; (4) University of Gent, GENT, BELGIUM*

Two high-resolution seismic reflection surveys (single channel sparker) were performed in the western part of the Gulf of Corinth. aboard HCMR's R/V ALKYON, within the frame of SISCOR ANR Project. This intra-continental marine basin is related to Late Cenozoic to Present extension separating "continental" Greece from Peloponnese. The connection of this active rift with the Ionian Sea (Mediterranean) is nowadays a 62 m deep sill, a situation which implies possible separations during low stands of global sea level, especially the last ones (MIS 2 and MIS 6). The western part of the Gulf, which is the most seismo-tectonically active part, appears as a transfer zone with both normal and strike slip faulting, identified through a dense grid of seismic lines.

As a consequence, the offshore northern edge between the Mornos River delta and the Trizonia island shows a complex morphology due to the interaction between these structures, huge terrigenous feeding, deltaic development and sediment failures. Pre-Quaternary basement (Hellenids) was partly submitted to aerial erosion and paleodeltas are superimposed on the induced relief, visible at a depth of 110 m below Present sea level. The paleovalleys are filled with onlapping layered sediments, affected by several WSW-ENE and W-E oriented faults, part of them still active.

An attempt to decipher both sources of relief genesis and evolution is presented. Beside, location and slip rate of active faults are discussed.

\*\*\*\*\*

**Geomorphological mapping of complex submarine slides (Apulian ridge, eastern Mediterranean Sea): implication for geohazard assessments**

*SAVINI A.(1), VERDICCHIO G.(2), MARCHESE F.(1)*

*(1) Milano-Bicocca University, MILANO, ITALY ; (2) Impresub, TRENTO, ITALY*

Over the past 10 years a large dataset of bathymetric, seismic and sedimentological data, that covers more than 2000 km<sup>2</sup>, was acquired along the Apulian ridge (northern Ionian sea), between 80 and 1400 m of water depth. The ridge is, a NW-SE elongated structural high, crosscut by a NNW-SSE penetrative normal fault-system; this tectonic setting controls the large scale morphology of the margin, shaped by prominent scarps and ridges. The sedimentary setting of the area is indeed characterized by complex mass-wasting deposits, most likely related to the local high seismicity of the margin, which is considered the result of the activity of the normal fault network. Clear morphological evidence of mass-wasting is given by the presence of a number of arcuate head-scarps, indenting the shelf break, and a variety of superficial deformation (i.e. compressional and extensional ridges, low scarps, lineations and a noteworthy blocky pattern that extends over more than 600 km<sup>2</sup>). Large areas of mass-movement deposits appear exposed on the seafloor. Sub-bottom profiles and sediment core data suggest this deposits took place before 13ky, although the presence of younger deposits can be hypothesized in some areas.

The occurrence of recent widespread mass-wasting deposits, along with possible evidences of incipient failures on the upper slope and the present-day activity of the normal faults suggest that future slope failure events can eventually affect the area.

This work provides high-resolution geomorphological dataset of the topographically complex seabed of the Apulian upper slope, for evaluating geo-hazards associated to possible slope failures.

### **Holocene evolution of the Northern Adriatic Platform: morphologic and stratigraphic evidence**

FONTANA A.(1), CORREGGIARI A.M.(2), SLAVEC P.(3), REMIA A.(2), MASELLI V.(2), ZERJAL A.(3), POGLAJEN S.(3), CELARC B.(4), BAVEC M.(4), ROSSATO S.(1)

(1) University of Padova - Department of Geoscience, PADOVA, ITALY ; (2) CNR-ISMAR, BOLOGNA, ITALY ; (3) Harpha Sea d.o.o, KOPER, SLOVENIA ; (4) Geological Survey of Slovenia, LJUBLJANA, SLOVENIA

The northernmost part of Adriatic Sea lies between Istria, Karst and the Friulian Plain and it is divided between Italian, Slovenian and Croatian waters. A robust chrono-stratigraphic framework of the Northern Adriatic shelf was supported by the geophysical, bathymetric and stratigraphic data collected during cruises VE2004, VE2005 and RISA2009, that led to the production of the geological map of the Italian seabed. Moreover, in the last years Harpha Sea Inc. carried out a multibeam bathymetric survey of the Slovenian waters, leading to the production of a very high-resolution DEM. This was a key tool for understanding the sea-floor morphologies. During cruise NAD2012 the oceanographic vessel "Urania" surveyed the Italian and Slovenian shelf, acquiring 750 km of CHIRP-sonar seismo-acoustic profiles and 10 gravity cores. These new data allowed for the first time to observe in continuity the transition from the rocky coast of Istria to the Friuli plain.

The area between Monfalcone and Piran Bay is characterized by a mud-dominated body, consisting of Holocene marine deposits, with a maximum thickness of about 25 m in Piran Bay and that thins toward the Friulian coast, where the delta system of Isonzo River (Soca in Slovenian) is present. The marine sediments seal the alluvial plain that characterized the area until ca. 7.5 ka BC, when sea-level rise led the Adriatic to re-occupy the Gulf of Trieste. The ancient alluvial plain is characterized by a complex network of fluvial ridges fed by the valleys draining Karst and Istria; moreover, DEM highlight an incised meandering paleochannel, recognizable from the Italian shelf to Koper Bay.

The evolution of the Trieste Gulf was constrained by a main morphologic threshold corresponding to the deep morpho-structural depression existing in front of Savudrija Promontory. Some very large submarine dunes are connected to this incision.

\*\*\*\*\*

### **Aeolian to shallow-marine shelf palaeo-landscapes off a major desert since the Late Pleistocene (Northern Mauritania)**

HANEUBUTH T.(1), MERSMEYER H.(1), KUDRASS H.(1), WESTPHAL H.(2)

(1) MARUM, BREMEN, GERMANY ; (2) ZMT, BREMEN, GERMANY

Continental shelves off desert regions are not expected to host substantial amounts of sediments due to long-lasting, unfocused material supply and a high re-mobilization potential of aeolian material. This study demonstrates significant volumes of sediments have accumulated on the hyperarid northern Mauritanian shelf during the past climatic cycle.

Using high-resolution seismo-acoustic data and sediment cores, eight late Pleistocene/Holocene depositional units are identified, each reflecting an individual depositional history. Based on (1) an older Pleistocene palaeo-landscape, (2) a continental dune complex (MIS-4), (3) a thick regressive shallow-water clinof orm (late MIS-3), (4) a regressive to lowstand shore deposit (latest MIS-3), and (5) a local transgressive cover (LGM to deglacial) have developed. During the Holocene sea-level highstand, (6) an open-shelf highstand cover, (7) an outer-shelf highstand wedge and (8) mid-shelf mud depocenters have formed.

The common formation of locally confined depositional units, and in particular the MIS-3 progradational unit, is related to an interplay of a) partly pronounced arid climatic conditions resulting in enhanced aeolian and coastal sediment input, b) shelf current patterns focusing sediment deposition at certain locations, and c) early post-depositional sediment stabilization providing protection against erosion. Prominent internal surfaces at 63 and 115 m modern water depths indicate widespread and intense erosional activity during late MIS-3 regression and MIS-2 lowstand to transgression, hosting coarse shell sands and gravels from beach and shoreface palaeo-environments. Reasons for the surprisingly high preservation potential of confined stratigraphic units are a) carbonaceous cementation, b) sediment composition (massive widespread shore-related gravel and shell beds; subtle minor admixture of cohesive material), and c) morphological protection (inside seafloor depressions; behind sheltering relief).

### **Axial and off-axial morphology of Arctic and Polar Atlantic spreading ridges (analogous modeling)**

KOKHAN A.

*Moscow State University, Earth Sciences museum, MOSCOW, RUSSIAN FEDERATION*

Spreading ridges of the region are presented with Reykjanes, Kolbeinsey, Mohns, Knipovich, Gakkel ridges. Crust in their rift zones extends with ultra-slow velocities less than 20 mm per year. Each of these ridges develops in specific geodynamic and kinematic conditions. They result in formation of specific axial and off-axial morphology. In order to distinguish basic structure-forming factors for each of the ridges we collected information covering their morphology, geological and geophysical structure, used morphostructural mapping and morphometrical analyses based on detailed bathymetry and unique analogous experimental method. Reykjanes and Kolbeinsey ridges develop under the influence of Iceland plume. This influence is asymmetric, concentrated mainly on Reykjanes ridge. Their morphology changes with increase of distance from Iceland. Axial volcanic ridges become higher and shorter, amplitude of offsets increases. Axial rise transfers to axial valley. Changes are defined by changes of width of heating zone and thickness of brittle crustal layer with increasing distance from Iceland plume. Mohns ridge is developing in conditions of narrow heating zone and strongly oblique spreading. Knipovich ridge forms in the transition zone between Mohns and Gakkel ridges along the Spitsbergen continental margin. It is subdivided into several segments each with its own obliquity. Morphology is defined by orientation of each segment relative to direction of regional extension. Gakkel ridge is the slowest portion of world system of spreading ridges (spreading velocity is less than 13 mm per year) and the longest of examined ridges. Its morphology is defined by changes of velocity, obliquity and, presumably, mantle temperatures along the ridge. Mohns, Gakkel and Knipovich ridges have amagmatic and magmatic segments. Length of amagmatic segments increases with decrease of spreading velocity and increase of obliquity.

\*\*\*\*\*

### **Poster presentations:**

#### **River-Sea interaction and paleo-Yangtze giant delta system studies**

WANG Y., ZOU X., YIN Y., ZHANG Y., LIU S.

*Dept. of Coastal Ocean Science, Nanjing University, Nanjing, Jiangsu, CHINA*

Recent researches indicated that the Paleo-Yangtze giant delta system distributed in South Yellow Sea and East China Sea was formed during mid-late Pleistocene, originating from the huge river sediments, discharged from ancient Changjiang and Yellow River, and being shaped by monsoon waves and tidal currents. Upon the huge delta base, there are four delta unions superimposed on the top, and developed in different geological time: Paleo Changjiang-Yellow river delta, radiative sand ridge field, Holocene-modern Changjiang river delta and abandoned Yellow River delta. The Paleo-Yangtze giant delta system geographically covers most areas of East China Sea and South Yellow Sea, which also presents the characteristics of local continental shelf sediments. A pioneering multi-dimensional survey to this region is proposed in the paper, which includes RS analysis, water depth and hydro-dynamic survey, seismic profile survey on bottom stratigraphic structure, sea-bottom surface and sedimentary core sampling, followed by multi-disciplinary scientific studies of marine geology, marine sedimentology, marine dynamics, land-sea interaction, sea-level change and marine GIS etc. Through the comprehensive study, it is expected that the geographical range of Paleo-yangtze giant delta system be identified, the sedimentary structure and geomorphologic features of the delta system be revealed. Furthermore, the study will re-build the land-sea interaction process and dynamic mechanisms during mid-late Pleistocene in the region, and supply case study on the development of accumulative continental shelf, which will also provide theoretical input to marine geology. Further study of this giant delta system will help to understand the developing trend of eroding-depositing dynamics of modern tidal flat, to legitimately plan potential land resources in the region, and to contribute important scientific evidences to guard the National territorial sea-rights.

### Geodynamical analyses of relief of rift zones of ultra-slow spreading ridges

KOKHAN A., DUBININ E., GROKHOLSKY A.

*Moscow State University, Earth Sciences museum, MOSCOW, RUSSIAN FEDERATION*

The ultra-slow spreading ridges with extension velocities less than 20 mm/year are presented with Reykjanes, Kolbeynsey, Mohns, Knipovich and Gakkel ridges situated in North Atlantic and Arctic, and South West Indian (SWIR) and American-Antarctic ridges (AAR) situated in south Atlantic and southern part of Indian ocean. All of them develop in specific geodynamical conditions, which result in influence of certain geodynamical factors (kinematics, underlying mantle temperature, crustal structure). We see different patterns of structure-forming factors leading to formation of different relief of rift zones. Analyses of morphostructure and morphometry on a basis of detailed bathymetry, published data and results of experimental modeling let to distinguish morphotectonic types of ultra-slow spreading ridges and key structure forming factors leading to formation of their relief and tectonic patterns. Reykjanes and Kolbeynsey ridges, central part of SWIR form under influence of hotspots. Relief changes from fast-spreading-like to slow-spreading like with increase of distance from hotspots. Knipovich ridge and AAR formed as a results of regional changes of plate kinematic patterns and have significant strike-slip components in their kinematics. Relief is formed by long strike-slip segments with absence of magmatic activity and short magmatic segments. Central part of Gakkel ridge and eastern part of SWIR form in conditions of «cold» spreading and are largely amagmatic. Basalts are almost absent and replaced by serpentinised peridotites. Large portions of the ridge have no volcanic features. Western part of SWIR and Gakkel ridges, presumably, form in conditions of increased mantle temperatures. They have relief same with slow spreading Mid-Atlantic ridge. Thus, relief is formed under different combinations of tectonic, magmatic and metamorphic (serpentinisation) geomorphodynamical processes. Geodynamical conditions of ultraslow spreading are considered also.

\*\*\*\*\*

### Underwater geomorphological survey revealing past temporary standstills of the relative sea level in carbonate rock areas

EVELPIDOU N.(1), PIRAZZOLI P.(2)

*(1) University of Athens, ATHENS, GREECE ; (2) CNRS-Laboratoire de Géographie Physique, MEUDON, FRANCE*

Tidal notches can form on carbonate coasts during periods of relative stable sea-level, or when sea-level changes occur at a rate lower than the rate of bioerosion. Tidal notches have often been used for Quaternary sea-level reconstructions and for estimating tectonic movements, especially in uplifting areas.

Underwater geomorphological survey may reveal evidence of submerged tidal notches. Detailed, accurate and systematic survey along the coastal zone by boat is necessary, to access all sites and establish lateral continuity of observation. During the survey, the local lithology is taken into account. For each site, the time and the GPS coordinates are collected. Underwater, the observed features are measured in relation to sea level and photographed. Notch geometries (height, vertex and inward depth) are measured and interpreted. The accuracy can be improved by multiple measurements and by corrections based on air pressure and tidal records.

submerged tidal notches cannot be dated directly, but their age can be inferred from coastal cores or archaeological data. Information on the duration of the various sea-level positions can be deduced from assumptions on the minimum and maximum values of intertidal bioerosion in carbonate rocks.

Through this methodology new evidence concerning the rates of subsidence in the investigated area may be provided. The profiles of submerged notches, resulting from different combinations of RSL in sheltered areas, allow to qualitatively distinguish the way of subsidence e.g. co-seismic event, gradual relative sea-level rise, etc.

Some examples of tidal notch development and tectonic movements are provided from fossil submerged notches in Greece. Although tidal notches are not forming anymore in the present-day mid-littoral zone, underwater marks on carbonate cliffs may still provide evidence of submerged tidal notches corresponding to former sea-level positions, or to recent vertical shoreline displacements of seismic origin.

### **Late Holocene shorelines deduced from tidal notches on both sides of the Ionian Thrust: Fiscardo Peninsula (Cephalonia) and Ithaca Island**

*EVELPIDOU N.(1), KARKANI A.(1), PIRAZZOLI P.(2)*

*(1) University of Athens, ATHENS, GREECE ; (2) CNRS-Laboratoire de Géographie Physique, Meudon, PARIS, FRANCE*

A submarine survey along the coasts of Ithaca and Fiscardo has permitted the identification of fossil shorelines produced by recent co-seismic movements.

In both areas a tidal notch slightly submerged below present MSL was observed at various sites. This "modern" notch is known to have been submerged by the global sea-level rise during the 19th and 20th centuries. The depth after tide and air-pressure correction of the vertex of the "modern" notch (= MSL before the recent sea-level rise) was measured between  $-19\pm 6$  and  $-25\pm 6$  cm at Fiscardo and between  $-34\pm 6$  and  $-43\pm 6$  cm at Ithaca. The presence of this "modern" notch at the same depth on both sides of the Ionian Thrust would give evidence that both areas were not affected by the co-seismic vertical movements that occurred in 1953 in the wider area, while a greater depth in Ithaca could be an effect of co-seismic subsidence. Both cases are discussed and analysed in this paper. Assuming that the development of the "modern" notch was produced by bioerosion, it is possible to deduce a period of relative sea-level stability before the 19th century during 2.4 to 4 centuries at Ithaca and 1.5 to 4 centuries at Fiscardo.

Over the longer term, the tectonic behavior of Ithaca differs from Fiscardo. At Ithaca no evidence of emergence has been found and Holocene vertical movements have been only of subsidence: fossil submerged tidal notches can be distinguished below MSL at depths ( $\pm 6$  cm) of about  $-40$  (modern),  $-60$ ,  $-75$ ,  $-90$ ,  $-100$ ,  $-120$ ,  $-130$ ,  $-140$ ,  $-150$  and  $-220$  cm. A southward tilting of the island is suggested from the  $-110$  cm notch, but this is not the case for the  $-70$  cm shoreline.

On the east coast of Fiscardo Peninsula impacts of ancient earthquakes have left some marks ( $\pm 6$  cm) of emergence at about  $+15$  and  $+40$  cm, and of submergence at about  $-20$  (modern)  $-35$ ,  $-50$ ,  $-60$ ,  $-70$ ,  $-80$ ,  $-90$ ,  $-100$  and  $-230$  cm, with even some evidence of past uplift and subsidence at the same sites.

\*\*\*\*\*

### **Raft Tectonics in SE Brazil as an example of large-scale gravitational collapse on continental margins**

*PIEDADE A.(1), ALVES T.(1), ZÉZERE J.L.(2)*

*(1) Cardiff University, CARDIFF, UNITED KINGDOM ; (2) RISKam.University of Lisbon, LISBON, PORTUGAL*

The SE Brazil continental margin is dominated by continental-slope embankment, incision of submarine channel system and significant mass-gravitational processes, with salt tectonics playing a significant role in upper-crust deformation. It is known to comprise a margin rich in oil and gas, in which raft tectonics plays an important role in their migration and accumulation.

The interpreted high-resolution 3D seismic-reflection volume covers an area of  $2400 \text{ km}^2$  offshore Espírito Santo, SE Brazil. This seismic volume was used in this study to evaluate the processes previously invoked to explain the gliding and deformation of rafts. Interpreted horizons include the base and top of Albian rafts, Late Santonian and seafloor.

To critically understand the relationship between rafts deformation and sediments was the key theme of this study, with the aim of ultimately answering the following questions: 1) how the post-raft overburden influences the gliding and deformation of Albian rafts?; 2) what other factors that overburden loading and slope gradient control the gravitational gliding of the raft tectonics?

Statistical analyses, surface images and thickness maps helped to describe and understand relationship between (i) thickness of rafts and slope gradient; (ii) overburden thickness and thickness of rafts and (iii) spacing between rafts and sediment overburden. The acquired statistical data show a positive correlation between the degree of deformation observed in rafts and the thickness of overburden strata. The distance between adjacent rafts was also shown to be influenced by the weight of the sediments overburden. We interpret these data as a proof that underlying salt was a primary control on raft tectonics in the study area, overriding the effect of overburden thickness and variable slope gradients on the rafts' internal compartmentalisation. This study will show different styles of compartmentalization observed in Albian rafts from SE Brazil.

### **Morphological alterations of the seabed related to relict sand dredging for beach nourishment**

*NONNIS O., PAGANELLI D., PROIETTI R., PAZZINI A., NICOLETTI L., GABELLINI M.  
ISPRA, ROME, ITALY*

Beach nourishment with relict sands has been carried out for several years as a way to counter coastal erosion problems. It has proven to be a successful beach protection method and it is considered to be one of the main tools for coastal management. These deposits, located along the continental shelf, at variable depths, generally contain a large amount of sediments that have sedimentological characteristics similar to the actual beach sediments. It is however known that relict sand dredging may have significant physical and biological effects on the marine environment (seabed, water column and benthic and fish assemblages), especially in highly biodiverse environments and sensitive habitats, such as the Mediterranean marine-coastal system.

Within this framework, ISPRA has performed specific environmental studies related to relict sand dredging aimed at beach nourishment of a deposit situated offshore Montalto di Castro (Central Tyrrhenian sea) in order to assess the effects of relict sand mining on the marine environment.

The relict sand-dredging activities in this area took place in three different periods, July 2004, June and September 2005. For the first dredging, an anchor dredge was used, whereas for the second and third dredging a trailer dredge was used. The monitoring environmental surveys were carried out from May 2004 to October 2006, before, during and after the dredging activities.

The present study focuses on the morphological impact of relict sand extraction, and aims to examine the results of acoustic investigations performed before and after the dredging activities in Montalto di Castro deposit. These techniques represent an essential tool for an effective management of the marine environment and are particularly useful to accurately study the impact of human activities on the seabed.

\*\*\*\*\*

### **Geomorphology of the Cyclades plateau (Aegean Sea, Greece)**

*SKENTOS A.(1), PAVLOPOULOS K.(1), KAPSIMALIS V.(2)  
(1) Harokopio Univeristy, ATHENS, GREECE ; (2) Hellenic Center for Marine Research, ATHENS, GREECE*

The Cyclades plateau is located in the central Aegean Sea and represents a shallow platform with an average depth of about 200 m. The sea floor is characterized by a complex morphology as a result of the recent geodynamic activity of the Aegean Sea. The purposes of this study are the identification and mapping of the submarine landforms, and the interpretation of the geomorphological particularities of the Cyclades shelf. High resolution seismic profiles and existing bathymetric data were used for mapping the seabed relief by using semi-automated cartographic tools. Further analysis and interpretation of the seismic profiles led to the identification of the sedimentary processes, stratigraphy, internal structure occurred in the study area since the Middle-Upper Quaternary. All data were imported into a Geographical Information System (G.I.S.) and were properly managed with main object the creation of a medium scale geomorphological map of the Cyclades plateau.

### **Geomorphology of submarine canyons and channels in the St. Lawrence Estuary (Eastern Canada)**

NORMANDEAU A.(1), LAJEUNESSE P.(1), ST-ONGE G.(2)

(1) *Centre d'études nordiques & Département de géographie, Université Laval, QUÉBEC, CANADA* ; (2) *Institut des sciences de la mer de Rimouski, Université du Québec à Rimouski, RIMOUSKI, CANADA*

The morphology of the seafloor of the St. Lawrence Estuary is characterized by a deep submerged valley along its axis, the Laurentian Channel. In many sectors between the mouth of the Saguenay River to the west and Pointe-des-Monts to the east, the northern slopes of the Laurentian Channel are highly incised by many submarine canyons and channels. Despite that the stratigraphy and sedimentology of this region has been relatively well studied, the geomorphology, origin and evolution of these submarine landforms still remain poorly documented. These canyons and channels can provide important information on past environmental changes such as deglaciation history and relative sea-level fluctuations as well as past and present land-to-sea sediment transfer. In order to investigate these canyons and channels, multibeam echosounder, high-resolution subbottom profiler and sedimentary data were collected between Tadoussac and Pointe-des-Monts and allow their detailed examination. The newly acquired data reveal a wide variety of types of canyons with different sediment sources. Some canyons and channels are located at the mouth of rivers while others are found at the end of a littoral cell. Other canyons and channels are presently inactive and appear to have been activated during past higher relative sea-levels or during deglaciation.

\*\*\*\*\*

### **Seafloor undulations in the Policastro gulf (South-eastern Tyrrhenian Sea): description and possible genetic mechanism**

PALAMARA S., SAVINI A.

*URL - CoNISMa, Milano-Bicocca, MILANO, ITALY*

Sea-floor undulations have been observed in different contexts, from continental shelves to abyssal plains; such bedforms range from few meters to hundreds of meters in length and from centimetres to meters in height. Several genetic mechanisms have been suggested: some authors support the hypothesis that sea-floor undulation are depositional structures induced by bottom currents and/or hyperpycnal flows, others relate sea-floor undulations to slope instability, while some other authors attribute such structures to the combination of currents and gravity processes.

Our study focus on sub-bottom profiles and multibeam swath-bathymetry data collected in the Policastro Gulf (South-eastern Tyrrhenian Sea), by the Italian R/V *Universitatis* in 2004. The whole data set revealed the presence of a sea-floor undulations field, off Policastro, along the Bussento River prodelta, in water depth ranging between 50 and 70m.

To evaluate a possible genetic mechanism, in relation to the local hydrodynamic and morphologic condition, the sea-floor undulation off the Bussento River were mapped, described and measured; in summary they range from 20 to 130 m in wavelength and from 1.40 to 1.60 m in height. The crests orientation is WSW-ENE, following the trend of the shelf isobaths. Based on measured morphological parameters and a comparing with other undulation fields described in literature, we assume that these bedforms are produced by hyperpycnal flows generated by the Bussento river.

**Detached blocks from submarine slides investigated using quantitative geomorphological techniques**

MARCHESE F., SAVINI A.

*Milano-Bicocca University, MILANO, ITALY*

Quantitative analysis on Digital Elevation Models (DEMs) are rarely conducted on submarine landscapes. Only recently the application of quantitative geomorphometric techniques to the bathymetry data set has been effectively tested and the authors demonstrated their utility in improving the geological interpretation of submarine environments.

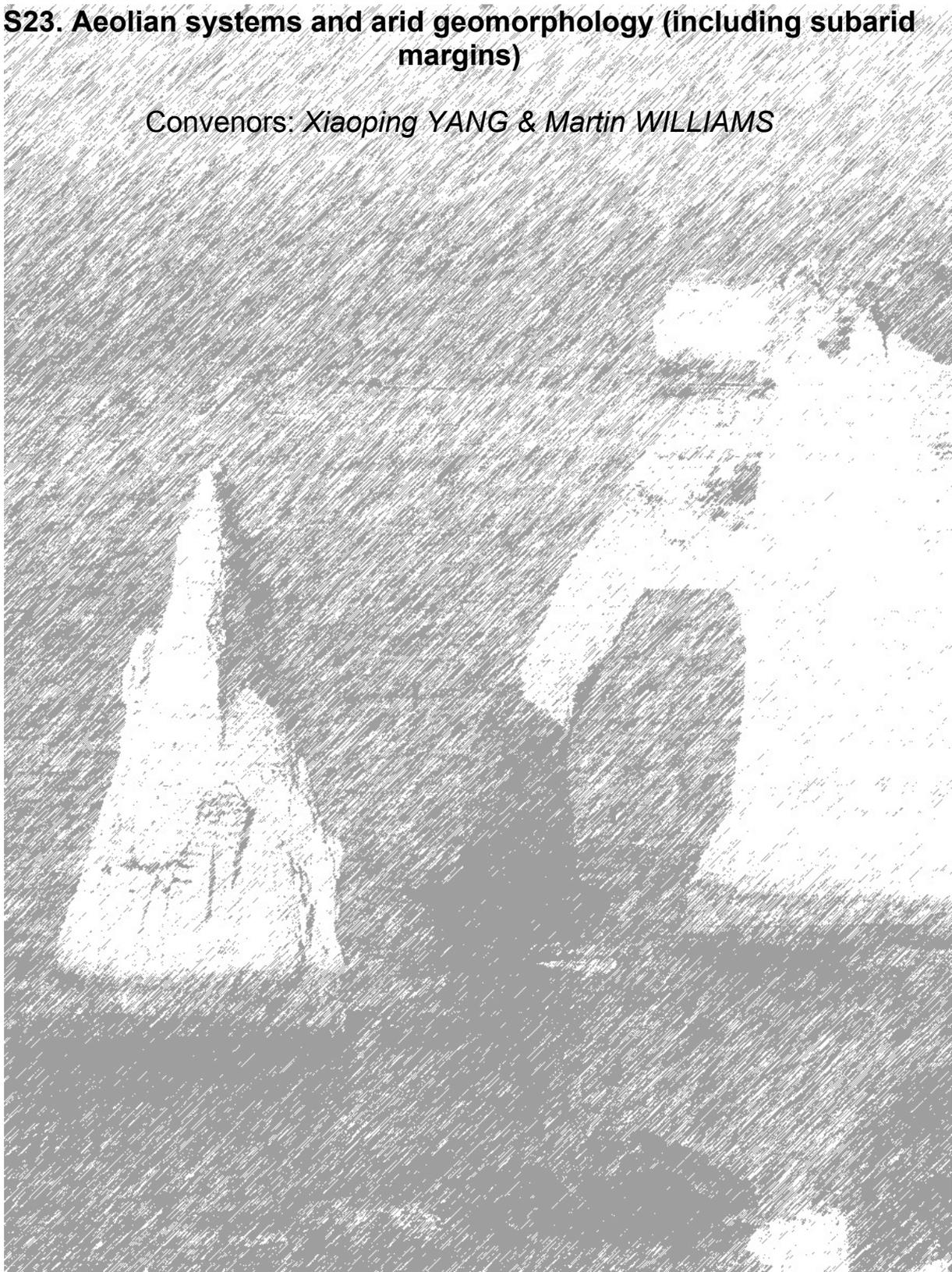
In this paper geomorphometric analytical techniques were applied to a high-resolution bathymetry data set acquired along 2000km<sup>2</sup> survey area located on the upper part of the southern Apulian slope (Northern Ionian sea), between 80 and 1400 m of water depth. The DEM provided by multibeam data processing and the computed terrain parameters, well show a broad area affected by mass-transport deposition, which results in a very complex hummocky seafloor, shaped by detached block-like features. We focus our analysis on the automatic extraction of the most significant morphometric features of the surveyed area. The objective identification of morphologic features represents indeed a significant step in defining spatial units that are related to geomorphological processes. Our computation was in particular applied to observe the seafloor distribution of the complex pattern of the identified detached-blocks like-features. The quantitative analysis of these features showed that the blocky pattern is more pronounced where it regionally faces NE and SW on the more elevated sectors of the margin, where tectonic deformations generated a suite of vertical offsets; whereas fewer blocky features are evident within the more depressed areas. Since these blocky features are colonised by carbonate framework building organisms (i.e.: cold water corals), our quantitative results strongly support the hypothesis that in this area cold water coral growth has tended to enhance the complex morphologies of the seabed, originally formed by a variety of mass-transport processes.

\*\*\*\*\*



**S23. Aeolian systems and arid geomorphology (including subarid margins)**

Convenors: *Xiaoping YANG & Martin WILLIAMS*





## **Oral presentations:**

### **Mean residence time in barchan dunes from numerical modelling**

ZHANG D.(1), YANG X.(1), NARTEAU C.(2), ROZIER O.(2)

*(1) Institute of Geology and Geophysics, Chinese Academy of Sciences, BEIJING, CHINA ; (2) Institut de Physique du Globe de Paris, PARIS, FRANCE*

How the bedforms affect the motion and the storage of sedimentary particles is still an open issue. Then, there is still no satisfactory residence time distribution and transport laws to describe the evolution of individual grains in sedimentary layers sheared by a fluid flow. We analyze sediment particles motions in steady-state barchan dunes by tracking individual cells of a 3-D cellular automaton dune model. The overall sedimentary flux may be decomposed into various physical processes to show how advective and dispersive fluxes contribute to the barchan dune shape. The net lateral sediment transport from the center to the horns indicates that dispersion on the lee slope is more efficient than avalanches on the stoss slope. However, the combined effect of these two antagonistic dispersive processes enhances the lateral mixing of sediment particles in barchan dunes. We find that the mean residence time of sediment particles in barchan dunes is equal to the surface of the central longitudinal dune slices divided by the input sand flux. We infer that this central slice contains most of the relevant information about the barchan dune morphology. Finally, we use the relationship between the mean residence time and the characteristic migration time of barchan dunes to discuss sediment transport and memory and transport in presence of bedforms.

\*\*\*\*\*

### **Complex Geo-Ecological responses to climate change in dry-land areas: Northern Negev desert, Israel**

YAIR A.

*Hebrew University of Jerusalem, Department of Geography, JERUSALEM, ISRAEL*

Semi-arid and arid areas are often regarded as highly sensitive to climatic changes. A positive relationship between average annual rainfall and related environmental variables is usually assumed for such areas. This approach disregards the fact that a climate change in dry-land areas is often accompanied by a parallel change in surface properties, such as sand deposition during a dry climatic phase and loess during a wet phase. The new surface properties can be expected to exercise a strong influence on infiltration, runoff, soil moisture regime and water availability for plants. The sandy area, along the Egyptian-Israeli border offers a good opportunity to study the complex relationships between climate and various environmental variables along the present day rainfall gradient (86-170 mm average annual rainfall). Along a transect, 35 km long, several different gradients have been identified (geomorphological, micro-biological, botanical, hydrological, organic matter content etc.). Some of the variables are positively related to average annual rain amounts, while others show an opposite relationship. On the whole, data collected show a differential development of the biological crusts along the rainfall gradient. The crust, in the wetter area, is better developed, richer in fine grained particles and organic matter content than the crust in the drier area. However, the better developed crust is able to absorb, and retain, all rainwater at most rainstorms, limiting thus the depth of water infiltration and water availability for higher plants. At the same time, the crust in the drier area absorbs less water and generates surface runoff. The overall result is deeper water penetration and water availability for the perennial vegetation, very well expressed by the extent of the vegetation cover and species diversity.

## Dynamic stone pavements - insights from experiments and numeric modelling

DIETZE M., KLEBER A.

TU Dresden, DRESDEN, GERMANY

Stone pavements are prominent surface phenomena of arid environments. Although most stone-pavement properties may be explained by vertical processes, there remain several features (buried clast stratae, recovering surface disturbances, preferred bimodal, slope-aspect-symmetrical clast orientations) that argue for lateral processes to restore and maintain stone pavements. Field experiments identified two mechanisms that may contribute to lateral clast transport: unconcentrated overland flow and creep. Both processes are described in terms of i) conceptual models, ii) physical equations used for numerical modelling and iii) laboratory experiments to test the models.

The vesicular horizon plays a decisive role for both processes. It is a prominent surficial formation in the fine-grained aeolian sediments typically deposited below stone pavements. Unconcentrated overland flow of a few centimetres depth is able to drag clasts and rotate them upon collision with obstacles (e.g. other clasts). This angle-dependent force equilibrium is able to exactly reproduce the natural bimodal clast orientation pattern and is confirmed by flume experiments. The creep process is exceptional, as it affects only clasts whereas finer sediments remain essentially in place. Upon rain-water infiltration into the vesicular horizon, an advancing wetting front replaces soil air, which preferentially escapes from the soil under the dry clast undersides thereby lifting them. This lifting results in an average downslope displacement of 100 µm per wetting event (or up to a few metres per thousand years). Colliding clasts become rotated, similar to water-dragged objects. Thus, both lateral processes contribute to stone pavement recovery from disturbance. Including lateral dynamics to existing stone pavement formation models allows to more fully explain the observed properties.

\*\*\*\*\*

## What makes Australian desert dunes so stable? Vegetation and sand transport response to variable rainfall

HESSE P.

Macquarie University, MACQUARIE UNIVERSITY, AUSTRALIA

The vegetated sand dunes of Australia's dunefields have shown lateral stability over tens of thousands of years and episodic vertical accumulation. How much of their present stability is dependent on the vegetation cover, and how sensitive is that cover to climate variability?

Sand dunes in the Simpson and Strzelecki Deserts were monitored through the 2000-2010 drought and during the subsequent wet La Nina period. Vegetation and sand transport indicators were measured on the dune crests. Sites included vegetated longitudinal dune crests and bare patches with small slip-faces.

There is a negative relationship between the amount of mobile sand and the areal cover of vascular plants but an even stronger relationship with the areal cover of binding cyanobacterial crusts. However, there is no relationship between the frontal area of the vegetation and sand transport indicators. In summary, vegetation stabilises the dune crests by sheltering the surface and binding the sand, but not by increasing surface drag.

This may be due to the complex vegetation structure. Several components of the vegetation were observed to vary greatly over the ten year period of measurement, more or less independently. There is a weak dependency of cyanobacterial crust on short-term (3 month) rainfall. Tall vegetation (> 50 cm) shows a relationship to longer term rainfall (up to 3 years) for perennial vegetation and previous summer rainfall for some ephemeral megaforns.

The stability of the protection offered by vegetation stems from the relatively high frequency of large rainfall events, even during drought, and the lagged response of vegetation, even continuing after death.

To destabilize these dunes would require many consecutive months without large (>20 mm) rainstorms and extended periods of many years with annual rainfall less than 100 mm. This is more severe than the current driest average climate of the Simpson Desert but occurred for several years during the the early 20<sup>th</sup> Century.

### **The relative efficacy of wind and fluvial erosion of bedrock in northern Chile**

PERKINS J.(1), FINNEGAN N.J.(1), DE SILVA S.L.(2)

(1) University of California Santa Cruz, SANTA CRUZ, CA, UNITED STATES ; (2) Oregon State University, CORVALLIS, OR, UNITED STATES

Yardang fields testify to the dominance of wind erosion of bedrock in many arid settings. However, landscapes that apparently arise from the interaction of wind and fluvial bedrock erosion processes are also common on Earth and Mars, suggesting that fluvial and aeolian bedrock incision processes can occur at similar rates. Such a finding would have important consequences for interpreting arid bedrock landscapes, however to our knowledge rates of fluvial and wind erosion processes have not been quantified in the same setting. Here we exploit a natural experiment within the 4.09 Ma Puripicar ignimbrite along the western slope of the Andes in the Atacama desert. The Puripicar is incised by a series of bedrock river gorges with large knickpoints that likely reflect a transient response to the emplacement of the ignimbrite. These knickpoints are nested behind a broad north-south escarpment that is retreating headwardly from wind erosion via undercutting and block toppling of the bedrock, resulting in an array of megayardangs between the gorges. Strong geologic evidence indicating the original extent of the Puripicar allows us to map the initial escarpment location and thus directly measure windward escarpment retreat since its emplacement. To quantify bedrock incision rates, we use well-established approaches that relate vertical bedrock incision rate to knickpoint retreat rate. These calculations yield a median vertical incision rate of 0.1 mm/yr from analysis of 17 channels. Measurements of windward escarpment retreat, however, yield a median value of 0.8 mm/yr from analysis of 18 megayardangs. Thus wind erosion is by far the dominant driver of landscape evolution along the western slope of the Andes in northern Chile. As far as we know, this study is one of the first direct comparisons of aeolian and fluvial incision rates within a bedrock landscape, and highlights the significant geomorphic impact of wind even where bedrock river gorges are present.

\*\*\*\*\*

### **Form-flow interaction of star dune arms**

BIEJAT K., DLUZEWSKI M.

Faculty of Geography and Regional Studies, University of Warsaw, WARSAW, POLAND

The focus of the study was to analyze different types of star dunes' arm shape, which depend on the locally induced wind flow. The study was made on compound star dunes differentiated in size, in the area of bimodal wind regime. In this area the direction of main arms is related to two dominant wind directions. The vertical arms development depends on locally induced wind direction, which inclination must be more than 30° to the arm direction.

We distinguished 3 main types of arm shape. The first one has sharp crestline and high slope inclination on both sides. Its development relates on high acceleration of streamline on the stoss side and formation of strong reverse flow on lee side. It causes the vertical grow of arm, with low impact on lateral migration. The second type has also sharp crestline but a different slope inclination. On the slope of lower inclination the streamline acceleration is lower than in first type of arms, but the avalanche on the lee slope does occur. On another side the reverse flow is weak and doesn't give the opportunity to transport the material up the lee side slope. The arm migrates laterally but doesn't grow vertically. On the third type, the upper part of arms has convex shape, with no sharp crestline. On both sides the slope inclination is low to moderate. The development of this type of arms depends on streamline acceleration on stoss side, which is related to the slope inclination. On this type the convex streamline curvature is also very important: it encourages flow stabilization and a decrease in shear stress.

We found that the types of star dune arms don't depend on its size. The analyses of the shape of main and subsidiary arms show that on main arms mostly occur first and second type of arms shape and on subsidiary arms mostly the third one. The occurrence of the first type of arms shape on subsidiary arms is very rare. Our study shows that especially on development of star dune arms flow-form interaction is very important.

### **Sand bulk density as an indicator of form-flow interaction on barchan dunes**

DLUZEWSKI M., BIEJAT K.

*Faculty of Geography and Regional Studies, University of Warsaw, WARSAW, POLAND*

The aim of the study was to analyze the sand bulk density of the surface layer of barchan dunes. The bulk density measurements were made in the natural conditions with the use of densimeter prepared specially for the field study. Before the measurements were made, the densimeter was tested and calibrated with height level of goodness of fit. To check the universality of our results, we ran the measurements in 2 periods and in two areas differentiated on wind regime, sand texture and mineralogical composition. In each of 42 dunes we made 300 sand bulk density measurements on average. The position of each point on the dunes surface was done with the use of GPS RTK.

We distinguished 3 main zones of different sand bulk density. Obviously, the lowest bulk density is on the avalanche slope where flow separation takes place. The highest bulk density is on the barchan arms where the flow is decompressed and decelerated. The most interesting is the zone on the stoss slope, which is the area of wind flow acceleration. The density depends there on slope topography and on wind direction changes. If the wind comes from dominant direction, the main factor influencing the density distribution is only the dune morphology. In the direction of the symmetry axis, the size of low density zone depends mainly on the length of the slope with highest inclination and the streamline curvature. In the areas of higher wind directional variability, the dune is wider and becomes a bigger barrier which causes the extending of low density zone in the direction perpendicular to the symmetry axis. If the wind direction changes, the zone of low density will move to the front of incoming wind. Our results show that bulk density distribution can be a good indicator of form-flow interaction and short time variability of wind direction. The comparison of the results from 2 investigated areas shows that the position of the analyzed zone doesn't depend on textural or mineralogical composition of dunes sand.

\*\*\*\*\*

### **Vegetation change and geomorphological response of dryland hillslopes**

CAMMERAAT E.(1), KAKEMBO V.(2)

*(1) IBED-Earth Surface Science, AMSTERDAM, NETHERLANDS ; (2) Geosciences Department, Nelson Mandela Metropolitan University, PORT ELIZABETH, SOUTH AFRICA*

The geomorphological response of ecosystems often changes as a result of vegetation cover alterations. These changes can either be due to human or climatological factors. We compare in this study two rangeland ecosystems with respect to their geomorphological and hydrological response, one in SE Spain and one in SE South Africa respectively.

In southeastern Spain degradation occurs through extension of rill and gully systems in semiarid semi-natural tussock grass dominated rangelands. In southeastern South Africa sub-humid grasslands on abandoned soils are spontaneously being invaded by the exotic shrub *Pteronia incana* (Blue bush) originating from the semi-arid and arid Karoo region. This results eventually in the occurrence of bare patches and the development of bare patches.

In both cases the connectivity between bare areas is increased leading to increased soil loss and rill and gully erosion and consequently loss of soil quality. This in consequence is changing the eco-hydrological response of the hill-slopes leading to a dramatic increase of runoff and erosion.

We analyzed high resolution low altitude images of vegetation patterns in combination with terrain model analysis. We applied this procedure for different patterns reflecting a time series covering the observed changing patterns. By doing so we may be able to unravel critical processes as indicated by changes in vegetation patterns that might enable us to mitigate degradation of dryland ecosystems.

### **Fog-induced slumping in a hyper-arid dunefield, Namibia**

BOURKE M.(1), VILES H.(2), CONWAY S.(3), GOUDIE A.(2)

(1) Trinity College, DUBLIN, IRELAND ; (2) University of Oxford, OXFORD, UNITED KINGDOM ; (3) Open University, MILTON KEYNES, UNITED KINGDOM

Fog is the principal mode of moisture precipitation in the hyper-arid Namib Desert. It is an important resource for humans, plants and animals. The influence of the fog regime in aeolian systems is not well understood, despite the significant volume of moisture (and salts) that can precipitate. This paper presents data from a field campaign in Namibia that measured the diurnal-scale cycling of fog precipitation on dunes. Data were collected on moisture, and temperature at the surface, in the shallow sub surface (<5cm) and to 50 cm depth over 5 consecutive diurnal cycles under conditions of fog precipitation. Soil samples were analysed for salt composition and amount and grain size.

Fog collectors deployed at the dune surface show daily variation in total moisture receipts between 28% and 58% weight. Our data show that while there is some limited effect of dune aspect on the receipt of moisture, the fog moisture penetration front is shallow, detected only in the upper 2 cm of mobile sand. Natural drying of moisture from the dune surface occurred rapidly each day during the sample period.

Dune surface sands had between 7 and 33 ppm cations and 7 and 52 ppm anions. Pilot samples indicate a decrease in concentration with distance from the coast. There is significant variation in the concentrations of salts in the dune and interdune sediments. This reflects an enrichment of interdune sediments by a high local watertable.

Extensive shallow slumping of dune slopes indicate a geomorphic threshold was crossed on the dunes when >55% and <58% (weight) fog moisture was precipitation on the dunes. Meso and micro fissuring of the moist surface sand was extensive on the steep dune slopes with the development of large slump areas (1-4 m wide) with concomitant sand blocks, overthrusts and tangential fracture systems. The failure plane developed between the moistened surface and dry underlying sand. Sediment transport during wind gusts may have played a role in destabilising slopes.

\*\*\*\*\*

### **The Kufrah paleodrainage system in Libya: Mapping the past from space**

PAILLOU P.

Univ. Bordeaux - OASU, FLOIRAC, FRANCE

Using sub-surface mapping capacities of spaceborne radar, we mapped a major paleodrainage system in eastern Libya, the Kufrah River, that could have linked the Kufrah Basin to the Mediterranean coast through the Sirt Basin, possibly as far back as the middle Miocene. Radar images acquired by the Japanese PALSAR sensor revealed a 900 km-long river system, which connects the Kufrah Basin to a large alluvial fan in the Sarir Dalmah region. Despite the sand dunes of the Calanscio Sand Sea prevent orbital radar penetration, a 300 km-long link to the Gulf of Sirt through the already known Wadi Sahabi paleochannel is likely. New results, obtained by combining radar images and topography from the SRTM mission, confirm the hypothesis of an uninterrupted sediment pathway between the Kufrah Basin and the Mediterranean coast. The Kufrah River paleowatershed, at its maximum extent, would have then covered more than 400000 km<sup>2</sup>, representing close to a quarter of the surface area of Libya. It represents a likely corridor for fauna and human dispersal in the eastern Sahara, and thus indicates locations where further paleontological, paleo-anthropological and archeological field exploration should be conducted.

### **The Southern Westerlies in Central Chile during the last glacial cycle as documented in coastal dunes and paleosols**

VEIT H.(1), PREUSSER F.(2)

(1) *Geographical Institute, Univ. of Bern, BERN, SWITZERLAND* ; (2) *Stockholm University, STOCKHOLM, SWEDEN*

The long term dynamics and changes in the position of the Southern Hemisphere Westerly Winds (SWW) during glacial-interglacial cycles have been discussed since decades. In South America related paleoclimatic information is mainly based on marine and limnological/pollen records. Here, we discuss for the first time results obtained from the investigation of dunes and paleosols along the semiarid central Chilean coast ("Norte Chico", 33-30°S). Rainfall in that area originates exclusively from the SWW during their northernmost position in wintertime which itself, is controlled by the position and intensity of the South Pacific Anticyclone (SPA). This geographical position makes the Norte Chico to a very sensitive region for changes in the position and intensity of the SWW/SPA.

Coastal dunes and their interbedded paleosols were studied at three locations, applying geochemical analysis and OSL-dating. Altogether, four dune generations during the last glacial-interglacial cycle could be identified. The older three paleosols are characterized by Bt-horizons with well developed clay cutans. The Holocene soils, in contrast, are weakly developed Cambisols. Dune formation and soil evolution seem to follow a periodic pattern during the last 100.000 years, showing a strong match with the precession cycle and the insolation at 30°S. Accumulation of sands predominantly occurred during periods with low summer and high winter insolation. This mode could have led to a relatively southern position of the SPA during winter, blocking the westerly storm tracks and leaving the Norte Chico dry. Probably, wind speed also increased during that mode, distributing the Aeolian sand relatively far inland. Vice versa, during periods with high summer and low winter insolation, the SPA remained in a relatively northern position during winter and rain from the SWW could penetrate further north. This allowed soil formation with deep clay illuviation at the coast.

\*\*\*\*\*

### **Causal links between Eastern Mediterranean sapropel formation, Nile floods and White Nile source-bordering dunes confirmed by OSL and radiocarbon dating.**

WILLIAMS M.(1), DULLER G.(2), WILLIAMS F.(1), MACKLIN M.(2), WOODWARD J.(3), EL TOM O.(4), MUNRO N.(5)

(1) *UNIVERSITY OF ADELAIDE, ADELAIDE, AUSTRALIA* ; (2) *Aberystwyth University, ABERYSTWYTH, UNITED KINGDOM* ; (3) *The University of Manchester, MANCHESTER, UNITED KINGDOM* ; (4) *Agricultural Research & Technology Corporation, WAD MEDANI, SUDAN* ; (5) *Old Abbey Associates, DIRLETON, UNITED KINGDOM*

It has long been hypothesised that beds of highly organic mud or sapropels seen in marine cores from the floor of the Eastern Mediterranean accumulated during times of high fluvial discharge and sediment input. Our recent fieldwork in the valleys of the Blue Nile and main Nile has for the first time revealed a sequence of extreme flood episodes synchronous with sapropel units S9 (240 ka), S8 (217 ka), S7 (195 ka), S6 (172 ka), S5 (124 ka), S4 (102 ka), S3 (81 ka), S2 (55 ka) and S1 (13.5-9 ka). During times of extreme floods, wide distributary channels of the Blue Nile flowed across the Gezira alluvial fan in central Sudan and transported a bed load of sand and gravel into the White Nile valley. The sands were reworked by wind to form source-bordering dunes, all of which contain heavy minerals of Ethiopian provenance. Three conditions are necessary for source-bordering dunes to form. The first prerequisite is a regular supply of bed load sands brought in by rivers that dry out seasonally, leaving their sandy point-bars exposed to deflation. The second requirement is an absence of riparian vegetation so that sand movement out of the channel through deflation is not impeded. The third condition is a regime of strong unidirectional winds, in this case from the north. For the dunes to develop and continue to extend downwind, the alluvial sand supply needs to be regularly replenished. These dunes were active at 115-105 ka, 60 ka and 12-7 ka, all times of extreme Blue Nile floods. The flood and dune sediments were dated using a combination of OSL and radiocarbon analyses. The Nile floods discussed here show a precessional signal and reflect episodes of stronger summer monsoon and more northerly seasonal movement of the ITCZ, linked to times of higher insolation in northern tropical latitudes. Progressive aggradation of Holocene Nile channels in northern Sudan had a profound influence upon human settlement in the last 8000 years.

**From dune accumulation to soil formation - Is climate change required?**

FAUST D.(1), WILLKOMMEN T.(2), YANES Y.(3), ZOELLER L.(4), RICHTER D.(1)

(1) TU Dresden, DRESDEN, GERMANY ; (2) TU-Dresden, DRESDEN, GERMANY ; (3) CSIC, GRANADA, SPAIN ; (4) Uni Bayreuth, BAYREUTH, GERMANY

The northern part of Fuerteventura is characterized by large dune fields. We investigated dune-palaeosol-sequences in four pits to establish a robust stratigraphy supported by some OSL-datings. According to our results we propose a standard section for the eastern Canary islands. An interaction of processes like dune formation, soil formation and redeposition of soils and sand are most important to understand the principles of landscape development in the study area. To our mind a process cycle seems to be important: First climbing-dunes are formed by sand of shelf origin. Then soil formation took place (or not). Soil and/or sand were then eroded and deposited at toe slope position. This material in turn is the source of new sand supply and dune formation. The described cycle may be repeated several times and this ping-pong-process holds on.

We ask if palaeoenvironmental conditions may change without disturbing dominant process combinations. Our geochemical data and mollusc assemblages point to changing environments in space and even climate oscillation in time. One fundamental question still remains unanswered. Do we in deed need climate change to change process combinations (e.g. from dune formation to soil formation)?

Assuming that different processes may happen under one climate, increasing soil forming intensity could be mainly a function of decreasing sand supply. This in turn could be caused by reduced sand availability. These ideas may stimulate a new discussion in geomorphology about geomorphic changes (soil formation vs dune accumulation) regardless of the climate.

\*\*\*\*\*

**Climate change and sandy aeolian deposition during the Last Glacial Maximum and Late Glacial in northwest Europe with special reference to the Lutterzand type locality, eastern Netherlands**

KASSE C.

*Faculty of earth and life sciences, Vrije Universiteit, AMSTERDAM, NETHERLANDS*

Periglacial aeolian sand sheets and dunes of the last glacial cover extensive areas of northwest and central Europe. Four sedimentary facies have been identified that are related to fluvio-aeolian and cryogenic processes, moisture content of the depositional surface and surface morphology. Three phases of aeolian sand deposition have been distinguished. High-resolution dating using optically stimulated luminescence of the type locality Lutterzand in the eastern Netherlands has recently improved the age control. Phase I (c. 28-19 ka) with predominant fluvio-aeolian deposition was related to continuous permafrost conditions of the Last Glacial Maximum. The first climate warming and permafrost degradation occurred at circa 19-16 ka during the formation of the Beuningen Gravel Bed, an erosional unconformity and desert pavement. Phase II (c. 16-14 ka) represents a short period of coversand formation at the waning stage of the last glacial. The rapid climatic improvement at the start of the Lateglacial (c. 14.7 ka) resulted locally in a decreased aeolian accumulation rate and formation of the Lower Loamy Bed. Aeolian deposition came to a hold during the Allerød interstadial when the Usselo Soil developed. Phase III (c. 13-11 ka) with more localized deposition occurred in the Younger Dryas stadial probably related to opening of the vegetation cover. In contrast to the Pleniglacial-Lateglacial climatic warming, the Younger Dryas to Holocene transition is reflected by an immediate system response and cessation of aeolian deposition. It is shown that the aeolian phases not strictly coincide with glacial or stadial conditions. Climatic aridity, limited vegetation cover and delayed responses of the aeolian environment to climate and vegetation changes determine the duration of the aeolian phases.

### **Pleistocene cold-climate wind system in the foreland of the Pannonian Basin**

SEBE K.(1), ROETZEL R.(2), FIEBIG M.(3), LÜTHGENS C.(3)

(1) University of Pecs, Dept. of Geology, PECS, HUNGARY ; (2) Geological Survey of Austria, WIEN, AUSTRIA ; (3) Institute of Applied Geology, BOKU, WIEN, AUSTRIA

During cold periods in the Quaternary, the intracontinental Pannonian Basin was part of the European periglacial zone, and aeolian erosion had a profound effect in shaping the landscape. Geomorphologically most effective winds were channelled between the Alps and Carpathians and entered the Pannonian Basin from the NW. To assess the nature of meteorological conditions producing these winds, field studies were carried out in the foreland of the basin entrance, in Eastern Austria.

As a result, we report on the first bedrock ventifacts from Austria and aeolian sand occurrence in the Bohemian Massif. Through a compilation of published data and field work, the distribution of ventifacts was mapped and appears to be controlled primarily by available lithologies. Paleo-wind directions were identified using ventifact mesoforms, especially flutes. The acquired air flow directions are accordant with the orientation of erosional landforms on soft sediments and form a coherent system, with westerly winds in the west, which turn toward the entrance of the Pannonian Basin in the east. There are no directions referring to the direct influence of katabatic winds, instead, the wind system must have been driven by synoptic-scale patterns, e.g. polar fronts. The narrow distribution of wind directions suggests that the low-altitude air flow system was relatively stable even without a funneling topography as in the Pannonian Basin, though the Alps could have acted to deflect the winds. The results provide data for aeolian transport studies, among them for loess provenance analyses.

\*\*\*\*\*

### **Timing and spatial distribution of loess-like sediments and late Quaternary alluvial fans in Mongolia and adjacent areas**

LEHMKUHL F.

Department of Geography, RWTH Aachen University, AACHEN, GERMANY

Geomorphological and sedimentological investigations in the mountain areas of northern Mongolia (lower and middle reaches of the Orkhon River) and investigations of aeolian sediments in southern Mongolia (Khangai and Gobi Altai) provide evidence for late Pleistocene terraces and huge alluvial fan development. Pleistocene and lateglacial luminescence data were obtained for basal sand deposits overlying slope bedrock and the Pleistocene terraces and alluvial fans of the Orkhon River. During the Holocene soil development occur in mainly silt-size aeolian deposits in the mountain areas and in northern Mongolia. OSL and radiocarbon data from aeolian sediments and paleosols indicated soil formation at around 11-10 ka, 7-6 ka and 3 ka. In the deserts of southern Mongolia a more humid early and mid Holocene can be divided from a more arid late Holocene.

### **Landforms of the hyper-arid Northern Emirates, United Arab Emirates**

PAIN C.

*University of Seville, OLVERA (CADIZ), SPAIN*

The first important event in the evolution of landforms in the Northern Emirates was the Miocene uplift of the Hajar Mountains, which form much of the eastern half of the Northern Emirates. This initiated erosion of deep valleys in the mountains, transport of the resulting sediment out into the surrounding areas, and development of alluvial plains. These plains extended at least as far as the present coast and are now covered by relatively thin sand dunes.

Quaternary sea level and climate changes have played an important role. Low sea levels exposed large areas from which sand was blown from the west to the east, leading to dune building. High sea levels cut off the sand supply and allowed alluvial erosion and deposition from the mountains to dominate in the east. Wetter climates led to erosion on the mountains and alluvial deposition on the plains, while drier climates meant more eolian activity and dune building.

During glacial periods the Arabian Gulf was almost dry and the sea retreated to the Strait of Hormuz. The Tigris and Euphrates rivers extended the entire length of the Gulf, and carried large loads of sediments that were reworked by the dominant north-westerly Shamal winds. The Shamal is primarily responsible for the formation and continued evolution of the dunefields seen in the Northern Emirates today. These winds created extensive dune fields and also deflated areas, leaving small plains of alluvial material exposed between dune systems, where groundwater levels approach the surface. Dust storms continue to add dust and calcium carbonate to the dunes.

The current marine incursion into the Arabian Gulf limits the source of new material to continue feeding the dune fields of the Northern Emirates. This shortage has led to minor deflation of existing coastal flats to a level that reflects the extent of the capillary fringe from the underlying saline water tables. The formation of coastal landforms was dominated by the effects of the current high sea level.

\*\*\*\*\*

### **Morphoclimatic significance of eolian plugs on the northern margins of Sahara desert**

BENAZZOUC M., BOUREBOUNE L.

*Faculty of Earth Sciences, University Mentouri Constantine, Algeria, CONSTANTINE, ALGERIA*

The actions of the aeolian morphogenesis through the Northern margins of the Sahara desert result to triggering a partial disorganization of the hydrographic network in Saharan atlas mountains during the upper Pleistocene. This disorganization of runoff puts in evidence the major role of the aeolian plugs filling bottoms of valleys and plains. The interaction of the wind actions and fluvial actions is at the origin of the setting up of the aeolian plugs with blackish paludal formations and travertinous beds as indicators of temporary paralysis of the runoff and could be good indicators of the palaeohydrological variations.

These aeolian plugs are located on the borders of the eastern Saharan Atlas mountains and develops a length and a width of a few hundreds of meters to some kilometers and a thickness of 10 to more than 30 meters.

These accumulations are composed of two superposed forms:

- The sandy dam with convex forehead constitutes the sedimentary body obstructing,
- The sandy aeolian plug in progress uphill and linking down to a terrace or glacis level. The study concludes to identify arid climatic fluctuations of this period confirming the influence of the desert outside the northern limits of the Algerian Sahara.

## **Mapping China's deserts and desert margins: A database approach to understanding form, process and causality**

SCUDERI L.(1), WEISSMANN G.(1), YANG X.(2), KINDILIEN P.(3)

(1) Dept of Earth & Planetary Sciences, University of New Mexico, ALBUQUERQUE, UNITED STATES ; (2) Institute of Geology and Geophysics, Chinese Academy of Sciences, BEIJING, CHINA ; (3) Center for Rapid Environmental Assessment and Terrain Evaluation, U. New Mexico, ALBUQUERQUE, UNITED STATES

Despite decades of research on China's desert and desert margin systems, fundamental questions remain about how they function and interact with other environmental systems both regionally and globally. The predominant focus of past desert research in China, and globally, has been location specific with case studies within distinct subdisciplines. This narrow view makes development of a comprehensive understanding of desert system dynamics difficult. In part, a great deal of the current research weakness is due to the lack of a unifying conceptual approach and the failure to appreciate the value of synoptic overviews provided by highly structured and synthesized compilations of data, organized in user-friendly formats. Recent developments in platforms and sensors, as well as the ability to access these rich new data sources in real time present scientists with both opportunities and problems. We now record data about the physical world at unprecedented rates with extremely high spatial/spectral resolution. Yet the ability to extract scientifically useful knowledge from such immense data lags considerably. The fields of database creation, data mining and modern statistics all focus on such interdisciplinary data analysis problems and in recent years these fields have made great advances in analyzing complex real-world data. However these methods have enjoyed relatively modest penetration into the sciences. We report on the application of these new technologies to the desert environments of China as well as to other global scale systems and illustrate the value of well-constructed databases and tool-rich analysis environments for understanding form, process and causality in these systems. We also show that our approach provides a "living" archive that allows us to capture change currently occurring in all of China's deserts as well as to assess human efforts to modify desert and desert margin environments.

\*\*\*\*\*

## **Aeolian sand landforms in the Mainling Wide Valley of the Yarlung Zangbo River**

ZHOU N., ZHANG C.

State Key Laboratory of Earth Surface Processes and Resource Ecology, Beijing Normal University, BEIJING, CHINA

Aeolian sand landforms are a distinctive geomorphic feature of China's Mainling Wide Valley. We measured topographic parameters in the field and via remote sensing to characterize their distribution, aeolian sand activity, and evolutionary sequence. The landforms displayed a banded, discontinuous pattern along the river valley. Belts of aeolian sand on river terraces play a key role in transporting sand uphill from the river. Three sand belts were identified: in the embryonic belts (EB), an erosive air stream combined with relatively high vegetation cover (10%) produced sparsely (degree of closeness,  $B = 0.32$ ) and irregularly (degree of fluctuation,  $E = 0.40$ ) distributed parabolic dunes; in the adolescent belts (AB), an erosive air stream followed by a slightly depositional air stream, combined with low vegetation cover (3%), formed denser ( $B = 0.35$ ) but more regular ( $E = 0.35$ ) barchans and barchan chains; and in the mature belts (MB), an erosive air stream followed by a strongly depositional air stream, combined with low vegetation cover (2%), produced the densest ( $B = 0.73$ ) and most regular ( $E = 0.32$ ) complex dunes. Dune size and patterning increased from EB to MB, and increased within the MB from erosion to deposition areas. Unidirectional winds, lateral linking and merger of dunes, and time explain the evolution of these aeolian landforms. Aeolian sand belts appear to evolve from disordered embryonic parabolic dunes to isolated adolescent barchans and regularly distributed barchan chains, and then to well-organized, large-scale mature complex dunes. Sand accumulation on valley slopes also produces large climbing dunes.

### **Aeolian sediments on the north-eastern Tibetan Plateau**

STAUCH G.(1), LEHMKUHL F.(1), HILGERS A.(2), ZHAO H.(3)

*(1) Department of Geography, RWTH Aachen University, AACHEN, GERMANY ; (2) Institute of Geography, University of Cologne, COLOGNE, GERMANY ; (3) Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Sciences, LANZHOU, CHINA*

Aeolian sediments in high mountain environments often show a complex spatial pattern. Different types of aeolian deposits have been studied in the catchment of the Donggi Cona on the north-eastern Tibetan Plateau in elevations between 4,100 and 5,000 m asl. Four distinct groups were classified according to the related process and the grain-size composition: loess, sandy loess, reworked loess and sand dunes. The spatial distribution of these different groups is related to the local topography and the activity of the sediment source areas. Beside the spatial differences, the timing of deposition varies. 51 OSL datings have been obtained to develop a numerical timescale ranging from the Lateglacial nearly to the present. The deposition of aeolian sands started around 14 ka. However, a phase of intensive deposition of sands occurred between 10.5 to 7.5 ka. The accumulation of the loess occurred during the same period (10.5 to 7 ka). The formation of these deposits is related to the strengthening of the Asian summer monsoons. Wetter climatic conditions lead to an enhanced trapping of the aeolian sediments. This pattern is different from the accumulation processes in the Chinese Loess Plateau. In the high mountain environment formation of aeolian deposits in the early Holocene is mainly related to the conditions in the depositional area and only to a lesser degree to the sediment availability. Fluvial erosion of the deposits under full monsoonal conditions was strongest between 9 to 6 ka. From 3 ka onwards reactivation of sands took place. This is coherent with drier and cooler climatic conditions, and probably an enhanced human influence in the area. Additionally new sediment sources from exposed lake bed influenced the grain-size composition of the archives.

\*\*\*\*\*

### **North Sinai Sand Sea, Egypt: Dune Types and Forms, Sediments, and Hazards**

EMBABI N.

*Department of Geography, Faculty of Arts, Ain Shams University, CAIRO, EGYPT*

This study represents a part of a research project on the Egyptian sand seas, aiming at a better understanding of sand accumulations dynamics and their relationship to present/future economic projects in Egyptian deserts. The North Sinai Sand Sea extends from the Mediterranean coast to the northern slopes of Gabal Maghara and Halal in the south, and from the eastern borders of Egypt to the Suez Canal in the west, covering an area of 13 000 km<sup>2</sup>. The aim of this paper is to analyze local variations in dune types & forms, and to pin point areas where sand dunes represent a hazard for economic projects. To achieve these goals, topographic maps, aerial photographs, Landsat & Google Earth images, and climatic data of North Sinai were analyzed, and assisted by field work to check some of the aspects extracted from maps and photos and to collect some sand samples.

This study revealed that this sand sea has the most complex dune system among Egyptian sand seas and is composed of at least two superimposed generations of dunes. Nearly all forms of dunes and patterns can be recognized. Drowned dunes are spotted in Bardawil Lagoon on the Mediterranean coast. Of these dune forms, small linear ones are the most widespread. Dune orientation varies greatly from one locality to another, but it can be said that nearly all directions are present. Sand dune movement represent a major hazard to development projects in the region of Sinai.

The analysis of dune sediments revealed that they were originated from Nile sediments, ancient local fluvial deposits, beach sand and the product of digging and deepening the Suez Canal. Also, it was found that wind regime, the presence of a chain of mountains in the south, climatic and sea level changes are the main factors affecting this sand sea.

## Geomorphology of western desert Iraqi

HAMED W.

*Plymouth University, PLYMOUTH, UNITED KINGDOM*

The study area geomorphological effected including several factors such as the River activities, gully erosion, the land masses movement and dissolving phenomena, geomorphological units classified by Google Earth images and filed work. The Majority of the geomorphological features were formed under the arid conditions however well-developed drainage pattern and the relics of older ones bear the evidence of the influence of some more humid periods. Recent climate corresponds, according to the observation in the Rutba station Dennis, 1953 during the year 1937-1952 to the arid and semiarid one yearly mean precipitation in that period was 100mm/min 50 max 150mm/, yearly means temperature was 20°C. Rainfall occurs during the winter months in the form of heavy local showers influencing the whole surveyed area only exceptionally. For the compilation of the geomorphological map the geomorphological analysis was used exploiting detail data on the land forms, their relationships, genesis and lithology of the bedrock gained by the field geologists. Besides that many special geomorphological traverses were completed and some important sections and localities were studied in detail, for example the whole area was sampled for the pebble analyses to solve the problem of the arid environments sediments. The Majority of the geomorphological features were formed under the arid conditions; however, well developed drainage pattern and the relic of older ones bear the evidence of the influence of some more humid periods. Recent climate correspond, according to the observation in the Rutba station. During the past (50) years ago the arid to semi-arid yearly mean precipitation of Rutba station has been 100 mm and the mean temperature was 20°C in day. Rainfall occurs during the winter months in the forms of heavy local showers, influencing the whole surveyed area only exceptionally for the compilation of the geomorphological map.

\*\*\*\*\*

## Complex dune patterns of the northern Rub' Al-Khali, UAE ' age and origins

LANCASTER N.(1), SINGHVI A.(2), GLENNIE K.(3), TELLER J.(4), PANDEY V.(2)

*(1) Desert Research Institute, RENO, UNITED STATES ; (2) Physical Research Laboratory, AHMEDABAD, INDIA ; (3) University of Aberdeen, ABERDEEN, UNITED KINGDOM ; (4) University of Manitoba, WINNEPEG, CANADA*

The northern Rub' Al-Khali sand sea in the area of the United Arab Emirate exhibits a complex pattern of dunes, comprising large compound crescentic dunes in the south and W-E trending linear dunes in the north and east, in addition to marginal crescentic dunes and sand sheets. The linear dunes are modified in many places by superimposed crescentic dunes. Understanding this complex pattern requires integration of multiple data sets on dune morphology, chronology, and sediment characteristics

The complex pattern of dune generations reflects a long history of sand accumulation involving both quartz-rich and carbonate-rich sands., as well as modification of pre-existing dunes in response to climatic and sea level changes that affected sediment supply, availability, and mobility. Sediment sources include quartz rich sediments derived from the Zagros Mountains and the highlands along the Red Sea Rift, as well as carbonate rich sand derived from the floor of the Arabian Gulf during periods of low sea levels. In conjunction with analysis of dune patterns and geomorphic relationships between dune generations, a synthesis of currently available chronometric information enables identification of multiple periods of aeolian accumulation over the past 200ka. Prior to 80 ka, the preserved record is dominated by crescentic dune accumulation, and now-buried carbonate-rich sediments (aeolianites). From 30 to 9 ka, the preserved record is characterized by quartz-rich linear dune formation. The period 8-2 ka was one of very rapid reworking and accumulation of quartz-rich sand in both crescentic and linear dune environments, as well as formation of coastal crescentic dunes.

### Particle-size fractionation of eolian sand along the Sinai - Negev erg

ROSKIN J., KATRA I., BLUMBERG D.G.

*BEN-GURION UNIVERSITY OF THE NEGEV, BEER-SHEVA, ISRAEL*

This study examines changes in the eolian sand fractions along the west - east transport path of the northern Sinai Peninsula – northwestern (NW) Negev erg of Egypt and Israel. This erg is composed of active linear (seif) dunes in northern Sinai (its western part), and stabilized vegetated linear dunes (VLDs) in the NW Negev dunefield (its eastern part). Sand samples were analyzed for sand grain morphology, particle-size distribution (PSD) and optically stimulated luminescence ages.

Linear seif dunes differ from VLDs in their vegetation cover, linearity, and dynamics. Although both are continuous landforms with similar orientations and sand-grain roundness values, the linear dunes of Sinai are coarser-grained than the Negev VLDs. The VLDs have a significantly higher proportion of very fine sand (125-50  $\mu\text{m}$ ) content and a varying but lower *sand fining ratio* defined as the ratio of fine sand percentage to very fine sand percentage. From these observations we infer that fractionation of sand occurred along the studied eolian transport path. Very fine sands are suggested to have been winnowed by saltation and low suspension from source deposits and sand sheets.

We suggest that the very fine sand fraction of Nile Delta and Sinai sands has been transported downwind since the late middle Pleistocene. In the late Pleistocene, linear dunes reached the Negev due to last-glacial period windiness of intensities unprecedented today and probably larger sediment supply. Generally decreasing wind velocities and increasing precipitation along the west - east dune transport path enhanced vegetative cover in the NW Negev and enabled deposition of the very fine sand component that was also transported by low suspension. We hypothesize that these very fine sands also probably compose a partial fraction of the Negev loess deposits, still farther downwind. Our results suggest that PSD can elucidate much about erg and dunefield history over timescales of a glacial-interglacial cycle.

\*\*\*\*\*

### Windy silt deposits (or loess) in Southeast Tunisia (Northern borders of the Great Sahara): chronostratigraphy and paleoenvironments of their deposition

BEN FRAJ T.

*Faculty of Letters and Humanities of Soussa, Geography department, KSIBET MADIOUNI, TUNISIA*

Geomorphological researches conducted in the northern Jeffara plain and north-eastern part of Matmata-Dahar plateau (S-E Tunisia) have allowed us to determine the place of windy silt deposits (or Loess) in the chronostratigraphy of the Quaternary and redraw the outlines of the paleoenvironmental and geomorphological evolution in this nowadays arid domain.

The thickness of the windy silt deposits, rich of calcareous concretions, ranges from 1 to 8 m. Two red levels of variable decimeters thickness or two calcareous crusts separate two or three generations of these silts. The first calcareous crust is zonal and about 10 cm average thick. The second is about 2 to 3 cm thick and it has spongy appearance.

Windy silt deposits overcome always a conglomeratic deposit sealed by a pudding or a clayey-silty-gypseous deposit sealed by a gypsum crust. All of these deposits can be formed into terraces, alluvial fan or erosion surfaces.

Geomorphological data, Prehistory data and those provided by radiometric dating ( $^{14}\text{C}$ ), allowed identifying two major phases of accumulation of windy silts. The first took place during the second half of the upper Pleistocene. The second is attributed to the lower/middle Holocene.

Stratigraphic and lithologic data indicate the occurrence of two major phases of climatic fluctuations during these two periods. There were passages from semi-arid to arid shades but they remained wetter than the current.

The analysis of heavy minerals and the transposition of the current wind regime in southern Tunisia can be linked to the hypothesis of an origin of silts from the "Grand Erg Oriental". But, possible deposits from the Great Chotts or from the coastal domain and its sebkhas are not, however, excluded. These deposits are most likely related to seasonal variations in wind directions.

## **The role of active sand seas in forming desert loess sequences with implications to the Chinese Loess Plateau.**

*AMIT R.(1), ENZEL Y.(2), ONN C.(3), MUSHKIN A.(3), JIGJIDSUREN B.(4), GILLESPIE A.(4)*

*(1) Geological Survey of Israel, JERUSALEM, ISRAEL ; (2) Institute of Earth Science, Hebrew University of Jerusalem, JERUSALEM, ISRAEL ; (3) Geological Survey of Israel, JERUSALEM, ISRAEL ; (4) Department of Earth and Space Sciences, University of Washington, SEATTLE, UNITED STATES*

In earlier work we demonstrated that coarse silt quartz grains that comprise most of desert margin loess, must have been formed through aeolian abrasion within upwind active sand seas. In the Sinai-Negev desert, the coarse mode of silts is composed mostly of abraded quartz grains and increases in percentage and in grain-size with time, and therefore indicating a time-transgressive advancing proximal dust source. In the carbonate bedrock terrain of that region, the only proximal dust source for high amount of coarse quartz grains are the sands of northern Sinai derived from the Nile that were transported coevally with the loess accretion during the late Pleistocene. Examined available data for loess in the margins of the deserts of Sahara, Arabia, South America, and the Thar revealed that all these desert loess sequences are located downwind of adjacent sand seas at present and during the Pleistocene. These observations suggest that sand dunes must have been an important source for desert loess and silt grains are generated through active aeolian abrasion of sand grains during episodes of intense windy conditions, primarily in glacial times. A detailed study of potential dust sources in south and central Mongolia, one of the suggested major dust and loess source for the Chinese Loess Plateau (CLP), revealed that this desert cannot be a major source for the coarse silt fraction of CLP. However, a compilation of all available data regarding particle size distribution of the CLP indicates that processes, similar to those outlined above for the warm desert margins, can be associated with sandy areas in the Mongolian Gobi and with several of the largest sand seas in the world surrounding the CLP. Our results stress the primary role of long-lasting active ergs and aeolian abrasion associated with frequent strong winds in the formation of Quaternary desert loess sequences.

\*\*\*\*\*

## **Dust emission dynamics and source area variability: field measurements for climate modelling**

*WIGGS G.(1), KING J.(1), THOMAS D.(1), WASHINGTON R.(1), ECKARDT F.(2), BRYANT R.(3), NIELD J.(4), VICKERY K.(2)*

*(1) University of Oxford, OXFORD, UNITED KINGDOM ; (2) University of Cape Town, CAPE TOWN, SOUTH AFRICA ; (3) University of Sheffield, SHEFFIELD, UNITED KINGDOM ; (4) University of Southampton, SOUTHAMPTON, UNITED KINGDOM*

Climate models must account for aeolian dust in order to avoid large radiative and dynamical errors. The simulation of the dust cycle depends on a wide range of earth system components but begins with the realistic representation of source areas. However, there are very few measured data from dust source regions and none of emission processes operating at model grid-box resolution. This paper presents field results from the Do4 Models (Dust Observations for Models) project that aims to understand the variability in dust emission processes at relevant scales for climate modelling. Specifically, the project aims to evaluate the value added to predictions of aeolian dust emission with the measurement of erosivity and erodibility parameters at differing scales within source areas.

Data are presented from a field campaign across a 12 km x 12 km grid cell in Sua Pan, Botswana. 11 meteorological stations were deployed consisting of anemometer arrays, sediment transport detectors, high-frequency dust monitors, soil moisture meters, and shallow well networks. Further data were gathered across the grid on the dynamics of surface characteristics and erodibility parameters that impact upon erosion thresholds. Our data show for the first time the substantial variability in erodibility of an apparently homogenous surface in both time and space as a result of changing moisture and crustal characteristics, coupled with irregularity in erosivity due to variations in surface roughness. Such variability results in the identification of dust emission 'hot-spots' even within the area of a single regional climate model grid cell. This dataset provides a starting point from which to construct and test new dust emission schemes at scales relevant for climate modelling that incorporate the sensitivity of erosion thresholds to small changes in surface and atmospheric conditions.

### **Soil organic carbon enrichment of dust emissions: magnitude, mechanisms and its implications for the carbon cycle**

STRONG C.(1), WEBB N.(2), CHAPPELL A.(3), MARX S.(4), MCTAINSH G.(1)

(1) Griffith University, BRISBANE, AUSTRALIA ; (2) USDA-ARS Jornada Experimental Range, MSC 3 JER, NMSU, Box 30003, , NM 88003-8003, USA, LAS CRUCES, UNITED STATES ; (3) CSIRO Land and Water, CANBERRA, ACT, AUSTRALIA ; (4) GeoQuEST Research Centre, School of Earth and Environmental Science, University of Wollongong, WOLLONGONG, AUSTRALIA

Soil erosion is an important component of the global carbon cycle. However, little attention has been given to the role of aeolian processes in influencing soil organic carbon (SOC) flux and the release of greenhouse gasses, such as carbon-dioxide (CO<sub>2</sub>), to the atmosphere. Understanding the magnitude and mechanisms of SOC enrichment in dust emissions is a necessary step in evaluating the impact of the wind erosion part of the dust cycle on the carbon cycle. This research examines the SOC content and enrichment of dust emissions measured using Big Spring Number Eight (BSNE) wind-vane samplers across five land types in the rangelands of western Queensland, Australia. Our results show that sandy soils and finer particulate quartz-rich soils are more efficient at SOC emission and have higher SOC dust enrichment than clay-rich aggregated soils. We also show from two months data, that size selective sorting of SOC during transport can lead to further enrichment of SOC dust emissions. These preliminary results provide impetus for additional research into dust SOC enrichment processes to elucidate the impact of wind erosion on SOC flux and reduce uncertainty about the role of soil erosion in the global carbon cycle.

\*\*\*\*\*

### **Dust Sources of Southern African**

ECKARDT F.

University of Cape Town, CAPE TOWN, SOUTH AFRICA

Southern African dust sources have been identified using a variety of remotely sensed products including Photography, TOMS, SeaWifs, MODIS and MSG. While each sensor introduces its own observational bias it is the true colour rendition of MODIS which appears to provide the most versatile and consistent product, capturing both low level coastal plumes as well as those originating from larger inland sources. Southern African sources include ephemeral recharge playas of the interior as well as coastal discharge sabkhas from Namibia in addition to dry river valleys with headwaters in the western escarpment and beyond. The Kalahari and Namib consistently produce plumes while dust in the Karoo region has remained undetected from space. The temporal plume detection record from remote sensing combined with reanalyses data suggests distinct synoptic drivers at play, which include west coast troughs intensified by continental high pressure systems at a regional scale and berg winds in coastal slope settings. Ground based observations have added important dimensions to our understanding of the processes. Applying the Gobabeb weather observations to the Kuseb River plumes suggest persistent winds and topographic channelling of air flow may be an additional factor for many of the Namibian River valleys. Saltation as an agitator appears a lesser driver but cannot be discounted in the proximity of active dune fields. Intensive ground based observations as part of DO4 (Dust Observation For Models) have been underway since 2011. In general southern African sources are supply limited in nature and availability of material is controlled by flooding history for both river and lake systems, while playas feature the additional limitation of crust formation and fluff retention. Southern Africa may not be the dustiest place on earth but numerous discrete sources including Sua Pan and Namibian West Coast have enhanced our understanding of surface process geomorphology.

## **Poster presentations:**

### **Eolian terrain of the lower course of the river Vilyui (Central Yakutia)**

PAVLOVA M.

*Tomsk State University, TOMSK, RUSSIAN FEDERATION*

Ere now in the XIX century researches knew about the wide spread occurrence of the unique eolian land forms called tukulans (massive deflated hilly sands) in a lower course of the river Vilyui. The first information about them is cited in the writings of R. Maak (1886). In subsequent years tukulans were researched by various scientists: E. Katasonova (1963), S. Skryabin, P. Pavlov (1977).

Tukulans of the lower course of the river Vilyui are situated between the rivers Umulun (Vilyui's left tributary) and Lungh (Lena's left tributary), on the surfaces of the terraces above the flood-plain and on the territory of the dividing stretches with the altitudes up to 270 metres above the sea level. Blown sands massives area is 2056 km<sup>2</sup> (total area of the region is 21540 km<sup>2</sup>).

The largest tukulans of the lower course of the river Vilyui are Hotugu-Ulahan-Tukulan (square 302 km<sup>2</sup>), Kyundul-Tukulan (51 km<sup>2</sup>), Berende-Tukulan (49 km<sup>2</sup>), Chiertike (29 km<sup>2</sup>), Balagannah (16 km<sup>2</sup>).

Tukulans surface is covered with young and old parabolic dunes, deflation basins and other eolian formations. Dunes form is different crescent-shaped, javelin-shaped or annular-shaped. Their high amounts to 10–30 metres, width amounts to 50–60 metres. The windward slope is usually gentle (5–15°), the downwind slope is steeper (to 30°). Deflation basins width amounts 200–300 metres. Generally the sources of the sand accumulation are the local underlying rocks.

Today, the insufficiency of data about eolian terrain of the lower course of the river Vilyui complicates the decision of the practical questions (for example, how to protect forest areas and farmlands from tukulans invasion). The detailed research of the peculiarities and regularities of the eolian terrain of the lower course of the river Vilyui enables to get more accurate trend concerning the problem of origin and formation of these land forms and to get the data about tukulans quantitative characteristics substantiation.

\*\*\*\*\*

### **Study on Arid Geomorphologic Features in the Queletag Mountain in Southern Piedmont of the Tianshan Mountains, Xinjiang, China**

ZHAO X.

*Xinjiang Institute of Ecology and Geography, Chinese Academy of Sciences, URUMQI, XINJIANG, CHINA*

In this paper, the geomorphologic features and forms in the Queletag Mountain in southern piedmont of the Tianshan Mountains, Xinjiang, China, were studied using the GIS spatial analysis and the methods of geologic structure, formation lithology, altitude, relief amplitude and geologic profile. The results show that the Queletag is a folded mountain consisted of the Cainozoic lacustrine and fluvial amaranthine sandstone, siltstone and conglomerate, and it is precipitous and runs from east to west. These reveal that the earth surface was strongly folded by a south-north compression under neotectonics, with the fold some thrust faults of parallel anticline axes, shear faults of chamfer anticline axes and steep or gentle anticlines and synclines were developed, and the strata were crushed seriously. All these reveal that the tectonics in the southern piedmont of the Tianshan Mountains is currently at an active stage, and the development of landforms is at the metaphase of postadolescence. The features of altitude contour lines show that the surface weathering has been dominated by mechanical disintegration since the mid-Pleistocene under the effects of extreme arid climate, violent drying denudation and wind erosion, rainstorm wash, topography dissected by seasonal flood, lithologic difference weathering, gravity landslip, etc. Thus, the various particular arid landforms were developed in geomorphologic process in this arid area, which include the large peaks with clear stratification, deep valleys, steep cliffs, marvelous Yadan landforms, salty dunes, etc.

Keywords: GIS spatial analysis, geologic structure, altitude, arid landform, Queletag Mountain, southern piedmont of the Tianshan Mountains

**Intensified, gusty latest Pleistocene winds forced abrasion of Sinai/Negev sand into a continuum of finer grains downwind**

ENZEL Y.(1), AMIT R.(2), CROUVI O.(2), PORAT N.(2)

(1) *The Hebrew University of Jerusalem, JERUSALEM, ISRAEL* ; (2) *Geological Survey of Israe, JERUSALEM, ISRAEL*

Data from the edge of the Sinai-Negev sand field indicate that ergs are mega-grinders of sand into very fine sand and silt under gusty, windy late Quaternary climates and in ancient aeolian deserts environments. In the carbonate terrain of the northern Sinai-Negev desert, only sand abrasion in an active erg could have produced the large quantities of quartzo-feldspathic silts constituting the late Quaternary northwestern Negev loess. In this poster presentation we focus on the continuum of downwind fining of grain size distributions from this identified source (with its medium sand-size grains of the dunes and without silts or very fine sand), to the silts of the accreted loess. We point that the very fine sands, unaccounted for in enough quantities in the record are deposited at the dune field margins. In the current research we focus on and demonstrate that as predicted by experiments, abrasion by the last and relatively fast advancing dunes at 13-11 ka, generated large quantities of very fine sand (60-110  $\mu\text{m}$ ) deposited within the dune field and in close proximity downwind. This very fine sand is absent from the particle size distribution of the dunes and must have been generated 13-11 ka, possibly under gusty winds and sand/dust storms during the Younger Dryas in the SE Mediterranean. These very fine sands filled small basins formed by the blocking advancing dunes under these same winds; elsewhere, outside these sampling basins it is difficult to identify these sands as a distinct product that point to extremely windy episodes. Past proposals for common gaps in the formations of eolian grain sizes should be reconsidered by tighter spatial sampling.

\*\*\*\*\*

**Tukulan Phenomena - Specific Cryoarid Landforms of Central Yakutia**

GALANIN A., URBAN A., PARFYONOV M., TANANAEV N.

*Melnikov Permafrost Institute SB RAS, YAKUTSK, RUSSIAN FEDERATION*

Tukulans are unique natural phenomena of Central Yakutia, representing aeolian cryoarid landscapes in permafrost surroundings, well-developed in the central part of the Lena River Basin and its major tributaries – Viluy, Linde. They are polychromic complexes of frozen parabolic or crest-shaped dunes of different sizes. Typical tukulan section was studied on the 4-km long exposure site on the right bank of the Viluy River. Marker layer of swamp-lacustrine deposits with buried peats, disrupted by ice wedges, was established within the cross-section. Radiocarbon dates of  $4470\pm 95$ ,  $4450\pm 90$  and  $4060\pm 95$  cal. BP, obtained from buried wood within the marker layer, evidence colder and wetter environment. Thus the studied deposits can be attributed to the late Atlantic period of Blytt-Sernander sequence, marking transition to early Subboreal. This marker layer separates underlying alluvial deposits from typically aeolian deposits of Late Holocene. The latter include a number of buried soil horizons and vertically buried tree trunks, related to the periods of relative dune stability under soil and vegetation cover. These can potentially be attributed to the periods of weaker wind activity, reflecting the increased stability and intensity of the Siberian Maximum, defining the Central Yakutia climate during Holocene Little Ice Age. Six radiocarbon dates, obtained from stratigraphically distinct soil horizons, are unexpectedly young, not exceeding 150-200 y. BP. They reflect changes in wind activity and evidence intensive tukulan area increase after that time. This studies were supported by Russian Fund of Basic Research, Projects # 11-05-00318-a 12-05-98507-vostok\_a.

**Application of SRTM and ETM in identification of unknown geomorphologic forms, Case Study: Lut Plain in south east of Iran**

NAEIMINEZAMABAD A.

*.Islamic Azad University Saveh Branch, SAVEH, IRAN*

According to the World Meteorological Organization (WMO), the highest temperature measured on Earth in September 13, 1922, were in El Azizia, Libya, reached 58.0°C (136.4°F). study landsat Data Obtained in July 6, 1999 by Landsat 7 obvioued that in seven years of global land surface temperatures , the Lut Desert in Iran ranked as hottest in five of the years. In five of the seven years -2004, 2005, 2006, 2007 and 2009 - the highest surface temperature on earth was found in the LUT desert. the single highest LST recorded in any year in any region, occured there in 2005, when MODIS recorded a temperature of 70.7°C(159.3°F)—more than 12°C (22°F) warmer than the official air temperature record from Libya. For determine geomorphologic structure in this wild and unknown area we at the first used from new technologies and new data's. Based analyzed of SRTM data that achieved in 2003 we found a hole in center of LUT Desert. 3D analyses of SRTM data obvious that depth of hole is about 100 meters from the marginal lands. Areas and this hole was about 900 hectare. Analyses of Satellite images, especially ETM obvious that we are faced with an expanse of mud and wet. Based these results, Geology Maps of Iran and other Data Reviewed that no detailed information was obtained from this area. For identify of geomorphologic character of this hole an expedition was organized. after 5 day Hard drive in the center of Lut desert we achieve to the this hole and found that this hole created based Collision of a meteorite because we found many meteorites that separated in that place and morphology of this hole were different with other place of that area. Geomorphologic forms of this hole were similar study SRTM data and ETM satellite image analyses, we found a hole with depth about 100 meter and that were muddy and wet. In result application of new data's and technologies specially GIS and RS pioneering for discover unknown places in the world.

\*\*\*\*\*

**Hydrochemical characteristics of natural water and origins of dissolved salts in the eastern Hunshandake Sandy Land, Eastern Inner Mongolia, China**

REN X., YANG X., ZHANG D., LI H.

*Institute of Geology and Geophysics, Chinese Academy of Sciences, BEIJING, CHINA*

In order to understand the hydrochemical characteristics of natural water and the origins of the dissolved salts in the water in the eastern Hunshandake Sandy Land, eastern Inner Mongolia of China, we collected water samples in 2011 and 2012 from the rivers, lakes, springs and wells of the region. Temperature, pH, electrical potential (EP), electrical conductivity (EC), total dissolved solids (TDS) and salinity were examined immediately on site by a portable multi-parameter analyzer. Major cations and anions were measured using a ion-chromatograph and titration with HCl in laboratory. The alkalinity was measured using Gran Titration Method. The TDS-EC and EP-pH ratios confirm that our measurements were precise. The value of TDS shows that the river, lake, spring and ground waters are mostly of fresh water quality in this desert environment. The pH value indicates that the spring and ground waters are neutral or even slightly acidic, the river and lake waters are neutral to slightly alkaline. The alkalinity in all natural waters is low, but the ground water's alkalinity is higher than other natural waters', and its TDS also the highest in all samples.  $\text{HCO}_3^-$ ,  $\text{CO}_3^{2-}$  and  $\text{OH}^-$  content indicates that the alkalinity is mainly caused by the  $\text{HCO}_3^-$ . In all samples the main anions are  $\text{HCO}_3^-$ ,  $\text{SO}_4^{2-}$ ,  $\text{Cl}^-$  and  $\text{HCO}_3^-$  is the predominantly one in all river and lake samples, and in the majority of the spring and ground water samples. However,  $\text{SO}_4^{2-}$  is the predominant anion in the rest of spring and ground water samples. The main cations are  $\text{Ca}^{2+}$ ,  $\text{Mg}^{2+}$  and  $\text{Na}^+$ , and  $\text{Ca}^{2+}$  is the predominant one in all water samples. The appearance of  $\text{NH}_4^+$  and  $\text{NO}_3^-$  in some samples may suggest evident anthropogenic impact on the water bodies in this region. We conclude that the ions in natural waters of the region are sourced mainly from carbonate rocks, rather than the desert evaporites, as having occurred in the deserts of western China.

### **Desertification and human impact in the arid region of Northwestern Argentina**

SAYAGO J.M.

*Consejo Nacional de Investigaciones Cientificas y Tecnicas, SAN MIGUEL DE TUCUMON, ARGENTINA*

Since the beginning of the Spanish colonization and up to our days the region was affected by deforestation, overgrazing or cultivation un restricted explaining the severe box desertification affecting this vast region. In parallel, the climate changes of the last millennium influenced the settlement of the pre-Hispanic cultures and during the Hispanic period to the present day. In a preandean valley, taken as pilot area, analyzed the genesis and evolution of desertification which starts on downhill pediments with the disappearance of the primitive herbaceous vegetation being replaced by a xerophytic shrub layer in response to the loss of surface horizons whose soil sediments carried to the plains of major rivers modify the fluvial geometry and drainage pattern. During arid periods the floodplain area are the source of input for the development of a dune landscape developed to the sides of the river valleys. Today the region is characterized by soils in the foothills totally degraded, where prevailing wind and water erosion. In the summit areas and transverse valleys natural vegetation has not been completely changed, while the presence of high terrace with dune pattern provides a marked fragility and low terrace, with saline and alkaline soils, has only a moderate fitness pastoral rustic species, especially during the wet season. An inventory of desertification at semi detailed scale from geoecological and socioeconomic perspective is suggested as a necessary condition to define sustainable management, especially facing the prospect of future environmental changes.

\*\*\*\*\*

### **Geochemical properties of loess-paleosol sequence in the Haemi area, West Coast of South Korea**

YOON S.O.(1), HWANG S.(2), PARK C.S.(1)

*(1) Dept. of Geography and Research Institute for Basic Sciences, Kyung Hee University, SEOUL, SOUTH KOREA ; (2) Dept. of Geography, Kyungpook National University, , DAEGU, SOUTH KOREA*

The Haemi section found in the Haemi area, Seosan-si consists of loess-paleosol sequence (LPS), transitional layer I (TL I), transitional layer II (TL II) and marine terrace deposits from top to bottom. This study tries to estimate the physical properties using the MS measurement and grains size analysis and consider the formative processes, provenance and weathering properties using geochemical analysis. The LPS in the section indicates very similar geochemical compositions to each other and the Chinese Loess Plateau (CLP), and different from the bedrocks around the section. However, the elements sensitive to weathering processes indicates large differences to the CLP. These means that the LPS has originated from the CLP and/or its source areas and experienced intensive weathering process under the climatic environments in the Korea after the depositions. These weathering properties can be found in the Korean loess reported as well as the sequence and slight spatial differences in weathering intensities within the Korea are also found. The differences of elemental compositions among the samples in the TL I and TL II are larger than those in the LPS and their elemental compositions are different from the LPS and the degree of differences are greater in the TL II than in the TL I. The TL II has the similar compositions to the bedrocks around the section. Therefore it can be suggested that the TL II consists of mainly the weathering products of bedrocks with small inputs from the materials of sequence. On the other hands, the TL I indicates the similarities to the sequence rather than the TL II and thus it contains a great deal of the materials of sequence with small inputs from the weathering products of the bedrocks.

### **Eolian denudation in the baikal region under conditions of climate aridity**

TIUMENTCEVA E.

*East-Siberian State Academy of Education, IRKUTSK, RUSSIAN FEDERATION*

Eoliation is shown on considerable spaces of the Baikal region. Their development is promoted by dryness of climate, high speeds of wind, an insignificant snow cover, a repasture, considerable recreational loading, etc. The process study was carried out using modern methodic on the expedition stations. The main peculiarities of the modern relief and the role of eoliation were found out. At the western coast of Baikal processes are most intensive in the mouth parts of valleys of the rivers of Sarma, Goloustnaya, etc. The physiognomical shape of landscape testifies the leading part of deflation in formation of modern relief. The maximum size of deflation reaches 2-4 cm on a surface of abrupt slopes and on tops of manes on flood plains. At east coast it is observed twisting sandy thicknesses and formation moving eolian forms mainly in a coastal strip.

Environmental conditions against high seismic activity of region define intensity and features of development modern exogenous processes.

During the dry periods the arid condition of geosystems is observed. In system exogenous formation of relief the component dominates eolian environment. The higher levels of superficial sediments are exposed to deep eolian processing, the rock debris increases, on a surface of slopes a pavement of detrital material is formed, ventifacts are marked. The slopes are polished by winds. All circles of a relief become an arena of eolian substance migrations. The eolian material is redistributed between winded and leeward slopes of Baikal regions ridges.

Eoliation manifested itself in high sensitivity and fast response on climate change. The strengthening tendency of eolian processes in Prebaikalia in the last years resulted from increase of dry climate and rising of the role of meridional circulation. The area of eolian formation is expanded on the background of natural forest-steppe where mountain-steppe soils communities with a spare vegetative cover are formed.

\*\*\*\*\*

### **Provenance analysis of aeolian sediments in the wide valleys of Middle Reaches of Yarlung Zangbo River in Tibet, China**

ZHENG Y.(1), WU Y.(2), LI S.(3)

*(1) College of real estate, Beijing Normal University, Zhuhai, 519087 P. R. China., ZHUHAI CITY, GUANGDONG PROVINCE, CHINA ; (2) MOE Engineering Center of Desertification and Blown-sand Control at Beijing Normal University, Beijing 100875, P. R. China, BEIJING, CHINA ; (3) College of Geography and Environment Science, Northwest Normal University, Lanzhou 730070, P. R. China, LANZHOU, CHINA*

The Cha'er Section is located in the northern bank terrace (about 30m average height above the river level) of Yarlung Zangbo River at a 3856m altitude, 5km west away from the township government of Cha'er, Namling, Shigatse, Tibet, China. This section is 3.68m thick, and sediments of interbedded aeolian sands and paleosols. The characteristics of grain diameters and heavy minerals of aeolian sands in the Cha'er Section and surface deposits around the section are contrastively analyzed. The results suggest that, the aeolian sediments of the Cha'er Section is mainly composed by medium sand and fine sand, whose mean grain diameter and grain composition are very similar with those of mobile dunes around the section, the mountain front diluvium, and the river alluvium at the marginal bank and second terrace of the Yarlung Zangbo River wide valleys. The heavy mineral contents of aeolian sediments in the section are between 2% and 2.5%, mainly composed by unstable minerals, such as augite, hornblende and epidote. The contents and major constituent of heavy minerals are similar with those of local river alluvium, diluvium and bedrock weathering substance, but the characteristics of relative content of heavy minerals and composition of minerals in the aeolian sediments in this section mainly inherit the heavy mineral characteristics of river alluvium at the marginal bank and terrace. Therefore, most of the aeolian sediments in the wide valleys of Middle Reaches of Yarlung Zangbo River are proximal deposition, whose sources are probably local surface deposits, consisting mainly of river alluvium of Yarlung Zangbo River.

Keywords: provenance analysis; aeolian sediment; Yarlung Zangbo River; Tibet;

Acknowledgements: This work was supported by the National Natural Science Foundation of China (41071129) and National Basic Research Program of China (2013CB956001).

### Using a 3D laser scanner to monitor the wind erosion in wind tunnel test

YAN P., ZHENG S., GUO J., LI X.

State Key Laboratory of Earth Surface Processes and Resource Ecology, Beijing Normal University, BEIJING, CHINA

Wind erosion is one of most serious environmental problems in the arid, semi-arid and dry sub-humid areas around the world. Accurate measurement of wind erosion rates is essential and urgent. The complexity, randomness, and boundlessness of the wind erosion process make it difficult to measure wind erosion rates precisely. Current methods including field observation, wind tunnel tests, and wind erosion models have numerous limitations in their practicability, cost, and accuracy. Hence the 3D laser scanning technique was used to measure the wind erosion in the wind tunnel. Three incased soil samples (soil box) with original structure were collected in the steppe of Inner Mongolia, and blown by six wind velocities (10、15、17、20、25、30 m/s) to simulate wind erosion in the wind tunnel. The soil surfaces after each test were scanned by a Trimble 3D Laser Scanner to create DEM by ARCGIS. Then the wind erosion rate, micro-morphology and surface roughness of soil samples can be quantified.

Comparing with weight method for wind erosion measurement, which is strenuous for transit in the lab and impractical in the field, the scanning test of three samples can reach an overall error value of wind erosion rate between -1.59—10.23%, averaging 6.28%. That means the wind erosion rate may overestimate about 6% by scanning, likely to be attributed to the scanner's precision, shelter from the laser and image treatment. Image analysis indicates that as the wind erosion strengthens, the micro-morphology of soil surface has changed from smooth plain, to smallstripes, grooves and finally to blowouts. And the roughness has varied mildly as wind velocity less than 20 m/s, and increased sharply by 4 times of the origin after the velocity exceeds 20 m/s. The preliminary results of this test show that the 3D laser scanning technique is valuable for its convenience, high efficiency and accuracy to measure the wind erosion rate directly and non-contacted, especially in the field's observation.

\*\*\*\*\*

### Exceptional preservation of Pleistocene aeolian forms in an outwash plain. Central Ebro Basin (NE Spain)

LUZÓN A.(1), RODRÍGUEZ-LÓPEZ J.P.(2), PÉREZ A.(1), SORIANO M.A.(1), GIL H.(1), POCOVÍ A.(1)

(1) Universidad de Zaragoza, ZARAGOZA, SPAIN ; (2) Universidad Complutense de Madrid, MADRID, SPAIN

Although proglacial Pleistocene aeolian sands in Europe are mostly located between 50°-54°N and their southern boundaries roughly coincide with the Pleistocene maximum ice sheet, during this epoch an aeolian dunefield developed and exceptionally preserved in the central Ebro Basin (41.50°N) in Spain. It was located in the distal part of the outwash system constructed by water flows coming from ice caps in surrounding areas, mainly the Pyrenees. Periods of ice fusion favoured high-energy meltwater flows organized in a braided fluvial pattern and dominated by tractive processes. Among fluvial deposits longitudinal gravel-bars and channels prevailed that evidence high volumes of both water and sediment discharges. During more intense glaciation of highlands, river discharges reduced and wide extensions in the outwash plain became exposed. These areas were subjected to aeolian processes with subsequent development of landforms and different sedimentary structures. Windblown deposits are integrated by fine-grained very well-sorted sands with a dominant saltation population. The main features of the aeolian deposits indicate the presence of sandsheets, transverse dunes, complex dunes and loess. During periods of sub-saturated winds deflation lags with ventifacts generated. Meltwater flows led to aeolian forms destruction with generation of hyperconcentrated flow deposits. The distal outwash plain spread over a thick Tertiary evaporite series and synsedimentary karstification prevented aeolian deposits from erosion favouring their exceptional preservation under such high-energy water flows dominated environment.

### **The Effect of Wind Barriers on the Airflow Field in A Wind Tunnel**

ZOU X., WU X., ZHANG C., WANG R., ZHAO J.

*State Key Laboratory of Earth Surface Processes and Resource Ecology, Beijing Normal University, BEIJING, CHINA*

Porous wind barriers are widely used and proven more efficient than solid barriers. In this study, the shelter quality of wind barriers of different porosity, row space and row number was compared based on wind-tunnel measurements. The 14 cm-high scaled models of wind barriers were placed perpendicularly to the wind direction in the wind tunnel, and rough elements were placed upwind of the models to obtain a reasonable self-simulation zone and Reynolds number. The results show that the airflow field changes little in the area above one-row wind barriers. In the area below the models, the airflow field is rearranged into four energy regions. The best shelter effect achieved downwind is always obtained using a 0.35-porosity wind barrier, so we suggest the optimal porosity of 0.3-0.4 for wind barriers in sand-control engineering. The shelter effect comparison of two-row 0.35-porosity wind barriers indicates that 6 H is the optimum row space. Two-row and three-row wind barriers obviously provide better shelter than one-row barriers. Therefore, we suggest 5-7 H as the optimal row spacing for multi-row wind barriers. Our results indicated good agreement with previous studies regarding porosity, row number and row space, with some exceptions about wind barrier design regarding porosity.

\*\*\*\*\*

### **Active sand seas are a major source of desert loess**

CROUVI O.(1), AMIT R.(1), ENZEL Y.(2), GILLESPIE A.(3)

*(1) Geological Survey of Israel, JERUSALEM, ISRAEL ; (2) The Hebrew University of Jerusalem, JERUSALEM, ISRAEL ; (3) University of Washington, SEATTLE, UNITED STATES*

Loess is a widespread eolian deposit dominated by coarse silt-sized quartz particles, which serves as an important archive of information on Quaternary climate change. Despite the intensive research during the past century on desert loess formation, its origin remains poorly understood and is still a fundamental problem in sedimentology and in Quaternary paleoclimatology. The ongoing debates are focused on the sources of the loess and on the production of coarse silt quartz grains. Although laboratory experiments indicate the potential of dunes with their abundant quartz sand grains as a primary source for generating coarse silt grains, this concept has been generally rejected as field-based evidence for abrading from sand grains (eolian abrasion) is rare. Here we adopted a global view to examine desert loess sources and to suggest possible processes for the formation of coarse silt grains in loess. We examined in detail several well-known late Pleistocene loess regions in different subtropical deserts (North Africa, The Sahel, Middle East and Arabia) and found that all these loess regions are located downwind of adjacent sand seas. Together with evidence of mineralogical similarity between the loess and the sand dunes and their contemporaneous activities, these observations suggest that sand seas are an important source for desert loess. Since there is only limited silt grains storage in sand dunes, we postulate that the silt grains comprising most of the loess are not reworked from the dunes but are generated probably through active eolian abrasion of the medium sand grains under past climates characterized by intensified winds. As a result, the role of sand dunes and eolian abrasion in formation of desert loess can be more important than previously thought.

**Field evidence for the upwind velocity shift at the crest of low dunes**

CLAUDIN P.(1), WIGGS G.(2), ANDREOTTI B.(3)

(1) CNRS - ESPCI, PARIS, FRANCE ; (2) School of Geography and the Environment - Oxford Univ., OXFORD, UNITED KINGDOM ; (3) Univ. Paris Diderot, ESPCI, PARIS, FRANCE

Wind topographically forced by hills and sand dunes accelerates on the upwind (stoss) slopes and reduces on the downwind (lee) sides. This secondary wind regime, however, possesses a subtle effect, reported here for the first time from field measurements of near-surface wind velocity over a low dune: the wind velocity close to the surface reaches its maximum upwind of the crest. Our field-measured data show that this upwind phase shift of velocity with respect to topography is found to be in quantitative agreement with the prediction of hydrodynamical linear analysis for turbulent flows with first order closures. This effect, together with sand transport spatial relaxation, is at the origin of the dune instability mechanism.

\*\*\*\*\*

**Understanding the causes of increased sand influx at the Begrawiya (Meroe) pyramids archaeological site, Sudan: initial findings to support the implementation of a mitigation programme**

MUNRO R.

Dept Earth & Environmental Sciences, Leuven University, Belgium, NORTH BERWICK, UNITED KINGDOM

In Pharaonic and Mediaeval North Sudan / Nubia infrastructure burial, mostly by aeolian sand deflated from the Nile, was a severe problem and often uncontrollable. Today, drifting sand sources at the same sites are largely from the Sahara and Nubian deserts; deflation of sands from wadis and bedrock augment this supply. Since the 1970s a drastic increase in accumulation of aeolian sand has been observed at the Royal Pyramids of Meroe at Begrawiya, Sudan [Hinkel, 2004: *Sudan & Nubia*, 4]. Today, dunes now partly cover the site, resulting in inability of access to the monuments, while sand blasting damages stonework. Our regional reconnaissance [Munro et al, 2012: *Sudan & Nubia*, 16] has drawn on Hussien Abuzeid's work: over 885 days (2005-07) he measured sand drift in N Sudan to provide an accurate view of drift rates. Most sands drift from the north, but during the *khareef* SW monsoon winds reverse and sand is from south: irrigation planners use these data to design canal alignments and establishment of structured windbreaks. At Begrawiya, working with the NCAM we are utilising this knowledge too in a feasibility study that is assessing the sand drift problem and preparing a mitigation plan that will aim to reduce future sand influx and also clear the site of existing sands by deflation, or manual methods. Work includes an assessment of the dynamics of winds and sand deposition in the area; examination of historical ground and aerial photography to gauge change; assessment of land use and climate change scenarios as a cause of the sand movement into the site; processing of satellite imagery to observe regional and local trends in sand movement; preparing specifications and costs for the design and implementation of an irrigated shelterbelt that could entrap sand upwind of the site; establishing criteria for monitoring and evaluation indicators; and disseminating the experience gained for application at other sites in Sudan affected by sand incursions.

## **The Study of Relationship between Moving of the Farming-pastoral Boundary and Preaching of Catholic Church in Kalgan, Northern China**

ZHANG X., SUN T., XU J.

*Institute of Chinese Historical Geography, Fudan University, SHANGHAI, CHINA*

The area along the Great Wall is the transition belt between subhumid region and arid / semiarid region, and was the boundary between agriculture area and nomadic area in northern China since Qin Dynasty (221-206 BC) . Although the political forces in the central area and nomadic area might have influence on the location of the farming-pastoral boundary, this boundary basically was fixed on the Great Wall belt for over 2000 years. However, as soon as the farming land crossed the Great Wall since late Qing Dynasty(1840), the boundary between farming and animal husbandry was pushed northward and westward about 3-6 miles a year in Mongolia Plateau substantially.

Based on the data from local archives, Christian materials and investigation, the research aims to study the mission and social works of Catholic Church, from Lazarist to Congregation Immaculate Cordis Mariae(CICM), in Kalgan Area, beyond the Great Wall since 1840, especially on the influence of the land reclamation in the region. In the case study, the authors found that Catholic Church had become an important force in the pushing of the farming-pastoral boundary northward and westward in late Qing Dynasty after they took the strategy of preaching the Han Chinese rather than the Mongols in Kalgan region. In the process, Catholic Church achieved success in their missionary work in Inner Mongolia by immigrating the Catholics and establishing Catholic villages there. As more and more Han Chinese Catholics entered Inner Mongolia, the former grassland began to change to farm land. At the same time, the organizational form and social policy of CICM was suitable for the natural and social condition of Inner Mongolia. In view of this, the study has a significant scientific value as to discover the law of environmental evolution in arid/semi-arid region. Meanwhile, it could analyze how the natural ecological pattern and environmental evolution influence the local political form, economic structure, and cultural pattern.

\*\*\*\*\*

## **Aeolian activity in DingJie area(southern Tibet, China)during Holocene**

PAN M.(1), WU Y.(2), ZHENG Y.(3)

*(1) Northwest Normal University, LANZHOU, CHINA ; (2) Beijing Normal University, BEIJING, CHINA ; (3) Institute of Geographic Sciences and Natural Resources Research, BEIJING, CHINA*

In Dingjie area (southern Tibet) where the aeolian deposition is concentrated, the author selected XL, JJ and TG profile of paleo-aeolian deposition in Holocene and established chronological sequence of each section by the means of OSL, AMS <sup>14</sup>C and <sup>14</sup>C dating. With the main method of grain size, referring to the methods of magnetic susceptibility, organic matter contents and chroma characteristics, the paper rebuilt the process of aeolian activities in Holocene in Dingjie. The results of deposition record of paleo-aeolian show the development of aeolian geomorphy experiences multiple strong to weak and to strong shifts of aeolian activities and soil fixing with the alternations of cool-dry and warm-humid climate in Dingjie since Holocene. 12.8 kaB.P. to present, the climate has fluctuated frequently and experienced following 5 processes: being warm-humid with weak wind and less sandy paleosol developing during 12.8~11.6 ka B.P. and 6.6~4.9 ka B.P.;in the period of 11.6~9.3 ka B.P. and 2.4~0.2 ka B.P., the sandlot expanded with cool-dry climate and strong wind and aeolian activities, and the moving dunes were developing; Being cool-dry relative to warm-humid back ground with strong aeolian activities and fixed and semi-fixed dunes during 9.3~6.6 ka B.P. and 4.9~2.4ka B.P.. Compared with the records of ice-core, lacustrine deposits and tree rings, the time of origin of Holocene events recorded by paleo-aeolian deposition is corresponded with that is recorded by other methods as a whole but with little discrepancies.

**Keywords:**Holocene; aeolian activity; aeolian geomorphy; climate change; Dingjie area

\*This work was supported by the National Natural Science Foundation of China (41071129) and National Basic Research Program of China (2013CB956001).

### Recent development of coastal sand dunes, Parangtritis, Yogyakarta, Indonesia

SRIJONO S., HENDRATNO A., HUSEIN S., FRESKY Y.  
Department of Geological Engineering, UGM, YOGYAKARTA, INDONESIA

Parangtritis Beach is located 30 km south of Yogyakarta, Central Java, Indonesia. Facing to the Indian Ocean, this beach is considered to be unique due to the presence of coastal sand dunes, a rare geomorphic phenomenon in the equatorial Southeast Asia, hence became the main reason to develop the area into a major tourist destination. This study attempts to investigate the recent development of Parangtritis sand dunes under the influence of tourism.

This research involves multi-temporal aerial photos analysis. Field mapping was conducted to identify the existing land use and to collect surface sand samples, whilst auger hand-drilling was completed to collect sub-surface sand samples and to identify soil horizons. Laboratory analysis was performed to study sedimentological aspect of sand samples, i.e. mineralogical composition and granulometry.

The sand dune complex of Parangtritis is composed of longitudinal, barchans, and transversal. Sand mostly composed of andesitic transported from the active Merapi Volcano, 55 km to north from the beach. Dune-forming wind is the southeast trades from Indian Ocean. Granulometric analysis suggests that those dunes were built by fine sands (23.3 – 68.4 %) and medium sands (22.6 – 72.9 %) with good sortation.

Area coverage of the sand dunes complex at 1960 was approximately of 4.5 km<sup>2</sup>, but it shrinks to just about 1 km<sup>2</sup> at present-day, suggesting a 80% decreasing rate for 50 years. For the last 5 years, barchan dunes were poorly developed, due to growth of tourism area and extension of agricultural area. Sand supply from Merapi Volcano also significantly reduced due to lahar-controlling dams in upstream of Opak River that effectively cut the sediment transport to the lowland. A serious method need to be implemented to preserve the sand dune complex of Parangtritis, considering the consequences of volcanic sediment supply reduction and expansion of tourism and agricultural areas.

\*\*\*\*\*

### Modeling aeolian coastal dunes mobility in Aquitaine, South Western France

GABARROU S.(1), LE COZANNET G.(2), PARTELI E.(3), PEDREROS R.(1), OLIVEROS C.(1), BRIVOIS O.(1), MULLER H.(1), GUEBER E.(1), MALLET C.(1)  
(1) BRGM, ORLEANS, FRANCE ; (2) BRGM / Univ Paris 1 / LGP, ORLEANS, FRANCE ; (3) Universidade Federal do Ceará, Departamento de Física, FORTALEZA, BRAZIL

The aquitaine coast (South western France) comprises a 230 km coastline of sandy beaches and dunes. Since 1979, most of the coastal dunes of Aquitaine are softly managed by maintaining their vegetation. When wind erosion landforms appear, they are stabilized by bringing vegetation debris and wind obstacles. One question is to understand if dunes management could become softer without strong consequences for assets located behind the dunes. In absence of vegetation, such as in the Pyla dune, ongoing dune mobility is expected to affect a road and a tourism facility in the future. Finally, changing wind patterns potentially due to climate change or variability may affect Aeolian sand transport. These questions motivated a modelling study of coastal dunes mobility based on examples in Aquitaine.

In this study we used an aeolian dunes model previously validated in deserts, in order to evaluate its potential for representing dunes movements. The results show poor capabilities to represent the competition between vegetation growth and winds in the case of vegetated dunes. In the case of Dune du Pyla, while the profile of the dune is not modelled satisfactorily, the modelled dune velocity (3m/year) are in good agreements with an analysis of maps (between 2 and 4 m/year from 1964 to 1994). We used a statistical model that generates longer wind time series in order to estimate uncertainties and longer term dunes mobility due to changing wind patterns. Model uncertainties are lower than the variability due to observations, highlighting the fact that strong winds transport is underestimated in the model. According to the model, an intensification of winds by 15% would lead to increase dune velocity of 9%. More frequent storms would lead to averaged mobility rates of up to 4m/year. Although these modelling results must be considered carefully, the approach of combining a stochastic model for winds with a physical dune model provides some insight to their future evolution.

### **Dust Observations for Models (DO4Models): Project Overview**

WIGGS G.(1), WASHINGTON R.(1), KING J.(1), THOMAS D.(1), WOODWARD S.(1), ECKARDT F.(2), HAUSTEIN K.(1), BRYANT R.(3), NIELD J.(4), VICKERY K.(2), MURRAY J.(5), BRINDLEY H.(5), JONES R.(6)  
(1) University of Oxford, OXFORD, UNITED KINGDOM ; (2) University of Cape Town, CAPE TOWN, SOUTH AFRICA ; (3) University of Sheffield, SHEFFIELD, UNITED KINGDOM ; (4) University of Southampton, SOUTHAMPTON, UNITED KINGDOM ; (5) Imperial College, LONDON, UNITED KINGDOM ; (6) UK Meteorological Office, EXETER, UNITED KINGDOM

Climate and weather prediction hinge on numerical models. Most of the climate models included in the Coupled Model Intercomparison Project 5 (CMIP5) and which will underpin the Intergovernmental Panel for Climate Change 5th Assessment Report (IPCC AR5) include a dust module because dust is known to play an important role in the Earth system. However dust emission schemes in climate models are relatively simple and are tuned to represent observed background aerosol concentrations most of which are many thousands of kilometres from source regions. The physics of dust emission in the models was developed from idealised experiments such as those conducted in wind tunnels decades ago. Improvement of current model dust emission schemes has been difficult to achieve because of the paucity of observations from key dust sources. Dust Observations for Models (DO4Models) is a project designed to gather data from source regions at a scale appropriate to climate model grid box resolution. The UK NERC funded project, led by the University of Oxford, aims to: 1) Generate a data set at an appropriate scale for climate models which characterises surface erodibility and erosivity in dust source areas from remote sensing and fieldwork 2) Quantify how observed erodibility and erosivity influence observed emissions at the climate model scale 3) Test, develop and optimise the dust emission scheme for the Met Office regional model (HadGEM3-RA) using this unique dust source area data set 4) Quantify which component(s) of observed erodibility and erosivity, and at what spatial scale, make the largest improvement to physically-based, observationally optimised dust emission simulations in climate models. This paper provides a project overview and some early observational and modelling results from the 2011/2012 field seasons.

\*\*\*\*\*

### **More than 5000 years of interaction between aeolian, fluvial and anthropogenic systems in the central Egyptian Nile valley**

VERSTRAETEN G., MOHAMED I., NOTEBAERT B.  
KU Leuven, LEUVEN, BELGIUM

Interactions between aeolian processes and the Nile fluvial system have been illustrated for the late Pleistocene at many sites along the River Nile, but for the Holocene period almost no data is available on this interaction. In this study we reconstruct the interaction between the South-Rayan Dune Field (SRDF) and the Nile valley in central Egypt for the last 5000 years by applying a field-based geomorphic approach, combining geophysics, sediment coring, quarry stratigraphy, geochemistry and radiocarbon dating. Three main units/periods could be distinguished: the Pleistocene Nile braidplain, the aggrading Holocene Nile silts, and the Late Holocene desertification, with dune expansion from the Western Desert into the Nile floodplain. The latter is indicated by an intercalation of flood deposits and dune sediments, with increasing thickness of Nile silt layers at greater depths. The transition from the second to the third unit most probably corresponds to the drying period characteristic for the Nile River Basin and the Sahara since the Mid-Holocene. Several cultivation layers, the oldest dating from the onset of the Old Kingdom, could be detected illustrating the presence of humans in a fluvial landscape that becomes influenced by aeolian processes. Through time the Nile floods were more and more blocked by invading dunes, although the sand flux into the Nile valley was insufficient to block the Nile itself. It is, however, suggested that invading sand dunes shifted the Bahr-Youssef channel further east. At present, the major process shaping the interaction area is of anthropogenic origin. Field observations and satellite images from 1963, 1984 and 2003 showed that dunes are being removed at high rates by quarrying activities, leveling, irrigation and the establishment of agriculture. As such, these sediment archives providing valuable information on the Holocene fluvial-aeolian interactions are being obliterated.

**Process and causes of neo-exoreism in Sahel: 'Koris' study case in the area of Niamey (Niger)**

MAMADOU I.(1), GAUTIER E.(2), BOUZOU-MOUSSA I.(3), DESCROIX L.(4)

(1) Dept of Geography University of Zinder, ZINDER, NIGER ; (2) Dept Geography University Paris 8 - Laboratoire de Géographie Physique (LGP) / CNRS UMR 8591, Meudon, PARIS, FRANCE ; (3) Dept of Geography University of Niamey, NIAMEY, NIGER ; (4) IRD - LTHE, GRENOBLE, FRANCE

This paper focuses on rapid endoreism bursting in the area of Niamey within the context of changing environmental conditions in order to evaluate the impact of anthropogenic factors and West Africa drought. Since the late 1980's numerous new "koris" (wadi) have developed in the area of Niamey; some of them were created during a single event of summer storm. Rapid runoff caused by intense rainfall has connected together former seasonal or perennial pounds and the new created channels have evolved downstream and upstream during the following humid seasons. The main origin of the neo-exoreism process is the rapid land-use change that causes a pronounced increase in runoff and soil degradation. The long drought acting since 1968 in West Africa (in spite of a recent rainfall increase) also participates to the desertification process. The paper first presents the evolution of land-use for the last 40 years in two basins that are representative of the significant increase in crops and disappearance of natural bushes in the whole Sahel. The two study cases clearly show the strong correlation between extension of bare surfaces, soil crusting and runoff coefficients. Secondly, the study analyses in details the koris functioning: hydrological processes, sediment transfers and morphological changes. It emphasises the part played by the koris (mainly by bank retreat) on the sediment supplied in the Niger River. Huge alluvial fans deposited by the koris at the Niger River junction trigger fluvial dynamics and human activities (water resources, navigation...). Finally, the study proposes a typology based on pattern evolution and dynamics of the koris.

\*\*\*\*\*

**The structure and development of a star dune, Lala Lallia, Erg Chebbi, Morocco**

BRISTOW C.(1), DULLER G.(2)

(1) Birkbeck University of London, LONDON, UNITED KINGDOM ; (2) Aberystwyth University, ABERYSTWYTH, UNITED KINGDOM

Star dunes have a pyramidal form with radiating arms, and are the largest and most complex type of desert sand dunes (Lancaster 1989). They are reputed to be the largest sand dunes on Earth (Wasson & Hyde 1983) and are certainly the tallest type of sand dune, reaching 300m in the Badain Jaran Desert (Chen et al. 2004). Star dunes are relatively widespread amongst the world's major deserts with examples in the Northern Sahara, Namib Sand Sea, Gran Desierto, Gobi Desert & Rub al Khali; they have also been identified on Mars (Edgett & Blumberg 1994, Fenton et al 2003, Hayward et al. 2007). On Earth, star dunes are believed to comprise around 11% of all desert dunes (Pye & Tsoar 1990) and contain a greater volume of sand than any other dune type (Wasson & Hyde 1983). However, in spite of, or possibly because of, their large size there has been very little research into star dune morphodynamics, or their deposits.

Given the widespread distribution of star dunes today, often at the heart of the world's largest sand seas, their large volume, and association with sediment accumulation it is reasonable to expect that star dunes should be preserved within the rock record. However, ancient examples are exceptionally rare and we know of only two documented examples (Clemmensen 1987, George & Berry 1993) – it is not clear whether this paucity of ancient star dunes is real, or a reflection of the lack of sedimentary studies of star dunes, although the latter appears to be a strong possibility.

The visualisation of star dune stratigraphy using GPR in this paper provides the information required to develop a sedimentary model to address this conundrum. In addition, we provide the first chronology for star dunes by optical dating showing the rate at which they can form. We challenge the paradigm that star dunes are old and relatively static by demonstrating that a star dune has accumulated 65m in under 1000 years in a low wind energy environment.

### **Size distribution of barchan dunes with a cellular model**

KATSUKI A.

*Nihon University, FUNABASHI, JAPAN*

Sand dunes are found in many places such as deserts, the sea bottom and the surface of Mars. They are formed through interplay between sand and air flow or water flow. When a strong flow blows, sand grains are dislodged from the sand surface. The entrained sand grains collide with the ground and are sometimes deposited. This process takes place repeatedly, resulting in the formation of a dune. The profile of the wind flow is modified by dune topography. Most fascinated dune is barchan, which is crescent dune. We reproduced many barchans in numerical simulations and investigate the dynamics.

The motion of sand grains is realized by two processes: saltation and avalanche. Saltation is the transportation process of sand grains by flow. The saltation length  $L$  and the amount of transported sand  $q$  are modeled by the following rules,  $L = a + bh(x,y,t) - ch^2(x,y,t)$ , where  $h(x,y,t)$  is local height. In the avalanche process the sand grains slide down along the locally steepest slope until the slope relaxes to be (or be lower than) the angle of repose which is set to be  $34^\circ$ .

We reproduced a few hundred of barchans in numerical field by above model. Barchan releases sand from tips of two horns. The downwind barchan can capture the sand stream. Also, barchans sometimes collide each other. These direct and indirect interaction forms complex barchan fields. The size distribution of a few thousand of barchans is fitted by lognormal distribution well. The average size of barchans increase as the amount of supplied sand do. Next, when two barchan corridors collide, the size of barchan in the boundary between corridors has three type. Type (I) is not decoupling distribution, which shows superposition of each distribution. Type (II) is a distribution of uniform size. Through collision and inter-dune sand stream, the size of each barchan become uniform. Type (III) shows a enhanced distribution of the barchan's size.

\*\*\*\*\*

### **Non-linear differentiation in fluid thresholds for wind-induced sediment mobilisation in low-pressure, high-altitude mountain environments**

DE VET S., CAMMERAAT E.

*IBED-Earth Surface Science, Unviversity of Amsterdam, AMSTERDAM, NETHERLANDS*

In planetary research, atmospheric pressure has been a parameter in experimental simulation for decades. In spite of the well-developed cadre, only little attention has been given to the pressure gradients that exist in high-alpine region on Earth. Global climatic change causes upward migration of climate zones that will heighten hydrological stress and therefore the effects of aeolian erosion might increase. We therefore carried out experiments using a hypobaric (low-pressure) wind tunnel to measure sediment transport by rolling at the fluid threshold. In addition to a systematic variation in particle diameters we also varied the atmospheric pressure in a gradient from 1024-240 mbar to quantify the altitudinal variation in these aeolian thresholds. The used pressures correspond to altitudes of 0-10 km above sea level and make the observed thresholds applicable for ecosystems at sea level, the European Alps, Andes and Himalayas, up to the summit of Mt. Everest. We found that the upper range for rolling of dry sediments at the fluid threshold can be up to 56-125% higher in many of the world's high-alpine areas. However, these thresholds increased nonlinearly for different textures with decreasing pressure. Mobilisation is thus more selective by winnowing of e.g. sandy textures. Compared to a given state, dehydration of a high-altitude ecosystem can shift the force balance in sediment in favour of rolling and this will increase sand fluxes. As these thresholds differ with altitude, rates of aeolian erosion can be much higher in high-altitude environments than suggested by studies under ambient sea level conditions.

## **A Global Digital Database and Atlas of Quaternary Dune Fields and Sand Seas**

LANCASTER N.(1), HALFEN A.(2)

(1) *Desert Research Institute, RENO, UNITED STATES* ; (2) *University of Kansas, LAWRENCE, UNITED STATES*

Sand seas and dune fields are globally significant sedimentary deposits, which archive the effects of climate and sea level change on a variety of temporal and spatial scales. Dune systems provide a valuable source of information on past climate conditions, including evidence for periods of aridity and unique data on past wind regimes. Researchers have compiled vast quantities of geomorphic and chronological data from these dune systems for nearly half a century, however, these data remain disconnected, making comparisons of dune systems challenging at global and regional scales. The primary goal of this project is to develop a global digital database of chronologic information for periods of desert sand dune accumulation and stabilization, as well as, pertinent stratigraphic and geomorphic information. This database can then be used by scientists to 1) document the history of aeolian processes in arid regions with emphasis on dune systems in low and mid latitude deserts, 2) correlate periods of sand accumulation and stability with other terrestrial and marine paleoclimatic proxies and records, and 3) develop an improved understanding of the response of dune systems to climate change. The database currently resides in Microsoft Access format, which allows searching and filtering of data. The database includes 4 linked tables containing information on the site, chronological control (radiocarbon or luminescence), and the pertinent literature citations. Thus far the database contains information for 990 sites world wide, comprising 2780 luminescence and radiocarbon ages, though these numbers increase regularly as new data is added. The database is only available on request at this time, however, an online, GIS database is being developed and will be available in the near future.

\*\*\*\*\*

## **Initial investigations of the age and provenance of the dunes of Rooisand in the Great Escarpment region of western Namibia**

STONE A.(1), GARZANTI E.(2)

(1) *School of Geography and the Environment, University of Oxford, OXFORD , UNITED KINGDOM* ; (2) *Laboratorio di Petrografia del Sedimentario, Dipartimento di Scienze Geologiche e Geotecnologie, Università Milano-Bicocca, MILANO, ITALY*

In a topographic low point between the Hakos Mountains and the Gamsberg, where the Great Escarpment separates the Khomas Highland from the Namib Desert plain, there is a distinctive patch of red sand, covering about 10 km<sup>2</sup>. This appears to be of aeolian origin, however to the best of our knowledge almost nothing is currently known about the potential origin and depositional age of these sediments. This poster presents the results of a reconnaissance investigation using bulk-petrology and heavy mineral analysis and optically stimulated luminescence dating. Our hypothesis is that the sediment is derived from the Namib Sand Sea, and has been transported north-west during some point of the Quaternary. However, it is also possible that the material has been derived from the Kalahari to the east of the Escarpment, meaning the material has blown from the east of the site, or that the sediments represent the product of local-weathering. Whilst the petrology is likely to yield definitive results about sediment provenance (e.g. Garzanti et al., 2012) the challenge to establishing the timing of the initial deposition of these sediments is that luminescence ages record only the last phase of sedimentary deposition. It is arguably not only possible but also likely that these sediments have gone through a number of cycles of deposition, erosion and re-deposition by the wind and possible fluvial transport by the small tributaries of the Kuiseb River in this region. Establishing the source region will allow palaeoenvironmental inferences to be made about dominant wind directions and if these sediments prove to be from the Namib Sand Sea, perhaps the northernmost travelled preservation of Orange River delta material.

Garzanti, E., Andò, S., Giovanni, V., Lustrino, M., Boni, M., Vermeesch, P. (2012) Petrology of the Namib Sand Sea: Long-distance transport and compositional variability in the wind-displaced Orange Delta. *Earth Science Reviews* 112 (3-4), 173-189.

**Modelling the interaction between sand dunes and rivers, and the impact on geomorphology**

BAOJIL, COULTHARD T., MCLELLAND S.  
University of Hull, HULL, UNITED KINGDOM

Aeolian and fluvial systems are usually studied independently which leaves many questions unresolved in terms of how they interact. When sand dunes and rivers coincide with each other, the interaction of sediment transport fluxes between the two systems may lead to change in either or both systems therefore can significantly change surface morphology. An inventory is presented from 187 globally distributed study sites from locations where fluvial and aeolian systems interact with each other.

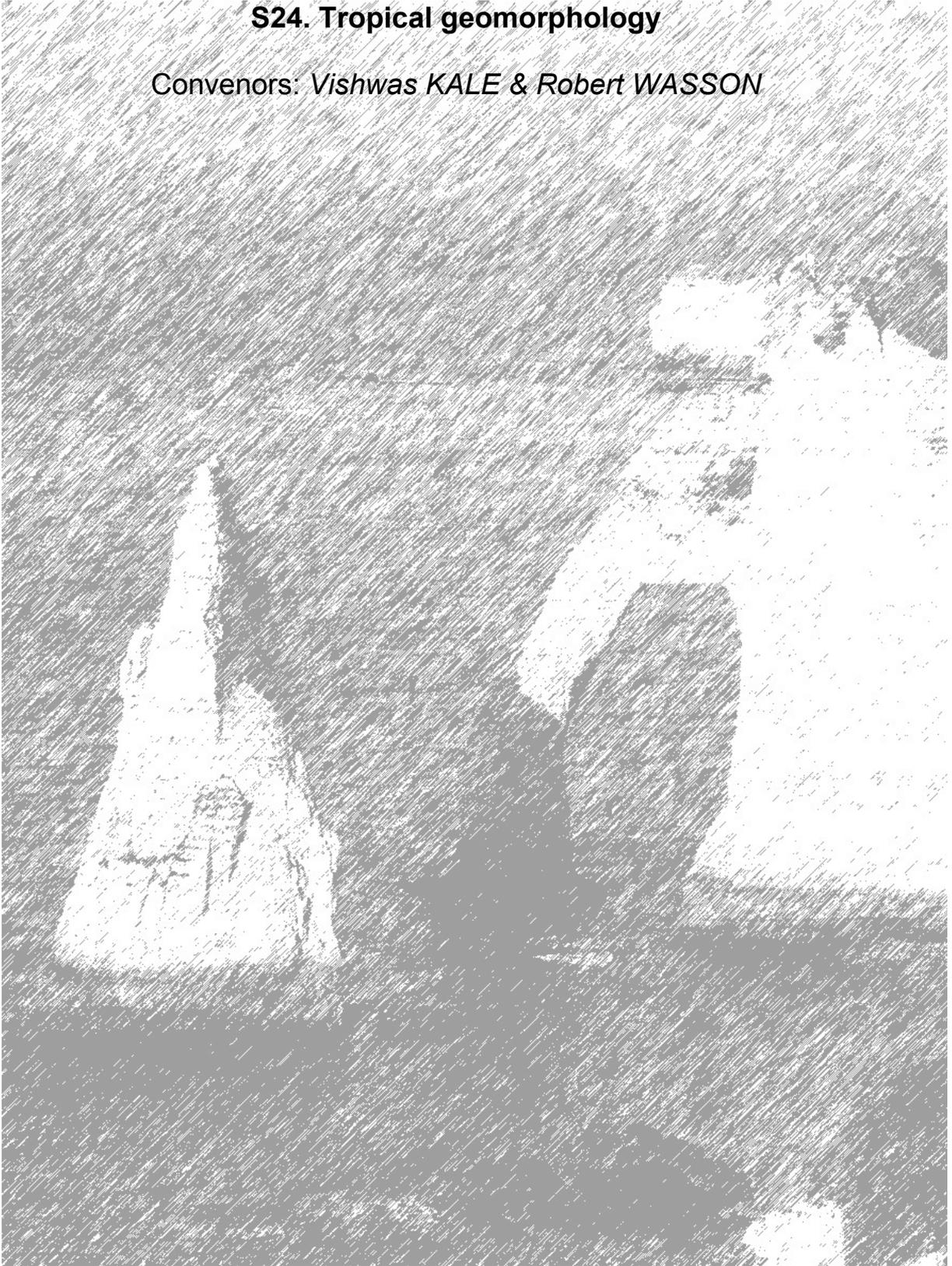
From this field survey, 6 different types of interaction are classified and the results have been analyzed to understand the most frequent modes of interaction. There are about 47% of all examples in which the rivers flow parallel to the wind direction and braided rivers are the dominant channel pattern (42%). Longitudinal dunes rather than transverse dunes are most frequently associated with these braided channel patterns, possibly due to transverse dunes being associated with low sediment availability and therefore the aeolian sediment flux is insufficient to change the river channel type. In contrast meandering rivers occur more frequently when sand sheets dominate the aeolian system. Overall, crescentic dunes are the most common dune type (55%) where fluvial and aeolian systems interact.

Based on this analyzes, a cellular aeolian/dune model and fluvial model are used to simulate interacting processes which presents different interacting behaviours. Different factors (wind/water speed, sediment supply) are examined to investigate the triggers that may switch the dominance between processes and the consequent changes in morphology that may occur.

\*\*\*\*\*

## **S24. Tropical geomorphology**

Convenors: *Vishwas KALE & Robert WASSON*





## **Oral presentations:**

### **Anabranching patterns in large rivers: state of the art and clues from the tropics**

LATRUBESSE E.

*The University of Texas at Austin, AUSTIN, UNITED STATES*

I proposed a new category of large rivers, including the nine largest rivers on Earth: mega-rivers, which are those with a  $Q_{\text{mean}}$  of more than  $\sim 17,000 \text{ m}^3/\text{s}$ . They are the Amazon, Congo, Orinoco, Yangtze, Madeira, Negro, Brahmaputra, Japura and Parana. As noted, six of the largest rivers of the world are located in South America (four of them in the Amazon basin). The understanding of why the largest rivers differ from smaller rivers and how this response is observed in the planform channel geometry is a critical topic in fluvial geomorphology. The decoupling of knowledge between large and smaller fluvial systems represents a central current scientific concern. Such big rivers are few in number but spectacular in size. Considering the importance of large rivers and river floodplains to a range of global-scale ecological issues, such as sediment flux, carbon sequestration, and water resources, this represents a significant problem for river management. Indeed, most of the runoff on Earth is transported by a few very large rivers, with  $\sim 16$  to 20% of the runoff discharge by the Amazon.

Over the past two decades, there has been a growing appreciation of the distinctiveness and importance of anabranching rivers and slowly the interest on large tropical rivers also have been increasing. When applying the concept of a channel pattern continuum I obtained a surprisingly result: the universal end member pattern for large alluvial rivers is anabranching. All the rivers in the world with mean annual discharge larger than  $17000 \text{ m}^3/\text{s}$  are not capable in maintaining a relatively pure "braided" or meandering pattern.

On the other hand the floodplain characteristics of large anabranching rivers are different than other smaller systems.

I discuss in this presentation the state of the art on anabranching channel characteristics and classifications as well as the morphological-morphodynamics processes that generate anabranching patterns in large rivers.

\*\*\*\*\*

### **Monsoonal rivers of Australia's "Top End" in the late Quaternary**

MAY J.H., NANSON G.C.

*School of Earth and Environmental Sciences, Uni Wollongong, WOLLONGONG, AUSTRALIA*

Due to their strategic position between significant atmospheric phenomena, subtropical and tropical river systems are considered unique and sensitive archives for the detection of past changes in global circulation patterns. In Australia, most data on the Mid- to Late Quaternary evolution of fluvial systems comes from the southeast of the continent as well as its dry interior. Even though here peaks in discharge and effective moisture do not appear to have occurred everywhere synchronously, much of the hydrological variations in Central Australia have generally been attributed to variations in monsoon strength and position. Given these issues, unravelling the impacts of past changes in monsoonal intensity on fluvial systems in Australia's tropical north - the 'Top End' - will substantially contribute to our understanding of causes and mechanisms of climate changes in Australia.

Our study will present first results from the major river systems draining the 'Top End' (Adelaide, Mary, and South Alligator Rivers). Upstream of bedrock constrictions and the effects of sea-level change, extensive but currently inactive floodplains have accreted along the middle reaches of the catchments. Virtually no data is so far available from these floodplains although their stratigraphic and sedimentary record should contain valuable information on the late Quaternary evolution of the fluvial system in northern Australia. Here, we (i) present first stratigraphical data for these floodplains, (ii) document their geomorphologic setting based on the analysis of elevation models and remote sensing data, and (iii) discuss the significance of these results in terms of the larger-scale paleoclimatic evolution in the seasonal tropics.

### **The Quaternary Mekong River terraces: sediments, climate and former river courses**

MESHKOVA L., CARLING P.

*University of Southampton, SOUTHAMPTON, UNITED KINGDOM*

Due to the environmental and economic significance of the Mekong River in South East Asia there is an increased attention to understand the modern fluvial processes. However the present river dynamics together with the future dynamics, in part, are conditioned by the longer-term climatic and tectonic contexts of the river. The knowledge of the Quaternary fluvial landforms of the Mekong in Cambodia are currently basic but have been advanced by investigations of the river terraces into which modern channel has incised. Three terrace levels can be recognised, separated in the vertical, lateral and temporal dimensions with distinctive sedimentary signatures. The terraces are composed of sand and gravel beds, lying above weathered bedrock or clay deposits with frequently observed laterites developed in the uppermost parts of the terrace sections. The highest (notionally at 100+ masl) is deeply dissected into bedrock with a veneer of sand and gravel dated as ~700Ka. The river then incised to form a strath terrace before aggrading to produce a distinctive level between 60 and 40masl (40+masl terrace). A further terrace is locally developed at 20+masl and floods during exceptional flood events. Petrified wood is locally abundant in the terrace gravels and has been used as a tracer to examine prior hypotheses concerning palaeo-courses of the river. Satellite images and DEMs have been used in a GIS framework to map the terraces and delineate main course palaeochannels. Mapping the various outcrops of Quaternary river alluvium within the Lower Mekong Basin, notably in Thailand, have extended our knowledge of Mekong terrace development through the basin and together with the tectonic history allow suggestions as to the development of the Mekong in the region during the Quaternary. Altogether these observations comprise a picture of regional pattern of fluvial development in the region due to the combination of climate cycles and neotectonic movements.

\*\*\*\*\*

### **Quaternary Evolution of the Pearl River Delta, China, Inferred from Terraces and Boreholes**

YU Z., ZHANG K.

*Sun Yat-sen University, GUANGZHOU, CHINA*

The Pearl River Delta, one of the largest deltas in China, is located at north margin of the South China Sea. The evolution of the delta is subject to both sea level changes and local neotectonic movement. Previous research indicates that the delta has 6 formations representing 2 marine transgression cycles. Although there has been consensus on the age of the 2nd cycle, which resulted from a postglacial sea level rise, the age of the 1st cycle is greatly debated. Based on <sup>14</sup>C and TL dating (40-50 ka BP), the 1st cycle was regarded as deposits during MIS3. But the sea level of MIS3 was about 50m lower than present, and the altitudes of the marine deposits of the 1st cycle, i.e. -25m~-10m, in the delta do not match with the sea level of MIS3. The radiocarbon range is limited to 40-50 ka and the samples may also be contaminated. Comparison of the terraces in the delta area and boreholes provides a new perspective to solve these problems. Based on detailed field investigation, environmental proxies, and dating of OSL and <sup>14</sup>C, the relationship between the sediment on the terraces and in the cores can be revealed: (1) The sedimentary sequences on the terraces are uplifting parts of the 1st cycle; (2) the 1st cycle deposits covered the period of MIS6(150ka OSL dating) and MIS5 without deposits of the time interval of MIS4-MIS2; (3) the layers on the terraces connected with 1st cycle indicate uplifting and tilting after MIS5. Furthermore, the comparison of the delta sedimentary sequence with that in continental shelf of Northern South China Sea illustrates besides 2 cycles in Pearl River Delta, there are more older cycles on the continental shelf. So the subsidence in the delta area is the result of northwestward extension of subsidence in the continental shelf, and only records the last 2 transgression cycles.

### **Sedimentary Records of Monsoon Variability from Historical Tanks in the rainshadow zone of the Western Ghat, Deccan Trap Region, India**

*KALE V.S.(1), MAGAR A.(1), BASAVIAIAH N.(2), RAJSHEKHAR C.(3)*

*(1) Department of Geography, University of Pune, PUNE 411 007, INDIA ; (2) Indian Institute of Geomagnetism, New Panvel, NAVI MUMBAI 410 021, INDIA ; (3) Geology and Palaeontology Group, Agharkar Research Institute, PUNE 411 004, INDIA*

The Deccan Trap Region covers an area of about half-a-million square km. In this youngest morphotectonic region of India, the reconstruction of the palaeo-monsoon history on different time scales is hampered by limited potential of traditional climate-proxy archives such as natural lakes, tree rings and speleothems. The fluvial records are limited in extent and, thus, not very helpful in the reconstruction of climate over the last few centuries. Lakes are generally considered as one of the most reliable natural archives of basin-wide precipitation and the catchment response. However, there are no natural lakes in the climate-sensitive rainshadow zone of the Western Ghat to perform a multi-proxy climate reconstruction. Developing a baseline of late-Holocene monsoon precipitation variability using a multi-proxy methodology is key to understanding monsoon variability of the present and the future. Therefore, about half-a-dozen historical tanks were identified and investigated. These tanks were constructed between the 16<sup>th</sup> and 20<sup>th</sup> century. The historical tanks under investigation receive runoff and sediments only from the local catchment. Consequently, any change in physical, chemical and mineral magnetic properties of the tank sediments directly reflects variations in the input from the catchment. Sediment samples were collected for textural, geochemical and magnetic susceptibility analyses as well as for chara studies. By and large, the sediments do not reveal significant vertical variations in sediment characteristics in terms of texture, magnetic susceptibility and Chemical Index of Alteration (CIA). The remarkable similarity denotes only subtle variations in the water budget and environmental conditions. The main conclusion of the study is that the rainshadow zone of the Western Ghat has not witnessed dramatic changes in the monsoon rainfall strength and intensity during the last two to four centuries.

\*\*\*\*\*

### **Holocene alluvial records of the northeast monsoon dominated rivers of south India**

*ACHYUTHAN H.*

*DEPARTMENT OF GEOLOGY, ANNA UNIVERSITY CHENNAI, CHENNAI, INDIA*

The sub-tropical area around the coastal Chennai, Tamil Nadu, is drained by three parallel to sub-parallel meandering rivers (Koratallaiyar, Cooum and the Palar) that debouch their sediments into the Bay of Bengal. These rivers bear signatures of past phases of aggradation and incisions. Detailed mapping and logging of the fluvial litho section stratigraphy supported by sediment texture and structure, <sup>14</sup>C and OSL dates have been used to infer the periods of aggradation and incision. The dated alluvial sequences show that a major periods of aggradation occurred in the early Holocene 9000 to 8400, mid Holocene period 6000-5000 yrs BP and late Holocene to recent periods (2000 and 1300 yrs BP, 800-600 yrs BP) and around 200 yrs back. The period in between these clusters implies fluvial erosion and channel incision events cutting down to the present river-bed in the recent years. The gap of radiocarbon and OSL dates (5000 to 2000 ka cal BP) approximately begins with the 4200 cal BP short-term event (onset of aridity) and ends with 2000 cal BP enhanced monsoon event due to the dominant NE rains. Older terraces north and north west of the Koratallaiyar are preserved due to tectonic uplift; protected by the Late Neogene- Early Pleistocene ferricrete profiles of the Upper Gondwana sandstone and shale and Early Holocene sea level rise. The younger ages of the southern flowing streams indicate that they have not preserved older terraces, eroding them due to subsidence and late Holocene meandering. These rivers have been alluvial plains under the strong driving force of the north-east monsoon and the alluvial surfaces show a good correlation with patterns of precipitation and discharge. Presently it is difficult to decouple the control of climate and tectonics.

### **Hydro-climatic trends of the Upper Ganga Plains how significant in water resources management**

ROY N.(1), SINHA R.(2)

(1) Presidency University, KOLKATA, INDIA ; (2) IIT Kanpur, KANPUR, INDIA

Hydro-climatic trends at basin scale are required for developing strategies related to planning, development and management of water resources in a river basin. In order to identify hydro-climatic trends of the Upper Ganga Plains (UGP) discharge and rainfall data along the major and minor rivers and from their associated catchment area were collected from Indian Government agencies. Trends at individual station were evaluated based on the Mann-Kendall non-parametric statistical test. For obtaining the basin wide trends of the parameters Belle and Hughes (1984) chi-square test method was adopted.

The analysis of rainfall and discharge time series from 1960 to 1997 shows decreasing trends (sometimes significant) of discharge along the major rivers, particularly during monsoon season (June - September), while minor rivers do not have any basin wide consistent trends. However, the minor rivers show significantly increasing trends during non-monsoon season (October - May). The decreasing trends of rainfall are significant and basin wide consistent throughout the year. The statistical homogeneity test showed that the climatic trends are regional whereas the hydrologic trends are more localized in nature lacking a distinct basin-wide significance.

The assessment of anthropogenic inputs showed that the population of Uttar Pradesh State (UGP) grew at a compound rate of about two percent per annum during the past four decades. The comparison of discharge diversion through side canal from the major river Ganga for irrigation and the comparison of the land-use changes in the Uttar Pradesh State (UGP) between 1930 and 1990 reveal noticeable trends which are found to be in favour of localized decrease of the discharge of the major rivers in UGP.

Key words: hydrological trends, climatic trends, trends homogeneity, anthropogenic impact

\*\*\*\*\*

### **An appraisal of geomorphic complexity of a large tropical river, Ganga River system, India**

JAIN V.(1), TANDON S.(2), SINHA R.(3)

(1) Department of Geology, Centre of Advanced Studies, University of Delhi, DELHI, INDIA ; (2) Shiv Nadar University, Greater Noida, GAUTAM BUDH NAGAR - 203207, INDIA ; (3) Indian institute of Technology Kanpur, KANPUR - 208016, INDIA

Understanding the complex geomorphic response of a large river dispersal system to external disturbances is a major geomorphic challenge, because multiple compartments (landforms) in a large river system are characterized by threshold driven differential sensitivity and equilibrium stages. Geomorphic records of the Ganga River system, a large tropical river that also supports dense population in its basin has been analysed to understand its response to external forcing. The landform scale geomorphic records have been integrated to analyse spatio-temporal variability of the large dispersal system. Different tributaries of the Ganga River basin are characterized by diverse geomorphic sensitivity due to which similar climatic events have generated contrasting landforms related with erosional or depositional processes. Further, different reaches in the large Ganga river system may not be connected at millennial time scale, as available data on sediment residence time in different landforms varies from 100 ka to 1000 ka. The disconnected nature will be responsible for dissimilar response by various compartments (landforms) of the dispersal system, as each component will respond independently to any climate change event. Further, the magnitude of sediment contribution from any particular hinterland area has also temporally changed in the Ganga River system, which adds extra complexity and unpredictable behaviour of river response. In terms of magnitude-frequency analysis, high magnitude floods are more significant for effective sediment transportation, which suggests dominant role of extreme events on the geomorphic system of this region. This analysis highlights significance of the threshold and the connectivity in controlling the nonlinear and complex behaviour of river response to any external disturbances. Quantification of threshold condition and connectivity index is a major challenge for better geomorphic understanding of the Ganga River system.

### Long term geomorphic landscape evolution and gold deposits in the Central African Republic (CAR, Bandas Greenstone Belt)

RUNGE J., EISENBERG J.

Goethe-Universitaet, FB 11: Institut fuer Physische Geographie, FRANKFURT, GERMANY

A new project funded by DFG (German research Foundation) is introduced. Focus is on long term landscape evolution in the *Bandas Greenstone Belt* north of Bambari in CAR. The site is a geologically old and resource-rich area. Main objective is to glean new findings and knowledge on the geomorphic landscape evolution of the planated multilevel relief complex. The denudational zone, originally located in a landlocked geographical position, was characterized by arid climate. Triggered by the Jurassic/Cretaceous break apart of Gondwana, weathering and denudational processes changed fundamentally. Nowadays the landscape is characterized by extended strongly mineralized, auriferous lateritic crusts. The composition of *in situ* formed crusts reflects the underlying rocks. Zoogenic sediments accumulated over the crusts give evidence of the composition of the saprolite. Geomorphological and pedological mapping and field trips are applied. Remotely sensed data and GIS support the interpretation and documentation. Exposure dating of iron crust levels is conducted by cosmogenic nuclides. Results will complement the relative dating approach of the geomorphological interpretation of landscape evolution by means of the surface schemata by absolute dating (minimum age) of different surface levels. Deduction of a "geological fingerprint" by lateritic crusts as well as by the characteristics of soil and saprolite leads to the development of a landscape "palaeo-environmental scheme". An applied result of this study on Gondwanian and Post-Gondwanian surfaces is an estimation of distribution and concentration of gold in the parent rock on the basis of lateritic crusts. A Canadian mining company has conducted extensive drillings for exploration during the last five years. Until 2015 six open pit mines shall be go up for gold exploitation. If the methodological approach and hypothesis are confirmed high gold exploration costs can be minimized in future.

\*\*\*\*\*

### Hydro-geomorphologic comparison of two Amazonian rivers: Napo river and Beni river

GARCIA-GOVEA C.(1), GAUTIER E.(2), BRUNSTEIN D.(3), LARAQUE A.(4), GUYOT J.L.(5), ROSALES-SIERRA V.(1)

(1) INSTITUTO MEXICANO DEL PETROLEO, MEXICO, D.F., MEXICO ; (2) Université paris 8/CNRS LGP, MEUDON, FRANCE ; (3) CNR LGP, MEUDON, FRANCE ; (4) IRD, TOULOUSE, FRANCE ; (5) IRD, PEROU, PERU

Nowadays, fluvial systems in tropical environment are still little known. This work proposes a hydro-geomorphologic analysis of two important tributaries of the Amazon river: Beni river and Napo river which are in different hydro-climatic and morpho-tectonic contexts. The objective is to compare the evolution of these two rivers by the distinction of morphological styles: Beni river is characterized by a style of meanders of fast migration while Napo river is characterized by an anabranching pattern with individual islands covered by vegetation and sand banks. We have traced the evolution of the two rivers in space and time (diachronic) from satellite images and in situ measurements using a Geographical Information System (GIS). With this diachronic analysis (annual and multi-annual) we have characterized the dynamics of the two rivers and we have established a link between water discharge and solid discharge. The results show the construction mechanism of alluvial plains and place Beni river and Napo river in the Amazonian context improving the understanding of it.

### Were tropical glacier fluctuations synchronous with mid-latitudes during the Holocene?

JOMELLI V.(1), FAVIER V.(2), KHODRI M.(3), BRAUCHER R.(4), BLARD P.H.(5), RINTERKNECHT V.(6), LEANNI L.(4), BOURLES D.(4), BRUNSTEIN D.(1), GRANCHER D.(1), FRANCOU B.(7)

(1) Université Paris 1 Pantheon-Sorbonne CNRS UMR 8591, MEUDON, FRANCE ; (2) OSUG UJF LGGE, GRENOBLE, FRANCE ; (3) IRD LOCEAN, PARIS, FRANCE ; (4) Université Aix-Marseille Cerege CNRS-IRD, AIX EN PROVENCE, FRANCE ; (5) Centre de Recherches Pétrographiques et Géochimiques (CRPG) UPR2300, NANCY, FRANCE ; (6) Université St Andrews, ST ANDREWS, UNITED KINGDOM ; (7) IRD, LA PAZ, BOLIVIA

Updated worldwide studies based on a large moraine record from glaciers selected in mid-latitude regions revealed different deglaciation patterns in the two hemispheres during the Holocene. In the Southern Hemisphere extra-tropical glaciers reached their maximum extent at the beginning of the Holocene and since then, have experienced a continuous retreat interrupted by minor advances. Northern Hemisphere extra-tropical glaciers underwent several large advances during the late Holocene in contrast with the overall trend in the Southern Hemisphere. As tropical regions reflect the interplay between the two hemispheres, it is not clear whether tropical glaciers fluctuated like those at extra-tropical latitudes and if so, which extra tropical pattern they followed. We explored the issue of tropical deglaciation chronology during the Holocene using the most complete preserved moraine sequences from different Andean tropical glaciers providing the missing link needed to compare interhemispheric history throughout the Americas. To allow a precise reconstruction of the palaeoglacier extents, we used <sup>10</sup>Be published chronologies of moraine landscapes. To better constrain glacier evolution during period without moraines we simulated glacial extents using a glaciological model forced by GCMs outputs for selected glaciers. Comparisons of the moraine dating with the ice core records, and the current knowledge about processes driving tropical glacier melting and climate made us possible to underline the hemispheric influences and the major climate controls on glacier evolution.

\*\*\*\*\*

### Poster presentations:

#### **Neo-tectonics in Central African river catchments evidenced by lineament analysis - Examples from Southern Cameroon**

EISENBERG J., RUNGE J.

Goethe University, FRANKFURT AM MAIN, GERMANY

Remote sensing and field work was carried out on south Cameroon fluvial systems to reconstruct their evolution since the opening of the South Atlantic 95 Ma ago (Eisenberg, 2012). In the framework of DFG (Deutsche Forschungsgemeinschaft – German Research Foundation) funded research geological lineaments were recorded at different scales by using DLM, SAR and Landsat data. Regional focus was set on the north-western swell of the Congo Craton. The main strike directions are representing the thrust fold of the pan-African Yaoundé series (Neoproterozoic) as well as the Archean Ntem faults (E-W) and the Palaeoproterozoic thrust fold of the Nyong series (NE-SW).

A repeated remobilisation of the faults is assumed which was triggered by the Cretaceous opening of the South Atlantic. Uplift which has increased since the Miocene due to the collision of Africa with Eurasia is also the reason for geomorphological modifications as incision or denudation on the one hand and extensional fractures at the rise of the Congo Craton on the other hand. Earth quakes along the pan-African South Cameroon Shear Zone (Kribi earth quake in 2002) and the Sanaga Shear Zone (Yaoundé, 2005) give evidence for a sub-recent to ongoing remobilisation. As a result of lineament analysis and field work mainly linear features striking in N-S, E-W and NE-SW directions were neo-tectonically remobilised.

Examples from the upper catchment areas of Nyong and Ntem Rivers are introducing the geomorphological forms of the region and its interpretation by means of neo-tectonic activity as well as climate modifications.

Eisenberg, J. (2012): Geomorphic evolution of the Nyong and Ntem River basins in Southern Cameroon considering neo-tectonic influences. – In: Runge, J. (ed.): Landscape Evolution, Neotectonics and Quaternary Environmental Change in Southern Cameroon. *Palaeoecology of Africa* 31: 31-136.

### **Soil transformation system and lake Mandacarú formation in the Três Cantos compartment area, at Maracaí, São Paulo, Brazil**

ALVES G., QUEIROZ NETO J.P.

*USP - Universidade de Sao Paulo, SAO PAULO, BRAZIL*

The Três Cantos compartment, defined by Alves (2010), located at Paranapanema River's medium haul shore, presents a series of closed depressions. These are situated at the extension of a basaltic plateau with sandy coating, which presents Oxysol of medium texture. The plateau is supported by a lateritic cover which overlays the basalts; outcrops of this cover appear on the inside and on the edges of Três Cantos compartment. At the edge of the lake a 26.6 m of length and 9% steepness trench was observed. Upstream, Oxysol with microaggregates and ferruginous concretions, which increase in depth until the laterite, occurs. It presents yellowish spots due to degradation, and some clay and manganese skins in the cracks. The yellowish spots increase downstream in soil and laterite, without modifying the structure, and the laterite becomes more friable. Hereafter, gray spots appear both on the ground and on the laterite, already severely degraded. Downstream the concentration of sand increases, especially in the upper horizons. Clay skins become common at the end of this yellower sector. Hereafter, a gray sector, where the laterite is completely degraded, shows bigger increase of clay as it deepens and upwelling groundwater at the base of the trench. Silty and olive yellow materials, with tonsils filled with quartz and fragments of olive brown color, were observed below the degraded laterite, indicating the presence of much altered basalt.

Observation of this pedological cover shows that in passing from Oxisol microaggregate to Ultisol clay elimination occurs in the surface horizons, residual sand accumulation is a consequence of this process, as well as gradual laterite disappearance as it deepens. This loss of material causes soil deformation originating the depression.

\*\*\*\*\*

### **Geomorphic processes in tropical environment: a study in pilões-pb city**

HENRIQUE F.M., FERNANDES E.

*Universidade Federal do Rio Grande do Norte, NATAL, BRAZIL*

In tropical landscapes, geomorphic processes acting on model originating different materials and shapes from other climates on Earth. Understanding the relationship between morphogenetic and pedogenic processes has provided the understanding of relief modeling in largely of wet tropics and sub-wet areas. Tied to erosion occurring on the surface, these processes cause a deeper weathering mantle causing deep soils and slopes with convex shapes. This research analyzes the relationship between pedogenic-morphogenetic processes and anthropic activities present in Pilões-PB city, Brejo region in Brazilian northeast through the morphopedological approach (TRICART; KILLIAN, 1982, CASTRO; SALOMÃO, 2000) by proposal-based toposequences (BOULET, 1993). Collected samples were subjected to treatments and mineralogical and physical-chemical analyses which enabled the understanding of the relief sculpturing processes of area of research. Pilões city has a relief marked by convex shapes and amphitheater-like headwaters, in addition to mantles of deep change, a result of the decomposition of Precambrian gneiss, yielding clay type kaolinite. Four morphopedological compartments in the city were identified, called the MP-I, MP-II, MP and MP-III-IV. These compartments are products of the interrelation between the geological substratum, relief and soils, constituting homogeneous and intrinsic temporal-spatial units in physical environment. It was found that the erosions have been concentrated in MP-I and-II compartments, because they showed more favorable characteristics to the erosive processes, such as steep slopes, morphologies favoring the concentration of superficial flow, and soils with textural discontinuities.

Keywords: Tropical Geomorphology. Morphopedology. Erosion, Pilões.

## **Ethnogeomorphology as a methodological resource, applied to land use planning, semiarid ceara state, Brazil**

MARCAL M.(1), RIBEIRO S.(2)

(1) *Universidade Federal do Rio de Janeiro - UFRJ, RIO DE JANEIRO, BRAZIL* ; (2) *Universidade do Cariri - URCA, CRATO - CEARÁ, BRAZIL*

The planning of natural resources has been discussed by various sectors of society responsible for building methodologies that lead to environmental sustainability. The enormous diversity of landscapes in Brazil shows that planning natural resources must necessarily pass through the regional understanding of the relationships between its physical environment, social and cultural.

This paper aims to point the knowledge of Ethnogeomorphology as a methodological resource applied to the planning of land use in the sub-basin of the Salgado River, in the southern state of Ceará, Brazil.

We accomplished the systematization of theoretical and methodological knowledge of the physical and empirical experimentation by the same traditional cultures. We visited rural communities, where scripted interviews provided data for this analysis ethnogeomorphological understanding.

The Ethnogeomorphology corresponds to the study of landforms and their formative processes to better organization and the use of landscape management by human societies. The prefix ethno refers to aspects and skills of people or ethnic groups that is the knowledge of groups of individuals who share a culture. Ethnogeomorphological studies are those who seek to understand the geomorphology of the area linking it to the attention of communities with their own culture. Such knowledge comes from generations of experimentation between these societies and their environment seeking better ways to use and manage natural resources through time.

In the sub-basin of the Salgado River we realized there is an ethnogeomorphological knowledge from the rural farmer of semiarid northeast that has been handed down through the generations, since the settlement of the region, so vernacular. This knowledge is intrinsically related to the agropastoral practices and it produces a classification / designation of the facts and geomorphic processes very peculiar.

\*\*\*\*\*

## **The Erosional features of Espraiado basin, São Paulo, Brazil**

DANIEL E., VIEIRA B.C.

*Universidade de São Paulo - USP, SÃO PAULO, BRAZIL*

The occurrence of the erosional features in Brazil is notorious, especially in cities hinterland the state of São Paulo, as in the case of São Pedro, where there are many of these features that cause social and economic damages. The aim of this research was evaluate the origin and distribution of the erosional features in the Espraiado basin, where there is a high concentration of erosion. We evaluated the morphometric parameters (curvature and slope) and the land use (1962 and 2006) by using the integrated and quantitative analysis. In this analysis we used the Erosion Potential (EP), which is the ratio between the number of cells with gullies, in each class, and the total number of cells of that same class. The results showed a reduction of the total area of features, but an important concentration in the channel head. Regarding the land use we observed the increase of the percentage of forest, urban area consolidated and forestry. The reduction of the exposed soil and pasture classes was important to the erosion decrease, although the urban area consolidated also have influenced the arise of new features and the evolution of others. The concave curvature, the slope between 20 and 40% and the exposed soil and pastures show highest susceptibility, and the convex and rectilinear curvatures and slopes between 0 and 15%, with low levels of EP, when significantly modified by land use, were recorded several erosional features. On the other hand, the use classes with low EP when associated with morphometric parameters of high provided an increased formation of erosional features. Therefore, the analysis from the combination of maps (erosional features, land use and morphometric) contributed to the assessment of the role play of these parameters on the origin and distribution of the erosional features.

### **Geomorphological and Geological Control on the Chemistry of Groundwater: A Case Study from the Meghna Basin, Bangladesh**

HOSSAIN S.(1), HASAN M.A.(2), AHMED K.M.(3)

(1) Dept. of Civil and Env. Engineering, Saitama University, SAITAMA CITY, SAITAMA, JAPAN ; (2) Dept. of Geology, University of Dhaka, DHAKA, BANGLADESH ; (3) Dept. of Geology, University of Dhaka, DHAKA, BANGLADESH

The eastern part of the Meghna basin, Bangladesh comprises of three different geomorphic units of distinct geologic ages. As groundwater arsenic contamination is severe in the eastern Meghna basin of Bangladesh, it is crucial to identify the controlling factors on changing groundwater chemistry. This study was aimed to investigate the geomorphological and geological controls on groundwater chemistry along a transect down the flow line. Fifty-eight groundwater samples were collected along the transect from shallow (<100 m) and deep (140-275 m) aquifers. Integrated interpretation of hydrochemical data along with the geomorphological and geological characteristics revealed considerable spatial and vertical hydrogeochemical variations along an east-west transect passing through a number of geomorphic units of the Meghna basin. Hydrogeochemical profile of major ions along the transect shows that the shallow aquifers in the Flood Plain and Delta Plain are relatively high in  $\text{HCO}_3^-$ ,  $\text{Na}^+$  and  $\text{Cl}^-$  whereas the deeper aquifers are low in  $\text{HCO}_3^-$  but relatively high in  $\text{Na}^+$  and  $\text{Cl}^-$  with maximum concentrations in the eastern side i.e. the delta plain. High chloride concentrations in middle part of the Meghna basin in deep aquifer is indicative of the presence of inlet of the bay or tidal stream in the geological past. Concentrations of dissolved arsenic are found mostly low (<10 ppb) in shallow aquifers of Plio-Pleistocene age in the Terrace part, whereas arsenic concentrations are high (<10 to 1000 ppb) in the shallow aquifers of Delta Plain and Flood Plain of Holocene age. The deep aquifers are generally low (<10 ppb) in arsenic along the transect.

\*\*\*\*\*

### **The role of gallery forest in semi-arid fluvial system dynamics: case study from the Yamé River (Mali, West Africa) during the Holocene**

GARNIER A.(1), LESPEZ L.(1), CAILLAULT S.(2), DUFOUR S.(3), EICHHORN B.(4), NEUMANN K.(4)

(1) LETG Caen -Géophen. Université de Caen Basse-Normandie, CAEN, FRANCE ; (2) Institut National d'Horticulture et de Paysage, AGROCAMPUS OUEST, ANGERS, FRANCE ; (3) LETG Rennes-Costel. Université Rennes 2, RENNES, FRANCE ; (4) Goethe University, Institute of Archaeological Sciences, FRANKFURT AM MAIN, GERMANY

In tropical areas, especially in the Sahelian zone where water is irregularly distributed in space and time, riparian vegetation is an important component of landscapes and fluvial system. Floodplain forests have greater diversity and ligneous density than the surrounding savannas and are subject of a high human pressure. The extent of these vegetated areas is extremely variable in space and time. Until recently, studies on fluvial system have demonstrated the fundamental and complex controls that hydrological processes impose on riparian vegetation. However, gallery forest may significantly control hydrological and geomorphic processes and have strong impacts on landforms dynamics.

This presentation aims to discuss the role of riparian vegetation on fluvial system dynamics during the last 6000 years in the Yamé valley (Mali, West Africa). First, a reconstruction of the gallery forest has been conducted by satellite images for the recent time (1967-2007) and by phytolith analysis recorded in sediment deposits for the Holocene period. Phytolith analysis coupled with geomorphological studies is a good tool to delimit the spatial scale of vegetation reconstruction in particular floodplain vegetation from savanna grasslands. Then, changes in riparian composition and density were compared with the fluvial system variations during the last 6000 years.

The results show an openness of the gallery forest during the last 2 millennium in response to climatic changes and a general increasing impact of societies. It results to an increase in sediment supply and colluvial inwash to valley bottom. More recently, the Sahelian drought crises in the 70-80's associated with an intensification of the shepherd pressure on gallery forest have contributed to a change in a fluvial style of the Yamé River. Indeed, in response to an augmentation in sediment supply the channel became wider and straighter shifting from meandering to braided river pattern.

## **Typology of tropical elementary landforms based on 30 m SRTM data: Example from the French Guyana shield**

CAROZZA J.(1), CORNU J.F.(2), GUITET S.(3), BRUNEAU O.(4)

*(1) University of Strasbourg - GEODE UMR 5602, STRASBOURG, FRANCE ; (2) UMR BOREA, IRD 207, National Museum of Natural History, PARIS, FRANCE ; (3) UMR AMAP and National Forest Office, MONTPELLIER, FRANCE ; (4) National Forest Office, CAYENNE, FRENCH GUIANA*

In shield area, large scale peneplain and plateau relief are composed of repetitive and monotonous landforms *i.e.* multiconvex shape landforms. Despite their apparent homogeneity, multiconvex landforms show a strong diversity that has been correlated in previous works with lithology, climatic factors and/or geodynamic context.

In this work, we explore the geomorphodiversity of elementary landforms of the French Guyana shield by geomorphometric analysis. The first challenge to reach is the individualization of elementary landforms and landscape segmentation. In regions of high drainage density, repetitive elementary landforms unit can be defined as areas of relative high (terra-ferma) relief surrounded by lowlands/waterlogged talwegs. The recognition of such topographic structure was done using a three dimensional fractal index, Box Counting Algorithm type. About 230000 elementary landscape units were delimited by this way. This automatic method allows an objective extraction of elementary landforms and give results close to manual extraction.

For each of these landforms, eighteen specific geomorphometric criteria were computed in order to characterize they planar and vertical shape geometry and outline complexity. These criteria were then used to perform a CPA analysis and K-mean clustering. Twelve basic landforms type are identified and composed the landscape diversity. Spatial repartition of landforms type is highly auto-correlated and landforms type seems sensitive to both lithological and climatic factors. This new analysis improves previous large scale geomorphologic maps proposed by Boyé (1979) and reworked by Paget (1999) based on photo-interpretation. Landforms type seems sensitive to both lithological and climatic factors.

\*\*\*\*\*

## **Multiconvex landform object-based segmentations: Regions vs. edge based approaches with different DEM**

CORNU J.F.(1), GUITET S.(2), BRUNEAU O.(3), CAROZZA J.M.(4)

*(1) UMR BOREA, IRD 207, National Museum of Natural History, PARIS, FRANCE ; (2) UMR AMAP and National Forest Office, MONTPELLIER, FRANCE ; (3) National Forest Office, CAYENNE, FRENCH GUIANA ; (4) University of Strasbourg - GEODE UMR 5602, STRASBOURG, FRANCE*

Landforms represent the central cartographic units for many geomorphological works aiming to represent terrain configuration. The recent multiplication of studies focusing on the definitions and methods associated with this cornerstone concept encourage automatic landforms and terrain cartography which is presently a fruitful and active research field of applied geomorphology. Landforms identification and terrain segmentation are the objects of many published works. Nevertheless, the methodological choices (pixel vs. object, region-based vs. edge-based) are not neutral and are strongly associated with the geomorphometrical theoretical framework retained (continuous vs. specific vs. discrete geomorphometry) and the area under study (main geomorphological processes shaping the terrain).

In this context, only few studies have focused on wet tropical areas where multiconvex landforms represent one principal types of landform. Therefore applicability and efficiency of published landform segmentations were not sufficiently assessed and compared in these areas.

In this study we propose to test some continuous pixel-oriented (unsupervised classification), region-based (local variance) and edge-based (mean-curvature watershed) object-oriented segmentations published in the literature with a new one based on the use of a local fractal operator. Three areas localised in French Guiana representative of (1) littoral and low relief landscapes, (2) moderately incised topographies and (3) mountainous reliefs will serve as test areas. Finally, we will assess the ability of these approaches to mimic human work with a reference segmentation done manually by an expert based on the interpretation of topographic maps.

**Sediment distribution and flux patterns of active boulder bars in a montane tropical river ' Rio Pacuare, Costa Rica**

LIND P., MCDOWELL P.

*University of Oregon, EUGENE, UNITED STATES*

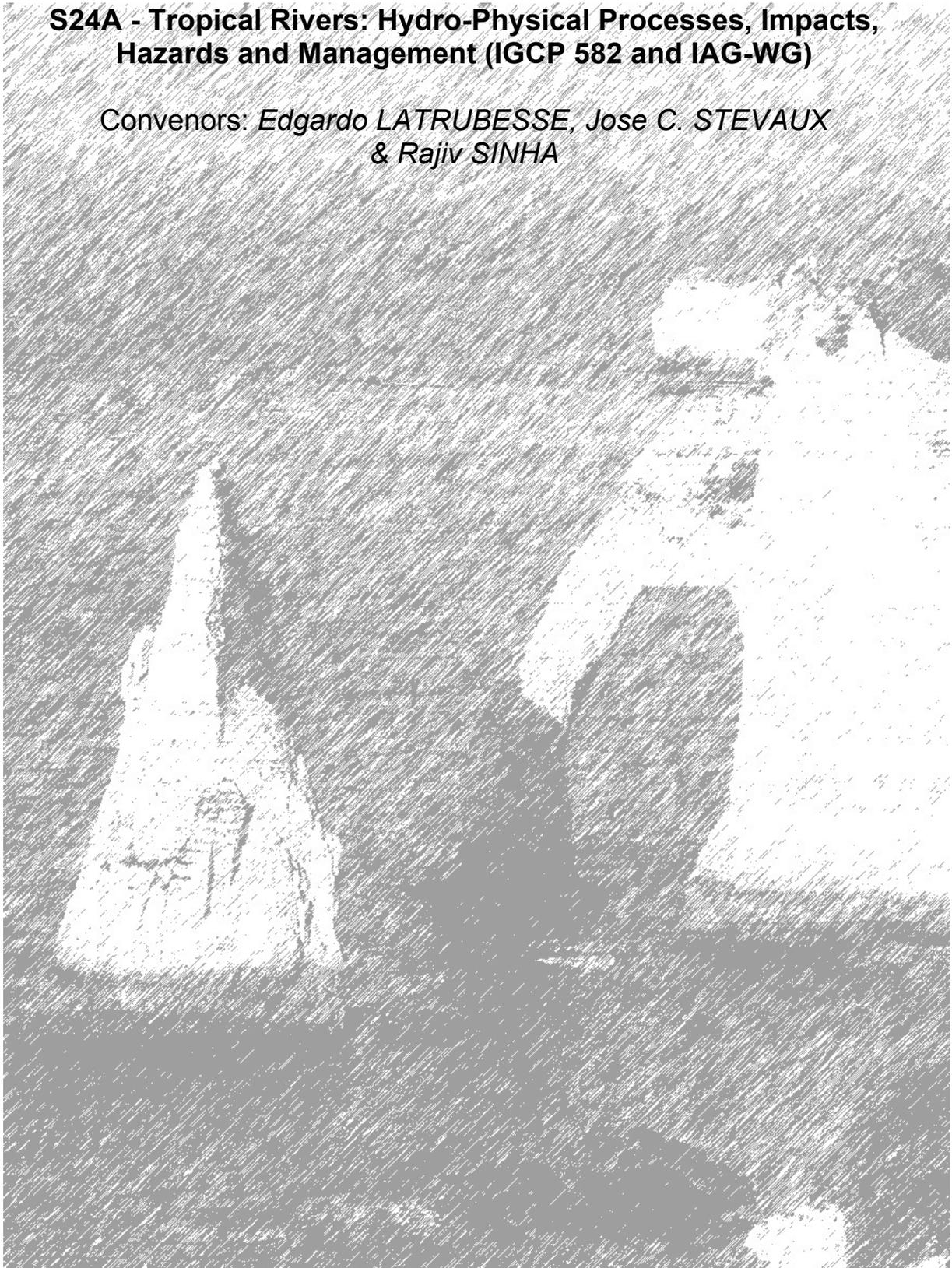
Humid tropical montane rivers convey large magnitude floods that have the potential to mobilize boulder-sized bed material multiple times during a year. On the Rio Pacuare active boulder deposits with surface areas of up to 300 x 75 meters influence channel form in this otherwise hillslope confined river. The rate of sediment flux occurring within and between reaches provides insight into the geomorphic sensitivity of the system. This research project has produced digital maps and volumetric estimates of the Rio Pacuare's sediment sources including active-channel deposits, tributary inputs, hillslope coupling, and small inset terraces. Data collected on site (Nov 2012-April 2013) combined with GIS analysis and hydraulic modeling have generated preliminary sediment transport rates for the  $D_{84}$  and  $D_{50}$  at seven sites within the four montane reaches. Results indicate that grain-size distribution at a site can vary slightly throughout the year depending on seasonal discharge patterns and upstream sediment inputs. Boulder bar shape may also vary slightly but surface area is generally maintained when there is no significant change to upstream sediment inputs. These preliminary results suggest that the Rio Pacuare and similar tropical montane rivers are geomorphically sensitive to changes in discharge regimes (climate change) or channel impoundment (dam construction).

\*\*\*\*\*



**S24A - Tropical Rivers: Hydro-Physical Processes, Impacts,  
Hazards and Management (IGCP 582 and IAG-WG)**

Convenors: *Edgardo LATRUBESSE, Jose C. STEVAUX  
& Rajiv SINHA*





## **Oral presentations:**

### **Physiogeographic features and hydrological characteristics of the Congo and the Oubangui drainage basins, Central Africa**

RUNGE J.

*Goethe-Universitaet, FB 11: Institut fuer Physische Geographie, FRANKFURT, GERMANY*

The Congo River occupies a total of 3.747.320 km<sup>2</sup> between 9°15' North to 13°18' South and 15°18' to 34°02' East. The Congo-Lualaba River is in total 4374 km long and describes an initially south to north, from Kisangani down-stream, a westerly oriented, bow to curve like river pattern that crosses the equator twice. The Oubangui River is the largest right bank tributary of the Congo that drains at the Bangui gauge station an area of 488.500 km<sup>2</sup>. It is this river that reflects by its discharge environmental dynamics on the North-Equator swell. The poster focuses on the present and past physiogeographic properties of the Congo basin and shows recent environmental trends evidenced by discharge and floods, mainly for the Oubangui River. Frequency analysis of floods resulted in return periods between 7 and 35 years. Regional extensions of urban floods – severely affecting the town of Bangui – were reconstructed for events in 1916, 1962 and 1999. The economic importance of the two rivers for transport infrastructure (river steamers), fishing and hydropower is also taken into consideration.

\*\*\*\*\*

### **Catchment-scale hydrology of and sediment transport by the Ayeyarwady (Irrawaddy) River and landforms of its catchment**

*FURUICHI T.(1), WIN Z.(2), LIN S.(2), OGASAWARA M.(3), YAMAMOTO M.(4), OCHIAI S.(4)*

*(1) Department of Science, IT, Innovation and Arts, BRISBANE, AUSTRALIA ; (2) Myanmar Hydrological Study Group, YANGON, MYANMAR ; (3) Geological Survey of Japan, AIST, TSUKUBA, JAPAN ; (4) Low Level Radioactivity Laboratory, Kanazawa University, KANAZAWA, JAPAN*

The Ayeyarwady (Irrawaddy) River, whose ca. 414,000 km<sup>2</sup> catchment is almost entirely in the country of Myanmar, is one of the least known tropical large rivers in the world. We present results of analyses on recent hydrological data, recent and previous sediment transport data and sediment geochemistry of the river.

The Ayeyarwady rises at 5,900 m above sea level to the east of the eastern Himalayan syntaxis. It flows through the Central Burma Basin which formed as fore-arc and backarc basins associated with subduction of the Indian Plate beneath the Eurasian (or Indochina) Plate. The river then forms extensive delta whose coastline is thought to be in equilibrium, that is sediment deposition currently balances subsidence and sea level rise.

The catchment-scale monthly water budgets indicate that discharge (inputs) from the middle reach area (Central Dry Zone) to the main channel is small or negative in most months. The small or negative values of inputs (increase) in the water budgets are not attributed to the evaporation from river surface but are supposedly consequence of small precipitation and large evapotranspiration in the Central Dry Zone and of considerable intake of water within this reach of the Ayeyarwady.

Comparison of annual sediment load data in the past (late 19th century and late 20th century) and in the present (year 2010) shows apparent decrease of the annual sediment load in the Ayeyarwady. Geochemical compositions of river sediments from two major upstream sub-catchments (the Upper Ayeyarwady and the Chindwin) are clearly different, and the geochemical characteristics suggest sediments from the Chindwin contribute more than those from the Upper Ayeyarwady.

### **Analysis of the state of the flow and morphology interaction in the hydropower dominated Middle Zambezi subcatchment**

MWELWA E.(1), CROSATO A.(1), WRIGHT N.(2), BEEVERS L.(3)

(1) UNESCO-IHE Institute for Water Education, DELFT, NETHERLANDS ; (2) University of Leeds, Department of Civil Engineering, LEEDS, UNITED KINGDOM ; (3) Heriot-Watt University, School of Built Environment, ADINBURGH, UNITED KINGDOM

The research work in the Middle Zambezi sub-catchment has the key objective to investigate the state of the river and its flood plains in terms of flow and morphological variation for both the pre and post damming situations. From the rich biodiversity that this area supports, both Zambia and Zimbabwe have established national parks, with Mana Pools National Park, Sapi and Chewore safari areas being designated as UNESCO World Heritage Sites in 1984. The sustenance of these wild areas depends on the river channels and associated morphological features together with the river flow regime whose modification can lead to negative environmental consequences.

The research results highlight: the dominance of hydropower regulation in the water balance of the Middle Zambezi river reach, river channel morphology changes associated to dam operation and important consequences for the floodplain habitat. Based on one- and two-dimensional modelling, the future state of the Middle Zambezi River has been analysed taking into account the following scenarios: absence of damming; continuation of current water regulation and operations; modification of water regulation to induce favorable changes and; climate-related variation of droughts. The implications for maintaining the current dam operation practices are outlined in relation to the sustainability of the hydro-morphology of the river corridor which supports a rich wildlife habitat.

The study output will provide information that will be useful for broadening the understanding of the complex floodplain (sub-surface and surface) flow and morphological interactions at a range of spatial and temporal scales. This understanding can feed into decision making frameworks for the water resources managers in charge of hydropower generation management in order to consider modifications to the current dam operating rules and water allocation for environmental flows.

\*\*\*\*\*

### **Stream power based threshold identification for explaining channel morphological variability, Yamuna River system, India**

BAWA N., JAIN V., SHEKHAR S.

*Department of Geology, Centre for Advanced Studies, University of Delhi, DELHI, INDIA*

Channel morphology is one of the fundamental parameter to define river health. Morphological variation not only depicts dynamic nature of the river but also it defines the riverine habitat. Morphological characteristics at a given state are governed by the balance of driving and resisting forces. Hence, stream power distribution pattern, which is a measure of driving force in fluvial system has been analysed to identify the threshold for geomorphic change at different scales. The analysis was carried out on the Yamuna River system, the largest tributary of the Ganga River, India.

Channel morphological mapping was carried out using LANDSAT data of 30m resolution. Morphological attributes at different scales were used to classify the basin area into different landscapes and further used to define various River Styles reaches in different landscapes. Stream power variability was analysed using 90 m SRTM and 30 m ASTER data. Stream power is characterized by significant variability, which is mostly controlled by channel slope variation except at confluence points.

The Yamuna river basin is characterized by three landscapes namely Himalayan mountainous area in north, badland topography in south and alluvial plain in the midstream area. These landscapes are characterized by distinct range of stream power values, which decreases from 12,000 W/m at mountain reaches to 4,000 W/m at plains reaches, and further increases significantly upto 35,000 W/m in the Badland topography. At reach scale, the confined and partially confined River Styles reaches are characterized by high stream power (13,000 W/m to 40,000 W/m). Further, percentage of bar area in channel reaches increases with decrease in stream power. Mostly, the midchannel bars and alluvial islands types of bars are associated with lower values of stream power. The identification of threshold condition will assist in analysing the river sensitivity for geomorphic changes in response to external control(s).

### **Rivers in Northern Thai History: Implications for Management**

NG S.(1), WOOD S.H.(2), ZIEGLER A.D.(1)

(1) National University of Singapore, SINGAPORE, SINGAPORE ; (2) Boise State University, BOISE, UNITED STATES

This study investigates the historical interactions between the Ping River and the population of Wiang Kum Kam. Wiang Kum Kam was the former Lannathai capital located on the Ping River near Chiang Mai Thailand; it was buried under flood sediments several centuries ago. We challenge two previous paleoflood studies suggesting that an elongated mound on the floodplain in Wiang Kum Kam was an old levee system of the paleo-Ping River channel. Instead, we show the mound was a man-made dyke, constructed after 1411 AD to alleviate effects of persisting floods. One distinct layer in the floodplain stratigraphy consisted of a 30 cm of coarse sand overlain by 10-15 cm of fine-silty sand. Radiocarbon dating of charcoal found in this layer suggests that the sediments were deposited by a large flood ca 1477 AD to 1512 AD. Comparisons with deposits of 2005 and 2011 Ping River floods revealed that this flood event was a high-energy, destructive event that likely caused the migration of the Ping River and the abandonment of Wiang Kum Kam. Our work demonstrates that the historical importance of rivers in northern Thailand was anchored upon society's dependence on them for sustenance and defense. Rivers also have religious and cultural meaning. The proximity of settlements to rivers enhanced the susceptibility of the population to flood hazards. This vulnerability exists today despite advancements in flood prediction and mitigation technologies.

\*\*\*\*\*

### **Geomorphic considerations for environmental flow and habitat suitability in the Ganga river system, India**

SINHA R.(1), MOZUMDER C.(2), JAIN V.(3)

(1) Indian Institute of Technology Kanpur , KANPUR, INDIA ; (2) Indian Institute of Technology Kanpur, KANPUR, INDIA ; (3) University of Delhi, DELHI, INDIA

Environmental flows (e-flows) in rivers are defined as the flows required for the maintenance of ecological integrity of rivers, their associated ecosystems and the goods and services provided by them. Major geomorphic considerations for determination of e-flows include geomorphic connectivity (longitudinal, vertical and lateral), sediment supply and dynamics, bank characteristics and riparian vegetation and bed characteristics. Satellite remote sensing data coupled with field measurements of river channel form were used to characterize selected stretches of the Ganga River for habitat suitability and to derive input parameters for e-flow assessment. These parameters were integrated in GIS environment using Analytical Hierarchical Process (AHP). Finally, a Habitat Suitability Index (HSI) was derived to classify the river system into four classes viz. excellent, good, degraded and poor. Separate weightage schemes were developed for the reaches in mountainous and plains areas. Our results suggest that the mountainous reaches in the selected window are generally in 'good' condition but the reaches in the plains are significantly 'degraded' geomorphologically either due to engineering interventions or due to planform dynamics and flow reduction due to poor longitudinal connectivity. The only exceptions are the reaches upstream of the Narora barrage that are classified as 'excellent' due to ponding of water for the nuclear power plant and sustained efforts by the WWF for maintaining a dolphin sanctuary. Geomorphic data was integrated with the hydraulic models to compute flow volumes necessary for channel maintenance from geomorphic perspective and these were integrated with similar inputs from the ecological data to arrive at a common value of e-flow.

## Fluvial Forms, Processes and Sediment Characteristics of River Teesta in India

GUPTA S.(1), GHATAK S.(1), SHARMA S.(1), KATURI A.(2)

(1) Geological Survey of India, NEW DELHI, INDIA ; (2) CEPT University, AHMEDABAD, INDIA

The present day landscape and Quaternary fluvial records of Teesta River draining the Himalayan upland, pediment and the foredeep in India represent an outcome of complex interplay of Himalayan tectonics, geology, climate, hydrogeomorphology and various anthropogenic practices. The landform characteristics and geomorphic evolution of River Teesta has been evaluated by synthesis of time series data of Teesta and its tributaries (between 1969 & 2012) using multi dated maps/imagery, digital terrain model data (SRTM 90m, Aster GDEM 30m) and field studies. The present study reveals that Teesta forms a rectangular drainage in hilly terrain and braided pattern after it debouches onto the plain. Significant spatio-temporal geomorphic variation along this alluvial tract during Holocene times had been brought in by variable tectono-climatic influences and is manifested in terms of development of sheet flood to stream flow dominated alluvial fan, unpaired terraces, river piracy (along NW-SE trending Teesta Lineament), avulsion of Teesta, development of terraced landscape further downstream, frequent channel abandonment and formation of paleochannels in the flood plain (<1° slope and ~100m elevation). Quaternary deposits from fan apex up to the flood plain of Teesta are dominantly sandy. The time series analysis indicates that Teesta River is highly avulsive and dynamic in nature. In recent past (between 1993 & 2005) a general increase in braiding intensity along Teesta has been observed from the changing planform character of mid channel bars and this has been attributed to anthropogenic intervention and local climatic behavior. The present study provides a framework for hydrogeomorphic evolution of the Teesta basin with special reference to river dynamics and flood hydrogeomorphology in the Jalpaiguri Town and adjacent areas, which are under the threat of floods due to massive siltation in the river bed.

\*\*\*\*\*

## Homogeneous Sections of Suspended Matter in a heterogeneous large tropical river: the Orinoco river (Venezuela)

CASTELLANOS B.(1), LARAQUE A.(2), LOPEZ J.(1), PEREZ J.(3), RODRIGUEZ M.(3), ROSALES J.(3), STEIGER J.(4)

(1) IMF UCV, CARACAS, VENEZUELA ; (2) IRD GET, TOULOUSE, FRANCE ; (3) CIEG UNEG, CD GUAYANA, VENEZUELA ; (4) GEOLAB, CLERMONT FERRAND, FRANCE

For the Orinoco the well-known lateral asymmetry within its main stem, from the source to the river mouth, is maintained by the continuous supply on its left-bank by white waters tributaries rich in TSS (Total Suspended Solid) concentrations flowing from the Andes, while right-bank tributaries are characterized by black waters, which deliver only very small quantities of TSS from the Guiana Shield. However, this lateral heterogeneity may be interrupted locally, as for example at the Ciudad Bolivar cross-section on the Orinoco River. In this section, using a point sampling protocol for eleven suspended flow measurements operated at different water stages, it was shown that one sample taken close to the water surface is representative of the mean of TSS concentrations sampled at various points over the whole channel cross-section.

For this one large river, the unusual spatial homogeneity of TSS concentrations in this section is also favored by the conjunction of various geomorphological factors, which, begin several kilometers upstream, with a structural control point marked by:

(i) a succession of closed meanders with opposing curves which send the water from one bank to the other, (ii) the presence of a place of intense rapids named "boca del infierno", (iii) the existence of crossing stream lines, downstream of the river islands, (iv) the alternation of contractions and expansions of the river cross section as the variable relief riverbed, (v) and at the place of the bridge of "Angostura" (old name of Ciudad Bolivar city, which illustrates the narrowness of this section), the presence of a funnel form, where, after a wide section of 8 km, the Orinoco flows crossing a narrow canyon (1 km), where several bedrock outcrops of the Guiana Shield, provokes flow vortices and turbulence which cause a certain homogenisation of the TSS.

It seems appropriate to preferentially look for this kind of section pattern to study the TSS fluxes in large rivers.

### **Amazon River suspended sediment behavior on water surface - observations at the Manacapuru hydrometric station, Amazonas, Brazil**

*FILIZOLA N.(1), MARTINEZ J.M.(2), FRAIZY P.(3), ARMIJOS E.(4), SOARES C.(5), SAMPAIO F.P.(1), MARINHO T.(1), MARTINELLI A.(6), ZUMAK A.(1), SONDAG F.(7), GUYOT J.L.(8)*

*(1) Universidade Federal do Amazonas, MANAUS, BRAZIL ; (2) IRD, TOULOUSE, FRANCE ; (3) IRD, MANAUS, BRAZIL ; (4) INPA/UEA, MANAUS, BRAZIL ; (5) SIPAM, MANAUS, BRAZIL ; (6) CPRM, MANAUS, BRAZIL ; (7) IRD, BRASÍLIA, BRAZIL ; (8) IRD, LIMA, PERU*

The results show a heterogeneity behavior in the field which is very coincident when viewed under satellite image. Average and maximum concentrations are higher in low water period (October) and early in the period of high water (February-March). The variance and standard deviation are also higher than the same periods the average and maximum. The minimum values are a little more homogenous. However, they trend to be lowest in the high-water period (June), with other values despite coming heterogeneous pattern for the low water period and the beginning of rising waters. The variance and standard deviation are much greater in the dry season (October). The variance and standard deviation are much greater in the dry season (October). The figure of a plume seen in the satellite image is more visible, so the low water period. However if the classes of concentrations of suspended solids are adjusted to the extent identified in each period, it is possible to identify a picture image in all results of sampling in the mesh. Thus it is notable heterogeneity, even on at all time periods. The heterogeneity in surface is to be expected, most likely, a heterogeneity in depth. More data, collected at the same times, but depth in vertical profiles are being analyzed to obtain planning this. This site investigation indicated heterogeneity in terms of suspended solids determined in surface correlated with plume figure visualized by satellite images. This figure can be related to a strong relationship with a local geological structure that seems to be the responsible for a special mixed trend in terms of suspended sediment load distribution at the river section (Filizola et al, 2009). Also, hydrological data marked that this trend varies seasonally. These results put in evidence another view about the Amazon Basin internal suspended sediment behavior.

\*\*\*\*\*

### **The Mekong River, a reappraisal of sediment transfer based on geomorphology and grain size**

*BRAVARD J.*

*University Lyon2, VILLEURBANNE, FRANCE*

The Mekong River is commonly considered as a river carrying mostly silt and clay to the ocean, the yearly sediment discharge averaging 140-160 millions tons (suspended load only). Most of sediment transport is related to the monsoonal high discharge period which occurs from August to October.

Several recent papers underlined upstream-downstream discontinuities in suspended sediment concentration and in suspended load, tentatively explained by conveyance losses, dilution effect by tributaries, and different sampling procedures. The impacts of Chinese dams since 15 years increase the complexity of the question.

For documenting the present study, field surveys were performed at low flow in March 2011 and 2012. They allowed a detailed description of sand deposits on riverbanks from Lao PDR mountains to the delta. In each site, sampling was performed at different elevations on the banks. Samples were processed by sieving and the CM image technique was used for understanding transport processes during floods. The results show that deposits originate mostly from graded suspension, and in rare cases from uniform suspension (including some amount of fine sand). Wash load is not deposited upstream of Cambodia. We may demonstrate that, according to energy (unit stream power) available along discrete river reaches, sand can be transported both as bed load, or as suspended load. These results suggest a reappraisal of the yearly bed load transit at Kratie, the lowest station in the Cambodian reach, since most of the sand is transported as bed load in the downstream reaches.

However natural processes have been already altered by reservoir trapping in China and on tributaries (irreversible impact), and by aggregate harvesting (reversible impact), notably in the downstream reaches. It is now to late to monitor precisely natural transport processes.

## Processes of Sediment and Carbon Sequestration within Large Tropical Rivers

AALTO R.(1), AUFDENKAMPE A.(2)

(1) University of Exeter, EXETER, UNITED KINGDOM ; (2) Stroud Water Research Center, AVONDALE, UNITED STATES

Dating (high-resolution  $^{210}\text{Pb}$  &  $^{14}\text{C}$ ), imaging (sub-bottom sonar & ERGI) and biogeochemical analysis have facilitated the characterization and inter-comparison of floodplain sedimentation rates, timing & carbon loading across several large tropical river basins. We present examples from the 72,000 km<sup>2</sup> Beni River basin in Northern Bolivia and the 36,000 km<sup>2</sup> Strickland River in Papua New Guinea – fluvial systems that are located on either side of the Equatorial Pacific warm pool that drives the ENSO phenomenon.

Our research suggests that rapid-rise, cold-phase ENSO floods account for the preponderance of sediment transport & accumulation within these two tropical systems. New results better delineate the full distal extent of modern (~100 yrs) deposits within both systems & provide a deeper perspective into how these extensive floodplains developed over the Holocene, both in response to external forcing (climate and sea level) and internal system dynamics. The vast scale of these temporally discrete deposits (typically 10s of millions of tonnes emplaced over relatively short time periods) equate to high burial rates, which in turn support the high carbon loadings that are sequestered within the resulting sedimentary deposits. We have identified the principal source of this carbon and sedimentary material to be extensive landslides throughout the high-relief headwaters - failures that deliver huge charges of pulverized rock, soil, and plant material directly into canyons (in both the Bolivian Andes and the PNG Highlands), where raging floodwaters provide efficient transport to lowland depocentres. We present recent research results from these basins, providing insight into the timing, distribution, and geochemistry of such enormous relocations of mass that result in significant carbons sink within the floodplains. Processes, timing, and rates are compared between the two tropical dispersal systems, illuminating the nature of geomorphic hillslope-channel coupling.

\*\*\*\*\*

## Tropical multichannel rivers: processes, forms and evolution

STEVAUX J.(1), LELI I.(2), GON P.(2), ASSINI M.(2)

(1) Universidade Estadual de Maringá, MARINGÁ, PR, BRAZIL ; (2) UNESP/Rio Claro, RIO CLARO, SP, BRAZIL

Nine of the ten largest megarivers in the world present multichannel pattern. In spite of it, models for this type of rivers were developed, in its majority, for relatively small river systems under semi-arid climate. The present study is related to the upper Paraná River, the second large fluvial basin in South America and the 10th largest river in the world concerning water discharge ( $Q_m = 13,000\text{m}^3\cdot\text{s}^{-1}$  at the study reach and  $18,000\text{m}^3\cdot\text{s}^{-1}$  at the mouth ). The present alluvial plain has a complex history initiated with the increasing in humidity at the Pleistocene-Holocene limit. The increasing in discharge promoted, during the "Holocene Climatic *Optimum*" (ca. 8-7ka BP), channel incision that generated a multichannel river of 8 km in width, with large islands up to 90km long and 15km width. At this time channel occupied totally the present alluvial plain (channel plus floodplain). This scenario maintained up to 3-2ka when, by a combination of light climatic change and small tectonic movements, the channel shifted to left bank abandoned islands and channels that became the substratum of the present floodplain in the right side. Under the new hydrological condition, the specific stream power increased and a different channel pattern is settled. The channel eroded partially the ancient morphology and generated a new anabranching pattern constituted of long, narrow and relatively stable islands formed by annexation bar processes that keeps active at the present. Riparian vegetation rapidly adapted to new dynamics and system seems to be in equilibrium. The impacts introduced by dam construction (closed in 1999) have begun to modify change this condition and many alterations can be seen in the reach.

### **The Perils of Human Activity on Andean Rivers: Lessons from Colombia's Experience with Soil Erosion**

RESTREPO J.

*EAFIT University, MEDELLIN, COLOMBIA*

Many anthropogenic influences, including deforestation, an agriculture and pasture increase by 75%, poor soil conservation and mining practices, and increasing rates of urbanization, may have accounted for the overall increasing trends of sediment transport in Colombian rivers. The percentage of forest cover in the Andes of Colombia was estimated to have declined from 66% in 1970 to 22% in 1990, with an annual deforestation rate of 1.9%, or 274,000 ha yr<sup>-1</sup>. For the whole country, a recent assessment of deforestation between 2000 and 2008 indicates a national rate of forest loss of 336,000 ha yr<sup>-1</sup>. This rate is considered to be among the highest in the world.

All the previous facts indicate that human induced activities have dramatically altered the fluvial fluxes from Colombian rivers. According to our recent study of human activities in terms of deforestation, 32% of the observed variance in sediment transport from the Magdalena River is explained by deforestation! Thus, the amount of sediment transported by the Magdalena to its delta plain, approximately 50 Mt annually, is due to deforestation. Also, the Patía River in the Pacific coast has witnessed an increase in sediment transport by 45% during the last decade, an increase mainly accounted by deforestation.

In the last decade, scientific studies on sediment transport and its controlling variables by Universidad EAFIT allow us to suggest that there is an increase in the rate and magnitude of natural disasters along lowlands and delta plains associated with soils (floods, landslides) that could be due mainly to growing land-surface modification caused by human activity, and to a lesser extent, by climate change. If this hypothesis is proved for the Colombian rivers, it could have a major impact on mitigation strategies, since funds could be directed towards soil conservation within river catchments rather than climate change mitigation.

\*\*\*\*\*

### **The igapó of the Negro River in central Amazonia: Linking late-successional inundation forest with fluvial geomorphology**

MONTERO J.(1), LATRUBESE E.(2)

*(1) Institute of Silviculture, University of Freiburg, FREIBURG, GERMANY ; (2) Department of Geography and the Environment, University of Texas, AUSTIN, TEXAS, UNITED STATES*

Despite important progress on Amazonian floodplain research, the flooded forest of the Negro River "igapó" has been little investigated. In particular, no study has previously focused the linkage between fluvial geomorphology and the floristic variation across the course of the river. In this paper we describe and interpret relations between igapó forest, fluvial geomorphology and the spatial evolution of the igapó forest through the Holocene. Therefore, we investigate the effect of geomorphological units of the floodplain and channel patterns on tree diversity, composition and structural parameters of the late-successional igapó forest. Our results show that sites sharing almost identical flooding regime, exhibit variable tree assemblages, species richness and structural parameters such as basal area, tree density and tree heights, indicating a trend in which the geomorphologic styles seem to partially control the organization of igapó's tree communities. This can be also explained by the high variability of well-developed geomorphologic units in short distances and concentrated in small areas. In this dynamic the inputs from the species pool of tributary rivers play a crucial role, but also the depositional and erosional processes associated with the evolution of the floodplain during the Holocene may control floristic and structural components of the igapó forests. These results suggest that a comprehensive approach integrating floristic and geomorphologic methods is needed to understand the distribution of the complex vegetation patterns in complex floodplains such as the igapó of the Negro River. Thus, by integrating the past into macroecological analyses will sharpen our understanding of the underlying forces for contemporary floristic patterns along the inundation forests of the Negro River.

**Channel morphodynamics in semiarid areas: Jaguaribe River, Ceara, Brazil**

ALMEIDA CAVALCANTE A.

UNIVERSIDADE ESTADUAL DO CEARE, FORTALEZA, BRAZIL

This paper discusses channel morphodynamic in northeast of Brazil and observes the effects of the Castanhão Dam in the Ceará State during the last decade. The Jaguaribe River extends 610 km and its catchment area is 74,000 km<sup>2</sup>. It is a typical semiarid basin, where precipitation concentrates 700mm yr<sup>-1</sup> between February and May. The Pre Cambrian predominates in the entire catchment and slopes are 1 m km<sup>-1</sup> in high course and 0.30 m km<sup>-1</sup> in low course. Channel profile and erosion bank (pins of erosion) measurements in 11 stations distributed downstream of the Castanhão dam were collected during field work (2009-2010). Comparative analysis of aerial photographs and images from different years allowed for the observation of channel morphological changes and potential bank erosion areas, as well as the evolution of the human use and occupation of the floodplains. The morphological analysis has shown erosion sites with bank retraction of around 1-7m yr<sup>-1</sup> during the period analyzed (1958-2010). Nevertheless, 23km at the base of the Castanhão dam demonstrated accelerated bank retreat two times faster between 2003-2010 (15m yr<sup>-1</sup>) when compared with the period before (1958-2002). Findings from this research indicate that the Jaguaribe River tends to go through a slow but progressive change in its level base as the reduction of the river's capacity and competence resulted from the controlled discharge flows by dam. Thus the construction of Castanhão dam in 2002 appears as a milestone that altered the hydrological, morphological and sedimentological dynamic of the Jaguaribe, which now seeks other forms of equilibrium.

\*\*\*\*\*

**Moving forward, locking backwards: preparing for the next large Asian floods**

ZIEGLER A.(1), LIM H.S.(1), WOOD S.H.(2)

(1) National University of Singapore, SINGAPORE, SINGAPORE ; (2) Boise State University, BOISE, UNITED STATES

The abundance of large floods in Asia over the last decade is not necessarily an indicator of anthropogenic climate change, nor an obvious result of land-cover change, especially deforestation, which has been occurring for several decades. Analysis of a 90-year streamflow record on the Ping River in Thailand shows that high peak flows occur typically in response to large late-season tropical storms, sometimes in conjunction with monsoon anomalies. At this spatial scale (> 10,000 km<sup>2</sup>) the effects of land-cover change are not discernable. At this temporal scale (< 100 years), the influence of regional-to-global climate phenomena, particularly ENSO, is not apparent. The record shows no significant increase in peak flows since 1920; but an observed decrease in low flows is related water management. Elsewhere, major floods have occurred on the Chao Phraya river in each of the last few decades. The current attitude of fighting flooding via engineering works is potentially flawed because it fails to address the underlying issue of vulnerability. Furthermore, paleo-flood evidence on the Ping and Mekong rivers suggests much larger floods than those witnessed in the recent past have occurred in the last 5000 years. Given the current situation of lucrative business ventures and millions of people encroaching the flood plains of major rivers, future floods could be devastating.

### **River response to European-style agriculture in a large, subtropical catchment: Brisbane River, Australia**

KEMP J., OLLEY J., MCMAHON J., ELLISON T.  
Griffith University, BRISBANE, AUSTRALIA

The sensitivity of rivers to land use change can be difficult to define. In southeastern Australia, rivers in temperate areas experienced substantial alterations to sediment and channel characteristics, or complete floodplain metamorphosis, following the introduction of European-style agriculture after 1788. By contrast, tropical and subtropical catchments are comparatively little studied, and less is known about the post-European transition. Here we describe c.190 years of channel change in the Brisbane River, a large, subtropical river characterised by regular extreme flooding, most recently in 2011 when suburban areas were inundated up to 15 m depth and one million tonnes of fine sediment was deposited in its estuarine reaches. Channel characteristics at the time of European settlement were reconstructed from documentary and historical records, including maps and surveys, aerial photographs, early photographs and historical accounts, and 103 years of instrumental streamflow record. These suggest that increased hillslope erosion was responsible for higher bedload transport rates within 15 years of forest clearance. Localised bank erosion was recorded around 40 years after settlement in lower reaches of the river, probably owing to removal or thinning of riparian vegetation. Widespread, discontinuous bank erosion was triggered by large floods in 1893, 1974 and 2011. The compound channel form and flood-dominated floodplain of the Brisbane River has remained essentially unchanged. Channel position since at least 1885, and bed level since at least 1894 has remained stable, despite the completion of large water supply and flood control reservoirs in 1958 and 1984. This suggests that hydrologically variable, subtropical rivers are less sensitive to changes in sediment supply and runoff than more temperate systems. This has important implications for the management of large river systems in the wet-and-dry tropics.

\*\*\*\*\*

### **High-Resolution Characterization of a Tropical Montane Stream: Using Terrestrial Laser Scanning to Relate Channel Morphology to the Distribution of Stream Power and Shear Stress**

LISENBY P.(1), WASKLEWICZ T.(2), SLATTERY M.(1)

(1) School of Geology, Energy, and the Environment, Texas Christian University, FORT WORTH, TX, UNITED STATES ; (2) Department of Geography, East Carolina University, GREENVILLE, NC, UNITED STATES

Mountain streams provide great opportunities to study dynamic channel morphologies despite the challenging topographic and climatic conditions of their basins. In this study, we show that a detailed understanding of the reach-scale channel morphology/flow hydraulics relationship can be gained using an innovative terrestrial laser scanning (TLS) technique in a tropical mountain stream in north-central Costa Rica. An orthographic channel-reach surface is derived by suspending a Leica HDS 7000 terrestrial laser scanner upside-down from a frame placed in the streambed. The technique accommodates the tropical canopy, steep stream gradient and boulder-bed material to produce a high-resolution point cloud. After data filtering and cleaning using Leica Cyclone software V. 7.4, the points are interpolated into a 2cm planimetric resolution digital elevation model (DEM) using ArcGIS software. Using the River Bathymetry Toolkit (RBT) we measure a cross-section for every meter of channel length on the DEM surface. We calculate the streamwise distribution of mean stream power and boundary shear stress by defining bankfull elevations, measuring hydraulic geometry and calculating velocity, using the standard deviation of bed elevations ( $\sigma_z$ ), at each cross-section. We show the partitioning of shear stress for a cross-section by assuming that the bed contributes the majority of resistance to the flow. Finally, we symbolize each cross-section to display mean stream power and boundary shear stress values and overlay them on the DEM. By effectively utilizing the high resolution of the DEM surface through the dense sampling of hydraulic geometry, we are able to accent the linkages between channel morphology, flow hydraulics, and large woody debris (LWD) distribution in a high-energy channel reach under variable flow conditions.

## **Geomorphology and interaction river-sea changes after construction of large dams in Sao Francisco river, Brazil**

*DA SILVEIRA FONTES L.(1), LATRUBESSE E.M.(2), STEVAUX J.C.(3)*

*(1) Universidade Federal de Sergipe, ARACAJU-SERGIPE, BRAZIL ; (2) University Texas, AUSTIN, UNITED STATES ; (3) UNESP Universidade Estadual de São Paulo, RIO CLARO, BRAZIL*

The lower course of the river São Francisco, has undergone marked changes since the late 90s, with the proliferation of marginal erosion and formation of new sandy bars in the channel. The region of the mouth, in the Atlantic Ocean, has been subjected to an episode of severe coastal erosion, promoting the complete destruction of the Cabeço village. Moreover, since the '70s has been promoted to regularization of river flows by building a cascade of large dams upstream. An investigation was conducted to verify the role played by anthropogenic interventions in hydro-sedimentological fluvial regime and the outbreak of changes in river and coastal dynamics. The initial step was to understand the natural dynamics of the river system, with the identification of geomorphological controls, geological, climatic, hydrological and fluvial geomorphologic compartments. Then, we performed a comparative analysis between the multitemporal periods pre-and post-dam, with identification of changes in the morphological features in the river channel, floodplain, shoreline and bar mouth. Geomorphological changes observed were compared with changes in hydro-sedimentological regime promoted by the construction and operation of large dams. The natural river regime was characterized by large annual floods and high sediment transport and river in the new situation regularized occurred a drastic reduction in peak flows, elimination of annual floods and 94% reduction in sediment delivery to the ocean. After construction of the dam Xingó in 1994, outbreaks occurred proliferation of marginal erosion and, in the region of the mouth, there is a continual retreat of the shoreline and the mouth bar migrated south, accompanied by the inflection of the underwater extension of the river channel. The episodes identified in the coastal zone were confronted with changes in regime hydro-allowing fluvial sedimentological evidence of the role played by large dams on the changes underway.

\*\*\*\*\*

## **Poster presentations:**

### **Oscillation of River Ganges through time and its predicting tendency for vulnerability analysis with Remote Sensing and GIS**

*LAHA C., BANDYOPADHYAY S.*

*Department of Geography, University of Calcutta, KOLKATA, INDIA*

Ganga river bank erosion has been a long lasting chronic problem since remote past in West Bengal, India. She changes her path so frequently, that bank erosion, land loss generating a huge mass of refugees as well as administrative boundary problem come up as a devastating natural hazard. From the imprints of ancient river channel e.g. meander scars, buried channels, meander scrolls, it can be seen that, since historical times, the river continued to swing within its playfield in between Rajmahal Hard rocky terrain and Farakka Barrage, two obstructions to river flexibility. Before 1900, Ganga was flowing through GOUR, a historical site, 17 km away from present bank. Evidences say that, Up to 1929-30, river had a westward shift. But, afterword, a huge left bank shift happened every year till 2005. Around 2001, total discharge was bifurcated into three channels: Right, Central and Left channel. Among them left channel carried the maximum discharge resulting left bank failure. But after 2005, a tendency of huge sedimentation in left channel has been observed which gives an indication to the returning tendency of 1977 river course. The river has been swinging within its playfield from ancient time and by analyzing changing mid channel characteristics, we can predict a upcoming river course associated with vulnerable zone identification to help the management to take preventive measures. So, this study enlightens the mitigation to the geomorphic hazard with the help of space technology to step forward towards the solution of human problems.

Key-words: River course change, bank erosion, land lost, mid-channel, sedimentation, mitigation.

## **Geomorphology and Ecosystem Based Management of Tropical Montane Streams in Puerto Rico**

SCATENA F.

*University of Pennsylvania, PHILADELPHIA, UNITED STATES*

This paper synthesizes recent geomorphic and ecological studies conducted on streams in NE Puerto Rico. These stream drain land uses that range from old growth tropical forests to high density urban areas and are characterized by frequent high magnitude flows, boulder and bedrock lined substrates, and diadromous aquatic life. Geomorphic studies indicate the streams are supply limited with respect to sediment, and that hydrogeomorphic riparian features can be used to identify active channel boundaries that occur at constant flow frequencies. After decades of urban development, the morphologic changes that occur in response to urban runoff are less in these channels that are already subject to frequent large magnitude storms. Studies of species distributions also indicate that aquatic communities are resistant to urbanization as aquatic diversity in urban areas can be comparable or higher than streams in adjacent mature forests. Geomorphic migratory barriers do influence species distribution and maintaining baseflow and migratory pathways is critical in developing ecological flow requirements for these streams. Although their morphology, hydrology, and ecology have distinctive characteristics, the streams do not appear to have diagnostic landforms that can be solely attributed to their low-latitude locations. An emerging view is that their morphology and dynamics results from a combination of high rates of weathering and a high frequency of significant geomorphic events rather than the absolute magnitudes of individual floods. Their bedrock reaches and immobile boulders combined with their ability to transport finer-grained sediment suggest that they are relatively resistant to environmental change. However the restorative processes in these systems may be less responsive than in other fluvial systems.

\*\*\*\*\*

## **Petrified wood as a tracer of the Mekong River palaeo-course**

MESHKOVA L., CARLING P.

*University of Southampton, SOUTHAMPTON, UNITED KINGDOM*

Investigations of Quaternary terraces of the Mekong River in north-east Cambodia have clarified the nature of the sedimentary profile of the river development during the last 700000 years. However, doubt remains as to former courses of the river during the Quaternary. For example, it has been suggested that the Mekong in Laos diverted to the east and flowed around the Bolovens Plateau via the "Saravan loop" in contrast to the present day north-south river course which demarcates the international boundary between Laos and Thailand before the Mekong enters Cambodia. The river is believed to have abandoned the southern direct route when it was blocked by Neogene-Quaternary basalt flows emanating from the Bolovens Plateau, only to reoccupy the former course when the basalts were finally dissected by the river. To verify this hypothesis petrified wood has been used for the first time as a fluvial tracer. Petrified wood occurs commonly in the Mekong terraces. It also occurs as a weathering product on the surface of outcrops at numerous locations across Thailand and Laos where it can also be found in situ. Previous studies of the petrified wood demonstrate that there are two genera which are unique for each country and absent in another. This geographical differentiation in genera at outcrops allows determining the geographic origin of petrified wood found in the terraces. Computer tomography (3D) and thin sections (2D) were used to identify wood genera and show their distribution at outcrops and in ancient gravel. Preliminary results demonstrate that the method has promise both for use as a tracer in South East Asia but also elsewhere, as petrified wood is widely distributed across the continents and has been neglected as a potential indicator of river development.

### **Channel Pattern variability along the Pastaza River (Ecuador and Northern Peru)**

BERNAL I.(1), CHRISTOPHOUL F.(2), DARROZES J.(2), LARAQUE A.(2)

(1) *Escuela Politécnica Nacional, QUITO, ECUADOR* ; (2) *GET, TOULOUSE, FRANCE*

The aim of this study is to analyse the channel pattern variability and its causes within the Pastaza River. This river is born in the Ecuadorian Western Cordillera (from the confluence of the Patate and Chambo rivers) and flows down into the Marañón River in the Peruvian Amazonia. Along the Pastaza River (in a reach 431 Km long) the geologic, geomorphologic and hydro climatic conditions change dramatically. These particular conditions mean that phenomenon like channel pattern could have different causes depending on the setup of every area. Changes in channel pattern appear to be controlled by 1) upstream, due to its passage around active tectonic structures, and 2) downstream, where tectonic influence diminishes and factors controlling channel pattern are more correlated with the lithology, low slope and aggradation processes. Moreover the configuration of the Pastaza River floodplains show an anastomosed system that was formed by full avulsion. These processes occurred in the anastomosed system area since the Plio-Quaternary and their trace reinforces the idea of the main western shift of the Pastaza River.

\*\*\*\*\*

### **Floods of the Mekong at Chiang Saen, northern Thailand: Archaeological and OSL dating of large floods**

WOOD S.H.(1), ZIEGLER A.D.(2), RITTENOUR T.M.(3)

(1) *Geosciences, Boise State University, BOISE, IDAHO, UNITED STATES* ; (2) *Geography, National University of Singapore, SINGAPORE, SINGAPORE* ; (3) *Geology, Utah State University, LOGAN, UTAH, UNITED STATES*

Floodplain sediment, 1.5-m thick, buries AD 14-15<sup>th</sup> C brick temple ruins and cultural layers on the Laos floodplain of the Mekong, across from Chiang Saen Noi. Dark soil layers separating three flood-sediment layers suggest the soils developed on sediment layers deposited by large floods. The upper flood layer was probably deposited by the September, 1966 flood that inundated Chiang Saen city to a depth of three meters, with maximum gage height reaching 13.82 m, and peak flow of 23,500 m<sup>3</sup>/s. In comparison, the depth of the August 2008 flood in the flood plain at the sample site was about 1.3-m: maximum gage height was 10.57 m and peak flow ~15,000 m<sup>3</sup>/s. Although stage was at least 10 m for three days, the event did not deposit a recognizable sediment layer at the sampling site.

In June 2012, during the annual low water period (stage = +2.45m at Chiang Saen), we sampled flood layers from the 11-m high Laos riverbank for single-grain quartz OSL dating. The top of the riverbank is equivalent to a river stage of 13.45 m. The floodplain, extending about 1 km to either side of the channel, presumably accumulates 0.35-0.6m thick sediment layers during infrequent large overbank floods that inundate the plain 3-4m deep.

On the Thai side are the ruins of Chiang Saen Noi, founded in AD 1329 on similar banks about 10-m above low water (described by Wood et al., 2008, *Geomorphology*, 101, 510-523). Subsequently we obtained small-aliquot quartz SAR OSL ages on floodplain silt 4-7-m deep of 4,750 ± 260, and 5,600 ± 310 years. Thus, this site began accumulating floodplain silt over bedload gravel of the former channel about 5,000 years ago. No clear flood layers occur in the surficial 0.5-m thick AD 14-15<sup>th</sup> C cultural layer. The new Laos site is the best paleoflood record discovered to date for the upper Mekong River. Once dated, the stratigraphy will provide a better understanding of the frequency of large floods on the Mekong.

### **Morphodynamics of the Brahmaputra River in upper Assam, India using a GIS based approach**

SINHA R.(1), LAHIRI S.(2)

(1) Indian Institute of Technology Kanpur , KANPUR, INDIA ; (2) Indian Institute of Technology Kanpur, KANPUR, INDIA

Among the large tropical rivers of the world, the Brahmaputra has undergone significant spatio-temporal changes in its planform and interchannel geometry over a time span as short as ninety plus years. Three major rivers of the eastern Himalayas namely, the Lohit, the Dibang, and the Siang meet in the extreme NE part of India to form the Brahmaputra River. A 240 km long stretch of the Brahmaputra River extending from its 1915 confluence point at Kobo to the end of the old Majuli Island was divided into three units on the basis of the presence of exceptionally large river islands termed locally as the 'Majuli' (means land locked between two rivers). Majuli Islands differ from other sandbars in the sense that the latter develops directly as the consequence of the sediment load redistribution whereas the former represents older floodplains now incorporated within channel belt due to anabranching or avulsion. Formation of Majuli-like landforms is thus a part of river dynamics that might be related either purely to the variability in the sediment dispersal pattern or neotectonic influences and or interplay of both. This paper focuses on understanding the nature and causal factors of bankline shift and channel belt width variation and their interrelationships. It was observed that during 1915-2005, the Brahmaputra River banks made overall positive excursions causing thereby continuous widening of the river. Both units 1 and 3 represent major sites of aggradation. However, the site of aggradation seems to be switching lately from unit 1 to 3. The variability in the widths of the channel belt seems to be controlled by bankline shift on either side. We have also done a trend analysis of the bankline shift (cycles/unit length), which provided us a scheme of classifying the nature of *forcings* operational in shaping the bankline.

\*\*\*\*\*

### **Continental-Scale Morphometric Analysis of Andean Basins**

BEAN R., LATRUBESSE E.

The University of Texas at Austin, AUSTIN, TX, UNITED STATES

Presently there are no regional-scale morphometric analyses of Andean fluvial basins. Therefore, we created a continental-scale database of these basins. Morphometric parameters such as the circularity ratio, hypsometric integral, slope, relief index, longitudinal profiles and measures of basin concavity were calculated based on a SRTM terrain model (90 m resolution). Thus we gain insight into differences among basins based on present-day conditions, which gives a better understanding of the tectonic evolution of the Andean basins. Further, we demonstrate how the database provides a platform that can integrate other data such as lithology, soils, vegetation, and climate for studies that link geomorphic structure to hydrologic and ecologic function.

**The Ucamara depression, Peruvian Amazonia: Quaternary fluvial record and present day hydro-sedimentological dynamics**

BEAN R.(1), LATRUBESSE E.(1), STEVAUX J.(2), ABAD J.(3)

*(1) The University of Texas at Austin, AUSTIN, TX, UNITED STATES ; (2) UNESP, Department of Geosciences, RIO CLARO, BRAZIL ; (3) The University of Pittsburgh, Department of civil and Environmental Engineering, PITTSBURGH, PA, UNITED STATES*

The Ucamara Depression is the largest wetland system in the Peruvian Amazon. Located in-between the Ucayali and Marañón Rivers, which are part of the Andean foreland basin, the study area is over 100,000 km<sup>2</sup> in size. We investigate the Quaternary fluvial record using remote sensing and fieldwork including coring and dating of sediment to ground reference. A Quaternary geomorphologic map of the basin, was generated.

The area has acted as a sink during part of the Pleistocene and perhaps, during part of the Holocene. Remote sensing analysis allowed us to assess the present day fluxes of sediment from the major rivers draining into the Ucamara depression.

\*\*\*\*\*

**Fluvial morphometric analysis of the Pardo River basin (SP-MG, Brazil) and morphotectonic inferences**

CELARINO A.(1), LATRUBESSE E.(2), LADEIRA F.(3)

*(1) Unicamp/University of Texas, CAMPINAS, BRAZIL ; (2) University of Texas, AUSTIN, UNITED STATES ; (3) Unicamp, CAMPINAS, BRAZIL*

The Pardo river basin in Brazil, has a drainage area of 17752km<sup>2</sup>, flowing from the Mantiqueira ridge in Minas Gerais state to its mouth at the Grande river. The Pardo River flows on both ancient bedrocks and on younger sedimentary bedrocks. The river basin was studied using morphometric parameters from forty five topographic sheets and Arcmap software. The aim was to identify drainage anomalies and connect them with neotectonic movements in the entire river basin, as the most of the previous work in this area is concentrated in specific compartments, mainly the upper Pardo. A longitudinal profile and tens more on its larger tributaries, drainage density analysis and stream gradient index were carried out. For drainage density analysis, seventy sub-basins were selected in order to make an interpolated map using the Kriging method. For stream gradient index, the fifty larger streams including the main river were selected. Indices were measured per drainage segment in order to interpolate by kriging. The results suggest that both that the identified anomalies on stream profile analyses and on stream gradient index come from right side of the main river, towards Brazilian crystalline bedrocks, as well as the main geological lineaments. Some of these anomalous features were: channel migration, structural control of drainage and rapids. These features are linked with recent reactivation of ancient shear structures of Ouro Fino and Campo do Meio, Cabo Frio tectonic seismic and passive lineaments at the border of Paraná Basin sedimentary rocks and crystalline bedrocks. Meanwhile, the drainage density analysis results are better correlated with soil types founded in different sectors, as a result of the influence of the rock types on soils.

## Historical Evaluation of the distribution of PAHs in samples from lakes in Southern Brazil

VIEIRA L.(1), FROEHNER S.J.(2), COUTO E.V.(2)

(1) Federal of Parana Technical Federal University, CURITIBA, BRAZIL ; (2) Federal of Paraná Federal University, CURITIBA, BRAZIL

The development and growth of humanity also brought about growth in the alterations of the quality of water and aquatic ecosystems. Some effects are visible, such as silting, hydric pollution, presence of toxic chemical compounds, eutrophication, loss of biodiversity, biomagnification of contaminants, as well as the loss of the potential of the body of water for multiple uses in a basin. In order to control the pollution of such hydric resources it is necessary to know the pollution process which caused current conditions. Within this context, it is necessary to obtain information about the past of the hydrographic basin related to the disturbances to which the environment was subjected in the past, for such information make it possible to understand the current pollution scenario within a historical context; it also assists in establishing a standard in a temporal scale. The sediments contain substances of low solubility. Among the compounds investigated which are associated with pollution processes, are the aromatic and aliphatic hydrocarbons. PAHs are compounds which are usually produced by anthropogenic activities; their formation takes place by three chemical processes: pyrolytic, petrogenic or biogenic. Due to their physical and chemical properties, PAHs hardly ever decompose within a short period of time, thus they are often found in sediment. Thus, we evaluated the distribution of PAHs in two samples taken from Igapó Lakes I and II in Londrina, State of Paraná. Greater amounts of PAHs are clearly found in the first centimeters of the sediment, while the smaller amounts are found in the deeper layers. Such behavior is typical of PAHs. Anoxic environments make biodegradation more difficult, thus it is possible to associate their distribution with past events, such as the removal of organic matter or debris by burning, which was very common at the beginning of the occupation of this region.

Keywords: PAHs, Igapó Lakes, biomarkers, sediments.

\*\*\*\*\*

## Tropical erosion: the story of Panama

SOSA-GONZALEZ V.(1), BIERMAN P.R.(1), NICHOLS .K.K.(2), ROOD D.H.(3)

(1) University of Vermont, BURLINGTON, UNITED STATES ; (2) Skidmore College, SARATOGA SPRINGS, UNITED STATES ; (3) University of Glasgow, EAST KILBRIDE, UNITED KINGDOM

Background erosion rates place human-induced erosion in context and are necessary for evaluating, regulating and remediating human impacts on erosion. This study presents the first broad quantification of background erosion rates in Panama and relates these to landscape variables including climate, seismicity, landuse, rock-type, and topography.

Using measurements of *in situ*  $^{10}\text{Be}$  in river sand, we calculated erosion rates for 40 watersheds (14 to 2410 km<sup>2</sup>). 44 variables were quantified for each watershed to assess their relationship to erosion rates using bivariate linear regression, multiple regression, and ANOVA. We used grain size analysis as well as sampling up and downstream of a landslide to assess the impact of landslides on calculated erosion rates.

$^{10}\text{Be}$ -inferred erosion rates ranged from 26 to 600 m/Myr. The strongest and most significant relationship is between erosion rate and silicate weathering rate, the mass of material leaving the basin in solution. None of the physiographic variables showed a significant relationship with erosion rate at the 95% level. The relationship between erosion rates and seismicity varied with quake distance from the watershed and average quake depth.  $^{10}\text{Be}$  concentration and grain size were inversely related in landslide samples. Landslide material has lower  $^{10}\text{Be}$  concentration than stream sediments.

Erosion rates in Panama are higher than other published  $^{10}\text{Be}$ -derived erosion rates in tropical climates – including those from Puerto Rico, Madagascar and Sri Lanka – likely the result of Panama's active tectonic setting. Although many cosmogenic studies have concluded that physiography controls erosion, Panamanian data are unique because they show little if any relationship between erosion rates and landscape-scale variables. We speculate that controls on erosion in humid, tropical climates are more complex than those elsewhere in the world – perhaps the result of widespread landsliding.

### **Channel morphology and morphodynamics of the Madeira River in Brazil**

BONTHIUS C.(1), LATRUBESSE E.(1), ABAD J.(2), STEVAUX J.(3), FILIZOLA N.(4), AQUINO S.(1)

(1) *Department of Geography and the Environment, The University of Texas at Austin, AUSTIN, UNITED STATES* ; (2) *Department of Civil and Environmental Engineering, The University of Pittsburgh, PITTSBURGH, UNITED STATES* ; (3) *Geosciences, UNESP-Rio Claro and Maringa State University, MARINGA, BRAZIL* ; (4) *Department of Geography, Universidade Federal do Amazonas, MANAUS, BRAZIL*

Severely understudied and poorly understood, the Madeira River offers the opportunity to investigate the roles of geomorphologic controls and hydraulic mechanisms in large anabranching fluvial systems. The Madeira River is a mega-river and demonstrates an unusual anabranching channel pattern. The channel alternates between a single straight channel and multiple-channel structure, indicating that the river is on a geomorphic and hydraulic threshold. Three distinct channel patterns are present in the selected study reach: a single-channel meandering stretch, a box-shape meandering stretch, and an anabranching stretch with sinuous second order channels. Analyses of multi-temporal satellite and radar imagery show that the channel morphology demonstrates overall stability. The lateral movement of the channel is geologically constrained by a variety of floodplain morpho-stratigraphic Quaternary units. Large islands are persistent features in the river channel. Measurements of suspended sediment, water velocity, and bathymetry collected with an Acoustic Doppler Current Profiler (ADCP) indicate that bed and channel morphology affect hydraulic characteristics of the Madeira River and its observed channel patterns. Several cross sections present unusual deep pools in the outer bank, which might indicate geological constraints in the exaggerated depths or that water flow is preferentially downwards due to depositional patterns. Measurements of channel width in the study reach reveal a wave-like tendency to increase and decrease with the widest range of widths seen in the meandering stretch. The greatest differences in water velocity are also seen in this part. The interaction between channel width, depth, and water velocity suggest that channel pattern reflect losses and gains in water momentum through the study reach. The analyses presented here represent a synthesis of baseline conditions of the Madeira River.

\*\*\*\*\*

### **Flood flows and their Implications in Humid Tropical and Urbanised Catchments: A Case-study of the Mfoundi River (Yaounde-Cameroon)**

DZANA J.G., KUATE S.

*University of Yaounde 1, YAOUNDE, CAMEROON*

Hydro-geomorphic effects that are induced by flood flows through the channel/floodplain complex of the Mfoundi River –considered as an archetype of humid tropical urban hydrosystems– have been examined.

Channel movement initiated by sub- to bankfull discharges have been documented by comparing three sets of cross-sectional survey data collected at the reach scale and by computing volumes of sediment eroded and deposited. Although the overall cross-sectional adjustments may appear minor for the studied river, they are more significant for sites that are located downstream from major tributaries. A detailed analysis along studied reaches has permitted to realise that there is a juxtaposition of flow sections alternatively marked by channel dilatation, stability and contraction.

Field investigations on floodplain inundation, overbank deposition and its associated sediment transporting mechanisms, have provided evidence permitting to analyse and interpret the movement and action of floodwaters beyond the channel compartment. The inundation maps reveal that the processes, extent and patterns of flooding are determined by the morphology of the alluvial plain. The floodplain accretion reflects this topographical variability, with the highest rates (0.27-0.62 kg m<sup>-2</sup>) recorded within proximal depressions. The CM image of the overbank deposits shows that the Mfoundi River is competent enough to transport and deposit sandy material onto the floodplain surface as graded and uniform suspensions. This reflects conditions where the supply in fine-grained material is strictly limited.

### **Late Quaternary shifts in drainage morphology in the Demini River area, northern Amazonia: paleoenvironmental implications**

CREMON E.(1), ROSSETTI D.(2), ZANI H.(2)

(1) *Brazilian National Institute for Space Research, SAO JOSE DOS CAMPOS, BRAZIL* ; (2) *Brazilian National Institute for Space Research, S?O JOS? DOS CAMPOS, BRAZIL*

The morphological characterization of megafans is an issue still under development. Due to the wide extent (> 1000 km<sup>2</sup>), this depositional system has been described mostly with basis on remote sensing data. A set of megafans has been recently recognized in association with late Quaternary deposits of a tropical humid area of northern Amazonia. In the present work, we provide a geomorphological characterization of one of these megafans, known as the Demini megafan, which is the largest one in that region. Our morphological study was based on topographic characterization derived from the digital elevation model (DEM) provided by the Shuttle Radar Topography Mission-SRTM. Color composite TM/Landsat-5 images recording different hydrological periods were used additionally with the SRTM data. The topographic characterization was performed using trend surface analysis considering only areas of the megafan morphology that display open vegetation and bare soil to avoid the influence of tree height. The results showed that the study area displays concentric contour lines that are distributed radially from upstream to downstream, with a slope of 0.008°. The Demini River, which is the main river currently present in the area, flows through a confined meander belt ~5m below the average surface. This modern drainage is dissectional, being constituted by a series of tributaries, with the main river flowing southeastward into the Negro River. In contrast, the paleodrainage is composed of elongated and sinuous belts that define an older branched network with a distributary pattern. This type of paleodrainage morphology is typical of braided megafans. This suggests a significant change in the landscape of this region during the late Quaternary. A detailed morphological analysis might provide the basis to discuss the main factor that led to this drastic shift from distributary to tributary drainage in this area.

\*\*\*\*\*

### **Characteristics of the Solimões-Amazon River bed: implication of neotectonics**

FRANZINELLI E., IGREJA H.

*Federal University of Amazonas - UFAM, MANAUS, BRAZIL*

The more frequent depth of the Solimões-Amazonas River bed is around 30 meters, but an analysis of the bathymetrical data related in the Brazilian Navy nautical charts from Iquitos (Peru) to Macapá, on the Amazon mouth, shows the occurrence of holes irregularly scattered along the channel of the river. These holes are more frequent in the central part of the Amazon Basin. They have variable depths (up to 100 meters), lengths (up to 30 km) and common trends NW/SE or NE/SW, rarely N/S or E/W. In general they are parallel to the "Barreiras Vermelhas", outcrops of the Alter do Chão, Solimões-Pebas and Barreiras Formations, cretaceous and tertiary geological unities that form the floor of the quaternary alluvial plain and sometimes the bed and the banks of the Amazon. The origin of these holes is attributed to the actions of neotectonics since the channel of the Amazon is located in a belt submitted to expressive neotectonic movements. In this paper we show some configurations originated by neotectonics in the Amazon plain coinciding with the holes in the bed of the river to justify their origin.

Keywords: Solimões-Amazon River, Channel bed, Neotectonics

## **Processes, forms and rates of floodplain building in a large South American river: the Middle Paraná River, Argentina**

RAMONELL C.(1), LATRUBESSE E.M.(2)

(1) *Facultad de Ing. y Cs. Hídricas - Universidad Nacional del Litoral, SANTA FE, ARGENTINA* ; (2) *Dept. of Geography and the Environment, University of Texas at Austin, AUSTIN, UNITED STATES*

The Middle Paraná River (mean discharge: 17,100 m<sup>3</sup>/s) flows with an anabranching pattern along ca. 800 km downstream the junction with the Paraguay River (27°17'S). Its floodplain extends over 20,000 km<sup>2</sup>, with large areas without sediments occupied by minor and large lakes. The main channel (effective width: 1500 m), major secondary branches (ca. 200 to 500 m-width), and deltaic splays accounts for the most of the present morphodynamics in the river.

The main channel has a sinuous to meandering thalweg. By means of thalweg shifts and cut-offs, and bar and island formation, the main channel swept a belt similar to its width in the last century, with mean shift rates of dozens m/year or higher. Submerged sandy bars have linguoid shapes, evolving to more diverse and complex forms when emerge. Emerged bars are transformed in entirely vegetated (and higher) islands in few years.

Secondary branches are straights or meanderings, with shift rates ranging between 1m/year and 25 m/year. Exceptionally, some of them formed alluvial belts of few kilometres-width in the last 100 years, by avulsions. Typical forms in these branches are scrolls bars and "within-channel levees" (a new-recognized fluvial form likes to natural levees, but formed inside channels below the bankfull levels).

Deltaic splays prograde in the floodplain lakes or in abandoned tracts of the main channel. These forms become very active during the last 30 years following the occurrence of large floods; expansion rates up to several hundreds of m/year were measured in some of them. Singular geomorphic processes, such as formation of deep scour holes (up to 20 m depth) and sedimentation downstream were detected in the deltaic splay channels.

The vertical accretion of fine sediments in the floodplain is small, although reach local rates in the order of cm/year or dm/year near of the major channels. It is noticeable the high variability of these siltation, even in short distances of a same geomorphic unit.

\*\*\*\*\*

## **Renaturalization of streams and rivers - Institutional arrangements in Urban Planning and Flood Mitigation**

LINDOSO T., QUINTELA M.F., MIGUEZ M.

*Universidade Federal do Rio de Janeiro, RIO DE JANEIRO, BRAZIL*

The Brazilian legislation of the 60's and 70's decades of the past century, encouraged the occupation of wetlands and riparian areas. In urban areas, the public administration encouraged the canalization of rivers. Nowadays, the disastrous results of these works are visible and have their damages multiplied, due to the demographic explosion in urban centers in the last decades.

The overall objective of this work is to present the relationship between the Teresópolis Mayor's Department of Environment (SMMA), as the executing agency, the State Public Ministry (as the intervener) and the property owners of an watershed of approximately 1.4 ha, involved in the issue of inappropriate land use and occupation, in order to implement corrective and preventive actions, aiming to minimize the problems resulting from the numerous interferences in natural water flows, such as landfills of lowlands and canalization of the river.

This area has been chosen to implement a pioneer project for Teresópolis in order to reverse the environmental degradation. This project is based on the diagnosis of the watershed and the identification of past interferences in the natural drainage system and their negative impacts. The diagnosis of the flood situation was supported by a mathematical model, called MODCEL, developed in order to allow simulations of many hydraulic processes that interfere mainly with the quantity of water in the watershed. The design of this model assumes that a watershed can be divided into a set of homogeneous interconnected compartments which cover the watershed plan in an arrangement capable of reproducing the flow patterns.

The following solutions were proposed by SMMA: the construction of a detention basin with controlled output flow, the renaturalization of the river, the partial recovery of the marsh that once existed and the increase of permeable area. Each owner takes part in proposed activities, based on the damage arising from his property.

### **Geomorphological-ecological-sedimentological evolution of Chuksar Island, Hugly estuary, India: a neoichnological approach**

CHAKRABORTY A.

Jogamaya Devi College, KOLKATA, INDIA

Dynamic control of geomorphological, ecological and sedimentation processes on coastline evolution has been studied in Chuksar Island (N21.5676°-21.5784/ EN88.0128°-88.0272°), outer Hugly Estuary, India, since 2008 based on sediment-animal interactions *in space and time*. Neoichnological record preserved in soft sediments reflects impacts of net loss in substrate relief and concomitant occurrences of repeated storm events with occasional reversals in sedimentation. A gradual replacement of *Psilonichnus* ichnofacies by *Skolithos-Cruziana* transitional ichnofacies in this intertidal part of north-ward advancing macrotidal sand ridge is consistent with the inferred high stand system tract, at least on a localized scale, as inferred from sedimentological and geomorphological observations. Anthropogenic interferences through sediment dredging-dumping in the adjacent Haldia Port area is predicted to have a substantial contribution influencing the natural sediment dispersal system in the vicinity of this dynamic regime of sedimentation.

\*\*\*\*\*

### **Impacts of rainforest disturbance and conversion to oil palm on large river catchments in Borneo: evidence from sediment fingerprinting and long-term monitoring**

WALSH R.(1), ANNAMMALA K.V.(2), NAINAR A.(2), BLAKE W.H.(3), BIDIN K.(2), DOUGLAS I.(4)

(1) Department of Geography, Swansea University, SWANSEA, UNITED KINGDOM ; (2) School of Science and Technology, Universiti Malaysia Sabah, KOTA KINABALU, MALAYSIA ; (3) School of Geography, Earth and Environmental Science, Plymouth University, PLYMOUTH, UNITED KINGDOM ; (4) Manchester University, MANCHESTER, UNITED KINGDOM

This poster presents results of studies into the downstream consequences of upstream rainforest logging and land-use change (chiefly conversion to oil palm plantations) in some large river catchments (notably the Segama, Brantian and Kalabakan basins) in Sabah (Malaysian Borneo). These downstream consequences include enhanced suspended sediment transport, sedimentation, channel change, river pollution and flooding. This paper uses a multi-proxy sediment fingerprinting approach to reconstruct changes over the past 50 years in sedimentation rate and the relative contributions of different sub-catchments to the downstream sediment budget of the large Segama catchment in eastern Sabah. The catchment has been subject since the 1970s to rotational selective logging and conversion of part of the lower catchment to oil palm plantations. Downstream evidence is derived from a 1.6 m deep sediment core on a high lateral bench protected by a bankside tree on the Lower Segama. Bed-sediment samples were taken from channel-margin sites at low flow for the major upstream tributary catchments (the hypothesized sediment sources) of the Segama. All sediment samples, both from the Lower Segama pit and the upstream sub-catchments, were dried and sieved to obtain the fine (<63<sub>μ</sub>m), inferred suspended sediment fraction and analysed using a portable Niton XRF elemental analyser to obtain the elemental composition. Distinct down-profile changes in individual elements are evident and some of these are related to distinctive geochemical signatures of upstream tributaries, allowing changes in their relative contributions to the downstream sediment budget through time to be inferred. Finally monitoring evidence of the impact of logging and conversion to oil palm on suspended sediment transport and river pollution is also presented for the Brantian and Kalabakan catchments.

**The influence of standards morphometric on changes in the levels of water in Madeira Basin - Brazil: an assessment of damages under extreme conditions hydrological**

MUNIZ L.(1), FILIZOLA N.(1), FRAIZY P.(2), MELO E.(3)

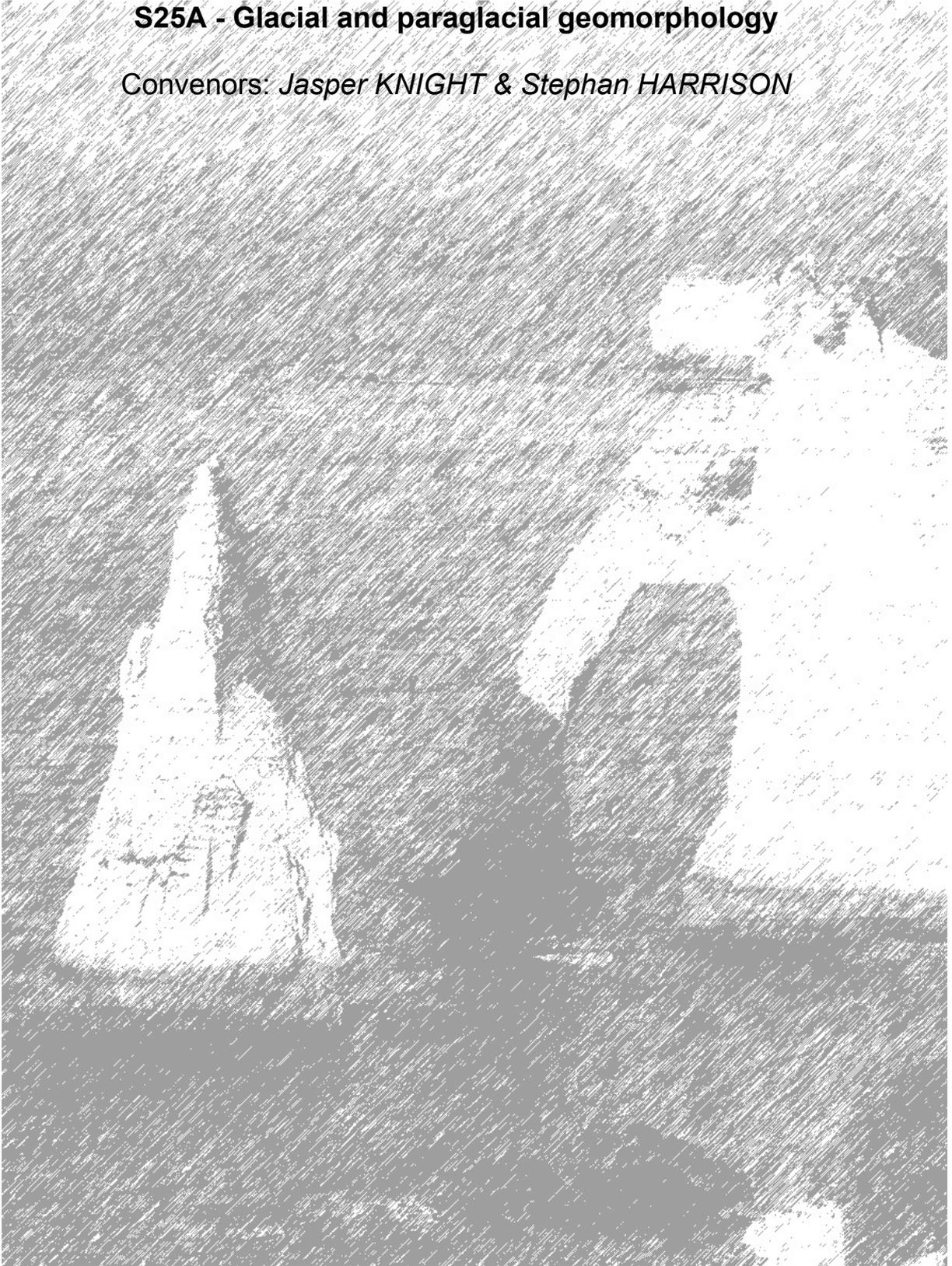
*(1) Universidade Federal do Amazonas, MANAUS - AM, BRAZIL ; (2) Institut de Recherche pour le D'veloppement, MANAUS, BRAZIL ; (3) Pós-graduação em Clima e Ambiente - INPA/EUA, MANAUS, BRAZIL*

This study presents an analysis of the spread and variation of water level in extreme hydrological events (droughts and floods) through a comparison between the morphometric parameters of sub-basins and patterns of variability fluvioimetric. The study area is the Madeira River Basin (in the Brazilian portion), whose main river is the largest tributary of the Amazon River on its right. This basin covers an area of almost 1.4 million km<sup>2</sup>, which represents 23% of the entire area of the Amazon basin, involving portions of three South American countries: Bolivia, Brazil and Peru, is a huge drainage network only in Brazil occupies 671,841.648 km<sup>2</sup>. The authors use data from hydrological stations of the National Water Agency - ANA ([www.ana.gov.br](http://www.ana.gov.br)) and the Center for Environmental Hydrology and Geochemistry of the Amazon Basin Geodynamics - ORE / HYBAM ([www.orehybam.org](http://www.orehybam.org)) the historical period analysis is 30 years, and especially under extreme hydro-year events. The SRTM images available on the home page of the Brazilian Agricultural Research Corporation - EMBRAPA ([www.relevobr.cnpm.embrapa.br](http://www.relevobr.cnpm.embrapa.br)) were the basis of the mosaic to obtain morphometric parameters extracted using GIS' tools. The results of hydrological variability on the basis described above were also compared with reports of assessing damage from Civil National Defense Database ([www.defesacivil.gov.br](http://www.defesacivil.gov.br)). This type of analysis is being conducted to understand the dynamics of extreme events. This result is part of baseline studies for future comparisons with new patterns of taxes Madeira River Basin due to construction of two reservoirs for hydroelectric plants under construction on the Madeira River in Brazil.

\*\*\*\*\*

**S25A - Glacial and paraglacial geomorphology**

Convenors: *Jasper KNIGHT & Stephan HARRISON*





## **Oral presentations:**

### **Glaciers, rock avalanches and 'the buzzsaw' in cirque development**

EVANS I.

*Durham University, DURHAM CITY, UNITED KINGDOM*

The close relation between cirques and climate is convincing evidence of the dominance of glacial erosion, rather than rock avalanching, in mountain cirque development and distribution. Cirque floor altitudes have a lower limit that varies with snowfall by 1000 m or more between windward and leeward sides of mountain systems. Glaciation Levels and Equilibrium Line Altitudes implied by cirques vary in parallel with those for modern glaciers. Cirques are often found mainly on the poleward or leeward slopes of individual mountain ranges, as are modern small glaciers (because of solar radiation and wind effects on ablation and accumulation).

The 'overdeepening' (rock basins with reversed slopes) found in a large minority of cirques cannot be due to rock avalanching, fluvial or periglacial erosion. Degree of cirque development can be related to duration of exposure to glaciation. Scars from rock avalanches may resemble poor or moderately developed cirques, but tend to be more scattered and closely related to geology, whereas glacial cirques develop on all rock types. Often rock slope failures are found adjacent to cirques, or in glacial transfluences; only a proportion are well situated to develop into glacial cirques.

The proposal that most cirques are "source-area depressions of large, deep-seated rock slope failures" should therefore be rejected, in favour of the traditional glacial explanation. Rock slope failure is an ancillary process of cirque extension or widening through collapse of glacially-oversteepened slopes.

Headward extension of adjacent cirques on a ridge leads to displacement of the divide, sometimes by 1 or 2 km. When a relatively lower snowline has led to cirque erosion on all sides of a mountain, cirque intersection lowers ridge altitudes; the so-called 'buzzsaw' effect. The buzz-saw hypothesis is not applicable, however, where remnants of a preglacial summit surface survive.

\*\*\*\*\*

### **Glacial and paraglacial dynamics inside glacial cirques. A 3D morphometric analysis**

VALCARCEL M., OTERO-OTERO M., MARTÍNEZ-CORTIZAS A., BLANCO-CHAO R.

*Universidade de Santiago de Compostela, SANTIAGO DE COMPOSTELA, SPAIN*

We studied the geomorphology and morphometry of 93 glacial cirques in Ancares mountains, in the NW of the Iberian Peninsula. We propose a paraglacial morphodynamic evolution that explains the geomorphology during and after the glacial stages.

The cirques were classified in those cirques with no evidences of periglacial activity (type I) and those cirques with two sections; one covered by periglacial deposits or rock glaciers, and one with evidences of glacial overdeepening (type II). The perimeter of the cirques was digitized from topography, orthophotos and field data for reference. Slope and aspect were calculated from a Digital Elevation Model with a pixel size of 5 m. The mean, maximum and minimum values of elevation and slope were extracted for each cirque. The aspect directions were classified in classes of 22.5 degrees. The total area for each aspect class was calculated and the frequency expressed as percentage of the total area of the cirque. The mean orientation of each cirque was calculated in a spreadsheet taking each direction as a vector with a module equal to the corresponding percentage of the area of the cirque. The results gave a mean orientation of 103° for cirques type I and of 33° for the type II. Those sections of cirques of type II that were subjected to glacial overdeepening has a mean orientation of 54.36°, meanwhile the areas covered by slope deposits of periglacial origin and/or rock glaciers the mean orientation is of 340°.

The analysis reveals that those cirques with a complex evolution show a glacial dynamic in the sides of the cirque with a NE orientation and paraglacial in the sides with a NW orientation. The sides oriented to the NW are characterized by steep rock slopes that under cold, but not glacial, conditions favoured the development of rock glaciers or thick slope deposits at elevations close to the ELA. Those conditions existed inside the studied cirques and support the paraglacial control of the landform evolution.

### **Geomatics techniques applied to the rock glaciers, glaciers and ice-patches in Spain (1991-2012)**

BERENQUER F.(1), JOSÉ JUAN DE SANJOSÉ BLASCO J.J.(2), ATKINSON GORDO A.(2), DE MATIAS J.(2), SERRANO E.(3), RICO I.(4)

(1) UNEX, CACERES, SPAIN ; (2) UNEX, CACERES, SPAIN ; (3) UVA, VALLADOLID, SPAIN ; (4) UPV, VITORIA, SPAIN

Nowadays there are several types of geomatic techniques, terrestrial (total station, GPS, close-range photogrammetry, scanning laser) or aerial (remote sensing, aerial photogrammetry, LIDAR, radar interferometer,...), for study of rock glacier dynamic. From 1991 a little research group have used some of mentioned techniques to study rock glaciers in Spain.

During these years appear new different types of geomatic instruments and several of them were used in glacier measurement: total station, terrestrial scanning laser, convergent photogrammetry and GPS. Not on all glaciers can be used all geomatic techniques, changing depending of characteristics of emplacement (cirque, valley, slope) and the ice body. In this work, it is analyzed how each instrument has limitations in some situation and why all the tools are not useful in all places.

Studied ice bodies have been Corral del Veleta rock glacier (Sierra Nevada), Argualas, Posets and Maladeta rock glaciers (Pyrenees), La Paul glacier (Pyrenees) and the ice-patches of Jou Negro and Llambrión (Picos de Europa). From 1991 to 2012 they have been surveys at different periods. The dynamic of each glacier, rock glacier and ice-patch are different depending on ice characters and geographical influences, but in each individualised geographical area the ice bodies have a homogeneous comportment.

Besides horizontal and vertical displacement surveys, detailed topographic maps, cross sections, volume and contour of glaciers are obtained. Works permits us measurements with  $\pm 3$ cm accuracy, useful precision to know the evolution and dynamic of studied ice bodies in short times.

Key words: Cartography, Geomatics, Climatic change, ice bodies dynamics.

\*\*\*\*\*

### **The role of glacial/permafrost interactions in patchy alpine landscape development**

BERTHLING I.(1), ETZELMÜLLER B.(2)

(1) Norwegian University of Science and Technology, Department of Geography, TRONDHEIM, NORWAY ; (2) Department of Geosciences, University of Oslo, OSLO, NORWAY

Alpine landforms shaped by cirque and valley glaciers are prominent features in southern Norway. In many areas, landforms from these glaciers are well developed, while they are lacking in others. In southern Norway, we observe a gradient of the degree of such alpine glacier imprint, with only a slight imprint in the eastern parts towards a fully alpine landscape further west. In some areas, the alpine landscape coexists with pre-glacial surfaces that remained untouched by glacial erosion, mainly in areas close to or above the present mountain permafrost limit in the central parts of southern Norway. In these areas blockfields consisting of weathering material of pre-glacial or periglacial origin has been left more or less intact even if southern Norway was repeatedly covered by Quaternary inland ice sheets. This pattern has been attributed to cold based ice, preserving subglacial ground cover. One paradox remains in this explanation: if cold-based ice sheets protected pre-glacial surfaces and sediments, why did they not protect the sedimentary landforms formed by these cirque and valley glacier systems? No lateral and terminal moraines in cirques and alpine valleys in these areas have been found to be of pre-Holocene age. A likely scenario is that as the inland ice sheets grew, the moraine systems and sediments in front of former cirque and valley glaciers were incorporated into the basal ice of the ice sheet and exported, while neighbouring areas were left untouched. Permafrost/glacier interactions may be a key factor for an explanation of such a scenario. Ground ice within the glacial forefield, especially within ice-cored moraines, will respond to the stress of a growing glacier above it by deformation, which may cause large-scale sediment deformation and also sediment export; while the coarse-grained neighbouring blockfields may contain ground ice amounts too small to render this surface liable to subglacial deformation.

### **Glacial and periglacial erosion rate inferred from five years of detrital flux monitoring (Bossons stream, Mont-Blanc massif, France)**

GUILLOH H.(1), GODON C.(1), GOUPY B.(2), POHL A.(2), BUONCRISTIANI J.F.(2), MUGNIER J.L.(1)  
(1) *ISTerre, LE BOURGET-DU-LAC, FRANCE* ; (2) *Biogéosciences, UMR/CNRS 5561, DIJON, FRANCE*

A better knowledge about present-day erosion is needed to understand the long-term relief evolution in glacial and periglacial context. The rapidly retreating glacier des Bossons was chosen to estimate the sediment budget in its partially glaciated watershed and thus determine the part of glacial erosion versus periglacial denudation.

Sediment budget was determined using: i) three calibrations curves – suspended load/water discharge, suspended load/turbidity and bed-load/water discharge – built through high frequency sampling of water discharge and turbidity since 2009; ii) annual DGPS measurements of elevation evolution; iii) transit time for coarse particles given by radio-frequency monitoring of 185 pebbles.

Sediments come from two reservoirs : the glacier and the lateral moraines. Both interact with a third reservoir: the alluvial area through which the subglacial Bossons stream flows and where hillslope processes provide material. Telling the difference between each sedimentary flux is allowed by determining: i) the hydrologic behaviour of the partly glaciated catchment by using the degree-day GSM-Socont model; ii) relationships between the sedimentary flux that enters in the alluvial area, the released one and the stored one; iii) granulometric and lithologic characteristics of each sedimentary source and how they mix in the river and its exported load.

Results show that i) 75% of the 4000 t/y of exported material are fine particles (silts/sands), mainly coming from lateral moraines during extreme rainy events; ii) the stored sediment volume corresponds to about 25% of the exported sediments (1000 t/y); iii) the subglacial erosion is smaller than 0.8 mm/y beneath the glacial tongue.

This combined methodology applied to the Bossons glacial and periglacial watershed demonstrates that erosion mainly concerns the recent exposed periglacial surfaces (i.e. moraines), and that subglacial erosion contributing weakly to the total exported sediment flux.

\*\*\*\*\*

### **Rock slope failure in the mountains of Europe: paraglacial-parafluvial transitions**

JARMAN D.(1), HARRISON S.(2)

(1) *mountain landform research, GLASGOW, UNITED KINGDOM* ; (2) *University of Exeter, CORNWALL CAMPUS, UNITED KINGDOM*

Rock slope failure (RSF) occurs in most mountain ranges, on hectometric to kilometric scale, and in more catastrophic to more deformational modes. Its spatial incidence is often clustered, and may indicate "concentrated erosion of bedrock" with consequent excess slope stresses inducing rebound ruptures. In the mountain ranges of Europe, RSF has been assumed to be a 'paraglacial' response to glacial erosion. Such erosion may for example be concentrated at and below breaches of recent origin or enlargement - possibly indicating later Pleistocene shifts in icesheds, ice piracy, and icestream dispersal routes.

However recent work identifies similar RSF forms in weakly or non-glaciated contexts. This is proposed as 'parafluvial' RSF. Local and regional transitions from paraglacial to parafluvial predominance suggest that the bulk of the concentrated erosion may often be fluvial. A recurring pattern associates such parafluvial RSF clusters with fluvial invasions of asymmetric divides; glacial occupation of their headwaters may only be a minor factor, influencing the cyclical occurrence of RSF rather than driving the process. Fluvial incision may also be maximised at times of climatic stress, including deglaciation. Even where significant directly parafluvial major RSF is absent, paraglacial RSF incidence can be greater on the steep side of divides, or where long-term uplift has driven fluvial reincision, preventing glacial troughs from stabilising.

This paraglacial-parafluvial spectrum is explored in the Scottish Highlands, northern England, central Alps, eastern Pyrenees, Tatra, and Carpathians. The utility of GoogleEarth imagery in systematically identifying such RSFs is examined. Although valuable in regional scoping, detection rates are variable. Groundtruthing, aided where available by high-detail conventional mapping, is usually essential.

**The Vatn landslide, Skagafjörður, northern Iceland: early Holocene dating and Holocene palaeoenvironmental reconstitution potentialities**

DECAULNE A.(1), MERCIER D.(2), COSSART E.(3), FEUILLET T.(2), JÓNSSON H.P.(4), SÆMUNDSSON Þ.(5)

(1) CNRS - Geolab, CLERMONT-FERRAND, FRANCE ; (2) Université de Nantes, CNRS Laboratoire Géolittomer-UMR 6554 LETG, NANTES, FRANCE ; (3) Université Paris 1, Laboratoire PRODIG, France, PARIS, FRANCE ; (4) Northwest Iceland Comprehensive College, SAUÐÁRKRÓKUR, ICELAND ; (5) Natural Research Centre of NW Iceland, SAUÐÁRKRÓKUR, ICELAND

The Vatn landslide is located in the Skagafjörður fjord, in northern Iceland (65°57,337'N, 19°23,900'W). Of modest size (estimated to 830,000 m<sup>3</sup>), the slide deposit exhibits a poor spatial dispersion and longitudinal runout. The morphology of the northernmost lower part of the slide shows a flat area trapped between the slide deposit and an elongated raised beach; the contact between the slide and the beach is open by a deep anthropogenic ditch.

By examining stratigraphic sections along the ditch, and opening log sections on the flat area at the slide contact and onto the slide deposit, numerous dating elements were obtained. The lower pits are rich in organic material and tephra layers (the oldest one, H4, is dated to 3,826±12 cal. yr BP), while the upper pit revealed little accumulation over the slide deposit surface, exhibiting only tephra layers separated by poor organic units.

The combination of radiometric method and geochemical analysis of the tephra layers results in a good time constrain for the landslide occurrence, before 9070±86 cal. BP and 8677±181 cal. BP (oldest tree remnants).

Such a result reinforces the hypothesis of a major paraglacial geomorphologic activity at the early Holocene time, leading to numerous slope failures following the last glacial maximum retreat. The presence of the raised beach at the lower contact with the landslide seems to indicate an occurrence later than 11,000-11,400 cal BP (intrapolated age of the raised beaches located at 22-31 m asl).

The lower pit section encompasses the full Holocene period, exhibiting a succession of organic layers and a poor accumulation in minerogenic material. Those 2 m (i) document the palaeoenvironmental settings throughout the Holocene with potentialities for palynology and diatoms analyses; (ii) shows the decoupling of slope processes triggered in the rockwall upper part from the lower slope, as during the last ca. 10000 years, no minerogenic material was archived in the lower pit sections.

\*\*\*\*\*

**Geomorphological data for the recognition of mountain areas prone to glacial-related hazards, French Alps**

GARDENT M.(1), DELINE P.(1), SCHOENEICH P.(2)

(1) EDYTEM - University of Savoie, LE BOURGET DU LAC, FRANCE ; (2) PACTE, University of Grenoble, GRENOBLE, FRANCE

Since the end of the Little Ice Age, one of the most obvious impacts of the climate change in the Alps is the glacial retreat. In this context, more hazards linked to glacial shrinkage are expected. A geomorphological approach mainly based on mapping is proposed to recognize areas that could potentially be affected by glacial hazards in the French Alps.

Geomorphological maps of proglacial margins were realized by means of field work and analysis of recent orthophotographies and old documents. Three types of geomorphic data are collected: (i) the present glacier extension, as a part of an inventory of the today French glaciers; (ii) landforms and formations (till, moraines, roches moutonnées) that record past glacier extensions, especially the Little Ice Age ones; and (iii) markers of active processes (e.g. debris-flow, glacial lake outburst flood, landslide in moraine) that inform about potential instabilities. All these data are integrated in a GIS.

Combining these geomorphic data with DEM and geological data, or with maps of the permafrost distribution, we localize areas that could be affected by glacial hazards. Automatic methods of recognition are developed through the GIS software, but additional manual work is still required.

For instance, we map areas of debris flow potential occurrence (DFPO) in proglacial margins by using simplified existing methods where slope angle and till volume are the main predisposing factors. These two factors are classified from lowest (1) to highest (3) susceptibility to debris flows, and combined to generate an index from which 3 DFPO classes (low, moderate, and high) are derived.

Another approach deals with rockfall potential occurrence. Steep rockwalls towering above a glacier can be destabilized by its shrinkage. The overlapping of glacierized bedrock and glacial extension during the LIA in the GIS defines areas that could potentially be affected by rockfall.

## **Mechanisms controlling the post-Little Ice Age evolution of paraglacial coasts in Svalbard Archipelago**

STRZELECKI M.(1), LONG A.(2), LLOYD J.(2)

*(1) 1. Department of Geography, Durham University, UK; 2. Department of Geology, UNIS, Norway; 3. Department of Cryospheric Research, AMU Poznan, Poland , DURHAM, UNITED KINGDOM ; (2) Department of Geogrphay, DURHAM, UNITED KINGDOM*

In contrast to mid and low latitude coasts, relatively little is known regarding the potential impacts of climate and sea-level change on high latitude coastal margins. Indeed, many of the existing intellectual paradigms regarding the functioning of polar coasts are now out-dated, based on descriptive geomorphology and a limited process-based understanding.

This paper aims to address this deficiency by improving our understanding of the mechanisms of recent adjustment of the High Arctic coastal zone to non-glacial conditions associated with the paraglacial period following the end of Little Ice Age.

The pristine coasts of Svalbard provide a superb opportunity to quantify how High Arctic coasts are responding to rapid climate warming. These (largely) terrestrial processes are interacting with glacio-isostatic land emergence and on-going global sea-level rise. Existing sediment budget approaches in Svalbard have focused attention on quantifying the volumes of sediment transported by glacial rivers and derived from glacier erosion and reworking of fluvial sediments. Little attention has been paid to the functioning of sediment storage and reworking systems within coastal zone

In this paper, we summarize results of several case studies carried out along paraglacial coast of Svalbard during the last decade. Research was based on the combination of methods including aerial photogrammetric and GIS analyses, sedimentological tests of coastal deposits and field-based geomorphological mapping.

The presented results document dramatic changes in sediment flux and coastal response under intervals characterized by a warming climate, retreating local ice masses, a shortened winter sea-ice season and melting permafrost.

Our work highlights the need for a greater understanding of the controls on paraglacial coastal sediment budgets in High Arctic settings, especially given the potential for accelerated warming and sea-level rise in the coming decades and centuries.

\*\*\*\*\*

## **Geomorphological sensitivity: implications for landscape responses to climate change in glacial environments**

HARRISON S.

*Exeter University, PENRYN, UNITED KINGDOM*

Climate sensitivity is defined as the equilibrium temperature response of the climate system to a doubling of atmospheric CO<sub>2</sub> levels from pre-industrial levels. Despite three decades of debate in the climatological literature on the estimation and significance of climate sensitivity, very little appears in the geomorphological literature on the implications of this for geomorphological systems. This paper examines the concept of climate sensitivity and applies its findings to an assessment of future landscape change in cold regions. It is concluded that paraglacial processes will become the dominant mechanism of sediment transfer in currently glaciated catchments and that this period of sediment mobilization will be the last episode of major sediment movement for geological time periods.

### **Toward a comprehensive paraglacial model: case studies from Iceland**

MERCIER D.(1), COSSART E.(2), DECAULNE A.(3), FEUILLET T.(1), COQUIN J.(1), BOURGEOIS O.(4), POCHAT S.(4), JÓNSSON H.P.(5), SæMUNDSSON Þ.(6)

(1) Université de Nantes - Laboratoire LETG-Géolittomer (UMR 6554), NANTES, FRANCE ; (2) Université Paris 1, Laboratoire PRODIG, PARIS, FRANCE ; (3) CNRS Laboratoire Geolab-UMR6042, CLERMONT-FERRAND, FRANCE ; (4) Université de Nantes - Laboratoire de Planétologie et Géodynamique de Nantes, UMR 6112, NANTES, FRANCE ; (5) Northwest Iceland Comprehensive College, SAUÐÁRKRÓKUR, ICELAND ; (6) Natural Research Centre of NW Iceland, SAUÐÁRKRÓKUR, ICELAND

From the end of the Weichselian period and during the early Holocene, the landscape in Iceland underwent major changes. During this short-time interval, while glaciers were retreating from the lowlands, an exacerbation of geomorphic activity is noticed, due to lowering of the relative sea level, large glacial rivers flooding from the retreating ice margins and hillslope debuttressing. As a consequence, many of the major paraglacial landforms that carved the Icelandic landscape are still visible nowadays.

Two kinds of early Holocene paraglacial landforms can be identified in Iceland: (i) paraglacial denudation landforms (some slope failure deposits such as sackungs, rock avalanches and various other landslide types...), and (ii) paraglacial deposition landforms (alluvial fans, terraces, valley-train deposits, outwash plains or "sandurs" with outburst floods or "jökulhlaups", coastal deposits...). By using the sediment cascade framework, several paraglacial sources and sinks are also identified. This classical geomorphological approach privileges forms, processes to typify their temporal evolution through the Holocene. Some post-little ice age analogues in Iceland are also clear examples of such paraglacial evolution.

To those external paraglacial dynamics we also propose to couple the consequences of the deglaciation to the internal earth dynamics (such as seismicity and volcanism, i.e. internal paraglacial effects). All around Iceland, glacio-isostatic rebound can explain the formation of numerous raised beaches, deltas, and strandflats. Also, an intense volcanic activity phase occurred within the early Holocene in Iceland, highlighting a link with the ice pressure release on the magma transfer.

Based on our own researches and on literature review, we develop a spatial analysis at different time and space scales and propose a comprehensive paraglacial model, including external and internal earth dynamic implications.

\*\*\*\*\*

### **Spatial and temporal patterns of paleoglaciation across Central Asia**

HARBOR J.(1), STROEVEN A.(2), BLOMDIN R.(1), CAFFEE M.(1), CHEN Y.(3), CODILEAN T.(4), FU P.(2), GRIBENSKI N.(2), HÄTTESTRAND C.(2), HEYMAN J.(1), IVANOV M.(5), LI Y.(6), LI Y.(6), LIFTON N.(1), LIU G.(3), PETRAKOV D.(5), ROGOZHINA I.(4), USUBALIEV R.(7)

(1) Purdue University, WEST LAFAYETTE, IN, UNITED STATES ; (2) Stockholm University, STOCKHOLM, SWEDEN ; (3) Peking University, BEIJING, CHINA ; (4) GeoForschungsZentrum, POTSDAM, GERMANY ; (5) Lomonosov Moscow State University, MOSCOW, RUSSIAN FEDERATION ; (6) University of Tennessee, KNOXVILLE, UNITED STATES ; (7) Central Asian Institute for Applied Geosciences, BISHKEK, KYRGYZSTAN

Understanding the evolution of mountain landscapes and testing global climate models require well-constrained information on past spatial and temporal patterns of glacier change. Particularly important are transitional regions that provide a sensitive record of past climate change and that may have high spatial and temporal variation in glacier activity. Central Asia is an extreme continental location with glaciers that respond sensitively to temporal variations in the dominance of several major climate systems.

As an international team project, we are reconstructing glacial histories along the Tian Shan, Altai and Kunlun Mountains, as well as several areas of the Tibetan Plateau. Remote-sensing-based geomorphological mapping, building on previous maps produced by local and international scholars, is being augmented with field observations of glacial geomorphology and the maximum distribution of erratics. We are using cosmogenic nuclide, optically stimulated luminescence and electron spin resonance dating of moraines and other landforms that constrain the former maximum extents of glaciers. Comparing consistently dated glacial histories across central Asia will allow us to examine potential shifts in the dominance patterns of climate systems over time in the region. Results to date show significant variations in the timing and extent of glaciation, including areas in the southeast Tibetan Plateau and Tian Shan with extensive valley and small polythermal ice cap glaciation during the global last glacial maximum in contrast to areas in the central Tibetan plateau that had very limited valley glacier expansion during the global last glacial maximum.

## Topographic controls upon moraine distribution

BARR I.D.

*Queen's University Belfast, BELFAST, UNITED KINGDOM*

Ice-marginal moraines are the most direct and ubiquitous indicators of former glacier dimensions, and are frequently used as a foundation for palaeoglacier reconstructions, which are, in turn, used as proxies for palaeoclimate. Despite being widely applied, this procedure is based upon the following assumptions, which are rarely explicitly discussed in palaeoglaciological literature: (i) the distribution of moraines reflects the former dimensions of glaciers, and (ii) glacier dimensions may be linked to palaeoclimate. Here, these assumptions are discussed by considering a population of more than 8,000 moraines in Eastern Siberia. Ultimately, it is argued that the distribution of these moraines reflects a complex signal of palaeoclimatic and topographic controls upon glacier dimensions, dynamics, and moraine preservation; and that extracting a palaeoclimatic signal from this landform record is a difficult task.

\*\*\*\*\*

## Landform development at the High-Arctic valley glacier landsystem, Ragnarbreen, Svalbard

EWERTOWSKI M.

*Department of Geography, Durham University, DURHAM, UNITED KINGDOM*

Evolution of a small High-Arctic valley glacier landsystem was analyzed based on Ragnarbreen, Svalbard. Study area is located near Petuniabukta in the northern part of Billefjorden in the central part of the Spitsbergen Island. Landforms transformations were quantified using time-series digital elevation models (DEM) constructed from aerial photographs from 1960, 1990 and 2009. Small scale transformations were also quantified by field surveys in 2007, 2011 and 2012. Furthermore, the time-series geomorphological maps were also created. The elements of the landsystem of the Ragnar glacier have undergone several transformations since the LIA maximum:

- 1) Increasing amount of water flowing from the glacier was blocked by end moraine complex and the ice marginal lake was created.
- 2) As a consequence of lowering of the glacier surface non covered by debris and formation of the distinct lateral moraines, the debris delivery from the valley sides has been limited only to very narrow zone of the glacier.
- 3) Accelerated recession of the ice mouth and limitation in delivery of debris from sides of the valley caused that amount of deposits released at the contemporary ice margin is small.
- 4) The debris cover on the lateral moraines is relatively thin. Moreover, as a consequence of lowering of the clean ice surface, slopes of the lateral moraines are very steep. It causes that mass movement processes (especially debris flows) are ubiquitous.

The spatial and temporal transformations of the landforms on the glacier foreland indicate that the dominant geomorphological processes influencing high-Arctic landscape are very varied and include among other mass movements, fluvio-glacial, lacustrine and glacial deposition. The model of Ragnarbreen landsystem development can serve as a very good analogue for reconstructions of geomorphological processes in similar settings.

Project was founded by Polish National Science Centre (decision number DEC-2011/01/D/ST10/06494)

## **Character and rates of glacial sedimentary processes in the terrestrial part of Billefjorden basin (Svalbard)**

RACHLEWICZ G.

*Adam Mickiewicz University in Poznan, Institute of Geoecology and Geoinformation, POZNAN, POLAND*

In the Atlantic sector of the Arctic, where Svalbard is located, due to intensive glacier covers decay of last decades, large amounts of glacially derived sediments are discharged within the valley systems, building up marginal zones, being transferred by proglacial rivers, partly stored on land and finally supplying coastal environment.

Based on detailed mapping and quantitative analysis of processes in three partly glacier covered catchments in the head fragment of Billefjorden basin (central Spitsbergen, inner fjord area, about 78.7°N and 16.6°E), the structure of present-day behavior of the remaining basin part, composed of five drainage basins, glaciers covered in between 12 and 80%, was determined. GIS enhanced geological and geomorphological investigations allowed to estimate the sediment yield, based on its stored amount, in the range between 1.2 and 2.8 mm per year, from which 62% were delivered by meltwater. Depending on the basin structure the rates of denudation are between 0.1 and 1.0 mm per year, within which chemical denudation constitutes even up to 70%, depending in quantity and character on their source of supply.

In spite of general similarities of glacier systems functioning in the frame of regional features, a wide range of individual patterns as ice body size, geology, initial relief, ice covers dynamics, arrangement of glacially generated landforms etc., influence the rates of glacial sedimentary processes observed on land, before a part of deposits find their place at the bottom of the fjord building up a geological archive.

\*\*\*\*\*

## **Glacial geomorphology of the High Atlas, Morocco**

HUGHES P.

*University of Manchester, MANCHESTER, UNITED KINGDOM*

This paper presents the evidence for glaciation in the Toubkal area of the High Atlas in Morocco. Valley glaciers emanated from a central ice field during the largest glaciation and moraines are present at altitudes as low as 1900 m a.s.l. There is also evidence for ice cap glaciation in some areas. The lowest moraines have yielded  $^{10}\text{Be}$  and  $^{36}\text{Cl}$  exposure ages of 30-80 ka and indicate that the oldest recorded glaciation occurred well before the last global last glacial maximum (LGM). Higher moraines yielding  $^{10}\text{Be}$  exposure ages of 19-24 ka correlate with the global LGM. A third, higher, suite of moraines are present in all valleys have yielded a tight scatter of  $^{10}\text{Be}$  exposure ages of 11-13 ka and these moraines correlate with the Younger Dryas. The lowest Pleistocene glaciers formed on the northern flanks of the High Atlas. Here, equilibrium line altitudes (ELAs) were < 3000 m a.s.l. during the most extensive glaciation. Permanent snow fields still survive today in some places on north-facing slopes. Several glaciated valleys contain large rock avalanche deposits. However, these landforms yield Holocene cosmogenic exposure ages and appear unrelated to Pleistocene glaciation, although rock wall over-steepening may make glaciated valleys prone to rock slope failure long after deglaciation. The glacial record of the High Atlas has important implications for understanding moisture supply to the Sahara region during Pleistocene cold stages.

## Cirque development and the glaciation of the Romanian Mountains

MINDRESCU M.(1), EVANS I.(2)

(1) UNIVERSITY OF SUCEAVA, SUCEAVA, ROMANIA ; (2) UNIVERSITY OF DURHAM, DURHAM, UNITED KINGDOM

The moderate altitudes of the Carpathian Mountains limited glaciation to cirque and short valley glaciers, but these were widespread in the Romanian Mountains, and many well-developed cirques were eroded. The 'marginal' nature of glaciation means that glaciers formed first on the most favourable (shadiest and leeward) mountain slopes, giving valuable indications of former wind directions (from west-northwest). Some cirques are completely isolated from others, but several mountain ranges rose sufficiently high above snowline that glaciers and cirques developed on all slopes, as in the Retezat, and Făgăraş Mountains.

Cirque development is measured both subjectively (5 grades) and objectively: the relation between these measures is shown by an  $R^2$  of 62% when grade is predicted from maximum gradient, minimum gradient, and plan closure. Cirques larger in horizontal dimensions have better grades. Cirque enlargement in plan is faster than vertical enlargement, as shape changes with size (allometry).

Despite being in an active orogenic belt, Romanian cirques are more similar to those in Britain than to those in British Columbia, where relief and thus vertical dimensions are greater. 'Cirque-in-cirque' forms are common in the higher ranges of Romania: Retezat, Godeanu and Făgăraş. Isolated cirques are relatively simple. Lakes are most frequent on granite, as in the Retezat. Geology affects especially vertical dimensions and gradients. Cirque form relates firstly to glaciological (climatic) factors and secondly to geologic (lithological and structural) factors.

Uplift of the Carpathians is recent and ongoing, so that traces are found only of recent glaciations, and glacial transformation is immature or incomplete. Mountain ranges can be ranked in terms of glacial modification, from the Retezat to the Suhard, Ciucaş and Bihor Mountains. This correlates with the degree of local asymmetry (of cirque aspect).

\*\*\*\*\*

## 10Be exposure dating of onset and timing of Neoglacial glacier advances in the Ecrins massif, French Alps

LE ROY M.(1), DELINE P.(1), CARCAILLET J.(2)

(1) EDYTEM, UNIV SAVOIE, LE BOURGET DU LAC, FRANCE ; (2) ISTERRE, GRENOBLE, FRANCE

Alpine glaciers are known to be highly sensitive to change in temperature and precipitation on decadal to centennial time scales. For two decades, numerous studies on Holocene climate revealed a period marked by abrupt cold reversals (e.g. 8.2 ka event) with increasing frequency and magnitude after the Holocene Climatic Optimum, during the so-called Neoglacial period (roughly the last 4 ka). State-of-the-art studies indicate that largest alpine glaciers failed to exceed their Little Ice Age (LIA) extent during these LIA Type-Events, unlike certain smaller glaciers.

In the French Alps, very few investigations were conducted to date on Holocene glacier variability. Almost all studies focused on the most glacierized area: the Mont Blanc massif, where suitable organic remains to apply radiocarbon dating and dendrochronology are available. Other glacierized massifs are poorly studied, without any Holocene/Neoglacial glacier chronology up to now.

Here, we present the results of a study focusing on six glacier forefields distributed in the Ecrins massif. Detailed geomorphological mapping and *in-situ* produced  $^{10}\text{Be}$  dating were carried on multi-crested so-called "LIA composite moraines". The targeted ridges are located in distal position with respect to late LIA drift in order to identify Holocene cold pulses that have led to (or slightly exceeded) LIA-like glacier extent.

The 35  $^{10}\text{Be}$  ages obtained revealed that the onset of Neoglacial occurred at ~4.2 ka, and that at least two other advances were recorded at ~3.3 ka and ~0.85 ka. One site has yielded a nearly complete Neoglacial record as four discrete events have been dated. These results highlight the potential of lateral moraine ridge stratigraphy which could yield accurate record when sufficiently preserved, but also the different preservation of landforms along the glacier margin which could censor the record.

### **Measurements of glacial and subglacial mass exchange of Gepatschferner (Ötztal Alps, Austria)**

STOCKER-WALDHUBER M.(1), SCHMIDT K.H.(2), KUHN M.(1), MORCHE D.(2), LAMBRECHT A.(3)

(1) Institute for Meteorology and Geophysics, University of Innsbruck, INNSBRUCK, AUSTRIA ; (2) Institute for Geosciences and Geography, Physical Geography, Martin-Luther-University of Halle-Wittenberg, HALLE (SAALE), GERMANY ; (3) Alfred Wegener Institute for Polar and Marine Research, BREMERHAVEN, GERMANY

Within the subproject "Glaciology and Geomorphology" which is part of the DFG/FWF joint project PROSA (Proglacial Systems of the Alps), all of the changes of the tongue of Gepatschferner (2150 – 2850 m.a.s.l., Ötztal Alps, Austria) and the production of sediments due to the glacier are being investigated.

The mass balance at the surface is determined by using the direct glaciological method and the whole glacier mass balance by using the geodetic method including multiple high resolution airborne laser scans. Surface velocity is ascertained by DGPS and feature tracking with two digital cameras. In order to obtain the resolution and the periodic change of the sediment layer between rock and ice, which seems to play an important role as a sediment source to the forefield, the new method of vibroseismic comes into operation. Additionally the ice thickness is measured with ground penetrating radar and a comparison of the two methods shall be aspired.

A first analysis of the vibroseismic data shows that the spatial resolution exceeds the thickness of the subglacial sediments. At the upper part of the tongue were the ice is about 100 meters thick a sediment layer of more than ten meters of depth was detected. Due to the high surface velocity of the glacier of more than 50 meters per year at the root zone of the tongue, the erosion of the subglacial sediments is expected to be very high. With the effort to get these changes in thickness the vibroseismic measurements will be repeated.

\*\*\*\*\*

### **Transition from glacial to periglacial processes in the Dolomites: the case of Cima Uomo area (Eastern Italian Alps)**

ZANONER T.(1), SEPPI R.(2), CARTON A.(1), NINFO A.(1), BONDESAN A.(1), FRANCESE R.(3)

(1) Department of Geosciences - University of Padova, PADOVA, ITALY ; (2) Department of Earth and Environmental Sciences - University of Pavia, PAVIA, ITALY ; (3) National Institute of Oceanography and Experimental Geophysics (OGS), TRIESTE, ITALY

Several glaciers of the Dolomites were progressively covered by debris during the retreating phase occurred after the LIA, allowing their preservation at relatively low altitudes. In some cases, these ice-debris systems are currently developing under permafrost conditions, leading to examples of transition from glacial to periglacial processes. In this study, we analyze the relationships between ground temperature and climatic parameters (air temperature, snow cover and topographic solar radiation) in order to understand which are the main factors controlling the morphodynamic processes of these environments.

The study area is located in upper Val San Nicolò (Dolomites) between 2200 and 3000 m of altitude. Here, a cirque glacier fed by avalanches was present as a clean glacier until the '50s. This glacier was depicted in historical maps, where its evolution from clean to debris-covered glacier can be observed. Now it is completely covered by a thick layer of debris and the surface morphology suggests that is developing in a rock glacier-like landform.

In order to detect if Cima Uomo ice-debris mass is under permafrost conditions, BTS and GST measurements were carried out. The observed low ground temperatures suggest that permafrost conditions are largely present in the debris body. In particular, BTS measurements performed in 2010 showed temperatures consistent with permafrost existence (from -3 to -4°C). The GST data of 2009 and 2010 showed winter equilibrium temperature (WEqT) lower than -2°C. The topographic solar radiation was calculate (on a Lidar-DEM) to correlate its influences to the measured ground thermal condition. The geophysical surveys confirmed the existence of an ice body under the debris layer and the topographic measurements have detected small movements of the ice-debris mass.

The study of this transitional processes on Cima Uomo can be consider representative of many other ice-debris masses of the Dolomites.

## **Poster presentations:**

### **Paraglacial - a comparative study of German and Anglo-Canadian usage**

*EMBLETON-HAMANN C.(1), SLAYMAKER O.(2)*

*(1) University of Vienna, Department of Geography, WIEN, AUSTRIA ; (2) University of British Columbia, Department of Geography, VANCOUVER, CANADA*

The meaning of the term paraglacial has been defined in the Anglo-Canadian literature between 1972 and the present (e.g. Church and Ryder, 1972 and Ballantyne, 2002). Many of the ideas discussed in the Anglo-Canadian literature were implicit in the early 20<sup>th</sup> century German literature. However, the German literature does not seem to have imbedded the paraglacial idea into an overarching framework for the study of postglacial glaciated landscapes. It was not until the end of the 20<sup>th</sup> century that the Anglo-Canadian paraglacial model was directly applied to the interpretation of the European Alps (Müller, 1999).

This poster reviews the two favoured definitions of paraglacial from the Anglo-Canadian literature and then provides examples of implicit uses of the model and explicit uses of the term "paraglacial" in the German literature. Implicit uses are illustrated from the work of Ampferer, 1931, and Patzelt, 1987. Explicit uses of the term "paraglacial" in the sense of "ice-marginal" are found in Klebelsberg, 1950, and several other references. Most recently Kuhle, 1991 and Iturrizaga, 2007 state that the proper meaning of the term "paraglacial" is "ice-marginal". Examples of the explicit use of the Anglo-Canadian paraglacial model in the German literature can be found in Hinderer, 2001 and Schrott et al., 2003.

The Anglo-Canadian paraglacial model views the postglacial glaciated landscape as a landscape of transition between the full glacial of the LGM and the present almost entirely deglaciated landscape. This conceptual framework provokes the question "what is the degree of transition" of a specific landscape as indicated by the paraglacial elements in that landscape.

\*\*\*\*\*

### **The survival of preglacial landforms in basement complex areas**

*HUGUET F.*

*Université Paris-Nord, PRES Sorbonne Paris Cité, VILLETANEUSE, FRANCE*

European basement complex areas which have been widely glaciated during the cold phases of the Quaternary, for instance the Black Forest, the Welsh mountains and the south-western Kerry (Ireland), show remarkable glacial features, such as glacial troughs and cirques. However, those glacial features did not totally obliterate the preglacial topography and it is possible to evidence, close to the glacial cirques, remnants of the preglacial topography, namely remnants of stepped landforms and piedmont staircases. Glacial cirques in basement complex areas frequently occur about the break of slope separating two successive benches or to the slope separating a culminating hill from its pedestal. That frequent location, statistically significant, can be easily accounted for, because those breaks of slope and steps facilitated the piling of snow and reduced the volume of rock to excavate.

### **Contemporary sub-glacial landscapes: case studies from three Antarctic ice streams**

KING E.

*British Antarctic Survey, CAMBRIDGE, UNITED KINGDOM*

The formation mechanism of subglacial landforms such as drumlins and mega-scale glacial lineations remains controversial. Factors include the type and properties of subglacial sediments; the availability and pressurization of water; and the thickness and flow speed of the overlying ice. While new survey techniques have allowed increasingly sophisticated quantification of the morphology of palaeo-bedforms, observation of contemporary examples has remained difficult, thus inhibiting the development of viable models of formation. I have undertaken ground-radar surveys of three currently-active Antarctic ice streams (Rutford Ice Stream, Talutis Inlet and Pine Island Glacier) to map the type and distribution of subglacial landforms to provide primary observations to inform this debate.

The observed bedforms cover a wide range of elongation ratios and degrees of streamlining and the locations of the surveys cover a range of flow speeds from 70 m/yr to >1000 m/yr. While there is some correlation between flow speed and bedform elongation, the juxtaposition of bedforms of different types within the same flow regime demonstrate that flow speed is not the only controlling factor. It is clear that the physical properties of the basal sediment and the availability of water are also key to the spatial distribution of drumlins, hummocks and mega-scale glacial lineations.

\*\*\*\*\*

### **Subglacial processes and drumlin formation in west Connemara, Ireland**

KNIGHT J.

*University of the Witwatersrand, JOHANNESBURG, SOUTH AFRICA*

In western Ireland, Late Weichselian ice flow dynamics and resultant patterns of landforms and sediments reflect the interplay between intrinsic (glaciological) and extrinsic (climate and geologic) forcing on the eastern Atlantic fringe. Landform and sediment patterns in the flat lowland region (>100 km<sup>2</sup> below 30 m asl) to the south of the Twelve Bens mountains reflect the interplay of these intrinsic and extrinsic controls across an igneous and metamorphic substrate. Sculpted bedrock forms (whalebacks, rock drumlins, roches moutonnées, striae) are present across the region and reflect areal subglacial abrasion. Subglacial sediments that are shaped into drumlins are found only in isolated bedrock valleys and around the western margins of the area and ahead of incised valleys (Nye channels). Drumlin sediments are exposed at Ardmore and Ballyconneely. Here, leeside stratification sequences dominated by cyclic debris flows overlie an overconsolidated basement comprised of lodgement till. Growth of the drumlin form in these specific locations in west Connemara reflects positive feedback (emergence) and self-organisation of subglacial sedimentary processes in a sediment-limited subglacial environment.

## **Last Glacial Maximum to Holocene glacial and paraglacial landscape reconstruction in the Cachapoal valley (Southern Central Andes, 34°22'S/70°05'W)**

ITURRIZAGA L.

*Institute of Geography / University of Goettingen, GOETTINGEN, GERMANY*

The research project focusses on a glacial geomorphological reconstruction from the Last Glacial Maximum to the Holocene glacier extent in the Cachapoal valley with their specific characteristic glacial landform assemblages. The E-W trending Cachapoal valley, a tributary of the Rapel River, drains one of the most southern located mountain massifs exceeding altitudes of 5000 m (Picos Barroso 5180 m). In climatic respect the valley is situated in the transition zone from the Dry Central Andes towards the Wet Andes with increasing annual precipitation amounts. Thus, the upper catchment area inhibits one of the largest debris-covered glaciers of the region, the 13 km long Cachapoal glacier. The research work has been carried out on a multi-proxy-approach based on geomorphological mapping,  $^{10}\text{Be}$  dating, the analysis of satellite images and historical data. The preliminary analysis of the field investigations suggests a detritic LGM-Cachapoal-glacier-ice stream with the affluents of Cachapoal, Las Leñas, Cortaderal and Cipreses reaching a length of at least 60 km and flowing down to about 800 m a.s.l.. A special emphasis has been put on the genetic interfingering of moraines and landslides. In the last decades a lot of classical moraines in various regions of the world have been reinterpreted as landslides. Recently the question has been even raised in how far end moraines can be used as climatic indicators when the influence of landslides dominates. The Upper Cachapoal valley is located in a seismic active and therefore landslide-prone region crossed by the El Diablo-El Fierro-thrust fold. The present study aims to highlight the interplay of glaciation and landslides. Moreover the historical glacier surging dynamics of the Cachapoal glacier have been considered in the study. Research work has been financed by the Alexander von Humboldt-Foundation and the Universidad Andrés Bello (Santiago de Chile).

\*\*\*\*\*

## **The age of the Last Glacial Maximum in the Asian North-East**

GALANIN A.

*Melnikov Permafrost Institute SB RAS, YAKUTSK, RUSSIAN FEDERATION*

The analysis of geomorphic and biostratigraphic data on four key Late Glacial complexes located in the mountains of Chersky Range and Kolyma Upland has demonstrated that the Last Glaciation had reached its maximum in the second part of Karginy Termochrone (MIS 3) and it had formed in the conditions of moderate humid and cool (subarctic) climate. The Glaciation had considerably reduced to the end of Karginy Termochrone (MIS 3). During Sartan Cryochrone (MIS 2) the degradation of the Glaciation had continued and the Periglacial Area was widespread and accompanied with eolian and permafrost processes. On the boundary of Pleistocene and Holocene the small cirque-type glaciation had occurred due to the marine transgression. The Last Holocene glacial activity is related to Neoglacial Epoch and it appeared with the rock glaciers formation development. This study was supported by Russian Fund of Basic Research, Projects # 11-05-00318-a; 12-05-98507-vostok\_a.

**Differentiation of the younger saalian ice-sheet dynamics in the interfluvium of the Krzna and Bug Rivers (E Poland))**

GODLEWSKA A.

*Maria Curie-Skłodowska University in Lublin, Department of Geoecology and Palaeogeography, LUBLIN, POLAND*

According to the commonly accepted model, during the younger Saalian glaciation the area of eastern Poland was subjected to areal deglaciation conditioned by continental climate. My recent studies reveal a differentiation of the younger Saalian ice-sheet dynamics in the interfluvium of the Krzna and Bug rivers. The research conducted in the marginal zones of the ice lobes -Liwiec, Toczna and Klukowka -suggests as follows: 1) recession of the Liwec Lobe was frontal, disturbed by local re-advance (along the pra-Liwiec valley filled with fine deposits); 2) recession of the Toczna Lobe was frontal on flat substratum; 3) recession of the Klukowka Lobe was areal over substratum high.

Spatial differentiation of dynamics of the ice masses in the marginal zone of the ice sheet was conditioned by relief and lithology of ice substratum. It is best reflected in extremely contrary mechanisms of dynamics of the Liwec and Klukowka lobes: the valley filled with fine deposits conditioned re-advance of the Liwec ice masses, and the substratum high determined the Klukowka lobe disintegration into dead-ice blocks. These conclusions question the hitherto accepted model of only areal deglaciation and also bring down the belief about an influence of continental climate on dynamics of the younger Saalian ice sheet in eastern Poland.

\*\*\*\*\*

**The overlapping problem of paleoglacial and periglacial landforms under an evident scenario of global warming but a tectonic uplifting in the central Andes (Northwestern Argentina)**

BUSNELLI J.

*National University of Tucuman, TUCUMAN, ARGENTINA*

The upper basins above more than 5000 m.asl in the mountain regions of Northwestern Argentina have a continuous history of glaciation and tectonic movements. During the whole Quaternary, there were many glaciations resulting from temperature decrease and snow fall increase due to high values of humidity. Nonetheless, the mountain glaciers have just developed due to the presence of the orographic front that promoted the air masses raised, chilled and condensed in snow precipitation. But, in the other hand, during interglacial dry period, the original glacial landforms, such as moraines and cirques, turned into complex forms under hydric, fluvial and mass movement processes that followed the cold period. All these processes masked the original glacial forms, so their recognition becomes difficult. The second and more important problem is the neotectonic that began with the Andean Orogeny and continues nowadays. This diastrophic effect affects the current geomorphological processes that yields active rock glacier. In the current research the aim was, first, to distinguish between relict or fossil and inactive rock glaciers from active rock glaciers, and then between glaciogenic (derived from quaternary glaciations) and geocriogenic (derived from typical periglacial processes). The rock glacier mapping was carried out through photointerpretation and satellite image analysis using Geographic Information Systems (GIS's) and field control documenting the active morphodynamic periglacial processes. Concluding, it was determined that the mountain tectonic uplifted has had a differential movement in the analyzed basin. The western upper basin have low slope U shape valley with remnant cirques and fossil rock glaciers, while the south exposition basins have a higher rate of uplifting having high slope valleys and dominant active rock glaciers. In this way, the current research proposes a method of neotectonic analysis using paleoglacial and periglacial geoindicators.

### **Fluvial adjustments in response to glacier retreat: Skaftafellsjökull, Iceland**

MARREN P., TOOMATH S.

*University of Melbourne, PARKVILLE, AUSTRALIA*

Glacier retreat has accelerated globally since the mid-1990s. Changes in discharge and proglacial topography will lead to changes in the morphology and functioning of proglacial rivers. At present, most of our knowledge of river response to glacier retreat is based on studies of Quaternary landscapes. Few studies have examined annual changes in glacier extent and related them to changes in proglacial drainage patterns.

The proglacial drainage network of Skaftafellsjökull, Iceland was monitored from 1998 to 2011. Skaftafellsjökull has retreated at an average rate of 53 m per year since 1999. From 1999 to 2003, the river incised and formed a sequence of now abandoned channels and fluvial terraces extending ~1 km downstream from the glacier. Retreat of the glacier from an ice-contact slope meant that there was a positive correlation between distance of glacier retreat and amount of fluvial incision. Incision was episodic, occurring in response to annual drainage reactivation and reorganization. The annual rate of retreat is moderately negatively correlated with the rate of incision. This is because the ice-contact slope decreases away from the position of maximum glacier extent, and also because faster retreat releases more sediment, counteracting the effect of retreat down an ice-contact slope. In 2003, proximal terrace formation ceased, as a proglacial lake was established. Downstream of the lake outlet further incision deepened the channel, with most change occurring during a flood in 2006, where incision in the upstream confined reach was accompanied by downstream aggradation and terrace formation.

Proglacial changes in response to glacier retreat are a result of the interactions of river channel incision, terrace formation, aggradation, lake development, and flooding, which together control river channel changes, sediment redistribution and sandur stratigraphy. Further work will extend this model away from lowland outlet glaciers into other proglacial settings.

\*\*\*\*\*

### **Micromorphology and macrofabrics of Late Quaternary sediments in the Aragonese Pyrenees, Spain**

HIRSCH F., RAAB T.

*BTU Cottbus, Chair of Geopedology and Landscape Development, COTTBUS, GERMANY*

Within the scope of the research project *Post-LGM pedogenesis and geomorphodynamics in the Aragonese Pyrenees* we used a combination of field and laboratory methods to differentiate and classify Late Quaternary sediments. Our analyses indicate no post sedimentary erosion of the LGM lateral moraines in the Aragon and Gallego valley. Precipitation of calcium carbonate led to the fixation of the diamictos and thus stabilized the glacial landforms. Clasts in the glacial sediments are orientated parallel to the Pleistocene glacial flow direction and therefore underpin the stability of the glacial deposits during paraglacial times. Grain size analyses and OSL ages indicate the covering of glacial sediments by an eolian deposit before the onset of the Holocene.

### **The Glacier des Bossons protects Europe's summit from erosion**

*GODON C.(1), MUGNIER J.L.(2), FALLOURD R.(1), PAQUETTE J.L.(3), POHL A.(4), BUONCRISTIANI J.F.(4)*  
(1) *Université de Savoie, LE BOURGET DU LAC, FRANCE* ; (2) *CNRS University of Savoy, LE BOURGET DU LAC, FRANCE* ; (3) *CNRS, Université Blaise Pascal, CLERMONT FERRAND, FRANCE* ; (4) *Université de Bourgogne, DIJON, FRANCE*

The relative efficiency of erosion beneath cold glacier, beneath temperate glacier, and on ice-free mountain slopes is one of the key parameter in the development of relief during glacial periods. Detrital geochronology methods have been applied to the sub-glacial streams of the north face of the Mont Blanc massif in order to estimate the efficiency of erosional processes. The lithology of this area is composed of a ~303 Ma old granite intruded within older polymetamorphics. In this study, we use macroscopic criteria (on ~10 000 clasts) and U-Pb dating of zircon (of ~500 grains) to determine the provenance of the sediment transported by the glacier and by the sub-glacial streams. The lithology of sediment collected above or below the glacier is compared with the distribution of bedrock sources. The analysis of this distribution takes into account glacier characteristics (areas above or below the ELA, beneath temperate or cold ice), its surface flow lines and the extent of the watershed of the three sub-glacial outlets, located at altitudes of 2300 m, 1760 m and 1450 m, respectively.

A comparison between the proportion of granite and polymetamorphics in these samples indicates that: 1) glacial transport does not mix the clasts derived from sub-glacial erosion with the clasts derived from supra-glacial deposition, except in the lower tongue where supra-glacial streams and moulins move the supra-glacial load to the base of the glacier; 2) the glacial erosion rate beneath the tongue is smaller than the erosion rate of adjacent non-glaciated areas; 3) glacial erosion beneath cold ice is at least sixteen times less efficient than erosion beneath temperate ice. Our results indicate that the low rates of subglacial erosion on the north face of the Mont Blanc massif means that the glaciers are protecting Europe's summit from erosion. A long-term implication would be a growing of the maximum altitude of the Alps.

\*\*\*\*\*

### **Determination of La Bana Lake (NW Iberian Peninsula) Origin using clast macro-fabric analysis**

*SANTOS-GONZALEZ J., REDONDO-VEGA J.M., GONZÁLEZ-GUTIÉRREZ R.B., GOMEZ-VILLAR A.*  
*UNIVERSITY OF LEON, LEÓN, SPAIN*

La Baña Lake is located in the northwestern Iberian Peninsula, SW of León province. The lake and its surroundings were declared Natural Monument in 1992 and were included in Castilla y León Natural Protected Areas Network due to its natural interest and glacial geomorphology landforms. Since then, and because the clear glacial features in the valley, a glacial origin was accepted for both, the lake and the small pond located a bit further north.

However, the field study and the analysis of the deposit's structure and morphology which dams the lake and the pool undoubtedly show a postglacial origin, probably within paraglacial dynamics, from a great rockslide of the substrate slates. In order to characterize and demonstrate its postglacial origin, we carried out six fabrics (25 clasts each) in different areas of the deposit that dammed the lake. In addition, the same analysis was carried out for other deposits, one of them on a scree slope and, the other one located in the bottom valley downstream of the lake (interpreted as till due to its characteristics).

The comparative analysis of all data shows clear differences between the three deposits concerning their composition, lithological diversity, matrix, and the A-axes inclination and direction. Furthermore, this analysis demonstrates that the lake was dammed by a great accumulation of materials from a rockslide developed in the side of the glacial valley, not by a glacial moraine as previously researched indicated.

### **Till fabric and grain size analysis of glacial sequences in a complex paleoglacial system, the case study of the upper sil valley, cantabrian mountains, NW Spain**

*SANTOS-GONZALEZ J.(1), SANTOS J.(2), REDONDO-VEGA J.M.(1), GONZÁLEZ-GUTIÉRREZ R.B.(1), GÓMEZ-VILLAR A.(1)*

*(1) UNIVERSITY OF LEON, LEÓN, SPAIN ; (2) UNIVERSITY OF COIMBRA, COIMBRA, PORTUGAL*

During the Last Glacial Maximum(LGM) a complex glacial system developed in the Upper Sil basin of NW Spain. An extensive area with twelve main transection glaciers generated an ice tongue, which received fourteen other valley glaciers with lengths between 3 and 20 kilometers long. In summary, the glacial ice extent in the basin was approximately 450 km<sup>2</sup>, the largest in the Iberian Peninsula outside the Pyrenees. Close to Páramo del Sil four main glaciers, Sil (46 km), Valseco (19 km), Salentinos (14 km) and Valdeprado (11 km) merged in an area with low relief and generated several ice-dammed lakes in small lateral valleys.

Scarce glacial landforms are present today due to a weak lithology (slates, sandstones and quartzites) and rapid postglacial erosion, but many glacial deposits are still preserved mainly on flat surfaces at relatively low altitudes (750-900 m). Stratigraphic sequences with till, glacio-lacustrine and fluvio-glacial deposits are visible in some exposures up to 20 meters tall, indicating a progressive glacier front recession.

Till fabric and grain size analysis of diamictons from eight exposures allowed the reconstruction of the palaeo-glacial dynamics of the Sil glacial system. A-axis fabrics of 100 clasts in each deposit and grain size analysis (four samples per deposit) were conducted in order to infer glacial dynamics. Subglacial tills display a moderate to strong clast fabric ( $S_1$  eigenvalues of  $> 0,70$ ) and a fine-grained matrix when compared with supraglacial melt-out tills.

In conclusion, the results confirm the magnitude of the Upper Sil Valley glaciation and explain glacial dynamics in a very complex area. Fabric analysis combined with grain size analysis are relevant not only to discriminate supraglacial and subglacial tills, but also to reconstruct paleo-glacial dynamics in an area where glacial landforms aren't preserved due to a weak lithology and rapid postglacial erosion.

\*\*\*\*\*

### **Reconstruction of Late Holocene fluctuations of La Mare Glacier (Eastern Italian Alps): a combined approach**

*CARTURAN L.(1), BARONI C.(2), CARTON A.(3), CAZORZI F.(4), DALLA FONTANA G.(1), DELPERO C.(3), SALVATORE M.C.(2), SEPPI R.(5), ZANONER T.(3)*

*(1) Department of Land, Environment, Agriculture and Forestry - University of Padova, LEGNARO, PADOVA, ITALY ; (2) Department of Earth Sciences - University of Pisa, PISA, ITALY ; (3) Department of Geosciences - University of Padova, PADOVA, ITALY ; (4) Department of Agriculture and Environmental Sciences - University of Udine, UDINE, ITALY ; (5) Department of Earth and Environmental Sciences - University of Pavia, PAVIA, ITALY*

High-resolution glacier length curves provide valuable insights on glacier fluctuations as response of past climate. Since the end of the XIX and the beginning of the XX century, the Italian Glaciological Committee (CGI) coordinates the systematic monitoring of frontal variations of the Italian glaciers, which however can locally display interruptions or inhomogeneities, supplying anyway one of the longest series of observations of frontal variations in the world.

Here we present a combined approach, which uses different sources of data and modern technologies of terrain analysis, for reconstructing the Late Holocene fluctuations of La Mare Glacier, a 4 km<sup>2</sup> wide valley glacier located in the Ortles-Cevedale massif (Eastern European Alps). This glacier built one of the most impressive and well-studied Holocene morainic complex of the Italian Alps, and displayed significant fluctuations during the 19<sup>th</sup> and 20<sup>th</sup> Centuries, experiencing a frontal withdrawal of about 2.4 km since the maximum Holocene position reached during the Little Ice Age.

Frontal variations occurred before the direct monitoring were reconstructed by detailed geomorphologic surveys of the proglacial area, integrated with high-resolution Digital Elevation Models analyses. The chronologic constrain of moraines was assessed by the reconstruction of soils chronosequence on different moraine ridges, comparing historical documents (e.g. maps, paintings, photographs), by lichenometry, radiocarbon dates and surface exposure dating of glacial deposits and relict landforms. The retreat curve deriving from systematic field observations was checked with multitemporal photographs and maps, which enabled the identification of landmarks used by the observers and the reconstruction of fluctuations in periods lacking measurements.

### **The largest Italian valley glacier with little ice during the Sub-Boreal: evidences from a buried log in the Forni Glacier forefield**

LEONELLI G., BOLLATI I., DIOLAIUTI G., MERLINI A., TROMBINO L., SMIRAGLIA C., ZERBONI A., PELFINI M.

Università di Milano, MILANO, ITALY

The assessment of past climate variability is a crucial issue in palaeoclimatic studies for the understanding of the ongoing global warming compared to past natural conditions. Precise information on past climate conditions can be derived from geomorphologic features as well as from several natural proxies that can be found in glacial and temperature-limited environments, both at high altitudes and latitudes. The combination of morphological interpretation of glacier deposits, radiocarbon dating, dendrochronological techniques and sedimentological analyses has allowed to reconstruct Holocene fluctuations of the Forni Glacier. Based on the retrieval of a buried subfossil log found along the right side of the Forni valley and an integrated multidisciplinary approach, we could develop new hypotheses about the position of the Forni Glacier tongue. The anatomical analysis revealed that the retrieved log belongs to a specimen of *Pinus cembra*, the most widespread species in the Forni Valley and the dendrochronological analyses revealed that the minimum age of the tree was 273 years. The radiocarbon dating gave as result  $3920 \pm 25$  yr BP, i.e. 4426-4256 cal. yr BP. Since about 50 yr around the pith were not measured because of bad wood conditions, the oldest tree ring in the log can be dated at 4526-4356 cal. yr BP. Grain size analyses substantiate the presence of two distinct pedostratigraphic units. At present the area where the trunk was found is colonized only by very young trees, especially of *Picea abies*, suggesting a higher tree line and a different widespread of tree species in the proglacial area.

Field data are evidence of warmer temperature conditions in the analysed time period thus suggesting an upper glacier terminus position respect to the present one (at c. 2600 m asl) and also the possibility that in the sub Boreal the largest Italian valley glacier could be fragmented into three smaller ice bodies (which are presently the three glacier accumulation basins).

\*\*\*\*\*

### **The spatial distribution of cirques during Quaternary glaciations in Greece**

BATHRELLOS G., SKILODIMOU H., MAROUKIAN H.

National & Kapodistrian University of Athens, Faculty of Geology & Geoenvironment, Department of Geography & Climatology, ZOGRAFOS, ATHENS, GREECE

Large parts of northern Europe and North America were covered by ice sheets during the Quaternary glacial periods. There were, however, numerous locations outside these areas which were affected by mountain glaciations. Naturally, as one moves towards the Equator these become more localized and occur at higher altitudes.

In Greece, mountain glaciations appear to have been quite extensive, along the mountain range of Pindus, on Mt. Olympus and in the highlands of Peloponnese, during the Last Glacial Maximum (LGM).

This study focuses on the extent of the Quaternary glaciations in Greece based on the examination of cirque formations. An initial spatial database of these glacial forms was created for the first time in Greek Territory. Some of the glaciated sites have been taken from previous literature, but most of them were recorded from topographic maps (scale 1:50,000) and air photos. ArcGIS 10 software was used to process the glaciated sites. A map depicting the glaciated areas of Greece was compiled with about 140 cirques. Detailed geomorphological maps of each location and morphometric analysis of the glacial and glaciated features were performed. The stages in dissection and lithological conditions of each cirque were examined.

The vast majority of cirques occur at altitudes varying from 2,700 to 1,500 m.a.s.l. The preservation of ice for longer periods of time is more likely at altitudes higher than 1,500 m.a.s.l. The few cirques observed at altitudes lower than 1,500 m.a.s.l., may be due to karstification.

Cirques have developed on north, northwest and northeast facing slopes. During the last glacial period, a high barometric system over central Europe carried cold air masses to the south resulting in increased snowfall on the northern slopes of Pindus range and the other mountains of Greece. As a result, most cirques in Greece are open towards the northern quadrant.

### The Greenland Ice Sheet erodes its bed some places but not in others

BIERMAN P.(1), CORBETT L.(2), GRALY J.(3), NEUMANN T.(4), ROOD D.(5), SHAKUN J.(6), NELSON A.(1)  
 (1) University of Vermont, BURLINGTON, UNITED STATES ; (2) Dartmouth College, HANOVER, UNITED STATES ; (3) University of Wyoming, LARAMIE, UNITED STATES ; (4) NASA Goddard Space Flight Center, GREENBELT, UNITED STATES ; (5) Scottish Universities Environmental Research Centre, EAST KILBRIDE, UNITED KINGDOM ; (6) Harvard University, CAMBRIDGE, UNITED STATES

The rate and spatial distribution of erosion done by ice sheets is poorly known. We are using the cosmogenic isotope  $^{10}\text{Be}$  as a proxy to understand where and how much the Greenland Ice Sheet (GIS) erodes its bed through isotopic analysis of exposed boulder and bedrock surfaces and sediment transported by the ice sheet. To study subglacial erosion, we measured meteoric  $^{10}\text{Be}$  in samples from the basal, dirty-ice zone of the GISP2 ice core and both in situ and meteoric  $^{10}\text{Be}$  in >200 samples collected from the ice sheet margin.

Silt in 17 samples from the basal 6.5 meters of the GISP2 ice core (summit of GIS) has high concentrations (0.6 to  $3.8 \times 10^8$  atoms  $\text{g}^{-1}$ ) of meteoric  $^{10}\text{Be}$ , far more  $^{10}\text{Be}$  than could be accounted for by short, interglacial exposures. The silt contains 0.3 to 1.7% organic carbon and has an average C/N ratio of ~10, consistent with incorporation of a long-lived, cold-region soil. The existence of this ancient soil for several million years after formation of the GIS indicates extremely low rates of subglacial erosion at Summit, Greenland, consistent with the ice being frozen to the bed for most, if not all, of the Quaternary.

Analysis of in situ cosmogenic  $^{10}\text{Be}$  in boulders and bedrock around the margin of the GIS indicates that areas near outlet glaciers, where ice is warm-based, are effectively eroded whereas other areas, especially highlands, retain evidence for multiple periods of exposure and burial, indicating that there ice was cold-based and did not erode its bed. Sediment in and leaving the ice today tells a similar story. 86 clasts, collected directly from the ice margin, have measurable but very low levels of *in situ*  $^{10}\text{Be}$  indicating they were sourced from areas where both preglacial regolith and rock exposed during interglacial times were effectively eroded by ice. Sand-sized sediment collected from outwash streams exiting the ice margin has more  $^{10}\text{Be}$ , suggesting that different grain sizes are sourced from different subglacial locations.

\*\*\*\*\*

### Early Warning of Glacial Lake Outburst Floods and Climate Change Monitoring in the Karakoram Mountains, P.R. China

HAEMMIG C.(1), KEUSEN H.(1), HESS J.(2), TOBLER D.(1)  
 (1) GEOTEST SA, BERNE, SWITZERLAND ; (2) Federal Office for Environment, LAINAT, BERNE, SWITZERLAND

Yarkant River is located in the southwest of Xinjiang Uygur Autonomous Region, at the western margin of the Tarim Basin. In the last decade, 5 glacial lake outburst floods (GLOF) damaged infrastructure and claimed human lives along Yarkant River. The spontaneous floods are a threat for over 1 Mio inhabitants in the floodplains and are causing an annual monetary loss of 10 Mio €. There are 33 recorded flood disasters during the last 50 years. The floods are provoked by melt-water, rainstorms and glacial lake outbursts (peak discharges >  $6'000 \text{ m}^3/\text{s}$ ). The largest and most frequent GLOF occur in the area of Keleqin River. Keleqin is one of several tributaries of Yarkant River.

In 2011 a project was launched with the goal to implement an early warning system, allowing authorities and population to take the necessary measures in order to avoid victims, to raise the safety of settlements and livestock and to minimize damages to infrastructure and agricultural land. A further goal is to assess the long-term development of the flood hazard situation in the catchment area of Yarkant River by analyzing past and real-time information on the glacier lake situation. In addition, scenario based forecasts of the future glacial lake developments are elaborated, considering Climate Change.

As a first step, a GLOF early warning system (EWS) was implemented combining satellite remote sensing, an automatic terrestrial observation and warning station. Two automatic gauge and warning stations are operational since autumn 2012. Both water level fluctuations and EWS functionality are continuously monitored. Because the volume of Kyagar Glacier Lake is directly linked to its blocking ice-dam, mass-balance calculations are crucial. Such calculations and climate change monitoring are needed to define future hazard scenarios and to plan protection measures. Flood modelling, the elaboration of a hazard index map and an emergency risk management plan are other key issues of the project.

## **The Glaciation of southwest England**

HARRISON S.

*Exeter University, PENRYN, UNITED KINGDOM*

Until recently, the geological consensus was that southwest England escaped glaciation during the Quaternary. However, the recent evidence for the widespread glaciation of Dartmoor and valley glaciation on Exmoor has demonstrated that the moors of southwest England were capable of developing glacial ice at relatively low altitudes. Missing from this debate has been any discussion of the development of small glacial features in the southwest landscape. Here we assess the evidence for widespread glaciation of the region's uplands and also show the evidence for smaller glacial features with reference to nivation hollows from Exmoor and extreme west Cornwall. We argue that these features were likely more numerous during the LGM than previously thought, and this has implications for reconstruction of LGM ice extent and climate in areas previously considered to be extra-glacial.

\*\*\*\*\*

## **Glacial erosion in northern Ostrobothnia, Finland**

ESKOLA T., PEURANIEMI V.

*University of Oulu, Department of Geosciences, OULU, FINLAND*

The study area in northern Ostrobothnia, Finland, is located in the central part of the Pleistocene Fennoscandian ice sheet. Inferences of glacial erosion is based on observations of striae, glacial grooves, crescentic gouges, crescentic fractures and lunate fractures on roche moutonnées and whaleback forms of bedrock outcrops. Erosional forms were studied in 44 different sites and approximately 500 measurements were registered. The length, breadth and depth of erosional forms were measured and the rock type of every observation site was registered. Multiple striae orientations were discovered with the evidences of cross-cutting striae. Prevailing and dominant orientation is from WNW. Orientations from NW were commonly registered on the lee sides of roche moutonnées. Some faint but clear striae from WSW and from NNW were also observed. Some of these erosional forms probably date back to the pre-ice lobe phase of the Weichselian glaciations whereas some might be related to the late Weichselian Oulu ice lobe phase.

\*\*\*\*\*

## **Glaciomorphic depositional formations in northern Ostrobothnia, Finland**

ESKOLA T., PEURANIEMI V.

*University of Oulu, Department of Geosciences, OULU, FINLAND*

The morphology and inner structure of different glaciogene moraine formations and glaciofluvial formations were studied in northern Ostrobothnia, Finland, by using aerial photographs, field observations and LiDAR (light detection and ranging) data. The study area is situated in the central part of the former Fennoscandian ice sheet. The Quaternary sediments consist of different glacial and glaciofluvial deposits. Typical moraine formations in the area are cover moraine, drumlins and hummocky moraines. The formations are composed of different depositional facies as lodgement, melt-out, flow and deformation tills and sorted material such as sand and gravel lenses and beds occur in places. Drumlin swarms occur on higher ground and hummocky moraine trains on lower ground. Some cross-cutting drumlin ridges have been observed in one specific part of the study area. These drumlins represent older and younger ice flow directions and can be termed as palimpsest glacial landforms. Glaciofluvial formations are composed of esker chains where both deltaic parts and ridges occur in the esker chains. Some observations have been made on till covered eskers.

### **From minor to major: understanding the LGM Adige-Brenta-Astico glacial system in the eastern Southern Alps through the analysis of transfluence tongues**

ROSSATO S.(1), MOZZI P.(1), MONEGATO G.(2)

(1) *University of Padova - Department of Geosciences, PADOVA, ITALY* ; (2) *National Research Council, Institute for Geoscience and Earth Resources, TORINO, ITALY*

The Adige River valley is one of the major Alpine valleys. It is located in the eastern Southern Alps, North of the Garda Lake. The Brenta Valley is located few km eastwards of the Adige Valley, to which it is connected via some saddles and narrow gorges (average altitude: 500 m a.s.l.). The Astico valley is located South of the Brenta Valley; the connection between the two valleys is provided by the Carbonare saddle (1075 m a.s.l.). During the LGM these valleys hosted an interconnected glacial system.

According to the reconstructed glacial mass and the sand petrography of glaciofluvial deposits, the Astico glacier during major Alpine glaciations was fed by glacial transfluences from the Adige and Brenta valleys, and could not be sustained only by local ice accumulation. Hence, the glacial collapse derives from the ceasing of the transfluence and provides an accurate estimation of the onset of glacial downwaste in the whole system. Such event is well recorded in the minor Prealpine Astico Valley, whilst it is more difficult to be detected in the main Adige and Brenta valleys.

Three distinct glacial pulses are well recorded in the Astico Valley, in good agreement with other nearby Alpine glaciers (i.e., Piave and Tagliamento glaciers) which show several oscillations during LGM after 27.5 cal ka BP. Radiocarbon datings of glaciofluvial deposits indicate that the collapse of the Astico glacier may have occurred between 20.5 and 16.5 cal ka, while the withdrawal of the Brenta glacier started at around 17.5 cal ka. The last glacial pulse in the Adige glacier took place after 25.0 – 20.0 cal ka, while the onset of deglaciation is not well constrained by radiometric dating.

\*\*\*\*\*

### **Thickness constraints of the Patagonian Ice Sheet over the last glacial cycle using surface exposure dating**

GEIGER A.(1), FABEL D.(1), GLASSER N.(2)

(1) *University of Glasgow, GLASGOW, UNITED KINGDOM* ; (2) *Aberystwyth University, ABERYSTWYTH, UNITED KINGDOM*

The Patagonian Ice Sheet (PIS) was the largest ice body in the southern hemisphere outwith Antarctica stretching a unique span of latitudes (36-54° S). Over the past ten years glaciological and glacial geomorphological investigations have provided some insights into the paleo-glaciology of Patagonia and its function within the climate system. For example, numerical modeling experiments have been used to estimate ice thickness, the timing of glacier disintegration, volumetric configurations and consequent sea level contributions since the global last glacial maximum. However critical empirical field based constraints on vertical ice extent are lacking. In-situ produced cosmogenic <sup>10</sup>Be and <sup>26</sup>Al in quartz are utilized to date the surface exposure of erratic boulders and/or bedrock of present-day and palaeo-Nunataks which are used as dipsticks recording vertical ice downwasting. The surface exposure ages presented here are the first to constrain ice thickness and rates of ice surface lowering at the former centre of the PIS (49°S, 72°W) over the last glacial cycle up to the mid-holocene. Based on the geomorphology and the exposure ages discussion of the complex climate interactions within Patagonia, southern South America, will be provided.

**Modelling depth of river incision caused by meltwater discharge from the retreating Cordilleran Ice Sheet, Alberta, Canada**

MALOWANY K., OSBORN G., MARTIN Y., MARSHALL S.  
University of Calgary, CALGARY, CANADA

Rivers flowing eastward from the Canadian Rockies across the Alberta plains are situated in narrow, flat-bottomed valleys located 15 to 120 m below the plains surface. It is assumed that rivers were established in their present courses following deglaciation because valleys cut local till-bedrock contacts. We hypothesize that large amounts of meltwater from the Cordilleran Ice Sheet caused rivers to incise rapidly for a period of about 2 000 years following the retreat of the ice sheets (14-12ka.) In this study, a combined ice sheet-climate model is used to estimate the amount of water derived from the melting Cordilleran Ice Sheet between 14 and 12ka. Resulting annual discharges allocated to each basin indicate that major rivers were approximately 3 times greater in discharge than their modern counterparts. Two approaches are taken to estimate the ability of these discharges to cause incision through till and local bedrock. First, a bedrock-incision equation is applied to a situation of very erodible material to estimate incision through shale and weak sandstone. This approach yields incision rates greater than those observed for these rivers. Second, the Bagnold sediment transport equation is used to estimate the amount of soft material removed from the system during periods of high discharge. Together these two approaches provide estimates of incision depths that could result due to increased discharge from meltwaters of the Cordilleran Ice Sheet. Uncertainty concerning the duration and magnitude of large floods operating during deglaciation creates large variations in results; however, even the most conservatively estimated discharges are shown to be capable of causing incision of rivers to depths greater than indicated by field observations.

\*\*\*\*\*

**Cosmogenic nuclide constraints on Late Quaternary glacial chronology on the Dalijia Shan, northeastern Tibetan Plateau**

WANG J.(1), KASSAB C.(2), HARBOR J.M.(2), CAFFEE M.W.(3), CUI H.(1), ZHANG G.(1)

(1) Key Laboratory of Western China's Environmental Systems (Ministry of Education), Lanzhou University, LANZHOU, CHINA ; (2) Department of Earth, Atmospheric, and Planetary Sciences, Purdue University, WEST LAFAYETTE, UNITED STATES ; (3) Department of Physics, Purdue Rare Isotope Measurement Laboratory, Purdue University, WEST LAFAYETTE, UNITED STATES

Cosmogenic nuclide apparent exposure dating has become a widely used method for determining the age of glacial landforms on the Tibetan Plateau with >1200 published ages. We present the first Be-10 exposure ages from the Dalijia Shan (4636 m a.s.l), the most northeastern formerly-glaciated mountain range on the Tibetan Plateau. The moraine groups identified from field and remote sensing imagery mapping record four glacial events at  $37.07 \pm 3.70$ – $52.96 \pm 4.70$  ka (MIS3),  $20.17 \pm 1.79$ – $26.99 \pm 2.47$  ka (MIS2),  $16.92 \pm 1.49$ – $18.76 \pm 1.88$ ka (MIS2), and  $11.56 \pm 1.03$ – $11.89 \pm 1.06$ ka (Younger Dryas). These ages indicate that glaciation in the northeastern Tibetan Plateau is much younger than previously thought.

Ice completely filled the valley at ~39 ka and probably spilled into the neighboring valley to the east. As the glacier retreated, boulders were deposited in Dalijia Pass (~23.5 ka) that is equivalent to the age of the next youngest lateral moraine (~21.8 ka). A terminal moraine from this older glaciation is not preserved. We assume it reached far down valley and has since been destroyed or covered by fluvial processes. A ~17.3 ka terminal moraine is preserved just below the junction of the Deheisui Valley and Qitai Valley, recording the limited extent (<10 km) of the MIS2 advance. The youngest event, ~11.7 ka, records either a small advance or a period of time when the glacier reached a stillstand during retreat, possibly recording a Younger Dryas event. Even though we are confident that only two boulders provide reliable estimates of depositional age due to their close agreement, future work should include increasing the sampling size to better determine if this moraine is truly a Younger Dryas event, which has not been noted in many parts of the Tibetan Plateau.

In addition, this record is consistent with many other regions on the Tibetan Plateau, with a local last glacial maximum during MIS3 asynchronous with Northern Hemisphere last glacial maximum during MIS2.

### Glacier recession from 1955 to 2007 on Sat (Ikiyaka) Mountains, Southeastern Anatolia, Turkey

YESILYURT S.(1), DOGAN U.(2), SENKUL C.(3)

(1) Cankiri Karatekin University, CANKIRI, TURKEY ; (2) Ankara University, ANKARA, TURKEY ; (3) Afyon Kocatepe University, AFYON, TURKEY

In the present study, present glaciers of Sat (Ikiyaka) Mountains (3794m) located in Southeast Anatolia, one of the most important recent glacier areas of Turkey, is dealt with within the context of the impacts of climatic changes on glaciers. Alpine type present glaciers of these mountains, which quickly respond to climate changes, provide significant data for Turkey and Middle East that limited number of study is available. In this study, based on aerial photographs taken in 1955, 1968 and 1988 together with Quickbird satellite images taken in 2007, four main stages were examined using remote sensing and GIS technologies. The results of *performed analysis demonstrate that* the paleo-glacier cover of the Last Glacial Age (most likely the Last Glacial Maximum) on the Sat Range was about 80 km<sup>2</sup> in area as compared to the actual glaciers found an area of only 1.5 km<sup>2</sup>. 730 meter recession has been detected in glaciers located around the Satsivrisi peak for the 52 years period from 1955 to 2007. These glaciers have retreated between 2 and 14 meter per year depends on their thickness-mass characteristics and the geomorphologic characteristics of the cirques that they located in. Some of the glaciers have significantly lost their mass in 52 years (for example, Geverok glacier has lost 47% of its mass) due to this retreat rate. According to the temperature records of meteorological stations located near environment of the mountainous area, both long-term average (1961-2003) summer and annual temperatures indicates a warming trend. Also, new moraines around the glaciers clearly show the area that glaciers covered during the last progression phase. According to the retreat speed of these glaciers which created the moraines for the last half century, it is understood that they have been rapidly retreating since the end of the Little Ice Age to the present. Therefore, new moraines are evidences of Little Ice Age glaciation.

\*\*\*\*\*

### The Quaternary glacial maximum in the center of the Cantabrian Mountains (northern Iberian Peninsula): Aller-Nalón-Porma catchments

RODRIGUEZ RODRIGUEZ L., JIMÉNEZ-SÁNCHEZ M., DOMÍNGUEZ-CUESTA M.J.

*Departamento de Geología, Universidad de Oviedo, OVIEDO, SPAIN*

The Cantabrian Mountains is a coastal range up to 2648 m altitude that is considered the westward projection of the Pyrenees in north Iberia (~43°N 5°W). Like in Pyrenees, the occurrence of well-preserved glacial landforms and deposits in this mountain range has proved the occurrence of former glaciers during the Quaternary. Previous research here supports a regional glacial maximum prior to ca 38 cal ka BP and an advanced state of deglaciation by the time of the global Last Glacial Maximum (Jiménez-Sánchez et al., in press).

A geomorphologic database has been produced in ArcGIS at 1:25,000 scale details for an area about 220 km<sup>2</sup> that partially covers the Redes Natural Reservation and Picos de Europa Regional Park. A reconstruction of the ice extent and flow pattern of the former glaciers is presented for this area as a previous step to plan further chronological studies. Our reconstruction shows that an icefield covered ca 156 km<sup>2</sup> of the study area (72.3 %) during the maximum extent. The altitude difference between the glacier fronts of both mountain slopes was ca 100 m. The ice tongues that drained the icefield also showed a remarkably asymmetric length between both slopes, being 1 to 6 km-long and up to 19 km-long in the north and south faces respectively. This asymmetric character of the ice tongues can be related to geologic and topo-climatic factors.

Jiménez-Sánchez, M., Rodríguez-Rodríguez, L., García-Ruiz, J.M., Domínguez-Cuesta, M.J., Farias, P., Valero-Garcés, B., Moreno, A., Rico, M., Valcárcel, M., in press. A review of glacial geomorphology and chronology in northern Spain: timing and regional variability during the last glacial cycle. *Geomorphology*, doi: 10.1016/j.geomorph.2012.06.009.

Research funded by the project CANDELA (CGL2012-31938) of the Spanish national research program in Earth Sciences and Hydric Resources (MINECO). L. Rodríguez-Rodríguez has developed her research under a grant of the Severo Ochoa Programme (FICYT- Asturias).

### **The Norwegian strandflat - glacial or periglacial erosion?**

BERTHLING I.(1), LANDSNES E.(2), FREDIN O.(3)

(1) Norwegian University of Science and Technology, Department of Geography, TRONDHEIM, NORWAY ; (2) Norconsult AS, SANDVIKA, NORWAY ; (3) Geological Survey of Norway, TRONDHEIM, NORWAY

The strandflat is a prominent feature along many coasts that experienced Quaternary glaciations. The strandflat is developed along a major part of the Norwegian coastline, including Svalbard. In some areas it is several tens of kilometers wide from the outermost islands to its typical abrupt termination in steep cliffs towards backing mountains. Periglacial weathering and sea ice action has been regarded the main processes responsible for its development. The main object of this study was to test this hypothesis by calculating denudation rates based on volumetric estimates of Quaternary strandflat erosion in some test areas. An automatic classification of the Norwegian strandflat between Karmøy and Trondheimsfjorden based on topographic parameters was performed. The classification was based on primary topographic parameters, generated from a 100 meter digital elevation model. Secondly the preglacial paleic landscape was reconstructed at two locations (Bømlo and Smøla). At both locations a minimum and maximum preglacial surface was created. The present topography (at Smøla also bathymetry) was subtracted from the preglacial landscape envelopes. Based on a maximum age of 2.8 Myears, denudation rates ranged from 0.15 – 0.27 mm/year, while average Quaternary glacial conditions (600 Kyears) yielded rates between 0.7 and 1.25 mm/year. The obtained denudation rates seem more consistent with glacial processes than periglacial weathering. This does, however, not preclude repeated reworking of the strandflat by subaerial processes in periods without large ice sheets. We conclude that glacial processes are the main agent behind strandflat erosion, but that the characteristic features of the strandflat may have been shaped by a combination of weathering and mass wasting in a periglacial environment.

\*\*\*\*\*

### **Ice shelf structural and (geo-)statistical mapping: a case study using satellite imagery**

SAMYND.(1), GLASSER N.(2)

(1) Nagaoka University of Technology, NAGAOKA, JAPAN ; (2) University of Aberystwyth, ABERYSTWYTH, UNITED KINGDOM

Antarctic ice shelves have attracted much scientific and media attention recently. Knowledge on their dynamics and stability has become of primary importance for predicting Antarctica future behaviour, as it contributes to a better understanding of the physical mechanisms behind ice shelf collapsing and coastal glacier shrinking in Polar Regions. We present herein an application of new mapping methods using GIS tools to reconstruct the formation history of glaciological and marine ice features in ice shelves and to determine their influence on ice shelf dynamics and stability. The method was applied to Nansen Ice Shelf, a small ice shelf in Terra Nova Bay, Antarctica, of which three ASTER images (Jan. 2001, Oct. 2001 and Dec. 2004) were extensively analysed and compared. A total of more than 7,250 recognizable points were surveyed across the ice shelf to produce velocity fields, and more than 20,000 features (including longitudinal flow structures, crevasses, rifts, ice blocks and debris lineations) were mapped to define local zones of specific flow. Combined with (geo-)statistical analysis, we used this information to localize the grounding line, often considered as the best indicator for ice shelf activity, and followed its behaviour through the studied period. It is suggested that topographical confinement might play an as important role as grounding line activity on the ice shelf dynamics. The degrees of anisotropy of velocity fields and of other characteristics of mapped features were also obtained by autocorrelation analysis. Finally, probability distributions of mapped features were intercompared to determine the degree of filiation between these features.

\*\*\*\*\*

### **Surface exposure dating of rock slope failures in Northern Romania**

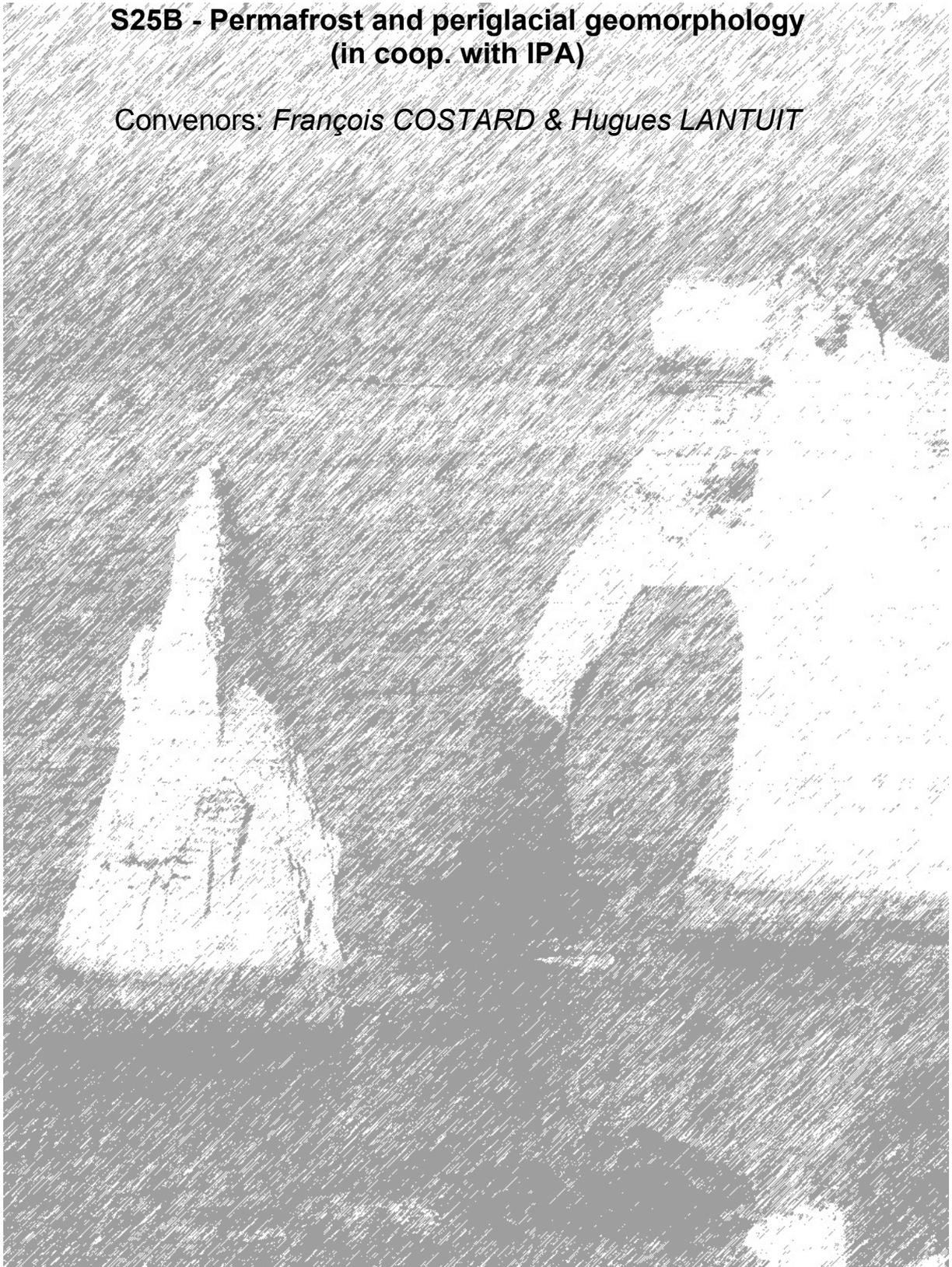
GHEORGHIU D.M.

SUERC, University of Glasgow, GLASGOW, UNITED KINGDOM

The Romanian Carpathians are prone to rock slope failures (RSFs). Several RSFs have been investigated in the northern part of the country, especially in the Maramureş and the Rodna Mountains, where the RSFs are up to 1.6 km<sup>2</sup>. These failures reflect the combination of high relief, lithological and structural controls. As the temporal pattern of paraglacial adjustments is unknown in these areas, the surface exposure dating method was employed in 3 locations. Preliminary data suggest that the RSFs are associated with areas subject to the over-steepening by glacial erosion during the Last Glacial Maximum (LGM) and the subsequent loss of support after deglaciation.

**S25B - Permafrost and periglacial geomorphology  
(in coop. with IPA)**

Convenors: *François COSTARD & Hugues LANTUIT*





## **Oral presentations:**

### **Assessing the factors that affect growth and propagation of 'mega-slumps' in Canada's Northwest Territories**

*KOKELJ S.(1), TUNNICLIFFE J.(2), LACELLE D.(3), LANTZ T.(4)*

*(1) Northwest Territories Geoscience Office, YELLOWKNIFE, CANADA ; (2) School of Environment, University of Auckland, AUCKLAND, NEW ZEALAND ; (3) Department of Geography, University of Ottawa, OTTAWA, CANADA ; (4) School of Environmental Studies, University of Victoria, VICTORIA, CANADA*

In this study, we examine processes associated with major retrogressive thaw slumps (>40 ha) that have developed in formerly glaciated foothills of the Richardson and Mackenzie Mountains (Peel Plateau) of NW Canada. The upslope growth potential and perpetuation of a thaw slump is related to the evacuation of materials from the scar zone. Analysis of climatic timeseries and timelapse photography show strong relationships amongst temperature, precipitation, net radiation and resultant sediment flux from these mega-slumps. Warm, wet periods drive considerable slug flow from the scar zones: in one case, a slump has filled its master valley, forming a lake upstream. A single mega-slump may displace more than  $10^6$  m<sup>3</sup> of material, severely impacting downstream river and riparian ecosystems; the slumps may entirely reconfigure local slopes and channel networks in drainages of less than 1 km<sup>2</sup>. Monitoring of suspended sediment clearly indicates impacts at a catchment scale of 1 000 km<sup>2</sup>. The relatively high relief of the incised Peel Plateau provides sufficient transport gradient to evacuate slump detritus and thus propagate into much larger features, distinguishing these features from smaller slumps in low-relief terrain. There are notable feedbacks amongst sedimentary cover, vegetation and ice-melt; slump propagation may accelerate if ground ice is exposed, or be arrested when it is covered. Mega-slump features persist for decades, although the magnitude of such slumps, and number of such features found within the study area, is increasing. The intensification of thaw slump activity has been associated with climate warming, however, our data point suggest that warm and wet conditions are likely most conducive to the initiation and perpetuation of thaw slump activity.

\*\*\*\*\*

### **Retrogressive thaw slumps: structure, evolution and relevance to carbon cycle of the Arctic Ocean**

*LANTUIT H.(1), FRITZ M.(1), KRAUTBLATTER M.(2), ANGELOPOULOS M.(3), POLLARD W.(4)*

*(1) Alfred Wegener Institute for Polar and Marine Research, POTSDAM, GERMANY ; (2) Technical University Munich, MUNICH, GERMANY ; (3) Golder Associates, MONTRÉAL, CANADA ; (4) McGill University, MONTRÉAL, CANADA*

Retrogressive thaw slumps (RTS) are spectacular lateral thermokarst features occurring in ice-rich permafrost regions. They develop along streams or coastlines and expand inland to form landslide-like U-shaped scars exceeding a kilometer size in selected locations. These slumps are a major source of sediment, organic carbon and nutrients that have a large effect on the aquatic environment. The consequences of the occurrence of RTS, which have been shown to occur at increased frequencies in the Arctic are not well understood, mostly because they have only been studied over the past ten years. The impact of RTS sediment delivery on coastal ecosystems is even less known, even though RTS contribute quantities of sediment sometimes greater than coastal erosion itself.

In this study, we present the results of a systemic multidisciplinary study attempting to understand the structure, the evolution and the fate of RTS on Herschel Island, Yukon Territory, in the southern Canadian Beaufort Sea. Herschel Island for the exceptionally ice-rich nature of the permafrost and the occurrence of multiple RTS. We use information stemming from cryostratigraphic sampling in the ice headwall of the RTS, from cores collected above the headwall and in the slump floor, from sediment and water samples collected in the slump outflow, from timelapse photography, from outflow channel discharge measurements and from geophysics (mostly Direct Current and Capacitive Coupled Resistivity) to describe the structure of the slump. We emphasize the role of ground ice distribution, sea water vicinity and sensible and radiative heat input in dictating the pace at which slump initiate, stabilize and re-activate. We compare this information to past knowledge on slumps to emphasize the transient nature of slump occurrence in the arctic coastal zone and the existence of "pulses" of slump activity with potentially important impacts on the nearshore ecosystem.

### **Important melting of ice-wedges and formation of thermocirques on slopes of thermokarst lakes in Central Yakutia (Siberia)**

SEJOURNE A.(1), FEDOROV A.(2), COSTARD F.(3), GARGANI J.(3), SKORVE J.(4)

(1) *WROONA Group, Institute of Geological Sciences PAS, WROCLAW, POLAND* ; (2) *Permafrost Institute, Russian Academy of Sciences, YAKUTSK, RUSSIAN FEDERATION* ; (3) *Univ. Paris-Sud XI, CNRS, Laboratoire IDES, ORSAY, FRANCE* ; (4) *Norwegian Space Agency, OSLO, NORWAY*

On Earth, permafrost containing a high ice volume (referred as ice-rich) are sensible to climate change and have been regionally degraded (thermokarst) during the early Holocene climatic optimum forming numerous thermokarst lakes in Central Yakutia (eastern Siberia). Nowadays, recent temperature increases in the Arctic and Subarctic have been significantly greater than global averages. The frequency and magnitude of terrain disturbances associated with thawing permafrost is increasing in these regions and is thought to intensify in the future. Therefore, understand how is the current development of thermokarst is a critical question.

Here, we describe the significant melting of ice-wedges on the hill-slopes of thermokarst lakes in Central Yakutia that leads to formation of amphitheatrical hollows of tens of meters. The evolution of thermocirques in Central Yakutia has been little studied and analyzing their formation could help to understand the recent thermokarst in relation to climate change in Central Yakutia. We studied the thermocirques at two scales: (i) field surveys of different thermocirques to examine the processes and origin of melting of ice-wedges and; (ii) photo-interpretation of time series of satellite images to study the temporal evolution of thermocirques (KH-9 Hexagon images of 6-9 m/pixel and GeoEye images of 50 cm/pixel).

\*\*\*\*\*

### **Thermo-erosional landforms in Siberian ice-rich permafrost**

MORGENSTERN A.(1), GROSSE G.(2), ARCOS D.R.(1), GÜNTHER F.(1), OVERDUIN P.P.(1), SCHIRRMEISTER L.(1)

(1) *Alfred Wegener Institute for Polar and Marine Research, POTSDAM, GERMANY* ; (2) *Geophysical Institute, University of Alaska Fairbanks, FAIRBANKS, UNITED STATES*

Of major concern in periglacial research is the question of how arctic permafrost landscapes react to climate change. Warming and thawing of ice-rich permafrost may result in substantial hydrological, geomorphological, ecological, and biogeochemical feedbacks which may have local to global impacts. While numerous studies have investigated thermokarst as one main process of permafrost degradation, data is sparse on thermal erosion, another widespread process of permafrost degradation. Siberian coastal lowlands underlain by ice-rich permafrost often feature streams, valleys, and valley networks that have formed under the influence of thermal erosion, but systematic regional studies have been lacking. We present an inventory of streams and valleys in three ice-rich lowland areas adjacent to the Laptev Sea using GIS-based analysis of remote sensing data, elevation models, and field investigations. The calculated total stream length is 4,153 km in the Cape Mamontov Klyk area, 1,541 km in the Lena River Delta area, and 2,047 km in the Buor Khaya Peninsula area; valley densities are 1.8, 0.9, and 1.0 km/km<sup>2</sup>, respectively. Strong variations in the morphology and spatial distribution of streams and valleys are observed and can be attributed to differences in the size and relief characteristics of the study areas as well as to their predominant cryolithological properties, which are also influenced by previous degradation of the study areas by thermokarst. Based on the results, the evolution of different valley types in continuous ice-rich permafrost landscapes is discussed. The current valley pattern is largely the result of the late Holocene evolution of the hydrological system that is strongly connected to the degradation of ice-rich permafrost by thermal erosion.

**A reassessment of the erosional potential of fluvial thermal process during ice breakups of the Lena river (Siberia)**

COSTARD F.(1), GAUTIER E.(2), FEDOROV A.(3), KONSTANTINOV P.(3), DUPEYRAT L.(1)

(1) UMR 8148 IDES, ORSAY CEDEX, FRANCE ; (2) UMR 8591, MEUDON, FRANCE ; (3) Permafrost Institut, YAKUTSK, RUSSIAN FEDERATION

We analyze the impact of the breakup on the erosional process on the head of several fluvial islands from one of the largest Arctic fluvial systems – the Lena River (Yakutia). The purpose of this work was to reevaluate the role of the thermal erosion during ice breakup of the Lena River. In 2008-2011, a 4-years observation program was initiated to quantify the relative influence of fluvial thermal erosion during the ice breakup of the Lena River. During the initial stage of the ice breakup, ice pushes into river banks and produces huge accumulations of sediment that protect the island head against the mechanical and thermal effects of the river flow. That initial stage is relatively short, and occurs within a few days period. In a second phase after the fluvial ice thawing, the island heads are ice-free. In the case of high water levels, the flood, in permanent contact with the frozen river bank, undergoes efficient thermal and mechanical erosion, sometime through the fall season during a secondary discharge peak. The careful analysis of the annual data shows a high variability of the erosion rate, mostly due to the variability of the duration and timing of the flood season.

\*\*\*\*\*

**Features of suffosional processes in permafrost (Central Yakutia, Russia)**

GAGARIN L.

Melnikov Permafrost Institute, YAKUTSK, RUSSIAN FEDERATION

In Central Yakutia, suffosional processes are best developed on the Bestyakh terrace of the Lena River. The terrace is composed of fine- to medium-grained sands of Middle Pleistocene age varying in thickness from 5 to 80 m and underlain by Lower Jurassic sandstones and Middle Cambrian limestones. The development of suffosional processes is related to the site-specific permafrost and groundwater conditions. Permafrost is 200 m in thickness and its temperature is on average -0.2 to -0.5°C, lowering to -2.5°C in the river and creek valleys. The frozen sediments contain open and closed taliks maintained by the thermal effects of solar heat, surface water and confined subpermafrost water, referred to in the Russian literature as radiation-thermal, hydrogenic and hydrogeogenic taliks. Recharge of aquifers occurs predominantly through the radiation-thermal and hydrogenic taliks, while the hydrogeogenic taliks provide a path for groundwater movement to discharge areas.

The complex permafrost structure and the specific hydrodynamic groundwater regime promote the development of suffosional processes in the groundwater discharge areas. Suffosional processes are defined here as mechanical erosion and removal of soil particles or lumps by groundwater flow. In permafrost areas, suffosion development has some specific features related to the heat exchange between water flow and permafrost; thus suffosional processes are closely related with thermal erosion. Under the combined action of these processes, cavities form in the Bestyakh terrace sands within the groundwater discharge areas. The cavities gradually grow in size, and their roofs eventually collapse to create sinkholes on the surface. Over time, the depressions can grow significantly, from initial 0.5 - 2 m in diameter and 0.5 - 1 m in depth 30 m in plan and 15 m in depth. All suffosional depressions form along the groundwater flow line and string for 350 m or more. Gradually expanding, sinkholes may merge to form gullies.

### **Thermal and Moisture Regimes in the Active Layer of Western Dronning Maud Land, Antarctica**

*DWIGHT R.(1), SCOTT D.(1), MEIKLEJOHN I.(1), MATCHER G.(1), LEE J.(2)*

*(1) Rhodes University, GRAHAMSTOWN, SOUTH AFRICA ; (2) Stellenbosch University, STELLENBOSCH, SOUTH AFRICA*

Ground temperatures have been measured in shallow boreholes in Western Dronning Maud Land for between four and six years, while soil moisture readings have been logged for three years. The active layer was found to vary in depth from less than ten centimetres in the interior (altitudes greater than 1 200masl) to over 20cm near the coast and at altitudes below 400masl. The mean annual ground temperature in the region ranges from -8.7°C at the coast to -17.9°C at over 1 200masl in the interior. Two distinctive thermal regimes were identified, namely longer-term (seasonal) and shorter-term (diurnal) frost cycles. The number of cycles across the 0°C isotherm was location dependant and ranged from just over 30 to nearly 70. However, at only one site was soil moisture detected and, therefore, in reality there were effectively only an average of 25 frost cycles per summer season. At this and other locations where moisture and fine substrates were present, diurnal frost activity has produced sorted patterned ground, while at locations where no effective frost cycles were identified, only thermal cracking was evident. This study represents exploratory research that is being used to understand landscape controls on the distribution and abundance of biota. In Antarctic ecosystems abiotic factors are thought to take primacy in determining patterns of biological distribution. It is argued that abiotic processes provide the habitat in which the biotic components of the environments survive. However, the precise form of the interactions between abiotic variables and community structure is poorly understood, much less how it will change in the future. Given the rapidly changing climates in the region, improving knowledge of what drives patterns of biodiversity at a local and regional scale is vital to assess consequences of environmental changes.

\*\*\*\*\*

### **Cold region geomorphology and Permafrost Evolution in the North-Atlantic region**

*ETZELMULLER B., LILLEOREN K.S.*

*University of Oslo, OSLO, NORWAY*

Since 2003 numerous shallow boreholes have been equipped to monitor ground temperatures in Norway, Svalbard and Iceland. The monitoring stations are setup to characterize the ground thermal regime in different periglacial landforms and environmental settings, and to validate spatially distributed, equilibrium and transient permafrost models. We evaluate variations in the ground thermal regime during the period of meteorological observations since the end of the Little Ice Age c. 1870 (Svalbard since 1912) until today on monthly and daily basis. Furthermore, selected sites have been forced by Holocene climate parameters to address the relative age of permafrost. These analyses display clear regional differences, providing important insights to the climatic response of mountain permafrost in the north-Atlantic region, and allow us to relate this information to geomorphological processes within the framework of the cryo-conditioning of landform and landscape evolution. In this presentation we will discuss the development of ground thermal regime in the study areas, and subsequently relate this to geomorphological processes and longer-term cryo-conditioned landscape development.

## **Modelling alpine permafrost distribution in the Hohe Tauern region, Austria**

SCHROTT L.(1), OTTO J.C.(1), KELLER F.(2)

(1) Department of Geography and Geology, University of Salzburg, SALZBURG, AUSTRIA ; (2) Academia Egiadina, SAMEDAN, SWITZERLAND

Knowledge concerning permafrost distribution in the Alps is an important prerequisite to estimate potential developments caused by climate change. An assessment of natural hazards or the creation of risk maps in high alpine catchments very often requires the consideration of potential permafrost occurrence. This study for the first time shows a high resolution and index based permafrost distribution for the region Hohe Tauern (approx. 4400 km<sup>2</sup>), which is based on the empirical model PERMAKART 3.0. The approach integrates three different relief classes (rock walls, steep slopes, foot slope position) in a topoclimatic key. The used thresholds were calibrated with field observations (geophysical soundings, mapping) from six different test sites. The modelling results were validated with more than 600 BTS (bottom temperature of snow cover) measurements. At present an area of 550 km<sup>2</sup> is affected by permafrost to a lesser or greater extent. Low altitude sporadic permafrost occurrence is possible in shady northerly exposed slopes at 2000 m a.s.l., whereas southerly exposed rock walls remain permafrost free even above 3000 m a.s.l. In the national park "Hohe Tauern" (1856 km<sup>2</sup>) 25% of the area is underlain by permafrost. A major challenge remains the estimation of the future development of permafrost in the Alps. Thawing permafrost is one consequence of warming trends in the European Alps which causes a continuous change in permafrost distribution and influences a number of earth surface processes such as rock falls or debris flows. A simple scenario taking into account a possible temperature increase of 1 K would lead to widespread permafrost degradation. The produced permafrost map assists planners and decision-makers and contributes to better understanding of our mountain ecosystem.

\*\*\*\*\*

## **Permafrost investigation in the Mont Blanc massif steep rock walls: a coupled measurement, modelling and geophysical approach**

MAGNIN F.(1), DELINE P.(1), RAVANEL L.(1), GRUBER S.(2), KRAUTBLATTER M.(3)

(1) Université de Savoie - EDYTEM Laboratory, LE BOURGET DU LAC, FRANCE ; (2) Glaciology, Geomorphology and Geochronology, Department of Geography, University of Zurich, ZURICH, SWITZERLAND ; (3) Monitoring, Analysis and Early Warning of Landslides, Technische Universität München, MÜNCHEN, GERMANY

The intense rockfall activity affecting high-elevation steep rock walls in the Mont Blanc massif is presumably linked to permafrost degradation in response to climate change. We investigate this link at various temporal and spatial scales within the massif.

Mean Annual Rock Surface Temperature (MARST) is derived from Mean Annual Air Temperature (MAAT) and direct solar radiation calculations in a GIS-based statistical model based on a 4 m resolution DEM of the massif. While the quality of this model can be assessed with MARST measurements at individual points, the relationship between MARST and permafrost occurrence in the rock wall at depth is unknown. Here, we address this issue by comparing simulated MARST rock temperature monitoring and Electrical Resistivity Tomography (ERT) measurements.

The Aiguille du Midi site, a set of granite peaks (3842 m a.s.l.), has been steadily instrumented since 2005 with rock temperature sensors inserted in near surface and three 11-m-deep boreholes. Records show that at a single point measurement, MARST differs of about 7-8°C between North and South, warm (>2°C) and cold permafrost are coexisting within a few tens of meters, and active layer thickness varies from 2 m to 6 m depending on aspect and inter-annual variations. MARST can deviate by about 1 to 3°C from permafrost temperature under various surface conditions (snow cover, rock discontinuities).

Five ERT transects have been realised on steep rock walls for evaluating the MARST model. They are focused on simulated temperatures between -1°C and 3°C, aiming to detect zones with and without permafrost in each profile. Survey lines are 160 m long and the median depth of investigation reaches up to 30 m.

Currently, ERT data are processed and we expect a clear distinction of frozen and unfrozen bedrock. This will help to evaluate the relationship between simulated MARST and permafrost occurrence at depth. An overview of these investigations and their first results will be presented.

## Identification of geomorphic and climatic controls on degradation of Alpine rockglaciers

GAERTNER-ROER J., MUELLER J.

*Dept. of Geography, University of Zurich, ZURICH, SWITZERLAND*

Rockglaciers are known as typical landforms of the high mountain cryosphere and serve as indicators for the occurrence of permafrost. It is assumed that changes in the temperature regime lead to respective changes in geomorphological processes. Thus, for the future, distinct changes in structures and processes are expected in the periglacial belt, which is most sensitive to temperature changes.

Spatio-temporal characteristics of rockglacier kinematics are quantified for several landforms in a small catchment in the Swiss Alps. Measurements are taken between 1975 and 2012 by combining in-situ and remote sensing techniques. Some landforms exhibit significant changes in the last decade. The changing geometry (thickness change, horizontal velocities) gives insight into ongoing processes, such as "normal" creep behavior, ice aggradation/degradation or destabilizations such as collapsing tongues or the development of deep crevasses. The differentiation between normal creep behavior versus degrading landforms helps to identify and describe geomorphic and climatic controls on rockglacier kinematics.

The purpose of this study is to describe different types of rockglacier movements and derive a better understanding of the ongoing processes. The findings allow for a first description of rockglaciers sensitivity towards geomorphic and climatic controls.

\*\*\*\*\*

## Permafrost existence in rock glaciers of the Southern Carpathians (Romania)

URDEA P.

*WEST UNIVERSITY OF TIMISOARA, TIMISOARA, ROMANIA*

Knowledge of permafrost distribution in Romania is still very limited since only a few investigations were attempted as for the permafrost environment in the Southern Carpathians. This study gives an overview of the investigations performed for mapping mountain permafrost in Romania in the last 5 years. Spatial distribution of mountain permafrost was assessed using geophysical methods (DC resistivity tomography and GPR measurements) as well as measurements of Bottom Temperature of Snow Cover (BTS) and Ground Surface Temperature (GST). In order to determine the spatial extension and the characteristics of permafrost 9 rock glacier from three sites - Retezat, Parâng and Făgăraș Mountains - , were studied using geophysical surveys. Thermal investigations were carried out on 20 rock glaciers from: Țarcu, Godeanu, Retezat, Parâng, Făgăraș and Iezer Mountains to detect the existence of permafrost. The results revealed that isolated patches of permafrost could exist in very favorable sites for permafrost conservation (e.g. north-facing bouldery rock glaciers) in Southern Carpathians above 1950 m. According to the geophysical measurements the moderate resistivity values of the materials suggest that the ice content within the investigated rock glaciers is low to medium (sediments cemented by interstitial ice and ice lenses). Considering the mean annual air temperature (between 1 and -2,5°C), the depth of the active layer (3-10 m) and the limited thickness of permafrost layer (below 10 m) it is possible to conclude that permafrost from Southern Carpathians exists in marginal conditions and the permafrost occurred during a cold phase of the Early Holocene. That is why the preservation of permafrost is dependent on site-specific conditions and is strongly controlled by solar radiation, snow cover depth and duration and surface characteristics like debris cover.

Authors: *P. Urdea, A. Onaca, A. Ardelean, R. Șerban, F. Sirbu*

## Rock glaciers debris accumulation for assessment of rockwall retreat

LE COEUR C.

University of Paris 1, PARIS, FRANCE

Rock glaciers can be considered as down slope debris accumulation. In some case, rock tongue results from periglacial reactivation of former debris covered glaciers located in upper valleys. In other cases, rock glacier extending below talus were mainly nourished by rockwall block detachment. These rock glaciers are material sinks within the debris transport system of mountain areas. Consequently, the amount of rock material stored within rock glaciers can be used to estimate geomorphic process rates (Barsch, 1977; Humlum, 2000; Brenning, 2005) in relation to rockwall surface.

In Western Vanoise (French Alps) a set of rock glaciers located in different morphostructural arrangements and into various lithology allow an assessment of Holocene debris production. Research sites are located in the Gebroulaz glacier area and in the Cerces massif.

An assessment of debris volume implies to discriminate possible inherited stocks (from a former till stock) and to evaluate internal ice content. The second point is to set a chronology and possibly some datations in order to establish rockwall retreat rates. This approach offer evidence of different accumulation rhythms resulting from uneven processes from scree production to large rockwall collapse. From these exemples we could assume contrasting rates matching different conditions and durations in cold debris production.

\*\*\*\*\*

## Dendrogeomorphology in the Arctic regions - methods and case studies

OWCZAREK P.(1), MIGALA K.(1), NAWROT A.(2), MALIK I.(3)

(1) University of Wroclaw, Institute of Geography and Regional Development, WROCLAW, POLAND ; (2) Polish Academy of Sciences, Institute of Geophysics, WARSZAWA, POLAND ; (3) University of Silesia, Faculty of Earth Sciences, SOSNOWIEC, POLAND

The activity of geomorphic processes in the High Arctic area was changed during last few decades. Fast increase of temperature and retreat of glaciers influences the course of these processes. This study demonstrates the possibility of analyzing environmental changes using growth-ring series of the Arctic dwarf shrubs. The research was carried out in the Svalbard Archipelago. Two plant species were chosen to dendrochronological analysis - *Salix polaris* and *Salix reticulata*. These low, creeping plants have well-defined growth-rings which ranged from 0.2 mm to less than 0.01 mm in width. The wooden samples, including the root and branch systems, were collected from different geomorphic sites: debris flow tracks, talus cones, fluvio-glacial terraces and abandoned river channels. The samples were sectioned with GSL 1 sledge microtome, taking 15-20µm cross-sections from 4 to 6 different locations along the length of the individuals. Serial sectioning, which reduces dating errors, was necessary for construction of the ring-width chronologies. The chronologies cover a period of max. 120 years. Dendrochronological methods were used to determine minimum age of the geomorphic landforms. Field observations show that debris flow processes attains the highest intensity in the first and last phase of the short Arctic summer and are connected with increase water input to the active layer. The dendrochronology approach confirms this statement. Detailed research indicates several periods, when the debris flows and talus cones activity was increased during last 100 years (1950-1960, 1968-1975, 1992-1997, 2004-2008). The fast retreat of the glaciers affects the changes of sediment mass balance in the contemporary river channels. The transition from glacial to fluvial dominance is observed in the research area. The wooden dwarf shrubs allow dating the age of fluvial landforms (terraces, paleochannels) and identify tendency of the river runoff and geomorphic activity in the future.

**Late pleistocene sand wedges along the Patagonian Coast (Argentina): chronological constrains and implication for coastal permafrost distribution**

*RIBOLINI A.(1), BINI M.(1), CONSOLONI I.(1), ISOLA I.(2), PAPPALARDO M.(1), ZANCHETTA G.(1), FUCKS E.(3), PANZERI L.(4), MARTINI M.(4), TERRASI F.(5)*

*(1) Dipartimento di Scienze della Terra University of Pisa, PISA, ITALY ; (2) Istituto Nazionale di Geofisica e Vulcanologia, PISA, ITALY ; (3) Facultad de Ciencias Naturales y Museo, Universidad Nacional de La Plata, LA PLATA, ARGENTINA ; (4) Dipartimento di Scienza dei Materiali, University of Milano Bicocca, MILANO, ITALY ; (5) Dipartimento di Scienze Ambientali, University of Naples 2, NAPOLI, ITALY*

Several wedge features have been detected in the continental deposits covering the marine sediments of MIS 5 along the St Jorge Gulf coast and in the Puerto Deseado area, in the Patagonian coast of Argentina. The lab analyses of the infilling sediments report for fine sand, moderately sorted, with a symmetrical skewness and a mesokurtic kurtosis, consistent with a depositional environment dominated by aeolian transport. Also the microtextures of quartz grains observed at SEM point to an aeolian environment, favoring mechanical collisions during the transport by saltation process. The existence of fragments of Andean volcanic rocks (glass shards) in the wedge infillings indicates a long-distance transport with a west component of wind direction. These data, together with the evidences of polygonal networks on the surface, enable us to interpret the wedge features as primary sand wedges formed in a permafrost environment.

The OSL age ( $14,670 \pm 750$  yr BP) obtained in the sediment affected by sand wedges and the  $^{14}\text{C}$  ages (25-27 kyr BP) of pedogenetic crust cross cut by the sand wedge indicate that these sedimentary features have formed during the Lateglacial.

These results imply that the reduction/reversal in the trend of temperature rise (Antarctic Cold Reversal, 14,500 to 12,900 cal. yr BP) during the post LGM deglaciation has been registered in the coastal continental deposits with the formation of primary sand wedges, indicative of permafrost condition.

Beside a general condition of aridity, the coastal environment was affected by westerlies, capable to transport volcanic material of Andean origin, coherently with an unvaried position of the South Western Wind atmospheric current during the ACR.

\*\*\*\*\*

**New periglacial features on the ancient terraces of the lower Rhône valley (Costières, Gard, France): mapping, datings and implications for the taphonomy of the palaeolithic lithic remains**

*BRUXELLES L.(1), JORDA C.(2), MOURRE V.(3), RAUX A.(3)*

*(1) Inrap, SAINT-HIPPOLYTE-DU-FORT, FRANCE ; (2) INRAP, VILLENEUVE-LÈS-BEZIERS, FRANCE ; (3) INRAP, NIMES, FRANCE*

The Costières formation corresponds partly to old alluvial terraces deposited by the Rhône River during the end of the Pliocene and the first part of the Pleistocene. Between the lower and the middle Pleistocene, this valley was abandoned and the Rhône took a more direct way toward the sea, through the Camargue plain. There remain several levels of terraces affected by a strong fersialitic soil.

For two years, several teams of Inrap have led a huge archaeological diagnosis prior to the building of a high speed railroad between Nimes and Montpellier. Thousands of soundings permit us to reappraise the stratigraphy of all the superficial formations.

Some periglacial features were already known. Polygonal soils, ice wedges, vertical pebbles and loess deposits were described in previous works. They become more prominent in the vicinity of the Rhône valley due to the cold brought in this southern area by the Mistral wind.

Our work permits us to precise but also to complete these observations. We studied several sections through all the area and we can clearly see the periglacial features becoming more and more important toward the Rhône valley, confirming the role of the Mistral. In addition with the features already described in this area, new ones such as lamella structures or reworked loess deposits were identified and studied. But the most important is the discovery of thermokarst features which confirm the existence of permafrost. Numerous closed depressions are now identified and mapped in the eastern part of the Costières. These depressions vary from one to hundred meters in diameter and can reach several meters of depth. They were formed by the partial molten of the permafrost during the Tardiglacial period, which is confirmed by the OSL datings. These depressions subtracted the pleistocene colluviums and part of the loess cover from the erosion. The lower palaeolithic remains were also trapped in the same time and sites appear as a secondary concentration.

## **Poster presentations:**

### **The Spatial Distribution of Rock Glaciers and Protalus Ramparts in the Central Italian Alps**

BRARDINONI F., SCOTTI R., CROSTA G.B.

*University of Milano-Bicocca, MILANO, ITALY*

We present a regional inventory of rock glaciers (1514) and protalus ramparts (228) from the central Italian Alps. To identify and classify the landforms we inspect air-orthophoto mosaics and a 2m-DSM, and conduct field work. The inventory forms an empirical basis to analyze: (i) the significance of hillslope and glacial processes to rock glacier sediment supply; (ii) linkages between periglacial landforms and topographic attributes; (iii) the spatial variability of periglacial activity in relation to a parsimonious set of environmental variates (i.e., elevation, precipitation, and lithology); and (iv) the effects of the Pleistocene-Holocene climatic transition on the distribution of intact and relict landforms. This analysis reveals that the elevation of rock glacier termini can vary over 200 m as a function of slope aspect. In turn, the distribution of periglacial landforms among aspect categories is controlled by the structure of the valley network that promotes NW and SE exposures. Talus rock glaciers prevail numerically over the glacier-derived typology, even though the latter population appears to have increased during the Holocene. Relict and intact rock glaciers have distinct spatial patterns in that the former display, on average, a 400-m elevation drop and a less clustered distribution towards northern aspects, suggesting that they have developed in more "permafrost-prone" climatic conditions. Analyzing the study region through a 27.5 km-grid has been instrumental for showing that rock glacier specific area and terminus elevation are: (i) positively correlated with terrain elevation; and (ii) negatively correlated with mean annual precipitation. As a consequence, in relation to Holocene generalized climate amelioration, intact rock glaciers have progressively disappeared from the wetter and milder portions of the area. Analysis of rock glacier occurrence across litho-tectonic sectors does not provide conclusive dependences and requires further analysis.

\*\*\*\*\*

### **Age and structure of perennial frost mounds in Yakutia region**

URBAN A.

*Melnikov permafrost Institute SB RAS, YAKUTSK, RUSSIAN FEDERATION*

Frost mounds (canadian "pingo", yakutian "bulgunnyakh") were forming during Late Pleistocene and Holocene. Analyze of frost mound's age shows its active formation started more than 8500 years ago. Frost mounds age is established from 150 to more than 8500 years.

Holocene period is characterized significant climatic and geographical conditions changes, which is approached to modern climate. During 2500–8000 years period cyclic warming and cooling of climate happened. It due to ideal for frost heaving processes conditions was formed sufficient ground moisture, good conditions for peat accumulation, subsequent cooling and ground ice forming processes. Modern trend of frost mound development is determined mostly by climatic and permafrost conditions of territory. Now we talk a lot about it degradation, however we have enough examples of stable state and its active formation.

Territory of Yakutia differ variety climatic and geocryological conditions. Mutual influence of these factors in different part of Yakutia cause different mechanism of frost mound's formation.

This paper presents materials of field researching conducted by author. As a result we got subsurface profiles, temperature data and age of perennial frost mounds.

### **Characteristics and Development of an Autochthonous Blockfield, Western Dronning Maud Land, Antarctica**

MEIKLEJOHN I.(1), HANSEN C.(1), DWIGHT R.(1), LEE J.(2), SCOTT D.(1)

(1) Rhodes University, GRAHAMSTOWN, SOUTH AFRICA ; (2) Stellenbosch University, STELLENBOSCH, SOUTH AFRICA

An autochthonous blockfield on the Northern Buttress of the Vesleskarvet nunatak in Western Droning Maud Land, Antarctica was studied to document its characteristics and to investigate its origin. The blockfield is located on a dolerite sill in a permafrost environment with an active layer that is currently 16cm deep. Initial fracturing by dilatation, following glacial retreat, has produced the blocks that comprise the blockfield and which have been subsequently displaced from their original positions. In places, the individual blocks are separated from adjacent and underlying material by an ice matrix. Well-developed case hardening and patination are indicative of a substantial period weathering subsequent to initial bedrock fracturing.

The dimensions and orientations of more than 300 individual blocks were measured along predefined transects, while the characteristics of each face of the rocks sampled were noted. In addition, an Equotip and Schmidt Hammer were used to investigate rock hardness and, hence, relative weathering. Rebound values were mapped and interpolated over the extent of the study area. While no statistically significant relationship was found to occur between different aspects of individual rocks sampled, differences over the entire nunatak reflect the variability in aerial exposure and moisture conditions brought about by the spatial distribution of snow cover.

The development of the blockfield is suggested to have resulted from the freezing of moisture derived from snowmelt that has flowed into bedrock cracks through the active layer to the upper surface of the permafrost. During the cooler winter, freezing of the liquid water heaved and displaced the pre-existing blocks to produce the observed blockfield. These findings are the first known field observations that support this model of blockfield formation.

\*\*\*\*\*

### **Ground temperature regime and periglacial dynamics in three different sites from the summit area in Sierra Nevada (southern Spain) from 2006 to 2012**

SALVADOR-FRANCH F.(1), OLIVA M.(2), SALVÀ-CATARINEU M.(1), GÓMEZ-ORTIZ A.(1)

(1) Universitat de Barcelona, BARCELONA, SPAIN ; (2) Universidade de Lisboa, LISBOA, PORTUGAL

Ground temperatures and its control on snow cover are crucial factors conditioning the activity of current periglacial processes in the highest lands of Sierra Nevada (Bétique Range, Iberian Peninsula).

We present summary results of the monitoring period from September 2006 to August 2012 in three sites with contrasting topography, aspect and snow cover. Temperatures loggers have recorded data at 2 hours time lapse at: a) Veleta glacial cirque, an environment with marginal permafrost and a small active rock glacier in it (3107 m asl), b) the *flat summit* plateau of Collado de los Machos (3297 m) characterized by the existence of inactive sorted circles with scarce snow cover, and c) the southern cirque of Rio Seco, an area with moderate snow cover and widespread solifluction lobes (3105 m).

We discuss the periglacial activity in the three study sites in relation with ground temperatures. Results show evidence of the decisive control played by snow cover (duration and thickness) in the thermal regime of the ground (rhythm, depth and intensity of freezing). Only the site in the Veleta cirque has revealed the existence of permafrost, which is inexistent at the summit plateaus and southern cirques. The freezing and thawing of the ground depends substantially on the geographical characteristics of the sites, although a common pattern is detected: the thawing occurs more rapidly than the freezing and the number of freeze-thaw cycles in air temperatures is substantially higher than in ground temperatures.

## **Mapping the consequences of global change on permafrost extent: a case study from the Clarée valley, southern French Alps**

PERRIER R.(1), COSSART E.(2), FORT M.(1)

(1) *Université Paris-Diderot, UMR 8586 PRODIG CNRS, PARIS, FRANCE* ; (2) *Université Paris 1 Panthéon-Sorbonne, UMR 8586 PRODIG CNRS, PARIS, FRANCE*

Global warming could affect the evolution of permafrost and lead to its degradation. In this context, mountain areas may be affected by an increase of natural hazards such as rockfalls, debris flows or slope instabilities. As mountain areas may provide locations for urban water sources, construction borrow sources, drill sites, transport infrastructures, ski lifts, and dams, it becomes essential to determine spatially relevant sectors that may be affected by permafrost degradation.

Here, we present a first approach of a permafrost degradation distribution model through the use of field data and GIS (Geographical Information System). Two statistical models are developed, one for permafrost distribution and one for degraded permafrost spatial extent. For both models, a logistic regression model was used and respectively based on presence/absence of permafrost occurrence and presence/absence of permafrost degradation symptoms.

Both distribution models are based on a combination of permafrost/permafrost degradation evidence and statistical analysis. For permafrost distribution model, empirical data was obtained using spring water temperature collection method (60 points collected between summer 2007 and 2011 in the Clarée valley, southern French Alps). For permafrost degradation model, permafrost degradation symptoms (thermokarst, melt furrow, mass movements) were collected during field campaigns between 2008 and 2011. For both models, topographic variables (altitude, slope, curvature) and climatic variables (latitude, longitude and incoming solar radiation) are used as predictor variables and derived from a 25 m DEM (Digital Elevation Model) (BdAlti-IGN) in a GIS. Finally, both spatial distribution models are represented at different scales by interpolation with the help of a GIS.

Results show that potential permafrost degradation areas are heterogeneously distributed as they depend on local glacial/permafrost history as well as local topographical conditions.

\*\*\*\*\*

## **The distribution and climatic implications of granite tors on the Great Dividing Range, Australia**

SLEE A.

*University of Queensland, BRISBANE, AUSTRALIA*

Tors in mountain environments have long been considered to be indicative of periglacial environmental conditions. In Australia many of the highest regions of the Great Dividing Range are composed of extensive granitic plutons that form flat topped plateaus that rise above the surrounding landscape. While periglacial landforms in the form of block streams and solifluction deposits are prominent in the southern parts of the Great Dividing Range they are related to basalt and metamorphic lithologies and are poorly developed or absent within granitic terrain. While block streams are absent from granite terrain; tors are common throughout the Great Dividing Range as far north as Warwick in south-eastern Queensland at a latitude of 28°15'S. Mapping and classification of granite terrain along the length of the Great Dividing Range has revealed patterns of granite tor distribution. These are related to cold climate processes controlled by altitude and continentality or coastal weathering regimes.

### Geophysical signatures of permafrost in SW Spitsbergen

KASPRZAK M.(1), KONDRACKA M.(2)

(1) University of Wrocław, WROCLAW, POLAND ; (2) University of Silesia, SOSNOWIEC, POLAND

In the periglacial zone there exist various landforms, which contain an ice-core or are formed in the presence of ground ice. We examined internal structures of such forms in the test area on the west coast of Wedel Jarlsberg Land, SW Spitsbergen. The main aim of this work was to investigate structures of depositional landforms in different but typical terrain situations.

In this work geophysical methods were applied. We used the 2D electrical resistivity tomography (ERT) with chosen method of electrodes arrays: Wenner-Alfa, Schlumberger and Dipole-Dipole. We surveyed more than 20 profiles (78–235 m long, 2–5 m unit electrode spacing) – across ice-cored end moraine of the Werenskiöld Glacier, debris and debris-flow taluses, rock glaciers and Holocene marine terraces.

Results allow us to detect strong freezing of bedrock under ice-cored moraine. ERT profiles demonstrate very significant differences in structure and ice content inside individual lobes of rock glaciers. Obtained resistivity models confirm strong correlation between the presence of ice inside talus and its thickness, shape, slope and slope water runoff. However, most interesting are results concerning thickness of permafrost across marine terraces. Here, the influence of sea water causes elimination of permafrost bed and its discontinuous character near ground surface.

Electrical resistivity methods determined non-invasively and in a dynamic manner what is the impact of the ice in the structure of examined terrain forms. Finally, results make possible to verify earlier views on internal structure of medium- and small-size landforms in the periglacial zone and formation of permafrost on Greenland Sea coast. The method is particularly useful in protected area of Svalbard where excavations are not allowed.

\*\*\*\*\*

### 3D geophysical imaging to study the evolution of a debris covered glacier in the Dolomites (South-Eastern Italian Alps)

ZANONER T.(1), FRANCESE R.(2), BONDESAN A.(1), GIORGI M.(2), CARTON A.(1), SEPPI R.(3), NINFO A.(1)

(1) University of Padova - Department of Geosciences, PADOVA, ITALY ; (2) National Institute of Oceanography and Experimental Geophysics (OGS), TRIESTE, ITALY ; (3) University of Pavia - Department of Earth and Environmental Sciences, PAVIA, ITALY

The Cima Uomo glacier is located in the upper San Nicolò Valley (Dolomites, Italy) between 2200 m and 3000 m a.s.l. It was a cirque glacier fed by avalanches and, during the 50s, it was initially classified as a clean glacier. Later it evolved into a debris-covered glacier and it is currently developing in a rock glacier-like landform.

The internal structure of the ice-debris mass and the morphology of the bedrock were investigated using a 3D resistivity imaging and 2D radar profiling.

Field data were collected with 48-electrode Syscal R1 Georesistivimeter and with a GSSI SIR-2000 radar system equipped with an unshielded 75 MHz antenna. The resistivity spread was 48-electrode, 3 m electrode spacing longitudinal profile recorded both in pole-dipole, using 6 remote poles, and Wenner mode. The radar scan was also a longitudinal profile of about 350 m of length. The stations were georeferenced conducting a DGPS and total station survey.

Data processing was not straightforward as the electrical field was severely distorted due to the surface morphology and the difficulties in coupling the radar antenna with the ground. After a comprehensive processing with the removal of about 10% of noisy values and a careful selection of the modelling parameters, electrical data turned out to be good quality. To improve radar data quality some specific processing routines were coded.

Subsurface geophysical images show a close correspondence, indicating the existence of a thick ice layer ranging from few tens of decimetres below the surface to a depth larger than 10 m. The ice body has a complex shape with two distinct frontal lobes and a clear physical continuity from its front to the back part located at higher altitude. The radar signature in the higher portion of the ice-debris mass seems to be quite different with a sudden increase in the amplitude decay function, probably due to a major percentage of the silty matrix in the uppermost layers.

## Biodiversity and thermal regimes on cold scree slopes

STROHMEYER V.(1), HUC S.(2), DESPLANQUE C.(3), SCHOENEICH P.(1), CECILLON L.(4), HUSTACHE E.(5), ROBERT Y.(3)

(1) Institut de Géographie Alpine, GRENOBLE, FRANCE ; (2) Conservatoire Botanique National Alpin, GAP, FRANCE ; (3) Office National des Forêts, GRENOBLE, FRANCE ; (4) IRSTEA, GRENOBLE, FRANCE ; (5) Natura 2000 Dévoluy, ASPRES-SUR-BÛECH, FRANCE

Cold scree slopes are particular geosystems in mountain areas, due to internal, alternating seasonal ventilation of the scree deposit. They can contain an ice lens and a permafrost patch in the distal part, far below the lower limit of discontinuous alpine permafrost. These cold screes often bear boreo-alpine plant species constituting “abyssal” ecosystems at low altitudes where they normally do not grow.

A “cold scree slope” network was created as part of the PermaFRANCE observing system and Alpine Flora Conservation group. Its objective is to better understand the relations between temperature regimes and the development of specific vegetation on these scree slopes. The first step was an inventory of the sites in the French Alps, and a typology of related ecosystems. A total of 38 cold scree slopes were identified, and some sites have been equipped for ground temperature measurements.

Field surveys show that cold scree ecosystems are located mainly on north-east to north-west exposed slopes, with mean elevations ranging from 900 to 2000m. These shady and cold situations maintain strong ventilation (winter/summer) and allow the development of a typical boreo-alpine vegetation even at low altitude.

First botanical surveys reveal a great variety of ecosystems. The main characteristics are dwarf trees (*Pinus uncinata*, *Picea abies*) growing on a very thick raw humus layer, and forming patches of upper subalpine character within the lower subalpine or the upper montane belts. They are accompanied by shrub (*Rhododendron ferrugineum*) herbaceous (*Dryas octopetala*), moss and lichen species normally found in alpine meadows or even tundra environments.

The inventory and the measurements allow investigating the relations between lithology, temperature and ecosystems. The botanical survey will serve as a reference for further surveys, in order to monitor the sensitivity of abyssal ecosystems to climate change or to modifications of the ground thermal regime.

\*\*\*\*\*

## Past and present dynamics of a potentially hazardous rock glacier (Dérochoir, Mont Blanc Massif, France)

BODIN X.(1), KRYSIECKI J.M.(2), SCHOENEICH P.(2)

(1) Laboratoire EDYTEM, UMR 5204 CNRS / Université de Savoie, LE BOURGET-DU-LAC, FRANCE ; (2) Laboratoire PACTE, UMR 5194, CNRS / Université Joseph Fourier, GRENOBLE, FRANCE

In the late 19th century, the Arandellys steep catchment has been subjected to several torrential floods that damaged the city of Les Houches, in the Mont Blanc Massif. At that time, the investigation pointed out the potential role of a debris accumulation with locally high ice content, now identified as the Dérochoir rock glacier. This morphological crisis finally ended up after 1897, but the rock glacier has nevertheless been recently identified as one of the few sites in this highly touristic area where the degradation of permafrost might generate hazardous situations.

We present here the main findings of a collaborative study that aimed at i) reconstructing the past dynamics of the rock glacier and the geomorphological and climatological context that led to the crisis, ii) estimating the evolution of the rock glacier during the XXth century, iii) quantify the present dynamics in terms of surface displacement and ground thermal regime and iv) precisising the present geomorphological context and the internal structure of the rock glacier.

We observed that the surface velocity experienced by the rock glacier during the last years (until 2008), estimated by air photo comparison, is twice higher (0.51 m/yr) than between 1974 and 2004, whereas the velocity over the 1895-1974 period, more roughly estimated by comparing the distance between the rock glacier edge and the path, seems to have been even lower (0.19 m/yr). Spatially, the highest velocities have moved from the West lobe, as testified by the strongest deformations of the path, to the East lobe where surface displacements measured by differential GPS reach 0.69 m/yr in 2009-2010. In terms of internal structure, the geoelectrical soundings performed in summer 2012 revealed that the probable highest amount of ground ice is presently found in the slowly moving West lobe, whereas on the fast-moving one the ice is probably present in lower quantity and/or at higher temperature and/or with a higher water content.

**Ice sheet - permafrost interactions inferred from landform and sedimentary structures, Weichselian Ice Sheet, Poland**

EWERTOWSKI M.(1), KASPRZAK L.(2), SZUMAN I.(2), TOMCZYK A.(2)

(1) Department of Geography, Durham University, DURHAM, UNITED KINGDOM ; (2) Faculty of Geographical and Geological Sciences, Adam Mickiewicz University, POZNAŃ, POLAND

Past cryogenic structures and landforms related to them were used for interpretation of the past permafrost and its relationship with Weichselian ice sheet. Study area is located in the central Wielkopolska (west-central Poland) and characterized by moraines, fans, till plains, mega scale glacial lineations, tunnel valleys and outwash plains formed during the recession of the Weichselian Ice Sheet from maximum extent (Leszno Phase) to Poznań Phase and further to the north. Varied types of sedimentary structures and landforms were used to infer about environmental conditions in the foreland as well as beneath the ice sheet. The most important ones were ice-wedge ice-wedge pseudomorphs located beneath the subglacial till and with till infilling, which suggest that the ground was permanently frozen during ice advance. Other common features like frost cracks, sandy intraclasts and glacial moraines also indicate the frozen ground conditions. Spatial distribution of these features as well as their vertical variations (below and above the subglacial till layer) suggests that thermal conditions greatly varied with time and space.

Results of the research suggest that in west-central Poland: (1) permafrost exist on the forefield of the Weichselian ice sheet during Last Glacial Maximum (LGM); (2) permafrost developed on freshly deglaciated areas and had an important impact on shaping post-glacial landforms; (3) degradation of permafrost were slow and the thermokarst processes played an important role; (4) there were no abrupt changes of climatic condition after the LGM – rather gradually change from glacial to periglacial conditions.

This work was supported by Polish National Science Centre (project number N N306 599640)

\*\*\*\*\*

**The influence of altitude, exposure and declivity on freeze-thaw processes in non-permafrost mountain areas: the Southern Carpathians, Romania**

VASILE M., VESPREMEANU-STROE A.

Faculty of Geography, University of Bucharest, BUCHAREST, ROMANIA

The distribution of freeze-thaw cycles on free rockwalls could be used as an indicator of frost processes control on mountain slopes evolution. This study presents the conditions of freeze-thaw cycles regime in the Southern Carpathians, a mountain range that mainly lacks permafrost or it preserves it in sporadic patches. In terms of intensity and frequency, frost behaviour is defined by a sum of controlling factors of which, the present work evaluates the weighting of the altitude, exposure and declivity. Thermal regime was monitored at more than 40 sites in order to find the rockwall facets that are probably the most affected by thermal weathering. The measurements were extended between 1600 and 2450 m a.s.l., on northern, southern, eastern and western rockwalls, on slopes varying from 0 to 90 degrees. Both seasonal and diurnal freeze-thaw cycles were taken into account. Thermal amplitude, duration and freezing index were calculated for each cycle and used in the estimation of freeze-thaw cycles efficiency and frost depth.

Southern rockwalls are twice to three times more affected by efficient diurnal freeze-thaw cycles than the northern ones, while seasonal frost propagates to estimated depths of about 5.5 m on South and up to 8 m on North for elevation higher than 2000 m. No obvious correlation was set between the total number of freeze-thaw cycles and elevation levels. Nevertheless, the magnitude (expressed by the frost depths) increases with altitude and the maximum of freeze-thaw efficiency is encountered within 2000 - 2300 m level. Mean and high slopes (30 to 90 degrees) are the most responsive to thermal weathering, except for the northern rockwalls where declivity is less significant.

### **Distribution and characteristics of mountain permafrost under the Tropics: insights from an inventory of rock glaciers on the Altiplano, Chile and Bolivia (20-22°S)**

ANETAS G.(1), BODIN X.(1), SORUCO A.(2)

(1) Laboratoire EDYTEM, CNRS / Université de Savoie, LA BOURGET-DU-LAC, FRANCE ; (2) Instituto de Investigaciones Geológicas y del Medio Ambiente, Universidad Mayor San Andres, LA PAZ, BOLIVIA

Located in the dry area of the tropical Andes in Chile and Bolivia, the Altiplano is a high elevation plateau surrounded by numerous volcanics edifices that reach more than 6000 m asl. and host a few glaciers and many rock glaciers. When they are active, rock glaciers are typical indicators of the creeping of ice-rich mountain permafrost in debris accumulations. These landforms can play a significant role in shaping the geomorphological landscape and also contribute to the hydrological regime in a still poorly understood way. In several mountain ranges of the world, it has been observed that rock glaciers, as a cryospheric feature, react to climate change in substantially modifying their dynamics, and recent observations suggest that the warming of ice in permafrost may lead to increasing deformation rates and even to terrain destabilization. Nevertheless, under the Tropics little is known regarding permafrost and rock glaciers, although it is proved that tropical glaciers has been severely retreating since several decades as a consequence of a warming trend and modifications in the ENSO regime. Therefore, the aim of this study is to compile an exhaustive database of rock glaciers in order to improve our understanding of the factors that control the permafrost distribution and its state in this region.

Around 150 active and inactive rock glaciers have been inventoried and mapped using Google Earth images, between 20 and 22°S (South of Bolivia and North of Chile). According to existing GIS-based methodologies, the morphometric, topoclimatic and geomorphological characteristics were extracted in a geodatabase using available DEM and satellite imagery. The distribution of rock glaciers was compared to geological settings, including volcano activity, and to regional climatological datasets, such as meteorological stations records and reanalysis gridded datasets.

\*\*\*\*\*

### **Age and dynamics of blockstreams in the eastern velay highlands, Massif Central, France: preliminary findings**

DEFIVE E.(1), LE COEUR C.(2), VIRMOUX C.(3), PEIGNELIN C.(1), POIRAUD A.(4), GUNNELL Y.(5)

(1) Université Blaise Pascal, GEOLAB, UMR 6042-CNRS, Maison des Sciences de l'Homme, 4 rue Ledru, F-63057 Clermont-Ferrand, France, CLERMONT-FERRAND, FRANCE ; (2) Université Paris 1 Panthéon-Sorbonne, Laboratoire de Géographie Physique, UMR 8591 CNRS, 1 place A. Briand, 92195 Meudon principal Cedex, PARIS, FRANCE ; (3) Laboratoire de Géographie Physique, UMR 8591 CNRS, 1 place A. Briand, 92195 Meudon principal Cedex, MEUDON, FRANCE ; (4) GEOLAB, UMR 6042-CNRS, Maison des Sciences de l'Homme, 4 rue Ledru, F-63057 Clermont-Ferrand, France / Bureau d'étude "Inselberg", 261 allée des Bauges, 73000 Chambéry, France, CLERMONT-FERRAND, FRANCE ; (5) Université Lumière-Lyon 2, UMR 5600 CNRS Environnement, Ville, Société, 69635 Lyon Cedex 07, France, LYON, FRANCE

Many blockstreams occur in the Miocene volcanic area of Mont Mézenc, eastern Velay, SE Massif Central, France. They were supplied by frost-shattered exposures of lava-flow boundaries, phonolitic domes and other intrusions. These 'rivers of rock' are ribbons of chaotically upheaved blocks presenting an openwork structure, are 400 to 1100 m long and 20 to 200 m wide, and are today disconnected from the rock exposures that supplied the debris. Some occur on very low gradient slopes. The largest blockstreams offer evidence of compression ridges and post-depositional block subsidence. Their dynamics and age are not precisely known in the study area and they have been interpreted by default as Late Pleniglacial rock glaciers. Field observations (stratigraphic relations with other surficial deposits, topographic position, distance from bedrock source areas and from talwegs, structural context), however, indicate that the situation is more complex, with new implications for their age, origin and past dynamics. This reconnaissance study proposes a typology of blockstreams for the area. The base of the blockstreams remains inaccessible to direct observation but several ground-penetrating radar transects were carried out in order to map the topography at depth. Results show that the blocks fill gullies 5 to 15 m in depth. At the surface, a sharp textural transition with other slope deposits is clearly detected but the latter grade topographically to the surface of the blockstreams, not to the gullies beneath them. These cross-cutting relations provide a relative chronology not previously established in the case of blockstream deposits.

**Phytomass and soil organic carbon inventories related to land cover classification and periglacial landscape features at Ari-Mas and Logata, Taimyr Peninsula**

RAMAGE J.(1), HUGELIUS G.(1), PALMTAG J.(1), LASHCHINSKIY N.(2)

*(1) Department of Physical Geography and Quaternary Geology, Stockholm University, STOCKHOLM, SWEDEN ; (2) Central Siberian Botanical Garden, Russian Academy of Sciences, NOVOSIBIRSK, RUSSIAN FEDERATION*

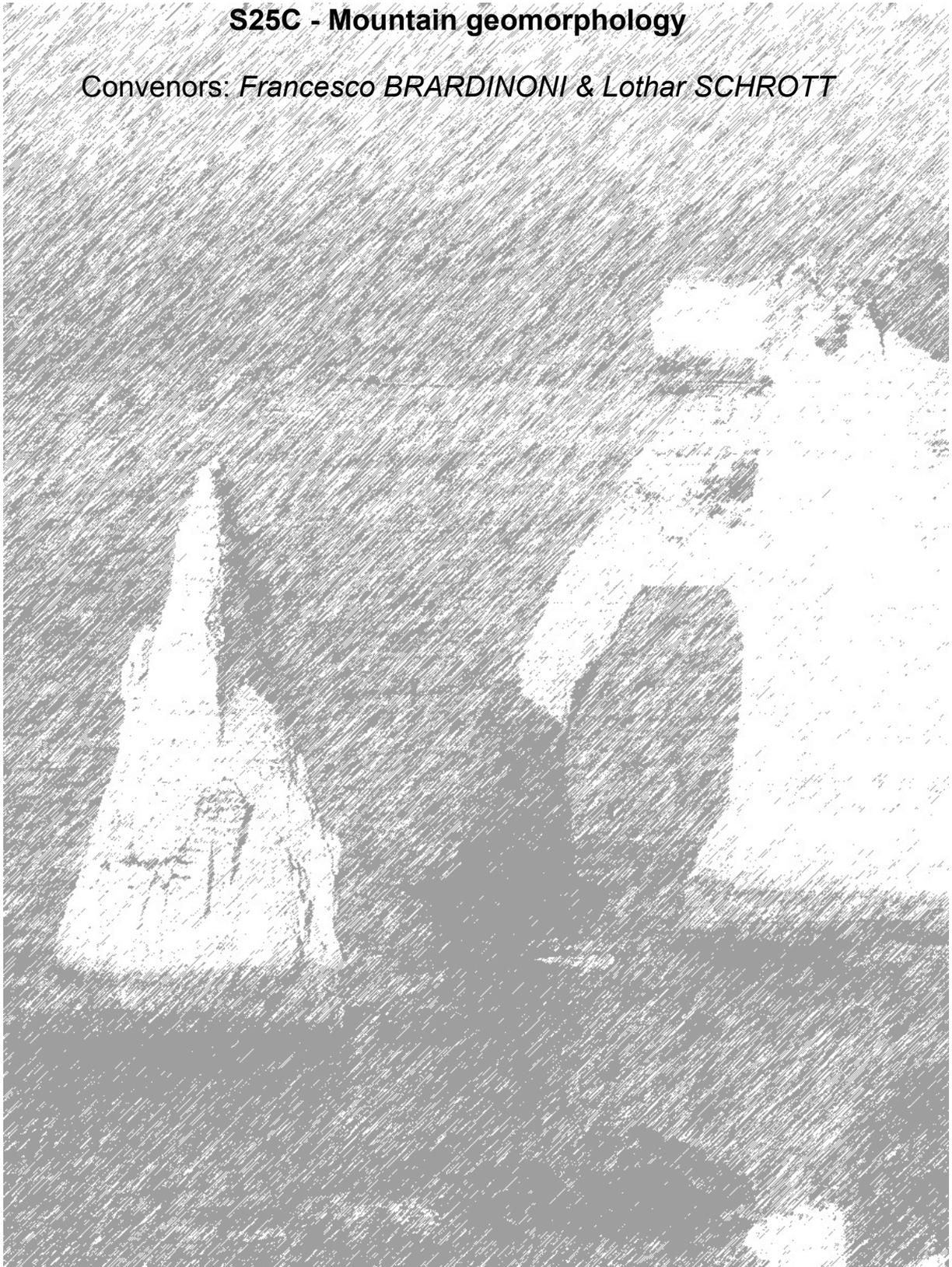
Permafrost presents a sensitive response to temperature changes. Changes in the ground thermal regime, due to an increase in atmospheric temperatures in the Arctic, are expected to alter the turnover of soil organic carbon (SOC) through changes in the ground properties. This study assesses the landscape diversity in two sites within the typical tundra in the Taimyr Peninsula (Russian Arctic) and associates it with the differing patterns of SOC storage and partitioning in the first top meter of soil. The results were obtained from soil and vegetation inventories in combination with remote sensing analysis. Upscaling methods were used to estimate the amounts of carbon at a landscape scale, based on a land cover classification.

On average, 29.5 kg C m<sup>2</sup> were stored, mainly in mineral horizons found in the active layer. However, the carbon distribution shows a tremendous variability across the tundra at a large scale. High amounts of SOC are found in upland areas and within the patterned ground features found in peatlands. The vegetation stores a small percentage of the total carbon, a mean C phytomass storage of only 1.38 % of the total SOC storage, but is assumed as an important parameter for controlling the ground thermal regime. Highest amounts of aboveground phytomass carbon are found in deciduous shrubs and moss layers. The large variability in SOC due to complex land cover emphasizes the necessity of conducting detailed field investigations and challenges the use of land cover classification in SOC storage assessment.

\*\*\*\*\*

**S25C - Mountain geomorphology**

Convenors: *Francesco BRARDINONI & Lothar SCHROTT*





## **Oral presentations:**

### **Lightning strikes and their influence on mountain geomorphology and sediment supply**

*KNIGHT J., GRAB S., MAYET N.*

*University of the Witwatersrand, JOHANNESBURG, SOUTH AFRICA*

Lightning strikes are common along the Drakensburg escarpment of east-central Southern Africa in particular where they are driven by rapidly-rising and moist air masses. Although lightning climatology is not fully known and is subject to high spatial and temporal variability, the geomorphological impacts of cloud-to-ground lightning strikes have been described from many bedrock mountain surfaces worldwide. This evidence includes angular and shattered bedrock fragments, conjugate fractures that penetrate into bedrock, and heat-fused quartz grains (fulgarite). Despite this wide-ranging evidence, no examples have yet been described from Southern Africa nor has the role of lightning strikes on mountain geomorphology and sediment supply over long time periods been previously considered. This is important, however, since lightning strikes can contribute to mountain weathering and denudation and produce materials that may appear morphologically similar to those produced by other mountain weathering processes. As such, understanding the role of lightning strikes in mountain sediment supply is not geomorphically insignificant for reconstructing past mountain-shaping processes and products. In this paper we discuss for the first time, geomorphological evidence for lightning strikes on hilltops in eastern Lesotho (c. 3200 m asl), including their number, locations, size and relative age based on rock surface hardness and lichenometric methods. From these observations, we then present a geomorphological model that outlines the relative role of lightning-produced debris with respect to other mountain weathering processes, and their interrelationships.

\*\*\*\*\*

### **Debris talus and cones dynamic in a calcareous Atlantic high mountain (Picos de Europa, Northern Spain)**

*SERRANO E.(1), SANJOSÉ J.J.(2), GONZÁLEZ-TRUEBA J.J.(3)*

*(1) University of Valladolid, VALLADOLID, SPAIN ; (2) University of Extremadura, CÁCERES, SPAIN ; (3) CIESE-Comillas, COMILLAS, SPAIN*

The high mountain of the Picos de Europa is characterised by a nivoperiglacial environment and the most important geomorphic processes are the nivation, linked to the depth, changes of snow cover and snow avalanches, karstification, solifluction and gelifraction. Talus and debris cones are the most extended active landform in the Central Massif of Picos de Europa (Cantabrian Range). Located in the north of Iberian Peninsula, it is a glaciokarstic relief featured by Pleistocene glaciations.

The aim of this work is to know the mechanisms working in the debris transfer from walls and high cirques to the valleys in calcareous Atlantic High Mountain (nival processes, snow avalanches, debris flow, rockfall, frost creep) and estimate the movement and deformation of debris cones. Techniques applied in this work have been a detailed geomorphological map (1:10.000), a surface morphological and sedimentological analysis, soil thermal regime control by dataloggers around Peña Vieja Group and in the La Vueltona area have been analysed the winter snowcover changes by images and the movements and deformations of talus and cones by Terrestrial Laser Scanner (TLS). The TLS is a useful tool for monitoring changes, movements and deformations on surface of landforms. The surface of three debris cones have been scanned in summers of 2008, 2009, 2010, 2011 and 2012 and permits to know surface changes and deformations in the debris body.

Processes involved in the dynamic of debris talus are rock fall by gelifraction, debris flow, related to the spring melt and stormy episodes, creep, small movements not related to frost, and nival processes. The debris and talus cones are complex, and three debris cones types can be differentiated: gravitational debris cones with debris flow, snow avalanches debris cones and mixed debris cones. The TLS show small displacement and deformations affecting at all body. The most important changes take place in the debris flow channel by infill of sediments.

## **Holocene rockwall retreat in an inner-alpine headwater catchment (Gradenmoos Basin, Schober Mountains, Austrian Alps)**

GÖTZ J., SCHROTT L.

*University of Salzburg, Dept. of Geography and Geology, SALZBURG, GERMANY*

Alpine denudation and rockwall retreat has been investigated on various spatio-temporal scales resulting in a wide range of rates (~10–4000 mm/ka). This study quantifies postglacial sediment storage in the glacially overdeepened Gradenmoos Basin – an alpine lake mire with adjacent floodplain deposits and surrounding hillslope storage landforms (subcatchment size: 4.5 km<sup>2</sup>) – in the central Gradenbach catchment (32 km<sup>2</sup>, Schober Range, Austria). Using the sediment budget approach, postglacial rockwall retreat is accurately reconstructed from these volumes due to several reasons:

- Holocene sediment output of the basin is negligible due to lake existence after deglaciation for ~7500 years as observed by core-drillings.
- Sediment volumes are accurately assessed as a consequence of the multi-method approach (geomorphologic mapping, terrestrial laserscanning, geophysical methods (refraction seismic, ground-penetrating radar, DC resistivity), core-drillings, GIS and 3D modelling).
- Postglacial sediment storage is corrected by pre-Holocene basal till derived from drilling data.
- Landform based sediment volumes can be associated to clearly delimitable source areas.
- A time period available for postglacial sedimentation and rockwall retreat is established by radiocarbon dating, palynologic and stratigraphic analyses of the sediment cores.

Postglacial sedimentation commenced ~11 ka BP and the (latest) Egesen glacier oscillation effectively scoured the basin leaving a shallow layer of basal till (~1.4 x 10<sup>6</sup> m<sup>3</sup>; 8 % of entire basin storage). Total (postglacial) sediment storage amounts to ~19.7 (18.3) x 10<sup>6</sup> m<sup>3</sup>. Single landform volumes range from ~0.03 (0.01) - 6.26 (5.97) x 10<sup>6</sup> m<sup>3</sup>, whereas hillslope storage overbalance basin fill deposits by a factor of five. As will be discussed, three scenarios of rockwall retreat provide relatively low rates of up to 520 mm/ka considering the highly weathered mica-schist lithology and the glacial imprint in the study area.

\*\*\*\*\*

## **Geomorphological and climate context of debris flow regional occurrence in the Northern French Alps**

PAVLOVA I.(1), ECKERT N.(2), GRANCHER D.(1), JOMELLI V.(1), BRUNSTEIN D.(1)

*(1) Laboratoire de Géographie Physique, CNRS, MEUDON, FRANCE ; (2) Erosion torrentielle, neige et avalanches, Cemagref, GRENOBLE, FRANCE*

The general objective of this study is to determine with high accuracy triggering factors of debris flows occurrence in the Northern French Alps over the last thirty five years. Among all factors resulting in debris flow initiation meteorological conditions and geomorphologic context are considered as the most relevant. Both factors are quite well explored separately but we have a poor knowledge about the combined analysis of both geomorphic and climatic initiation factors at regional scale.

Our multivariate statistical approach aimed to determine climate and geomorphologic parameters responsible for debris flow activity changes on the base of one probabilistic model. A hierarchical Bayesian annual logistic regression probability model of debris flow triggering was fitted between the climate characteristics and geomorphic catchment characteristics over the last 35 years. Individual catchment characteristics of nearly 300 debris flow events consisted of morphometric (altitude of the area, exposure, mean slope and others) and qualitative (dominant lithological type, dominant land use type) data. Regional annual meteorological parameters (such as mean annual temperature and precipitation) were computed from mean values of reanalyzed Safran data.

Globally, hierarchical probabilistic analysis demonstrates a dominant influence of geomorphological parameters (55%) compared with climate parameters (29%) in the explained regression. Such global approach gives better estimates of triggering probabilities and highlights new significant variables compared with climatic and geomorphic variables analyses separately. Most significant geomorphological factors explaining debris flow spatial variance were surface area and presence of specific land use type, whereas mean slope or lithological type parameters are less important. Temporal regional changes are explained by annual number of rainy days and maximum temperature.

### **Geomorphic change detection using LiDAR DTMs in two small basins of the Italian Alps**

*GOLDIN B.(1), CAVALLI M.(1), BRARDINONI F.(2), COMITI F.(3), MARCHI L.(1)*

*(1) CNR - IRPI, PADOVA, ITALY ; (2) Department of Earth and Environmental Sciences, University of Milano-Bicocca, MILANO, ITALY ; (3) Faculty of Science and Technology, Free University of Bozen-Bolzano, BOLZANO, ITALY*

The description and quantification of landscape changes as modulated by geomorphic processes, at different spatial and temporal scales, constitute the core of modern geomorphic research. The high resolution and accuracy of currently available airborne digital terrain models (DTMs) allow the development of new methods for the quantitative monitoring of geomorphic changes. In this context, DTM of difference (DoD), which can be created by subtracting one elevation model from another, represents a convenient way to estimate volumetric changes across landscape components between successive topographic surveys.

In this contribution we quantify the topographic variations associated with the activity of rapid geomorphic processes (e.g., debris slides and debris flows) in Gadria and Strimm catchments, two adjacent basins, covering a total area of 14.7 km<sup>2</sup>, in the Eastern Italian Alps. To this purpose we perform DoD on two LiDAR-derived DTMs (2 m resolution), acquired respectively in the summer of 2006 and 2011, applying a fuzzy logic-based method (Wheaton et al., 2010) which considers the uncertainty in the surface representation of the topographic data.

Results indicate that shallow rapid failures and channelized processes such as debris flows and debris floods have been by far the dominant processes in both basins over the study period. In particular, we are able to track the effects of a debris-flow event (July 12<sup>th</sup> 2010) originating on the western slopes of Strimm basin and that has been estimated to transport 15,000 m<sup>3</sup> of sediment down to the confluence with Gadria Creek. Not surprisingly, upland terrain characterized by subdued topography and dominated by slow periglacial processes does not exhibit any appreciable change.

Reference: Wheaton J.M., Brasington J., Darby S. E., Shear D. A., 2010. Accounting for uncertainty in DTMs from repeat topographic surveys: improved sediment budgets. *Earth Surface Processes and Landforms*, 35, 136-156.

\*\*\*\*\*

### **Temporal variations of bedload transport in a glacierized mountain basin**

*COMITI F.(1), DELL'AGNESE A.(1), MAO L.(2), ENGEL M.(1), LUCÍA A.(1), PENNA D.(1), BERTOLDI G.(3)*

*(1) Free University of Bozen-Bolzano, BOLZANO, ITALY ; (2) Pontificia Universidad Católica de Chile, SANTIAGO, CHILE ; (3) European Academy EURAC, BOLZANO, ITALY*

Glaciers in the European Alps have retreated substantially over the last century, but the role of their remaining portions on downstream channel dynamics is presumably still relevant. However, only few studies have analyzed the influence of the hydrological regime on sediment transport processes in glacier-fed streams.

This contribution will present sediment transport measurements associated to a water runoff analysis in the Saldur basin, a high-elevation glacierized watershed (19 km<sup>2</sup> drainage area, 3 km<sup>2</sup> covered by a glacier) lying in the Eastern Italian Alps. Bedload transport is monitored continuously at 2100 m a.s.l. by means of a hydrophone and by fixed antennas for tracing clasts equipped with PITs. Bedload samples are collected at the same location and at a cross-section further upstream (drainage area 11 km<sup>2</sup>) by using "Bunte" bedload traps. Turbidity is measured continuously by a fixed turbidimeter installed at the lower section and by a portable one at the upper section during bedload sampling times. Water samples are collected at different sources and sections in order to assess the spatial and temporal variability of tracers (i.e. electrical conductivity and stable water isotopes) in the channel network.

In the period 2011-2013, bedload was sampled from June to August during daily discharge fluctuations associated to snow- and glacier-melt, up to near-bankfull conditions. These daily cycles showed variations of electrical conductivity and isotopic content of stream water which permitted to assess the relative contribution of snow and ice to the total runoff. Parallel cycles in suspended and bedload transport were detected, and most importantly bedload transport rates turned out significantly higher - for the same discharge range - during August glacier-melt flows. Season-dependent hysteresis effects in bedload transport were also observed, likely due to the activation of different sediment sources.

**Root-exposure: a new tool to quantify medium term erosion rates in gypsum areas (Massif de la Vanoise, France)**

ROVERA G.(1), CORONA C.(2), LOPEZ SAEZ J.(3), STOFFEL M.(4)

(1) University J. Fourier, laboratory PACTE UMR5194 CNRS, GRENOBLE, FRANCE ; (2) Laboratory GEOLAB UMR6042 CNRS, CLERMONT-FERRAND, FRANCE ; (3) IRSTEA UR EMGR, laboratory PACTE UMR5194 CNRS, GRENOBLE SAINT MARTIN D'HERES, FRANCE ; (4) Laboratory of Dendrogeomorphology, University of Berne, BERNE, FRANCE

In the Northern Alps, gypsum slopes are subject to intense erosion (karstic forms and gullies). Many studies have been carried out on the meteorological degradation of carbonate outcrops, but only a few exist to date on gypsum. In the Vanoise Massif (French Alps) erosion rates were obtained with surface elevation change-based methods and the monitoring of weight and volume losses of calibrated gypsum tablets. Measurements indicate denudation rates between 3 and 6 mm yr<sup>-1</sup> in the subalpine zone (1800–2100 m a.s.l.).

On forested slopes, such continuous denudation processes are sufficient to expose roots while allowing them to keep their tips in the ground. In the past, the assessment of erosion rates based on root exposure has been applied successfully on a large variety of lithologies (marls, quaternary deposits), in climatic contexts where tree growth is restricted but where annual increment rings are therefore being formed. In this study, data from continuous field monitoring based on micrometric method and gypsum tablets covering the past 10 years, have, for the first time, been compared with an alternative method based on dendrogeomorphology. A total of 45 exposed roots of *Pinus montana* were sampled in the gypsum bad lands and the anatomical variations in annual growth rings due to exposure caused by denudation were analysed. The first year of exposure was determined via the peculiar size reduction of earlywood tracheids.

The medium-term erosion rates (4–5 mm.yr<sup>-1</sup>) as observed in the root-ring series match with erosion rates derived from monitored iron stakes. The detailed knowledge of anatomical changes in roots is though demonstrated a powerful tool for geoscientists to quantify minimal rates of soil erosion in areas where measurements of past processes are not readily available.

\*\*\*\*\*

**Glacial chronology in the Mérida Andes, Venezuela, deduced from cosmogenic <sup>10</sup>Be radionuclide dating**

ANGEL I.(1), CARCAILLET J.(2), CARRILLO E.(1), AUDEMARD F.(3), BECK C.(4)

(1) Universidad Central de Venezuela, CARACAS, VENEZUELA ; (2) ISTerre, Université de Grenoble 1, GRENOBLE, FRANCE ; (3) Fundación Venezolana de Investigaciones Sismológicas, CARACAS, VENEZUELA ; (4) ISTerre Université de Savoie, CHAMBERY, FRANCE

The Merida Andes are located in the west of Venezuela, in northern South America. This cordillera extends over 400 km and reaches a maximum elevation of ~5000 m. Despite numerous descriptions of glacial landforms, lack of available data prevents detailed reconstruction of the last deglaciation. This study documents the post-Last Glacial Maximum (LGM) glacier history using *in-situ* produced cosmogenic <sup>10</sup>Be nuclides. Samples were collected in the Mucubají and Gavidia valleys. In the Mucubají valley, the LGM has been identified as the most important phase for moraine development. The oldest evidence of glacier advance has been dated at ~18 ka, while the end of the LGM s.s. has been dated at ~16.5 ka. The youngest evidence of glacier activity was observed at 4000–4200 m elevation and dated at ~9.2 ka. The dataset evidences intensification of the vertical ice retreat rate from ~25 m/ka during upper Pleistocene to ~310 m/ka during early Holocene. In the Gavidia valley, results suggest that main of the glacier retreat occurred during the Holocene with ages ranging between ~4.7 ka to ~9.6 ka with a vertical retreat rate of ~270 m/ka. The dataset provides the first complete chronology of ice retreat in the tropical Venezuelan Andes. Moreover, our data have been compared with local and global paleoclimatic records. All the significant ice retreat phases are associated with global warming periods.

### Terrestrial cosmogenic nuclides dating of a sacking on a cirque in the Japanese Alps

NISHII R.(1), MATSUSHI Y.(2), MATSUZAKI H.(3)

(1) University of Tsukuba, SHIZUOKA, JAPAN ; (2) Kyoto University, UJI, JAPAN ; (3) The University of Tokyo, BUNKYO, JAPAN

Sacking features (scarps) have widely developed around Mt. Noguchigoro (2924 m a.s.l.), Northern Japanese Alps, as a result of gravitational deformation. These scarps are distributed in the upper slopes which consist of Cretaceous granite. In particular, a large scarp (400 m long and 8 m high) lies on a cirque wall which experienced deglaciation after the Last Glacial Maximum. To evaluate gravitational deformation in the cirque after deglaciation, the concentration of cosmogenic nuclides ( $^{10}\text{Be}$  and  $^{26}\text{Al}$ ) was measured in the scarp face (slip plane); Two samples were taken at ca. 70 cm and 270 cm vertical distance from the top of the scarp. In addition, the timing of glacier retreat and the activity of debris production were also evaluated from dating of roche moutonnee and gravels rolled down from the cirque wall, respectively. The results indicated that the concentration of cosmogenic nuclides at the upper part of the scarp was four times higher than that at the lower part. Such a concentration difference in the same scarp suggests that the scarp had grown slowly or step-by-step. The minimum exposure age showed that the glacier retreated during 8–11 ka. Then, the scarp started to grow at 6 ka at least. The growth of the scarp seems to have accelerated at or after 1.5 ka. Such a change in the rate may reflect climate change (increase of precipitation) and/or earthquake activity.

\*\*\*\*\*

### Geomorphic landscape evolution along the river valleys in Ladakh region of NW Trans Himalayan range during Late Quaternary: implications to climate and tectonics

PHARTIYAL B.(1), SINGH R.(1), NAG D.(1), KOTHARI G.C.(2)

(1) Birbal Sahni Institute of Palaeobotany, LUCKNOW, INDIA ; (2) Institute of Seismological Research, GANDHINAGAR, INDIA

The Himalayan system is a complex and youngest fold mountain chain, which stretches across six countries-Afghanistan, Pakistan, India, Nepal, Bhutan and China. The Trans Himalayan sector exhibits a cold desert environment and is a part of the rain shadow area for the ISM and comes under the Westerly influence. The area receives an annual rainfall of around 30 mm and is dry and barren. Indus river and its tributaries Shyok, Nubra and Tangtse are major drainage patterns and all have played a major role in shaping the geomorphology of this region. These rivers follow courses along major tectonic fault/thrust lines; Indus Suture Zone, Shyok Suture Zone and Karakorum fault. The river valleys have enormous Quaternary deposits of glacial, lacustrine, palaeo-lacustrine, fluvial and aeolian origin. The major geomorphic landforms are U-shaped glacial valleys, gorges, glacial moraines, fill terraces, strath terrace, alluvial fans, debris cone, lacustrine deposits, varves, deflected stream courses, scree and talus cone, fossil valleys, abandoned channels, etc. The sedimentary records represent the changes in melt water and rainfall related hydrology of the river. The geomorphological landscape of young fold mountain belt can change drastically even within short time scales of few thousand of years. The existence of a 185 km valley lake during the Late Quaternary occupying the present day Tangtse and Shyok river valleys is one such example. Our Studies suggest that several lakes occupied parts of these river valleys at 40-30, 20-3 ka BP in Tangtse-Shyok sector and 17-14 ka BP and 12-3 ka BP along the Indus river valley. We have attempted to build geomorphic evolution history from ~50 ka to present in this region. Lying in the vicinity of the major fault lines tectonic disturbances is also evident in deformed lacustrine sediments and moreover these lakes are formed due to the damming of the rivers by different landslides (either due to tectonic activity or abrupt monsoon event).

### **Consequences of a subglacial lake outburst flood for a proglacial fluvial system (Fagge River, Kaunertal, Austria)**

*MORCHE D., BAEWERT H.*

*Martin-Luther-University Halle-Wittenberg, HALLE, GERMANY*

Recently deglaciated glacier forefields in high mountain geosystems are mainly covered by unconsolidated glacial and glacio-fluvial deposits such as (ice-cored) moraines and braid-plains. These sediment stores are vulnerable to surface changes. After deglaciation melt water channels are "imprinted" in the proglacial landscape either in the bed rock or as braided channels on outwash plains. The proglacial area of the glacier Gepatschferner (Ötztal Alps, Austria) is drained by the Fagge River. The river originates from two glacial meltwater channels which were separated by ice-cored moraines proximal to the glacier and further downstream by ruche mountonees. This landform configuration was valid for the last decade after deglaciation as analyses of aerial photographs show. The right channel is 10 m wide and has incised several meters in bed rock. The left channel had a width of about 2 m and run in a moraine-covered small valley. The relief between the higher right channel and lower left channel is 20 m. Concurrent discharge measurements in both rivers have shown that 90 % of the total melt water was discharged in the right channel.

During the 26th August 2012 a sudden partial collapse of the glacier tongue occurred and a subglacial lake outburst flood breached the moraine ridge which divided the two meltwater channels. This event has caused severe geomorphologic changes in the downstream course of the Fagge River. These consequences are comparable to outburst floods from landslide- or moraine-dammed lakes. Since the flood the drainage pattern has completely changed and >99% of the melt water is discharged through the left channel. In order to quantify surface changes of different sediment stores in the forefield of the Gepatschferner terrestrial and airborne laser scanning surveys are carried out. Starting our laser scanning survey a few weeks before the flood event we present a sediment balance of the glacier forefield based on pre-and post-event data .

\*\*\*\*\*

### **Ground ice distribution in a high mountain sedimentary environment and its influence on sediment fluxes and local hazards: results of geoelectrical tomography in the Rognes sector (Mont-Blanc, France)**

*BOSSON J.B.(1), BODIN X.(2), DELINE P.(2), SCHOENEICH P.(3), BARON L.(4), GARDENT M.(2), KRISIECKI J.M.(3), LAMBIEL C.(1)*

*(1) Université de Lausanne - IGD, LAUSANNE, SWITZERLAND ; (2) Laboratoire EDYTEM, Université de Savoie, CNRS, LE BOURGET-DU-LAC, FRANCE ; (3) Institut de Géographie Alpine, PACTE/Territoire, Université Joseph Fourier, GRENOBLE, FRANCE ; (4) Université de Lausanne - CRET, LAUSANNE, SWITZERLAND*

The major crisis experienced by the mountain cryosphere in response to climate change arises critical issues, especially because of the high energy potentially involved in the mobilization of large amount of rock/debris and ice/water. Such cold geomorphic systems respond in a complex way to the global warming, in particular through para- and periglacial processes of unusual intensity and rate that can be a source of hazards.

In high alpine areas, the dynamics of large sediment volumes are closely related to ground ice occurrence: a sound knowledge and understanding of the ground ice distribution and dynamics is therefore required.

Constituted from several sediment accumulations (glacier forefields, push moraines and rock glaciers), the Rognes ridge area (2450 – 3050m a.s.l) is one of the largest sector that contains ground ice in the Mont-Blanc Massif. We present here the main results of an electrical resistivity tomography (ERT) campaign held in August 2012 in order to characterize the internal structure of the landforms. The 10 48-electrode and the 5 24-electrode ERT profiles yield the following findings:

- Rognes area: a continuum between the upslope debris-covered glacier, the ice-free glacier forefield and frozen marginal push moraines. Because of the topography, the ice cementation of the distal part and the absence of efficient connection with hydrosystem, this continuum is a transport-limited system.
- Pierre Ronde area: an ice-free glacier forefield and a marginal rock glacier. Local till of this sector was the main solid supply of the water-pocket outburst of the Tête Rousse glacier in 1892. Our surveys show that, in case of a repeated water-pocket outburst, more than 10m thick of unfrozen till could be mobilized in the main channel flow.
- Dérochoir area: a talus-derived hanging rock glacier feeding torrential stream paths. The torrential crisis experienced by the torrent during the 19th century may be directly linked to rock glacier activity.

## Influences of Snow Cover on Permafrost in unstable Rock Walls

DRAEBING D.(1), KRAUTBLATTER M.(2)

(1) *Department of Geography, University of Bonn, BONN, GERMANY* ; (2) *Monitoring, analysis and early warning of landslides, Technische Universität München, MÜNCHEN, GERMANY*

Degrading permafrost in rock walls can cause instabilities due to changes in rock- and ice-mechanical as well as hydraulic properties. Snow cover can alter thermal and mechanical processes. We used seismic refraction tomography (SRT) to evaluate the degradation of permafrost in steep rock walls. Five parallel NE-SW transects were installed across a crestline in the Steintaelli, Matter Valley, Switzerland, at 3070-3150 m a.s.l.. Time-lapse p-wave velocity measurements were performed in the summers 2006, 2007 and 2012. August 2012 was the second warmest month ever measured after the heat summer of 2003.

(i) Snow depth was evaluated qualitatively 2006 and 2007 by digging snow pits as well as quantitatively with snow poles in 2012. Snow accumulates as a snow cornice on the crestline, as patches on rock ledges and on footslopes.

(ii) In the laboratory, p-wave velocities of Steintaelli rock samples were measured (Draebing & Krautblatter, 2012, doi:10.5194/tc-6-1163-2012) to use the results as a priori information for field measurements and to develop permafrost scenarios for the resulting SRTs.

(iii) Time-Lapse SRT was used to monitor monthly, annual and 6-year alterations of the thawing front. In 2006, the tomographies display ice-filled fractures and permafrost in depths of 4-8 m. Due to lateral onfreezing of glaciers and a persistent snow cornice, permafrost was obtained close to the surface in 2007 (Krautblatter & Draebing, in review). In 2012, the second warmest august since 2003 in combination with a little expanded snow cornice permafrost was degraded to depths of 5-15 m.

Here we show, that (1) snow cover significantly influences permafrost in steep unstable high-alpine rock walls and (2) p-wave refraction seismics is capable of measuring and monitoring permanently and seasonally frozen rocks.

\*\*\*\*\*

## Mapping and modelling the discontinuity of mountain permafrost: a challenging task

LAMBIEL C.(1), DELALOYE R.(2), DELUIGI N.(1), SCAPOZZA C.(3), BOSSON J.B.(1)

(1) *Institute of geography and sustainability, University of Lausanne, LAUSANNE, SWITZERLAND* ; (2) *Department of Geosciences, Geography unit, University of Fribourg, FRIBOURG, SWITZERLAND* ; (3) *University of Applied Sciences and Arts of Southern Switzerland (SUPSI), LUGANO, SWITZERLAND*

In the mountain periglacial belt, the geomorphology, the topography and the surface characteristics may vary strongly on very short distances. This leads to strong variations of the ground (surface) thermal characteristics from one location to another one, which has a strong impact on the permafrost occurrence. To get a precise knowledge of how permafrost is distributed at the local scale, large efforts of field data acquisition must be realized.

At the Universities of Lausanne and Fribourg, many field campaigns were carried out during the last 15 years in the Western Swiss Alps. They permitted to create a database composed by around 150 electrical resistivity tomography profiles, more than 200 vertical electrical soundings, a hundred of apparent resistivity mapping lines, about ten seismic refraction tomography profiles, 16 boreholes equipped with temperature sensors and more than 500 ground surface temperature locations. This database reveals an extremely large discontinuity in the permafrost distribution.

Modelling such a complexity is a challenging task. In order to reproduce the spatial heterogeneity of the phenomenon at the local scale, we tried recently to use Machine Learning algorithms to propose a new approach for mountain permafrost modelling (Deluigi & Lambiel 2012). The basic concept of Machine Learning is that the machine learns from the data. The first results show that, if the dataset is large enough, the high spatial discontinuity of mountain permafrost can be successfully represented. For instance, rock glaciers can be automatically recognized and, in some cases, permafrost is designed only in the lower part of talus slopes, which corresponds to several field data.

Deluigi N., Lambiel C. (in press). PERMAL: a machine learning approach for alpine permafrost distribution modeling. *Actes du colloque de la Société Suisse de Géomorphologie, 29 juin – 1<sup>er</sup> juillet 2011, St-Niklaus*

### **Permafrost landforms in the Tröllaskagi peninsula, northern Iceland - implications for the deglaciation pattern**

LILLEØREN K.(1), GÄRTNER-ROER I.(2), ETZELMÜLLER B.(1)

(1) Department of geosciences, University of Oslo, OSLO, NORWAY ; (2) Department of geography, University of Zürich, ZÜRICH, SWITZERLAND

In northern Iceland, relict rock glaciers are observed close to the present sea level. This observation has implications for how to interpret the deglaciation of this region, as the large relict rock glaciers must have required millennia of ice-free conditions in order to form. The formation of rock glaciers and long-lasting stable ice-cored moraines is constrained to areas subjected to permafrost, and the presence of such landforms is used as a direct indicator of present or former permafrost conditions. In the present study we used recently published air photos (2002-07), ALOS PALSAR data (2007), MODIS land surface temperature data (2003-2010) and field mapping, to systematically re-examine the Tröllaskagi peninsula for permafrost landforms. In this re-examination, intact and relict rock glaciers were separated by strict geomorphological criteria, i.e. surface structure, front slopes and vegetation cover. We also consider ice-cored moraines to be indicators of permafrost, if they appear stable and 'oversized' compared to the upslope glaciers. Ice-cored moraines are considered active features when they appear stable, but do not necessarily possess indications of creep.

This study will discuss present and relict permafrost distribution based on the mapped rock glacier and ice-cored moraines in Tröllaskagi. In addition, various characteristics of the landforms such as the state of activity are given. This study supports a previous permafrost landform inventory which indicated evidence of typical rock glacier formation at low elevations, indicating long ice-free and cold periods prior to the onset of the Holocene Thermal Maximum.

\*\*\*\*\*

### **Possible climatic controls on the recent (2004-2013) variations of surface displacements of cryospheric landforms in an Andean environment (Chile, 33°S)**

SCHIAVONE S.(1), BODIN X.(1), BRENNING A.(2), AZOCAR G.(2), QUENSE J.(3)

(1) Laboratoire EDYTEM, CNRS / Université de Savoie, LE BOURGET DU LAC, FRANCE ; (2) Department of Geography and Environmental Management, University of Waterloo, WATERLOO, CANADA ; (3) Instituto de Geografía, Pontificia Universidad Católica de Chile, SANTIAGO, CHILE

In semi-arid Andes, the dynamics of debris-covered glaciers and rock glaciers, in which large volumes of ice are stored, is of great significance for the hydro- and geosystems as it can influence water resource and natural hazard management strategies in inhabited areas. The effects of climate change on those cryospheric landforms are poorly known yet, but they might strongly depend on properties of the surficial debris layer and on the seasonal variations of the snow cover.

In this work, we monitored displacements of a hundred marked blocks with annual and pluri-annual differential GPS campaigns on a complex of one debris-covered glacier and two rock glaciers in a watershed that provides up to two-thirds of the drinking water supplies to Santiago, Chile. In parallel, a thermal monitoring has been ongoing since 2009 thanks to 45 stations spread over the debris-covered glacier and the rock glaciers. It records hourly the temperature and the presence/absence of snow at the ground surface and 50 cm above.

Over the whole studied period, the 3D velocity ranges from a few cm/yr up to 6 m/yr. A clear distinction can be made between debris-covered glacier patterns and rock glaciers ones. The former is characterized by a vertical change that can exceed the horizontal component due to high ice-melting rates. The latter have a horizontal component comparatively higher because of a movement mostly dominated by creeping, ice being protected from fusion by a thick debris layer. The seasonal velocity decomposition shows that 67-84 % of the rock glacier displacements are experienced during austral summer (dec. to apr.), moreover a significant speed up was measured in 2010-2011.

Using data from local weather stations, it is then discussed how nivo-meteorological conditions may influence the thermal regime of the monitored landforms, and consecutively, how it may control both ice-downwasting and creeping processes.

## The climatic significance of relict periglacial landforms in the New England Tablelands, Australia

SLEE A.(1), HAWORTH R.(2), GONTZ A.(3), SHULMEISTER J.(1)

(1) School of Geography, Planning and Environmental Management, University of Queensland, BRISBANE, AUSTRALIA ; (2) School of Behavioural, Cognitive and Social Sciences, University of New England, ARMIDALE, AUSTRALIA ; (3) Department of Environmental, Earth and Ocean Sciences, University of Massachusetts-Boston, BOSTON, UNITED STATES

While no permafrost landforms have been discovered in Australia, relict cold climate landforms that have formed by diurnal freeze-thaw processes are widespread in the Australian Alps and Tasmania (Barrows et al. 2004). However the altitude distribution and northern extent of periglacial landforms in Australia has been poorly documented. An important paper by Galloway (1965) suggests that during the Last Glacial Maximum periglacial climatic conditions may have been active as far north as the Northern New England Tablelands (New South Wales) at approximately 30°S. However to date no definitive periglacial landforms have been documented north of the Australian Alps at 35°S.

Here we report results from work aimed at testing the existence of late Quaternary periglacial landforms on the New England Tablelands. We have identified several locations near Guyra (30°13'08 S : 151°40'18 E, 1330m asl) where block slopes and solifluction lobes of apparent periglacial origin are present. The sites are extensive (tens of hectares in extent) but are all confined to south and south-west facing slopes. They occur at moderate elevations between 1200 and 1350 m, well below the highest peaks at c. 1500m. Cumulatively, the geomorphology is diagnostic of severe freeze-thaw environments and is the dominant landscape element on these southerly slopes.

Temperature logging of the best developed site over the last year indicates that freeze thaw processes are still very active at the site at the present day but cannot be responsible for the key periglacial features we have identified. At this site a probable nivation hollow bounded by a protalus rampart suggests that there was significant seasonal snow accumulation in the past. We conclude that freeze-thaw processes are significant at the present day but that the main landscape modification happened under colder conditions.

\*\*\*\*\*

## Poster presentations:

### Hypsometry of glaciated basins upon the Kamchatka Peninsula

BARR I.D.

Queen's University Belfast, BELFAST, UNITED KINGDOM

Hypsometry (distribution of land surface area with altitude) has been variously used to classify landscapes according to their geomorphic development. Here, the hypsometry of glaciated basins is used to assess the relative importance of glacial erosion and tectonic uplift in shaping the mountains of the Kamchatka Peninsula (Eastern Russia). This is achieved through consideration of hypsometric curves, hypsometric integrals, altitude frequency-distributions, Last Glacial Maximum equilibrium-line altitudes (LGM ELAs), cirque floor altitudes, and geomorphological indicators of former ice velocity. These attributes are analysed at a basin (catchment) scale, and it is argued that: (i) inter-basin variations in land-surface hypsometry are partly governed by variations in the intensity of former glacial erosion; (ii) in northern and southern sectors of the peninsula, an efficient glacial buzzsaw has limited mountain topography; and (iii) elsewhere, a number of high peaks appear impervious to topographic restrictions imposed by the glacial buzzsaw. Thus, the topography of the region is a function of neotectonics and Late Quaternary glaciations.

## Debris flow hazards in high mountain area, Moxi basin, Southwestern of China

TIE Y.

Chengdu Center of China Geological Survey, CHENGDU, CHINA

Moxi basin in southwestern of China is a unique high mountain region with high geo-dynamics activity, strong glacier erosion, strong freezing process and vulnerable geo-environment, this condition favors the form of debris flow. During the past 20 years, tourism resource exploitation in this region has experienced rapid economic growth. However, there are near 4000 local residents and more than 170 millions dollars wealth are vulnerable to 49 debris flow gullies. The potential risk from debris flow hazards in Moxi basin is a prominent problem.

Most of the debris flows initiate at high elevation, ranging from 2000 to 4500 m. These loose sources are mainly from moraine which distributed in Moxi basin widely. Based on the field survey and statistic, the potential volume of unstable moraine which in Moxi Basin is  $3012 \times 10^4 \text{m}^3$ , and the volume of loose moraine which can becoming the resource of debris flow directly is  $1247 \times 10^4 \text{m}^3$ . The starting zones of debris flows correspond to the uppermost occurrence of loose moraine, often located at the front of glacier, upstream or middle stream of stream, time range from early Gongga Ice Age to Little Ice Age. These moraines consist of thick 50-300m, wide distribution and instability. Under the erosion process, there moraine has been incised strongly, the erosion depths range from meters to decameters, with steep gully slope  $40 \sim 80^\circ$ , volumes range from several thousand cubic meters to ten billion cubic meters.

Topographic features of debris flow gullies have been calculated using GIS software. The analysis shows that 73.5% of the debris flow gullies are not randomly distributed but concentrated directly adjacent to the western side of Moxi gully, and only 26.5% are located to the eastern side. The numbers, frequency, catchments area, gully length, gully slope ratio of these debris flow gullies in Moxi basin were controlled by the glaciations and Moxi fault.

\*\*\*\*\*

## Hydrospatial assessment of streamflow yields and effects of climate change in the Australian alps

REINFELDS I.(1), SWANSON E.(2), COHEN T.(2), NOLAN A.(3), WILLIAMS S.(1)

(1) NSW Office of Water, WOLLONGONG, AUSTRALIA ; (2) University of Wollongong, WOLLONGONG, AUSTRALIA ; (3) Snowy Hydro, COOMA, AUSTRALIA

Australia's limited alpine areas form a critically important watershed, providing a reliable water source for the world renowned Snowy Mountains hydro-electric Scheme (SMS) and 40% of Australia's irrigated agriculture. During the development of the SMS, the Snowy Mountains were subject to the most intense hydrometric effort ever undertaken in Australia, averaging one gauging station per  $75 \text{ km}^2$ . GIS-based hydrospatial analysis of annual streamflow yields, catchment area-average annual precipitation and catchment topographic indices for 112 gauging stations demonstrates that elevation is the primary control on precipitation and yields. Catchments with mean elevations greater than 1850 m show a steep increase in yield over lower elevation catchments and have runoff coefficients greater than unity, a situation that is partly attributable to deep accumulations of drifting snow across the highest peaks of the Australian alps. Annual precipitation across the highest elevation catchments shows strongly significant declines of up to  $11.0 \text{ mm yr}^{-1}$  from 1944-2009, with the magnitude of precipitation declines increasing with elevation. Despite the magnitude of precipitation decreases, only the rivers that have the longest ongoing records dating to the mid-1950s show significant decreasing trends in annual runoff. Annual runoff coefficients for Australia's highest elevation river (the Snowy River), however, show a significant increasing trend since the 1950s due to drying of hydrophobic alpine humus soils, providing a buffering effect for streamflow yields against precipitation declines. Climate change effects on the timing of peak snowmelt discharges for the highest elevation rivers are pronounced. Regression analyses for the Snowy and Geehi Rivers show strongly significant shifts toward earlier peak discharges of 6.2 and 4.0 days per decade, respectively, in the ordinal (Julian) day of peak snowmelt discharges since the 1950-60s.

### **An inventory of the glaciers in the French Alps at the end of the Little Ice Age**

GARDENT M.(1), DELINE P.(1), SCHOENEICH P.(2)

(1) EDYTEM - University of Savoie, LE BOURGET DU LAC, FRANCE ; (2) PACTE, University of Grenoble, GRENOBLE, FRANCE

In spite of short advances, glaciers in the Alps are shrinking since the termination of the Little Ice Age (LIA). Before our study, there was no exhaustive data about glacial retreat between the end of the LIA and the 2000s for the whole French Alps. In order to fill this gap, an inventory of past (LIA) and present (2006-09) glaciers was realized and integrated in a GIS. Glaciers outlines of the present glaciers were manually delineated using 50-cm-pixel orthophotographies from 2006 to 2009. The LIA glacier inventory is based on reconstruction of the glacial extension through photo-interpretation, geomorphological field work, and analysis of old documents.

Two kind of geomorphic data were collected: (i) landforms and formations (till, moraines, roches moutonnées) that record the Little Ice Age glacier extension; (ii) markers of active processes (e.g. debris-flow, glacial lake outburst flood, landslide in moraine) that inform about potential instabilities, as these markers are the base for the recognition of areas prone to glacial-related hazards (EU-funded project *GlaRiskAlp*, Alcotra France-Italy). All these geomorphological data were integrated in a GIS.

Results for the whole French Alps will be presented. In the Vanoise massif for instance, the present glacier area is 92.5 km<sup>2</sup>, ~ 60 % less than at the end of the LIA when the glacial extension was about 236 km<sup>2</sup>. Some variations in the retreat rate are observed across the massif, from the strong post-LIA glacial retreat in the Péclet-Polset area (-60%) to the slightly lower one for the Glaciers de la Vanoise (-50%). Results of our study about parameters that control this glacial retreat since the LIA will be exposed.

\*\*\*\*\*

### **Using soils to reconstruct geomorphological history of a puzzling cirque in the Colorado Front Range**

TEMME A.(1), DECHIER D.(2), BIRKELAND P.(3), SCHWERING M.(1), DIEK S.(1)

(1) Wageningen University, WAGENINGEN, NETHERLANDS ; (2) Williams College, WILLIAMSTOWN, MA, UNITED STATES ; (3) University of Colorado, BOULDER, CO, UNITED STATES

4<sup>th</sup> of July cirque in the Colorado Front Range of the Rocky Mountains presents a number of puzzling questions related to the relative and absolute timing of minor early Holocene glaciations and other landscape features. Answering these questions is not easy, as evidenced by a number of conflicting interpretations in literature. Yet it is important, because it allows us to find out how the relatively arid Front Range has reacted to post-glacial climatic fluctuations.

We use soil chronology techniques that were pioneered in this mountain range, radiocarbon and luminescence dating to shed additional light on the area's history. Soil chronology results, based on the total amounts of iron and clay in the soil, suggest that existing relations between soil properties and age do not hold for this, highest part of the range. We suggest an extension to these relations, and use it to assign relative ages to the soils in the cirque and by extension the landforms that they cover. We discuss the strength of the soil-landform relation, illustrated by repeat soil observations on the same landforms. Radiocarbon and OSL dating support our main argument that soils and landforms in the cirque date from after the last glacial maximum, in contrast with some of the literature about the area. The extended relation between soil property and age is considered to be useful in wider areas of the Colorado Front Range.

### Can we make rockfall maps using climber's books? A semi-quantitative analysis

TEMME A.(1), EGLI M.(2)

(1) Wageningen University, WAGENINGEN, NETHERLANDS ; (2) University of Zürich, ZÜRICH, SWITZERLAND

Rockfall rates in mountain ranges are expensive to measure over large spatial scales, mainly due to the inaccessibility of mountainous terrain. Existing methods to measure rockfall include acoustic, spectral and volumetric methods. These methods, especially in combination, have allowed researchers to quantitatively derive rates (and changes of rates over time) of rockfall for several well studied locations.

However, the small spatial support of these methods means that results are only valid for small well-studied locations. This is a problem when we need information on rockfall rates over entire mountain chains and ranges – which is important to study their temporal distribution and their relation with climate change. This contribution explores the potential of information contained in climber's guidebooks to derive qualitative rockfall rates with large spatial and temporal coverage.

Climber's guidebooks have been published since the early 1900's, giving prospective mountaineers strongly codified information about routes and conditions expected along the way. The information about the looseness of rocks, which is clearly important for climbers from a safety perspective, may be linked to rockfall rates. I have used a series of guidebooks published at irregular intervals for the Bernese Oberland in Switzerland to study the change in descriptions of looseness of rocks for a number of famous climbing routes. These routes were selected because of the opportunity to complement information in guidebooks with other (visual and written) sources of information.

Results indicate that descriptions of looseness of rock can be used to derive a qualitative pattern of rockfall, especially over larger spatial scales. The value of the information is also valuable as a link to temporal changes in rockfall rates, but this use is hampered by the fact that text is sometimes copied between successive guidebooks without a stringent reassessment of actual conditions on the route.

\*\*\*\*\*

### Debris flows and relief evolution in the Tatra Mountains

KOTARBA A., RACZKOWSKA Z.

Institute of Geography and Spatial Organisation, PAS, Department of Geoenvironmental Research, KRAKOW, POLAND

Role of debris flows in the recent evolution of the high-mountain landforms in the Tatras is evaluated based on results of 20-years long field studies and interpretation of satellite images.

Geology, climate and vegetation are there differentiated both vertically and horizontally. The varied influence of glacial and periglacial morphogeneses in the Pleistocene made the Tatric slopes sets up different conditions for debris flows. In the High Tatra narrow crests and rockwalls dissected by rocky chutes (density 8-17 km/km<sup>2</sup>) with talus slope below predominate. In the Western Tatra ridge culminations, gradually change from gently inclined near-ridge slope segments into rocky slopes dissected by chutes (density 6 km/km<sup>2</sup>) with alluvial-avalanche fans below. The Belianske Tatry have a shape of asymmetric ridge of *crete* type.

Debris flows are dominant process which model the present-day relief of the Tatric slopes. They may develop in all geoecologic zones, although their relief-forming role is most apparent in the cryonival morphogenetic domain above the upper timberline. Over 3.5 thousand modern tracks occur in that small massif. The most of them (2300) and the largest forms (up to 1000 m long) are in the High Tatra. Sizes, number and distribution of the debris flows depend mainly on local topography and substrate properties.

Extreme rainfalls during summer seasons are the main trigger of debris flows. The latter are generated most often during short-lasting storms and very intensive convection precipitation confined to small areas. Therefore there is no clear relation between periods with high daily precipitation and debris flows. The minimum amount of rainfall, which can trigger a debris flow is 20 mm per hour. The zone of the highest precipitation on the northern side of the Tatra massif (1400-2000 m a.s.l.) co-occurs with the zone where the debris flows start (1290-2390 m a.s.l.), which emphasizes the role of precipitation in present-day relief evolution of the Tatras.

## Megafans and outsize fans in the Tirol Alps - incremental, episodic, or catastrophic ?

JARMAN D.

*mountain landform research, GLASGOW, UNITED KINGDOM*

A sequence of anomalously large debris fans emanating from tiny catchments occupies much of Vinschgau, South Tirol. The most extensive, the 11 km-long Malser Haide, has been published (2011) as a 1650 Mm<sup>3</sup> deposit with a reconstructable lost mountain of comparable volume above the side valleyhead. An even greater deposit of 2200 Mm<sup>3</sup> has been calculated (INQUA 2011) for the Allitz-Laas cone, again with a reconstructable lost mountain (Gadriaspitz) suggesting a catastrophic event or possibly a few large episodes.

Conventional interpretations for such fans assume incremental build-up by alluvial or debris-flow processes during numerous rainstorm events over the Holocene. However limited historical and archeological evidence suggests such processes often only rework or veneer pre-existing large landforms. The source catchments for incremental fans should be characterised by intense gullying and/or abundant small scars, rather than one or a few large cavities. Examples include Illgraben, upper Rhône, and Mieming, Inn valley. In Vinschgau, such distributed sources are less common.

Groundtruthing now confirms reasonably reconstructable lost mountain spurs, crests, or summits for episodic/catastrophic fans in Vinschgau, Munstertal, Antholzertal, Gailtal, and around Lienz. Similar anomalous fan-cavity assemblages are scattered across the Alps, eg. in Valtellina, at Chur (Rhine), and east of Trento, but are puzzlingly hard to identify in other comparable ranges.

Until such fans can be dated, evidence for oneshot/fewshot emplacement is geomorphological, statistical, and contextual. Their concentration on the steep south side of the main Alpine divide implies a response to sustained deep incision and bulk erosion in troughs. These fan-cavity assemblages should be assessed alongside the numerous rockslides and slope deformations in the same areas as part of the large-scale mass-movement component of the glacial-paraglacial landscape evolution cycle.

\*\*\*\*\*

## Recent dendrogeomorphic approaches in Romanian Carpathians. Spatio-temporal reconstruction and patterns of snow avalanche activity in Făgăraş massif and Bucegi Mountains (Southern Carpathians) - Romanian Carpathians.

VOICULESCU M., ONACA A., CHIROIU P.

*West University of Timisoara, Department of Geography, TIMISOARA, ROMANIA*

Usage of dendro geomorphologic method is new in Romanian geographical research.

We have done our research in two representative mountainous areas, where avalanche activity is high and where there were recorded over time the most cases of fatalities and casualties: there are the Făgăraş massif and Bucegi Mountains, located in the eastern half of the Southern Carpathians (Romanian Carpathians). In the semimountainous areas, snow avalanches endanger human lives and settlements (mountain huts and shelters in our case) and cause damage to forests, infrastructure or transportation routes.

They are characterized by the highest altitudes, above 2400-2500 m and by the most important glacial relief and very dynamic periglacial processes. The climate of Făgăraş massif and Bucegi Mountains is harsh, characterized by a long cold season: between 0.2 and -2.5°C average annual temperature, between 1,200-1,300 mm average annual precipitations, 140-180-220 days with snow cover, between 90 and 140 days with snowfall and 8-9-11 months/year with snow cover.

Also, both mountain areas are characterized by important winter tourism practices, in many situations climbers, skiers and tourists triggering snow avalanches.

In these mountains we chose a few representative sites where avalanches have a high incidence. The purpose of our study is: (i) to continue all studies on snow avalanche occurrence and to complement existing archival records, (ii) to establish an avalanche chronology, based on frequency and return period and (iii) to validate our results of snow avalanches reconstruction with historical archives from Mountain Rescuers and with nivometeorological database from Bălea Lake Work Laboratory- 2070 m (Făgăraş massif) and Vf. Omu (2505 m) and Sinaia (1500 m) Work Laboratories (Bucegi Mountains).

Since in the Romanian Carpathians the cadastral maps of snow avalanches or risk maps are missing, we believe that our work will bring valuable insights on the phenomenon.

## **Two Different Example for Glacio-Karstic Evolution in Western Taurus (SW Turkey): Akdag Mountain and Dedegöl Mountain**

BAYRAKDAR C.(1), ÇILGIN Z.(2)

(1) *ISTANBUL UNIVERSITY DEPARTMENT OF GEOGRAPHY, ISTANBUL, TURKEY* ; (2) *Technical and Vocational High School, ISTANBUL, TURKEY*

The study areas concerned are Akdağ (3014m) and Dedegöl Mountain (2992m) which were undergone glaciations in Pleistocene. Both mountains have lots of peaks higher than 2500m and seems high massives surrounded by faults. While Akdağ is located in Teke Peninsula western Taurus, Dedegöl is located the west of Beyşehir Lake and 200km the northeast of Akdağ. Both mountains mostly consist of carbonate rocks and the karstic evolution started in Oligocene when Anatolia surfaced beneath the sea an even though it was affected by tectonic activities and climatic changes the karstic evolution has continued so far. Due to the complex structure induced by the Lycian nappes Akdağ lithological units soluble and permeable rocks from the bottom or sides surrounded by the ophiolite is dominated by shallow surface karstification, Mountain Dedegöl due to the depth of a thousand meters, continuous thick carbonate sequence is dominated by karst. This structure affected the development and spread of the Pleistocene glaciations. Accordingly, these two factors both in the mountains, and the process product were found to be polygenic. In this study the Pleistocene paleo-karst features two different mountain glaciations driven out how to explain. Pleistocene glaciations; Akdag equilibrium line altitude Wurm glaciers on the plateau-shaped depressions growth of Paleo-karst. Cave systems were destroyed by the glaciers in the mountains of Dedegöl deep glacial valleys with steep walls and created a circus. As a result, litho-stratigraphic framework of Pleistocene glaciations in the mountains the course of the two locations with the Western Taurus Mountains close to each other seriously affected areas and the distribution of polygenic has created its own. GIS, morphometric analysis, geophysical methods, sedimentological analysis and OSL dating method were used in evaluation of glacio-karst evolution.

Keywords: Akdag, Dedegöl Mountain, Glacio-karst, litho-stratigraphy, Pleistocene glaciations.

\*\*\*\*\*

## **Relative age and Holocene distribution of permafrost in Norway**

LILLEØREN K., ETZELMÜLLER B., GISNÅS K., SCHULER T.V., HUMLUM O.

*Department of geosciences, University of Oslo, OSLO, NORWAY*

For Scandinavia in general and Norway in particular the present regional distribution of mountain permafrost is reasonably well known, both through ground temperature measurements in boreholes, geophysical soundings and spatial modelling exercises. An important question in this context is the dynamics of permafrost during the Holocene, as a major factor for landscape development and geomorphological processes in high mountain areas of Scandinavia.

In the present study we addressed the temporal and spatial Holocene permafrost distribution in Norway by 1D heat flow modelling in well-calibrated boreholes and 2D equilibrium modelling (CryoGrid 1.0) of selected time periods. The result of this study indicates an altitudinal zonation of permafrost age in Norway; (1) permafrost has existed continuously since the deglaciation in the highest areas, (2) permafrost degradation during the Holocene Thermal Maximum (HTM), and reappearance post-HTM, and (3) permafrost only during the Little Ice Age (LIA).

These findings also have implications for the subglacial temperature regime of the late-Pleistocene glaciations. Cold-based ice is often interpreted as a deglaciation phenomenon in Norway when considering landforms such as lateral meltwater channels and the lack of for example eskers within certain regions, but an ice-sheet transgression into permafrost areas is just as likely. One can expect most of the build-up areas of the ice sheets to have been underlain by permafrost at the time, and only areas where we positively find evidence of large-scale erosional landforms (hence U-shaped valleys and fjord systems) to have been permafrost free during the glaciations. Aggrading permafrost during interstadials must also have been important for the subglacial thermal regime while new ice-sheet transgressions took place.

### **Postglacial rockfalls controls on environmental partitioning of the Haute-Romanche valley (Massif des Écrins, french Alps)**

ROUSSEL E.(1), CHENET M.(2)

(1) *Université Clermont 2, MSH, USR-3550 CNRS, CLERMONT-FERRAND, FRANCE* ; (2) *Université Paris 1, LGP, UMR-8591 CNRS, PARIS, FRANCE*

The Haute-Romanche valley, located in the Massif des Écrins, was widely glaciated during the LGM. Nowadays, the Romanche river is an effluent of two separated glaciers: the Clot des Cavales and the Plate des Agneaux. From the current glaciers fronts to the downstream neoglacial moraines, five successive rockfalls were identified. Their locations are probably linked to preferential areas of postglacial debuitressing expression. These large rockfalls produce a semi-permanent environmental partitioning of the valley by controlling sediment flux and fluvial patterns. The objectives of the study are to quantitatively assess the partitioning functions of rockfalls of various volume on the streams long profiles, the downstream fluvial pattern succession and the spatial distribution of archaeological evidences. The topographic surveys of the Haute-Romanche valley floor and rockfalls were done using terrestrial multi-image photogrammetry coupled to a set of DGPS ground control points. The long profiles of the rivers were achieved with DGPS survey. Volumes of rockfalls were estimated by topographic modeling and volumetric computation using GIS software resources. Fluvial pattern analysis and archaeological mapping were completed based on photo-interpretation and field observations. Results show that river channel morphology is highly dependent of rockfall location and volume. Consequently, the downstream river patterns succession is deeply disturbed inducing a long-term segmentation of the fluvial continuum. This longitudinal partitioning of hydro-sedimentary dynamics has potentially major ecological, geoarchaeological and management implications.

\*\*\*\*\*

### **The topographical factors in the formation of gully type debris flows in the upper reaches of Minjiang River**

YU B.(1), ZHU Y.(2), QI X.(2)

(1) *State Key Laboratory of Geohazard Prevention and Geoenvironment Protection , CHENGDU, CHINA* ; (2) *State Key Laboratory of Geohazard Prevention and Geoenvironment Protection, CHENGDU, CHINA*

There are three groups of factors related to topography, geology and hydrology which have influence on the formation of gully type debris flows. In this study a single representative factor ( G-factor) for the topography is proposed, which can be used to give threshold values for debris flow formation. The study was carried out in the upper reaches of Minjiang River, which is located in the Wenchuan Earthquake area. During some rainfall events after the earthquake, some gully type debris flows were triggered in some catchments. In some catchments no debris flows were triggered even though these catchments were in the vicinity of gullies with triggered debris flows. We were able to isolate and analyze the influence of the topography on the formation of debris flows because during these rainfall events the hydrological conditions were almost the same in the investigated gullies. We could also neutralize the influence of the geological factors by selecting groups of neighboring catchments located in areas with the same geological characteristics. A new G-factor is proposed in this study as a topographical indicator:  $G=FJ(A/A_0)^{0.2}$ , in which F is the form factor of formation area, J is the average slope of formation area, A is the area of formation area, and  $A_0$  is the unit area ( $=1\text{km}^2$ ). Higher G-factor values are generally related to higher probabilities of debris flow formation. The roles of G-factor are analyzed in other areas with the same geological characteristics and almost same hydrological conditions. They show that the higher G-factor values, the higher probabilities of debris flow formation are in generally.

### **Glacial lake outburst flood hazard assessment, example of the Palcacocha Lake, Cordillera Blanca, Peru**

KLIMES J.(1), VILIMEK V.(2), EMMER A.(2), COCHACHIN A.(3)

(1) Institute of Rock Structure and Mechanics CAS, PRAGUE, CZECH REPUBLIC ; (2) Charles University, Dep. of Physical Geography and Geoecology, PRAGUE, CZECH REPUBLIC ; (3) National Water Authority, Glaciology Unit, HUARAZ, PERU

Glacial lake outburst floods (GLOFs) are one of the major natural hazards in high mountains worldwide including the Cordillera Blanca Mountains, Peru. In this country, GLOFs have claimed more than 30000 lives over the last century. GLOFs usually originate when ice and rock avalanches or landslides fall into the lake and cause displacement waves, which over top the lake dams. Slope movements are responsible for 80% of GLOFs with known origin in the Cordillera Blanca. Landslide as a trigger of GLOF has been reported from several sites within the Cordillera Blanca, e.g. Artizón Baja, Safuna Alta and Palcacocha Lakes.

Moraine-dammed lake Palcacocha was selected for detailed study since it was responsible for catastrophic outburst flood in 1941 which devastated large part of the regional capital city of Huaraz. Evaluation of moraine dam stability and its development was done by using set of historical aerial pictures, field mapping and geophysical investigation by the electric resistivity tomography. Slope stability model was calculated to specify conditions under which the moraine could fail by landsliding. At the same time the probability of sudden water release was assessed using qualitative, semi-quantitative and quantitative methods. Variety of lake basin and dam characteristics of the Palcacocha Lake were collected and compared with other lakes in the region. Detailed evaluation of the advantages and disadvantages of each method was performed, while most of them pointed out the Palcacocha Lake to be the most hazardous lake out of the investigated lakes.

\*\*\*\*\*

### **Current evolution of high mountain glacier systems: the case of the Rognes and Pierre Ronde systems (St-Gervais, Mont-Blanc, France)**

BOSSON J., UTZ S., LAMBIEL C.

University of Lausanne - IGD, LAUSANNE, SWITZERLAND

The negative mass balance of many glaciers can lead to their burial under debris which isolates partially the ice from atmosphere and leads to reduced melts rates. Moreover, due to climate history and without an efficient connection between the glacier systems and hydrosystems, important sediment accumulations are common in high alpine areas (above the isogeotherm of  $-2^{\circ}\text{C}$ ), where glacier/permafrost interactions are frequent. Thus, landforms with massive ice bodies, ice-cemented debris and unfrozen debris are present in high mountain. With their top-down position and the large amount of rock/debris and ice/water involved, deep knowledge and understanding of their internal structure and of their complex responses to global change need detailed studies.

This poster exposes the results from 2011-2013 measurement campaigns on the glacier systems of Les Rognes and Pierre Ronde (Mont-Blanc Massif, France). Located between 2600 and 3050m a.s.l., these small glacier systems ( $0.3$  and  $0.25$  km<sup>2</sup>) present different landforms such as snowfields, debris covered ice, glacier forefields, push moraines and rock glaciers. Electrical resistivity tomography, DGPS survey and ground surface temperature measurements have been carried out. The results show:

- Les Rognes: a continuum between the upslope debris-covered glacier, the ice-free glacier forefield and frozen marginal push moraines. Decimeters to meters movements have been measured in surface. Because of the topography, the ice cementation of the distal part and the absence of efficient connection with hydrosystem, this system can be considered as transport-limited.

- Pierre Ronde: an ice-free glacier forefield with a marginal rock glacier. Local till was the main solid supply of the water-pocket outburst of the Tête Rousse glacier in 1892. Our surveys show that more than 10m thick of unfrozen till fill the central depression. Current response to global change is characterized by slow gravity rebalancing (decimeter movements).

## **Changes in hardness of rock surface as a result of weathering through the Holocene in an alpine area in Switzerland**

*IKEDA A., ADACHI K., HATTANJI T.*

*Life & Environmental Sci. Univ. Tsukuba, TSUKUBA, JAPAN*

Systematic comparison of rock-surface hardness is one of field techniques to date relative ages of landforms, because weathering duration controls the hardness. In this study, we apply three methods to characterize weathering properties of bedrocks after deglaciation in the Swiss Alps where the former distribution of glaciers is well reconstructed. A number of rebound values of a Schmidt hammer and an Equotip hardness tester were measured on roches moutonnees and rockwalls. P-wave velocities of the bedrocks were also measured on several sites. Two timings of release from glacier beds, the end of Younger Dryas (YD) and the end of Little Ice Age (LIA), were clearly identified for the studied roches moutonnees and rockwalls from moraines mapped by glaciologists. In addition, bedrocks exposed previous to YD and after the Last Glacial Maximum were also compared. Four types of geology were chosen for the targets: granodiorite, diorite, gneiss and limestone/dolostone. The difference in hardness of the bedrock surfaces between the LIA age and YD age is obvious except for limestone, although the surfaces older than YD show no significant difference from those of the YD age. Ten thousand years are a duration enough that the surface hardness reaches stable in the study area. The P-wave velocities and uniaxial strengths of samples having the LIA and YD ages indicate that the weathering does not reach the subsurface. Contrary to the other rock types, limestone has the rebound values similar through the time, which indicates that chemical denudation keeps the surface fresh.

\*\*\*\*\*

## **Evidence of paraglacial and periparaglacial crisis in the evolution of sediment transfer in the Southern Swiss Alps since the Last Glacial Maximum**

*SCAPOZZA C.*

*Institute of Earth Sciences, University of Applied Sciences and Arts of Southern Switzerland (SUPSI), CANOBIO, SWITZERLAND*

Continental hillslope deposits – in particular talus slopes and alluvial fans – and valley floor deposits, can be read as important palaeoenvironmental archives for the reconstruction of the morphogenesis and the evolution of alpine valleys since the last deglaciation. The study of these deposits it is of particular importance because, especially in the actual context of a warmer climate, a «geosystemical» approach focusing on the sediment transfer in a whole alpine hillslope – from the rockwall to the valley floor – is of great importance to understand and evaluate the past processes and to try to assess how they might evolve in the future.

In this framework, the state of the art concerning the knowledge about sediment transfer in the Southern Swiss Alps is presented, allowing defining the major morphoclimatic crisis that has occurred during the Lateglacial and the Holocene. The quantification of the sediment transfer from rockwalls to talus slopes in the periglacial belt allow to show the existence of “paraperiglacial rockfall phases” related to the permafrost degradation in rockwalls which coincides with rapid climate warming periods, as at the beginning of the Bølling and during the Preboreal. A similar behaviour was found by the analysis of the infilling chronology of the Ticino valley floor and of the Ticino river delta progradation rates, with the erosion/sedimentation dynamic during the Lateglacial and the Holocene that was putted in relation with the paraglacial sedimentation model.

In future, these results will be improved by investigation at the local scale, including for example the assessment of sediment transfer from glaciers and rockglaciers to the valley floors, the study of the relationship between mass movements and alluvial fan development and the detailed study of the stratigraphy of some talus and alluvial cones thanks to the presence of outcrops dues to sand and gravel quarries or archaeological excavations.

### **Joint analysis of rock glacier kinematics and complementary permafrost monitoring elements observed in the Swiss Alps**

STAUB B.(1), DELALOYE R.(1), LAMBIEL C.(2)

(1) *University of Fribourg, Department of Geosciences, Geography Unit, FRIBOURG, SWITZERLAND* ; (2) *University of Lausanne, Institute of Geography, LAUSANNE, SWITZERLAND*

As characteristic landforms of the Alpine environment, active rock glaciers express both past and present periglacial processes through their morphology and morphodynamic behaviour. Former research has shown a close relation between ground surface temperature anomalies and inter-annual changes in rock glacier creep velocities, indicating a high and fast response of rock glacier activity patterns on external factors governing the ground thermal regime. Regarding also shorter time scales, strong fluctuations and a distinct seasonal rhythm of the creep velocities have been observed. For a better understanding of the processes involved and to assess the sensitivity of rock glacier kinematics to external driving forces, an integrative data analysis approach is being applied over a large data set of permafrost monitoring elements measured in the Swiss Alps (Swiss Permafrost Monitoring Network PERMOS).

The current research within the SNF Sinergia project "The Evolution of Mountain Permafrost in Switzerland" (TEMPS, 2011-2014) aims at a process-oriented understanding of the sensitivity of mountain permafrost to external effects (e.g. air temperature during the snow-free phase) by the use of a landform-specific approach. To get an overview about the recent evolution of different mountain permafrost properties, explorative data analysis methods will be performed relating kinematics to complementary permafrost observation data (e.g. ground and ground surface temperatures, geophysical data), indices and derivatives. Of particular interest are similarities and differences on a regional scale as well as the topographical context (e.g. exposure to wind and solar radiation) and subsurface characteristics (e.g. ice and water content, boulder size) on a local scale. The poster presents preliminary results of this study focussing on rock glaciers.

\*\*\*\*\*

### **Avalanches in relation to relief of the Tatra Mountains**

ROJAN E.(1), RACZKOWSKA Z.(2), KALAFARSKI M.(3), DLUGOSZ M.(2), KACZKA R.(3), GADEK B.(3)

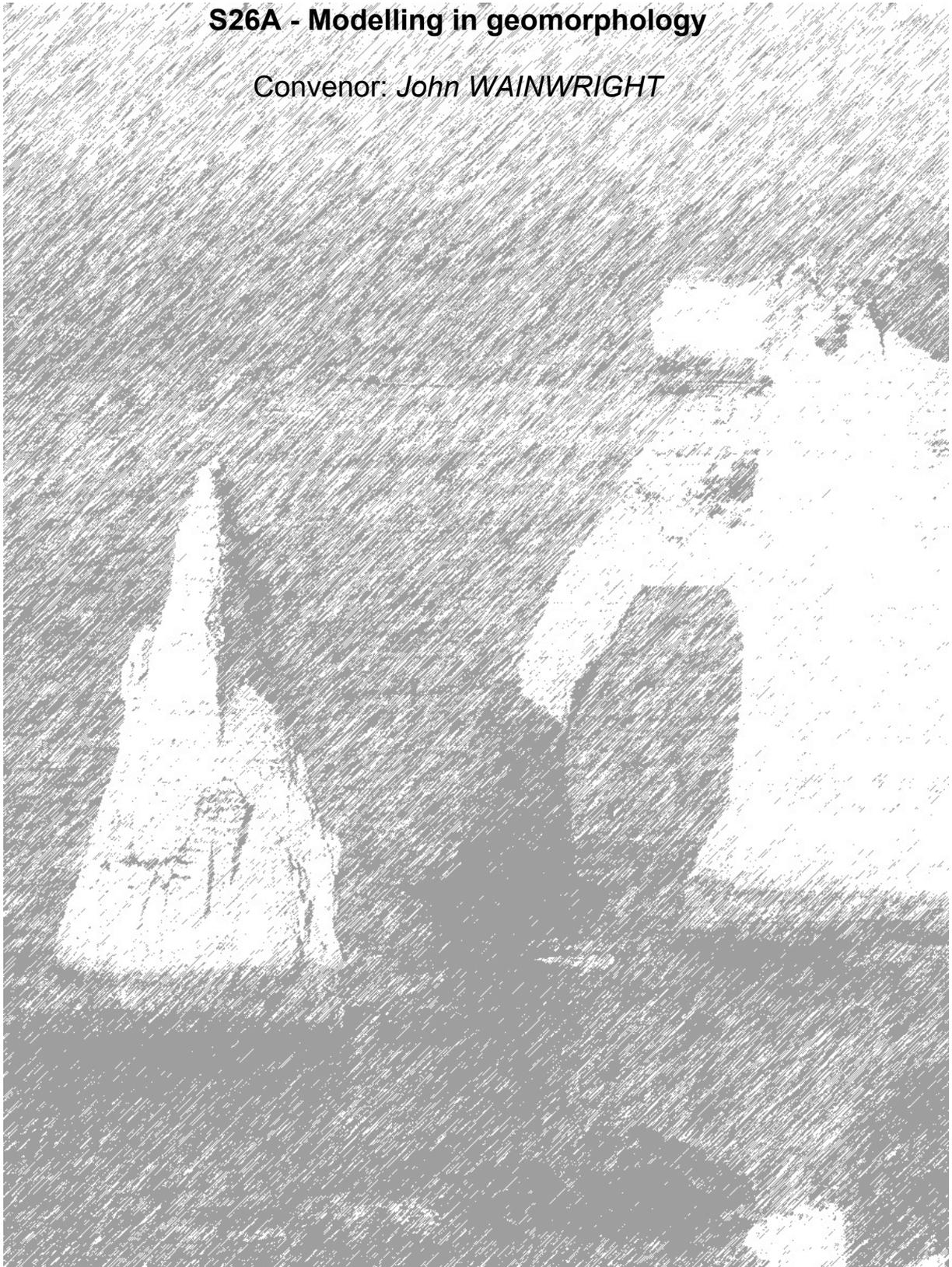
(1) *Faculty of Geography and Regional Studies, University of Warsaw, WARSZAWA, POLAND* ; (2) *Institute of Geography and Spatial Organization, PAS, Department of Geoenvironmental Research, CRACOW, POLAND* ; (3) *University of Silesia, Faculty of Earth Science, SOSNOWIEC, POLAND*

Snow avalanches are among main factors influencing the high-mountain environment of the Tatras. Avalanche tracks are common and occur regardless of slope exposure, and their frequency and size vary significantly. In Polish part of the Tatras 457 avalanches tracks was identified. More avalanche tracks occur in the High Tatras, where its density is one third higher than in the Western Tatras. Similar pattern of avalanche tracks is also in the Slovak Tatras. The reason is difference in relief, conditioning avalanche formation. Slopes in the High Tatras are steeper and have relatively dense net of chutes, while in Western Tatras chutes net is less dense, but gentle and wide upper part of valley slopes favour greater activity of avalanches. There is also great spatial variability of avalanche tracks, in some fragments of the Western Tatras its density is like in the High Tatras. Based on relief analysis 8 chosen avalanche tracks, located on slopes of different aspect, was chosen for detailed measurements of geomorphological effects and modelling the dynamics of avalanches, started in 2012 year.

Geomorphological work is done only by full-depth avalanches. The most of avalanches did not left permanent landmark in the landscape. Changes in the upper timberline are one of the most spectacular effects of avalanche activity. Analysis on air-photos from 1938, 1955, 2004 evidences temporal and spatial variability of avalanches. Regression in size and extent of great number of large avalanche tracks was found. The result of this analysis are important for evaluation of the role of avalanches in the transformation of landform not only at present but in the recent past. The extent of avalanches in the High Tatras in particular time span not change too much, opposite to the Western Tatras. The difference in relief between those two group could be also one of the reason.

**S26A - Modelling in geomorphology**

Convenor: *John WAINWRIGHT*





## Oral presentations:

### **Coupling 3D hydraulic numerical modeling and field survey to assess morphodynamics of a wandering gravel bed river (Durance River, Southern French Alps)**

*CHAPUIS M.(1), DUFOUR S.(2), PROVANSAL M.(3), COUVERT B.(4), DE LINARES M.(5)*

*(1) University of Waterloo, WATERLOO, CANADA ; (2) COSTEL, University of Rennes 2, RENNES, FRANCE ; (3) CEREGE, Aix-Marseille University, AIX-EN-PROVENCE, FRANCE ; (4) Artelia Group, MARSEILLE, FRANCE ; (5) Artelia Group, GRENOBLE, FRANCE*

The Durance River is a wandering gravel bed river located in the Southern French Alps. This large (mean width: 240m) and steep (mean slope: 0.28%) river is deeply impacted by flow diversion and gravel mining in its entire catchment area (14,000km<sup>2</sup>). The Durance River is characterized by a sediment deficit that led to a reduction of active channel width and river bed degradation (from 50 to 80% for the 1960-2000 period). These lateral and vertical modification of the bed lead to important issues in terms of landscape management, because of (i) maintaining the bed hydraulic capacity to evacuate flood discharges and (ii) planform evolution of the river that conflicts with landscape use.

In order to better understand the link between sediment fluxes and river bed morphodynamics for a flood event ( $Q=1,200\text{m}^3\cdot\text{s}^{-1}$ , recurrence interval: 4 years), we developed a hydraulic 3D model of the study reach to describe spatial distribution of shear stresses and flow directions at flow peak. We used the finite element Telemac 3D code to obtain steady-flow velocities and water height at each node (15,600 2D nodes, integrated on 10 planes). For this flood event, we also set up a sediment particle survey in the channel, using RFID tracking. Coupling hydraulic numerical modeling and particle displacement field data enabled us to link peak flow direction and particle displacement. We consequently validated the use of such a hydraulic model for studying the link between shear stresses and particle displacement at reach scale. As the Telemac 3D model is now functional and calibrated, we also validated the use of hydraulic 3D modeling for wandering river management purposes. However, the calibration with field data highlighted some limits of the numerical model: in such a dynamic reach of a wandering river, the steady-flow modeling cannot take into account the intra-event bedform mobility (bank erosion), and thus can explain only part of the particle displacement.

\*\*\*\*\*

### **Numerical simulation of turbulent sediment transport**

*CLAUDIN P.(1), DURAN O.(2), ANDREOTTI B.(3)*

*(1) CNRS - ESPCI, PARIS, FRANCE ; (2) Department of Geological Sciences, Univ. North Carolina, CHAPEL HILL, UNITED STATES ; (3) Univ. Paris Diderot, ESPCI, PARIS, FRANCE*

Sediment transport is studied as a function of the grain to fluid density ratio using two phase numerical simulations based on a discrete element method (DEM) for particles coupled to a continuum Reynolds averaged description of hydrodynamics. At a density ratio close to unity (typically under water), vertical velocities are so small that sediment transport occurs in a thin layer at the surface of the static bed, and is called bed load. Steady, or 'saturated' transport is reached when the fluid borne shear stress at the interface between the mobile grains and the static grains is reduced to its threshold value. The number of grains transported per unit surface is therefore limited by the flux of horizontal momentum towards the surface. However, the fluid velocity in the transport layer remains almost undisturbed so that the mean grain velocity scales with the shear velocity. At large density ratio (typically in air), the vertical velocities are large enough to make the transport layer wide and dilute. Sediment transport is then called saltation. In this case, particles are able to eject others when they collide with the granular bed, a process called splash. The number of grains transported per unit surface is selected by the balance between erosion and deposition and saturation is reached when one grain is statistically replaced by exactly one grain after a collision, which has the consequence that the mean grain velocity remains independent of the shear velocity. The influence of the density ratio is systematically studied to reveal the transition between these two transport regimes. Based on the mechanisms identified in the steady case, we discuss the transient of saturation of sediment transport and in particular the saturation time and length. Finally, we investigate the exchange of particles between the mobile and static phases and we determine the exchange time of particles.

### **Morphogenetic modelling of coastal foredunes**

ZHANG W., SCHNEIDER R., KOLB J.

*Institute of Physics, University of Greifswald, GREIFSWALD, GERMANY*

Coastal foredunes are developed as a result of interplay of multi-scale land-sea processes. The orientation, size and interval of well established foredunes and foredune sequences are directly linked to the prevailing wind direction, extreme wind-wave event frequency and sources of sediment supply. Basic driving mechanisms of the formation of coastal foredunes as well as natural processes and factors involved in shaping the foredune geometry are studied in the present work by a robust Cellular Automata model. The model, which consists of a set of rules to describe the aeolian sediment transport, the hydrodynamic effects on the beach and the growth of vegetation, is applied to simulate the coastal dune patterns developed by varied combinations of wind-wave climates, sediment supply and characteristic growth rates of vegetations. Simulations indicate that the formation of an established coastal foredune results from a subtle balance between the wind-wave impacts and the vegetation growth. Driven by a prevailing onshore wind and a boundary sediment supply, small embryo dunes start to develop on the beach and migrate landward. They are then trapped by vegetation. The first established foredune forms just behind the landward limit of a transitional zone (i.e., storm impact zone or scarp zone) due to the trapping of sediment by vegetation. According to the simulation results, the formation of an established foredune on an initially flat vegetation-free surface has to meet three preconditions: 1. a prevailing onshore component in the wind spectrum; 2. an onshore or lateral sediment supply; and 3. a favorable environment for vegetation growth (e.g., an appropriate moisture and nutrient level). The spatial interval between a new foredune and the present one is determined by a combination of the seaward progradation rate of the beach, the extreme wind-wave event frequency and the rate of vegetation growth in front of the present foredune.

\*\*\*\*\*

### **Numerical simulation of current driven sediment transport processes**

BURKOW M.

*Institute for Numerical Simulation, University of Bonn, BONN, GERMANY*

Current driven sediment transport causes the evolution of bedforms like dunes, ripples or scour marks. These bedforms are formed by the interaction of entrainment and deposition of sediment particles. In this study we use a numerical simulation of the three dimensional fluid flow and the simultaneous transport processes to reproduce these processes. To solve the incompressible Navier-Stokes equations we use NaSt3D as fluid solver for incompressible flow problems in three dimensions. High order discretization schemes provide a reliable algorithm for calculating fluid and sediment properties. The main variants of sediment transport are modelled by applying a advection-diffusion equation for Suspension load and Exner equation to bed load transport. The rearrangement of sediment leads to a new sediment surface height which results in new bedforms. To test our model we simulate the erosion of sediment from a dune crest and the evolution of a scour mark around an obstacle.

## 2D-Hydrodynamic modelling of large wood transport in rivers

RUIZ-VILLANUEVA V.(1), DíEZ-HERRERO A.(1), BODOQUE J.M.(2), BLADÉ E.(3), SÁNCHEZ-JUNI M.(3)  
 (1) Geological Survey of Spain, MADRID, SPAIN ; (2) University of Castilla-La Mancha, TOLEDO, SPAIN ; (3) Technical University of Catalonia (UPC), BARCELONA, SPAIN

Large woody material (LW) transported in the flow may be entrapped at critical stream geometry configurations (e.g. at bridges), and therefore may dramatically increase the destructive power of floods. This was the case in a mountain catchment where a flood event with LW loading took place in 1997, and relevant data was available. The aim of this study was to numerically simulate a bridge clogging process, modelling individual pieces of wood moving with the water flow and interacting with the bridge. First, the boundary conditions (inlet discharge and wood) were established, and then a 2D model was developed to simulate the transport of LW together with the hydrodynamics. A combination of weir and gate internal conditions was used to represent the bridge geometry, and the model simulated the way in which the wood's interactions with it affect the hydrodynamics. Different scenarios for the wood budget allowed us to study the influence of inlet boundary conditions in bridge clogging. For the studied event, the scenario which best reproduced the bridge clogging effect and the flood characteristics was the one in which 60% of total wood entered before the peak discharge. This dropped to 30% at the peak itself, and finally fell to 10% during the recession curve. In addition, the accumulation patterns of LW along the reach were compared with photographs, showing that the model succeeded in predicting the deposition patterns of wood.

\*\*\*\*\*

## Modelling soil erosion on medium-term: the application of a landscape evolution model in a Mediterranean catchment

CIAMPALINI R.(1), FOLLAIN S.(2), LE BISSONNAIS Y.(3), DAVID M.(4), COUTURIER A.(5), WALTER C.(6)  
 (1) INRA, InfoSol, ORLEANS, FRANCE ; (2) SupAgro, MONTPELLIER, FRANCE ; (3) INRA, UMR LISAH, MONTPELLIER, FRANCE ; (4) GEODE, UMR 5602, TOULOUSE, FRANCE ; (5) INRA, UR Science du Sol, ORLEANS, FRANCE ; (6) AGROCAMPUS OUEST, RENNES, FRANCE

Soil resources are being irreversibly lost and degraded (EEA, 2000). Pressure has been generated by the concentration of population and activities in restricted spaces as well as changes in climate and land use. Relevant human-induced changes include those implemented by farmers as well as those imposed by policy in a range of spatial scales. Climate-induced changes are those related to changes in the seasonal distribution of climate factors and in the frequency of extreme events predicted by projections of future climate change (IPCC, 2007).

The aim of this research is to evaluate the influence of land use on medium-term soil erosion delivery in a Mediterranean context, focusing on a small catchment (91 ha) located in the south of France and characterized by extensive vineyard land use. We used LandSoil (Ciampalini et al., 2012) – a landscape evolution model operating at the field/small catchment scale – to analyse different land use for the 21<sup>st</sup> century. Land use changes have been designed considering the actual scenario as stationary reference and introducing variations of soil use and landscape structure from the most conservative to the most degraded condition according to realistic hypothesis.

Results indicate that land use and landscape structure play a main role in sediment delivery: i) soil loss variations in favourable and unfavourable land-use scenarii range from -3.7% to more than ten times compared to the stationary scenario, ii) landscape structure variation represents a minor factor in soil loss variations ranging from -54% to +110%. Future strategies should consider adaptation to climate change and land use – landscape structure reorganisation.

## **Flash floods susceptibility assessment through cellular automata modelling: a case study in northern France**

DOUVINET J.(1), ESCUDIER A.(2), DELAHAYE D.(3), LANGLOIS P.(4)

*(1) University of Avignon - UMR ESPACE 7300 CNRS, AVIGNON, FRANCE ; (2) SCHAPI, TOULOUSE, FRANCE ; (3) University of Caen, UMR LETG-6554 Caen, CAEN, FRANCE ; (4) University of Rouen, UMR 6566 MTG CNRS, ROUEN, FRANCE*

In northern France (Upper-Normandy), flash floods are generated shortly following high rainfall ranged from 50 to up to 100 mm in less than 6 hours. Such phenomena present single features, as a sudden onset, a rapid rising time and a surge rushes down the main dry valley just a few minutes after rainfall has peaked in less than 1h. But assessing occurrence and dynamic of flash floods remain unknown at regional scale as real previous events never occurred on the same areas. In this study, we propose to better define the flash flood susceptibility by applying RUICELLS, a triangular Cellular Automata model developed for simulating the spatial evolution of water flow pathways in dry valleys. Our objectives are to further understanding of the effects of spatial interactions between basin morphology and land use on hydrological responses, and to enable identification of higher peak of discharges and shorter time-responses on 156 basins of less than 20 km<sup>2</sup>. The simulation results confirm the susceptibility changes following rainfall inputs. On one hand 73 basins present discharges up to 4m<sup>3</sup>/s following 40mm in 1h (against 10 basins for 40mm in 2h); among them, 26 have a specific discharges exceeding 1m<sup>3</sup>/s/km<sup>2</sup>, and 11 have a short time-response (in less than 2h). On the other hand the discharges are bigger than 4m<sup>3</sup>/s for 112 points of measurement (more than 10 m<sup>3</sup>/s on 25 basins) following 50mm in 1h; among them, 64 present a specific discharge up to 1m<sup>3</sup>/s/km<sup>2</sup>, and 25 have short response (in less than 2h). Finally this study enables detection of functioning thresholds on the 156 studied basins, and questions the "basin size" as a sufficient parameter to anticipate discharges or responses face to flash floods.

\*\*\*\*\*

## **The dynamic cellular automata landscape evolution modelling platform CDP**

BARKWITH A., WANG L., JACKSON C.R., HURST M., ELLIS M.  
*BGS, NOTTINGHAM, UNITED KINGDOM*

The CAESAR-DESC Platform (CDP) acts as a base for high-resolution modelling of environmental sensitivity over daily to centennial timescales. The Dynamic Environmental Sensitivity to Change (DESC) project couples cellular automata modelling from various backgrounds to generate the CDP; a geomorphological simulator that allows a variety of Earth system interactions can be explored. A derived version of the well established CAESAR model, CAESAR-Lisflood, is used as the platform kernel. The two dimensional modular design allows great versatility in the range of simulated spatio-temporal scales to which it can be applied. CAESAR has been used to investigate a variety of sediment transport, erosional and depositional processes under differing climatic and land-use scenarios in river reaches and catchments around the world. The recent addition of Lisflood to the code has improved river flow representation within the model by incorporating momentum. Non-Lisflood controlled surface hydrology is replaced with a new distributed model (SLiM), and an unconfined cellular automaton groundwater model. Surface-subsurface water exchanges within the CDP are coupled by recharge to groundwater and groundwater discharge to rivers. To deal with the complex energy and sediment fluxes that occur during a debris flow a modified version of the SCIDDICA model, originally developed to simulate flow-like landslides, has been incorporated into the CDP. As the surface hydrology drives the processes within the platform, CDP facilitates the analysis of climate change influences on a range of environmental processes. The dynamic application of climate factors also opens up the possibility of including a decadal-scale evolving vegetation within the model, which could be used to improve both the partitioning of water between the surface processes and the adhesion properties of vegetation-covered sediment with time.

### Physically based modelling of soil erosion from the plot scale to the catchment scale

CERDAN O.(1), LE M.(1), ROUSSEAU M.(1), CORDIER S.(2), LUCAS C.(2)

(1) BRGM, ORLEANS CEDEX 02, FRANCE ; (2) MAPMO, Univ. Orléans, ORLÉANS, FRANCE

In areas modified by human activities, accelerated erosion can lead to serious environmental issues such as the flooding of urban areas or the pollution of water bodies. In order to prevent or to mitigate such events, it is therefore necessary to be able to predict the dynamic as well as the spatial extent of runoff production and particle transfer. To meet this demand and to reflect the complexity of the processes involved as well as the spatial heterogeneity of the landscape, several modelling approaches of various complexities have been developed. Many research efforts are devoted to the development of physically-based models able to improve our understanding and modelling of these fluxes. One of the main obstacles to the application of such models is the difficulty to describe the spatial and temporal variability of the input parameters. In this context, the objective of this study is to develop a robust physically based modelling approach and to adapt its parameterisation to be able to incorporate coarse scale input parameter. A dynamic erosion model coupling the Shallow Water equations with the Hairsine-Rose model was developed. It uses a well-balanced numerical scheme with a hydrostatic reconstruction to preserve the equilibrium and the positivity of water height and to be able to capture spatial heterogeneities. A first application is realised at the plot scale to test the model predictive ability. In a second step, to integrate inner grid variability when modeling at the catchment scale, for each cell, we use the proportion of wetted area as a microtopography indicator. For the case of erosion, the system is coupled to the sediment transport equations. In such context, an additional equation describing the micro-topography evolution caused by erosion is introduced and the numerical scheme of Godunov-type for this model is implemented. The results of a second application at the catchment scale are presented.

\*\*\*\*\*

### Space time substitution in geomorphology (modelling by rainfall)

A. ALMODARESI S.A.

*civil engineerin dep. yazd branch, islamic azad university, YAZD, IRAN*

Between different categories In geomorphology, the course of Ergodicity has been one of the most important subjects. This field, adopted both in physical thermodynamic science and in geomorphology, has interested many researchers. However, because of its complexity, a significant dearth of theoretical studies exists in this regard. Put it simply, the growing importance of this subject is attributed to historical modeling, since one of the most important phenomena in biological geology and in geomorphology is time and its relationship with changes and successions. Phenomena which not only astronomical time is not able to describe the matter studying in their field but also there is not suitable time's substitution in their relation. Ergodicity theorem was born in physics. Ergodic hypothesis, in which observing a member of an ensemble is the same as the average of the ensemble at a definite time evolved in 1960 as an analogy in experimental sciences. However, this issue has not been widely studies in Iran, and hence, this project tries to explain the various dimensions of Ergodicity and its analog face in geomorphology and provides a background to start quantitative researches in Iran. The relationship between evolution, repetition, palimpsest, waves, the origin of phenomena and fractal geometry with Ergodicity are subjects that have been considered in this study. After explaining the physical dimensions and the Ergodic mathematical equations, Ergodic evolution of gullies at Koor-Biabanak district was case studied and its accuracy was evaluated. Further, a miniature model was created for a succession procedure through time and for defining Ergodicity of a small Basin in Yazd-Ardakan region where a lot of rifts appeared. The results provided important allometric rates for the stability of the basin through time. itis our hope that the work reported here will inspire others to further explore issues and enrichthe Ergodic literature in geomorphology.

## **Non-Linear Equilibrium Points in geomorphology**

SEPEHR A.

*Ferdowsi University of Mashhad (FUM), MASHHAD, IRAN*

The concept of “*equilibrium*” is quite basic to system theory and is considered here to imply a complete adjustment of the internal variables to external conditions. The external conditions usually change in two statuses: catastrophic and gradual changes. The response of a geomorphic system to these statuses is different, although in the two statuses, change towards equilibrium points is main goal of geomorphic system. The geomorphic systems are complexity systems with properties of open system. In these open systems the threshold is a bifurcation point. The path followed by the thermodynamic branch beyond the threshold may involve further thresholds and hence bifurcations. In passing through a bifurcation point, the system loses its structural stability and undergoes a sudden or catastrophic change to a new form. The new equilibrium point has new energy status. The energy flow creates patterns in the geomorphic system which can be an early warning signal to find thresholds and resilience limitation of geomorphic system to response geo hazards. In this article has been analyzed these equilibrium points in the geomorphic systems. If the constraints are strong then the system may change smoothly along a thermodynamic branch into non-equilibrium states in which the theorem of minimum entropy production still applies. At a certain distance from equilibrium, called the thermodynamic threshold, non-linear relationships emerge and the steady states along the branch are not of necessity stable. Beyond the threshold, the solutions of the equations governing the dynamics of the system may no longer be unique: the system may enter one of several new regimes. The results and discussion of this article can be a new conceptual paradigm in the geo-hazards risk management.

Keywords: non-linear equilibrium, early warning signals, Thresholds, thermodynamics

\*\*\*\*\*

## **Development of experimental landforms with rainfall-erosion and uplift of various rates**

OUCHI S.

*Chuo University, TOKYO, JAPAN*

A series of experiments with rainfall-erosion and uplift of various rates suggests the existence of threshold uplift rates, across which experimental landforms show different aspects of development. A mixture of fine sand and kaolinite compacted in a square-prism-shaped container (60x60x40cm) is pushed out at a constant rate from a flat ground surface under the artificial mist-type rainfall. In the experiment with a low uplift rate below the lower threshold, a certain low characteristic relief determined by the mound erodibility and rainfall intensity develops with exclusively fluvial erosion under the detachment-limited condition. In this case erosion may slightly exceed uplift to slowly lower the surface. When the uplift rate becomes higher than this lower threshold, uplift exceeds erosion in the upstream area where fluvial erosion works less. Hills grow and slope processes start working. While slope failures inside the uplifted area do not lower the average height unless the sediments are carried away by fluvial processes, the increased sediment supply from slopes helps streams become steeper with uplift and enhances their transport ability. Uplift and erosion then become balanced under the transport-limited condition to keep average height roughly constant and landscapes similar. The uplift of higher rate makes hills grow higher and increase the sediment supply from slopes more, and this works to keep average height higher corresponding to the uplift rate. The experimental landform seems to attain a certain steady state with the equilibrium between uplift and erosion. If the uplift rate becomes even higher and crosses the possible upper threshold, uplift overwhelms erosion and hills grow into high mountains until the relief hits the limit probably determined by the threshold slope. Whenever the uplift ends, the experimental landform starts decreasing its height and relief exponentially, and a peneplain-like surface develops in a long period of erosion.

## **Modelling stratigraphic and surface dynamics processes on a coupled thermo-mechanical lithospheric model: an example in oblique continental rifting**

MONDY L.(1), DUCLAUX G.(2), SALLES T.(2), THOMAS C.(1), REY P.(1)

(1) *The University of Sydney, SYDNEY, AUSTRALIA* ; (2) *CSIRO Earth Science & Resource Engineering, SYDNEY, AUSTRALIA*

Interlinks between deformation and sedimentation have long been recognised as an important factor in the evolution of continental rifts and basins development. However, determining the relative impact of tectonic and climatic forcing on the dynamics of these systems remains a major challenge. This problem in part derives from a lack of modelling tools capable of simulated high detailed surface processes within a large scale (spatially and temporally) tectonic setting.

To overcome this issue an innovative framework has been designed using two existing numerical forward modelling codes: *Underworld*, capable of simulating 3D self-consistent tectonic and thermal lithospheric processes, and *LECODE*, a forward stratigraphic and geomorphic modelling framework dedicated to simulating highly detailed surface dynamics. When coupled together, the resulting models can provide high-resolution data on the mechanical feedback between surface and tectonic processes. These include changes in deviatoric stress, strain, strain-rates, thermal evolution, as well as a stratigraphic record, grain-size variations, sediment provenance, porosity changes, fluvial hydrometric, and geomorphic evolution.

Here we illustrate via this coupling the feedback loop between surface and tectonic processes on an example of 3D oblique rifting. Our fully coupled model enables us to visualise the distribution of sediment sources and sinks, and how these evolve through time. From this we can extract and analyse at each simulation timestep the stratigraphic record anywhere within the model domain. Further to this, we can compare finite and instantaneous sedimentation and erosion. We compare a tectonic model with and without surface processes to assess the significance and magnitude of their interaction.

This work is supported by the CSIRO, and the John Stocker Scholarship.

\*\*\*\*\*

## **How stream piracy is initiated in landscape evolution models? Predictive study in the Meuse basin**

BENAICHOUCHE A.(1), STAB O.(1), COJAN I.(1), BRULHET J.(2), TIJANI M.(1), TESSIER B.(1)

(1) *Mines ParisTech, Centre de Géosciences, 35 rue Saint-honoré 77305, FONTAINEBLEAU, FRANCE* ; (2) *Agence nationale pour la de gestion des déchets radioactifs, 1-7 rue Jean Monnet 92298, CHÂTENAY-MALABRY, FRANCE*

Topography and hydrographic networks are in continual evolution. Drainage structures change over time and modify the landscape. Several piracy events (in the upper and middle Quaternary) are recorded in the North-East of France at the expense of the Meuse River. The specific morphology of the Meuse Basin let us suppose that other piracy events may occur in the future. But where and when? What impact can be expected on the topography at local and regional scale?

Mechanisms provoking piracy events are numerous and complex. In this paper, we focus on stream piracy by headward erosion and investigate geometric, analytic and physical based models. The later integrates the classical landscape evolution equations: diffusion in hillslope and advection in river (stream power). Finally, simulations are realized with GOLEM software (developed by Tucker & Slingerland).

Estimating piracy event ages with physical models requires accurate parameters fitting and classical approaches do not seem to be suitable (slope-drainage area relationship...). So, we opted for a sensitivity analysis in order to explore the solutions space. The results show that the location of piracy events is mainly controlled by the local topography and is not model-dependent. On the other hand, their chronology relies on the flux water exponent (of the stream power model) but is not sensitive to lithological characteristics. All solutions (of the 4500 simulations) can be regrouped according to three scenarios with various consequences on the topography. Finally, in order to estimate the piracy event ages, the Meuse and the Moselle terraces data were used for the calibration of the stream power model. But simulation gives piracy event durations that seem too long comparing with those recorded in the past. Integrating more complex processes (karst process, climate forcing...) and taking into account the Meuse river deposition tendency may accelerate the piracy event occurrences in our modelling.

## Relating landscape morphological complexity to catchment connectivity

BAARTMAN J., MASSELINK R., KEESSTRA S.  
Wageningen University, WAGENINGEN, NETHERLANDS

Connectivity relates to the coupling of landforms (e.g. hillslopes and channels) and the transfer of water and sediment between them. The degree to which parts of a catchment are connected depends largely on the morphological complexity of the catchment's landscape. Landscapes can have very different and distinct morphologies, such as terraces, V-shaped valleys or broad floodplains. The objective of this study is to better understand and quantify the relation between landscape complexity and catchment connectivity. We hypothesize that connectivity decreases with increasing landscape morphological complexity. To quantify this relationship we use artificially created DEMs with distinct morphologies in the landscape evolution model LAPSUS to simulate the connectivity of each landscape for different types of rainfall events. Secondly, the effects in terms of sediment redistribution and related connectivity were evaluated over time for different rainfall event time series. Thirdly, we tested the hypothesized landscape complexity – connectivity relation for some typical morphologies of real-world catchments. To quantify connectivity and landscape complexity several indices were selected. Landscape complexity was quantified by the mean slope, catchment dissection and the Topographic Convergence Index (TCI). The degree of catchment connectivity was assessed with the Borselli's index of connectivity (IC; Borselli et al., 2008). Preliminary results confirm the hypothesis and show that total erosion increases with connectivity and decreases with increasing landscape complexity. However, total deposition seems not to be related to connectivity, while it is related to slope variability and thus landscape complexity.

Reference:

Borselli L, Cassi P, Torri D. 2008. Prolegomena to sediment and flow connectivity in the landscape: A GIS and field numerical assessment. *Catena* **75**: 268-277.

\*\*\*\*\*

## Modelling response to local base level change using LAPSUS

VAN GORP W.(1), SCHOORL J.(1), TEMME A.(1), VELDKAMP A.(2)  
(1) Soil Geography and Landscape Group, Wageningen University, WAGENINGEN, NETHERLANDS ; (2) Faculty ITC, University of Twente, ENSCHEDE, NETHERLANDS

Multi-process modelling of long-term landscape evolution using reduced-complexity models has become increasingly popular in the last decades. Landscape Evolution Model (LEM) LAPSUS is such a LEM that has recently been enhanced to incorporate 3D geology and to identify newly deposited sediments. The aim of this study was to model landscape evolution with LAPSUS in a catchment that experienced base level change due to lava-damming. After modelling several scenarios with lava dams of different erodibilities using a test Digital Elevation Model (DEM), the LEM was applied in an actual catchment which is part of the Upper Gediz basin near Kula, Turkey. Here, lava flows have blocked the trunk river and tributaries several times since the Early Pleistocene until the Holocene. Model inputs are a DEM, results of geomorphological and geological fieldwork and a climate reconstruction using regional climate data. Age control is derived from Ar-Ar dated lava flows and Post-IR IRSL (Post-Infrared Infrared Stimulated Luminescence) dated sediments. Modelling results are evaluated using river profile evolution, cross-sections, sediment yield and spatial redistribution of sediments. Results are expected to show the influence of lava damming and breaching on catchment evolution and answer the question whether catchment response to these past events is still on-going. This is of importance to find out whether the trunk river is in dynamic equilibrium with large-scale tectonic uplift of the area. The technique that we use has potential for answering these and related questions in other dam-affected fluvial systems.

### Validating predictions of braided river morphodynamics: static and dynamical metrics

*WILLIAMS R.D.(1), HICKS M.(2), MEASURES R.(2), BRASINGTON J.(3)*

*(1) Aberystwyth University, ABERYSTWYTH, UNITED KINGDOM ; (2) NIWA, CHRISTCHURCH, NEW ZEALAND ; (3) Queen Mary, University of London, LONDON, UNITED KINGDOM*

Numerical morphological modelling of braided, gravel-bed rivers is gaining momentum as a technique to inform environmental management. In particular, “full process” models, such as Delft3d, are being used to simulate the morphodynamics of braided rivers using high resolution topography to provide initial boundary conditions. Whilst considerable attention has been paid to developing the hydraulic and sediment transport algorithms associated with such models, comparatively less attention has been paid to developing appropriate approaches to validate model predictions. This paper assesses a range of metrics that can be used to evaluate morphological predictions at the timescale of single flood events. First, DEMs are constructed using multi-temporal, high-resolution topographic data that were acquired during an eight-month monitoring campaign on a 2.5 km long reach of the braided, gravel-bed Rees River, New Zealand. This campaign acquired topographic data using a fusion of Terrestrial Laser Scanning and optical-empirical bathymetric mapping. Next, the pre-storm DEMs are used as boundary conditions for Delft3d morphological simulations of the same storm events. Two approaches to model validation are then presented. First, “static” metrics of the observed and modelled post-event DEMs are evaluated. These metrics include measures of braidplain planform, such as anabranch width and depth, inundation area at low flow, and braiding indices. They also include statistical comparisons of DEM similarity. Second, “dynamical” metrics are evaluated. These metrics include those that quantify sediment transport volumes and evaluate the dimensions of erosion and deposition patterns. Such techniques also provide an approach to validate results from sensitivity, or Monte-Carlo, runs of multi-parameter models.

\*\*\*\*\*

### A machine learning approach to estimate river bank erosion through multi-temporal LIDAR and spectral imagery

*IWASHITA F., BROOKS A., CURWEN G., SPENCER J.*

*Australian Rivers Institute - Griffith University, BRISBANE, AUSTRALIA*

This work presents an alternative approach to estimate river bank erosion at regional scale through the Self-Organizing Maps (SOM) technique. LIDAR data was used to calculate erosion values at local scale, while satellite imagery combined with digital elevation model (DEM) were used as predictive variables for regional scale. The LIDAR data was collected in the Normamby River Basin, Australia in 2009 and 2011, from which elevation, canopy height and percent canopy coverage were calculated. The differences in elevation between 2009 and 2011 produced values of erosion along the rivers that were used as training points in the modeling process. Landsat TM5 (Thematic Mapper) sensor images were corrected for atmospheric attenuation and converted into reflectance values to calculate band ratios to enhance spectral features. A subset of fifteen hundred points was randomly selected in areas where erosion was detected and associated to band ratios values and DEM derived measures (elevation, slope, aspect and hydrological flow accumulation). These points were used to train the SOM and construct the predicting model. The SOM are well-suited to analyze noisy, sparse, nonlinear, multidimensional, and scale dependent data enhancing nonlinear relationships while preserving the topology of the original dataset, one of the key advantages of this data mining method, since most of multivariate methods assume that relationships between predicted and predicting variables are linear. Results show an increasing trend of erosion from the headwaters to the lower reaches associated with bank retreat due to mass failures. Anomalous high values of erosion in the upper basin are likely related to alluvial gully erosion as observed during our fieldwork. Stochastic cross-validation indicates that the SOM is unbiased and provides a way to measure the magnitude of prediction uncertainty.

## **Massively parallel particle-based methods in landscape evolution modelling: geomorphic validity and performance**

MARTEL T., VAN DE WIEL M.

*The University of Western Ontario, LONDON, CANADA*

Landscape evolution modellers suffer from the dilemma of either having to take on considerable computational overhead with a reductionist physics-based approach, or using a highly simplified reduced-complexity approach. Particle-based methods for solving flow, such as smoothed particle hydrodynamics (SPH), are ideally suited to parallelization, inherently adaptive, and can interact with complex boundaries. As such, particle-based methods might bridge the spatio-temporal gap from sub-reach to catchment scales, and take the next step toward modelling full landscape evolution. However, particle-based approaches have not yet been adapted to perform sediment transport in a way proven to yield quantitatively accurate landscape morphologies. This paper presents preliminary results from a particle-based flow model which has been extended to simulate catchment- and reach-scale sediment transport. The model is evaluated with respect to geomorphic validity of the results, and with respect to performance gains relative to both reductionist and reduced-complexity models.

\*\*\*\*\*

## **PARALLEM: A new parallel-coded Landscape Evolution Model**

MADDY D.(1), MCGOUGH S.(1), WAINWRIGHT J.(2), TRUEMAN A.(2)

*(1) Newcastle University, NEWCASTLE UPON TYNE, UNITED KINGDOM ; (2) Durham University, DURHAM, UNITED KINGDOM*

PARALLEM is a new landscape evolution model designed to leverage the immense processing power of massively parallel GPGPUs in order to facilitate high spatial resolution modelling of large river catchments . Modelling catchments in excess of 10,000 km<sup>2</sup> from source to sink, even at modest spatial resolution e.g. 45m cells, requires computations based upon massive grids comprising millions of cells. Conventional CPU-based sequential models cannot perform this task within tractable execution time i.e. a few weeks. Such a task requires utilisation of high performance computing (HPC), where computation is spread across multiple processors in parallel.

PARALLEM has been coded to exploit the massively parallel CUDA architecture deployed in NVIDIA GPGPUs. Comparatively small grid models can be deployed utilising a single node with up to 4 attached GPGPUs but the model will scale for HPC deployment using associated MPI-based inter-node communication.

After a brief introduction to the process model underlying PARALLEM, this paper will present results from the initial testing of this model across a range of spatial and temporal scales; discuss how model sensitivity analysis is being undertaken using high throughput computing resources; outline the planned future extensions to the model; and discuss our initial target for full deployment.

### Parallel processing in WPS services for geological and geomorphological mapping

*ALVIOLI M., MARCHESINI I., ROSSI M., SANTANGELO M., CARDINALI M., REICHENBACH P., ARDIZZONE F., FIORUCCI F., BALDUCCI V., MONDINI A.C., GUZZETTI F.*  
 CNR-IRPI, PERUGIA, ITALY

Exploiting to the maximum possible extent the information contained in spatial data, along with specialized and optimized computing intensive analysis processes, is mandatory in order to cope with the challenges posed by the huge amount of existing and upcoming data. Dealing with spatial data and related computing processes can be a hard task for many subjects, preventing proper dissemination of information and modeling advances. One possibility for sharing data content, specialized model implementation and distributed computing power is represented by Web Processing Services, an Open Geospatial Consortium standard specifically designed to facilitate the inter-operability of geospatial data by client-server interfaces.

The client side of the interface presents the user with a choice of services exposed by the server, and the possibility of specifying parameter values and uploading own maps. The main advantages of such an approach are the possibility of publishing specialized and optimized processes, corresponding to sound and well-established models; the complexity of the implemented processes is hidden by the server side, where a number of chained procedures can be summarized in a single service, optionally using different programming languages and, most importantly, exploiting distributed and parallel computing. We have implemented tools for (i) statistical models of the distribution of landslide areas (ii) estimation of the attitude of bedding planes from the corresponding bedding traces (iii) production of maps showing the geometrical relationship between bedding planes and terrain slopes (iv) automatic delineation of hydrological slope units. These few prototype services for landslide modeling, representative of a vast class of processes from the algorithmic implementation point of view and the parallelization schemes we have used, represent a starting point for a systematic publication of models through similar web services.

\*\*\*\*\*

### Multivariate Global Sensitivity Analysis of a Landscape Evolution Model: Multiple Model-Ensemble Deployment on a High Throughput Computing Grid

*TRUEMAN A.(1), MADDY D.(2), MCGOUGH S.(2), WAINWRIGHT J.(1)*

*(1) Durham University, DURHAM, UNITED KINGDOM ; (2) Newcastle University, NEWCASTLE UPON TYNE, UNITED KINGDOM*

Landscape Evolution Models (LEMs) are now prevalent tools within geomorphology due to facilitating the investigation of research questions over spatial/temporal scales unviable within field/laboratory studies alone. In recognition of their value to geomorphological research, on-going development of LEMs has improved their sophistication and range of process representation. However, as with all models of natural systems, a degree of uncertainty is associated with the internal parameterisations/assumptions of these LEMs. Estimation of model sensitivity to their internal parameterisations is commonly studied with simple local sensitivity analysis (SA) techniques - which are not suitable for non-linear models such as LEMs. Global SA techniques overcome the limitations of local SA, but are rarely applied to LEMs due to the nature of the time-series outputs of LEMs often producing thousands of sensitivity indices.

Recently, a more parsimonious principal component analysis (PCA) based approach to global SA on time-series outputs has been developed. Yet, its widespread adoption has been deterred by computational limitations related to the need to execute a large number of model runs. However, High Throughput Computing (HTC) grids allow multiple model runs to be executed concurrently; greatly reducing the time required for the execution of all runs required for the analysis.

This paper presents the results obtained from the PCA-based global SA of an existing LEM, alongside the methodology undertaken for concurrent model execution on a HTC grid. Through concurrent execution on the HTC grid, a reduction of over two orders of magnitude in time required for the execution of all model runs has been achieved (when compared to serial execution). The results obtained from the PCA-based global SA have allowed an informed evaluation of the LEM's parameterisations, whilst also illustrating a current limitation associated with the model's vegetation component.

**Are 'Physically-based' soil erosion models physically-based? Some elements from a sensitivity analysis of the Hairsine and Rose model**

ROUSSEAU M.(1), CERDAN O.(1), ERN A.(2), LE MAÎTRE O.(3), SOCHALA P.(1)

*(1) BRGM, ORLÉANS, FRANCE ; (2) Université Paris-Est, Cemics, Ecole des Ponts ParisTech, MARNE LA VALLÉE, FRANCE ; (3) LIMSI-CNRS, ORSAY, FRANCE*

We study parametric uncertainty propagation and quantification for the simulation of erosion processes in the presence of rainfall and/or runoff. Uncertain input parameters of the Hairsine & Rose model are treated in a probabilistic framework, considering them as independent random variables defined by prescribed probability density functions. This probabilistic modeling is based on a literature review to identify the range of variation of the main input parameters. The output statistical analysis is realized by Monte Carlo sampling and by Polynomial Chaos expansions. Our analysis aims at quantifying uncertainties in selected model outputs and establishing a hierarchy within input parameters according to their respective influence on output variability by means of global sensitivity analysis (Sobol indices). The sensitivity of the output variability to the different parameters is discussed. Furthermore, our analysis of the Hairsine & Rose erosion model permits to conclude that, for the quantities of interest considered, the parametric interactions are not significant in the rainfall detachment model, but they prove to be important in the runoff detachment model.

## **Poster presentations:**

### **Effect Meander Development at change land cover in Mond River with Spatial Data Modeler**

NAEIMINEZAMABAD A.

*Islamic Azad University, Saveh Branch, SAVEH, IRAN*

A meander is a bend in a sinuous water course or river. Meanders formed when the moving water in a stream erodes the outer banks and widens its valley. The first impact of create a meander is changed in geometry of river and also change land use and land cover in bank of rivers. In this study we calculate structure of Mond river habitation in section of the plains where river flows until to Persian gulf. Based study of ETM, IRS and in some area's Quick Bird satellite image that receive from 2000 until 2008 and also aerial photo (Scale 20000) that photographed in 2005 and also use from Topographic Data, river Bathymetry we create Landover and river Geometry in four section. The all digital data's that create'd base satellite images and other data's were inputs for run a simulation model based SDSS in ArcGIS software. Based structure of river and land cover change we create a prediction model in Spatial Data Modeler. Prediction model in SDM were based Unsupervised Neural Network. To achieve the desired result in this part ,we developed this extension in VBA environment. all of data's joint with together in unsupervised neural network and in result we create a good simulation model with maximum 5% error. Based result of this simulation obvious that 38% of land cover in river banks will change until 6 years and in this change approximately 48% of existing land covers that will change are inside of meandering around erodable corner and 52% of land cover that will change are in deposition corner. Landcover digital layer refer to year 2008 werean indicator for compare result of model with existing condition. In result, based use for spatial simulation, be able identified behavior survey of river change and also knowledge of the nature change, especially aware of the changes in river geomorphology can help for better planning based sustainable development in areas affected by river flows.

\*\*\*\*\*

### **The use of ground models for the integration of geomorphological, geoenvironmental and engineering geological data**

GILES D.

*University of Portsmouth, PORTSMOUTH, UNITED KINGDOM*

The use of conceptual ground models (CGM) together with conceptual site models (CSM) is becoming an increasingly important tool for the characterisation and interpretation of engineering sites and in particular as part of the investigation and redevelopment of potentially contaminated Brownfield sites. The key data sets of geomorphology, solid and superficial geology, hydrogeology and site history which are necessary for the investigation, interpretation and risk management of a particular site can be complex to present together. The use of a visualised ground model allows for a clear interpretation of these data to be made in a format that is readily accessible by an end user.

A visualised ground model provides the geomorphologist and engineering geologist with a simple and easily understood vehicle to aid in the understanding of the three and often four dimensional variability of a given site. Complex interactions and potential geohazards, whether geomorphological or geological, can be identified and emphasised by the use of such models.

This paper will review the current approaches to ground model design and will highlight the need for geomorphological data to be integrated within them. Various examples will be presented of the different approaches that are available, particularly with regard to contaminated former Brownfield sites.

**Regional characterization based on a new drainage network parameter. The case of the Coatzacoalcos fluvial system.**

*RAMIREZ NU EZ C., PARROT J.F.  
UNAM, MEXICO D.F., MEXICO*

Fractal measurements are generally used to characterize different drainage network patterns. The fractal dimension would be closely related to the flux configuration. As the fractal dimension is not only related to the configuration but also to the way in which the pattern fills the space, this measurement is not sensible enough to really distinguish different drainage network features. This is the reason why it was necessary to develop the algorithm presented here in order to study the complex fluvial Coatzacoalcos river system (State of Veracruz, Mexico) characterized by the development of numerous meanders, anastomosed and dendritic structures.

The method consists on using a moving window of size  $m \times m$  centered on a pixel  $i, j$  ( $i$  for the line,  $j$  for the columns); in a first step the program labels the different segments of the drainage network encountered and only takes into account the segment passing through the window center. The total number ( $Np$ ) of pixels describing the chosen segment as well as the total number of confluents ( $Nc$ ) are calculated. The proposed new parameter ( $R_{cj}$ ) is calculate as follows:  $R_{cj} = (R_2/R_1) \times 100$  where  $R_1 = 100 - (Nc \times 10/Np \times 100)$  and  $R_2 = [Np/(m \times m)] \times 100$ . The parameter  $R_{cj}$  is able to distinguish the dendritic drainage network from the meandric drainage network and its value is reported on the resulting image at the position  $i, j$ . For instance, in the studied region the meandric configuration has a  $R_{cj}$  around 3.6 meanwhile the  $R_{cj}$  value for a dendritic drainage network is greater than 5.

As the  $R_{cj}$  values are only reported at the position occupied by the pixels belonging to the drainage network, the regionalization of these values in a second step requires using another moving window (of size  $m \times m$  or  $n \times n$ ) in order to calculate the mean value of  $R_{cj}$  of the pixels that do not correspond to the drainage network.

\*\*\*\*\*

**Morphology and dynamics of star dunes from numerical modelling**

*ZHANG D.(1), NARTEAU C.(2), ROZIER O.(2), COURRECH DU PONT S.(3)*

*(1) Institute of Geology and Geophysics, Chinese Academy of Sciences, BEIJING, CHINA ; (2) Institut de Physique du Globe de Paris, PARIS, FRANCE ; (3) Laboratoire Matière et Systèmes Complexes, Univ Paris Diderot, PARIS, FRANCE*

Star dunes are giant, pyramid-shaped dunes composed of interlaced arms. These arms are marked by sinuous crests and slip faces of various directions. Their radial symmetry and scale suggest that the star dunes form as a result of complex interactions between a multidirectional wind regime and topography. However, despite their ubiquity in modern sand seas, comparatively little is known about their formation and evolution. Here we present a discrete numerical model of star-dune behaviour based on the feedback mechanisms between wind flow and bedform dynamics. Our simulations indicate that the morphology of star dunes results from the combination of individual longitudinal dunes. We find that the arms of the star dunes propagate only under favourable wind regimes. In contrast to dunes that form from an erodible bed, the crests of the propagating arms are oriented such that sand flux is maximized in the direction of arm growth. Our analysis of the simulated three-dimensional structures suggests that the morphodynamics of the arms are controlled by the frequency of wind reorientation, with a high frequency of reorientation leading to smaller arm dimension and high rates of growth. We suggest that arm propagation is an important process of mass exchange in dune fields.

## Predicting river morphology after restoration. Application to a Brazilian case of the methodology VALURI

NARDINI A.(1), GOMEZ MIGUEZ M.(2), PITZER JACOB A.C.(3)

(1) Italian Centre for River Restoration -CIRF ([www.cirf.org](http://www.cirf.org); mail: [a.nardini@cirf.org](mailto:a.nardini@cirf.org)), MESTRE, ITALY ; (2) Universidade Federal do Rio de Janeiro, Polytechnic School and Civil Engineering Program PEC-COPPE (mail: [marcelomiguez@poli.ufrj.br](mailto:marcelomiguez@poli.ufrj.br)), RIO DO JANEIRO, BRAZIL ; (3) Universidade Federal do Rio de Janeiro, Polytechnic School and Civil Engineering Program PEC-COPPE (mail: [carolinepitzer@coc.ufrj.br](mailto:carolinepitzer@coc.ufrj.br)), RIO DO JANEIRO, BRAZIL

River Restoration (see for instance [www.ecrr.org](http://www.ecrr.org)) is increasingly recognized as a core discipline not only to improve the ecological status of rivers (a requirement of the European Water Framework Directive), but also to combat flood and hydro-morphological risk. After the application of a River Restoration project which foresees significant changes in the system of defence and exploitation works as well as man-made morphological adjustments (e.g. reconnection of an incised main channel with the surrounding ex-floodplain), river morphology will change and its hydraulic and geomorphic dynamic as well. It is hence key to predict in advance the future morphology and geometry that the river will assume after the project, in order to evaluate whether the effects of the foreseen project are indeed desirable or not.

Nardini and Pavan (2012, *J. of River Basin Management*, 10/1) proposed a semi qualitative, articulated methodology to carry out such a prediction and applied it to the Italian case study of the Chiese river. In this paper, a twofold exercise is conducted, by adopting the same methodology, for a Brazilian case study: the Dona Eugenia river. On the one side, a prediction is carried out for few RR alternatives proposed within a more general project of RR of the area, exactly as it had been done for the Italian case study, but with all the modifications due to the different nature of the river and its context. On the other hand, a partial attempt to validate the methodology itself is carried out through an ex-post prediction exercise; i.e., we try to predict current morphological status, starting from a point in the past before great land use modifications and hydraulic works had occurred.

Although several weaknesses can still be identified in the methodology adopted, the need for it is evident and additional validation exercises and successive improvements can pave the way for an important and effective tool complementing traditional mathematical modelling.

\*\*\*\*\*

## Analysis of methods of potential environmental fragility in a small sized watershed

CORREA E.A., PINTO S.D.A.F., MORAES I.C.  
Sao Paulo State University, RIO CLARO, BRAZIL

The aim was to analyze the methods of Universal Soil Loss Equation-USLE (WISCHMEIER e SMITH, 1974) and the Empirical Analysis of Fragility of natural environments anthropogenic, with support in the slope classes (ROSS, 1994), referring to potential environmental fragility in the small sized watershed, considering that the same is located in an area with sub-tropical climate, predominantly wavy/strong wavy relief and predominantly sandy soil. The variable that constitutes both methods was obtained by cartography, statistics and geoprocessing techniques, being raised slope-steepness, type of soil, erosivity, erodibility and slope-length variables, all scale 1:10.000. The variables erosivity, erodibility, slope-length and slope-steepness were crossed in GIS, as formulation of Wischmeier e Smith (1974) and reclassified as Bertoni e Lombardi Neto (1999), obtaining the map of potential environmental fragility of USLE. Also in GIS, the map of potential environmental fragility obtained through of Empirical Analysis of Fragility of natural environments anthropogenic, was prepared by superimposing the information sheets of slope-steepness, erosivity and type of soil as methodology proposed by Ross (1994). In both products, the areas of higher fragility localized in sectors of greater slope and the presence of vulnerable soils were classified as strong/very strong fragility. Also, the areas localized in sectors of lower slope and soils with low erodibility were classified as low/very low fragility. However, it was verified that the products derived from method Ross (1994) showed 40% of area classified as strong/very strong fragility because of greater importance given to factors geomorphology and slope. The conclusion is that areas of high slope, the method of Ross (1994) can present excessive results compared to reality. GIS demonstrated effective in the analysis of environmental fragility, being possible the applying of methodology in studies of environmental planning.

### **Comparative study of overland flow modeling with different numerical resolutions**

ROUSSEAU M.(1), CERDAN O.(2), DELESTRE O.(3), DUPROS F.(2), CORDIER S.(4), JAMES F.(4)  
(1) BRGM, ORLANS, FRANCE ; (2) BRGM, ORLANS, FRANCE ; (3) Laboratoire de Mathématiques J.A. Dieudonné & EPU Nice-Sophia Antipolis, Université 11 de Nice-Sophia Antipolis, NICE, FRANCE ; (4) MAPMO, Université d'Orléans, ORLANS, FRANCE

In the last decades, more or less complex physically-based hydrological models have been developed to solve the shallow water equations or their approximations using various numerical methods. Model users may not necessarily know the different hypothesis lying behind those developments and simplifications. Therefore it might be difficult to judge if a code is well adapted to their objectives and test case configurations. Our study aims at comparing the predictive abilities of different codes and evaluating potential gain by using advanced numerical scheme for modeling runoff. We present four different codes; each one based on either shallow water or kinematic waves equations and using either finite volume or finite difference methods. We compare these four numerical codes on different test cases which allow emphasizing their main strengths and weaknesses. Results show that, for relatively simple configurations, kinematic waves equations solved with finite volume method represent an interesting option. Nevertheless, as it appears to be limited in case of discontinuous topography or strong spatial heterogeneities, for these cases we advise the use of shallow water equations solved with the finite volume method.

\*\*\*\*\*

### **Assessment of annual streamflow responses to different land use and land cover in a mountainous area of Rio de Janeiro, Brazil**

SILVA A., FERNANDES N.  
Federal University of Rio de Janeiro, RIO DE JANEIRO, BRAZIL

Risk assessment of future land use changes with respect to their ecological impact is still a problem. The application of hydrological models to quantify the effects of different land use and land cover on the streamflow response of the catchment can clarify the processes involved and support management decisions. This study investigates the contribution of different types of land use and land cover on the streamflow of Bonfim river basin through analysis of the hydrological response by sub-basins using the distributed hydrological model Soil and Water Assessment Tool (SWAT). Located in the mountainous region of Rio de Janeiro, the basin is covered predominantly by forests with different stages of succession, rocky outcrops, agriculture and small portion of urbanized area. Based on the sensitivity analysis, calibration and verification, the hydrologic response was simulated. The results indicated that the levels of flow varied according to the use and coverage. Subbasins with forest presented reduced levels of flow than subbasins with predominance of agriculture. The subbasins with urbanized area, even associated with forest, were those that produced higher levels of flow. We can conclude that in mountainous areas, with slopes ranging from 20 to 75° degrees, associated with urbanized areas hold a higher concentration of water flow. Results of this study improve our understanding of how the production of water is spatially distributed, the role of forests to contain the flow of the watershed even with different stages of succession and the contribution of rocky outcrops and slope to flow levels. The expansion of agricultural or urban areas could represent a significant increase in the levels of flow in Bonfim's catchment. SWAT has the potential to simulate the streamflow of the watershed presenting reasonable results and given support to expand research aimed scenarios with replacement coverage for different uses.

### **Concept of sustainable management involves landscape geodiversity of hydrogeomorphological units: the Dębnica River, Poland**

*BORYSIAK J.(1), MAZUREK M.(2), ZWOLINSKI Z.(2)*

*(1) Institute of Physical Geography and Environmental Planning, Adam Mickiewicz University, POZNAN, POLAND ; (2) Institute of Geoecology and Geoinformation, Adam Mickiewicz University, POZNAN, POLAND*

The concept of sustainable management of landscape geodiversity for the Dębnica drainage basin, representing the lakeland areas formed by the Vistulian ice-sheet, is presented. A geoecosystem model is used for solving planning dilemma. The model treats natural environment as a system of abiogenic, biogenic and anthropogenic components (and their state) described as hydrogeomorphological units. Within the research procedure GIS framework the following main tasks are conducted: 1 – designing and delimitation of a geoecosystem map, based on catchment divisions (HRU), potential natural vegetation, present-day vegetation and types of land cover/use, showing a spatio-functional structure of landscape subsystems, 2 – analysis of geoecosystem linkages, 3 – classification of the distinguished geoecosystems in terms of landscape geodiversity. Geoecosystem model of the Dębnica River drainage basin allows to assessment of classified units from the ecosystem services point of view. The sustainable management of classified units enables identification and elimination of risks for existing and potential ecosystem services. Therefore geoecosystem model of any drainage basin determines optimal functions for hydrogeomorphological units.

\*\*\*\*\*

### **The Importance of the USLE L Factor in Erosive Modeling: a Brazilian perspective**

*PINHEIRO L.(1), CUNHA C.(2)*

*(1) Universidade do Estado de Minas Gerais, FRUTAL, BRAZIL ; (2) Universidade Estadual Paulista, RIO CLARO, BRAZIL*

The sheet erosion, due to its peculiar characteristic, is hardly detected by most of the population, especially in the early stages, so there is a need for the establishment of correct practices for soil conservation. Universal Soil Loss Equation (USLE) seeks to estimate soil loss by sheet erosion, considering the factors that influence in the erosion, it is a model of erosion widely applied in national and international research. However, there are limiting factors, the USLE does not consider the geometry of the sides and partially addresses the question of extending the slopes. Thus, the main objective of this research was to analyze how the systematic collection of data length strands affect the results obtained with USLE, and from this analysis, propose an efficient way to produce data extension slopes. As the study area was selected Watershed of Stream Ibatinga, inserted in municipality of Rio Claro, with headwaters in rural production area and its middle and lower course in the area of the Sustainable Use and Conservation of Environment Unit, of the Environment Secretariat of State of the São Paulo, the Edmundo Navarro de Andrade Forest (FEENA). This paper was applied on soil loss, considering the erosive modeling (USLE) and the implementation of erosion plots, with emphasis on Factor L (extension slopes), analyzing systematically obtaining such data. Activities were carried out in the field, laboratory and office to survey and analysis of soil loss and erosive modeling. It was noted that the L factor significantly influenced the generation of the Letters of Potential Natural Erosion and Soil Loss Estimates. The quantification of the slopes extents by three methodologies pointed to satisfactory results on the research proposal. The slopes segmentation technique was more appropriate, differentiated values presented LS Factor along the lower slope and small generalization of data, was presented the highest values coincidence with the experimental plots.

### **A GRASS GIS model for high-mountain multihazard assessment at the regional scale**

*MERGILI M., GRUBER F.E., SCHNEIDER J.F.*

*Institute of Applied Geology, BOKU University, VIENNA, AUSTRIA*

High-mountain areas are commonly experiencing pronounced environmental changes, caused by atmospheric temperature increase. Such changes include both permafrost melting and the retreat of glaciers. Together with earthquakes, they disturb the dynamic equilibrium of the fragile high-mountain geomorphic systems, leading to an increased occurrence of rapid mass movements, sometimes with long travel distances. Here we demonstrate a scheme for a regional-scale high-mountain multihazard assessment, including (1) Lake outburst floods; (2) Rock-ice-avalanches; and (3) Rock slides.

The scheme is developed in the Open Source Geographic Information System GRASS GIS and applied to a 100,000 km<sup>2</sup> study area in the Pamir (Central Asia). First, the susceptibility of each type of event is determined and a score is assigned to each object (lakes, hanging glaciers) or pixel (rock slides). This score is increased for areas with melting permafrost, which are particularly susceptible to mass relocation processes: a solar irradiation model is used to determine permafrost areas under the current conditions and under projected conditions in the future.

Second, the possible travel distances and impact areas of all types of processes are computed using empirical relationships. Inaccuracies of the relationships are accounted for by applying multiple random walks with the key parameters varied within the confidence interval. The results for all processes are overlaid, so that a multihazard impact susceptibility score is assigned to each pixel.

The impact susceptibility score is then superimposed with a layer of settlements, farmland and infrastructures, in order to derive a pixel-based risk indication map. The risk indication scores are summarized by village. The results shall represent an objective base for (1) the prioritization of areas requiring mitigation measures and (2) the identification of safe places.

\*\*\*\*\*

### **Modelling river evolution: conceptual and numerical model on the river pellice (North-Western Italy)**

*PASCULLI A., AUDISIO C., SCIARRA N.*

*Department of Engineering and Geology, University Chieti-Pescara, CHIETI, ITALY*

Models are a simplifying abstraction of reality. Furthermore, they provide one of the crucial links between the study of processes and the study of the world around us, the two traditional activities of geomorphology.

Particularly, the fluvial geomorphologic models have been developed to address problems both on pure scientific research and river engineering. In general, in the first step of modelling processes for identifying the river reaches for more detailed investigation, the conceptual models are most often used. However, together with the computational hardware, the use of numerical simulation models in fluvial geomorphology has rapidly increased in the last twenty years.

Starting from these considerations, the present research illustrates the reconstruction of spatial variation in channel morphology and sediment dynamics in the long, medium and short-term period using the traditional methods of investigation through historical maps (1880-1945), aero-photographs (1945-1999) and ortho-photographs (2007). This reconstruction allows a preliminary comparison with a conceptual model but it leaves several doubts on river evolution in the short-term periods. As a consequence, a numerical model (cellular automaton) has been introduced in order to trying to estimate and evaluate a set of evolutionary scenarios of the river.

In our research activity, we have applied the Conceptual Evolution Model (CEM) proposed by Surian and Rinaldi in 2003 and its following adjustments and CAESAR modeling at the case-study of the River Pellice, left tributary of the River Po. It drains a 905 km<sup>2</sup> wide catchment in the Central Cotian Alps in Piedmont and for about 40 km it runs in the plain sector of North-Western Italy.

## **Estimates of river flows, floodplain inundation and land-atmosphere feedbacks in tropical African wetlands**

DADSON S.

*School of Geography and the Environment, University of Oxford, OXFORD, UNITED KINGDOM*

The response of African rivers and floodplains to climate variability and change is of interest to hydrologists, meteorologists and water managers. Over wet surfaces, high daytime evaporation rates and suppressed sensible heat fluxes induce a shallower, moister planetary boundary layer, which affects atmospheric instability and favours the initiation of new storms. Yet because models of the Earth system do not usually represent fluvial floodplain processes, little is known about the ability of regional models to reproduce regional patterns of hydrological response to climate variability and change, and few studies have directly addressed the impact of fluvial inundation on water, energy and carbon fluxes between the atmosphere and the land surface.

Here the JULES land surface model is used to produce estimates of river flows over Africa. This model uses a probability-distributed model of soil moisture and runoff production coupled with a discrete approximation to the 1D kinematic wave equation to route river water downslope. Subgrid-resolution topographic data are used to derive a two-parameter frequency distribution of inundated areas for each grid box which we then employ to represent overbank inundation in the model. The model was configured at 0.5 degree resolution and driven using the WATCH Forcing Data. The model reproduces the salient features of observed river flow and inundation patterns including substantial evaporative losses from inundated regions accounting for increased land-atmosphere water fluxes during periods of greatest flooding. Results are evaluated against observed estimates of inundation extent obtained using satellite infrared and microwave remote sensing and the implications of these findings is considered in relation to future changes in climate, wetland extent and carbon fluxes.

\*\*\*\*\*

## **A GRASS GIS-based deterministic model for the analysis of deep-seated slope stability in complex geology**

MARCHESINI I.(1), MERGILI M.(2), SANTANGELO M.(1), BUCCI F.(1), CARDINALI M.(1), ROSSI M.(1), FELLIN W.(3), GUZZETTI F.(1)

*(1) CNR IRPI, PERUGIA, ITALY ; (2) Institute of Applied Geology, BOKU University of Natural Resources and Life Sciences, VIENNA, AUSTRIA ; (3) Unit of Geotechnical and Tunnel Engineering, University of Innsbruck, INNSBRUCK, AUSTRIA*

We present a GIS-based, three-dimensional slope stability model capable of dealing with deep-seated slope failures in complex geology. The model is developed in GRASS GIS as the raster module *r.rotstab* and builds on a slight modification of the three-dimensional sliding surface model proposed by Hovland and revised and extended by Xie et al. (2003). Given a Digital Elevation Model (DEM) and a set of thematic layers, the model evaluates the slope stability over a large number of randomly determined potential ellipsoidal slip surfaces. In addition, truncated ellipsoids can be used to simulate the presence of weak layers, most commonly delimited by regolith discontinuities or the interfaces between geological layers. Any raster cell may be intersected by various sliding surfaces, each associated with a computed safety factor. The lowest value of the safety factor is stored for each raster cell together with the depth of the associated slip surface. This results in an overview of potentially unstable regions without showing the individual sliding areas.

We apply the model in the Collazzone area, Umbria, Central Italy. Initially, we assume homogeneous regolith. Even though the model successfully predicts much of the observed deep-seated landslides, it fails in a significant number of cases. According to field observations in the Collazzone area, morpho-structural settings – and therefore the bedding attitude of the geological layers – play a crucial role for deep-seated landslide distribution. Therefore, we prepare a 3D model of the geological substrate, based on the superficial strike and dip directions of each layer, and use this model as input for the *r.rotstab* model. The results for selected subsections of the Collazzone area are shown and evaluated in comparison with the results yielded with the assumption of a homogeneous substrate.

## Using field data to evaluate modeling input parameters and attempt to include spatial distribution of flow bulking of lahars in three valleys at Cotopaxi volcano, Ecuador

ETTINGER S.

*Clermont Université, Université Blaise Pascal, GEOLAB & CNRS, UMR 6042, GEOLAB, CLERMONT-FERRAND, FRANCE*

LaharZ is a computer model that estimates areas of potential inundation from volcanic debris flows often termed lahars. The software, that runs within a geographic information system (GIS), requires estimates of flow volume and a digital elevation model (DEM) as input data. Rapid and reproducible results make the software amenable to use during volcanic crises to assess hazard and aid mitigation measures in potentially affected floodplains. LaharZ algorithms and input parameters affect the output. Both the estimates of volume and quality of the topographic data influence the results. This study analyzed geomorphological parameters of potentially inundated areas at Cotopaxi volcano, Ecuador, using aerial and oblique photographs and morphometric measurements to assess whether input data would improve output by changing various local hazard scenarios. DEMs of different generic type (remote sensing derived DEMs compared to derived from contours) and spatial resolution had observable differences in lateral and longitudinal extent of potentially inundated areas. In addition, a new LaharZ-macro attempted to incorporate field data to simulate flow bulking of lahars along their downstream path, changing the volume and output areal extent. In this example, using simple cross-section measurements and deposit volume calculations, the algorithm attempts to emulate progressive total erosion of existing lahar deposits along the valleys. Estimated sediment bulk volume is  $< 0.79 \times 10^6 \text{ m}^3$  and thus too small to result in change inundated cross-sectional and planimetric areas in well-confined drainage segments. However, these changes increase lateral spreading in less confined segments and runout distance. Such field observations may improve model outputs as well as interpretation of those outputs.

\*\*\*\*\*

## Innovative Modelling Techniques to Upscale Novel Field and Laboratory Estimates of Soil Erosion

WAINWRIGHT J.(1), PARSONS A.J.(2), COOPER J.R.(3), LONG E.J.(4), HARGRAVE G.(4), KITCHENER B.(2), HEWETT C.(1), ONDA Y.(5), FURUKAWA T.(5), OBANA E.(5), HAYASHI H.(5), NOGUCHI T.(5), PATIN J.(5)

*(1) Durham University, DURHAM, UNITED KINGDOM ; (2) University of Sheffield, SHEFFIELD, UNITED KINGDOM ; (3) University of Liverpool, LIVERPOOL, UNITED KINGDOM ; (4) Loughborough University, LOUGHBOROUGH, UNITED KINGDOM ; (5) University of Tsukuba, TSUKUBA, JAPAN*

Erosion is a particle-based phenomenon, yet most current understanding and modelling of this process is based on bulk measurements rather than the movement of individual particles. Difficulties with measuring particle motions in dynamically changing conditions are being overcome with the application of two new technologies – particle imaging velocimetry (PIV) and radio frequency identification (RFID). It is thus possible to evaluate the entrainment, transport and deposition of individual particles

Both PIV and RFID tagging have been used in laboratory experiments to evaluate the detachment process by raindrops on bare surfaces and in shallow flows using rainfall simulation. The results suggest that the processes are more complex than hitherto thought with multiple detachment and transfer mechanisms. Because both mechanisms affect travel distance, they affect the ways in which estimates of soil erosion can be scaled from plot to hillslope and catchment scales. To evaluate movements at larger scales, we have also used RFID-tagged particles in field settings to look at sediment transfers following the Fukushima accident in Japan, 2011.

A marker-in-cell model (MAHLERAN-MiC) has been developed to enable the laboratory results to be upscaled and tested in a field setting. Markers (representing sediment particles), are initially distributed on a cellular grid. A cellular model is used to set up the boundary conditions and determine the hydrology and hydraulics on the hillslope. The markers are then moved through the grid according to these properties. This technique combines the advantages of Eulerian and Lagrangian methods while avoiding the shortcomings of each (computational efficiency vs. accuracy). We demonstrate how distributions of travel distances change as spatial and temporal scales of application change, and thereby how the laboratory and field experiments can be best used to develop more robust approaches to the upscaling of estimates of erosion rates.

### **Robust interpolation techniques for estimating suspended sediment yields in logged catchments, south-central Chile**

MOHR C., ZIMMERMANN A., FRANCKE T., KORUP O., BRONSTERT A.  
*University of Potsdam, POTSDAM, GERMANY*

Most estimates of suspended sediment yields rely on time series of both streamflow discharge and sediment concentrations (SSC). The step from discrete measurements to continuous time series, though, remains tricky and often complicates quantitative estimates of sediment transport. To this end either physics-based modelling or statistical interpolation comes into play. Both approaches, however, may be limited under disturbances such as land-use changes or environmental boundary conditions that otherwise change during the observation period: Recent research has amplified on effects of timber harvest or rare events such as rainstorms, wildfires, and earthquakes that may temporarily boost sediment dynamics. This implies that a robust quantification of soil erosion is critical in order to assess the impact of clear-cutting unbiased from such disturbances which in turn permits a firm basis for management recommendations.

Here we estimate sediment yields of catchments of similar size (~10 ha) under different forestry use in the Chilean Coastal Range using Quantile Regression Forests (QRF). QRF is a non-parametric regression technique that combines bootstrap aggregating with random variable selection. We calculated (annual) sediment yields and their uncertainties of a control catchment and two adjacent catchments of which one was clear cut during the rainy season while the other was harvested during the dry period. We then compared the results obtained with previous results based on physics-based modelling (WASA-Sed) and simple discharge-SSC-relationships.

Our findings show that QRF models may be a promising tool to estimate sediment yields under disturbed conditions such as clear-cuttings. Ultimately, our study suggests that conventional approaches employing physics-based modelling or simple regression approaches, i.e. sediment rating curves, may be prone to bias in disturbed environments dominated by hysteresis effects between streamflow and suspended sediment discharge.

\*\*\*\*\*

### **A Conceptual Understanding of Sedimentation in South African Catchments by a Sediment Flow Model**

BRYSON L., HUGHES D.A., ROWNTREE K.M.  
*Rhodes University, GRAHAMSTOWN, SOUTH AFRICA*

Increased sediment concentrations in rivers and sedimentation in reservoirs have been creating significant implications on land and water resources in South Africa. An understanding of the physical processes that determine sediment dynamics in semi-arid catchments is needed if erosion management is to succeed. Reliable sediment yield predictions are a useful tool for understanding and can be obtained by using a sediment model. There are a variety of models available, but issues such as scale, limited understanding of sediment dynamics and increased complexity limit application. What is needed in South Africa is a simple sediment model that can work in data poor environments and be representative of the landscape.

Probability distribution theory allows for a simple semi-distributed model which can be incorporated into a geographic information system (GIS). An erosion hazard probability distribution function (PDF) would be developed by incorporating PDFs of the erosion factors soil, vegetation and topography. This can be considered the sediment availability, whilst sediment production relies on rainfall. A modification of the Pitman rainfall-runoff model would provide daily and monthly runoff outputs to be incorporated with the erosion hazard distribution to determine sediment production. The addition of a storage component is also necessary as not all sediment produced reaches the catchment outlet. The end result of this model would be a conceptualisation of sediment dynamics that can be easily understood and be representative of a semi-arid catchment.

The timing and pattern of sediment movement in response to rainfall events are important in semi-arid regions such as South Africa where erosive events usually occur as the result of high-intensity, short-duration storms. This new sediment model provides a simple conceptualisation of sediment dynamics that has become increasingly necessary in a changing environment.

## Evaluating landscape evolution models with object-based landform classifications

ANDERS N.(1), SEIJMONSBERGEN H.(2), BOUTEN W.(2)

(1) Wageningen University, WAGENINGEN, NETHERLANDS ; (2) Institute for Biodiversity and Ecosystem Dynamics, University of Amsterdam, AMSTERDAM, NETHERLANDS

Dynamic landscape evolution models are recognized means for increasing the understanding of geomorphological processes and their impact on the environment over time. Evaluating model results remains, however, a challenge. We suggest integrating landform classifications with dynamic landscape evolution models to visualize and evaluate model dynamics. We introduce a modular erosion/sedimentation model to simulate post-glacial landscape development in a small alpine catchment. This model comprises three different modules, in which each module different geomorphological processes are described, namely the 1) mechanical weathering of bedrock and production, transportation and deposition of debris through rock fall, 2) fluvial erosion of converging water streams by incision into bedrock, and 3) redistribution of unconsolidated materials through superficial flow/slide processes. Model results are visualized with object-based landform classifications to interpret the dynamics of the model. The segmentation and classification procedure is applied at several time steps of simulated landscape evolution and clearly shows the development of fluvial erosion channels which accelerates mechanical weathering and rock fall. The classifications allow the analysis of simulated topographic change per landform type and reveal a transition from a glacial towards a fluvial landscape in a quantitative fashion. We concluded that categorizing landscape objects into functional landforms enables a quick but detailed overview of simulation results and model behavior. Using landform classifications we partly automated the interpretation which allows the investigation of the change of the functioning of a landscape during a simulation. Integrating landform classifications in landscape evolution modeling opens up new opportunities for e.g. evaluating complex dynamics in landscape evolution models, or analyzing scenario-based landscape development and specific landform evolution.

\*\*\*\*\*

## Gully Development Assessment with Google Earth, GIS and Statistics

QUENEHERVE G.(1), MÄRKER M.(1), ZAKERINEJAD R.(2)

(1) Heidelberg Academy of Sciences and Humanities, TUEBINGEN, GERMANY ; (2) Tübingen University, TUEBINGEN, GERMANY

In this study, we estimated the usefulness of Google Earth in order to map the different kinds of gully systems appearing in the study area of Northern Tanzania (linear, dendritic, anastomosing, and ephemeral gullies) and to distinguish with the help of Geographic Information Systems (GIS) old (inactive systems) from young (active systems) ones. Old gully systems are characterised as well developed and prolonged within their according watershed.

As previous studies stated (McInnes *et al.*, 2011), the use of Google Earth for the estimation of gully systems are in particularly useful where old, well developed gully systems are prevalent. As the Makuyuni River catchment is located in an area that suggests no or only very minor faulting prior to ~1 Ma (Ring *et al.* 2005), there are good reasons to estimate the age of a high number of existing gullies as old. Google Earth provides images at no costs for the detection of gully systems. For the whole of the Makuyuni River catchment (~3000 km<sup>2</sup>) gullies have been identified via Google Earth.

The delineations of the gullies have been supported and validated by auxiliary field studies for a part of the catchment. Additionally, we processed a WorldView-2 scene (~170 km<sup>2</sup>) with 2m panchromatic resolution as well as aerial photographs from the 1980s, both datasets covering the field work area, to countercheck the accuracy.

To distinguish between gully and streambank erosion, we defined streams as drainage lines of third or greater Strahler order (Strahler, 1952). To assess the gully evolution, we used the gully development concept proposed by Kosov *et al.* in 1978. As basis for the Digital Elevation Model (DEM), we used SRTM 30m data. A Maximum Entropy analysis (Phillips *et al.* 2006) validated our results with a training dataset for the whole of the catchment.

### **Methodological comparative assessment of the landslide susceptibility - case study: The Niraj River Basin (Transylvania depression, Romania)**

*ROSCA S.M., PETREA D., IRIMUS I.A., SURDEANU V.  
Babes Bolyai University, Faculty of Geography, CLUJ NAPOCA, ROMANIA*

The importance of hazard and risk mapping is unanimously recognized in the last decades due to the fact they provide extremely useful information within the frame of hazardous events prevention and the related planning decisions adoption. Unfortunately, depending on the quantity and especially on the quality of the data used in the analysis, as well as by the large variety of the quantitative and qualitative applied methods, the evaluation proceedings became heterogeneous, difficult and implicitly ambiguous. The main objective of the present study is to evaluate the landslide susceptibility for an area of 658 km<sup>2</sup> according to Romanian Governmental Decision No. 447/2003, by estimating the importance of each class of the eight factors involved: lithology, geomorphology, structure, hydro-climatic factors, hydrogeology, seismicity, forestry and anthropogenic factor. Each thematic map was built up and analyzed and after that for each factor influencing slope instability a specific coefficient was given according to the methodology and thus the average coefficient hazard was calculated. The case-study discussed here concerns the Niraj basin area that can be considered representative for the NE of Transylvanian Depression from different points of view: similar slope, aspect, average curvature, land-use, vegetation and lithology. Specifically, statistical model based on the bivariate probability analysis was applied to predict the spatial distribution by estimating the probability of landslide occurrence. In order to validate the model, the resulting maps were compared with the existing landslides identified by field research trips, topographic maps scale 1:25000 and SPOT 5 satellite images and calculate the percentage of landslides within each hazard map. The validations show that 98,7% of the landslides mapped are included in the high susceptibility (obtained by statistical approach), versus 89,7% (obtained by semi-quantitative approach).

\*\*\*\*\*

### **Modeling debris flow erosion in Alpine Holocene debris fans: application to the Spreitgraben catchment, Switzerland**

*FRANK F.(1), MCARDELL B.(1), DEUBELBEISS Y.(1), HUGGEL C.(2), KULL I.(3)  
(1) Swiss Federal Research Institute WSL, BIRMENSCHDORF, SWITZERLAND ; (2) Department of Geography, University of Zurich UZH, ZÜRICH, SWITZERLAND ; (3) Geotest AG, ZOLLIKOFEN, SWITZERLAND*

Debris fans are characteristic Alpine landforms constructed by some combination of modern, historical, or Holocene mass movements including rockfall, rock avalanches and debris flows. The geometry of debris-flow-dominated fans and their sediment deposits depend on the magnitude and frequency of the debris flows: relatively small and frequent debris flows (1000's of m<sup>3</sup> per event) are expected to produce generally steeper landforms than larger but much less frequent debris flows (on the order of 10<sup>4</sup> to a few 10<sup>5</sup> m<sup>3</sup> per event). The sudden onset of large and erosive debris flows has been observed recently in different catchments in Switzerland.

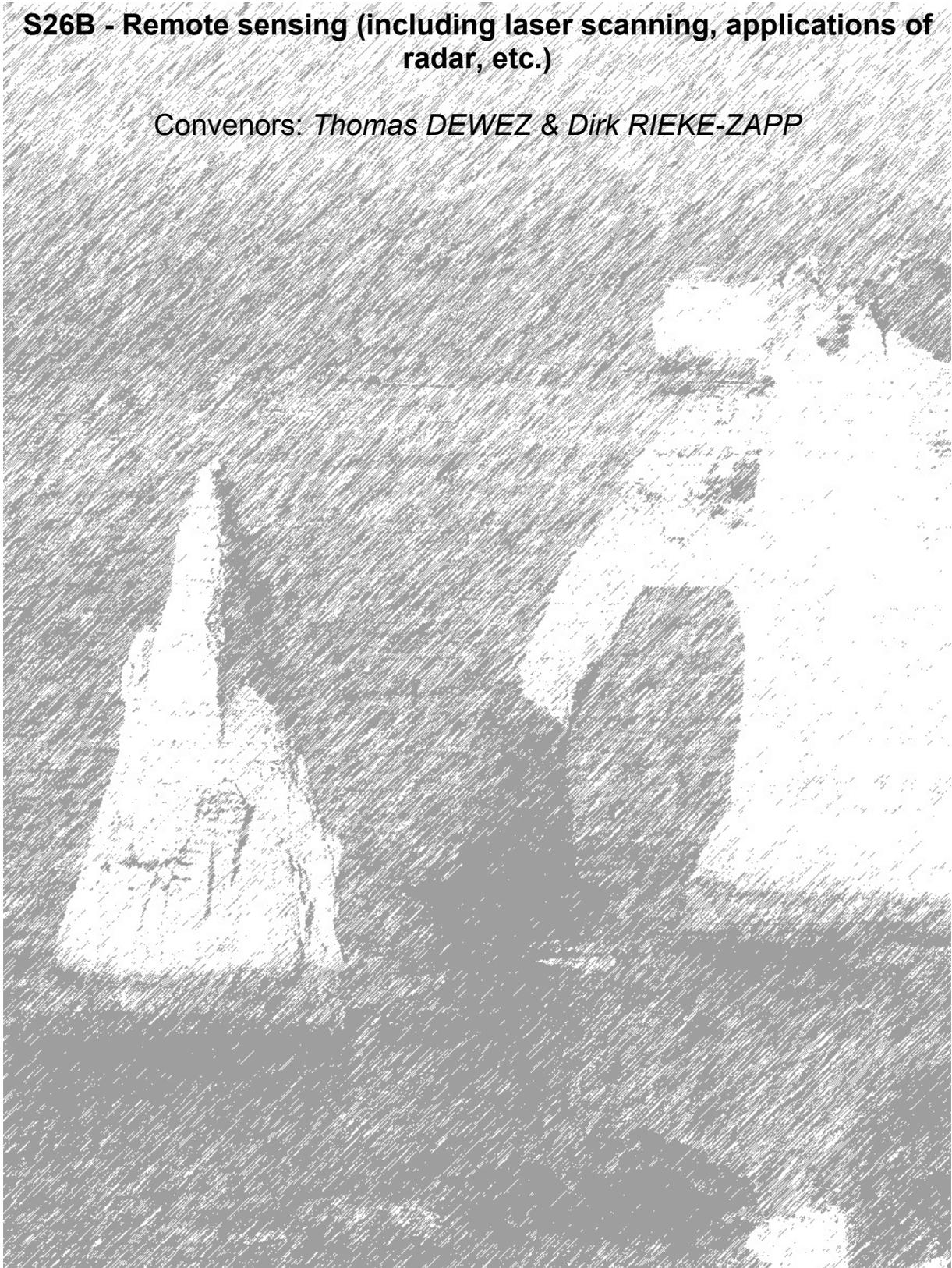
In the Spreitgraben catchment (Canton Bern, Switzerland; catchment area 4 km<sup>2</sup>) e.g. there has been a massive increase of the frequency of large debris flows. The cumulative magnitude of channel erosion since 2009 is on the order of several 10's of meters for certain channel sections. Consequently the banks have become over-steepened and there is significant channel widening, too.

Here we describe our attempts to interpret the erosion produced by debris flows using a debris flow runoff model. The RAMMS debris flow model solves the 2D shallow water equations of motion for granular flows, and it includes either the Voellmy friction relation (VF) or a modified version of the Voellmy relation (MVF) where the friction coefficients are adjusted as a function of the internal random kinetic energy due to particle collisions within the flowing mass. A corresponding erosion model is based on generalization of field data (maximum shear stress, with the VF relation) or proportional to the granular temperature of the flow (MVF relation). While the granular temperature-based erosion model contains a more physically realistic description of the erosion process, the VF relation, after calibration, also produces plausible results and may be more useful for practical applications until we gain more experience with the MVF-based erosion algorithm.



**S26B - Remote sensing (including laser scanning, applications of radar, etc.)**

Convenors: *Thomas DEWEZ & Dirk RIEKE-ZAPP*





## **Oral presentations:**

### **Differential SAR Interferometry in alpine geomorphology: Potential of this high precision technology for detecting and surveying landforms in mountain environment**

*BARBOUX C.(1), DELALOYE R.(1), LAMBIEL C.(2), STROZZI T.(3), COLLET C.(1), RAETZO H.(4)*

*(1) Dept. of Geosciences, Geography, University of Fribourg, FRIBOURG, SWITZERLAND ; (2) Institute of geography, University of Lausanne, LAUSANNE, SWITZERLAND ; (3) Gamma Remote Sensing, GÜMLIGEN, SWITZERLAND ; (4) Federal Office for the Environment FOEN, BERN, SWITZERLAND*

A large spectrum of mass wasting processes (e.g. deep-seated and shallow landslides, rock glaciers, debris-covered glaciers) are actively changing the surface topography of alpine mountain slopes over time. The rate of motion is typically ranging from millimeter to several meters per year. In the general context of investigating the cascading of sediment along mountain slopes, the use of Differential SAR Interferometry (DInSAR) has proven to be a valuable tool for detecting (recognition, identification) and surveying (monitoring) various types of slope motion phenomena at both local and regional scales.

This presentation will review DInSAR for detecting and surveying movement on mountain slope in an Alpine environment. After a brief presentation of basics, the use of the DInSAR technique for the detection and surveying of landforms surface deformation will be described. Through different examples, the presentation aims to suggest to geomorphologists different means of understanding and interpreting DInSAR signals in the specific environment. Actually, the capability of DInSAR for detecting both the location of moving zones and the magnitude of their displacement rate has been successfully tested in various regions of the Swiss Alps. Research challenges are now mainly focusing on the possibilities of using DInSAR for monitoring tasks to evaluate to which level DInSAR data could be used independently of field measurement. Thus, the presentation will overview some DInSAR projects dealing with the detection and the survey of moving zones in the Swiss Alpine periglacial belt allowing to show potential applications of this modern technique in mountain environment. Finally, requirements of the DInSAR technology will be discussed in order to show how this technique is really valuable for alpine geomorphology investigations, and perspectives for further applications will be suggested.

\*\*\*\*\*

### **Sea cliff erosion monitoring by boat-borne Laser-scanning**

*GIULIANO J.(1), DEWEZ T.(2), GODARD V.(3), LÉBOURG T.(4), MARCOT N.(5)*

*(1) BRGM / GEOAZUR / CEREGE, AIX EN PROVENCE, FRANCE ; (2) BRGM, ORLEANS LA SOURCE, FRANCE ; (3) CEREGE - Université Aix Marseille, AIX EN PROVENCE, FRANCE ; (4) GEOAZUR - Université Nice Sophia Antipolis, SOPHIA ANTIPOLIS, FRANCE ; (5) BRGM, MARSEILLE, FRANCE*

Laser scanning is an efficient method for cliff erosion monitoring, but available terrestrial or airborne systems are limited by particular constraints associated with the configuration of the coastline, as tidal range or cliffs slope. We need to qualify rock fall hazard in Carry Le Rouet (West of Marseille, Southeastern France) which is motivated by the high level of risk due to dense settlement. But, as along the 3.5-km-long coastline there is no suitable platform to set up a terrestrial scanner, we study cliff evolution by repeated boat-borne scanner surveys from the sea.

We discuss the performance of three subcontracted boat-borne scanner surveys of the cliff in February 2011, November 2011 and July 2012. The typical point spacing in the clouds is 5-10 cm. Initial results suggests that (i) delivered device position and altitude still contains location inaccuracies around 4.3 cm, (ii) the repeatability of measurements are within 5 cm, (iii) comparison between clouds needs careful co-registration at post-processing stage.

First comparison of results between February and November 2011 indicates that the total eroded cliff volume amounts to 20-30 cubic meters, for a total cliff surface of 36,000 square meters, which is equivalent to an erosion rate of 1 mm/yr. The erosion involves various processes ranging from gravitational collapse to gully erosion. Thus, boat laser survey appears to be a suitable tool for the study of coastal morphology and topographic change in previously inaccessible settings.

Keywords: laser scanning; boat borne scanner; cliff; erosion; coastal morphology; topographic change

## **Airborne laser scanning of forested rock extraction: Airborne parameterizations, quality assessment, and rockfall modeling**

RAZAK K.(1), QUAN LUNA B.(2)

(1) *University Teknologi Malaysia, KUALA LUMPUR, MALAYSIA* ; (2) *NGI, Norwegian Geotechnical Institute, ICG, International Centre for Geohazards, OSLO, NORWAY*

Modern remote sensing based approach has revolutionized the rockfall hazard and risk assessment. It enables the parameterization of topography, and natural barriers (e.g. vegetation) in a forested environment. The extraction of rock blocks under forests and their characteristics still remains difficult because of deficiency of high resolution geospatial data, e.g. insufficient number of airborne laser scanning (ALS) points and lack of reliable field data. The performance of ALS data for measuring and assessing the geomorphology, geological settings, structural discontinuities and mechanical characteristics of slopes and rock blocks is poorly investigated.

This research demonstrates the capabilities of high density ALS (HDALS) data: i) to map rock blocks beneath forest and characterize rockfall parameters, ii) to determine the rockfall trajectory and simulate the physical process of rockfall based on HDALS-derived rockfall parameters. A very high density ALS data was utilized, with a point density of 170 points m<sup>-2</sup> in the Barcelonnette region, the Southern French Alps, and supported by field evidences and historical forest reports.

We revealed airborne parameterization based on the hierarchical robust interpolation algorithm for extracting rock blocks under forest and quantified them. Very high resolution digital terrain and surface models from HDALS data were generated. HDALS data were used to extract forest attributes and 12 surface roughness values computed at different lithology units and landcover classes.

The rockfall trajectory was determined and its physical process was simulated solely based on HDALS product using Rockyfor3D. Spatial modeling was performed using Rockfall Analyst to compute the travel distance, velocity and energy of rockfalls. The results were compared with the output generated from a coarse data. We also critically addressed the numbers of limitations of the methods and highlighted research challenges.

\*\*\*\*\*

## **Predicting Rock-Movements by Interferometric Radar Measurements**

TOBLER D.(1), MEIER L.(1), GRAF K.(2)

(1) *Geopraevent SA, ZUERICH, SWITZERLAND* ; (2) *GEOTEST SA, ZOLLIKOFEN, SWITZERLAND*

During the last decade, advances in science and technology have improved the potential of early warning systems (EWS) to reduce human loss from natural hazards. Effective EWSs are widely recognized as good practice if evidence-based and people-centred, thereby empowering individuals and communities to take timely and appropriate preventive measures to reduce the possibility of injury, loss of life and damage to property and environment. EWS shall be reliable, redundant, low-maintenance and provide a high probability of detection. As climate change is likely to produce more extreme climate events, EWSs will become more important elements of public safety.

In May 2012 a large rockfall (volume of 300'000 m<sup>3</sup>) occurred, close to the village of Preonzo in southern Switzerland. The outcrop area, located 1000 m above the industrial park of the village, has been known as instable for long time. Since many years, the local authorities have monitored the instable rock mass using crackmeters and laser-based geodetic measurements. Prior to the event, an interferometric, synthetic aperture radar system has been installed to monitor the moving rockwall before, during and after the collapse.

The main advantage of a ground-based radar monitoring systems is the possibility to perform a permanent quasi real-time monitoring, independent of weather conditions. Furthermore, it allows the acquisition of information on the displacement over the entire observed area, without needing in-situ instrumentation on potentially instable and fast-moving elements. The detailed deformation history retrieved from interferometric radar observations is important when setting alerting procedures and alarm thresholds for EWS.

The presentation emphasises on measurements as well as advantages and disadvantages of radar-based monitoring of instable rock slopes. Furthermore, different strategies and methods for EWSs of rapid mass movements for an efficient emergency management will be presented and discussed.

## **The application of UAV's for high-precision glacial, periglacial and hydrological monitoring**

MOORMAN B.(1), WHITEHEAD K.(1), HUGENHOLTZ C.(2)

(1) University of Calgary, CALGARY, CANADA ; (2) University of Lethbridge, LETHBRIDGE, CANADA

With the recent advances in Unmanned Aerial Vehicles (UAV's), there are new opportunities to make geomorphological measurements at both temporal and spatial scales much greater than has been available to date.

Through the use of UAV airplanes and helicopters we have been able to collect remotely sensed imagery with sub-centimeter resolution, covering in the order of 10 square kilometers in less than 1 hour with great ease and at low cost. This has enabled rapid photogrammetric mapping of glacier and periglacial terrain and resulting in digital elevation models comparable to those generated by LIDAR at less than a tenth of the cost. As well, because the systems are very portable and simple to use, repeat surveys can be conducted up to several times a day to quantify rapid processes (such as hydrologic fluctuations).

These new opportunities are being made possible by a convergence of a number of advances in, UAV lift capacity, battery life, GPS technology, autopilot flight control systems and mission planning software. While airplanes offer rapid data acquisition, we have now developed helicopter based system as it offers the ability to fly lower and slower for extremely high resolution imagery. Through the use of a real-time point of view camera, the helicopter also offers the ability to interrupt a preprogrammed flight path to investigate areas of interest in greater detail.

The flexibility of these platforms offer the opportunity to rapidly interchange different sensors such as, visible, NDVI and thermal cameras or more advanced sensors such as LIDARs and radars.

\*\*\*\*\*

## **Rockglacier movement detection by D-InSAR in French Alps using ERS archive data and TerraSAR-X data**

ECHELARD T.(1), KRYSIECKI J.M.(1), SCHOENEICH P.(1), GAY M.(2)

(1) Grenoble University, Institute of Alpine Geography, GRENOBLE, FRANCE ; (2) GIPSA-Lab, GRENOBLE, FRANCE

Interferometric Synthetic Aperture Radar (InSAR) is a method of measurement based on the phase difference between two radar images, which represent the same area but at different time intervals. The technique generates interferograms, maps of surface deformation in two-dimensions allowing for the detection and quantification (in centimeters) of variations in distance between the target and the radar between two different data acquisitions. Recent research has shown that the InSAR technique can be used to quantify rockglacier deformation (under the assumption that certain conditions are respected with regard to generating and interpreting the interferograms).

ERS radar images (dating from 1991 to 1995) were obtained in courtesy of ESA with the aim of generating interferograms. In this study, we are interested by the detection of rockglacier movements in all the French Alps. We selected all ERS archive data and chose the more relevant of them. Finally more than 20 interferograms were generated. To analyse this amount of data two methods were employed : i) a GIS analysis of interferograms (helped by orthophotography and topographic data) by geomorphologists, ii) a comparison between interferograms and existing rockglaciers shape inventory to evaluate the quality of the radar detections. At the end of the analysis a map of the French Alps with all detected rockglacier movements was produced.

Another part of the present study uses TerraSAR-X data (in courtesy of DLR) on a local scale and tries to compare different kind of methods to detect and quantify rockglacier movements. Analyses focused on the Vanoise massif in the French Alps. We used and compared three different methods with brand new data from summer 2012 : i) differential SAR interferometry, ii) texture tracking and iii) permanent scatterers. Three continuous GPS were installed on rockglaciers during summer 2012 to compare radar data and GPS field data.

### **Time-lapse stereo-photogrammetric monitoring of volcanic slopes**

DEWEZ T.(1), MOSER S.(2)

(1) BRGM - French Geological Survey, ORLEANS LA SOURCE, FRANCE ; (2) ., STRABOURG, FRANCE

Piton de la Fournaise volcano (La Reunion Island) due to its crater collapse of April 2007 which created 200m to 300-m-high sub-vertical cliffs in a matter of minutes offers a rare opportunity to observe the morphological fingerprint of numerous rock avalanches. In the framework of ANR-Undervolc, a research project funded by the French Research Council to investigate geophysical determinants of volcano construction and destruction, a pair of time lapse photogrammetric packages was deployed along the active crater edge in October 2009. In this talk, we will discuss the qualitative and quantitative benefits and short-comings of time lapse stereo monitoring based on an hourly photo sequences captured between 28 December 2009 and 15 April 2010. In short, time synchronization between cameras must be guaranteed in order to capture the space and time location of detected objects, failure to do so results in erroneous instantaneous 3D locations. Synchronization requirement depends on the velocity of the monitored object. Visual change detection, by compiling movies from still shots, is hampered by the changing illumination of the scene throughout the day. To lessen its impact, we recommend making movies at constant time of day when the sun angle changes only on a slower seasonal time scale. For quantitative change detection, the stereoscopic capabilities of the camera setup enabled automated extraction of hundreds of Digital Surface Models (DSM). This was achieved by generating Photomodeler Scanner instruction from Matlab, though the so-called Dynamic Data Exchange (DDE) protocol. Three cases were investigated: DSM sequences of rock avalanche corridors, rockfall scar detection and eruption volume quantification. The volume of January 2010 volcanic eruption came out to  $1\,597\,200 \pm 95\,660 \text{ m}^3$ , i.e. a relative precision of 6%. Time-lapse stereo photogrammetry holds promises for in-situ geomorphological monitoring despite a few creases still needing ironing out.

\*\*\*\*\*

### **Continuous tracking of objects for characterizing landslide displacements from terrestrial images**

GANCE J.(1), MALET J.P.(1), DEWEZ T.(2), TRAVELLETTI J.(3)

(1) Institut de Physique du Globe de Strasbourg, STRASBOURG CEDEX, FRANCE ; (2) BRGM, ORLÉANS, FRANCE ; (3) BEG - Bureau d'Etudes Géologiques, APROZ, SWITZERLAND

Very high resolution terrestrial images can provide highly detailed observations over long periods. Such type of device is well adapted to monitor landslides characterized by large displacements (a few meters per year) because the cameras are installed out of the moving areas (contrary to total station, dGPS or extensometer surveys) and allows to infer spatially distributed information.

This work aims to present a methodology to characterize landslide displacements from very high resolution terrestrial images. The method is based on object detection-tracking and is applied on two images datasets acquired at the Super-Sauze landslide (French Alps).

The analysis of the first serie of images consists in the tracking of white Styrofoam spheres (e.g. benchmarks) regularly positioned on a profile in the most active part of the landslide. Pairs of images with a baseline of ca. 75 m and a B/h ratio ranging between 1.6 and 2.1 are used. The displacements observed over the period June-July 2011 range from 0.5 to 0.7m.

The analysis of the second serie of images consists in the monitoring of natural objects observed at the surface of the landslide, such as large blocks. Images taken from one single camera located at the toe of the landslide are used. The displacements observed in the image plane are projected in the ground coordinate system using a pinhole model. The results obtained for both applications are validated with dGPS observations (campaigns and continuous monitoring) and image correlation techniques.

A sensibility analysis is performed in order to characterize the robustness of the method and define the different sources of error. The displacement time series are further analyzed in terms of kinematics (velocity vs. acceleration) using "time to failure" approaches.

## High-resolution quantification of mountain permafrost displacements: insights from Terrestrial Laser Scanning and image correlation techniques

*BODIN X.(1), DEROUX B.(1), VACHER P.(2), THIBERT E.(3)*

*(1) Laboratoire EDYTEM, UMR 5204 CNRS / Université de Savoie, LE BOURGET-DU-LAC, FRANCE ; (2) Laboratoire SYMME, EA 4144, Polytech Annecy-Chambery, Université de Savoie, ANNECY-LE-VIEUX, FRANCE ; (3) Unite de recherche ETNA, IRSTEA, SAINT MARTIN D'HÈRES, FRANCE*

In the context of climate change, mountain permafrost is affected by a pluri-decadal warming that has strong implications in terms of slope stability and dynamics. Permafrost degradation is well exemplified by recent acceleration and destabilization of rock glaciers, suggesting that potentially catastrophic phenomena may threaten societies. Therefore, it is necessary to better understand the deformation mechanisms of ice-rich permafrost along mountain slopes.

In this sense, this study aims at using Terrestrial Laser Scanning (TLS) to accurately quantify surface deformation of rock glaciers at an interannual and pluri-annual scale. We focused on the Laurichard rock glacier (Hautes Alpes, France, □ 2500 m asl) which is already subjected to an annual geodetic survey since more than twenty years. The surface of the rock glacier was scanned three times with an average density of 7 points/m<sup>2</sup> and referenced using DGPS-measured fixed points.

The main challenges arose from the topographic variability: microtopographic features like plurimetric ridges and furrows shield some areas from the laser, whereas surface roughness of the pluri-decimeter coarse blocky cover is difficult to cope with when comparing point-clouds between each others.

We employed 3D point-cloud processing and image correlation tools to i) adjust separately annual scenes, ii) georeference them, iii) compare 3D-datasets together with a sub-decimeter precision and iv) extract various spatially-distributed measurements.

High resolution maps of surface kinematics quantities were validated from comparison to in situ high precision geodetic measurements: at the various considered time scales, the differences between TLS-derived measurements and geodetics measurements are lower than 5 cm/a. The spatially-distributed information provides rich insights into the deformation mechanisms of rock glaciers and open new challenging opportunities to move further into rheological laws and physical models.

\*\*\*\*\*

## Change detection of river channel utilising laser scanning, sonar survey and UAV-photogrammetry based bathymetric model

*ALHO P.(1), KASVI E.(1), VAAJA M.(2), FLENER C.(1), LOTSARI E.(1), KUKKO A.(3), KAARTINEN H.(3), HYYPPÄ J.(3), HYYPPÄ H.(4)*

*(1) University of Turku, TURKU, FINLAND ; (2) Aalto University, ESPOO, FINLAND ; (3) Finnish Geodetic Institute, KIRKKONUMMI, FINLAND ; (4) Metropolia, Univ. of Applied Science, ESPOO, FINLAND*

Field measurements for the acquisition of digital terrain models (DTMs) based on traditional approaches (e.g. tachymeter, GPS) are limited in riverine environment because steep riverbanks, curved point bars and dense vegetation create occluded areas on the sight of survey. Airborne laser scanning (ALS) has been applied for more detailed modeling of the riverine environment. Terrestrial laser scanning (TLS) is a more accurate approach than ALS for gathering topographical data, e.g. TLS-based DTMs have been employed in measuring landslide bodies, defining the influences of earthquakes, as well as in riverine change detection. Although TLS allows the collection of data at a higher resolution and accuracy than ALS at a lower cost, its areal coverage is considerably more restricted. This limitation can be improved using laser scanning from a mobile platform (MLS). In this paper, we demonstrate multi-temporal TLS and MLS approaches in change detection of the point bars and riverbanks. We gathered high-resolution aerial photography using a camera embarked on a low-flying unmanned aerial vehicle (UAV). We utilised spectrally based bathymetric modelling techniques based on the UAV images for riverbed. Based on this bathymetry and laser scanned point clouds, we created a high-resolution seamless DTM of a sandy-bed river. We also analysed how the flow characteristics of different stages affect to the morphological changes on river channel and point bars. Therefore, we measured the three-dimensional flow field of the channel using an Acoustic Doppler Current Profiler (ADCP) at different flow stages. Subsequently, we analysed fluvio-morphological changes on point bars and riverbanks based on multi-temporal DTMs of MLS and TLS. The associated ADCP measurements of the 3-D flow structure over the flow regime makes it possible to link the morphological changes to the flow field of the river channel.

### **Identification of factors disrupting remote bathymetry: experimental approach from ground imagery on the lower ain river (France)**

BENACCHIO V.(1), PIEGAY H.(2), MICHEL K.(3), VAUDOR L.(3)

(1) Université de Lyon, UMR 5600 - EVS, Université Lumière Lyon 2, LYON, FRANCE ; (2) CNRS UMR 5600 - EVS, LYON, FRANCE ; (3) Université de Lyon, UMR 5600 - EVS, ENS de Lyon, LYON, FRANCE

Airborne imagery was used to calculate bathymetry of the lower Ain River, France, but such approach is not always efficient because image radiometry is not only related to water depth but to other factors such as the cover of biofilm, which is not always homogeneously distributed in space. The purpose of this work is to survey the various factors, including biofilm, which limit bathymetry mapping from remote sensing, to optimize time schedule for image acquisition. A Reconyx Hyperfire PC800 camera was used to take every quarter photos perpendicular to the water surface. A pressure sensor was set so as to link each picture to water level. The work area is about 12 m<sup>2</sup>. Effects of various factors on the channel bottom visibility, then the images radiometry were studied.

The maximum water depth for which we can distinguish the channel bottom is 1.74 m. Probability of seeing the bottom of the river – and so to be able to determine the bathymetry - is 80% for water depths lower than 1.50 m, which occurs here 35% of the time during the spring-summer period. Then it decreases quickly and becomes null for all depths greater than 1.80 m (41% of time). To demonstrate the impact of biofilm on the image radiometry and water depth detection, the studied area was brushed in part. Radiometric spectrum recorded greater local heterogeneity when the biofilm was removed. However, the radiometric mean is not changed, probably because the biofilm seems pretty chlorophyllous. The wind produces ripples on the water surface which is another factor of disruption. Time was also studied, as an incident angle of sunlight on the surface of water. For given sunlight angles, water depth cannot be detected because of reflections. The best conditions to take pictures correspond to early morning hours: before 9:00 am, it was 50% more likely to see the bottom of the river, while the probability decreases gradually until the end of the day. However, all hours of the day are potentially workable.

\*\*\*\*\*

### **Kite aerial photogrammetry system for monitoring coastal change in the Netherlands**

SMITH M.(1), PARON P.(2)

(1) Kingston University, KINGSTON UPON THAMES, UNITED KINGDOM ; (2) UNESCO-IHE, DELFT, NETHERLANDS

Coastal protection is one of the main challenges for the Netherlands, where a large proportion of anthropogenic activity is located below sea level (both residential and economic). The Dutch government is implementing an innovative method of coastal replenishment using natural waves and winds to relocate sand from the side to the other of the country. This requires close monitoring of the spatio-temporal evolution of beaches in order to correctly model the future direction and amount of sand movement. To do so -on the onshore beach- we tested a Kite-Aerial Photography System for monitoring the beach dynamics at Zandmotor (<http://www.dezandmotor.nl/en-GB/>).

The methodology follows that of Smith et al., (2009), applied to a highly dynamic environment with low texture and small relief conditions. The method used here consists of: 1) setting up the Kite Aerial Photography System (KAPS); 2) locating the ground targets (ground control points); 3) surveying the targets for their XYZ position; 4) flying the kite over the area acquiring stereopairs for the whole area; 5) post-processing of the photos and GPS points.

In this case study we used a commercial DSLR camera (Nikon D7000 with a 20mm lens), a gyro-levelled rig, Sutton flow form kite and Leica GNSS Viva GS10, with GSM connection to the Dutch geodetic network. We flew using a 115 m line with an average inclination of 40 to 45 degrees, giving a vertical distance of the camera of about 80 metres and pixel resolution of 36 mm. We present here the results of the system set-up and data post-processing, including both an image mosaic and a digital elevation model.

Future repeat flights using the same system are planned over a period of six months in order to capture the spatio-temporal variability of beach morphology due to natural and anthropogenic interference. The research has been funded by Deltares R&D and supported by the UNESCO-IHE.

## **Integration of LiDAR and optical remote sensing for the study of fluvial and anthropogenic landforms in the Brenta-Bacchiglione alluvial plain (NE Italy)**

*NINFO A., MOZZI P.*

*Department of Geosciences University of Padua, PADOVA, ITALY*

The geomorphological study of alluvial plains takes great advantage from the integration of detailed altimetry with high resolution images, especially in the lower relief sectors, like those in the distal plain of the Brenta and Bacchiglione rivers near the city of Padua (mean slope 0.4‰). The LiDAR data which were specifically acquired for this research (Riegl LMS-Q560; mean density 7 points/m<sup>2</sup>, over 123 km<sup>2</sup>), were classified and interpolated in order to map fluvial and anthropogenic landforms. The DEM (z accuracy <5-10 cm) was processed and analyzed in integration with high resolution oblique and vertical (VIS+IR) aerial images, acquired in specific seasonal time windows, to maximize the vegetation response (cropmarks) to soils, deposits, and palaeohydrographic features. A detailed field survey (hand augerings, soil profile description, deep borehole stratigraphy) was conducted to validate the remote sensing interpretations.

The detailed topography allows to individuate low rise interfluves and scarps (<1-2 m), paleochannels, scroll bars and crevasse splays. The reconstruction of the precise "ground" surface has allowed a better definition of the geometry of the multi-stratified archeological mound in the historical center of Padua.

Cropmarks result the most appropriate to complete the mapping of the numerous fluvial forms, that have no topographic relevance being smaller (i.e. minor crevasse channels and splays) and/or flattened by anthropic activity (mainly ploughing). LiDAR intensity permits a precise individuation of LGM deposits that have shown peculiar reflectivity related to specific soil characteristics (i.e., presence of calcic and argillic horizons).

At this scale (cell size <0.5-1 m) the real complexity of this highly anthropized low plain environment fully emerges. The results bring advances in the comprehension of the Holocene evolution of the Brenta-Bacchiglione plain, also in close relation to ancient settlements.

\*\*\*\*\*

## **The application of radar and optical remote sensing to analyse dune dynamics at the dune-field scale**

*DELGADO BLASCO J.(1), MOHAMED I.L.(2), VERSTRAETEN G.(2), HANSSSEN R.F.(3)*

*(1) Division of Geography, KU Leuven, Belgium & Geosciences and Remote Sensing, Delft University of Technology, The Netherlands, LEUVEN, BELGIUM ; (2) Division of Geography, KU Leuven, LEUVEN, BELGIUM ; (3) Department of Geoscience and Remote Sensing, Delft University of Technology, DELFT, NETHERLANDS*

The increasing availability of remote sensing data for larger regions have made it possible to study (less) inaccessible regions such as large desert dune fields. Contrary to the detailed study on individual dunes, this has also made it possible to study the dynamics of entire dune fields. Multi-temporal analysis of remote sensing data offers to the potential to quantify dune migrations rates and sand fluxes. However, dunes usually appear bright in optical images due to the high reflectivity of the sunlight towards the sensor that is produced on sand dunes. Hence, the delimitation of the shape of the dunes is often a major problem in applying optical data. Active remote sensing data, such as SAR, may provide a solution as sand bodies used to appear with a huge contrast within their environment, being able to differentiate much better than the optical images. In this study, barchan dunes in the South-Rayan dunefield (SRFD) in central Egypt were examined through multi-temporal Landsat imagery as well as Envisat ASAR SLC images. Both images were used to detect and delineate dune shape, and to calculate dune migration rates using the centroid algorithm. Pros and cons of both methods are discussed. The method used for extracting dunes' shape from radar imagery is easier, faster and requires minimum human interaction than their extraction from optical data. Average dune migration rates in the SRDF are in the order of 4 m per year and rates are consistent between optical and radar images.

## Geophysics and Remote Sensing Data for the Detection of Soil Texture Distribution

QU N. HERV. G.(1), MÄRKER M.(1), BACHOFER F.(2)

(1) Heidelberg Academy of Sciences and Humanities, TUEBINGEN, GERMANY ; (2) Tübingen University, TUEBINGEN, GERMANY

Our main objective was to automatically map soil texture distribution within the semi-arid environment of the Makuyuni River catchment. The study area is located in the eastern branch of the East African Rift System and the environment is distinguished by a variety of degradation as well as erosion processes due to the long dry periods and short but intensive rainfall events.

Since field work is time assuming and expensive we propose a methodology which is integrating geophysics together with terrain analysis based on Digital Elevation Model (DEM) as well as multi-spectral remotely sensed data.

Geophysical methods such as electromagnetic induction (EMI), to measure the soil's apparent electric conductivity ( $EC_a$ ), provide a quantitative assessment of soil properties. In non-saline soils conductivity variations are primarily a function of soil texture. Such a methodology is able to distinguish between predominant sand, silt and clay fractions.

The DEM is based on a SRTM 30m satellite image and 16 primary and secondary topographic attributes have been calculated according to Hengl & Reuter (2009) and Wilson & Gallant (2000). Multi-spectral data derivatives have been gained of an ASTER L1B scene with 15m to 90m ground resolution according to their spectral channel. 34 different band combinations have been computed according to the standard ASTER enhancements products (after Kalinowski & Oliver, 2004).

A TreeNet™ [Salford Systems, USA] analysis has been carried out, to validate the gained information. The classified conductivities are the target variables and the 50 satellite-based attributes are the predictor variables. This approach, a stochastic gradient boosting method (developed by Friedman, 2002), is able to rank the predictors for each target variable according to their relative importance. This information is now used, to compute the according conductivity class for the whole of the available SRTM/ASTER scenes extent.

\*\*\*\*\*

## Estimation of Surface Runoff for an Urbanized Watershed Using Satellite Data: A Case Study of Ramnadi Basin, Maharashtra, India

DHORDE A.(1), DHORDE A.(2), KUMAR K.(2)

(1) Department of Geography, University of Pune, PUNE, INDIA ; (2) Department of Geography, Nowrosjee Wadia College,, PUNE, INDIA

The present work deals with the estimation of surface runoff in an urbanized watershed of Ramnadi, a tributary of river Mula in Maharashtra, using Landsat TM data of 1989 and 2011. Population calibrated impervious surfaces (IS) were extracted for the watershed by employing a regression analysis wherein IS was thought to be the function of band values, NDVI, TC band II, slope, elevation and population density. Runoff, seen as a function of imperviousness in the area, has been calculated using the SCS-CN method. Curve numbers (CN) were obtained from the standard tables provided in the National Engineering Handbook-4 (NEH-4) published by the USDA, USA. These were derived basically by analyzing the land use land cover pattern, hydrological soil group and condition for the entire Ramnadi basin. In order to compute the surface runoff these CN were incorporated in the standard equations given in the SCS-CN method.

The study indicated a major change in the land use land cover pattern in the last 22 years, as indicated by the net growth in built up area from 21.13 % (1989) to 45.43 % (2011). Growth in the built up area has led to the increase in IS in the basin. IS have gone well above 25 % especially, in the suburbs of Pune city & nearby villages and the transportation routes. The impact of increase in built up area and IS has intensified the surface runoff in the basin. Taking in to consideration a constant basin area of 52.48 sq. km and an average rainfall of 60.2 mm, the average antecedent moisture condition (AMCII) yielded an estimated runoff of 525 million cubic meters in 2011 as against 406 million cubic meters in 1989. Thus it is quite evident that the growth in built up area and impervious surfaces have enhanced the capacity of the Ramnadi basin to generate more runoff even with lower order storm events.

## **Poster presentations:**

### **Ortophoto and satellite imagery to monitoring charcoal in mountain soils (NW of Cantabrian Range, Spain)**

*FERNANDEZ S.(1), ROCES P.(2), RECONDO C.(2)*

*(1) University of Oviedo, MIERES, SPAIN ; (2) INDUROT, MIERES, SPAIN*

In the Northwest of the Cantabrian Mountain Range the climate is oceanic and the vegetation cover should be mainly wood forests and heathlands. However, frequent wildfires have led to a progressive degradation of the vegetation cover by enhancing the development of extensive moorlands and pyrophytes species of high combustibility. Previous studies have proved that this intense fire history promoted structural degradation, soil erosion (the average values of soil losses, measured with  $^{137}\text{Cs}$  on burned slopes, is around  $6,5 \text{ t/ha-year}^{-1}$ ) and degradation of the structure and hydraulic properties (infiltration rate increased from 0.0107 to 0.1070 cm/s) of burned soils. Also the fires altered the rates of carbon (C) transfer from vegetation to soil. In this way, C stocks of 32 Mg/ha and 90 Mg/ha were measured in unburned and burned forest soils, respectively. Satellite imagery and ortophotography could be useful in order to monitor the C sequestration in soils. We want to test the use of satellite imageries and ortophotos to monitoring the charcoal pool in soils of mountain areas with high rates of C transfer from vegetation to soil, promoted by forest fires. 55 georeferenced soil samples, taken in an area 100 km<sup>2</sup> located in the Northwest sector of the Cantabrian Range were crossed with ortophotos and satellite images taken in the winter season. Several spectrometric indexes related to soil properties (NDSI, NDBal.), color indexes from the visible part of spectrum (SWIR) and values from visible and thermal infrared were calculated for each soil sample. Results from multivariate linear regression analysis showed good adjust ( $R^2$  0,69) from soil organic carbon estimation using indexes and color variables calculated with Landsat images. Also models calculated using transformed color variables over ortophoto shows adjustment nearly to  $R^2$  0,54. The models were regionalized to large scales and validate with new soil samples RMSE was 6,4 and 16 % respectively.

\*\*\*\*\*

### **Digital elevation modelling from a Smartphone**

*LANE S.N.(1), CHANDLER J.H.(2), MICHELETTI N.(3)*

*(1) IGD, Université de Lausanne, LAUSANNE, SWITZERLAND ; (2) Loughborough University, LOUGHBOROUGH, UNITED KINGDOM ; (3) IGD, Université de Lausanne, LAUSANNE, SWITZERLAND*

Digital photogrammetric measurement as a means of creating digital elevation models has developed dramatically over the last decade, notably with the advent of Structure from Motion (SfM) technologies. The critical SfM development has been the ability to undertake automatic image matching using large numbers of oblique imagery, in which image registration, image correction for sensor distortion effects and image matching to extract data points are handled simultaneously. This opens up the use of a much wider range of sensors, in theory any kind of sensor that measures with sufficient pixel resolution. SfM is increasingly available via web based platforms, where images are sent via the internet for processing. In theory, this opens up the intriguing possibility: low cost, real time digital elevation modelling using images acquired by and sent from a Smartphone. In this paper, we test this approach for the construction of digital elevation models of three different scales: (1) high resolution models of pebble clusters; (2) medium resolution models of river banks; and (3) low resolution models of alluvial fans. We use comparison with high resolution laser scanned images to evaluate each scale of application. The results confirm the potential of this technology. There is some degradation of resolution and precision in comparison with scanning technologies, but the costs of the method are almost negligible and there is some additional flexibility gained from the ability to rapidly survey features from multiple angles, so reducing dead ground effects.

### Testing a Terrestrial Laser Scanner and photogrammetric techniques for studying badland dynamics

NADAL ROMERO E.(1), REVUELTO J.(2), LÓPEZ-MORENO J.I.(2), VICENTE-SERRANO S.(2), GARCÍA RUIZ J.M.(2)

(1) University of Zaragoza, ZARAGOZA, SPAIN ; (2) Instituto Pirenaico de Ecología, ZARAGOZA, SPAIN

Geomatic techniques have been routinely applied in recent years in Geomorphology studies. The aim of this study is to assess the *in situ* operational functioning of the TLS (Terrestrial Laser Scanning) and Photogrammetric techniques to evaluate badland dynamics and erosion rates in a humid badland area in the Araguás catchment (Central Spanish Pyrenees). By comparing different DEMs of the same area, obtained at different moments, variations in the terrain and temporal dynamics can be analyzed.

Data analysis has been carried out using the Riprofile Software. A density of about 1000 points/ m<sup>2</sup> (maximum about 2500 points/m<sup>2</sup> and minimum values of 500 points/m<sup>2</sup>) was reached with the TLS analysis.

The preliminary results show that TLS data sets and photogrammetric data provide new opportunities in the study of geomorphology dynamics in badland areas (highly erodible landscapes), given the rapidity of the hillslope evolution. These methodologies are potentially useful for erosion studies as they operates without contact with the ground surface, the acquisition time is relatively short and the precision is sufficient for detailed erosion studies and geomorphological dynamics in very active areas.

\*\*\*\*\*

### Reconstruction of past hillslopes morphology using aerial photographs: data quality and applications for the investigation of landscape changes at the decadal scale

MICHELETTI N.(1), LANE S.N.(1), CHANDLER J.H.(2)

(1) University of Lausanne, LAUSANNE, SWITZERLAND ; (2) Loughborough University, LOUGHBOROUGH, UNITED KINGDOM

The potential of archival digital photogrammetry to measure landforms surfaces and landscapes has been proved by its increasing use for the extraction of quantitative elevation information in geomorphology. With technological advances, digital photogrammetry has become increasingly automated and cost-effective. However, the increased use of terrain data generation remains complicated by the user needing to define critical parameter and choose appropriate algorithms. The choices affect data quality and hence surface description, which can be critical for measuring complex surfaces. Here, we present and test a workflow for reconstructing high mountain topography and topographic change using archival digital imagery. Aerial photographs from 1950s to present are used to generate DEMs at different dates, combining fieldwork data and manual stereo-matching with automatic tools. An investigation of the choice of parameters and the quality and uncertainty of related results is proposed. The latter is based on (1) the quality of the stereo-matching solution (2) the accuracy of spot heights based upon independent check data, and (3) quantification of the effects of data collection strategies upon surface features derived from the DEMs. Finally, and using the appropriate error propagation methods, we test the application of the generated models for change detection in deglaciated valley hillslopes in the Swiss Alps. Results demonstrate that archival photogrammetric methods can, with the appropriate care, be employed to reconstruct surface changes over hillslopes and mountainous regions in general, over decadal scale. However, it is not a 'plug-and-play' technology: that is, extracting reliable information is dependent upon optimization of data collection strategies and field campaigns, especially from imagery with sub-optimal scales.

### **Surveying Channel Morphology Using Ground-Based Photogrammetry**

ROUSSEAU Y.(1), ASHMORE P.(1), BIRON P.(2), VAN DE WIEL M.(1)

(1) *Western University of Canada, LONDON, CANADA* ; (2) *Concordia University, MONTRÉAL, CANADA*

Research projects in geomorphology often require the detection of morphological changes at a fine resolution. This is notably the case in river-related studies where changes in bank morphology are often subtle and difficult to detect. Accurate elevation models can be generated from devices such as terrestrial LIDAR and differential GPS units, but their acquisition costs remain high, limiting the number of detailed bank topographic surveys available for research experiments. Photogrammetry has recently been proposed as a method to produce continuous terrain models in a range of landscapes including small river channels. There, alternative technologies would be either too expensive to use or complicated by the presence of obstacles such as vegetation or by poor satellite reception. This research aims at testing the feasibility of surveying the topography of both the bed and banks of a river channel using a consumer-grade DSLR camera mounted on a portable, 7m tall pole. The experiment was conducted in a narrow, 16-meter wide, shallow semi-alluvial stream channel (Medway Creek, Ontario), along a 1.5-kilometer reach with riparian vegetation. The generated terrain model is compared with topographic surveys conducted in the same reach using a total station and a high-resolution DGPS. The resulting terrain models are statistically compared between the three surveying techniques used. Other aspects, such as acquisition, pre- and post-processing efforts, are also taken into account to produce an overall assessment of this low-cost surveying method which can provide very useful datasets for numerical modelling studies on bank erosion.

\*\*\*\*\*

### **Hyperspectral proximal and remote sensing applied to clay minerals identification and mapping**

DUFRECHOU G., HOHMANN A., GRANDJEAN G., BOURGUIGNON A.

*BRGM, ORLEANS, FRANCE*

Swelling soils contain clay minerals that change volume with water content and cause extensive and expensive damage on infrastructures. Based on spatial distribution of infrastructure damages and existing geological maps, the Bureau de Recherches Géologiques et Minières (BRGM, the French Geological Survey) published in 2010 a 1:50 000 swelling hazard map of France, indexing the territory to low, intermediate, or high swell susceptibility. At local scale, characterization of soil properties and identification of clay minerals using conventional soil analysis (DRX, chemical, and geotechnical analysis) are slow, expensive, and does not permit integrated measurements. VNIR (400-1100 nm) and SWIR (1100-2500 nm) spectral domains are characterized by significant spectral absorption bands that provide a largely unexploited tool for recognize swelling minerals. Hyperspectral proximal (*i.e.* field measurement) sensing, using an ASD Fieldspec Pro spectrometer, provides thus a rapid and less expensive field surface sensing that permits to measure soil spectral properties. The BRGM aims to combine proximal and remote (*i.e.* airborne measurement) sensing to apply and optimize hyperspectral reflectance imaging for mapping clay minerals and soil properties, so that local mapping of swelling clays susceptibility could be assessable from an economical point of view.

**Gullies detection on satellite imagery in an intra urban catchment of tropical region. Methodological development in river Bumbu catchment (Kinshasa, RD Congo)**

MAYAMBA AIME M., TSETA FELICIEN M., KOMANDA JULES A.

*Université de Kinshasa, KINSHASA, CONGO (THE DEMOCRATIC REPUBLIC OF THE)*

In contrast to the effort during the last decades to investigate sheet (interrill), rill and gully soil erosion processes in agricultural environment, relatively few studies have been focused on quantifying and/or predicting gully erosion in urban sites. The extension of the use of modern spatial information technologies, such as geographical information systems (GIS), differential global positioning system (DGPS) and remote sensing, have created new possibilities for research in this field. A key issue to be addressed, as the basis for predicting the effects of global changes such as land use and climate changes, is the mapping and quantification of gully erosion rates, including rate of retreat of gully walls and rate of sediment production. This research work presents a method to detect and map gully in tropical urban environment using a visual interpretation key.

The proposed method uses high resolution satellites images and DGPS data, both of which have been processed using GIS techniques. The research was applied to a sample catchment of 23 km<sup>2</sup> located in Kinshasa, DR Congo. Satellite image at 0.76 meter from 2006 and field data from 2009-2010 were used to map gully and validate interpretation keys used to detect gully.

51 gullies with different length and state were detected in the catchment from satellite image and 51 founded in the field in different states of activity. Too criteria dominate to determine gullies: shape and color. Some accelerated causes of gully erosion were also detected.

In comparison with the traditional visual interpretation of satellite image, the proposed method integrates local realities.

\*\*\*\*\*

**Terrestrial laser scanning methods as instrument of landslide and erosion processes study**

YERMOLAEV O., USMANOV B.

*Kazan Federal University, KAZAN, RUSSIAN FEDERATION*

Methods for estimating the intensity of hazardous exogenous geological processes are being developed. For this purpose laser scanning system used high precision instrument "Trimble GX".

Study of landslides held in the observation point Kamskoe Ust'e (Volga River, East Russian Plane, Russia), where under the action of the Kuibyshev reservoir, landslide processes actively destroys slopes, threatening buildings and destroying the old cemetery. The length of the landslide circus front is 180 meters. From remote sensing data and the results of field observations, the average retreat rate of the slope edge is 3 m per year, annually removed area ranges from 500 to 1,500 square meters, that allows to relate study area to dangerous category. Annual and intraseasonal rescan allowed us to estimate the intensity of the landslide processes more accurately over traditional methods, and get the exact volumes of slope destruction to the entire front of the landslide circus.

Erosion processes (rill and sheet erosion) studied in Kazan city (Russia) during April - June 2012 period on the experimental plot with the loamy slope without greensward, 40 sq m area, 30 degrees angle, measurements were taken after snowmelt and heavy rains. Maps of deviations between all stages of surveying and TIN-models build directly on point clouds. Obtained results may provide insight into the processes of erosion and accumulation on a slope and consider in detail the formation of erosion forms as a result of rainfall and snowmelt, also to calculate such quantitative characteristics as volume and layer of accumulation and erosion of the soil. For experimental plot erosion layer is 1.3 mm.

## Use Of Remote Sensing to Locate Subsurface Shallow Waters in Al Madinah Al Munawwarah, Western Saudi Arabia

AL-DOAAN M., DAOUDI M.

King Abdulaziz University, JEDDAH, SAUDI ARABIA

Al Medina Al Munawwarah, a city in the western part of the Kingdom of Saudi Arabia, is located in a dry area, with average annual precipitation of less than 70 mm. Due to the limited amount of water resources available to the city from traditional rain water or wells, the government has resorted to alternative sources, such as desalinated sea water to meet the city's growing water needs for the population. The aim of this study is to search for wadis, or riverbeds that might be abundant in subsurface waters in Medina. Such waterways were the main source providing the city with its water needs until 1970, before the availability of desalinated sea water. To locate rich underground water reservoirs and to provide maps of the area, satellite-borne data has been obtained using (TM+ Landsat 7, Ikonos, XI Spot 5) and the software program (ENVI) was used to digitally process the remotely-sensed data. Preliminary results show that new sources of rich underground water beneath the earth's surface are available, which can be accurately located and the water can be maximally extracted from these reservoirs that date back to the Pleistocene period, and lie under layers of volcanic lava.

Keywords : digital imaging, mapping technique, arid region, shallow water, Saudi Arabia.

\*\*\*\*\*

## InSAR as a complementary tool for identifying alluvial morphological units: Vega Media of the Segura River (SE Spain) case study

CONESA-GARCÍA C.(1), TOMÁS R.(2), HERRERA G.(3), LÓPEZ BERMÚDEZ F.(1), CANO M.(2), NAVARRO-HERVÁS F.(1), PÉREZ-CUTILLAS P.(4)

(1) Departamento de Geografía Física, Universidad de Murcia, MURCIA, SPAIN ; (2) Departamento de Ingeniería de la Construcción, Obras Públicas e Infraestructura Urbana, Escuela Politécnica Superior, Universidad de Alicante. Unidad Asociada de investigación IGME-UA de movimientos del terreno mediante interferometría radar (UNIRAD), ALICANTE, SPAIN ; (3) Geohazards Remote Sensing Laboratory, Grupo de Riesgos Geológicos, Instituto Geológico y Minero de España. Unidad Asociada de investigación IGME-UA de movimientos del terreno mediante interferometría radar (UNIRAD), MADRID, SPAIN ; (4) Centro de Edafología y Biología Aplicada del Segura (CEBAS), Consejo Superior de Investigaciones Científicas (CSIC), MURCIA, SPAIN

It is widely known that differential subsidence in a valley significantly controls its fluvial dynamics. Nevertheless, major uncertainty exists about the way in which alluvial forms respond to this process. Alluvial sediments constitute loose and unconsolidated deposits characterized by their low strength and bearing capacity. These sedimentary units have a moderate to very high compressibility (i.e. capacity for reducing a material volume by decreasing voids either filled with air or water) mainly depending on the grain size and the depositional conditions of the particles. The *Vega Media* of the Segura River is an alluvial area, affected by subsidence processes, mainly since the Pleistocene, whose current anthropization makes it difficult to delineate the limits of its morphological units. In this work, Differential SAR interferometry data from 1995 to 2008 were used, as a complementary tool to available geomorphological information, for identifying and delineating different alluvial units in the *Vega Media* of the Segura River, based on their different deformability rates. For this purpose, SLC SAR images from ERS-1 and ERS-2 satellites have been used for generating a total of 79 interferograms. The selected study area (100 km<sup>2</sup>) extends from the village of Alcantarilla to the city of Murcia and represents the typical morphological evolution of the whole *Vega Media*. The results obtained are shown and commented on in relation to the main issues involved in this topic. From the analysis of data, four deformational behaviours related with different alluvial units have been identified: a) Non-deformational units (consolidated alluvial fans and upper fluvial terrace); b) Slightly deformable units (lower terraces and abandoned meanders); c) Moderately deformable units (e.g. SW sector, old area of the Lower Guadalentín River flowing to the Segura River); d) and highly deformable areas (non-active flood plain and valley bottom).

## **Application of remote sensing for geomorphological mapping and reconstruction of geomorphological evolution**

PETROVIC D., PAVLOVIC R.

*University of Belgrade, Faculty of Mining and Geology, BELGRADE, SERBIA*

Geomorphological mapping in Serbia was conducted using instructions for reviewed (Gams etc., 1981) and detailed geomorphological map (Gams etc., 1985) which define content and technique of geomorphological maps in accordance with international standards (IGU, 1968). Mapping method is being changed during years. Basic instruction has been adjusted to specific requests, conditions as well as the development of new methods of geomorphological mapping.

Remote sensing is important part of geomorphological mapping and analyzes of geomorphological evolution of an area. In this paper, remote sensing include qualitative visual analysis of satellite and areal images. With these procedures, two different type of data can be pointed out. First data are morphostructural elements which present conditions for the development of some exogenetic processes and geomorphological evolution. Tectonic fabric, especially neotectonic active ruptures and blocks defined by them, seismological activity, epirogenetic-orogenic movements and volcanism present the basic endogenic factor in control of exogenetic processes. Analysis of satellite and areal images can be used for determination of important data about distribution and relationships between ruptures and morphological entities created by tectonic and igneous activity. Second data include morphosculpture elements, presented as single landforms and phenomena from different geomorphological processes. High resolution satellite images and aero images are excellent base for morphological analysis of landforms, determination of relationships between them and monitoring of their evolution. In this way, information about evolution and interaction of geomorphological processes in time has been acquired.

In this paper remote sensing was used for reconstruction of Oligocene-Miocene igneous activity, glaciation and landslides in Serbia and Montenegro. There are numerous examples for every of these processes.

\*\*\*\*\*

## **Vada Volaterrana (Italy). High-resolution Ground Penetrating Radar in Geoarchaeology: the application of STREAM X multichannel system**

PAPPALARDO M.(1), RIBOLINI A.(1), PASQUINUCCI M.(2), BARONI C.(1), BINI M.(1), MENCHELLI S.(2), MORELLI G.(3), SALVATORE M.C.(1), SANGRISO P.(2)

*(1) Dipartimento di Scienze della Terra, Pisa University, PISA, ITALY ; (2) Dipartimento Civiltà e Forme del Sapere, Pisa University, PISA, ITALY ; (3) Geostudi Astier, LIVORNO, ITALY*

*Vada Volaterrana* was the main harbour of *Volaterrae* in Etruscan and Roman times as documented by Latin sources. Based on geomorphologic and archaeological data, the harbour was located at the sheet of water in front of modern Vada settlement, protected by a large shoal system. Immediately northeast of this area stratigraphic excavations are in progress and a Roman quarter related to the harbour has been brought to light.

We started an integrated geoarchaeological project to reconstruct the landscapes. Because of its high-resolution data and 3D visualization capabilities, Ground Penetrating Radar (GPR) is one of the most frequently used geophysical techniques for geoarchaeological prospection. Routine data acquisition is based on single or double channel GPR systems moved on the surface following generally 30-50cm spaced cross profiles. The resulting lateral spatial resolution of acquired data might not be fully adequate to resolve the subsurface structures because of aliasing effects. The new generations of multi-channel GPR instruments avoid the spatial sampling biases reducing the antenna channel separation on the surface, allowing a significant increase in resolution up to few centimetres.

In *Vada Volaterrana* site, we employed the STREAM X system by IDS S.p.A, equipped with 15 antennas of 200 MHz central frequency, 12 cm spaced. The system was easily moved on the surface by means of a 4-wheel vehicle, while the positioning of the acquired data was provided by a RTK-GPS station interfaced with the acquisition software.

We obtained a 3D ultra-dense data volume, processed with a specific software according to a standard procedure. We interpreted the continuous and spatially coherent radar reflections, visible in the data volume section, which were cut parallel to the surface at different depths (depth slice). Selected areas of the investigated surface were explored by means of shallow coring, allowing a more liable interpretation.

### **Estimation of medium-term soil erosion rates by means of terrestrial laser scanner and exposed roots**

GOMEZ-GUTIERREZ A., SCHNABEL S., RUBIO-DELGADO J., BERENQUER-SEMPERE F., LAVADO-CONTADOR F.

*Universidad de Extremadura, CACERES, SPAIN*

The estimation of medium-term sheet erosion rates represents a challenge in areas with long land use history. In the present paper, a new methodology for estimating medium-term sheet erosion rates is presented. The methodology is based on the analysis of the morphology of tree stems, exposed roots and surface micro-topography using data obtained with a Terrestrial Laser Scanner. Specifically, botanical evidences were used to estimate the antecedent level of the surface. Later, previous and current surfaces were confronted in order to obtain a volume of soil loss. On the other hand, the age of the trees in the study area was estimated by means of an existing tree growth model. Finally, soil erosion rates were calculated using the volume of soil loss and the estimated age of every tree. The sampling was carried out in the farm *Buitrera de Villavieja* in Cáceres (Spain). The landscape and the management system is known as *dehesa* land use which is based on livestock grazing besides forest, and in some cases, agricultural exploitation (not in *Buitrera*). Climate is Mediterranean with mean annual temperatures about 17°C and an annual rainfall of 620 mm. Soils are very shallow, developed on schists, with low amounts of organic matter and classified as *distric leptosols*. A representative hillslope (260 m long and 190 m wide) within the catchment was selected for the sampling, obtaining a point cloud of 112 063 056 points in an area of 50 000 m<sup>2</sup>. A total of 134 trees were processed, with ages ranging from 40 to 250 years. High soil erosion rates were estimated for young trees while lower rates resulted for the older ones. A negative exponential relationship was obtained for soil erosion rates and tree ages, pointing out to a land-use intensification during the last century. Estimated soil erosion rates were also compared with the existing ones in the literature. The role of micro-topography was also explored; however no strong or significant relationships were obtained.

\*\*\*\*\*

### **Using UAV as a source of DSM data in geomorphological 3D modelling**

PANEK J., MACHACEK J.

*Palacky University in Olomouc, OLOMOUC, CZECH REPUBLIC*

A digital surface model (DSM) is a digital representation of ground surface topography, including all objects (houses, bridges, trees, etc). DSMs are often used in geographic information systems (GIS) and Computer Aided Design (CAD) environments, and are the most common basis for digitally-produced relief maps and true orthophotos. Industries such as mining, dredging, heavy engineering construction, etc. often rely on topographic ground surveyors for ground measurements and for accurate DSMs.

The unmanned aerial vehicles (UAV) allow users to create very dense point clouds - similar in density to a typical aerial LIDAR scanner - but with the advantage of requiring less demanding and costly equipment. This paper presents the results of a case study which introduces the use of unmanned aerial vehicles as a source of DSM data in geomorphological 3D modelling. As GIS and DSMs have become indispensable for geomorphological mapping and quantitative topographic research in the last decade, UAV mapping and data sourced from such devices will become a valuable source of spatial information, especially in relation to point clouds, in the next decade. This approach enables users to collect data in a short time and even in very complicated environments. The paper will outline the methodologies followed and the sources used in the process of UAV mapping and the visualisation of data. Secondly, the paper will share the results from the first Czech commercial use of UAV in quarry mapping and volume calculation. Thirdly, it will demonstrate how modern GIS and Remote Sensing methods can boost effectiveness within the Czech mining industry.

### **Integrated geomatic techniques for surveying glacial and recently deglaciated areas**

DAMIANO E.(1), BACENETTI M.(2), BERTOTTO S.(2), GIARDINO M.(2), GODONE F.(1), PEROTTI L.(2), CHIARLE M.(1)

(1) Istituto per la Protezione Idrogeologica CNR-IRPI, TORINO, ITALY ; (2) Università degli Studi di Torino, Dipartimento di Scienze della Terra, GeoSITLab, TORINO, ITALY

Climate changes are more and more attracting the attention of the scientific community because of their direct impacts on geomorphic systems and human activities.

A number of studies are currently under way to investigate the evolution of high elevation environments, which proved to be particularly sensitive to climate changes and point to increased instability in areas of cryosphere occurrence.

The here presented research has been developed in the framework of the Alcotra project n.56 "GlaRiskAlp", by CNR-IRPI Torino in collaboration with the DST Torino - GeoSITLab laboratory and is aimed to the validation of an integrated geomatic approach for the evaluation of geomorphologic changes, and related hazards, in glacial and periglacial areas, in the contest of present climatic trends.

The proposed approach is based on the coupling of remote sensing techniques and field surveys, in particular digital aerial photogrammetry and satellite imagery, terrestrial scanning LiDAR, and GNSS survey.

High-resolution terrestrial LiDAR acquisition, processing and interpretation are used to map periglacial areas in the three dimensions. Laser-generated models offer a visualization tool that, through the comparison of DEMs of different years, allow to detect and to interpret even small geomorphologic changes in time. GNSS-networks are suitable tools for detecting changes over larger surfaces, or horizontal ones. Digital aerial photogrammetry and satellite images can be used to create orthophotos and DTMs of different years, allowing the reconstruction of main geomorphologic changes over the last 50 years.

The proposed approach has been applied to case studies of the Piemonte region (Western Italian Alps).

\*\*\*\*\*

### **Monitoring geomorphological change with unmanned aerial vehicles**

ANDERS N.(1), KEESSTRA S.(1), SEEGER M.(2), SUOMALAINEN J.(3), BARTHOLOMEUS H.(3), KOOISTRA L.(3)

(1) Soil Physics and Land Management, Wageningen University, WAGENINGEN, NETHERLANDS ; (2) Department of Physical Geography, University of Trier, TRIER, GERMANY ; (3) Laboratory of Geo-Information Science and Remote Sensing, Wageningen University, WAGENINGEN, NETHERLANDS

Remote sensing of the Earth's surface is a valuable tool for analyzing the environmental setting of a landscape. Despite technological advances to increase the spatial resolution of satellite imagery, spaceborne data is not ideal for monitoring purposes due to cloud interference and low temporal resolution. Manned airborne imagery may be too expensive to use for frequent monitoring studies. In the context of the SMARTINSPECTORS project, we demonstrate the potential of using Unmanned Aerial Vehicles (UAVs) for analyzing and monitoring geomorphological processes in a changing landscape. We demonstrate the work flow and first results of a study in a small agricultural catchment (~2km<sup>2</sup>) near Pamplona, northern Spain. We used a small airplane (MAVinci, wing span of ~1.6m) with an integrated consumer 16MP digital camera (Panasonic GX1, 20mm lens). The airplane operated based on a predefined flight schedule and autopilot. From the raw photographs we created detailed orthorectified air photos and high-resolution digital elevation models (DEMs) at different moments in time. With automated mapping procedures we are able to rapidly register the geomorphological setting and landforms, and follow their development over the measured time. By subtracting different DEMs we were able to locate source and sink areas, and transport channels. Future applications may include analyzing hydrological connectivity, calculating local erosion rates and identifying areas vulnerable to land degradation. Other sensors can be integrated which are e.g. sensitive to near-infrared light, that provide information related to specific soil physical properties and soil moisture. Based on the first results, we claim that UAVs are valuable tools for a rapid geomorphological assessment and the monitoring of small-scale processes.

## **Vegetation and landslides in the Serra do Mar (SP), Brazil: evaluation by satellite images processing**

DIAS ALVES PORTELA V., CARVALHO VIEIRA B.

*University of Sao Paulo, SAO PAULO, BRAZIL*

Landslides have been the subject of studies mainly in the tropical, notably the role of vegetation in the distribution of these processes. By means of remote sensing is possible to argue the role of vegetation as indicator of landslides considering that this tool can analyze spectral properties of physiognomic types of species and canopies. This study aimed to relate the different vegetation cover and distribution of shallow landslides in the Serra do Mar, mountain range located along the SE Brazilian coast, in Caraguatatuba city (São Paulo state, Brazil). The Serra do Mar is characterized by steep slopes and elevation ranging between 20-1000m, with dominance of gneisses, migmatites, granites and micaschists. It acts as a barrier prevents the advance of moisture coming from the coastal zone to the mainland with the concentration of cold fronts and convection currents. The precipitation in the Serra do Mar is high with an annual average of 3000 mm that cause orographic rainfall. Because of your characteristics, shallow landslides are the major geomorphological processes in the evolution of this relief. In this research was conducted vegetation mapping by the processing of THEOS satellite images (year 2012) with the multispectral bands of the resolution of 15m and 2m in panchromatic band in the software Envi 4.5. We mapped the slope and aspect, 1:10,000 scale, the geomorphological units map (1:50,000 scale) and was also we prepared the landslide scars map. The interrelationship between vegetation data and geomorphological parameters was obtained using software ArcGIS 10.1. These results allowed to associate the types of vegetation and landslide scars and these were concentrated on the granites and gneisses and SW. The interrelationship of the data allowed to identify the importance of landforms and geomorphological processes in the vegetation structure and relate them to landslides scars in the study area.

\*\*\*\*\*

## **An insight into the mud volcanoes morphodynamics. A Romanian case-study**

GAL A.(1), BELL R.(2), MICU M.(3)

*(1) Faculty of Geography, Babe?-Bolyai University, CLUJ-NAPOCA, ROMANIA ; (2) Faculty of Earth Sciences, Geography and Astronomy, University of Vienna, VIENNA, AUSTRIA ; (3) Institute of Geography, Romanian Academy, BUCHAREST, ROMANIA*

Mud volcanoes are distinguished from igneous volcanoes by genesis, eruption products and magnitude-reduced derived forms and processes. Generally, they are triggered by natural gas and oil seepage, hydrothermal or seismic activity. In Romania mud volcanoes are widespread in various morphotectonic settings and are very often related to hydrocarbon reservoirs. The lithological structure of the discharged material reflects the structure of the geological formations through which the mud migrated towards the surface. The purpose of this paper is to outline the main morphodynamic characteristics of the mud volcanoes in two key-areas in Romania: the Transylvanian Basin and the Curvature Carpathians. Once the mud emerged and piled, the bulging volcano may form sometimes extended plateaus, (like those at Paclele Mari, covering approx. 30 ha) marked by scattered or grouped gryphons. The flows of mud, after drying, are affected by erosion forming impressive gullies. Using terrestrial laser scan measurements at two locations (Paclele Mari and Paclele Mici) we have started a time-series to quantify the outflow and accumulation of mud from the more active Paclele Mici mud volcanoes and erosion of the less active Paclele Mari plateau. With the next measurements in March 2013 the results will cover 3 measurements within a 2 years period, which so far shows significant accumulation and erosion. The results will be discussed in the general framework of morphodynamics of mud volcanoes in Romania.

**Imaging spectrometry for the geomorphological and spectral characterization of the lower Odiel river course (Huelva, Spain)**

GARCIA-MELENDEZ E.(1), BUZZI J.(2), RIAZA A.(2), CANTANO M.(3), MINGUEZ A.(4), RODRIGUEZ GARCIA A.(1)

(1) Universidad de Leon, LEON, SPAIN ; (2) Instituto Geologico y Minero de España, MADRID, SPAIN ; (3) Universidad de Huelva, HUELVA, SPAIN ; (4) Instituto Geologico y Minero de España, LEON, SPAIN

In this work, based on the interpretation of airborne hyperspectral HyMap images, the main geomorphological features of the Odiel river (southwest Spain) along its lower reach are mapped and their spectral responses are analyzed in compositional and textural terms. Hyperspectral imagery provides wide possibilities for mapping complex features of the surface of the Earth, by offering a high dimensionality of data. The procedure for feature extraction for thematic purposes used in this study is an interpreter oriented sequential spectral separability method using standard algorithms, leading to a spatial pattern and spectral identification for pixels within the scene. The standard sequence of algorithms begins with Minimum Noise Fraction Transforms, followed by Pixel Purity Index and n-dimensional Analysis to extract significant statistical populations, and finally a classification through the Spectral Angle Mapper algorithm. The obtained results show a good differentiation between gravel/sand bars occurring on alternating sides of the channel as point or lateral bars with a lower overall reflectance, and channel-fill deposits with predominant silty and muddy sediments located in abandoned secondary channels, with a higher overall reflectance. The spectra in both bars and abandoned channels are dominated by absorption features related to the precipitation of iron-oxides minerals associated with the presence of acid mine drainage. On the other hand, in the lower terraces and floodplain these absorption features are not present.

Keywords: fluvial sedimentation, HyMap, spectroscopy.

Acknowledgements: work supported by the Spanish PNI project CGL2007-6004/CLI

\*\*\*\*\*

**The use of Structure for Motion for repeat topographic surveys of active boulder bars on a hydrologically dynamic tropical river**

DIETRICH J., LIND P.

University of Oregon, EUGEN, UNITED STATES

Grain-scale alterations of boulder bar surfaces are not captured with traditional point-survey techniques due to the inherent uneven topography created by boulder grain size and shape. This study applies the close-range photogrammetry approach of Surface from Motion (SfM) to quantify changes in area, elevation, and grain mobilization of the surfaces of active boulder bars in the Rio Pacuare, Costa Rica during the 2012-2013 rainy season. High-resolution 3D landscape models of boulder bar surfaces were produced through photogrammetric surveys atop six boulder bar surfaces before and after flood events. Survey photos were taken with a pole-mounted camera in an overlapping grid pattern to maximize exposed surface area of each grain. This paper presents some of the challenges and the applicability of close-range repeat photogrammetric surveys on active coarse-grained surfaces.

**SRTM employment images in physiographic subdivision: a case study in the region of São José dos Campos - SP - Brazil**

SANTOS CORREA C.(1), TAVARES DE MATTOS J.(2), DIAS BRITO H.(1)

(1) UNESP, RIO CLARO, BRAZIL ; (2) UNESP GUARATINGUETA, GUARATINGUETA, BRAZIL

An important factor to promote the inclusion of relief in the identification and analysis of terrestrial systems comes from recent topographic data collection by remote sensing techniques. The project SRTM (Shuttle Radar Topographic Mission) comes from cooperation between NASA and NIMA (National Imagery and Mapping Agency), DOD (Department of Defense) of U.S. and space agencies of Germany and Italy. Of the total data collected by the SRTM data were processed for C-band coverage in 80% of the Earth's land area, between latitudes 60° N and 56° S (JPL, 2003). Thus, this article aims to demonstrate the results obtained from the use of SRTM images to the physiographic subdivision in the region of São José dos Campos (SP), Brazil. The study area is part of the Taubate Sedimentary Basin and is limited to the south and north by the Crystalline Basement, featuring morphologies linked to these rock types. The methodology consisted by the use of images and SRTM topographic maps at 1: 50,000 scale, which went through the process of Photoreading, Photoanalysis and Photointerpretation (SOARES & FIORI, 1976). The results showed the presence of the Subdivisions Basics Units, which are subject to environmental studies and geotechnical character geoenvironmental. Thus, images SRTM stand out as relevant tools in die geomorphological studies, since it allows the identification of landscape elements, such as slope and drainage.

\*\*\*\*\*

**Application of principal components analysis (pca) to detect geomorphological faces, case study: meaghan lake**

GHAHROUDI TALI M.

Shahid Beheshti University, TEHRAN, IRAN

Meaghan Lake, one of the places that have been preserved evidence of climate change as evaporating surfaces and destructive deposits. At present the lake collects water in its catchment area of approximately 5528 square kilometre which already has a dry climate, with evaporation over precipitation. This study was conducted to identify faces Geomorphologic Meaghan playa.

1:25000 topographic maps, Aster data, ETM + and IRSP6, images, 1:100000 geological maps and field research were used. Principal Component Analysis (PCA) has been used to identify Microgeomorphologis lands. The results were evaluated using field observations. The results showed, area of the lake has been 129 square kilometres during the last cold period. Due to landform are made of evaporate minerals including calcite, gypsum and halite. It can be found reduced precipitation and increased evaporation may lead to smaller the lake. And changes in lake levels caused to deposit evaporative minerals according to their solubility. Finally the levels of various forms have been left.

### **Acquisition, Resolution and Precision of Dieppe Costal Cliffs Point Clouds from Mobile Laser Scanning**

*MICHOUD C.(1), CARREA D.(1), AUGEREAU E.(2), CANCOUËT R.(2), COSTA S.(3), DAVIDSON R.(3), DELACOURT C.(2), DERRON M.H.(1), JABOYEDOFF M.(1), LETORTU P.(3), MAQUAIRE O.(3)*

*(1) Centre de Recherches en Environnements Terrestres - Université de Lausanne, LAUSANNE, SWITZERLAND ; (2) IUEM University of Brest, BREST, FRANCE ; (3) LETG-CAEN GEOPHEN University of Caen, CAEN, FRANCE*

Mainly formed by sub-horizontal deposits of soft chalk and flintstone, the Dieppe coastal cliffs, in Normandy, France, are destabilized by an intense weathering and the Channel sea erosion; moreover, small and large rockfalls are regularly observed and contribute to retrogressive cliff processes. Cliffs and intertidal topographies have been acquired during Autumn 2012 with a Terrestrial Laser Scanner (TLS) and a Mobile Laser Scanner (MLS), coupled with seafloor bathymetries realized with a multibeam echosounder (MBES).

MLS is a recent development of laser scanning based on the same theoretical principles of aerial LiDAR, but using smaller, cheaper and portable devices. The MLS system, which is composed by an accurate dynamic positioning and orientation (INS) devices and a long range LiDAR, is mounted on a marine vessel; it is then possible to quickly acquire in motion georeferenced LiDAR point clouds with a mean resolution of about 15 cm. For example, it takes about 1 h to scan of shoreline of 2 km long. MLS is becoming a promising technique supporting erosion and rockfall assessments along the shores of lakes, fjords or seas.

In this study, the MLS system used to acquire cliffs and intertidal areas of the Cap d'Ailly was composed by the INS Applanix POS-MV 320 V4 and the LiDAR Optech IIRs LR. On the same day with a calm sea at 2.5 Beaufort (small wavelets), three MLS scans with large overlaps (J1, J21 and J3) have been performed at ranges from 600 m at 4 knots (low tide) up to 200 m at 2.2 knots (up tide). Mean scan resolutions go from 25 cm for far scans to about 8 cm for the closest scan. Moreover, one TLS point cloud on this test site has been acquired with a mean resolution of about 2 cm, using a Riegl LMS Z390i. In order to quantify the precision of the methodology, comparisons between scans have been realized with the software CloudCompare, calculating shortest distances between points of one cloud and the interpolated mesh of the reference point cloud. A MatLab™ routine was also written to extract interesting statistics.

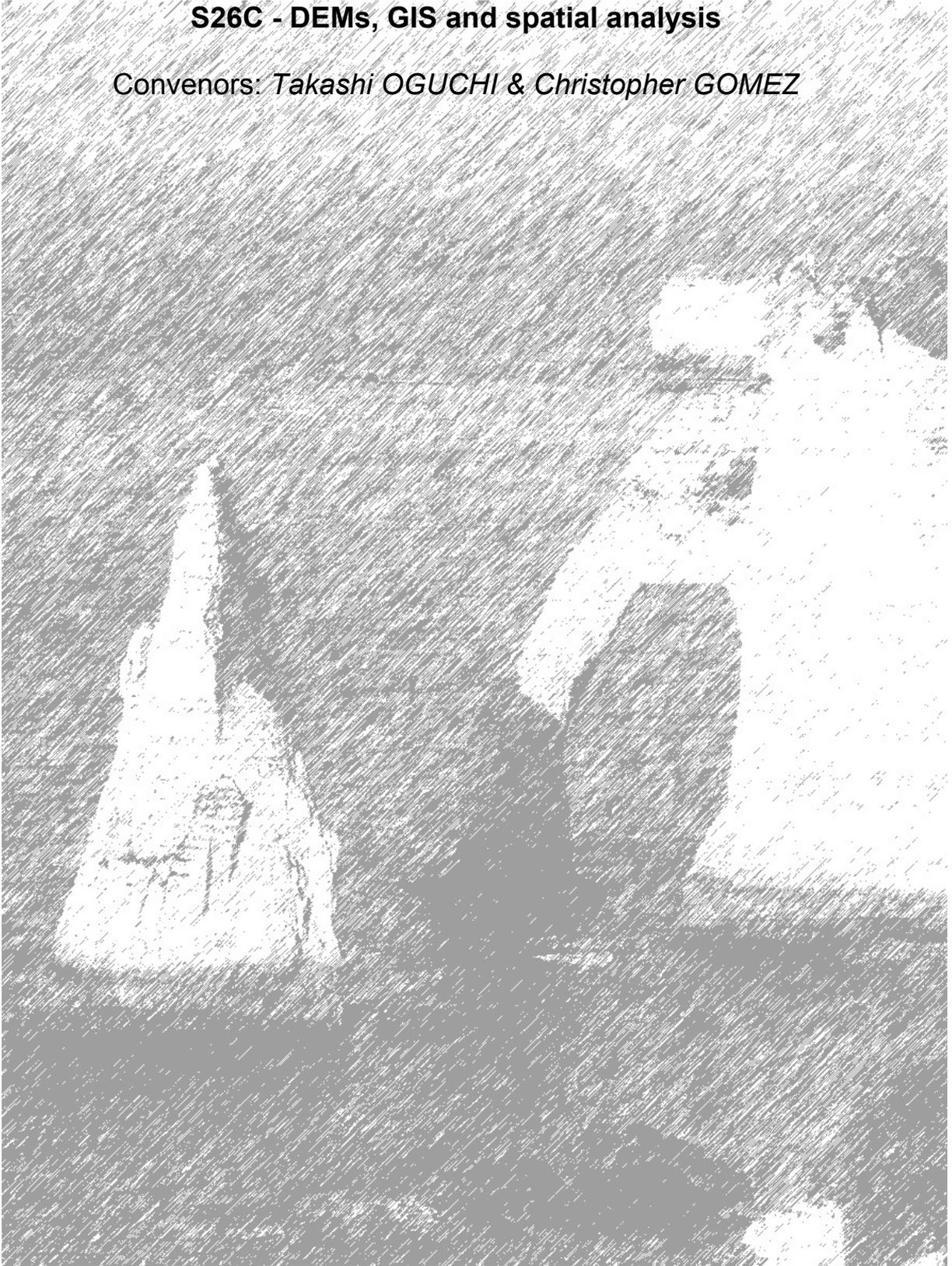
First, mean distances between points of the reference point clouds (J21) and its interpolated surface are about 0.35 cm with a standard deviation of 15 cm; errors introduced during the surface interpolation step, especially in vegetated areas, may explain those differences. Then, mean distances between J1's points (resp. J3) and the J21's reference surface are about 4 cm (resp. -17 cm) with a standard deviation of 53 cm (resp. 55 cm). After a best fit alignment of J1 and J3 on J21, mean distances between J1 (resp. J3) and the J21's reference surface decrease to about 0.15 cm (resp. 1.6 cm) with a standard deviation of 41 cm (resp. 21 cm). Finally, mean distances between the TLS point clouds and the J21's reference surface are about 3.2 cm with a standard deviation of 26 cm.

In conclusion, MLS devices are able to quickly scan long shoreline with a resolution up to about 10 cm. The precision of the acquired data is relatively small enough to investigate on geomorphological features of coastal cliffs. The ability of the MLS technique to monitor small and large rockfalls will be investigated thanks to new acquisitions of the Dieppe cliffs in a close future and enhanced adapted post-processing.

\*\*\*\*\*

**S26C - DEMs, GIS and spatial analysis**

Convenors: *Takashi OGUCHI & Christopher GOMEZ*





## **Oral presentations:**

### **Generating high spatiotemporal resolution digital terrain models for debris flow deposits from 3D structure-from-motion imagery and an unmanned aerial vehicle**

*STARHEIM C.(1), GOMEZ C.(1), DAVIES T.(1), OWENS I.(1), HADMOKO D.S.(2)*

*(1) University of Canterbury, CHRISTCHURCH, NEW ZEALAND ; (2) Universitas Gadjah Mada, YOGYAKARTA, INDONESIA*

Monitoring the evolution of landform morphology at high spatial and temporal resolutions can generate valuable insight on the erosion, remobilization, and emplacement of sediments in geomorphologically active environments. While conventional remotely sensed data (e.g. commercial aerial photography, satellite imagery, and airborne LiDAR data) are frequently used for this type of research, the availability and expense of datasets often limits the resolution of the findings and thus, the usability of the technique for small and/or highly active features. By contrast, the present study applies innovative structure-from-motion (SfM) technology to generate a time-series of high-resolution digital terrain models (DTMs) for an active debris flow fan deposit. Repeat photo-surveys of the deposit were completed with consumer-grade digital cameras from ground positions and from an unmanned aerial vehicle. Agisoft PhotoScan Professional software was then used to process the images with an automated multi-view SfM algorithm, which identified common points and features in the photos, calculated camera positions and orientations, and amalgamated the images into a 3D model of the deposit. Ground control points were established in each survey using a differential global navigation satellite system and were used to geo-reference each DTM. Analysis of successive DTMs revealed significant evolution in the debris flow deposit morphology associated with sediment erosion and remobilization. Further analysis of these DTMs, coupled with detailed field observations and subsurface deposit imagery is expected to improve debris flow deposit interpretation. Although the present study primarily focuses on alpine debris flow deposits, the methods and techniques discussed are applicable to a wide range of high-energy environments including fluvial, coastal, glacial, and volcanic.

\*\*\*\*\*

### **Impact of tsunami erosion on coastal valley formation in northeastern Japan: an airborne and terrestrial laser scanning approach**

*HAYAKAWA Y.S.(1), OGUCHI T.(1), SAITO H.(1), KOBAYASHI A.(2), KOMATSU G.(3), GOTO K.(4), BAKER V.R.(5), PELLETIER J.D.(5), MCGUIRE L.(5)*

*(1) The University of Tokyo, KASHIWA, JAPAN ; (2) The University of Tokyo, TOKYO, JAPAN ; (3) Università d'Annunzio, PESCARA, ITALY ; (4) Tohoku University, SENDAI, JAPAN ; (5) University of Arizona, TUCSON, UNITED STATES*

Devastating tsunami waves induced by the Tohoku-Oki megaeearthquake caused severe erosion of side-slopes in valleys along the ria-type coast of the Sanriku region, Japan. Removal of vegetation, soil, regolith and even erosion of bedrock induced by the tsunami wave is observed at inland areas of valleys facing the coast. One of the most typical cases is the valley of Aneyoshi, where a very high runup of tsunami wave (38.9 m) was recorded. We investigated detailed morphology of the eroded valley-side slopes using high-resolution topographic data obtained by airborne and terrestrial laser scanning (ALS/TLS). The ALS data were provided by the Geospatial Survey Institute of Japan, whereas we used a Topcon GLS-1500 scanner to obtain the TLS data. Morphological analyses revealed several characteristic features in the valley: 1) small cliffs and steps were found on the valley-side slopes, and their locations correspond to the tsunami-inundated heights; 2) the valley side slope is gentler at the outside of the incised meander bend and steeper at the inside, and this asymmetry is unusual and inverse to that of an incised meander formed by fluvial erosion; 3) the valley is extraordinary wide at its downstream reach compared to the discharge of the river, and suddenly narrows at just upstream of a major meander bend; and 4) a knickpoint is located near the maximum tsunami-runup point in the narrowed reach, c. 100-m upstream of the bend. These topographic features likely reflect tsunami wave erosion which could have occurred multiple times during the late Holocene. In other words, if such characteristic forms in coastal valleys are found in other areas, they suggest repeated attacks of tsunami, and future tsunami magnitudes there may be estimated from topographic characteristics.

## **Accuracy assessment of DEMs derived from low-cost UAV-based remote sensing for geomorphic landform representation**

CLAPUYT F.(1), VANACKER V.(1), VAN OOST K.(2)

(1) Earth and Life Institute, Georges Lemaître Centre for Earth and Climate Research, Université Catholique de Louvain, Belgium., LOUVAIN-LA-NEUVE, BELGIUM ; (2) Earth and Life Institute, Georges Lemaître Centre for Earth and Climate Research, Université Catholique de Louvain, Belgium. Fund for Scientific Research FNRS, Rue d'Egmont 5, 1000 Bruxelles, Belgium., LOUVAIN-LA-NEUVE, BELGIUM

This study investigates the construction of a digital elevation model (DEM) using aerial photographs taken from a drone in the perspective of geomorphic applications. In this context, a representation of the earth surface at very-high resolution is crucial to accurately quantify small geomorphic landforms with high precision. These very high resolution digital elevation models can then theoretically be used to quantify changes in earth surface topography over time, based on differencing of DEMs taken at various time periods. However, high accuracy topographic representation is compulsory in this case as DEM differencing automatically leads to error propagation.

As a low-cost alternative, we equipped an eight-propeller drone with a standard reflex camera. This equipment can easily be deployed in the field, as it is a lightweight, low-cost system in comparison with classic aerial photo surveys and terrestrial or airborne LiDAR scanning.

Here, we tested to methods to extract a high-resolution DEM on the basis of the aerial photos. (1) Aerial photos are individually georeferenced and then processed into professional DEM extraction software. (2) Aerial photos are first processed into free software which generates 3D point clouds from arbitrary image configuration. The entire generated point cloud is then georeferenced. The accuracy and precision of both earth surface representations is then assessed by comparing them with very high resolution topographic data from airborne LiDAR and very high-resolution GPS measurements.

\*\*\*\*\*

## **SfM vs. RTK: FIGHT! (Structure from Motion versus Global Navigation Satellite System Real Time Kinetic)**

GOMEZ C., STARHEIM C.

University of Canterbury, CHRISTCHURCH, NEW ZEALAND

Recent technological advances enabling the construction of high-resolution digital elevation models (DEMs) have opened the long-closed Pandora-box of research in geomorphology. As new technologies, including terrestrial laser scanning (TSL) and structure-from-motion (SfM) are introduced it becomes increasingly essential to properly evaluate the benefits and limitations of each technique. Differences often extend past the basic methods for data acquisition and processing to the types of data potentially recorded. In this contribution the authors offer a direct comparison between two point-cloud datasets for DEM generation collected using: first, real time kinetic (RTK) data acquired from a Trimble differential global navigation satellite system (dGNSS), and second, SfM data acquired from a 'low-cost' commercial digital SLR camera (Canon EOS 1100) equipped with the standard 35 mm lens.

The study focuses on an area measuring approximately 100 m x 20 m on an active debris-flow fan in the Cass region of the New Zealand Southern Alps. Detailed one-hour RTK-dGNSS and SfM surveys were completed with the intention of generating DEMs of the study site. While results indicate that the SfM technique is superior to RTK based on the number of data points collected, the ability to record supplementary data including the RGB-colour of features, and the resolution of reconstructions, it is argued that a combined SfM-RTK approach is best suited to monitoring changes in active micro-landforms, especially because SfM does not record any 'real-life' spatial benchmark and it is only developed in a relative space. Potential geomorphological applications of SfM datasets are further discussed with particular emphasis on the benefits of obtaining information on featured spectral values.

### Three dimensional reconstruction of paleotopography to assess the role of antecedent morphology before and after rapid deposition events

*KAIN C., GOMEZ C., HART D.*

*University of Canterbury, CHRISTCHURCH, NEW ZEALAND*

Three dimensional reconstruction of paleosurfaces using GIS aids analysis of rapid-deposition event deposits. Depositional patterns of a flow event are constrained by topography and thus deposits may vary significantly across a small area. Without pre-event surveys for comparison, deposit configuration with respect to original topography is difficult to quantify in three dimensions. Thus, the topography underlying paleodeposits is often not known at a high resolution spatial scale and this information gap can cause inaccuracies when reconstructing an event from its deposit.

This research develops a GIS-based method of assessing deposits with respect to paleotopography and considers the influence of their form on morphological evolution post-event. A suite of overwash deposits in an infilled coastal embayment on Banks Peninsula, New Zealand is used as an example. Components include constructing a surface DEM from differential GNSS surveying, subsurface structure investigation using Ground Penetrating Radar (GPR), and sediment fabric analyses to assess flow direction. ArcGIS was used to reconstruct topography and paleosurfaces and explore the spatial and temporal relationships between layers. Anisotropy of Magnetic Susceptibility (AMS) data determined the direction of flow during the deposition of the overwash deposits, which served two purposes. Firstly, where underlying topography was visually apparent, the influence of topography on deposition was confirmed. Where boundaries were unclear, AMS was able to distinguish between depositional directions in the absence of topographical evidence, enhancing process reconstruction. By combining separate DEMs of surface and paleotopography in three dimensions, then comparing these with flow directions and thickness of the intervening sand layers, the degree to which topography affects interpretation of paleodeposits and the influence of rapid landscape-change events on further morphologic development can be better understood.

\*\*\*\*\*

### 3D Mapping of liquefaction phenomena induced by May 2012 Emilia earthquakes (Po Plain, Northern Italy)

*ZIZIOLI D.(1), NINFO A.(2), MEISINA C.(1), ZUCCA F.(1), PELLEGRINI L.(1)*

*(1) Earth and Environmental Sciences Department - University of Pavia, PAVIA, ITALY ; (2) Department of Geosciences - University of Padova, PADOVA, ITALY*

Coseismic effects may have a very short life; most of the sand boils and cracks triggered by the main shocks of the May 20<sup>th</sup> and 29<sup>th</sup> Emilia earthquakes have disappeared just a few days after, both because of the atmospheric agents, and due to human intervention. In order to create an accurate database of these small micro-morphologies, several photogrammetric surveys were carried out using digital reflex cameras. Fixing in three dimensions the impact that shocks have made on the landscape allows to extract many morphometric parameters with high precision and, in a relatively simple way. Structure From Motion (SFM) algorithms are well known computer vision technique for the ability of reconstruct sparse point cloud from overlapping photographs; when they are combined with fixed calibrated optical and complemented with robust stereo-matching algorithms, detailed three dimensional models can be built with great resolution and accuracy. In order to obtain high resolution DEMs several convergent images were taken trying to cover all the angles and the whole area of the object. The first step called alignment, the reconstruction of the photograph shooting position is done by SFM that detect some images key points and subsequently correlates the movement of these along the image sequence. Once the basically geometry of the scene is known, dense stereo matching algorithm processes the scene trying to correlate every pixel for each photo in order to reconstruct a dense point cloud. Finally the obtained point cloud is triangulated and a detailed mesh is constructed. In order to build a local reference system suitable for use in GIS different targets of known size were distributed around every scene and ground control points were collected. More zenithal pictures were used to orthophotos production. Using this methodology we were able to develop DEMs with resolutions ranging from one millimeter for the small forms to some centimeter for the big ones.

**Digital Bathymetric Models (DBM) : multiple sources, multiple uses ... and multiple models. A comparison of known DBM for the Bay of Biscay**

*SCHMITT T.(1), BISCARA L.(1), LOUBRIEU B.(2)*

*(1) SHOM, BREST, FRANCE ; (2) IFREMER, BREST, FRANCE*

Bathymetry is vitally and economically important for our societies. Its primary use is to secure the transportation of goods and persons (navigation). Bathymetry also plays a key role in a variety of fields of marine geosciences (geology, oceanography, environmental, engineering ...) where it provides a driving physical variable for the description and monitoring of the environment. For example marine ecosystems, offshore resources, coastal risks are known to be correlated with the morphology of the seafloor. A detailed and representative morphological analysis is therefore dependant on the quality of the underlying digital bathymetric model.

Bathymetric data are nowadays commonly acquired using multibeam echo-sounders (swath mapping). But in reason of the vastness of the oceans and the cost for multibeam mapping, only 10% of the ocean is mapped with high resolution and accurate precision technology (Hall, 2006). Therefore, less accurate sources of data sets with lower density and accuracy (in both positioning and depth accuracy), such as historic (lead line or singlebeam surveys) or remotely sensed (satellite altimetry) data cannot be ignored.

In order to compute a representative bathymetric model, a number of different approaches are considered for both the selection of valuable datasets (resolution, sampling, processing of biases and/or noise, horizontal and vertical reference,...) and the interpolation models (Inverse distance weight, spline, ordinary krigging, ...). The main goal of this work is to propose a thorough description of existing bathymetric models, highlighting the advantages and disadvantages of the different approaches. The test area considered for this analysis is located in the Bay of Biscay, where a variety of morphological features exist and where multiple data types can be considered.

\*\*\*\*\*

**Graph theory - recent developments of its application in geomorphology**

*HECKMANN T.(1), SCHWANGHART W.(2), PHILLIPS J.(3)*

*(1) Catholic University of Eichstaett-Ingolstadt, EICHSTAETT, GERMANY ; (2) University of Potsdam, POTSDAM, GERMANY ; (3) University of Kentucky, LEXINGTON, UNITED STATES*

Graph theory has been widely applied across a range of disciplines as different as population and landscape ecology, sociology, economic and transportation geography, informatics and climatology – yet these disciplines have in common that they deal with systems consisting of multiple subsystems or compartments that are coupled by relations. Although geomorphic systems lend themselves to network representations (see e.g. Chorley and Kennedy's systems approach to physical geography, 1971), the application of the conceptual and methodological toolbox of graph theory has been quite rare and restricted. In the 1960ies, graph theory was used to study the topology of river networks; since the 1970ies, studies in geomorphometry have employed it to model the topological structure of topographic surfaces.

The recent re-discovery and development of graph theory applications in geomorphology run on two lines. (a) The spatially explicit analysis of sediment cascades in geomorphic systems where nodes represent their compartments (depending on the spatial scale of the study the latter can be single landforms or larger terrain subunits up to whole catchments), and edges represent the linkage of system components through water or sediment flux. This approach is closely related to the analysis of hydrological and/or sediment connectivity. (b) The analysis of geomorphic systems whose properties are represented by graph nodes, and the relations between them by graph edges. Graph theoretical measures, derived e.g. by eigenvalue analysis of the adjacency matrix, have been shown to reflect system properties such as synchronization and scale relations.

Our contribution reports on these recent developments. We present case studies and discuss future applications in geomorphology that could benefit from graph theory.

### **Spatial distribution of the sinkhole and sinkhole affecting factors in the vicinity of Karapınar (Konya, Central Turkey)**

OZDEMIR A.

*Selcuk University, KONYA, TURKEY*

There are several hundreds of sinkholes in the vicinity of Karapınar. Agricultural irrigation has accelerated the formation of sinkholes. About 20 big sinkholes occurred within the territory of the Obruk Plateau between 1970 and 2012. Formation of sinkholes is the most serious geological hazard in the study area, because they can damage engineering structures, settlement and agricultural areas. There is no study conducted on distribution of sinkholes in this region. In this study, spatial distribution of the sinkholes existing in the region and the factors affecting sinkhole formation were studied through the geographical information systems. In the study, first of all, 182 sinkholes, which had been formed in the region, were determined through a topographical map by examining the digital elevation model produced by using this map. Then, they were mapped after they had been checked through the field studies. On the other hand, topographic, geomorphologic, geologic and hydrogeological 30 factor maps, which were considered effective in sinkhole formation, were produced to investigate their relation with sinkholes. According to this investigation, it was determined that sinkhole formation around Karapınar has become more concentrated in the areas in which topographic elevation is low (972-1081 m). The sinkholes across the region have generally been formed as a result of dissolution of Neogene aged lacustrine Insuyu formation made of limestone and clayey limestone. Furthermore, sinkhole formation increases as drainage lines and faults become closer (<1000 m) and cover thickness decreases (<30 m). As a result, factors affecting sinkhole formation were identified. Injuries and property losses caused by sinkhole formation may be prevented or reduced by using sinkhole susceptibility and risk maps, which may be produced according to these factors.

\*\*\*\*\*

### **River basins of Russian Plane: geomorphometrical analysis and geomorphological zoning**

MALTSEV K., MALTSEV K., YERMOLAEV O.

*Kazan Federal University, KAZAN, RUSSIAN FEDERATION*

The article describes computer-aided delineation method for little river basin watersheds of Russian Plane. First, algorithm and vector planar map of basin's watersheds was created for this territory. The digital elevation model "GTOPO30" was used for creating 27630 river basins of 3-4 order. The average catchment area of these basins is 107 km<sup>2</sup>; minimum area - 1.4 km<sup>2</sup>; maximum area - 430 km<sup>2</sup>. Estimating of model accuracy was accomplished. The geomorphometrical analysis was realized for every river basin. Elevation, slope, magnitude of average catchment area, plan and profile curvature was calculated.

Second, algorithm of computer-aided geomorphological zoning was developed for Russian Plane. The self-organizing map (kind of artificial neural network) was used for this task. The basins were used for zoning as operational-territorial units. The morphometric parameters of river basins were involved in this process as classification features. The main classification features were elevation and slope. The 225 initial classes were used for zoning. This count was reduced to 13 thematic classes at the last stage of classification.

The verification of computer-aided zoning map shows rather good coincidence with map, which was made earlier by traditional method.

The laws of "Horton-Rzhanitsin" were validated for rivers from different natural zones and morpho-genetic types of relief. The regularities between count of different orders water flows, average length and bifurcation coefficient were confirmed during of spatial analysis.

### **Active hydrological stream network extraction: a GIS approach based on DEM and climate data**

CORNU J.F.(1), CAROZZA J.M.(2), OBERDORFF T.(1)

(1) UMR BOREA, IRD 207, National Museum of Natural History, PARIS, FRANCE ; (2) University of Strasbourg - GEODE UMR 5602, STRASBOURG, FRANCE

Rivers are major features of the Earth surface system. They are fundamental in shaping processes of continental landscape, life and ecosystems. Therefore, hydrological stream networks are among most common datasets used in GIS for hydrology, fluvial geomorphology or freshwater ecology applications. The large success of HydroSheds as other global (e.g. TRIP, STN-30, Hydro1k,) or regional packages (e.g. CCM2, etc) shows the expectation of the scientific and expert communities for such data.

Commonly, hydrological stream networks are mostly extracted from DEM based on geomorphological (e.g. concavity characters, etc.) and/or hydrological approaches (e.g. upstream area derived from flow direction models). Nevertheless, such approaches design the potential stream network (talweg) that reflect past fluvial erosion activity or a sufficient theoretical upstream precipitation catching area. Different landscape upstream area thresholds or geometrical (i.e. fractal dimension) and geomorphological characteristics (i.e. slope/area relationship) of the hydrological stream network are used to force the potential stream network to mimic the active one. Unfortunately, such approaches are spatially and temporally climate dependent and can not be used in the context of climate change.

To overcome these limits, we propose to include a climate component in the study of the slope/area relationship. Climate component will firstly be taken into account indirectly by climate segmentation of watersheds and in a second step directly by a climatic weighting of the area component in the slope/area relationship. We will apply and assess performance over the African continent with a reference hydrologic network previously digitalized on paper sheet maps. Finally, we will use 2090 IPCC climate projections to assess the future contraction/dilatation of stream networks.

\*\*\*\*\*

### **Assessing drainage network extractions in a low-relief area from Lidar-derived DEM and DEM-derived from other data sources: a case study from the Cuvelai Basin, Namibia**

PERSENDT F., GOMEZ C.

University of Canterbury, CHRISTCHURCH, NEW ZEALAND

Accurate delineation of drainage networks is crucial for modelling hydrological, hydraulic, and floodplain processes. Low resolution gridded DEMs are however not well-suited for drainage network extraction in areas of low topographical variations, especially when gridded DEMs are of low resolution. One solution of this problem is the usage of Airborne light detection and ranging (LiDAR) that provides high-resolution DTM (digital terrain model).

In the area of the Cuvelai Basin, in Namibia, sinuosity and longitudinal root-mean-square-error (LRMSE) analysis methods will be used to compare the extraction of drainage networks with the traditional grid-based delineation using TauDEM and a spectral imagery method. Moreover, this comparison has also been extended to the capacity of the different techniques to extract characteristics of the drainage networks and related parameters such as the numbers of streams, the stream orders, and the stream lengths.

The results show that the LiDAR-derived DEM present notably additional detail, in particular useful to identify low-order stream (headwater) segments. The study also proved that, with the significantly increased resolution of LiDAR data, smaller grid sizes yielded superior stream network delineations, based for example on LRMSE and sinuosity. The study concludes that drainage networks of low-land area with limited topographic variations should be preferentially derived from LiDAR-derived DEM and when possible combined with multi-, hyper-, and spectral imagery analysis to reach best delineation of drainage networks.

### Semi-automated identification of landforms intensity by geomorphometric signature

VASCONCELOS V.(1), CARVALHO JUNIOR O.A.(1), MARTINS E.D.S.(2), COUTO JUNIOR A.F.(1), GUIMARÃES R.F.(1), GOMES R.A.T.(1)

(1) University of Brasilia, BRASILIA, BRAZIL; (2) Embrapa Cerrados, BRASILIA, BRAZIL

Landforms extraction and classification from Digital Elevation Model (DEM) are main issue in geomorphometric studies. Several geomorphometric parameters have been described in an attempt to characterize the landscape, highlighting the altimetry and its first and second-order derivative. These attributes show different levels of generalization and applicability that should be used for specific conditions in the landscape stratification. One way to represent the terrain attributes in a landform is based on the establishment of a standard curve that describes it. In this paper, it is proposed the concept of geomorphometric signature, which is described as representative spectral curves of landforms attributes derived from DEM. The method considered a specific combination of pairs of curvatures: Longitudinal/Cross-section and Minimum/Maximum. There is composed a spectrum with the following curvatures: (i) longitudinal, (ii) cross-section, (iii) minimum, (iv) maximum. Thus, each grid cell unit (ground) is described by a curve of the attributes of the ground (spectrum) which can be compared with specific curves of landforms (signatures). This approach leads to the use of pattern recognition techniques from multivariate statistical methods commonly employed in digital processing of remote sensing images. The proposed method consisted in a classification system based on sequential architecture using *Shuttle Radar Topography Mission (SRTM)*. The procedures are based on hyperspectral image processing with the following steps: (a) reduction of the spectrum size, (b) reduction of the spatial size, and (c) identification of geomorphometric signatures using n-dimensional viewer. The results evidenced different landform classes and their intensities which represent distinct homogenous units in the studying area. The SAM classification using geomorphometric signature enabled a detection of hillside variations described by its spectral inflections.

\*\*\*\*\*

### Do highly resolved DEMs improve the quality of rockfall model output? - A case study from Central Spain

TANARRO L.M.(1), CORONA C.(2), STOFFEL M.(2), LUCIA A.(3), BALLESTEROS J.A.(4), TRAPPMANN D.(2)

(1) Dpto. Analisis Geografico Regional Y Geografia Fisica. Complutense University of Madrid, MADRID, SPAIN ; (2) Laboratory for Dendrogeomorphology. Institut of Geological Sciences. University of Berne, BERN, SWITZERLAND ; (3) Faculty of Science and Technology. Free University of Bolzano, BOLZANO, ITALY ; (4) A.I. en Peligrosidad y Riesgos Geológicos. Instituto Geológico y Minero de España, MADRID, SPAIN

Recent studies on rockfall focused on the development and application of GIS-based 3D simulation models. In general, these models use high resolution digital elevation models (DEMs) as main input.

In this study, two DEMs obtained from Terrestrial Laser Scanning (TLS; resolution 0.2m) and stereo-photogrammetric restitution (resolution 2m) were successively used as input for the Rockyfor3D model. Simulations were conducted in a small calcareous canyon, located in the northern piedmont of the Guadarrama Mountains, close to the city of Segovia (central Spain). The release area consists of a main vertical calcareous scarp of 15-20 m height and 65° slope linked to a talus of about 70 m length with a slope ranging from 15-35°. Soil has a low roughness although it is covered by boulders of past rockfalls.

Past rockfall activity is revealed by the presence of boulders on the talus. Additionally, a recent rockfall occurred during the night of 26-27 December 2011 and was accurately documented. The event was characterized by a mobilization of approximately 148 m<sup>3</sup> of rocks. The average size of the blocks, defined through their length, width and thickness, was 0.96 × 0.65 × 0.5 m. Most of the blocks were stopped at the foot of the scarp, but a large boulder (33 m<sup>3</sup>) travelled a distance of 64 m, leaving impact craters on its way downslope. The tracks of this boulder and the deposits of past events were used to validate the simulation runs.

In the simulation, the average and large-sized boulders of the recent rockfall reveal that both the TLS-derived DEM and the terrain model obtained with stereo photographs reproduce the trajectories and the reach of boulders in a similar way. Yet, for simulations with the largest boulder sizes, the TLS-derived DEM yields more realistic results in terms of travel pathways and extreme run out zones, whereas the DEM gathered with the stereo photographs tends to overestimate runout distances.

### **Geomorphological assessment of alpine watersheds using SLBL and steady-state profiles**

RUDAZ B., GAVILLET L., JABOYEDOFF M.

*University of Lausanne - Center of Research on Terrestrial Environment, LAUSANNE, SWITZERLAND*

The alpine topography is in a strongly transient state, with epigenetic gorges joining lateral valley to the main valley, and local cirques to the lateral valleys, creating strong, and thus unstable relief. Slope instabilities above torrential thalweg influence the torrent's sediment supply. Localisation of geomorphologically active areas inside a torrential watershed is thus crucial.

This method evaluates the geomorphodynamic state of a watershed using the DEM as input to determine the steady-state profile of the torrential streams, of their overlooking slopes, and of the long-term trend of such geomorphologic system, using the slope local base level method (SLBL) and the theoretical steady-state exponential longitudinal profile. This method gives respectively the steady-state profile of the streams, the total rock mass available above the actual thalwegs, and the rock mass available over a steady-state profile. In addition, the quaternary deposits volume stored inside the valley is estimated, based on the geomorphological map, again with the SLBL method.

The method is applied to five alpine torrential streams set in different geological settings and of different watershed area and to a complete mountain ridge. The legacy of the last glaciation is shown to be still dominating over torrential and gravitational processes, with little to no steady-state landforms being observed.

\*\*\*\*\*

### **Geomorphologic analysis method using ASTER GDEM v2 digital elevation model over the tropical rainforest: implementation to lakes problematic in Sangha National Park (Central African Republic)**

LEROUGE G., ROUSSELIN T., NAVARO B.

*Géo212, PARIS, FRANCE*

In the Sangha National Park tropical rainforest (SW of Central African Republic), photointerpretation detected a set of circular lakes in the middle of clearings. Old regional studies, through analogy with other landscapes of the country, associate those lakes with sinkhole ponds, traces of a deep karst under continental sands. This karstification, probably developed in a Proterozoic calcareous schist suite with unknown structural organization, has never been confirmed through field work, due to the difficult access to the area. With a SPOT 5 scene (2.5 m resolution) and a 30 m resolution digital elevation model ASTER GDEM v2, we conducted a geomorphological interpretation. Rainforest that covers the whole region, intact and only cut by the Sangha River and its tributaries, is an obstacle to classical photointerpretation. SPOT interpretation can accurately extract the river system through foliage, but reliefs remain imperceptible. On the other hand, GDEM resolution highlights the canopy irregularities related to topography. Shelf breaks inherited from selective erosion of the lithology are accessible. Their morpho-structural analysis and the analysis of the river system geometry show that the lakes spatial distribution is mainly controlled by complex and asymmetrical eroded anticline lines, with overall N-S axis, related to the side of a large dome located further east. This structure is intersected by two major directions of fracturing, NW-SE and NE-SW, the second corresponding to strike-slip fault. Lakes appear arranged in the axial and uniclinal coomb valleys of fold. Anticlinal ridge and crests guide flows and communication possibilities between these different man-made lakes. Based on a DEM available worldwide, our method allows to better understand and lead reconnaissance field work of those complex and poorly accessible areas.

### Remote sensing and GIS for environmental fragility assessment in the upper Coxim River Basin, Brazil

BACANI V.(1), SAKAMOTO A.(2), QUÉNOL H.(3), LUCHIARI A.(4)

(1) UNIVERSIDADE FEDERAL DE MATO GROSSO DO SUL, AQUIDAUANA, BRAZIL ; (2) UNIVERSIDADE FEDERAL DE MATO GROSSO DO SUL, TRÊS LAGOAS, BRAZIL ; (3) UNIVERSITÉ DE RENNES 2, RENNES, FRANCE ; (4) UNIVERSIDADE DE SÃO PAULO, SÃO PAULO, BRAZIL

The watershed of the Upper River Coxim (UCB) has an area of approximately 1375 km<sup>2</sup> located in the municipalities of São Gabriel do Oeste and Camapuã in the state of Mato Grosso do Sul, Brazil. It is pertinent to emphasise that the headwaters of watershed of the UCB occur on the Planalto of Mato Grosso do Sul state in the flow direction of Coxim-MS to the Pantanal plain. The aim of this work was to evaluate the environmental fragility of the UCB using fuzzy logic implemented at a Geographic Information System to propose a model of physical-territorial management through the preparation of an environmental zoning. The theoretical and methodological basis consisted of environmental integrated analyses starting from the systemic perspective of the concept ecodynamics unities. Spatial data used were arranged in a database implemented in a Geographic Information System (GIS). It consists in topographic maps at 1:100.000 scale, satellite image Resourcesat-1 LISS III (23.5 m), SRTM interferometric radar image (30m interpolated), thematic maps existing and field data. The generation of the physical-territorial management model was carried out considering preparation of UCB relief mapping, potential natural erosion, land-use and land-cover, environmental fragility and, environmental legislation. Results indicated a significant relationship between landforms and their uses: mechanized agriculture in the Chapada of the São Gabriel and livestock development on the Plateau Taquari hills. The major areas of environmental degradation were identified in the lower course associated with livestock activity mapped as the highest potential erosion and high fragility area. The guidelines set out by the type of land use proposals were: Priority areas for permanent preservation, priority area for rehabilitation and preservation and areas for sustainable use.

\*\*\*\*\*

### GIS-based methods to evaluate morphometric characteristics of small catchments within a debris-flow susceptibility assessment approach at a regional scale

BERTRAND M.(1), LIÉBAULT F.(1), PIÉGAY H.(2)

(1) Irstea, SAINT-MARTIN-D'HERES, FRANCE ; (2) CNRS UMR 5600 Plateforme ISIG, LYON, FRANCE

Debris-flows are recognized as one of the most damaging phenomenon in mountainous environments. Within a debris-flow susceptibility assessment approach, we propose GIS and statistical methods to identify catchments prone to trigger and propagate debris-flows. As a first step of debris-flow susceptibility assessment, we develop methods that allow the characterization of the torrents and catchments morphometry, and the extraction of control indicators of debris-flow susceptibility, i.e. the Melton ruggedness index and the channel slope. The Melton indicator is a normalized index of the gravitational energy of the catchment. Those two indicators combined within a logistic regression model give a probability of debris-flow response of the catchment.

The morphometric indicators are extracted from a spatial analysis of the 25m DEM along the hydrographic network in our study area (Southern French Alps). We proceed into three steps: (1) we identify the network we wanted to characterize (drainage area greater than 0.1km<sup>2</sup>), (2) we form geomorphic fluvial units, which are homogeneous reaches in term of slope (HSR), (3) we extract both Melton index and slope for each HSR and the probability of debris-flow response of the catchment.

As a second step, we cumulate erosion patches areas that are connected to the hydrographic network. Erosion patches are first automatically mapped with an object-oriented supervised classification of infrared orthophotos. The connectivity is addressed using a topographic indicator (convergence) whose scalar level is chosen through a proxy. It is based on the study of the relationship between connected erosion area cumulated from sources to the HSR and the geomorphic response materialized by the active channel width.

The most sensitive HSR are identified with the analysis of the DEM. GIS allows an automatic application of debris-flow susceptibility assessment through the characterization of morphometric indicators and sediment supply for each HSR.

### **A multi-scale GIS and hydrodynamic modelling approach to fish passage assessment: Clarence River gorge, NSW Australia**

*REINFELDS I.(1), BONETTI R.(2), BUTLER G.(3), BRODERICK T.(4), CHISHOLM L.(2)*

*(1) NSW Office of Water, WOLLONGONG, AUSTRALIA ; (2) University of Wollongong, WOLLONGONG, AUSTRALIA ; (3) Department of Primary Industries, GRAFTON, AUSTRALIA ; (4) Northern Rivers Catchment Management Authority, GRAFTON, AUSTRALIA*

Natural barriers such as waterfalls, cascades and rapids limit the dispersal and in-stream range of migratory fish, yet little is known of the interplay between these gradient dependent landforms, their hydraulic characteristics and flow rates that facilitate fish passage. The resurgence in dam construction in numerous river basins world-wide provides impetus to the development of robust techniques for assessment of the effects of downstream flow regime changes on natural fish passage barriers and associated consequences as to the length of rivers available to migratory species. This paper outlines a multi-scale technique for quantifying the magnitude of natural fish passage barriers in river systems and flow rates that facilitate their passage. First, a GIS based approach quantifies channel gradients for the length-of-river from a high resolution DEM, setting the magnitude of potential passage barriers in a length-of-river context. Second, LiDAR and bathymetric survey based hydrodynamic modelling is used to assess flow rates facilitating passage across barriers identified by the length-of-river gradient analysis. This multi-scale approach to fish passage assessment is applied to the Clarence River gorge, NSW Australia, where a series of 2-8 m high waterfalls situated only 35 m above sea level form one of the most severe natural barriers to fish movement at such a low elevation for a major river system on the eastern Australian seaboard. The fish passage analysis, confirmed by independent data on actual fish migration from an acoustic fish tagging and tracking program, highlights the importance of small floods with an average recurrence interval of 1.25 years in facilitating upstream passage across this natural barrier. Flow rates facilitating passage for Australian bass are exceeded, on average, for less than 2% of days per year highlighting the sensitivity of such barriers to flow regimes changes.

\*\*\*\*\*

### **GIS analysis of asymmetric valleys dissecting Pleistocene uplands in and around Tokyo, Japan**

*MORIOKA T.(1), OGUCHI T.(2), LIN Z.(3), YOSHIDA H.(4)*

*(1) Graduate School of Science, Univ. Tokyo, TOKYO, JAPAN ; (2) Center for Spatial Information Science, Univ. Tokyo, KASHIWA, JAPAN ; (3) Department of Earth Sciences, Zhejiang Univ., HANGZHOU, CHINA ; (4) School of Arts and Letters, Meiji Univ., TOKYO, JAPAN*

Previous studies pointed out that in valleys dissecting the Musashino upland in and around Tokyo, north- or northeast-facing valley-side slopes are gentler than south- or southwest-facing slopes. This asymmetry has been attributed to different effects of freezing and thawing due to microclimatic differences and tectonic ground tilting in northern direction. However, the previous studies did not quantitatively analyze the shape of valley-side slopes. Using a high-resolution DEM and GIS, we quantitatively examined valley asymmetry for six river valleys in the Musashino upland and the nearby Omiya upland. Lines perpendicular to each valley were set at an equal interval to derive many cross sections. Analysis of section form indicates that two of the six valleys have distinct asymmetry with gentler valley-side slopes facing N or NE, confirming the result of the previous studies. Two other valleys show relatively weak asymmetry, and the rest two valleys are almost symmetric. This result disagrees with the previous studies which attributed valley asymmetry to a factor affecting a wide area in a similar manner.

Investigation of landforms around the valleys revealed that large-scale tributaries from the south or southwest tend to flow into the valley where asymmetrical cross-sections are observed. This means that abundant water and sediments supplied from one side pushed the main stream toward the opposite side to induce lateral erosion, resulting in the steepening of valley-side slopes on the northern or northeastern side of the river. By contrast, when gradients of only uppermost parts of valley-side slopes are measured, north- or northeast-facing slopes tend to be gentler in all valleys. At the uppermost slopes, running water is weak, and creep and small collapses of sediment containing volcanic ash are the main geomorphic processes. Therefore, freezing and thawing seem to account for the consistent asymmetry at the uppermost valley-side slopes.

### Response of channel offsets to active strike-slip faulting of the Red River fault

LIN Z.(1), CHEN J.(2)

(1) Department of Earth Sciences, Zhejiang University, HANGZHOU, CHINA; (2) Department of Earth Sciences, Zhejiang University, HANGZHOU, CHINA

The right-lateral Red River fault is one of the largest strike-slip faults on the southeast margin of the Tibetan Plateau. To understand the response of channels to the active strike-slip faulting during the Pliocene–present, strike-slip offsets of stream channels along the Red River fault are extracted and investigated from Quickbird images, ASTER GDEMs and field observation. Firstly, we focus on the small scale offsets of gullies. The small deflected gullies mainly distribute along the northern part of the fault and decrease to the southeast, to zero southeast of a major bend in the fault, reflecting the tendency of the strike-slip motion from the late stage of Late Pleistocene. The smallest offset we find is 5 m, and the stream offsets appear at various groups of 5–10 m, 20–30 m, 50–70 m resulted from repeated large seismic events. We further examine the channels without river capture. The relation between the progressive offset  $D$  and the upstream length  $L$  from the deflected point is analyzed, and a linear relation,  $D = aL$ , is identified. Based on it, the correlations among  $a$  values and strike-slip rate  $s$  and erosion rate  $E$  of drainage are inferred, and the average-slip rates along the fault are constrained, which range from 0.8 mm/y - 6.9 mm/y. Since the largest channel offset without river capture along the fault is around 400 m, the average-slip rates are for the late Pleistocene–Holocene period. Finally, for the large rivers that river capture repeated, we reconstruct the stream nets. It reveals an largest displacement of 27 km near the middle part of the fault zone, and the displacement decreases both to the northwest and southeast along the fault. Combined with the ages of rivers in these regions, the long term average-slip rates along the fault from Pliocene are assessed. The study helps to understand the Pliocene to present activity along the Red River fault.

\*\*\*\*\*

### Relationship between geomorphology and dry forest in Parana Valley, Goias, Brazil, using sensor modis images and morphometric data

HERMUCHE P., GUIMARÃES R., CARVALHO JUNIOR O., GOMES R.

University of Brasília - UnB, BRASILIA, DISTRITO FEDERAL, BRAZIL

The Paranã River basin, located in central Brazil, has one of the largest Dry Forests fragments in the country. This Cerrado vegetations type is currently rather fragmented, mainly due to selective logging and pastures expansion. Several investigations have been made in order to maintaining its endemic biodiversity and understanding forest landscape dynamics. This study aims to identify regional Dry Forests in Paranã River basin to assess the relationship with the geomorphological aspects. The Dry Forests identification was based on analysis of multitemporal images of vegetation index NDVI derived from MODIS sensor (period of 10 years), since this vegetation type has typical spectral behavior due to seasonal variations (with higher values during the rainy season and low values during the dry season). The geomorphological units map was defined based on morphometric parameters derived from digital elevation model (Hydroshed). The methodology can be divided in to the following steps: (a) multitemporal NDVI data acquisition for Dry Forests location, (b) elaboration of geomorphological map based on morphometric parameters derived from DEM, (c) validation of geomorphological map by field investigation and previous map, (d) comparison between the classified image from time series of NDVI and geomorphological map generated. The results showed that the methodology used was able to determine the Dry Forests location in Paranã River basin, and also allowed to determine regional geomorphological units using MODIS sensor data and morphometric parameters. Thus, the results attest that the Dry Forests have a strong relation to Karstic relief found in the study area.

**Landslide susceptibility zonation by exploiting GIS tools and two statistical methods: binary logistic regression and multivariate adaptive regression splines. A test in western Sicily (Italy)**

*CONOSCENTI C.(1), CIACCIO M.(2), GÓMEZ GUTIÉRREZ Á.(3), ROTIGLIANO E.(1), AGNESI V.(1)*

*(1) Dipartimento di Scienze della Terra e del Mare, Università degli Studi di Palermo, PALERMO, ITALY ; (2) Dipartimento di Scienze Agrarie e Forestali, Università degli Studi di Palermo, PALERMO, ITALY ; (3) Geoenvironmental Research Group, University of Extremadura, CÁCERES, SPAIN*

In the recent years advanced statistical methods and GIS tools have been frequently used to assess landslide susceptibility. The latter is estimated by establishing statistical relationships between landscape characteristics and spatial distribution of past slope-failures. These are mapped mainly by recognizing changes on slope morphology produced by gravity. Despite of this, most of the researches on landslide susceptibility do not consider that slope-failures modify topography and associate high probability of landsliding with topographic characteristics that differ from those that led slope-failures.

In this research we analyzed landslide susceptibility in the basin of the Malvello river with two statistical methods: binary logistic regression and multivariate adaptive regression splines. The study area, which extends for 51 km<sup>2</sup> in western Sicily (Italy), is characterized by large outcroppings of clays and marls and is severely affected by shallow landslides. Bedrock lithology and land use were included as predictive variables, in addition to a set of primary and secondary topographic attributes. The latter were derived from a digital elevation model where altitude of areas hosting landslides was interpolated from adjacent undisturbed portions of the slopes. We assume that these artificial surfaces represent the old topography more efficiently respect to the morphology of depletion and accumulation zones of landslides. Ten random samples, with the same number of positive and negative cases, were used to train and test the susceptibility models. Accuracy, as well as overfitting and robustness of the models, were evaluated by drawing receiver operating characteristic (ROC) curves and calculating the area under the ROC curve. In addition of comparing the performance of the statistical methods, the validation results allowed us to highlight advantages/drawbacks of reconstructing original topography of slope-failures when mapping landslide susceptibility.

\*\*\*\*\*

**Evolution of volcanic landforms by construction and destruction events constrained from DEM-based numerical reconstructions**

*LAHITTE P.(1), LAVIGNE F.(2), GERMA CHARBONNIER A.(3)*

*(1) Univ. Paris-Sud, Laboratoire IDES, ORSAY, FRANCE ; (2) Univ. Paris 1 Sorbonne, Campus Bellevue, MEUDON, FRANCE ; (3) Univ. Of South Florida, Department of Geology, TAMPA, FLORIDA, UNITED STATES*

Quaternary volcanic landforms result from a complex evolution, involving volcanic constructional events and destructive ones by collapses and long-term erosion. Applied here to Rinjani (Indonesia) and Conil-Pelée (Martinique Island) volcanic complexes, our GIS-based geomorphologic approach quantifies erupted or dismantled volumes by numerically modeling the successive volcanic topographies resulting from each main evolution stages. We extract from the current DEM points these the altitude of which are analyzed as still representative to the resultant remnant surfaces. A primary elevation surface is firstly adjusted to these points by modeling a first-order pseudo-radial surface defined by: i) a generatrix curve fitting the average concave-upwards volcano profile; ii) the location and elevation of volcano summit around which the generatrix is rotated to form the surface; iii) eccentricity and azimuth parameters that allow to stretch and contract the generatrix as it rotates around the summit to obtain an elliptically-shaped surface in planar section. Residuals between the input point's elevations and those obtained by the first-order modeled surface are interpolated by kriging. The resulting residual surface is next summed to the first-order surface to obtain the definitive primary surface elevation of the considered event adjusted to its second order variations due to local heterogeneity. Independently, evolution of previous modeled landforms by either erosion or flank or caldera collapse is computed. Each modeled surface is then compared to the evolved previous ones to define the actual geometry of the volcano after the newly modeled event and to generate a new unit map. Finally volumes, provided with measures of uncertainty, of each constructive or destructive event are computed by integration of the height differences between the pre- and post- event elevation surfaces. Such method allowed us to define up to 10 paleo-landforms on the favorable studied volcanoes.

## **Poster presentations:**

### **Use of aerial photograph interpretation and Geographic Information Systems to study tidal channel changes: an example from the Venice Lagoon (Italy)**

RIZZETTO F.

*Istituto di Scienze Marine - Consiglio Nazionale delle Ricerche, VENICE, ITALY*

The geomorphological transformations of modern tidal channels were examined to identify the effects of sea-level fluctuations (i.e. relative sea-level rise and tides) on wetlands (Rizzetto and Tosi, 2011; 2012). The study was carried out in a salt marsh area not particularly modified by human interventions and located in the northern Venice Lagoon (Italy). The two-dimensional planform changes in channel morphology were analyzed through the interpretation of a chronological sequence of ultra-high resolution aerial photographs and satellite images, spanning the past 73 years, using Geographic Information Systems. Only high quality photographs were examined to reduce errors deriving from their rectification during the georeferencing process and to guarantee both the exact geographic position of the channels and the accurate identification of their morphological modifications. The tidal networks were manually digitized and the obtained maps, each showing the planimetric features in a different year, were overlaid and compared to identify exactly the channel planform changes. These modifications were quantified and compared to the yearly data of both sea-level rise and tides to highlight the control of water-level oscillations on channel evolution. In particular, the effects of long- and short-term sea-level variations were distinguished. These results were made possible by the availability of a high number of images, which gave a real detailed evidence of tidal network development, not based on theoretical models.

#### References

Rizzetto F., Tosi L., 2011. Aptitude of modern salt marshes to counteract relative sea-level rise, Venice Lagoon (Italy). *Geology* 39 (8), 755-758. doi: 10.1130/G31736.1.

Rizzetto F., Tosi L., 2012. Rapid response of tidal channel networks to sea-level variations (Venice Lagoon, Italy). *Glob. Planet. Change*, 92-93, 191-197, doi: 10.1016/j.gloplacha.2012.05.022.

\*\*\*\*\*

### **River flux modeling**

PARROT J.(1), RAMIREZ NUÑEZ C.(2)

*(1) LAGE, Instituto de Geografía, UNAM, MEXICO D.F., MEXICO ; (2) Posgrado en Ciencias de la Tierra, UNAM, México, MÉXICO, MEXICO*

The present resolution of digital data allows doing detailed observations of the Earth surface, in such a way that river networks do not strictly correspond to a thin line drawing the thalweg, but to the real river surface the slope of which as to be researched. Then, by using Digital Elevation Models, the river slope must be integrated as an essential element of the land, especially for following flooding events. In many digital data, the limit of the water bodies is supported by a unique code. For this reason, it was necessary to develop the method presented here. Before obtaining the final DEM interpolation, the "soul" of the river bed surface is researched and obtained using a skeletonization such as the  $k \times k$  thinning treatment. The different altitude points of the river soul are obtained when this soul crosses the contour lines. Then it is possible to (a) define river segments, (b) calculate the length of the segments (number of pixels in a first approximation), (c) measure the slope rate of each segment, and finally (d) calculate the altitude step attributing the altitude value to each pixel and describing the river soul. Hexagonal dilation using two different structural elements of the mathematical morphology treatments is applied to each pixel component until reaching the river banks in order to define the altitude value of the river surface. The resulting values are reported to the curve line image before the final interpolation. The document obtained (32 bits raster DEM) represents an important contribution to the study of flooding areas, because it is possible to follow the general water movement as the slope can be considered as an analogical representation of the current.

**The logarithmic slope as a critical geomorphological parameter.**

PARROT J.(1), HERNÁNDEZ M.(1), RAMIREZ NUÑEZ C.(2)

(1) LAGE, Instituto de Geografía, UNAM, MEXICO D.F., MEXICO ; (2) Posgrado en Ciencias de la Tierra, UNAM, México, MÉXICO, D.F., MEXICO

Generally, angular values of the slope do not reflect the morphology of the areas that are relatively flat or that are characterized by a low slope. Morphological features are more obvious only when the angular value of the slope increases. This is the reason why we tried to enhance the morphological features of the more or less flat zones in order to obtain information about their roughness. In fact this roughness enhancement is peculiarly needed when studying, for example, flooding events or oil spills. The proposed method consists on calculating the logarithm of decimal slope values incremented by the value 1 as it is not possible to obtain the logarithm of zero. Then the logarithmic scale is normalized between 0 and 255 (8 bits) and the correspondences between gray tones thus obtained and the decimal slope values are reported in a table. This method has been applied recently to the study in the Coatzacoalcos region (State of Veracruz, Mexico) where accidental petroleum spills are frequent due to pipeline ruptures as well as regular flooding events.

\*\*\*\*\*

**GIS analysis as a tool for identification of preglacial large-scale landform assemblages and quantification of glacial erosional impact on northern shields**

EBERT K.

Stockholm university, STOCKHOLM, SWEDEN

The use of quantitative assessment methods in large-scale bedrock geomorphology remains scarce. Yet analysis and integration of DEMs with other digital data in GISs now allows us to rapidly analyze landform assemblages and patterns across huge areas.

I analyze areas within the glaciated Fennoscandian shield to investigate preglacial landform patterns as well as to assess the effects of glacial erosion on the preglacial shield surface. Analyses of all data available from land surveys and geological surveys in Fennoscandia are the input parameters in the database. In the DEMs of 50m and 25m resolution, hypsography, relative relief and slope angles show preglacial landform patterns like stepped erosion surfaces and inselberg clusters that are not visible on first sight and that are difficult to detect and show only by field work or other forms of remote sensing. Integration of these patterns with rock type and structure helps us to assess the influence of geology on the surface morphology. Slope angles and bedrock types are statistically coupled to drill core databases with bedrock depth information. This 3D terrain analysis enables a picture of surficial glacial streamlining and the removal of the preglacial weathering mantles, and thereby assessment and comparison of different degrees of glacial modification of the shield bedrock surface.

In combination with field validation, DEMs and GIS analyses have brought us much further in identifying patterns of glacial erosion as well as quantifying glacial erosion depth on the shield surface. We find clear defined areas with negligible erosion in proximity to areas with clear glacial streamlining. However, even in areas of strongest glacial erosion, the preglacial large-scale bedrock landscape prevails. Comparison of these areas infers that maximal glacial erosion of shield bedrock was in the 0-50 m range, with extensive areas showing <10 m of erosion.

### **Effect of clear-cutting on landslide occurrences: Rainfall thresholds and topographic analysis at Mt. Ichifusa, Japan**

SAITO H.(1), MURAKAMI W.(2), DAIMARU H.(2), OGUCHI T.(1)

(1) Center for Spatial Information Science, The University of Tokyo, KASHIWA, JAPAN ; (2) Forestry and Forest Products Research Institute, TSUKUBA, JAPAN

Vegetation cover is an important factor influencing the occurrence of rainfall-induced landslides. We analyzed the effect of clear-cutting on initiation of landslides in terms of empirical rainfall thresholds at Mt. Ichifusa, Japan, which is characterized by granite rocks. Rainfall-induced landslides had occurred frequently in the northern part of Mt. Ichifusa since clear-cutting began around 1967. We interpreted orthorectified aerial photographs using GIS, and mapped clear-cutting areas and landslides in 1969, 1976, 1980, 1985, 1990, 1995, 1999, and 2005. We then analyzed all rainfall events in the warm season during 1952–2011 using raingauge data obtained around Mt. Ichifusa. This study used basic rainfall parameters, such as the mean rainfall intensity (mm/h), the peak rainfall intensity (mm/h), the duration (h), the cumulative event rainfall (mm), and the soil water index (SWI). Finally, we examined empirical rainfall thresholds for landslide occurrences in each period of aerial photographs, and the relation between landslide occurrences and topographic characteristics from DEMs.

Results show that landslides seldom occurred at the beginning of clear-cutting, but frequently occurred after clear-cutting, such as during 1976–1980, 1980–1985, and 1990–1995. In these periods, many landslides occurred at concave-steep slopes in the clear-cutting area, although few landslides occurred in the non-clear-cutting area. The rainfall analysis indicated that rainfall thresholds after clear-cutting declined to the one-third of those at the beginning of clear-cutting and in the non-clear-cutting area. This result is important for future forest management and landslide hazard assessments, and should be verified in other clear-cutting areas in Japan and other countries.

\*\*\*\*\*

### **Cluster analysis in watersheds using morphometric parameters in the state of Goiás, Brazil**

GOMES R., MENKE A., GUIMARÃES R., CARVALHO JÚNIOR O.

Universidade de Brasília, BRASILIA, BRAZIL

Basin is the fundamental unit in environmental studies, which are related to land form and its changing process. Watershed is used in environmental studies, mainly in morphometric studies, based on geographic information systems. The geomorphometry is defined as a science of quantitative analysis of the surface. In geomorphometry, the Digital Elevation Models (DEMs) are the main source of information. In this work, we use the model HydroSHEDS. From this model, it was possible to derive maps as slope, curvature, aspect, contribution area and flow direction. This work aims to obtain a classification of basins, from cluster analysis method, using morphometric attributes of drainage basins in the state of Goiás, Brazil. The methodology can be divided into the following steps: (1) HydroSHEDS SRTM processing, (2) automated basin delineation, (3) calculation of morphometric attributes, (4) Classification of drainage basins from K-means method. The K-means method allow to obtain groups with similar morphometric characteristics based on Euclidean distance. The maps show good results for basins classification. The classes have high correlation with the morphometric attributes and allowed to define units based on these attributes. The method can be extended to other morphometric studies, either regional or local. We obtained a geomorphometric units map with four classes: class 1; class 2; class 3; and class 4.

**GIS application in morphometric-statistical analysis of relief in the upper Dniester River catchment (East Carpathian Foreland, Ukraine)**

HOLUB B.

*Maria Curie-Sklodowska University in Lublin, Department of Geoecology and Palaeogeography, LUBLIN, POLAND*

Region of the East Carpathian Foreland (Carpathian Foredeep zone) in its north-western part is crossed by the European watershed between the basins of northern and southern seas. In this section it is the watershed between the San River (Baltic Sea) and Dniester River (Black Sea). The studies of relief evolution in this area indicate the common functioning of both rivers in the older part of Pleistocene when the San River was a tributary of the Dniester River, and again, temporarily, during the Central-European maximum extent of the San (= Elsterian, Oka) ice sheet, which reached the Carpathians margin and covered the valley of the upper Dniester River.

Within the Carpathian Foreland the area of the Dniester River catchment is composed of three partial catchments: Bolozivka, Stryvigor, and upper Dniester. In order to obtain a quantitative description of these catchments, there was used the classification of rivers according to Strahler, which was also the basic layer in all spatial analyses and the key to their interpretation. The selected physiographic indices of the partial catchments were supplemented with the morphometric-statistical parameters, which were calculated and presented graphically (among other things as base-level maps, maps of isolongs, goniobases) in detail and in various combinations of mutual connections using the GIS methods. Based on these data, many conclusions about relief of the upper Dniester basin were drawn, as well as about neotectonic activity of the area under study.

\*\*\*\*\*

**Coastal Quakes: using global datasets to expose an underrated hazard**

HART D.E., GOMEZ C., BEALING P.

*University of Canterbury - Geography, CHRISTCHURCH, NEW ZEALAND*

Since the late twentieth century, coastal populations have been growing at twice the global average. In this context, there exists an opportunity to mitigate future development-disaster cycles by understanding how coastal regions interact with a range of natural hazards. For example, in 2007, Woodroffe identified cities built on Holocene progradational plains as susceptible to non-linear threshold responses to accelerated sea level rise. Recent advances in earth system monitoring and measurement mean that we now have key global datasets to aid in such analyses. This paper describes novel research into coastal city vulnerability to earthquake disasters. Analysis of global DEMs along with seismic, geomorphic, population and infrastructure data shows that coastal cities are disproportionately susceptible to earthquake effects and earthquake-induced hazards.

On the surface, proximity to sea level means that even minor levels of uplift or subsidence across coastal plains can dramatically alter shoreline features and states while the vertical faces of relict marine cliffs are vulnerable to collapse. And where development occupies narrow coastal plains or complex shores, lifelines vulnerabilities are exacerbated by a lack of inbuilt network redundancy. More deeply, patterns of land damage including liquefaction, lateral spreading, slumping, and subsidence result from seismic interactions with coastal and fluvial deposits and elevated water tables. Evidence from a number of recent and historical coastal earthquakes is used, along with global dataset analyses, to forecast likely patterns of earthquake effects along coastal margins worldwide. These include initial responses to seismic events as well as the cascade of 'other' adjustments that can amplify pre-existing coastal hazards not traditionally linked to seismic events.

## Landform prediction and environmental constraints ' examples and geomorphological implications

ETZELMULLER B.(1), HJORT J.(2), LILLEOREN K.S.(1)

(1) University of Oslo, OSLO, NORWAY ; (2) University of Oulu, OULU, FINLAND

The combination of digital elevation models, digital terrain analysis and geomorphological maps or landform inventories allows for statistical prediction of distribution for landforms. In these analyses different types of predictor variables (topography, climate, geology) were used to evaluate the probability of certain landform existence within an environmental setting. Transferability of different types of statistical models between different regions in northern Europe has been tested earlier, along with scale problems and the relative importance of input variables. Overall, these models perform very well within certain limitations, resulting in AUC-values above 0.8. The exploration of response curves now allows for the evaluation of environmental constraints of particular landforms, leading to a better understanding of land-forming processes and ultimately landscape development. In our study we have evaluated the distribution of gravitational landforms in the periglacial realm, mainly solifluction and rock glaciers in southern and northern Norway, Svalbard and Iceland. The presentation discusses distributional patterns, which clearly are relatable to geomorphological processes and climatic development during the Holocene.

\*\*\*\*\*

## The ecological-geomorphological assessment of urban areas using GIS (a case study Yerevan)

ASMARYAN S.

Center for Ecological-Noosphere Studies NAS RA, YEREVAN, ARMENIA

Yerevan is the capital and social, economical center of Armenia. The most part of the industrial life with the population is concentrated here. So it increases the environmental load. The city of Yerevan grows spatially and the future spatial development requires data about the stability of the surface, which supposes special investigations. The main goal of this study was to assess the real state of the urban surface and to reveal the suitable and stable places for Yerevan future development. The tasks to achieve the goal were the analyzing the qualitative and quantitative characteristics of the relief of Yerevan city, analyzing and revealing the man made forms urban relief, revealing the characteristics of the distribution of man-made deposits, assessment of urban relief stability of Yerevan city. In this study the ArcGIS software were used. The Weighted overlay process in Model Builder has been used to do the analysis. To combine input themes with different kinds of data, we assigned the values in the input themes to values on a common evaluation scale. We weighted the themes of relief morphogenetical types exogenous relief forming processes, man made relief forms and deposits, seismic characteristics, hypsometry, slope inclination, slope exposition, depth and density of erosion dissection as to their influence. We have chosen three-point scale. Running the model we get the map of the relief stability of Yerevan city. As a result of the comparison of remote sensing data and the topographical maps of early data the principals of land-use the dynamic of the growth, the transformation of the territory of Yerevan city are found out. The geomorphological and environmental data base is formed, which we plan to update with the geochemical and geophysical data in order to perform the geomorphological and geochemical risk assessment.

### **Mass-Conservative Depression Removal from DEMs**

VAN DE WIEL M.(1), TEMME A.(2)

(1) *University of Western Ontario, LONDON, ONTARIO, CANADA* ; (2) *Wageningen University and Research Centre, WAGENINGEN, NETHERLANDS*

Many DEMs contain depressions, *i.e.* enclosed areas of lower elevation than the surrounding area. Regardless of whether these are real features of the landscape or whether they are spurious features arising from measurement error, they are usually considered undesirable elements in a DEM for many hydrological or geomorphological applications, because they hinder continuous surface flows. Consequently, many algorithms have been developed for eliminating DEM depressions, either by filling the low-lying area or by removing terrain that is obstructing the natural flow path. These techniques have the drawback of either artificially creating new elevation or artificially eliminating elevation from the DEM, *i.e.* the algorithms are not mass-conserving. Some combined algorithms have been developed that try to minimize these volume differences, but currently no algorithm achieves full mass-conservation.

This paper presents a new algorithm of removing depressions. The algorithm is, by design, fully mass-conservative and essentially relies on a redistribution of the DEM elevations in the depressed area and its downstream outflow zone. The algorithm is intuitive and straightforward to implement. For the current research it has been coded as a stand-alone program, but it can easily be implemented in existing terrain analysis software or GIS packages. Tests on a range of DEMs (artificial, LiDAR, SRTM, Aster GDEM2) show that the algorithm works well and does exactly what it is intended to do: remove pits and depressions from a DEM, whilst maintaining the total mass of the terrain. The corrected DEMs also avoid the spurious parallel drainage that often occurs with other depression removal algorithms. Computationally, however, the mass-conserving algorithm is slower than some of the existing non-mass-conserving routines.

\*\*\*\*\*

### **DTM models of coastal dune relief and dynamics as a tool for coast erosion and flooding prediction**

LABUZ T., OSOCH P.

*University of Szczecin, Faculty of Geosciences, SZCZECIN, POLAND*

Research on the influence of the sea on the coastal zone is an important element of the forecast of coastline changes and flooding threats. <span title="W badaniach projektu FoMoBi zwraca się uwagę na zmiany te, które zachodzą na akumulacyjnych odcinkach brzegu wydmowego w Polsce.">FoMoBi (www.fomobi.pl) project pays attention to the dune relief changes that occur on accumulative part of Polish coast. These changes are mainly periodic or continuous coastal erosion: reducing beaches and dune undercutting land structures.

Research are carried out using modern surveying equipment based on satellite location of surveyed sites. Application of GPS RTK technology allows high accuracy to obtain morphometric data forms found in marine coastal zone. Surface measurements for DTM creation is a key to understand potential threats for weak coastal structures. It also can be used for measurement of material volume changes due storm surge affection or designate potential areas that may be flooded. On the Polish Baltic coast each year storm surges are flooding area up to 3.5 m amsl. Runnels or previously developed storm gates, foot paths and other concave forms in coastal dune belt is a potential threat.

### Dynamic effects of catchment morphology in the Alcabrichel estuary, Portuguese Estremadura

ALEIXO C., RAMOS-PEREIRA A., TRINDADE J.

Centre of Geographical Studies, Institute of Geography and Spatial Planning, Univ. Lisbon, LISBON, PORTUGAL

This research has been accomplished under the project PCDT/CTE-GIX/104035/2008. Its objective is to identify the sediment supply of the alluvial plain estuary of River Alcabrichel, and mainly to explain the dominance of finer grain size sediments in the floodplain of Maceira despite the abundance of coarse sediments in the drainage basin.

The geomorphology of the basin is conditioned by the presence of consolidated and unconsolidated Mesozoic sedimentary materials, with different lithological competence that prints sharp differences into the relief, with presence of compact limestone gorges that confer a selective and differential action to agents of erosion and modelled landscape.

The sediments of a borehole in the floodplain of Maceira were studied for textural analysis. To access the apparent paradox mentioned above, several indices have been used, including sediment transport index (STI), stream power index (SPI) and wetness index (WI), and the results are discussed with those obtained with the core sediment samples.

The effect of topography on erosion (STI) is more pronounced in limestone, but the chemical weathering formed clay minerals. SPI shows similar results to STI. WI indicates that the areas of highest sediment supply stay upstream the first limestone gorge.

The hydrological modelling (with ILLWIS software) through these indices indicates that the coarser sediments are deposited upstream the geomorphological barriers and only the finest grain size of sediments reach the downstream floodplain of Maceira. The importance of the morphology will be pointed out.

Acknowledgements: This research was funded by research project, PCDT/CTE-GIX/104035/2008–FMI 5000-Environmental changes: Fluvio-marine interactions over the last 5000 yrs, from Portuguese Science and Technology Foundation (FCT-MCTES). Aleixo acknowledges the FCT scholarship of FMI 5000 Project.

\*\*\*\*\*

### Graph theory: the Ford and Fulkerson, and the Edmonds-Karp Algorithms to Model Dynamic Sedimentary Systems

GOMEZ C.(1), WASSMER P.(2), STARHEIM C.(1), HADMOKO D.S.(3), LAVIGNE F.(4)

(1) University of Canterbury, CHRISTCHURCH, NEW ZEALAND ; (2) Laboratoire de Géographie Physique, UMR8591, MEUDON, FRANCE ; (3) Universitas Gadjah Mada, Department of Geography, YOGYAKARTA, INDONESIA ; (4) Université Paris 1 Pantheon-Sorbonne, LGP UMR8591, PARIS, FRANCE

Graph theory is the study of graphs, which are mathematical structures used to model pairwise relations between interconnected objects in a system. In Geo-sciences, it has been mostly applied to transportation modeling, as it offers a precise and effective evaluation of flows organized in systems. It also enables researchers to evaluate the effects of different network modifications on overall system flows and assess subsequent reorganization of the network.

Despite the potential advantages in other fields of research, graph-theory has been largely ignored in environmental science and geomorphology.

The present contribution therefore resolves to test two graph-theory algorithms (the Ford and Fulkerson algorithm and the Edmonds-Karp algorithm) and how they can be successfully used with GIS (Geographical Information System) to assess change in an environmental network.

Early results have demonstrated that graph-theory may prove to be a valuable geomorphological tool in at least four applications including: (1) detecting the tipping points in a system; (2) identifying regions particularly vulnerable to changes in sediment supply, erosion rates, and formational processes, (3) identifying the maximum tolerance of a network before the flow modifies it (e.g. diversion) and; (4) finding preferential pathways depending on system energy. These algorithms and findings have been incorporated into GIS using the Matrix representation of networks. The successes, limitations and future directions of incorporating graph-theory into a GIS using Matlab and ArcGIS are discussed.

### **Morphometric models of lake's bottom as necessary tool for limnological investigations**

NAUMENKO M.

*Institute of Limnology of Russian Academy of Sciences, ST.-PETERSBURG, RUSSIAN FEDERATION*

Detailed digital maps of lake bottom are used for many purposes included comprehensive resources management plans, environmental impact assessments, limnological and geomorphological investigation.

The creation of digital bathymetric models of lakes allows not only collecting the data on depths and coasting line in a standard format, but also to estimation major morphometric characteristics of the reservoirs.

To calculate the water, thermal and chemical budgets of large lakes, it is important to know the distribution of their surface areas and volumes with depth. The built bathymetric models of largest European lakes - Ladoga and Onega have allowed updating the morphometric characteristics and can be used for ecological modeling of their lakes. Their models have been used during a two decades for thermal and hydrophysical investigations. We calculated two dimensional spatial autocorrelation functions for determination of relationship temperature and depth distribution/

In the presentations we discuss a variety of lake bottom digital models of the world and their usage for limnological investigations.

\*\*\*\*\*

### **Morphometric analysis of alluvial fans and source basins for regions with different climates**

OCHIAI S.(1), OGUCHI T.(2), HAYAKAWA Y.S.(2)

*(1) Graduate School of Science, Univ. Tokyo, TOKYO, JAPAN ; (2) Center for Spatial Information Science, Univ. Tokyo, KASHIWA, JAPAN*

Previous studies examined relationships between morphometric properties of alluvial fans and source basins. Although the increased availability of global DEMs allows us to explore details of the relationships in various regions of the world, such studies are still limited. Therefore, this paper discusses the effect of source basin characteristics on fan morphology in several areas of the world with different climatic conditions: Japan, the American Southwest, the southern Philippines, southwestern Turkey and the eastern coastal area of the Gulf of Alaska. Three geomorphological components are examined: the whole of a source basin as the area of sediment supply; the trunk stream of a source basin as the course of sediment transport; and an alluvial fan as the area of deposition. GIS is used to analyze DEMs and digital geological maps. Data of fan area, mean fan slope, basin area, mean basin slope, mainstream length, mean mainstream slope, and dominant geology in the source basin are obtained, and their characteristics and mutual relationships are analyzed.

In each study area, the fan area and fan slope depend on the basin area, and the fan slope depends on the basin slope. These reflect not only the amount of sediment supply but also differences in sediment production processes and the ratio of sediment to water runoff. In addition, with increasing regional precipitation, the fan area increases and the fan slope decreases for the same basin area. More precipitation leads to broader and more diffused sediment deposition. The mean fan slope tends to be smaller than the mean mainstream slope if basin area is larger than a certain value, and the value differs among the study areas. The value decreases with increasing precipitation, which may also reflect the effect of sediment dispersal. In contrast, dominant geology of source basins plays only a minor role in determining fan morphology, indicating the dominance of topographic and climatic controls.

## Multiscale Wavelet Analysis of ASTER DEM to detect geomorphologic and tectonic processes in the Gaxun Nur Basin, China

HAEDKE H.

*Freie Universitaet Berlin, BERLIN, GERMANY*

This study is focusing on the tectonic impact on the morphology of one of the world's greatest inland deltas, the Gaxun Nur Basin in Inner Mongolia, China. The main objective is, to extract geomorphological features from ASTER-DEM, which are linked to tectonic impacts or the interfingering of geomorphological processes on the basin margin. With Wavelet Transform (WT), the DEM of the basin can be split into several layers, according to the size, shape and orientation of the inherent surface structures. The DEM can be regarded as a 2D signal and structures can be considered as signal events. By using a respectively defined wavelet function which is dilated, translated and hence compared to the signal (the DEM), the resulting coefficient matrix works as a blueprint of the filtered structures. Choosing an eligible wavelet function and using the coefficient matrix holds the potential to not only detect, but enhance the signal of unseen surface structures. Each wavelet function responses to a distinct surface structure shape. Diverse structures on different scales, pointing to ongoing tectonic events or geomorphological processes, could be defined:

In the East and South basin margins two perpendicular lineaments, which are underlying the great Badain Jaran dunefield, could be detected. The North and West basin margins show a change of fluvial and lacustrine features (ancient beach bars, fluvial channel) which sustain the marks of successively proceeding tectonic events. In the central basin old river channels could be distinguished, which show perpendicular changes in the stream course and indicate tectonic impacts.

WT is sparsely used in geomorphology, nevertheless it can be presented here as a promising approach to find evidence of tectonic processes in sediment surfaces, which are not obvious to the naked eye. Further, we point out, that wavelet analysis of surface features provide intelligence about the chronology of sedimentary and tectonic processes.

\*\*\*\*\*

## Visibility and optimal routes from the Roman Camp Site of Via Carisa, Cantabrian Mountains (Asturias, NW Spain)

DOMINGUEZ-CUESTA M.J., JIMENEZ-SANCHEZ M., RODRIGUEZ-RODRIGUEZ L.

*University of Oviedo, OVIEDO, SPAIN*

A multidisciplinary research (funded by PC10-14 Project, FICYT-Rioglass S. A.) was carried out in the Roman Camp Site of Via Carisa, in the axis of the Cantabrian Mountain Range (NW Spain). This site has a great historical relevance, since it is interpreted as a military camp (*castra aestiva*), built under the legate of Publio Carisio (26-22 a BC). This research highlights the strategic position of the site of the Roman Camp, located near the Via Carisa, a historical path between the Cantabrian Coast and the interior of the Iberian Peninsula. Both, visibility and accessibility to the surroundings from the Roman Camp have been analysed with Geographical Information Systems (ArcGIS 9.3). A Digital Elevation Model (5 m pixel) has been used to extract the viewshed from the Pico Boya (1728 m asl), the highest elevation of the environment. A total area of about 450 km<sup>2</sup> could be seen from the camp, even coming to see Cabo Peñas, in the Cantabrian Coast, 60 km away to the North. This resulting visual basin has been superimposed to different influence areas of radius 1, 5 and more than 10 km from the Camp, respectively. Thus allows to take into account the immediate environment of the site and calculate the visibility around short, half and long distance. Moreover, accessibility analysis and costs displacement between the Roman Camp and different areas of availability resources (fluvial courses, outcrops of conglomerates providing rolling stones used as projectiles, etc.) have been calculated. The results of the work enhance the potential of the site as a strategic position of domain under the times of Roman occupation in the Mountains of NW Iberian Peninsula.

### **Digital mapping of geomorphological features in a tropical semiarid climate of Ceará State, Brazil**

SOUZA VALLADARES G.(1), AQUINO R.P.(2), CUNHA COELHO M.F.(1)

(1) Universidade Federal do Piauí, TERESINA, BRAZIL ; (2) Universidade estadual do Piauí, TERESINA, BRAZIL

The geomorphology interpretation improves integrated view of the physical aspects of a particular area of interest. The geomorphological map of watersheds has fundamental importance in classifying the vulnerability of land. This study aimed to identify the different geomorphological features of the lands in the Banabuiú River basin, located in the central part of Ceará State, Brazil. The study area corresponds to 1500km<sup>2</sup>. Using the altitude and slope gradient derived from SRTM digital elevation model, was possible to separate seven geomorphological features using GIS and Boolean logic. The altitude of the study area varies from 173 to 852 m above sea level, comprises generally the domain of dissected pediplain, and dries sierras. The geology comprehends metamorphic rocks of Precambrian and climate is tropical semi-arid. The altitude was subdivided into eight classes: <200m, 200-300m, 300-400m, 400-500m, 500-600m, 600-700m, 700-800m and > 800m. The slope gradient was divided in 0-3%, 3-8%, 8-13%, 13-20%, 20-45% and > 45%. The river valley of Banabuiú occupies the lowlands, identified by alluvial terraces, and lower portions of the slopes. The dissected pediplains correspond to lands with elevations up to 300m and a maximum gradient of 13%, characterized by hills. With altitudes varying from 300 to 400m and gradients between 3 and 13%, were separated slopes and hills in the transition between sierras and pediplains. Areas with elevations ranging from 200 to 500m with high gradients above 13%, were identified very dissected slopes in the sierras and residual inselbergs. The valleys in the interior of sierras correspond to altitudes between 400 and 600 m and a maximum gradient of 13%, characterized by hills and lowlands. Lands with elevations above 500 m with elevated gradient or higher than 600 m were considered dissected slopes of sierras or isolated interfluves.

\*\*\*\*\*

### **Unexpected geomorphic features of a sandstone tableland revealed by LiDAR-derived DEM**

MIGON P., KASPRZAK M.

*Department of Geography and Regional Development, University of Wrocław, WROCLAW, POLAND*

We studied geomorphology of the multi-storey Cretaceous sandstone tableland of the Stołowe Mountains (SW Poland) using DEM derived from airborne laser scanning. The area has a long history of research but coarseness of topographic maps, insufficient resolution of previously available DEMs, and dense forest cover were severe constraints in geomorphic mapping and analysis.

A new LiDAR-derived DEM at the resolution of 0.6 x 0.6 m reveals a wide range of previously undetected landforms and helps to recognize their actual spatial patterns. In particular it shows, in detail unparalleled before, the morphology of sandstone-capped escarpments and their foot zones.

In the presentation we show a few selected examples, illustrating features of different origin. [1] The mesa of Mt Szczeliniec Wielki is shown to be deformed by large-scale sagging at its eastern end. Vertical drop is c. 20 m and the subsided area is a chaos of huge sandstone blocks. Sagging induced bulging in the mid-slope which in turn caused rotational slides extending to the foot zone. [2] Tongue- and fan-like concentrations of big sandstone boulders in the foot zone of the mesa suggests catastrophic releases of large rock masses rather than steady supply from caprock through fall. [3] Extensive lower slope sections of the northern marginal escarpment, cut across weak Permian sedimentary rocks, show wavy surface topography indicative of the existence of shallow slides and earth flows. Thus, the occurrence of large sandstone boulders far away from caprock is reinterpreted in terms of passive transport on landslide bodies. [4] Hoodoo rocks in the NE part of the plateau are not randomly distributed but are subordinate to the grid-like pattern of troughs surrounding bedrock elevations. Regular distribution indicates strong joint control.

Our study confirms the great potential of high resolution DEMs in geomorphology, able to reveal unexpected features even in areas considered to be well known and understood.

## Generation of morphometric semantics for automated mapping of geomorphological process domains

PRASICEK G.(1), KRAUS A.(2), OTTO J.C.(2), SCHROTT L.(2)

(1) University of Salzburg, Department of Geoinformatics, SALZBURG, AUSTRIA ; (2) University of Salzburg, Department of Geography and Geology, SALZBURG, AUSTRIA

Geomorphometry is the quantitative analysis of terrain characteristics based on digital terrain models (DTMs) and its derivatives land surface parameters (LSPs). The transition from general to specific geomorphometry and the extraction of discrete entities from a continuous digital image has been a main research field for decades. Recently, object based image analysis (OBIA) has been used to decompose DTMs into homogenous units which offer a multitude of features for classification. This technique has been applied to delineate landform elements and landforms but, as opposed to investigations in the pixel-based realm, little attention has been paid to geomorphological process domains.

This investigation seeks to identify morphometric characteristics of geomorphological process domains based on DTMs and its derivatives to allow for automated delineation and classification of these units. The following research questions are addressed: How can morphometric characteristics of process domains be extracted from digital terrain data, and which LSPs or combinations of LSPs are most suitable to describe these characteristics. The methodology is based on the general relation between the shape of the land surface and drainage area. The study site, an alpine catchment revealing strong imprint of former glaciation, is located in the Austrian Alps. Process domains have been manually mapped as polygons based on field and aerial image mapping supported by DTM-analysis. From the DTM, drainage area and basic LSPs like elevation, slope and curvature are calculated and extracted for each mapped polygon. The derived data are visually analyzed by plotting LSP values against drainage area. The observed characteristics are reduced to indices and serve as main semantic input for automated extraction of process domains. Results indicate that the chosen LSPs provide a suitable basis. However, for some processes the input of thematic data would considerably enhance the outcome.

\*\*\*\*\*

## A new method for estimating ocean reference depth

WLOSINSKA M., NIEDZIELSKI T., MIGON P.

University of Wroclaw, WROCLAW, POLAND

We present a new method for computing the present-day value of the reference ocean depth ( $dr$ ). Variations in  $dr$  have implications for inferences on sea level changes in geological time scale, and our main objective is to verify the existing estimates of  $dr$  in the light of the most recent bathymetric data.

The Global Bathymetric Chart of the Oceans (GEBCO) dataset provides a global framework for the computation. The GEBCO consists of a sea floor topography raster, revealing global coverage with spatial resolution of 30 arc-seconds.

Oceanic lithosphere cools and subsides as it moves away from the ridge crest. Subsidence decreases asymptotically towards the ultimate oceanic lithosphere thickness  $a$ , where the ocean depth is  $dr$ . In the plate model of Parsons the  $dr$  value is equal to 6400 metres. Another approach (GDH1 model) relates ocean depths to the ridge axis (5651 m).

The analysis of individual cases in the vicinity of the subduction zones shows a number of situations where the depth of oceanic crust stabilises at a certain level (equilibrium point) before reaching the subduction zone at a depth which is much lower than 6400 meters. Therefore, in order to properly analyse the sea level variations, it seems important to verify the reference depth value using new methods that integrate powerful tools provided by the Geographic Information System (GIS) and statistical inference. We have developed a Python geoprocessing script that automatically generates numerous cross sections of the submarine terrain, along the lines that are perpendicular to the subduction zones. Such an approach produces  $B$  samples that show how sea floor topography varies in the vicinity of the subduction zone. Subsequently, we have applied our iterative procedure to quantitatively and statistically evaluate the asymptotic behaviour of  $dr$  and to re-visit its previous estimates. The methods has been tested for lithosphere of various ages.

### **Supervised testing of segmentation for automated delimitation of landforms in DEMs**

EISANK C.(1), SMITH M.(2), HILLIER J.(3)

(1) Department of Geoinformatics - Z\_GIS, University of Salzburg, SALZBURG, AUSTRIA ; (2) School of Geography, Geology and Environment, Kingston University, LONDON, UNITED KINGDOM ; (3) Department of Geography, Loughborough University, LOUGHBOROUGH, UNITED KINGDOM

Object-based image analysis (OBIA) offers a range of techniques promoting that the process of manual landform delineation on DEMs can be automated. Among those techniques, multiresolution segmentation (MRS), a region-growing algorithm, has recently been used to segment DEMs into homogeneous terrain patches. Usually, those patches have to be aggregated to model actual landforms. A more efficient way is to omit the aggregation step by optimizing MRS so that terrain patches approximate the size and shape of the targeted landforms. To achieve this, we proposed a supervised testing scheme for calibrating the algorithm for automated delimitation of landforms. Calibration of MRS mainly concerns the definition of optimal algorithmic settings and of optimal land-surface parameters (LSP) on which MRS is performed. The scheme was implemented in OBIA software and therefore is operational. It comprises three steps: firstly, iterative segmentation of the input LSP is performed with various settings to produce differently sized homogeneous terrain patches. Secondly, the spatial overlap between reference landforms and individual terrain patches is evaluated. Terrain patches that overlap reference landforms by 50% or more are automatically extracted. Once the set of best fitting terrain patches is identified, in the third step global measures of spatial accuracies are calculated to quantify how well the segmented landforms spatially match the reference landforms. Different settings and LSPs were tested, specifically for the delimitation of drumlins in synthetic DEMs. Highest accuracies pointed to the optimal MRS solutions.

\*\*\*\*\*

### **Multi-agent modeling as a tool of spatial analysis for monitoring sediment fluxes**

REULIER R., CAILLAULT S., DELAHAYE D., VIEL V.

Universit? de Caen Basse-Normandie, CAEN, FRANCE

Hydro-sedimentary transfers on agricultural watershed, acting from plots to streams, affect all levels of the hydrosystem (e.g., soils degradation, floods, pollution...). A good understanding of the role of the anthropogenic networks (e.g., hedges, roads, ditches) is essential to improve the knowledge of these hydro-sedimentary transfers. To this end, we developed a flow processes simulation including anthropogenic networks. This simulation is developed on a multi-agent programming language (NetLogo). As a complement to the GIS, the use of a tool of modeling on the basis of multi-agent allows to identification of the role of each linear network (local interaction) on the global response of watershed. The simulation is tested and applied to a 15 km<sup>2</sup> catchment area (Lingevres, Calvados, France) represented by patches referred to as pixels (10\*10m). Flow pathways are defined from the digital model elevation (DEM) in function of the slope unless there is presence of linear. If present, linear networks modify the flow directions. Many spatial analysis indices could be bringing thereby: area impacted, input points in the network, location of effective networks, and impact on the distance to the outlet...This simulation was completed and confronted to the reality by an expert approach with a rigorous field monitoring during different rainfalls events. These complementary approaches allowed testing the assumptions provided by the model and check the good reproducibility of the processes observed on the basin.

### **Measuring coral reef terrain roughness from a very-high resolution Digital Elevation Model (DEM) derived from Structure from Motion (SfM) Point Clouds**

JAVIER L.(1), PHINN S.(2)

(1) *The University of Queensland , ST. LUCIA, AUSTRALIA* ; (2) *The University of Queensland, ST. LUCIA, AUSTRALIA*

Coral reef hydrodynamics operate at several and overlapping spatio/temporal scales. Waves have the most important forcing function on reefs as they drive most ecological and biogeochemical processes by exerting direct physical stress, indirectly mixing water (temperature and nutrients) and transporting sediments, nutrients and plankton. The effectiveness of reefs to dissipate wave energy is related to the extreme hydraulic roughness of the coral reef benthic composition which provides an important ecosystem service protecting highly valued shorelines. Hydraulic roughness is usually obtained empirically from frictional dissipation calculations, as measurements of bottom roughness is a very labour and time-consuming task, particularly on reef environments. However, considerable improvements on modelling wave transformation over heterogeneous reefs have been observed when incorporating spatially-explicit bottom friction coefficients representing the variability of the reef structure. Traditional methods to measure bottom roughness (e.g. chain-method or profile gauges) are labour intensive and fixed in resolution and spatial scale. This study aims to investigate the hydraulic roughness across a reef flat derived from a very high resolution digital elevation model (DEM). The DEM is derived from overlapping photos using feature matching and Structure from Motion (SfM) photogrammetric techniques to create three dimensional point clouds that are subsequently interpolated into a continuous grid (cm-scale). Terrain roughness is estimated across different benthic substrate types and implications on wave modelling results discussed.

\*\*\*\*\*

### **Cluster Analysis of Watersheds as a Guideline for the Study and Sampling of Regoliths**

LAVARINI C., MAGALHÃES JR A.P., OLIVEIRA F.S.

*Universidade Federal de Minas Gerais, BELO HORIZONTE, BRAZIL*

Knowing a priori the variables, or factors, which influence the genesis of regoliths and their spatial distribution it is possible to deduce relevant information via statistical and geoprocessing analysis for the next research steps in a fieldwork. In doing so, this paper aims to demonstrate the possibility of watersheds clustering from the factors of soil formation as well as its subsequent relevance in an exploratory fieldwork. For these purpose, we extracted in *ArcGIS 10* some morphometric variables such as (i) relief, (ii) horizontal curvature, (iii) vertical curvature, (iv) slope and (v) hypsometric integral from the headwaters of Upper-Middle Course of Ribeirão Mata-Porcos in Quadrilátero Ferrífero, Minas Gerais state, Brazil. These variables were joined by clustering techniques broadly known as Hierarchical and Non-Hierarchical Cluster Analysis. The results showed that the Hierarchical Cluster was mainly significant for the possibility of exploratory analyzes of groups, elements and variables. According to the dendrogram, we observed eight groups which best fitted the dataset nevertheless these groups were reduced based on numerous non-hierarchical analysis tests to just seven statistically consistent groups. In the field, we found morphological evidences and/or pedostratigraphical records reflecting the regional complexity. Furthermore, since the results of the cluster analysis described above are naturally grouped data, with less intentionality and human subjectivity, they tend to represent the existing complexity much more reliably than the simple analysis of cartographic products.

## **Determining the optimal pixel size of topographical parameters for the prediction of hazardous geomorphological phenomena of different magnitude: gullies and landslides**

GOMEZ-GUTIERREZ A.(1), CONOSCENTI C.(2), ANGILERI S.E.(2), CARRASCO R.M.(3)

(1) *Universidad de Extremadura, CACERES, SPAIN* ; (2) *Università degli studi di Palermo, PALERMO, ITALY* ; (3) *Universidad de Castilla la Mancha, TOLEDO, SPAIN*

Nowadays, powerful tools are available to produce high-resolution DEMs and DTMs such as LIDAR, TLS or ground-photogrammetry. On the other hand, DTMs are one of the most common inputs of predictive models in geomorphology. However, pixel size effect is still a source of uncertainty. In this work, we explore the role of pixel size in the accuracy of statistical predictive models generated in order to obtain susceptibility maps for two very different geomorphological phenomena; gullies and landslides. Two study areas were selected to represent every process; 1) Mula Basin in Murcia (Spain) and San Giorgio Basin in Sicily (Italy) for gullies and 2) Trabiata in Sicily (Italy) and Jerte Valley in Extremadura (Spain) for landslides. Only topographical variables with resolutions ranging from 2 to 50 m were used as input in order to isolate the effect of pixel size. The relationship between the optimal pixel size and landform magnitude was also analyzed using datasets with a variety of landform sizes. The obtained models were able to reproduce the spatial distribution of gullies and landslides in the study areas only using the DEMs and derived topographical attributes with values for the Area Under the ROC Curve ranging from 0.67 to 0.90. Even, the accuracy of the models could be improved including variables related to lithology, land use, vegetation cover, climate, infrastructures, etc. A clear relationship between pixel size, landform magnitude and model performance was observed. In fact, the smallest pixel size did not produce the best results in all the cases. The importance of the different attributes was estimated for every study area-process, finding important differences. Finally, the complexity of the resulting models was not related with landform magnitude. The results obtained here could be used in the future to guide through the optimal selection of the pixel size for modeling purposes.

\*\*\*\*\*

## **DSGSDs diagnostic landforms: a morphometric LiDAR based approach**

NINFO A., ZANONER T., GRUBER N., MASSIRONI M., CARTON A.

*Department of Geosciences University of Padua, PADOVA, ITALY*

Deep Seated Gravitational Slope Deformations affect many Alpine slopes, but depending on the local environment, geological setting and stage of their evolution, they can be more or less seriously degraded up to the complete dismantling of the bulging at the lower part of the slope. This research aims to a more objective identification of DSGSDs focusing on the morphostructures (i.e. double ridges, scarps, counterscarps, trenches), considered by many authors the most "diagnostic" DSGSDs landforms. We propose a methodology based on the visual interpretation and statistics analysis of morphometric indices (i.e. slope, curvatures, openness, ruggedness, WI, etc.) derived from a LiDAR-DEM with a multi-scalar approach. Counterscarps results the most abundant on all the studied DSGSDs. These forms are generally mapped like linear features, but from a DEM based perspective an areal definition is needed and in this work was conducted through a value threshold on profile curvature and slope. About 300 counterscarps were mapped and statistically analyzed, resulting long 30 – 700 m and wide 10 to 150 m, with an average direction perpendicular to the maximum slope; despite the appreciable dimensions their morphological relevance is low (<1-2 m). Counterscarps morphometry results scale independent and characterized by well defined changes in curvature (-+) and mean values (>|0.4|), with an half concave part that changes to convex through an intermediate low gradient area (< 10°) the only DSGSDs "flat" zones. A detailed field survey was conducted to validate the derived indices and the interpretation. The statistical analysis allowed us to identify a common "morphometric signature" of the counterscarps. In addition different typologies of DSGSDs seem to be more discernable on the basis of counterscarp spatial-frequency distribution than on other shape factors; width is the only one showing some correlation with the local structural setting.

## Study of the reference levels of erosional surfaces in the western Cantabrian Mountains and Montes de León (northwest Spain) through Digital Elevation Models

MINGUEZ-MENENDEZ A.(1), GARCIA-MELENDEZ E.(2), MARTIN-SERRANO A.(3), SUAREZ-RODRIGUEZ A.(1), RODRIGUEZ-GARCIA A.(2), RODRIGUEZ-FERNANDEZ R.(3)

(1) Instituto Geologico y Minero de España, LEON, SPAIN ; (2) Universidad de León, LEON, SPAIN ; (3) Instituto Geologico y Minero de España, MADRID, SPAIN

The main objective of this research is to identify the remnants of old erosional surfaces developed over the Variscan basement bordering the tectonic Cenozoic depression of El Bierzo, in the Northwest of Spain. For this identification, a methodological approach using topographical profiles extracted from a Digital Elevation Model (DEM) was used. The study area was divided into 10 mountain areas belonging to different mountain ranges (sierras) in order to extract the topographical profiles of the main summit levels and interfluves. A total number of 213 profiles along more than 1600 Km were obtained for the analysis. The comparison of the adjacent profiles in each of the 10 sierras allowed the reconstruction of old surfaces through the global polynomial interpolation Trend of height values. Afterwards, the trend of these old theoretical surfaces was analyzed, calculating the slope and aspect of each of them, highlighting the relationships between adjacent surfaces. As a result, 21 surfaces were mapped and grouped into 8 categories ranging in height between 1000 and 2100 m. These categories probably belong to a lower number of original surfaces that have been dislocated into several fragments by the Cenozoic tectonic activity and highly dissected by fluvial processes.

Acknowledgements: work supported by the Spanish projects: "Junta de Castilla y León" LE311A12-2 and Consolider Ingenio 2006 CSD-2006, Topolberia Geociencias en Iberia.

\*\*\*\*\*

## New Algorithm to Extract Longitudinal Stream Profiles (LSPs) based on unfilled DEMs

BYUN J., SEONG Y.B.

Dept. of Geography Education, Korea University, SEOUL, SOUTH KOREA

Stream Profile Analysis (SPA) has played a major role in understanding the interaction between tectonics and surface processes. With widely accessible DEMs and tools for automatically extracting LSPs from them, SPA can be performed easily and it has led to increasing research into inaccessible areas. However LSPs based on DEMs have a serious problem due to the pretreatment of DEM to remove depressions. Nowadays many DEMs are made from the dense cloud point measurements of elevation, so DEMs with depressions could represent real topography. In that case, pretreatment of DEM could distort topography and it could lower the accuracy of analysis.

In this research, we invented a new algorithm to extract LSPs based on unmodified DEMs and tested its potential. This algorithm comprises the following procedures. First, it identifies not only all depressions in a DEM, but also their outlets through which water from around a depression overflows if water exceeds the volume of the depression. Second, it modifies flow direction of some cells within each depression for the water in that depression to reach to its outlet. Third, if a depression comprises more than one sub depression (composite depression), it finds the lowest ridge cell between the already modified sub depression and an adjacent sub depression, and then modifies flow direction of some cells within the adjacent depression connected to the lowest ridge cell again. This procedure continues until all sub depressions are visited. Fourth, it records stream path inversely beginning from the main outlet of the DEM to every channel head. Therefore, when it meets an outlet of a composite depression, it goes down until meeting the sink of a sub depression and moves up to a lowest ridge, then goes down until meeting the sink of an adjacent sub depression and then goes up again. The results show that LSPs based on this algorithm can trace the relatively deepest part along valley bottoms and they improve the accuracy of SPA.

### **Morphometric and morphotectonic indexes for quantitative geomorphology analysis of the Cannobino drainage basin (Piemonte, NW Italy)**

GHIRALDI L.(1), BACENETTI M.(2), MILLEMACI P.(3), PEROTTI L.(2), GIARDINO M.(2)

(1) Natural Sciences Museum of Torino, TORINO, ITALY ; (2) University of Torino - Earth Sciences Department, TORINO, ITALY ; (3) Freelance, CANNOBIO, ITALY

Preliminary studies have been conducted in the mountain area of Northern Piemonte (NW Italy) for characterization of the Cannobino drainage basin through morphometrics and morphotectonics indexes. From the geological point of view the valley belongs to the Southern Alps and his Hercynian basement is divided in two units: Ivrea-Verbano Zone (IVZ) and Serie dei Laghi (SDL). These units are separated by two discontinuities: the Cossato-Mergozzo-Brissago and Pogallo lines. The IVZ outcrops in the northern sector of the basin; main rocks types are: migmatized metapelitic schists (Kinzigite), amphibolites and mafic stratified complex (granulite, metagabbros and peridotite). SDL outcrops in the southern and central sector. It is divided in two complex: Scisti dei Laghi (metasedimentary schists, orthogneisses) and Strona-Ceneri (paragneiss, schists).

A DEM (5x5 meters, Piemonte Region) of the Cannobino drainage basin has been imported into the GIS environment in order to evaluate the basin and river network's geomorphometry. The workflow included several steps: a) lineament features digitalisation and interpretation; b) drainage network extraction and hierarchization; c) azimuthal distribution of drainage pattern; d) evaluation of linear and areal indexes: drainage density, bifurcation ratio, stream frequency, texture ratio, hierarchical anomaly index, elongation ratio, hypsometry integral and curves, transverse topographic symmetry factor, amplitude of relief, normalized stream length index. The values of these parameters have been interpolated by means of geostatistical algorithms for the creation of different thematic maps. Furthermore, major morphometric parameters have been identified: the significance of their geomorphic role have been evaluated by means of principal component analysis (PCA), and the statistical relationships with different type of rocks has been investigated.

\*\*\*\*\*

### **Geomorphological units and the risk of erosion in the central hinterland of Ceara, Brazil**

AQUINO R.P.(1), VALLADARES G.S.(2), COELHO CUNHA M.F.(2)

(1) UNIVERSIDADE ESTADUAL DO PIAUÍ, TERESINA, BRAZIL ; (2) UNIVERSIDADE FEDERAL DO PIAUÍ, TERESINA, BRAZIL

The establishment of environmental units from geomorphological approach constitutes an important instrument for planning and sustainable use of natural resources, in view of its importance for understanding the dynamics of how the environments work. This way, we performed a geomorphological subdivision of part of the river basin Banabuiú, located in the backlands of Central Ceará, Brazil, located in the field of cratonic areas and semi-arid tropical climate. The demarcation of the geomorphological compartments based on the demarcation on the image morphometry derived from SRTM, formed by a composition containing false color altimetry, slope, and curvature of field, taking into account the tone and greater or lesser closeness of the curves for level, which were overlaid on raster morphometry. We identified seven units of relief. Generally the higher altitudes (above 300 m) and the levels of dissection of the relief are in interfluvial structural crests in residual and structural slope dissected by looking up the domain of slope greater than 8%, characterizing undulated tightly curled. In the valley of Banabuiú and on the pediplano dissected it were identified the lower altitudes (below 300m) and the smaller slope (below 13%). Overlaying relief units maps and slope, allowed the establishment of different classes of erosion risk, and areas with slopes of up to 3% were considered very low risk, the 3-8% low risk, those of 8 to 13% of moderately high risk; those of 13 to 20% high risk, those of 20 to 45% of very high risk, and large areas with a slope exceeding 45% very high risk of erosion. It is observed throughout the study area, deforestation and land degradation, which are further impacted when used in agriculture, especially in hilly areas.

### **Fragility environmental analysis of River Basin Caulim - Sao Paulo/SP/Brazil**

DA SILVA SOUSA A., SOUSA A.  
*University of Sao Paulo, SAO PAULO, BRAZIL*

From the present study we sought to develop an empirical analysis of environmental fragilities shown in the basin of the River Caulim, using for that the concept proposed by Tricart Ecodinâmicas Units (1977) and developed by Ross (1990, 1994). The study is based on the partitioning of relief until the 5th level taxon (Ross, 1992) and finally to its association with land use in the area, allowing to establish a framework of potential environmental weaknesses.

\*\*\*\*\*

### **Application of a geographical information system to debris flows**

CARDOSO-LANDA G.  
*Instituto Tecnológico de Chilpancingo, CHILPANCINGO, MEXICO*

The last days of September and October of 1999 appeared extraordinary rains on the mountains of the north and the northeast of the state of Puebla and in the neighboring states of Veracruz and Hidalgo in the country of Mexico, generated by the tropical depressions 11 to 14, which, combined to other factors of genesis, triggered around 3000 mass processes in the zone, fundamentally debris flows, and falls, and slides, and combination of the previous ones. These events produced deterioration of the infrastructure of the zone, losses of human lives and disappear, mainly in the populations of Chachahuantla, Teziutlán and Totomoxtla, affecting 96 municipalities, 16511 houses in different degree, 199 schools, 59 federal public buildings, 50 buildings of the cultural patrimony, 8 health centers, in addition to 256 dead people and 55 missing ones. October 5 of 1999 very intense precipitations appeared on the city of Teziutlán, Puebla, generating around 30 debris flows and superficial ground slides of different magnitude and type, which produced 150 dead people.

It was developed a geographic information system of the study area and using Takahashi scheme were obtained the types of debris flows, and the angles of fault, and the average speeds of debris flows applying Takahashi equations. Finally were compared these results with the natural angles of the slope in the zone of Teziutlán México, showing the results in the full paper.

\*\*\*\*\*



**S26D - Statistics in geomorphology**

Convenors: *Ian EVANS & Delphine GRANCHER*





## **Oral presentations:**

### **Susceptibility analysis of landslide in the Bacia Do Marumbi (Morretes/PR) using bivariate and multivariate statistical methods**

UBER J.A.(1), ZÉZERE J.L.(1), SANTOS L.J.C.(2)

(1) Universidade de Lisboa, LISBOA, PORTUGAL ; (2) Universidade Federal do Paraná, CURITIBA, BRAZIL

This work aims to apply bivariate and multivariate statistical methods (the information value method and the logistic regression, respectively) to perform the landslide susceptibility assessment in the Bacia do Marumbi (Morretes/PR). The study area is a catchment with 102 km<sup>2</sup> located in the Serra do Mar, where landslides are very important processes within present geomorphic evolution. For the confection of the landslide susceptibility maps, the following procedures were made: (i) multi-temporal inventorying of landslides of slide type using aerial photo interpretation and field work validation; (ii) division of the landslide inventory in two subsets using a temporal criterion modeling group (landslides older than 2006, 39 cases), validation group (landslides occurred after 2006, 37 cases); (iii) identification and classification of landslide predisposing factors (elevation, slope, plan curvature, wetness index (inverse), lithology, soil type and land use); (iv) weighting of landslide predisposing variables; (v) integration of variable weights and production of landslide susceptibility map; (vi) evaluation of the predictive model performance (success rate and prediction rate; calculation of the Area Under Curve - AUC).

The predisposing factors that have the higher influence on the occurrence of landslides are elevation, slope and soil type. The smallest contribution was presented by the slope plan curvature.

According to the criterion of Guzzetti et al. (2005), the obtained results are considered very satisfactory, once the AUC of the success rate curve is 0.84, and the AUC of the prediction rate curve is 0.81 in both methods. However, although the rates are equal, the information value method shows a higher efficiency if we considered the 20% of the area classified as more susceptible by both methods. For this area, the predictive capacity is of 77.75% for the model built with the Information Value method and only 60% for the Logistic Regression model.

\*\*\*\*\*

### **Automated geomorphological classification for the creation of rigorous shaded relief maps**

VERONESI F., HURNI L.

ETH Zurich, ZUERICH, SWITZERLAND

Advances in remote sensing have increased the availability of high resolution digital elevation models. These data can be extremely useful for environmental studies, but they need processing in order to provide geomorphological insights. This can be done with two approaches: shaded relief maps and numerical identification of landforms.

In the first case, the landscape is classified by the cartographer, who is able to generalize different landforms and accentuate them in shaded relief maps. These are highly informative but also exposed to a certain degree of subjectivity. On the other hand, numerical landforms classification is mostly concerned with the identification of landforms elements, thus decreasing the informative power of the final output.

In this research we are trying to find a better way to classify major landforms, in order to provide a better framework for shaded relief mapping. For doing so we used Random Forest, trained on a set of interactively selected points, to classify a test area for rock outcrops, screes, alluvial fans and plains.

Random Forest is trained using DEM derivatives and imagery, and used for classifying the area of interest. The algorithm not only produces a classification value, but can also give a probability value, which can be used to show uncertainties.

With this approach the user select the training points where he is certain to find a particular landform, the boundary between landforms are set by the classification algorithm, thus creating a more objective result, keeping the user interaction to a minimum. On the other hand, the uncertainty map may shows areas where the prediction accuracy is low. The user can then easily go back to step one in order to optimize the training set and increase the overall accuracy.

Another advantage is that the map can be updated as soon as new data are available. This way even in highly dynamic environments the thematic map can be easily, automatically and almost effortlessly kept updated.

## **Interpreting wavelet-based decompositions of geomorphological features: the example of the Rhone river bathymetry**

VAUDOR L., PARROT E.

*CNRS (UMR 5600 Environnement Ville Societe), LYON, FRANCE*

Wavelet-based decomposition of signals is increasingly used in geosciences as a tool for describing time series or spatial series at multiple scales. Still, although it seems to be the obvious method to provide a multi-scale study of the river continuum's features, its use in hydrogeomorphology is rare. The main reason to this is that this method is both difficult to understand from a mathematical perspective, and purely descriptive, making the interpretation of the decomposition difficult to non-specialists.

In this study, we provided guidelines as to how to interpret wavelet-based decompositions, both in a descriptive and inferential way. In particular, we associated wavelet-based decomposition with statistical methods such as segmentation (on individual scales) and clustering (on several scales). First, we quantified its power to detect scale-specific changes according to various parameters (rate of change, series length, changes at close scales, etc.). Then, we tested its ability to classify river sections into groups according to their features on multiple scales.

Besides, we provided one practical example of wavelet-based decomposition of a signal: that of the bathymetry of the Rhone river (Southern France). We use this example, in particular, to illustrate the intricate nature of this kind of geomorphological signal in terms of scales interlocking and show to which extent wavelet-based decomposition might help analyze it.

\*\*\*\*\*

## **Accounting for uncertainty in fluvial geomorphology using Bayesian statistics**

SCHMELTER M.

*Freeport-McMoRan Copper & Gold, MESA, UNITED STATES*

The movement of eroded sediments from mountain highlands to the oceans is a complex process that involves several components of variability and uncertainty at a number of scales. Over the last 100 years advances have been made in the field of fluvial sediment transport including the development of numerous sediment transport models and theories. Despite these advances, however, uncertainty in predictions, models, and model parameters is a fundamental challenge for applied fluvial geomorphologists. In recent years, Bayesian statistics have been increasingly used in numerous disciplines including, among others, environmental and climate science as a framework for accounting for and estimating uncertainty in model predictions and parameters. These methods, however, have not yet received wide attention in the field of fluvial sediment transport.

Recent work by the author demonstrates the applicability of Bayesian methods in fluvial sediment transport—specifically, bed load transport in rivers. Bayesian statistical models marry deterministic sediment transport relationships with probability distributions making it possible to generally specify how sediment transport behaves while accounting for the reality that model parameters, such as critical shear, and model predictions are probability distributions and not fixed values. These can be applied to subsequent analyses such as sediment budgets and help inform river management strategies and quantify risk. Several models are illustrated ranging from simple uni-size excess shear equations to contemporary multi-fraction sediment transport equations. The model results use synthetic, laboratory flume, and field data collected on a gravel bed river to test the models. The results show that the Bayesian approach to sediment transport has many advantages over purely deterministic approaches and has practical implications for the practice of the art.

## Hierarchical Bayesian modelling for hydrological spatiotemporal mountain climate proxies

ECKERT N.(1), LAVIGNE A.(2), PAVLOVA I.(3), THIBERT E.(1), BEL L.(2), GRANCHER D.(3), PARENT E.(2), JOMELLI V.(3), NAVEAU P.(4), BOREUX J.J.(5)

(1) Irstea, GRENOBLE, FRANCE ; (2) AgroParisTech, PARIS, FRANCE ; (3) LGP, MEUDON, FRANCE ; (4) LSCE, SACCLAY, FRANCE ; (5) Université de Liège, LIÈGE, BELGIUM

High altitude mountain zones have been shown to be very sensitive to climate change. Climate proxies, i.e. indirect climate indicators such as tree rings, are useful to supplement direct measurements for reconstructing past climate. Among them, hydrological proxies such as glacier mass balance are particularly interesting since their changes result from a mixed temperature and precipitation signal. Furthermore, studying their past temporal fluctuations is help to anticipate the future evolution of related natural hazards (glacier outbursts, major avalanches, etc.).

Recently, Hierarchical Bayesian modelling has seen growing interest for processing gridded climate data. This framework is also particularly well suited for inferring a climatic signal from a set of partially correlated hydrological climate proxy series. The non-linear nature of their response to climate covariates can be acknowledged at the latent variable level. Furthermore, significant spatio-temporal patterns such as change points can be separated from “random” annual fluctuations, with the different sources of uncertainty treated rigorously.

The objective of this talk is to illustrate these statements using three complementary examples. The first is an analysis of seasonal glacier mass balance point measurements at Sarennes. The second is an analysis of debris flow activity in the Northern French Alps taking into account geomorphological and climatological covariates in a multivariate hierarchical logistic regression model. The third is an analysis of avalanche counts all over the French Alps where non-separable spatio-temporal effects are inferred in a hierarchical probit regression model. We will discuss the main common points and differences of these case-studies, including the covariates and model structure used, and point out the major statistical and applied challenges remaining.

\*\*\*\*\*

## Poster presentations:

### Landslide morphometric signature

ROSSI M.(1), MONDINI A.C.(1), MARCHESINI I.(2), SANTANGELO M.(1), BUCCI F.(2), GUZZETTI F.(2)

(1) Istituto per la Protezione Idrogeologica, Consiglio Nazionale delle Ricerche - Dip. Scienze della Terra, Università degli Studi di Perugia, PERUGIA, ITALY ; (2) Istituto di Ricerca per la Protezione Idrogeologica, Consiglio Nazionale delle Ricerche, PERUGIA, ITALY

Morphometric parameters are widely used in landslides mapping and modeling. Morphological information is used by geomorphologists to map landslides in the field or during aerial photo-interpretation and using remote sensing techniques. Landslide models can explicitly consider this information (e.g. slope in physically-based infinite slope modeling), or assess its importance through a statistical inference (e.g. morphometric variables used in statistical multivariate landslide susceptibility models). Investigators have attempted to quantify morphological changes produced by landslides locally or in small areas, but at present no common criteria, or set of variables or analysis tools exist to compare globally these changes. Here we present a framework to analyze the morphological fingerprints of landslides in a territory. We also define a method to group them in categories based on different triggers and environmental settings. For this purpose we identify a set of morphometric variables and a procedure to distinguish different morphological landslide signatures. Further we provide a web processing service to allow external user to apply the proposed procedure in specific areas. Our intent is to create a library of the landslide morphological signatures as much as possible complete. Results will be helpful to improve: (a) the ability to detect landslide on the surface, (b) the modeling capabilities, and (c) the knowledge of landslide processes.

### **Statistical approach to analyze evolutions of statistical long-term hydrological data sets on the loire river (France)**

RAMOND S.(1), GRANCHER D.(2), GAUTIER E.(1)

(1) University of Paris 8 Vincennes - Saint-Denis, CNRS, UMR 8591, Laboratory of Physical Geography, MEUDON, FRANCE ; (2) CNRS, UMR 8591, Laboratory of Physical Geography, MEUDON, FRANCE

The fluvial bed of the Loire River, the longest French river, tends to stabilize, and this is often explained by the disappearance of large floods since the mid-19<sup>th</sup> century. A lot of studies focus on fluvial landform adjustments of the Loire River without interest for other possible hydrological causes. The aim of this study is identification and characterization of hydrological evolutions in the middle part of the Loire River to better understand its geomorphologic behavior and to help river management.

The hydrology of the Loire River was altered by human society and river management. The construction of large dams, climate change and evolutions in land-use induce past and future hydrological changes at catchment scale.

This study is based on daily streamflow data provided by the DREAL Centre, and monthly meteorological data from Météo France. Fourteen streamflow-gauging stations and thirty weather stations, distributed across the upstream and middle sections of the river catchment, were selected. Data sets essentially begin in the mid-20<sup>th</sup> century, however a few temperature, precipitation and streamflow data sets start in the mid-19<sup>th</sup> century. In addition, three data sets of restored natural streamflow enable us to study in detail large dams influence on the Loire River hydrology.

After testing these data sets for anomaly, we extracted therefrom a total of 35 relevant indices, such as the monthly median streamflow, the minimum streamflow during ten consecutive days or the length of high water periods. We then applied statistical tools, such as continuity tests, to these indices, in order to either detect potential disruptions, or to show that the pattern of the data series does not suffer any discontinuity.

We could identify several changes : summer floods disappeared after the 1920's, and low water was completely transformed by the low water support policy.

\*\*\*\*\*

### **The discontinuous spatial distribution of Alpine Permafrost: an application of exploratory spatial data analysis**

DELUIGI N.(1), LAMBIEL C.(1), KANEVSKI M.(2)

(1) University of Lausanne - Institut de géographie et durabilité (IGD), LAUSANNE, SWITZERLAND ; (2) University of Lausanne - Centre de recherche en environnement terrestre (CRET), LAUSANNE, SWITZERLAND

A deep knowledge of the permafrost distribution at different scales, including the scale of the micro-topography, has both fundamental and applied importance. Up to now, none of the existing robust models have been able to simulate the high spatial discontinuity of mountain permafrost, especially in blocky loose sediments where the ground thermal regime may be strongly affected by air advection processes. An intelligent spatial data analysis and modeling by using a Machine Learning (ML) approach meets the requirements in order to integrate this complexity into spatial models. The key feature of the ML models is that they learn from data and can be used in cases where the modeled phenomenon is complex, not very well described or subject to multidimensionality, namely dependent on multiple factors which can vary if the distribution itself is characterized by a multi-scale component.

In this poster, preliminary results on *exploratory data analysis* (EDA) and *exploratory spatial data analysis* (ESDA) are presented. These techniques reveal underlying structures in data, detect the presence of anomalies, determine relationships among explanatory features and allow to preliminary select the appropriate modeling approaches and the related optimal calibration. They open the way to the *adaptation of the most efficient ML classification algorithms for environmental data modeling*. Field investigations of mountain permafrost in the Swiss Alps provide detailed empirical knowledge of the distribution and characteristics of permafrost in sedimentary terrains. Without any a priori user assumption concerning the relationship between permafrost and its explaining variables, ML algorithms are able to *detect spatial patterns in data and to understand their spatial properties*.

The results of this study should improve the understanding of spatial data in the alpine permafrost scientific field and would provide a new methodology for mapping the discontinuous distribution of this phenomenon.

### Robustness of fractal dimension estimators for vector talweg network characterization

*THOMMERET N.(1), BAILLY J.S.(2), BARDET J.M.(3), KAISER B.(1), PUECH C.(4)*

*(1) Laboratoire de Géographie Physique UMR 8591 CNRS-Université Paris 1 Panthéon-Sorbonne, MEUDON, FRANCE ; (2) UMR LISAH, AgroParisTech, MONTPELLIER, FRANCE ; (3) Equipe SAMM, Université Paris 1 Panthéon-Sorbonne, PARIS, FRANCE ; (4) UMR TETIS,Irstea, MONTPELLIER, FRANCE*

The fractal approach is often used to characterize natural objects. Numerous studies have focused on fractal analysis of river networks in particular. However, only few papers discuss the estimation methods and the uncertainty of the main fractal indicator, the fractal dimension. Firstly, the distinction between infinite mathematical fractal and nature fractal should be taken into account to estimate fractal dimension. Moreover, the networks are most of the time integrated in GIS database and represented by vector object. This type of representation possesses its own properties and we think that the impact on fractal measure should be evaluated.

In this context, the work we propose aims at testing the robustness of different fractal dimension estimators for the characterization of vector talweg networks. We focus on the two most popular estimators: a classical estimator for river networks, based on a topological approach with the Horton-Strahler ratios, and the box-counting dimension, based on a geometric approach. A third estimator, the less known correlation dimension, also based on a geometric approach, offers interesting possibility for calculating a stable fractal indicator, in particular in the case of a reduced number of stream-segments. These methods are applied on both virtual (such as Scheidegger network), and actual vector networks. The actual case is a network extracted from a high resolution DTM of the Draix badlands in the French Alps.

Three main methodological results can be highlighted: 1- the study of virtual network contributes to the assessment of the estimators relevance, according to the network branching structure; 2- an empirical fractal domain must be determined on the Log-Log curve with an objective method to estimate fractal dimensions that can be compared; 3- the observation of uncertainty of the fractal dimension is necessary for any valid comparison.

\*\*\*\*\*

### A flexible open-source toolbox for robust end-member modelling analysis - The R-package EMMAgeo

*DIETZE M.(1), DIETZE E.(2)*

*(1) TU Dresden, DRESDEN, GERMANY ; (2) GFZ German Research Centre for Geosciences, Section 5.2 Climate Dynamics and Landscape Evolution, POTSDAM, GERMANY*

Interpreting geomorphological and sedimentological processes from grain-size data in terrestrial archives runs into problems when source- and process-related grain-size distributions become mixed during deposition. A powerful approach to overcome this ambiguity is to statistically “unmix” the samples. Typical algorithms use eigenspace decomposition and techniques of dimension reduction.

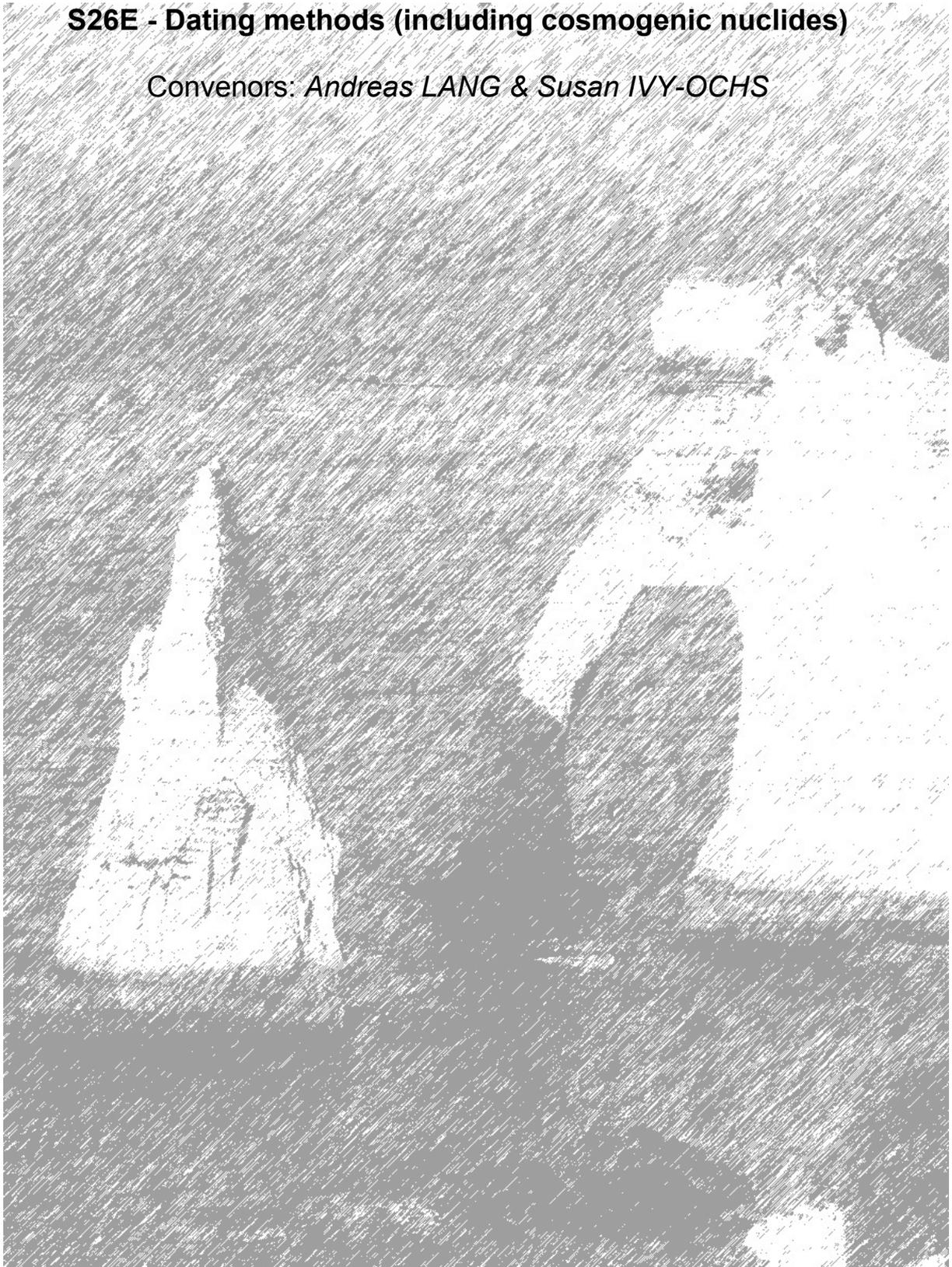
This contribution presents a package for the free statistical software R. It bases on a Matlab-based end-member modelling algorithm and contains several extensions and added functionality. Some of the great advantages of R are the open code structure, flexibility and low programming effort. The package contains several flexible functions for data test, preparation, modelling and visualisation tasks. The package supports simple modelling of grain-size end-member loadings and scores (eigenspace extraction, factor rotation, data scaling, non-negative least squares solving) along with several measures of model quality. It also provides pre-processing tools (grain-size scale conversions, tests of data structure, weight factor limit inference, determination of minimum, optimum and maximum number of meaningful end-members) and allows to model data sets with user-defined end-member loadings. EMMAgeo also supports uncertainty estimation from a series of plausible model runs and determination of robust end-members.

The contribution presents important package functions, thereby illustrating how large data sets of artificial and natural grain-size samples from different depositional environments can be analysed to infer quantified process-related proxies.



**S26E - Dating methods (including cosmogenic nuclides)**

Convenors: *Andreas LANG & Susan IVY-OCHS*





## **Oral presentations:**

### **Surface exposure dating of rock avalanche deposits in the Ferret Valley (Mont Blanc massif, Italy)**

*AKCAR N.(1), DELINE P.(2), IVY-OCHS S.(3), KUBIK P.W.(3), SCHLÜCHTER C.(1)*

*(1) Institute of Geological Sciences, University of Bern, BERN, SWITZERLAND ; (2) EDYTEM Lab, Université de Savoie, LE BOURGET-DU-LAC, FRANCE ; (3) Laboratory of Ion Beam Physics, ETH Zurich, ZURICH, SWITZERLAND*

One of the largest rock avalanches of the Alps occurred in the night of September 12<sup>th</sup>, AD 1717. A huge volume of rock and ice from Triolet Glacier was mobilized and more than 7 km travelled down valley in the upper Ferret Valley, Mont Blanc Massif (Italy). This mass destroyed two small settlements, causing seven casualties and loss of livestock. Although this rock avalanche was historically recorded, no detailed maps were made at the time. Later investigators attributed the accumulation of granitic boulders and irregular ridges covering the upper valley floor to either deposition by a Lateglacial glacier, or the AD 1717 rock avalanche, or a complex mixture of glacial deposition, earlier rock avalanche and AD 1717 rock avalanche origin. Can cosmogenic <sup>10</sup>Be be used to end this dilemma?

With the aim of answering this question, we sampled 16 boulders of this deposit and three from boulders outside of this deposit for surface exposure dating with cosmogenic <sup>10</sup>Be. Two boulders from distal Holocene glacier-free areas yielded <sup>10</sup>Be exposure ages of 10.9 and 9.7 ka, respectively. The third outside boulder, embedded into the Little Ice Age terminal moraine (*sensu lato*), yielded exposure age of around 240 years. <sup>10</sup>Be exposure ages of the granitic boulders within the upper valley deposit vary between 300 and 500 years within the limits of error. These results show that at least 14 of these boulders were deposited by the AD 1717 rock avalanche, and its deposits do cover the whole upper Ferret valley floor. With this study, we directly contribute to distinguish between rock avalanche deposits and older moraine sets in valleys of formerly glaciated mountains, two assemblages of landforms which often look alike, and to the assessment of the natural risks in the Mont Blanc Massif area.

\*\*\*\*\*

### **Age modelling of Mid-Holocene sedimentary sequences using a Bayesian approach**

*MONGE SOARES A., CESÁRIO PORTELA P.J., MATOS MARTINS J.M., RAMOS PEREIRA A.*

*IST/ITN, UTL, SCAVEM, PORTUGAL*

Accurate dating is essential for the construction of reliable paleoenvironmental and paleoclimatic models based in multi-proxy analysis of sedimentary records. Radiocarbon dating is one of the most common dating methods used to develop chronological frameworks.

In estuarine environments, where fluvial-marine interaction is more intense, the reworking of organic materials often affects the <sup>14</sup>C dates which induces difficulties in the establishment of a robust chronological framework. Bayesian analysis provides the necessary tool to evaluate the data set and to identify possible outliers and age-depth reversals.

To assess the evolution of interface environments along the Portuguese coast, a mesotidal estuary (Alcabrichel estuary) with an alluvial plain and a medium drainage basin and with different geological and geomorphological frameworks was selected. Two mid-Holocene sedimentary cores were collected in this estuary and radiocarbon dated, providing the necessary chronological dataset to establish a reliable paleoenvironmental and paleoclimatic reconstruction from these sequences.

In an attempt to overcome some difficulties related with the chronological data a bayesian approach was applied using the OxCal calibration software that allows the incorporation of the stratigraphic sequence and an outlier analysis of the dataset.

This analysis allowed the identification of outliers in our results and the assessment of deposition models for each sedimentary sequence, establishing a robust chronological framework for the sedimentary sequence in the Alcabrichel estuary, during the last 5000 years.

Acknowledgements: This research was funded by the research project, PTDC/CTE-GIX/104035/2008 - FMI 5000: Environmental changes: Fluvio-marine interactions over the last 5000 yrs, from Portuguese Science and Technology Foundation (FCT-MCTES). J.Martins acknowledges the PhDgrant SFRH/BD/45528/2008 from the same institution. P. Portela acknowledges the FCT fellowship of FMI 5000 Project.

**The utility of portable optically stimulated luminescence (OSL) readers in providing temporal contexts in clastic depositional systems: opportunities in geomorphology**

MUNYIKWA K.(1), BROWN S.(2), PLUMB E.(2)

(1) Athabasca University, ATHABASCA, CANADA ; (2) University of Alberta, EDMONTON, CANADA

The recent development of functional portable optically stimulated luminescence (POSL) readers has ushered in new opportunities in geomorphology. Although POSL readers do not necessarily provide absolute ages as in regular OSL dating, they can be used to readily acquire luminescence signals from clastic sediments. Such signals can be used to construct luminescence profiles which depict the variation of the luminescence signal with depth within a depositional sequence. Luminescence signals depend on dose rate, sensitivity of the mineral grains, mineralogy, degree of bleaching and burial age of the sediments. When all these parameters apart from burial age are held constant, the luminescence profile can serve as a proxy for the chronostratigraphy.

A number of studies we have carried out on the Canadian prairies with a POSL reader developed by the Scottish Universities Environmental Research Centre serves to illustrate the utility of the readers. Their portability means that the device can be carried to the field and analysis can be performed on bulk samples, negating the need for time-intensive mineralogical separations, as is required in regular OSL dating. In one study we used the POSL reader to profile Holocene eolian dune sequences to determine the relative ages of the depositional units as well as ascertain whether any lengthy depositional hiatuses exist within the sequences. In another study we profiled postglacial dunes that overlie glaciofluvial sands in an effort to delineate the interface between the two depositional facies. In a third study we used luminescence profiling to identify eolian dune sands that were still intact from those that had experienced post-depositional mixing. In all three cases, luminescence profiling afforded an enhanced temporal context of the stratigraphy, permitting better sample targeting for regular OSL dating. Overall the studies underscore the breadth of geomorphological settings in which the POSL readers can be used.

\*\*\*\*\*

**Last Glacial Maximum glaciers on Akdağ, southwest Turkey, inferred from cosmogenic  $^{36}\text{Cl}$  dating of moraines**

SARIKAYA M.(1), HIMMET H.(1), ATILTA Ç.(2)

(1) Fatih University, ISTANBUL, TURKEY ; (2) Hacettepe University, ANKARA, TURKEY

Past glaciations in the Eastern Mediterranean region provide useful information about the paleoclimate of the region. Determination of extent and timing of past glacial activities can be done by field surveys and measuring in-situ produced cosmogenic nuclides. For this purpose, we conducted a study on Akdağ, a small mountain located in the southwestern Turkey (36.54°N, 29.57°E, 3016 m above sea level). We mapped the past glacial extent in three glacial valleys and dated 40 limestone boulders on well-preserved terminal and lateral moraines by using cosmogenic  $^{36}\text{Cl}$  nuclide. Results showed that, during the Last Glacial Maximum (LGM) (about 21 ka ago; 1ka=1000 calendar years) glaciers in the mountain reached their maximum extents (about 6 km from their cirques). LGM moraines (dated in between  $23.8 \pm 1.8$  ka and  $19.5 \pm 1.4$  ka ago) were found at 2000-2300 m above sea level. They retreated until  $16.3 \pm 1.1$  ka ago. Today, there is no glacier in the mountain. These preliminary results are the first numerical data in this mountain and the obtained ages are consistent with the nearby mountains. This set of glacial activity during the Late Quaternary provides a basis for paleoclimatic proxy data, which can be used to reconstruct the history of climate change in the region since LGM.

### **A tragic flood but an invaluable opportunity to build a better model on catchment wide denudation rate (CWDR) using a pair of $^{10}\text{Be}$ and $^{14}\text{C}$**

SEONG Y.B.(1), LEE S.Y.(1), KIM D.E.(1), CHOI K.H.(2), YU B.Y.(3)

(1) Korea University, SEOUL, SOUTH KOREA ; (2) National Institute of Environmental Research, SEOUL, SOUTH KOREA ; (3) Korea Institute of Science and Technology, SEOUL, SOUTH KOREA

A tragic flash flooding occurred in the Seti River of Western Nepal on Saturday 5 May 2012, and caused the death of more than 70 people. Despite various arguments on the exact location of the source and the mode of the flash flood, this tragic event can provide us with a unique natural lab to check on the present model of CWDR using cosmogenic nuclides through comparing any variation in the concentration of cosmogenic nuclides such as  $^{10}\text{Be}$ ,  $^{26}\text{Al}$  and  $^{14}\text{C}$  of the active channel sediments deposited before and after the High-magnitude Low-frequency event, respectively. Total of 26 samples were collected for estimating the concentrations of cosmogenic  $^{10}\text{Be}$  and  $^{14}\text{C}$  in the fluvial sediments. This research has double-folds: to quantify the role High-magnitude Low-frequency event plays on the process of sediment evacuation and to estimate the storage effect of the fill deposits such as terraces, alluvial fans, etc. which hold sediments for substantial time but has been poorly constrained in CWDRs using single  $^{10}\text{Be}$  or a pair of  $^{10}\text{Be}$  and  $^{26}\text{Al}$ . Most of the present model on catchment-wide denudation rate using single cosmogenic nuclide of  $^{10}\text{Be}$  or a pair of  $^{10}\text{Be}$ - $^{26}\text{Al}$  tends to underestimate the effective denudation rate of the catchment, because single  $^{10}\text{Be}$  or even a pair of  $^{10}\text{Be}$ - $^{26}\text{Al}$  with long half-life is difficult to estimate any stored duration of sediments shorter than  $\sim 10^5$  yrs. However, the use of short half-life, in-situ  $^{14}\text{C}$  coupled with  $^{10}\text{Be}$  makes us better quantify the storage duration of sediments in depositional settings which in turn, are reincorporated into the active fluvial system. In the study area, there are two tributaries of the Seti River showing the widely different settings of sediment storage: the Seti Khola is extensively covered by thick (up to a couple of meters) terrace deposits and wide valley form whereas the adjacent, Mardi Khola shows typical, V-shaped valley form with little fill terrace but a few of narrow, rock-cut strath terraces.

\*\*\*\*\*

### **Timing of ice decay after the LGM in the high Alps**

WIRSIG C.(1), IVY-OCHS S.(1), ZASADNI J.(2), AKCAR N.(3), DELINE P.(4), KOBER F.(1), SCHLUCHTER C.(3)

(1) ETH Zurich, ZURICH, SWITZERLAND ; (2) AGH University of Science and Technology, KRAKOW, POLAND ; (3) University of Bern, BERN, SWITZERLAND ; (4) Université de Savoie, LE BOURGET DU LAC CEDEX, FRANCE

Extensive investigations over the previous century have produced a robust model of the extent of ice in the Alps during the last glacial maximum (LGM). In Switzerland, glaciers advanced far into the foreland fed by ice domes that formed in the high Alps. Constraining the timing of events proves to be a more challenging task.  $^{10}\text{Be}$  surface exposure ages and radiocarbon ages imply that the piedmont glacier in the Swiss Alpine foreland had retreated before 19 ka BP. This result is in excellent agreement with the end of the last glacial period spanning from 30 – 19 ka BP, as inferred from stable isotopes in marine and polar ice cores. Did the ice surface in the high Alps decay simultaneously? Here we will present  $^{10}\text{Be}$  surface exposure ages from several sites in the Swiss and Austrian Alps. Conclusions of previous attempts to date this event were fairly ambiguous. Their very nature does not allow studies using radiocarbon, OSL or other dating techniques to date the decay of the ice surface directly. Analyses of cosmogenic nuclides, in contrast, directly yield the duration that a surface has been exposed, i.e. since the retreat of ice formerly covering it. So far, the small number of studies using the same methodology report ages that are no older than 17.3 ka. The influence of temporary sediment or ice cover on the samples is generally taken to explain the age discrepancy compared to the ice retreat from the foreland and to the results from marine and polar ice cores. At the exposed locations of our study sites in supposedly ice-free conditions since the LGM we believe we can exclude these circumstances. Here we will present results from cosmogenic nuclide dating of these sites using  $^{10}\text{Be}$  and construct a comprehensive chronology of the decay of the Alpine LGM ice surface by comparing them to published ages.

### **A continuous high-resolution 700-yr snow-avalanche chronology from the Queyras massif recorded from tree-ring and historical archives**

*CORONA C.(1), LOPEZ SAEZ J.(2), STOFFEL M.(3), BERGER F.(2)*

*(1) GEOLAB, CNRS UMR6042 Geolab, CLERMONT-FERRAND, FRANCE ; (2) IRSTEA, UR EMGR, SAINT MARTIN D'HÈRES, FRANCE ; (3) Laboratory of Dendrogeomorphology, Institute of Geological Sciences, University of Berne, BERNE, SWITZERLAND*

Snow avalanches are mainly ruled by temperature fluctuations, heavy precipitations and wind regimes, so that climate change is likely to modify their frequency and magnitude both in terms of ordinary and extreme events. Papers dealing with this question generally analyze the evolution of the snow cover rather than the changes in avalanche activity and analyses of real avalanche data generally focuses on the past few decades. Some chronicles dating back to the 16<sup>th</sup> century have been realised by using historical documents reporting damage to buildings and fatalities. However, this kind of analysis cannot be used to assess the evolution of natural events because only catastrophic avalanches are generally reported in such data bases. Along forested avalanche paths, dendrogeomorphology has been demonstrated to greatly help documentation of past events.

In that respect, the purpose of this study was to reconstruct spatio-temporal patterns of avalanche events in forested avalanche paths of the Queyras massif (Echalp and Souliers avalanche paths, southeast French Alps).

Analyses of past events were based on tree-ring series from 315 heavily affected, multi-centennial larch trees (*Larix decidua* Mill.). Growth disturbances were identified in the samples permitting the reconstruction of destructive snow avalanches between 1338 and 2010.

At the Echalp avalanche path, the comparison of dendrogeomorphic data with historical records demonstrate that at least 18 events – six of which were undocumented – reached the hamlet of Echalp during the past seven centuries, but no significant temporal trend was detected concerning the temporal frequency of these extreme events. At Souliers, no event was documented in the archives. On a temporal plan, the study focused on the maxima in snow avalanche frequency reconstructed at the beginning of the 16<sup>th</sup> and 19<sup>th</sup> centuries and around 1850. These maxima were then correlated with fluctuations in meteorological data and in other proxies.

\*\*\*\*\*

### **Poster presentations:**

#### **Amino acid racemization analysis (AAR) as a successful tool for dating Holocene barrier island spit accretion: Examples of Southern Sylt (North Sea/ German Bight)**

*TILLMANN T.(1), ZIEHE D.(2), WUNDERLICH J.(3)*

*(1) Goethe-University Frankfurt a. M., Department of Physical Geography, FRANKFURT A. M., GERMANY ; (2) Johann Heinrich von Thünen-Institut, BRAUNSCHWEIG, GERMANY ; (3) Goethe-University Frankfurt a. M., Department of Physical Geography, FRANKFURT A. M., GERMANY*

Dating of Holocene sediments in shallow coastal areas of the German North Sea by conventional techniques often turns out to be difficult. Due to the marine reservoir effect radiocarbon dating cannot be applied to sediments younger than about 400 years. Amino acid racemization dating (AAR) is a viable alternative for dating young sediments. The method is based on the determination of ratios of D and L amino acid enantiomers in organic matrices of biogenic carbonates.

In this study we use AAR as a tool for dating Holocene barrier islands sediments. Based on these dating a model of barrier spit accretion has been generated, which describes the interaction between extreme events, coastal processes and sedimentary development. The stratigraphy has been figured out by using ground-penetrating radar (GPR) surveys and sedimentological coring data. AAR helps to define a chronological order and allow setting up a barrier island stratigraphy of Southern Sylt.

AAR provided high temporal resolution and has been used for dating stages of barrier spit accretion. These time lines are marked as storm surge generated erosion unconformities in the stratigraphic profile. Individual shells and shell fragments of *Cerastoderma edule*, *Mya arenaria*, *Mytilus edulis* and *Scrobicularia plana* have been accumulated by short-term storm events as shell layers at the erosion unconformities and have been dated by AAR.

Time lines reveal that the barrier spit accretion occurred episodically, depending on the provided rate of sand delivery and are going to be younger by approaching to the south. The time lines have been verified and correlated by historic maps and sea charts. As a result, spit enlargement increased significantly during the Middle

Ages (1593 – 1794) and was coupled with several intensive storm surges in this period. The findings indicate that AAR provides useful results of high accuracy for dating stages of barrier spit progradation.

**Investigations on anthropogenic shell accumulations in the Longotoma dune complex (central Chile) ' geochronological data and palaeoenvironmental context**

MAY S.M.(1), BRÜCKNER H.(1), HILGERS A.(1), KELLETAT D.(1), PÖTSCH S.(2), RIXHON G.(1), ZANDER A.(1)

(1) Institute of Geography, University of Cologne, COLOGNE, GERMANY ; (2) Institute for Geography and Geology, Ernst Moritz Arndt University of Greifswald, GREIFSWALD, GERMANY

Shell midden archaeology plays a significant role in the research on the colonisation of South America. However, geoarchaeological investigations on the palaeoenvironmental context of these cultures are rare though potentially providing important data for their interpretation. The Longotoma dune system is situated in the northern part of central Chile, framed by the estuaries of the rivers La Ligua and Petorca. Numerous cultural layers occur together with accumulations of mollusk shells, often related to stone fragments. While associated ceramics indicate a post-archaic age for some places, hunter-gatherer sites of pre-ceramic, mid-archaic age are described as well. A succession of fluvial terraces and two main dune generations are inferred from satellite images and preliminary field work, the younger characterized by migrating barchanoid dunes. Undercut slopes, formed by the La Ligua river, provide insight into the stratigraphy of the older dune generation at its eastern margin. Here we present first results from an international research project, dealing with the palaeoenvironmental context of these archaeological remains. A former alluvial terrace was found below the present dune field. A sequence of palaeosol sediments and an *in-situ* palaeosol were detected in the older dune generation, associated with a shell deposit. Bone fragments of small rodents, charcoal, leaves and abundant mollusk shells (*Mesodesma donacium*, *Concholepas concholepas*) confirm its anthropogenic origin. <sup>14</sup>C-AMS datings of shells and charcoal yielded similar ages of c. 5200 cal BP, giving further evidence for the presence of archaic coastal populations at Longotoma. IRSL datings provide a first chronological framework for the palaeoenvironmental context by (i) estimating the age of the fluvial terrace below the present dune field to ~4500-3500 BP, by indicating (ii) different phases of dune activity and (iii) a period of relative geomorphodynamic stability of several hundred years.

\*\*\*\*\*

**The land use interference on geomorphological aspects and sedimentation rates in the low course of the Piracicaba River basin, São Paulo State, Brazil**

CUNHA C.(1), CONCEIÇÃO F.T.D.(1), SIMON A.L.H.(2), PEREZ FILHO A.(3)

(1) UNESP, RIO CLARO, BRAZIL ; (2) Universidade Federal de Pelotas, PELOTAS, BRAZIL ; (3) UNICAMP, CAMPINAS, BRAZIL

Currently, the São Paulo State, Brazil, possesses more than 55 reservoirs. The geomorphological classical literature affirms that there is a tendency for the occurrence of silting in the area intercepted by artificial dams. The use of isotopes to obtain the sediment ages has important applications in studies of sedimentation rates in reservoirs, which may be changed after their constructions. Thus, the land use interference on geomorphological aspects and sedimentation rates in the low course of the Piracicaba River basin, São Paulo State, Brazil, was evaluated. The land use dynamics and geomorphological aspects in this area were made by mapping of scenarios of 1962 and 2006. Furthermore, the sedimentation rate from upstream Barra Bonita Reservoir was obtained using the Pb-210 method. The results indicate that changes in geomorphological features in the studied area have direct relationship with the Barra Bonita Reservoir construction, which transformed the landscape of the area, flooding the alluvial plain. About the land use dynamics, there was an increase in sugar cane crops areas in relation to pasture, the main land use in 1962. The sedimentation rates were 12.1 mm/yr and 15.4 mm/yr for the periods from 1974 to 1985 and 1985 to 2010, respectively. The sedimentation rates obtained in this work is higher than the other studies along the Piracicaba River basin (~5 mm/yr), indicating the influence of Barra Bonita Reservoir in the sediment processes in the low course of the Piracicaba River basin after its construction in 1965. Additionally, it is attributed to the expansion of areas with sugar cane crops in the early 1980s, due to Pro-alcohol Program developed by the Brazilian Federal Government, the increase in the sedimentation rate in the studied area. the increase in the sedimentation rate in the studied area.

### Surface exposure dating of the Chironico landslide (Leventina valley, southern Swiss Alps)

*CLAUDE A.(1), IVY-OCHS S.(2), KOBER F.(3), ANTOGNINI M.(4), SALCHER B.(5), KUBIK P.W.(2)*

*(1) Institute of Geological Sciences, University of Bern, BERN, SWITZERLAND ; (2) Laboratory of Ion Beam Physics, ETH Zürich, ZÜRICH, SWITZERLAND ; (3) Geological Institute, ETH Zürich, ZÜRICH, SWITZERLAND ; (4) Museo cantonale di storia naturale, LUGANO, SWITZERLAND ; (5) Departement of Geography and Geology, Salzburg University, SALZBURG, SWITZERLAND*

During the Lateglacial and Holocene, an increased activity in mass movements in the European Alps seemed to have occurred perhaps due to postglacial landscape response. In this study, we investigated the Chironico landslide in the Leventina valley in the southern Swiss Alps. About 530 million m<sup>3</sup> of crystalline granitic gneiss belonging to the Lower Pennic nappes detached from the eastern valley wall and slid along valleyward dipping exfoliation joints and fractures. The slide mass was deposited into the Ticinetta stream mouth and dammed the Ticino river. Wood fragments originated from lacustrine sediments in an upstream-dammed lake, yielded a minimum age for the landslide of around 13'500 cal yr BP.

In order to directly date the landslide, 14 boulders were sampled for surface exposure dating with the cosmogenic nuclides <sup>10</sup>Be and <sup>36</sup>Cl. Exposure ages indicate that the failure occurred around 13.3 ka, revealing that it was one event during the Bølling-Allerød interstadial and implying that the Chironico landslide is the oldest dated landslide in the Alps in crystalline rock. Runout modeling has reproduced the character and extent of motion of the landslide and the potential failure scenario could be identified. Geologic and geomorphologic investigations helped to reconstruct the temporal landscape evolution history of the Leventina valley around Chironico. It could be concluded that the landslide was triggered around 3000 years after deglaciation, suggesting that glacial unloading did not directly trigger the landslide. It however prepared the failure by decreasing the rock strength and oversteepening the steep SSW-dipping eastern flank.

\*\*\*\*\*

### Cosmogenic nuclide dating of Swiss Deckenschotter

*CLAUDE A.(1), AKÇAR N.(1), IVY-OCHS S.(2), GRAF H.R.(3), KUBIK P.(2), VOCKENHUBER C.(2), DEHNERT A.(4), MEINERT R.(4), SCHLÜCHTER C.(1)*

*(1) Institute of Geological Sciences, University of Bern, BERN, SWITZERLAND ; (2) Laboratory of Ion Beam Physics (LIP), ETH Zürich, ZÜRICH, SWITZERLAND ; (3) Dorfstrasse 40, GÄCHLINGEN, SWITZERLAND ; (4) Swiss Federal Nuclear Safety Inspectorate ENSI, BRUGG, SWITZERLAND*

Deckenschotter (cover gravel) are proximal glaciofluvial gravels of the Northern Alpine Foreland, showing locally interbedding with till and overbank deposits. These Quaternary sediments cover Tertiary Molasse or Mesozoic bedrock and occur beyond the limit of the Last Glacial Maximum. Based on their distinct topographic positions, these deposits can be divided into two main geomorphic units: Höhere (Higher) and Tiefere (Lower) Deckenschotter. Despite its topographically higher position, the Höhere Deckenschotter is older than the Tiefere Deckenschotter. A phase of incision separates the two units from each other. Both Höhere and Tiefere Deckenschotter bear evidence of at least four glacial advances that reached the Alpine foreland and are, therefore, complex lithostratigraphic sequences.

The age of the Deckenschotter complexes is poorly constrained. The only existing quantitative age is between 2.5 and 1.8 Ma, which is based on mammalian faunal assemblages (MN17) found in the Höhere Deckenschotter at the Irchel site. They are therefore the oldest Quaternary units in the northern Swiss Alpine foreland known so far. In this study, we apply burial dating, isochron dating and depth-profile dating with the cosmogenic nuclides <sup>10</sup>Be, <sup>26</sup>Al and <sup>36</sup>Cl in order to establish the timing of Early and Middle Pleistocene glaciations in the Alps. Reconstruction of the chronology of these glaciofluvial units will provide fundamental information about the onset of Quaternary glaciation in the Alps as well as about major incision history of the area.

### Late Pleistocene Glacier advances in North Anatolia deduced from cosmogenic $^{10}\text{Be}$ and $^{26}\text{Al}$

REBER R.(1), TIKHOMIROV D.(1), AKÇAR N.(1), YESILYURT S.(2), YAVUZ V.(3), KUBIK P.W.(4), SCHLÜCHTER C.(1)

(1) *Institute of Geological Sciences, University of Bern, BERN, SWITZERLAND* ; (2) *Department of Geography, Çankırı Karatekin University, ÇANKIRI, TURKEY* ; (3) *Faculty of Mines, Istanbul Technical University, MASLAK, ISTANBUL, TURKEY* ; (4) *Laboratory of Ion Beam Physics, ETH Zürich, ZÜRICH, SWITZERLAND*

Moraines are the morphological evidence for glacier oscillations in the past. Surface exposure ages from the erratic boulders and bedrock are used in the reconstruction of the chronology of these oscillations, which are directly correlated to extreme climate conditions. In this study, we focused on the Basyayla Valley in the northern part of eastern Black Sea Mountains (Turkey) in order to extend the existing knowledge about the late Pleistocene glaciations in Anatolia. In the Basyayla Valley, terminal and lateral moraines constrain at least three well-defined glacier advances. We collected 40 samples from erratic boulders for surface exposure dating with in-situ cosmogenic  $^{10}\text{Be}$  and  $^{26}\text{Al}$ . In addition, a bedrock outcrop on the crest line of the northwestern valley flank was sampled.  $^{10}\text{Be}$  exposure ages show at least one advance at around 35 ka, which extended down to an altitude of ca. 2350 m a.s.l. The subsequent advance occurred at around 21 ka and remained at ca. 2480 m a.s.l. The Lateglacial advance at around 16 ka was limited to a cirque glacier at an altitude of ca. 3050 m a.s.l. Since then, the valley was free of ice.  $^{10}\text{Be}$  and  $^{26}\text{Al}$  concentrations from the bedrock sample indicate a simple exposure history and that there was no ice contact to the adjacent valley at least during the last 37 ka. Our results correlate with the existing chronology from the neighborly Çoruh, Kavron and Verçenik valleys and from Uludağ, as well as with the existing chronologies from the other Anatolian Mountains. Our study provides a better understanding of glaciations in Anatolia prior to the global Last Glacial Maximum at  $21 \pm 2$  ka.

\*\*\*\*\*

### Geochronology of Danube terraces in Hungary, using cosmogenic $^{10}\text{Be}$ and luminescence dating

CSILLAG G.(1), RUSZKICZAY-RÜDIGER Z.(2), NOVOTHNY Á.(2), THAMÓ-BOZSÓ E.(1), FODOR L.I.(3), BRAUCHER R.(4)

(1) *Geological and Geophysical Institute of Hungary, BUDAPEST, HUNGARY* ; (2) *Department of Physical Geography, Eötvös University, BUDAPEST, HUNGARY* ; (3) *Geological, Geophysical and Space Sciences Research Group of Hungarian Academy of Sciences at Eötvös University, BUDAPEST, HUNGARY* ; (4) *Centre Européen de Recherche et d'Enseignement des Géosciences de l'Environnement, AIX EN PROVENCE, FRANCE*

The existing terrace chronology in the Hungarian Danube valley was based on geomorphological, sedimentological and palaeontological data. This old system has been questioned due to some new Th/U and luminescence dating results, obtained from travertine and loess, respectively, overlying the terraces and due to in situ cosmogenic  $^3\text{He}$  dating of andesite strath terraces. Major part of these data showed that Danubeterraces, and connected uplift of the surrounding hills are significantly younger than it was suggested before. On the other hand, some of them suggested older than expected ages. Accordingly, a novel terrace chronology is necessary, which we try to approach by using two different dating methods on the alluvial terraces: luminescence dating, which provides the burial ages and cosmogenic  $^{10}\text{Be}$  dating, which yields the exposure ages of the sediments. Cosmogenic  $^{10}\text{Be}$  and luminescence samples were collected from several locations from terraces IV and IIb ( at Győr, Bana, Mocsá, Dunaalmás and Tata). Cosmogenic  $^{10}\text{Be}$  sampling occurred along depth profiles, because this method allows determining both the exposure time and the denudation rate at each locality by using all particles involved in the cosmogenic nuclide production. Post-Infrared Infrared Stimulated Luminescence (post-IR IRSL) measurements were carried out on K-feldspar samples, comparing the post-IR IRSL 290 and post-IR IRSL 225 signals. Besides, younger quartz samples were also measured using optically stimulated luminescence (OSL).

Although preliminary results are promising and the luminescence ages are partly in good agreement with preliminary cosmogenic  $^{10}\text{Be}$  ages, it has to be taken into consideration, that the processes, which are dated with these methods are different. In case of disagreement the effect of surface erosion also has to be taken into account. The possible effect of post-depositional sediment mixing could be excluded by the observation of the original bedding of the alluvial material.

**Quantification of optically stimulated luminescence dating uncertainties based on the analysis of samples collected from a paleoseismological trench of an active fault in Central Greece**

TSODOULOS I.(1), STAMOULIS K.(1), PAPACHRISTODOULOU C.(1), IOANNIDES K.(1), PAVLIDES S.(2), CHATZIPETROS A.(2), KOUKOUVELAS I.(3)

(1) Department of Physics, University of Ioannina, IOANNINA, GREECE ; (2) Department of Geology, Aristotle University of Thessaloniki, THESSALONIKI, GREECE ; (3) Department of Geology, University of Patras, PATRAS, GREECE

Documenting the displacement in past faulting events, observed in excavated paleoseismological trenches across faults, stratigraphic and structural information contained within the walls should be interpreted. Since often it is difficult to correlate the lithologic units on the foot and hanging walls of the fault, the reconstruction of past displacements is a demanding task, requiring the application of various methods, such as radiometric dating or compositional and mineralogical analysis methods.

In this work, samples from a recently excavated paleoseismological trench were collected and analyzed with the method of the Optically Stimulated Luminescence (OSL) dating, in order to establish a reliable chronological framework. The trench was excavated in a typical active fault namely Gyrtani, Larissa, Thessaly plain in Central Greece. The initial preliminary interpretation of the trench wall structure provided indications of recent reactivations of the fault. Seven samples, one for each lithologic unit, were collected from the upthrown fault block and 9 samples were collected from the downthrown fault block. The samples were dated following the OSL dating method, using the Riso TL/OSL DA-20 reader. The single-aliquot regenerative-dose (SAR) protocol was followed for the equivalent dose (De) determination. Also, the natural radioactivity of soil from the surroundings of the original sample location was assessed, using gamma spectrometry. The dose rates were calculated using the appropriate dose conversion factors and corrected for the humidity content of the surrounding soils.

Since the application of the OSL dating method involves a number of intermediary factors and processes, all being the sources of uncertainties propagating to the total uncertainty, an exhaustive analysis of the involved uncertainties is presented and the implications to the derivation of conclusions used for paleoseismology are discussed.

\*\*\*\*\*

**GIS-based geomorphological mapping, dating of selected landforms and landscape evolution during the Lateglacial and Holocene, in the region of Val Tuoi, Grisons, Switzerland**

MESSERLI M.(1), IVY-OCHS S.(2), MAISCH M.(1)

(1) University of Zurich, ZURICH, SWITZERLAND ; (2) ETH, ZURICH, SWITZERLAND

The study of glacial and periglacial landforms provide important information about the climate history of the region. Since the Last Glacial Maximum (LGM) glaciers in the Alps have advanced and retreated many times leaving traces of their activities in the field. The Val Tuoi, Grisons, Switzerland offers a wide range of glacial and periglacial landforms. This valley forms a tectonic boundary, on the left orographic side is the lower Austroalpine from the geological window of the Lower Engadine (Unterengadiner Fenster) and the right side is predominated by amphibolites and orthogneisses of the Silvretta units. The bedrock differences are reflected in the abundance of slope instabilities on the left side (east). In contrast, the right side displays steep walls with a series of debris cones. Well developed lateral moraines indicate Lateglacial ice extents.

A detailed understanding of the geomorphological settings and the corresponding dating method are compulsory to reconstruct the regions climate history during the Lateglacial and the Holocene. To obtain absolute rock surface dates, 12 samples on moraines and three on rock-glaciers have been collected. Surface ages are calculated by <sup>10</sup>Be exposure dating method. To determine the relative age relation between selected landforms, Schmidt-Hammer technique was applied on 17 debris cones, 12 moraines, two active and one relictic rock glacier. Furthermore a GIS-based map will be produced and analyzed to show the spatial distribution and dynamics of the geomorphological shaping processes.

### **Assessing processes and timescales of sandstone landscape formation in Zhangjiajie Geopark of China**

HUANG H.(1), MAY J.H.(2), FINK D.(2), WRAY R.(2), GU J.(1)

(1) Institute of Geographical Sciences and Natural Resources Research, Chinese Academy of Sciences, BEIJING, CHINA ; (2) University of Wollongong, NSW 2522, AUSTRALIA

Sandstone landscapes around the globe exhibit a surprising variety in terms of their landforms and formative processes. Ultimately, this reflects the wide range of geomorphic controls that dominate on regional scales, such as lithology, physical and chemical weathering, tectonics, and climate. In Zhangjiajie Geopark of the Hunan Province, China, a unique landscape has developed in Devonian sandstone over an area of ~400 km<sup>2</sup>, which is characterized by more than 3000 sheer vertical sandstone pillars, peaks and walls of up to 350 m height. Due to these spectacular features, the area has become a major tourist attraction, and has recently been declared an UNESCO Global Geopark.

Uplift, a densely spaced joint pattern, and the uniformity of sandstone beds have been suggested as major prerequisites for the formation and preservation of the landscape. We aim to investigate the underlying processes and controls responsible for the development of this landscape by determining a chronological framework for its age, and assessing rates of formation and surface erosion. The initiation of uplift ~1 Ma ago and subsequent stepwise evolution of the landscape has been inferred from cave sediments and surrounding alluvial terraces. No direct information, however, is available on the shorter-term evolution of the vertical sandstone walls, peaks and pillars.

In this study, we (i) consider sampling strategies for applying surface exposure dating (SED) in this challenging morphological setting, (ii) present some first results, and (iii) discuss their significance in providing estimates on rates of catchment-wide denudation, weathering, retreat of the vertical sandstone walls, and bedrock incision. In combination with a GIS-based assessment of sediment volumes stored in and eroded from the catchment, these data will help to elucidate the relative roles of fluvial, mass-wasting, and weathering processes in the longer-term, late Quaternary formation of this distinct landscape.

\*\*\*\*\*

### **Application of fallout radionuclides for investigating recent overbank sedimentation rates on river floodplains: potential and limitations**

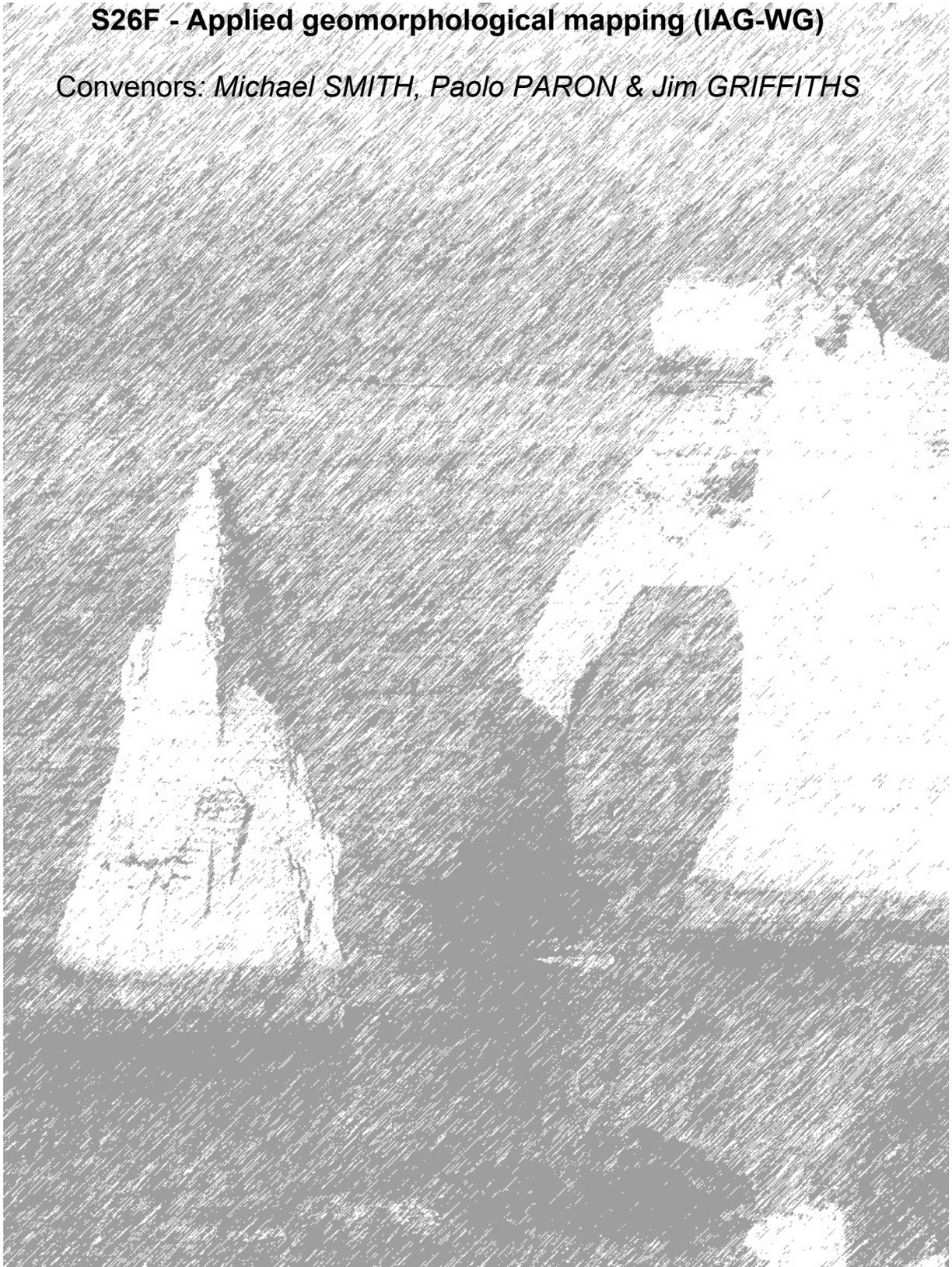
GOLOSOV V.(1), WALLING D.(2), BELYAEV V.(3)

(1) Faculty of Geography, Lomonosov Moscow State University & Institute of Ecology and Geography, Kazan Federal University, MOSCOW & KAZAN, RUSSIAN FEDERATION ; (2) Geography, College of Life and Environmental Sciences, University of Exeter, EXETER, UNITED KINGDOM ; (3) Faculty of Geography, Lomonosov Moscow State University, MOSCOW, RUSSIAN FEDERATION

Overbank sedimentation rates on river floodplains provide a key indicator of the intensity of sediment and sediment-associated pollutant redistribution in river basins and the efficiency of sediment delivery. Combined application of the fallout radionuclides <sup>137</sup>Cs (bomb-derived and/or Chernobyl-derived) and excess <sup>210</sup>Pb provides an effective means of documenting recent medium-term overbank sedimentation rates. This approach is particularly useful in areas of Europe affected by Chernobyl fallout, because it is frequently possible to determine sedimentation rates for three or more time intervals. In addition, it is possible to use the information on sediment chronology provided to reconstruct the history of industrial and agricultural pollution in the upstream river basin. However, despite the important advantages of fallout radionuclides for establishing overbank sedimentation rates and dating sediment deposits, it is necessary to recognize the possible limitations of the technique, as well as the sampling and sample analysis requirements which need to be considered when documenting and interpreting radionuclide depth distributions. Recently published studies indicate that the requirements for the successful application of fallout radionuclide tracer techniques are unfortunately sometimes ignored, leading to unreliable results or incorrect interpretations. The potential and limitations of fallout radionuclides for investigating overbank sedimentation rates on river floodplains will be reviewed, based on the authors' own studies as well as other recently published work.

**S26F - Applied geomorphological mapping (IAG-WG)**

Convenors: *Michael SMITH, Paolo PARON & Jim GRIFFITHS*





## **Oral presentations:**

### **Spectral properties of Southern Baltic bottom roughness**

SZEFLER K., TEGOWSKI J., NOWAK J.  
*Maritime Institute in Gdansk, GDANSK, POLAND*

Multibeam swath acoustic technique is very attractive for construction of the high resolution digital elevation model of the ocean bottom as the base for the geomorphological characterisation of measured area. In the years 2007-2010 the Maritime Institute in Gdansk conducted exhaustive research of the bottom in the Polish Exclusive Economic Zone (the Baltic Sea) collecting a large set of swath and subbottom acoustic data. A particular attention was given to six different areas of size up to 10 by 20 km, which demonstrate typical geomorphological seafloor features for the southern Baltic Sea. The acoustical measurements were accompanied by geological sampling and video inspection. This work is focused on development of consistent geomorphological classification system based on spectral properties of seafloor roughness. Two dimensional spectra (2D FFT) of the surface and the spectral parameters as maximal value of spectral density function, spectral exponent and strength, spectral moments, mean frequency, spectral width and skewness were computed for each analysed area divided by overlapped 200 by 200 m squares. Moreover, other features characterised the corrugated surface as fractal dimension, radius of autocorrelation, elevation slope and statistical parameters were estimated. The spectral parameters were the input to Principal Component Analysis and next to the unsupervised neural network algorithm, which produced maps containing morphologically classified seabed areas. Proposed method provides fast and efficient tool for seafloor classification taking into account scales and shapes of geomorphological forms.

\*\*\*\*\*

### **Geomorphological mapping of an active landslide on the south-east coast of the Isle of Wight, U.K.**

GRIFFITHS J.  
*University of Plymouth, PLYMOUTH, UNITED KINGDOM*

The Undercliff on the south-east coast of the Isle of Wight is one of the largest urban landslides complexes in Europe being over one kilometre wide and some ten kilometres long. Studies of this landslide complex have identified areas in varying states of stability that move intermittently primarily in response to changes in ground water conditions. In late 2000 to early 2001 at Binnel Bay, towards the western end of the Undercliff, a 300 metre long and 100 metre wide section of the landslide started to move damaging the coastal road and destroying a number of mobile homes. Geomorphological mapping of the landslide at a scale of 1:2,500 was undertaken whilst the landslide was actively moving at a rate of a few centimetres/day. The mapping identified the failure as a relatively shallow multiple translational landslide that was retrogressing rather than a deep-seated movement involving the main landslide complex. The shear surface was less than 10 metres deep and lay within a more plastic horizon in the Cretaceous Gault Clay. The failure, therefore, was found to be part of a general degradation process and not a reactivation on a larger scale of the whole Undercliff's pre-existing landslide complex. The mapping was used to provide recommendations for the safe evaluation of the site using standard ground investigation techniques as a prelude to the design of remedial measures.

## **Geomorphological mapping of himalayan terrain using multi-sensor data: a case study of himachal pradesh, India**

PANI P.

Jawaharlal Nehru University, NEW DELHI, INDIA

In the present [paper an attempt has been made to map geomorphological units of a middle inner Himalayan terrain using multi sensor data. The aim of the research work is to identify the geomorphic units and their attributes as geomorphology plays an important role in land use planning of the Himalayan terrain. Parvati valley of Himachal Pradesh is selected for such study using Remote Sensing and GIS techniques. Physiographically rugged topography, steep sided hills, escarpments, narrow valleys and interlocking spurs are the characteristics features of the area with a variation of altitudinal heights between 1300 – 3000 metres. Indian Remote Sensing satellite sensor LISS III, LISS IV data along with LANDSAT data of different years were used to map the geomorphological units of the mountainous terrain. In order to have an idea of the valley profiles DEM has been prepared and analysed from the Cartosat 1 data. The major geomorphic units are various dissected hills, river terraces, alluvial fans, levees, channel bars and glacial features. The geomorphic features are the product of fluvial as well as glacial action. Field verification of many geomorphic units of this Himalayan tract have been conducted with hand held GPS. The study of temporal changes of the geomorphological units for about forty years has been done to understand the type of phases under which the area is presently going on. The land use practice in the area is mostly confined to the alluvial terraces. It is concluded that geomorphology plays an important role in the land use practices of mountainous region of Himalaya.

\*\*\*\*\*

## **The influence of slope morphometry on erosion processes: the application of MSI (Morphometric Slope Index)**

BUCCOLINI M.(1), COCO L.(1), ARINGOLI D.(2), MATERAZZI M.(2)

(1) Università "G.D'Annunzio" Chieti, CHIETI, ITALY ; (2) Università di Camerino, CAMERINO (MC), ITALY

The morphodynamic processes and the development of drainage systems are strongly influenced by the topography of the slopes. Several authors investigated slope parameters individually, resulting in partial relations with morphogenetic processes, for instance between drainage density and slope inclination of some river basins, obtaining different results.

Slope geometry may be analyzed using the Morphometric Slope Index (*MSI*) and simplified through the tributary basin that influences the landform. *MSI* combines the slope main morphometric features, both linear and areal. Its formula is  $MSI = A_{3D}/A_{2D} \times L \times R_c$ , where  $A_{3D}$  is the three-dimensional area of the slope,  $A_{2D}$  is its plan area,  $L$  is the slope length and  $R_c$  is the circularity ratio. The statistical analyses demonstrated its effectiveness, giving the significant correlations between *MSI* and the parameters that constitute its formula, but also with the slope inclination, that is not explicitly contained in the formula.

*MSI* can be useful for many purposes, both for development studies and for predictive studies.

*MSI* can be calculated considering the initial slope topography, prior to the development of a landform, reconstructed tracing the straight contour lines that connect the points with the same height on the opposite sides of the slope, and measuring  $A_{3D}$  on the initial topography. In the study of calanchi processes, drainage density resulted inversely proportional to *MSI*, considering both the single hydrographical units in parallel *calanchi* and a set of dendritic *calanchi*. Moreover, the eroded volume in *calanchi* basins was directly proportional to *MSI*.

In a river basin, considering the landslides that occur in second-order sub-basins, the areal frequency of landslide resulted inversely proportional to *MSI*. Moreover, *MSI* influenced the amount of total eroded volume in the sub-basin.

Further use of *MSI* could be in a predictive way, using the three-dimensional actual surface of the slope.

## **Landslide susceptibility zonation using bivariate statistical analysis and GIS in Constantine city (North East of Algeria)**

*BOURENANE H.(1), BOUHADAD Y.(2)*

*(1) National Center of Applied Research in Earthquake Engineering (CGS), ALGER, ALGERIA ; (2) National Earthquake Engineering Center (CGS), ALGER, ALGERIA*

The town of Constantine, which is the third largest town in the northeast of Algeria suffers from frequent and severe progressive landslide phenomena during the last decade because of its geological, geomorphological and climatic settings alternated by the human activities. Its unstable urban perimeter covering total areas of approximately 706 hectares (7.124 km<sup>2</sup>) that represent about 11,84 % of its urban space. In order to reduce the risk emanating from potential landslide, there is a need to generate a comprehensive Landslide Susceptibility Zonation (LSZ) map of the area for an effective and efficient disaster management. In the present study, an attempt has been made to generate LSZ map of the town Constantine situated in north east Algeria using bivariate statistical modified Information Value (InfoVal) method in a GIS environment. The various causal factors responsible for landslide occurrence associated with landslide activity, have been considered and the corresponding thematic layers have been generated using remote sensing and GIS techniques. The relative importance of these layers for causing landslides has been evaluated using modified InfoVal method and a landslide susceptibility zonation (LSZ) map has been generated. The landslide susceptibility index was segmented into five zones, viz. very low, low, moderate, high and very high susceptibility. The accuracy of the LSZ map has been evaluated using frequency ratio and success rate methods and indicates more than 85 % of landslide prediction accuracy.

Keywords: Landslide susceptibility zonation (LSZ), InfoVal, GIS, Bivariate statistics, Constantine

\*\*\*\*\*

## **Subsurface geomorphology of the North Kelantan Plain, as revealed by geoelectrical resistivity surveys**

*ISLAMI N.*

*University of Malaya, KUALA LUMPUR, MALAYSIA*

The North Kelantan Plain is located in the northeastern part of Peninsular Malaysia adjacent to the South China Sea coastline, and is drained by the Kelantan and Pengkalan Datu rivers. It is covered by fluvial sediments of Quaternary age deposited on granite bedrock. The aquifer system of the area is confined within these sediments, and is largely controlled by subsurface geomorphology. Seventy-four geoelectrical resistivity surveys were conducted along the Kelantan River to reveal the subsurface structure and layering within the sediment. Important parameters that need to be determined for geomorphological studies are the location and extent subsurface geomorphology and its characteristics, and the spatial variability of the formation. All these parameters control the aquifer system in the study area. Four major geomorphological features were discovered. First, in the area within 2 km of the coast, profiles parallel to the shore are dominated by parallel discontinuities, while those perpendicular to the shore are dominated by discontinuities that are wavy, with an average wavelength of 15-20 m and amplitude of 3-6 m, indicating the influence of prevailing winds on the geomorphology at the time of deposition. Commonly, the pattern is similar to modern today. Second, in the delta of the Kelantan River, the shallow and deep aquifers are connected, indicating that the ancient Kelantan River has sifting and moving to the other traverse. Third, in the area between 10 and 25km landward from the shore, subsurface geomorphology controls the distribution of naturally polluted groundwater, and lastly, in areas where the elevation is greater than 30 meters above mean sea level, the granite bedrock is shallow, restricting the presence of fresh groundwater aquifers.

## Methodological procedures of digital geomorphological cartography in Brazilian Central Plateau

BARBOSA SOARES NETO G.(1), SOUZA MARTINS É.(2), VASCONCELOS V.(2), LLACER ROIG H.(1), B. J. MENEZES P.H.(1)

(1) University of Brasília, BRASÍLIA, BRAZIL ; (2) EMBRAPA, BRASÍLIA, BRAZIL

The objective of this paper is to present a standard procedure of geomorphological cartography. The proposed methodology involves geomorphometric elements as amplitude and slope of terrain. The integration of geomorphometric elements and geomorphological classification is performed by geoprocessing techniques. The process of classification of terrain units is dynamic and automated. The principle of the proposed methodology is the evaluation of terrain metrics without involving the genetic aspects. The absence of standardization in geomorphological representation associated with peculiarities of the process of obtaining data which characterize the surface could be mentioned as factors that hinder the elaboration of geomorphological charts. The area chosen for the application of the methodology was the Brazilian Central Plateau, embedded in a terrain mostly flat to gently undulating, interspersed with areas to the north with high level of dissection. The proposed methodology was implemented with a variety of ranges for morphological and morphometric classes. Using topologically consistent data it was possible to model, in GIS environment, structures that allow a better interpretation of morphological data and morphometric data description. The geomorphological units represented are associated with diversity of forms found in upland structures. The method applied obtained consistent and reproducible results, whereas previous methods that did the standardization of morphology primarily by visual analysis ended up not maintaining a standard of identified terrain classes, thus leading to inconsistency of the data analyzed. The methodology herein developed, besides standardizes the process of interpretation of classes, especially regarding to morphology, retains control of small nuances that determine the differences of terrain classes.

\*\*\*\*\*

## Open Geomorphological Map. Romanian case study

NICULITA M.

University Alexandru Ioan Cuza, IASI, ROMANIA

Geomorphological mapping is a finality of geomorphologic research. Geomorphological maps are very useful in natural resource and environmental management, in planning, and other areas. Classic geomorphologic map are sometimes hard to disseminate, while very few countries have national wide geomorphologic maps are high scales. GIS and digital cartography started a revolution in geomorphological mapping, because digital geomorphologic maps are easy to maintain and disseminate.

The rise of open data and open philosophy could also sustain this revolution in geomorphological mapping. Web mapping technology is one of the best option to use when digital maps need to be disseminated. Web maps are distributed in web browsers as raster or vector data using various web servers and applications. While tiled raster data is the easiest method for serving spatial web data, the vector data permit a high level of interactivity.

Web geospatial data have almost the same advantages as GIS data. The generalization is a strong component of web mapping, because the interactive zooming must be performed efficiently. The use of layers, integration with aerial and satellite images and the interactivity of the web maps gave the possibility to deliver a surplus of data.

We present an example of open digital geomorphometric maps obtained based on SRTM data and geomorphometric methods, for the Romanian territory. We believe that this type of approach will help the reviving of the geomorphological mapping.

The vector data is stored in a PostGreSQL PostGIS enabled database, and the conversion to tiled raster maps is made by Mapnik, while the web rendering is made by OpenLayers, being the cheapest and easiest option for delivering online geomorphologic maps.

## **Poster presentations:**

### **Geomorphological map of Northern Jeffara plain and North-eastern part of Matmata-Dahar plateau (Southeast Tunisia) 1/100 000**

BEN FRAJ T.

*Faculty of Letters and Humanities of Soussa, Geography department, KSIBET MADIOUNI, TUNISIA*

Following geomorphological researches conducted within the framework of a doctoral thesis at the Faculty of Humanities and Social Science of Tunis, a geomorphological map summarizing the results obtained was developed. The realization of this map is based on topographical and geological coverage of the northern Jeffara at 1/100 000, on various dates of aerial photographs and using maps of the exercise carried out in the field. The figures used are those of the "Legend for the geomorphological map of France at 1/50 000, R. C. P. 77, C. N. R. S. 1970".

The design was made clean using CorelDRAW 11. The result is a map of 120 by 80 cm in size.

The map helps recognize some topographic and hydrographic data of northern Jeffara, and the various structures and structural forms. It also shows the age, nature and spatial extension of different continental, coastal and marine Quaternary deposits and forms.

\*\*\*\*\*

### **Geomorphological mapping applied to regional planning and geoheritage: study on Figueira da Foz Nazaré area (western central Portugal)**

RAMOS A.(1), CUNHA L.(2), CUNHA P.(3)

*(1) CEGOT - University of Coimbra, COIMBRA, PORTUGAL ; (2) Department of Geography, CEGOT, University of Coimbra, COIMBRA, PORTUGAL ; (3) Department of Earth Sciences, IMAR-CMA, University of Coimbra, COIMBRA, PORTUGAL*

A geomorphological characterization of the Figueira da Foz – Nazaré area (Portugal), is here presented. The region shows a diversity of landforms that resulted from the action of marine, fluvial, aeolian and mass-wasting processes, but also of lithologic and tectonic controls that occurred mainly during Pliocene and Pleistocene times.

The study leading to the identification of geomorphological features was undertaken in three stages: (1) field mapping on topographical (1/25,000) and geological (1/50,000) base maps; (2) analysis of 1/26,000 black/white aerial photographs and of a digital elevation model (DEM) based upon a 1/25,000 topographic database, in order to improve the mapping and (3) ground-truthing in the field to refine the geomorphological map produced. The final representation of geomorphological features in a geomorphological map was built using GIS and includes information on morphometry, morphography, hydrography, lithology, structure, age, and process/genesis.

A main geomorphological unit is located at east, represented by the limestone reliefs of the Massif of Sicó and Massif Calcário Estremenho. It is in this unit that are recorded the higher elevations and slopes, presenting very high susceptibility to slope movements (collapse, landslide or flows), and forest fires. Another main unit, the Coastal Platform, is located at west, presents siliciclastic lithologies, lower elevations and slopes and the shore line. It is possible to identify the higher susceptibility to a larger number of dangerous natural processes: landslides (on rocky on sandy relieves), forest fires, earthquakes (along faults), flooding (on flood plain and river mouths) and coastal erosion.

The structural and lithological characteristics of the area are responsible for a diversified geomorphological framework that, for their uniqueness, representativeness, aesthetic importance and cultural, educational and scientific values deserve to be inventoried and conserved as geoheritage.

## **Remote sensing and gis applied to geomorphological mapping of the watershed stream Indaia, MS, Brazil**

CUNHA E.(1), BACANI V.(1), FACINCANI E.(1), SAKAMOTO A.(2), LUCHIARI A.(3)

(1) UNIVERSIDADE FEDERAL DE MATO GROSSO DO SUL, AQUIDAUANA, BRAZIL ; (2) UNIVERSIDADE FEDERAL DE MATO GROSSO DO SUL, TRÊS LAGOAS, BRAZIL ; (3) UNIVERSIDADE DE SÃO PAULO, SÃO PAULO, BRAZIL

The remote sensing data implemented in a Geographic Information System (GIS) allows the establishment of an advance in taxonomic mapping of relief, giving in this way, the bases for planning and land management. The watershed stream Indaia located in the State of Mato Grosso do Sul, Brazil, in the southwest of the city of Aquidauana, whose area is approximately 94.97 km<sup>2</sup>. The Indaia stream is a tributary of the Taboco river, which consequently enters the Pantanal wetlands. Technical scientific procedures employed consisted in the application of proposed methodology relief taxonomy developed by Ross (1992), Florenzano (2008) and image processing routines described in Novo (2008). The geomorphological compartmentation was developed from intermediate cartographic products derived from physiographic analysis (satellite image of LANDSAT 5 TM and GeoEye) and supported by morphometric of from radar interferometric SRTM (Shuttle Radar Topographic Mission). The mapping geomorphological was characterized by the 5th taxon, where it was possible identify the following units of relief: fluvial plain, hills convex slopes up to 6%, hills convex slope between 6% and 12%, hills convex slope between 12% and 20%, hill top convex, hill top convex. Among the mapped drives predominate convex tops of hills in approximately 90% of the basin area associated with slopes that do not exceed 20%, sustained over the Aquidauana Formation in essence consists of granulating medium reddish sandstones. The infiltration processes are favored by the constitution lithological unit favoring a low drainage density and consequently the development of medium and large hills, morphological this domain is one of the factors that influenced the current process for use and occupation through the installation of complex settlements Indaia, since this action emphasized removal of the canopy causing imbalances morphological (silting, gully) in the basin.

\*\*\*\*\*

## **Geomorphological map of Croatia 1:100.000**

BUZJAK N.(1), PAHERNIK M.(2), FAIVRE S.(1), BOCIC N.(1)

(1) University of Zagreb, Faculty of Science, Dept. of Geography, ZAGREB, CROATIA ; (2) Croatian Military Academy Petar Zrinski, ZAGREB, CROATIA

Within the task of geomorphological mapping and making of Geomorphological map of Croatia 1:100.000 in GIS environment, model of the geomorphological database and mapping data model were created. Spatial framework of geomorphological map series is related to the projection reference system HTRS96/TM based on ellipsoid GRS80. Division of map sheets is identical to that of topographic maps at the scale of 1:100.000 (56 sheets, sheet area 40×60 km). Within conceptual modeling of geomorphological database, methods of an object-oriented analysis were used, wherein the objects (landforms) with basic characteristics were defined. This included the identification of problem areas (units), classes, objects and their attributes. Landforms are grouped according morphogenetic characteristics in 10 data groups: slope, fluvial-denudational, fluvial, karst, fluviokarst, glacial, periglacial, aeolian, suffosional and anthropogenic landforms. Based on object-oriented design the logic of software objects was established. It is the basis for the implementation of the logical model into a physical model of geomorphological database. Using UML in object-oriented design, a scheme of geomorphological database was created and then implemented in the geodatabase logical model. Cartographic model of the geomorphological map is defined by 5 groups: geological structure, morphogenetic, morphographic, morphometric and morpho-chronological data. The advantages of such system are numerous. Using a modern GIS based geomorphological map system the process of determination of relief quantitative parameters was accelerated. Unifying of the geomorphological data in spatial databases improved synthetic display of geomorphological features using digital geomorphological map and updating of map content. Clearly defined objects within geomorphologic database also enabled easier correlation and connectivity with other geoscientific databases.

### **The geomorphological map of the Hérens valley (Switzerland)**

MAILLARD B.(1), REYNARD E.(2), KUMMERT M.(2), LAMBIEL C.(2), THELER D.(1)

(1) ECOTEC Environnement SA, SIERRE, SWITZERLAND ; (2) Institute of geography and sustainability, University of Lausanne, LAUSANNE, SWITZERLAND

Within a project dealing with debris flow hazards in the Hérens valley (Valais, Switzerland) a geomorphological map of the whole valley has been produced. The map is based on a legend developed in the 1980s at the Institute of geography of the University of Lausanne. The morphogenetic legend classifies the landforms according to the process(es) responsible of their formation (green for fluvial processes, pink for periglacial processes, etc.) and according to erosional (graphics on white background) or depositional (graphics on coloured background) character. The map has been produced within a GIS environment.

The poster will present: (1) the principles of the legend; (2) the mapping methodology; (3) how the map is used as the basis for the reconstruction of the valley morphogenesis.

\*\*\*\*\*

### **Geomorphological map of the Diablerets massif - Swiss Alps**

SCHOENEICH P.(1), LAMBIEL C.(2), BOSSON J.B.(2)

(1) Institut de Géographie Alpine - PACTE/Territoires, Université Joseph Fourier, GRENOBLE, FRANCE ; (2) Institut de Géographie et Durabilité, Université de Lausanne, LAUSANNE, SWITZERLAND

The Diablerets massif is part of the frontal limestone ranges of the Western Swiss Alps, and culminates at 3200 masl. Geomorphological processes range from glacial and periglacial in its upper part to gravitational, torrential and fluvial processes in the lower parts, and it is concerned by huge powder avalanches. The area includes a very well preserved lateglacial moraine complex, a fluvial terrace system, as well as limestone and gypsum karst. A detailed geomorphological map at 1:10'000 of its northern slope has been established, using the legend of the University of Lausanne. The field surveys were digitized using orthophotos and a 1 m resolution laser DTM. The map has been edited with GIS and CAD softwares.

The geomorphological survey has been used for lateglacial paleoglaciological reconstructions, for reconstruction of historical and recent glacier fluctuations, and for the assessment of hazards related to permafrost and of torrential hazard. The map covers several registered geomorphosites and will serve for public education as well.

The poster will present the geomorphological map, as well as maps of lateglacial and recent glacier fluctuations.

### **Adaptation of the geomorphological mapping system of the University of Lausanne for ArcGIS**

LAMBIEL C.(1), MAILLARD B.(1), MARTIN S.(1), PELLITERO ONDICOL R.(2), SCHOENEICH P.(3), REYNARD E.(1)

(1) *Institute of geography and sustainability, University of Lausanne, LAUSANNE, SWITZERLAND* ; (2) *Department of Geography, University of Valladolid, VALLADOLID, SPAIN* ; (3) *Institut de Géographie Alpine, PACTE/Territoires, Université Joseph Fourier, GRENOBLE, FRANCE*

The geomorphological mapping legend of the University of Lausanne has been used for more than 20 years for detailed mapping especially in high and middle mountain regions. It is a morphogenetic mapping system built on the following principles:

- The colours represent process categories;
- The signatures have a genetic significance and are drawn in the colour of the related process;
- The morphodynamic differentiation of erosion and accumulation areas is achieved by white and coloured surfaces respectively.
- The morphography, the slope gradient and the lithology are not represented.

The legend was developed first for mapping by hand with colour pencils in the field. In the 1990s, several attempts were made for developing computer-assisted maps, especially by using Adobe Illustrator software. The improvement of the graphical performance of GIS in the last years permitted the adaptation of the legend for GIS to be considered. Through various geomorphological mapping projects, a new version could be developed in ArcGIS 10.0. It consists in a geodatabase containing three Feature Datasets containing respectively the Features Classes "points", "lines" and "surfaces". Specific symbols were developed using the Representation tool in ArcGIS 10.0. For some landforms (e.g. alluvial fans, rockglaciers, deltas), it was necessary to combine two or three point, line or surface symbols. Thanks to the ArcGIS version of the legend, it is now possible to map the geomorphology in a GIS environment from the combination of orthophotos, topographical maps and high resolution DEM, that is with reduced field survey.

This poster will present the concept of the legend, the geodatabase and some illustrative examples.

\*\*\*\*\*

### **Survey the relationship between geomorphology and forest types (Case study: Kheirod forest, North of Iran)**

MOEINI A.(1), ALIZADE A.(1), AHMADI H.(1), ETEMAD V.(2)

(1) *Science and Research Branch, Islamic Azad University (IAU), TEHRAN, IRAN* ; (2) *University of Tehran, TEHRAN, IRAN*

In Iran, the literature about the relationship between geomorphology units and vegetation in rangeland has been studied, but, due to lack of multidisciplinary information to our knowledge in forest areas such researches have not been regarded. The goal of this study is to survey the relationship between geomorphologic factors and forest types. We studied the relationship in Kheirod forest in the North of Iran, with the longitude and latitude of  $36^{\circ}27' - 36^{\circ}40'$  and  $51^{\circ}32' - 51^{\circ}43'$ , respectively. Firstly, in this study we prepare a geomorphology map originating from slope, hypsometry, geology, and aspect maps with the aid of Arc GIS software. The final map was then reclassified.

We also develop a map of the forest types map. Then two maps (geomorphology and forest types maps) were overlaid. Finally we investigated of both. Using SPSS software, we investigate the relationship between geomorphology factors and evidence of forest types. We relied on ANOVA and found that the geographical aspect had the highest variance and standard error, showing the weakest relationship of the aspect mentioned with the forest types. Also hypsometry and slope represented the greatest correlation with forest types, respectively. The strongest correlations were between geomorphology units and forest types including, Acer Velutinum, Acer Mixed, Querceto–Alnetum, Alnus mixed, Querceto–Carpinetum, Carpineto – Quercetum, Alneto–Acertum, Alnetu–Carpinetum and Fraxinetu. The survey was showed that forest types including Fagus Orientalium, Carpinus Orientalium, Carpineto–Fagetum, Fageto – Carpinetum, Parotio – Carpinetum have the weakest correlation with geomorphology units. We found that these types have the highest adaptability with environment, and that such conditions help them grow in extensive areas of the North of Iran with same weather.

### The main geotouristic objects in the Lodz region (Central Poland)

*DZIEDUSZYNSKA D., WACHECKA-KOTKOWSKA L.*

*University of Lodz, Faculty of Geographical Sciences, Department of Geomorphology and Palaeogeography, LODZ, POLAND*

The Łódź Region is located in central Poland on the border of the Polish highlands and lowlands. The geological history of the area and variety of processes created landforms which nowadays may attract the tourists.

The oldest geotouristic objects of the Łódź Region are grouped in the south and are connected with the Mesozoic (e.g. limestones with dinosaur traces the Żarnów vicinity is called "Polish Solnhofen" acc. to Kin & Błażejowski 2012). The most numerous geotouristic objects go back to the last glacial episode of the Łódź Region – Wartanian Stage (MIS 6, Late Saalian, Middle Polish Complex). A peculiar group of attractive landforms of the region was formed under periglacial conditions in the Weischelian such as dunes, dry valleys, sections of river valleys, fluvial terraces and structures originating within the frozen ground.

The Holocene objects are connected both with natural and anthropogenetic processes. Human activity in the Łódź Region left the deepest outcrop in Europe at the Bełchatów vicinity (340 m deep) and other excavations, dumpling grounds and geological profiles exposed on the banks of artificial reservoirs.

Work in inventorying of geotouristic sites was carried out in order to compile the Geotourism in the Łódź Region map at a scale of 1:270 000. In the area of 18 218,95 km<sup>2</sup>, apart from the above mentioned object, additionally distinguished were objects protected by nature preservation regulations: 23 nature reserves, 11 nature monuments, 43 ecological areas, 32 geosites, geological exhibitions (3 museums, 5 lapidaries, 4 exhibitions).

In the Łódź Region there are 7 landscape parks. Potentially Łódź's Hills Landscape Park may be chosen as a geopark. It would represent combination of geoheritage - unique polygenetic relief of glacial, periglacial and recent stages in landscape evolution of the region and human heritage.

Investigation founded by Department of Touristic of the Marshal's Office of the Lodz Region.

\*\*\*\*\*

### Hydrogeomorphological mapping in hard-rock groundwater systems

*TEIXEIRA J.(1), FREITAS L.(2), AFONSO M.J.(1), ROCHA F.(3), PEREIRA A.J.S.C.(4), MARQUES J.M.(5), CHAMINE H.I.(1)*

*(1) Laboratory of Cartography and Applied Geology, School of Engineering (ISEP), Polytechnic of Porto and Centre GeoBioTec, University of Aveiro, PORTO AND AVEIRO, PORTUGAL ; (2) Laboratory of Cartography and Applied Geology, School of Engineering (ISEP), Polytechnic of Porto, PORTO, PORTUGAL ; (3) Centre GeoBioTec, University of Aveiro, AVEIRO, PORTUGAL ; (4) Laboratory of Natural Radioactivity / IMAR, Faculty of Sciences and Technology, University of Coimbra, COIMBRA, PORTUGAL ; (5) Centre for Petrology and Geochemistry (CEPGIST), Instituto Superior Técnico, Technical University of Lisbon, LISBON, PORTUGAL*

Hydrogeomorphology is an evolving interdisciplinary scientific domain including geomorphology and hydrology. Groundwater is a dynamic and renewable georesource, but in hard-rock terrains its availability is rather limited. Such type of groundwater systems require a comprehensive understanding of geology and morphotectonics, which are controlled by the ground characteristics like weathering grade, fracturing degree, permeability, slope, drainage pattern and density, land cover, and climate. Although hard-rock watersheds are essentially confined to fractured and weathered horizons, they are a source of valuable water resources at a regional level, namely for domestic, industrial and agricultural purposes, and public supply. Hydromineral and geothermal resources have a relevant economic value in the bottled water / thermal spas industry and energy supply, respectively. Hydrogeomorphological mapping was performed in two distinctive groundwater frameworks: an urban area and a hydromineral system. GIS based cartography provided an accurate way to improve knowledge on water circulation models and global functioning of aquifer systems. Thematic maps were organised from a geodatabase comprising several layers namely lithology, tectonic lineaments density, slope, drainage density, rainfall, net groundwater recharge and water quality. Hydrogeochemistry, natural radioactivity and hydrotoponymy issues were also cross-checked. Normalized weights were assigned to all these categories according to their relative importance to groundwater potential, based on their effectiveness factors. These maps were prepared and combined using a GIS platform with the purpose to elaborate an integrated hydrogeomorphological map that might outline the recharge potential areas and infiltration rates. This approach highlights the importance of hydrogeomorphological mapping as a useful tool to support hydrological conceptualization, contributing to water resources sustainability.

**Geomorphological analysis on the geological formations in downstream valley of the Da River, the Western Hanoi City, Vietnam**

NGUYEN XUAN N.

*Vietnam institute of geoscience and mineral resource, HANOI, VIET NAM*

Da River is the large river originates from China's Yunnan flows through northwest of Vietnam with a length of 527 km in the direction of the mainstream is Northwest-Southeast, but its downstream segment with 60 km in distance from Hoa Binh town change to the Northward into the Red River in Viet Tri town. This paper presents research results for Da River valley from Hoa Binh to Viet Tri with the semi-automated geomorphological mapping, analysis of 11 surfaces of geomorphological unit and their interaction with the geological formations, the results can be show that the topographical surface is dependent on the geological formations and based on that to determine more accurate surface topography as denudation, erosion, tectonic surface. The article also interprets the time that formed downstream valley of the Da river, through which shows the downstream valley of Da river has just appeared in the middle Pleistocene.

\*\*\*\*\*

**Use the of engineering geomorphological mapping for landslide hazard assessments in Hong Kong**

PARRY S.

*GeoRisk Solutions Ltd, SHEUNG WAN, HONG KONG*

As part of the review and updating of the current Hong Kong Government guidelines with respect to the assessment of landslide hazards from "natural terrain", an evaluation of the level of engineering geomorphological input, in particular mapping techniques, was undertaken. The first stage comprised a review of published literature and completed assessment reports. The geomorphological mapping typically undertaken can be classified as being direct geomorphological mapping commonly on a catchment basis at a scale larger than 1:2,000. The implications of the review of completed projects were that a significant number of completed studies are considered to have limited engineering geomorphological input. Consequently, "good practice" illustrated with case studies has been documented. This paper discusses the review and suggested "good practice".

### Mapping flood vulnerability. Case study: Tecuci Town (Romania)

COMANESCU L., NEDELEA A., ZAHARIA L., SAFTOIU L.  
University of Bucharest, BUCHAREST, ROMANIA

The aim of this paper is to assess and map the vulnerability to flooding of an area (Tecuci Town) where such phenomena have been present since 2007. In order to produce the flood vulnerability map the following variables will be taken into account: terrain features, assessed with GIS techniques; Hydrological characteristics of the Bârlad and Tecucei rivers, based on the data provided by the National Institute of Hydrology and Water Management; Meteorological conditions, relying on the data collected from the National Meteorological Administration.

All numerical data were analyzed and interpreted thoroughly, so that to avoid the occurrence of potential errors. The results were processed by using statistical techniques as well, which allowed the computation of a number of indices that emphasize the general evolution trend. Under the circumstances, we were able to use for our GIS analyses the most accurate datasets. In order to develop the flood vulnerability map we used the following software and digital outcomes: The digital terrain model provided by the National Agency for Cadastre and Land Registration, having an altimetric accuracy of 0.5 m along the main rivers and 0.5 – 2.5 m for the rest of the area; The watershed outline in ESRI format; The land use map of scale 1:50000 in ESRI ArcInfo shapefile format; The geological map of scale 1:200000 in ESRI ArcInfo shapefile format; Orthophotoplans of 0.5 m resolution of the entire watershed in ECW format;

The resulting vulnerability map suggests that Tecuci Town, through its geographical position and geomorphological features, lies in an area where floodings are a common phenomenon. Consequently, one can identify the following types of areas: areas never affected by floods, with low flooding vulnerability; areas affected by exceptional floods, with medium vulnerability, and areas affected by floods every year, where vulnerability is high. Every type of vulnerability was mapped differently, by using specific indices

\*\*\*\*\*

### Multi-scale and multi-purpose Geomorphological Mapping for landscape evolution, geotourism, slope instabilities, and medical geology

PIACENTINI T., MICCADEI E., DI MICHELE R., RANALLI O., SCIARRA M., URBANO T.  
Dipartimento di Ingegneria e Geologia - Università degli Studi "G. D'Annunzio" Chieti-Pescara, CHIETI, ITALY

Geomorphological maps are primary tools for landscape study and management. Mapping at different scales and mapping different features can be focused on different purposes: from basic research to land management, from geomedicine to geotourism.

This work is a contribution of data and examples to enhance modern geomorphological and geothematic maps; examples of Morphotectonic maps, Slope instabilities maps, Geomedical maps and Geotourist maps are presented, at different scales ranging from 1:10.000 to 1:50.000, realized in the main morphostructural sectors of the Abruzzo Region.

The creation of morphotectonic maps in the southern Abruzzo chain-piedmont area is based on drainage basin scale geomorphological analysis within GIS environment and provides a contribution to define the main phases of post orogenic landscape evolution of the piedmont area of the Apennines chain.

In the same area (Aventino - middle Sangro area), a geotourist map is presented. The map is reinterpreted from the geomorphological maps, distinguishing outcropping rocks as concern their surface expression into distinct geological landscapes.

Slope instabilities maps presented in this work outline geomorphological instabilities, triggered by heavy rainfall events that affected the Coastal area Abruzzo Region in the last six years, by means of aerial photo interpretation and field geomorphological mapping. These kind of maps are the base for flooding and slope instabilities hazard analysis and for the estimation of sediment volumes eroded during the events. This is particularly important for minor drainage basins of coastal slopes and coastal hills where erosion and hazard are frequently underestimated.

Finally, geomedical maps are recently developed in many countries incorporating multiple land features: bedrock lithology, surface deposits, pedology, geochemistry, disease distribution and incidence etc. In this work, the first geomedical maps realized in the Abruzzo region is presented.

## **Ecological-geomorphological features of transboundary interaction in the Irtysh river basin**

PLATONOVA S.

*Institute for Water and Environmental Problems, Russian Academy of Sciences, Siberian Branch, BARNAUL, RUSSIAN FEDERATION*

The paper presents the results of the analysis of environmental and geomorphological features of transboundary interaction in the Irtysh River basin on the border of Russia and Kazakhstan. The study was aimed at identifying the contribution of the border regions of different countries to the transboundary transport of pollutants depending on topographic features. The methodology was based on the evaluation of ecological and geomorphological characteristics of different ecological and geomorphological areas (V.I. Kruzhalin et al., 2004). The areas were defined with the schematic map of natural hazards and risks of geodynamic processes in the transboundary Irtysh basin, comparing the basin boundaries, hypsometric levels, morphological and climate conditions and the boundaries of morphostructural elements. The type of the region state was defined by the direction and nature of air, water and groundwater movement, i.e. divergent, transit, convergent, divergent transit and transit-convergent. Regionally, the divergence zones are presented by slopes of regional watersheds with prevailing denudation. The transit zones involve the channels of large rivers, where the material transport takes place. The convergent type is determined by accumulation of transported material which is found in the end pools. Transit-divergent type is prevalent within the areas with flat surface. Transit-convergent type characterizes the conditions of transport and accumulation of material from fluviolacustrine valleys. As a result of integrated assessment of areas by the type of state (the nature of water and sediment movement) and the total anthropogenic load all the border regions of transboundary Irtysh basin are considered by their ecological wellbeing in terms of transboundary pollutant transport as the "unfavorable", "relatively favorable", and "favorable". The results obtained can be used in the development of a program of international cooperation.

\*\*\*\*\*

## **Geomorphology explains the regional beta-diversity of French Guiana rainforest and furnishes consistent maps to optimize forest management, regional planning and biodiversity conservation**

*GUITET S.(1), RICHARD-HANSEN C.(2), BRUNAUX O.(3), CORNU J.F.(4), CAROZZA J.M.(5)*

*(1) INRA - ONF, MONTPELLIER, FRANCE ; (2) ONCFS, KOUROU, FRENCH GUIANA ; (3) ONF, CAYENNE, FRENCH GUIANA ; (4) IRD, PARIS, FRANCE ; (5) Univ de Strasbourg, TOULOUSE, FRANCE*

The aim of this study was to describe the floristic and structural diversity of terra-firme rainforest across the all French Guiana to identify and map different natural habitats in order to better take into account the biodiversity preservation issues in forest management and regional planning.

Twenty six sites distributed over the entire territory had been sampled using a rapid assessment method based on the repetition of 3km-long transects. 92 transects had been implanted and divided into 2750 contiguous 100mx20m plots. All trees larger than 17.5 cm diameter at breast height had been measured and identified using a vernacular nomenclature with a good reliability with taxonomic taxa. We used constrained and unconstrained ordination (Correspondence Analysis and Non-Symmetric Correspondence Analysis with or without Instrumental Variable) to analyze the variation in abundance of the 210 taxa and 50 families. The influence of several environmental factors, including geomorphologic ones, had been tested with partitioning methods and compared with multiscale spatial analysis to detect the most important patterns and the most efficient scales to explain beta-diversity.

This nested multi-scale approach allowed us to detect strong broad scale patterns showing a good correspondence with the geomorphologic landscape factor. Geology and rainfall shown less potential to explain beta-diversity and spatial variation. No more structure had been detected on intermediate and local scale but topography appeared to have a strong local but non-structured effect on forest composition. A simplified additive model including geomorphologic landscape and topography effects predict the abundance of 83 taxa out of 210 representing 77% of the trees.

In the context of very old and eroded terrain, as Guiana shield, geomorphologic landscape is the best predictor of trees diversity because of its integrative value summarizing both actual environmental filters and ancient ecological dynamics.

### Multi-temporal mapping of a large, slow-moving earth flow for kinematic interpretation

REVELLINO P.(1), GUERRIERO L.(1), COE J.A.(2), GRELE G.(1), GUADAGNO F.M.(1)

(1) University of Sannio, BENEVENTO, ITALY ; (2) U.S. Geological Survey, DENVER, UNITED STATES

Periodic movement of large landslides produces modifications of the topographic surface, creates faults and folds, and influences the locations of springs, ponds, and streams. The geometry of the basal-slip surface and the variation in the rate displacement are responsible for differential deformation of the landslide body which can control the position of structures. Thus, large landslides are often composed of several distinct morphologic elements, which often represent kinematic domains within the main landslide. They are broadly characterized by stretching of the upper part and shortening near the toe. On this basis, we mapped structures on the surface of the periodically active Montaguto earth flow in southern Italy between 1954 and 2010. We recognized several kinematic elements and associated structures. Within each kinematic element, the flow velocity was highest in the middle parts, and lowest in the upper and lower parts. As the velocity increased, stretching of the earth flow body induced the formation of normal faults. Conversely, decreasing velocity and shortening of the earth flow induced the formation of thrust faults. A zone with relatively few structures, bounded by strike-slip faults, was located between stretching and shortening areas. The spatial variation in movement velocity associated with each domain, mimicked the pattern of movement for the overall earth flow. That is, the earth flow displayed a self-similar pattern at different scales. Furthermore, the presence of other structures such as back-tilted surfaces, flank-ridges, and hydrological elements provide specific information about the shape of the basal surface. The study offer a preliminary interpretation of the long term-kinematic evolution of the earth flow and the influence of the basal-slip surface on its movement. Main faults remained stationary through time, despite extensive mobilization of material. We therefore assumed the slip-surface has remained relatively similar since 1954.

\*\*\*\*\*

### A new interdisciplinary approach to build a geomorpho-archaeological map: the case study of the Versilia plain (NW Italy)

BINI M.(1), BARONI C.(1), RIBOLINI A.(1), ANICHINI F.(1), GATTIGLIA G.(1), PARIBENI E.(2)

(1) Pisa University, PISA, ITALY ; (2) Soprintendenza per i Beni Archeologici della Toscana, PISA, ITALY

The geomorpho-archaeological map is an essential starting point for integrated studies that would like to depict the history of a territories with a holistic approach, considering both natural and human-induced changes. This aspect becomes more and more important taking in account both the open debate regarding the critical transition from natural to anthropogenic-dominated environments, and the time-period characterized by anthropogenic disturbance, almost globally recognized and informally called "Anthropocene". This study is focused on to identify a new methodological approach based on geomorphological, sedimentological, geophysical and archaeological data, finalized to build a geomorpho-archaeological map. The test area is the Apuo Versilian coastal plain which suffered a lengthy and intense human land-use history, documented by numerous archaeological sites and historical sources. At least since ca. 2700 BP, evidences of human settlement in the area exist, but these become more relevant during roman time as attested by several roman sites. Geologically the area is well studied because it hosts the type site of the so-called "Versilian", i.e. the Holocene transgression which followed the LGM. The progradation of this coastal plain has been starting since 3000 yrs BP when the coastline was located about 2,5 km landward in respect to its present-day position. The identification of four high-frequency small-scale transgressive-regressive cycles within the succession recording the Late Holocene phase of progradation points out that the progradation rate of the coastline was subjected to cyclic fluctuations. The managing of geomorphological, stratigraphic, geophysical and archaeological data via GIS techniques enables us to explore procedures to integrate natural and anthropogenic occurrences. The reliability of the reconstructed history of the Versilian coastal plain represents a good validation of our methodology.

## **Geomorphological Map of Piumhi Topographical Sheet (1:50.000) - Minas Gerais - Brazil**

RODRIGUES S.C., MARTINS T.I.S.

*Universidade Federal de Uberlândia, UBERLANDIA, BRAZIL*

This study presents a geomorphological map and research about Piumhi Sheet (1:50.000) located in the upper part of São Francisco River basin, in highlands of central Brazil. The study area presents a complex geological organization with three different structural domains, with sandstones, mudstones, conglomerates, intrusive rocks and Pleistocenic-Holocenic alluvial deposits. The methodology of studies uses GIS technology to generate basic morphometric information as topography, slopes angles, aspect and curvatures and delimitation of drainage basin. The morphogenetic approach was used to make a manual interpretation of satellite pictures and after field works a huge number of particular features were delimited. In the karstic area a complex landscapes with limestone massifs with lapiez fields, sinkholes, uvalas, poljes, blind valleys and caves was identified. The sedimentary region presents a homogeneous fluvial-dissected landscape, and the main rivers presents meandering pattern with large alluvial plains in which features as oxbow lakes and rounded lagoons are mapped. A ridge elaborated in the intrude rocks is located in the south part of the mapped area. The legend of the map was organized to present morphometric and morphogenetic information. The challenge of this study was to map a complex landscape in tropical area and uses a mix of traditional and modern technics of interpretation and presentation of geomorphological data about an area with little detailed information. The interpretation of the evolution of landscape in basis of past climatic changes and the occurrence of neotectonics in the area still a doubt and reinforces the necessity of complementary studies. This geomorphological map is a start that will be used a basis to new researches to be made in a near future.

\*\*\*\*\*

## **Database development for mapping fluvial channel variations: case study Cecina River (Central Italy)**

TERUGGI L.B.(1), CHIAVERINI I.(1), OSTUNI D.(1), FARENGA M.(2)

*(1) Dipartimento di Ingegneria Civile e Ambientale, FLORENCE, ITALY ; (2) Instituto de Geologia de Costas y del Cuaternario, MAR DEL PLATA, ARGENTINA*

Nowadays, in environmental studies the use of Geographical Information System(GIS) has become an indispensable tool. Advances in GIS technology has increased the contribute that historical maps and aerial photographs can give to the analysis of morphological variations. We report on a study achieved on fluvial morphological changes. Lateral channel migration were monitored and mapped and integrated with historical data of some representative reaches.

This study is carried out in the Cecina river watershed. It is located in southern Tuscany, central Italy, and flows into the Tyrrhenian Sea. The Cecina is a gravel bed river, is 79 km long and has a drainage area of 900 km<sup>2</sup>.

To analyze lateral changes a database has been developed using historical maps and aerial photographs of different scales.

Historical analysis of maps and aerial photography data has allowed to measure temporal and spatial changes in the river channel. Channel width and sinuosity index have been measured.

Two representative alluvial reach were selected for monitoring channel tendencies using light aircraft and commercial digital calibrated cameras for large scale analysis.

The surveys were repeated after two years. Photogrammetric procedures to generate Digital Elevation Models (DEM) were applied. The net accuracy was 50 x 50 cm. These surveys provided information about channel sediments behavior before and after flow events. The resulting 3D-data were processed with specific software. Comparison between the surveys enabled precise calculation of the volumetric differences between them and the total volume of material eroded and accumulated.

A map of channel surface was constructed in order to identify the distribution and intensity of erosion and sedimentation along channel reaches.

A map of lateral channel variation was developed. In some representative reaches, changes in land-use and forest cover floodplain were mapping and quantified by comparing aerial photographs using GIS data processing.

## **Using geospatial mobile applications and devices for geomorphological field data collection in mountain areas: a comparison test**

BACENETTI M., PEROTTI L., GIARDINO M.

*University of Torino - Department of Earth Sciences, TORINO, ITALY*

Classical methods for field data collection on geological and geomorphological features are based on the use of relatively simple tools, such as paper notebooks, coloured pencils, base maps... together with the personal skills of researchers. So far, data collected on the field had to be interpreted, summarised and redrawn in order to create base geological and geomorphological maps and/or more elaborated geothematic ones.

In the last 15 years, the use of computers and other electronic devices for collection, analysis and distribution of field data had a notable development also in the Geomorphology and their applications to environmental analysis. This originated effective improvements not only in the field activities, but also in the laboratory ones, in terms of enhancement in both rapidity and precision of data processing, interpretation, and representation. Still, many not-yet-resolved problems concern either the conceptual framework or the practical solutions for field data collection and their transposition into maps.

Technological developments in the geographical application of mobile geoinformation technologies make easier mapping of difficult terrains of rough morphologies and allow quantification of temporal and spatial dynamics of various geomorphological processes. While many developments in GPS and mobile GIS have been considered from the viewpoint of geodesy, their versatility in geomorphological situations has had limited attention.

The paper presents and discusses the results of laboratory and field researches conducted in mountain areas of Europe and Canada, including some considerations on essentials in mapping activities, attributes of geological/geomorphological features and characteristics of Geomatics tools, device and methodologies.

\*\*\*\*\*

## **Les inondations urbaines dans la ville de Khénifra (pied du Moyen Atlas occidental, Maroc) : caractérisation et cartographie**

EL GHACHI M., EL KHALKI YAHIA

*Université Sultan Moulay Slimane, FLSH, Av. Ibn Khaldoun, B.P: 524, Beni Mellal, BENI MELLAL, MOROCCO*

Le Maroc, comme les autres pays du pourtour méditerranéen, n'est pas à l'abri des inondations même s'il appartient à une zone climatique semi aride. Les inondations ont constitué durant ces 10 dernières années un risque majeur pour le territoire national, surtout pour les villes situées au pied de la montagne.

La ville de Khénifra est un exemple de ces villes qui connaissent en permanence des inondations avec une fréquence d'une année sur cinq (1/5). Cette situation de risque peut s'expliquer par divers facteurs liés à son site particulier :

- i) position de cuvette au pied du Moyen Atlas,
- ii) entre quatre grandes montagnes,
- iii) oued Oum Er Rbia qui la partage en deux du Nord au Sud,
- iv) présence des 9 châabates (vallée temporaire) qui débouchent sur la ville.

En l'absence des stations hydrométriques, nous avons fait appel à l'approche naturaliste géomorphologique, pour déterminer les zones à risque d'inondation au niveau de la ville de Khénifra. Cette approche se base essentiellement sur le travail de terrain.

En termes de résultats, cette approche cartographique a permis de déterminer les zones à risque d'inondation le long de l'oued Oum Er Rbia et le long des différentes châabates. Elle a permis aussi de caractériser la vulnérabilité et d'identifier les différents enjeux territoriaux.

L'objectif final de ce travail est d'aider la commune de Khénifra via les cartes d'aléa, de vulnérabilité et des zones à risque de prévoir le phénomène d'inondation et de prendre en considération ces zones dans les projets d'aménagement et de protection.

Mots clés : Risque d'inondation – Cartographie – Approche géomorphologique- Chaabates – Ville de Khénifra – Maroc

### **Geomorphological units of Mainland Portugal: definition and mapping**

*PEREIRA D.(1), SANTOS L.(2), PEREIRA P.(1), SILVA J.(2), HENRIQUES R.(1)*

*(1) Geology Centre of University of Porto / University of Minho, BRAGA, PORTUGAL ; (2) Geography Department, Federal University of Paraná, CURITIBA, BRAZIL*

A cartography of Mainland Portugal (89,015 km<sup>2</sup>) geomorphological units at 1:500,000 scale was produced, constituting the first map of this kind for this country. It follows the traditional definition of physiographic provinces started in the United States of America at the beginning of the XX century though automating the numerical and cartographic analysis of topography and increasing the detail and accuracy of the mapping using GIS procedures. Morphostructure and morphosculpture concepts developed recently in similar works in the states of São Paulo and Paraná (Brazil) were adopted. The 1:500,000 scale allowed the use of a three level classification of Morphostructural Units (level 1), Morphosculptural Units (level 2) and Morphosculptural Sub-Units (level 3). All mapping was performed using digital elevation models (DEMs) obtained from the Shuttle Radar Topography Mission data (SRTM; <http://srtm.usgs.gov>), supplemented with geological and topographic maps. The texture of the DEM reflects geomorphological elements that are visually distinguishable in the image (summit surfaces, slopes, valleys and drainage patterns). Variations in relief and drainage patterns were identified through image analysis and used to define different units. The unit boundaries were then checked in the field with their description, photography and coordinates registration. In laboratory all data was assembled into the computer and correlated with the mapping database. From the notes and photos it was possible to resolve conflicts, and to correlate polygons with field observations. The resulting geomorphic map allowed the identification of 3 morphostructural units at level 1, 9 morphosculptural units at level 2 and 56 morphosculptural sub-units at level 3. Quantification was made of parameters like the area of the mapped units, the length of all hydrographic channels, drainage density (horizontal and vertical), altitudinal and slope classes (in area and proportion) for each unit.

\*\*\*\*\*

### **A GIS based interdisciplinary analysis of Río Quequén Grande watershed in Argentina**

*TERUGGI L.B.(1), MARIN E.(2), CAPORALI E.(1), VACCARO C.(2), SALA S.(3), KRISTENSEN M.J.(3)*

*(1) Dipartimento di Ingegneria Civile e Ambientale, FLORENCE, ITALY ; (2) Dipartimento di Scienze della Terra, FERRARA, ITALY ; (3) Facultad de Ciencias Naturales y Museo, LA PLATA, ARGENTINA*

The Río Quequén Grande watershed covers an area of about 9.940 km<sup>2</sup> in southeast of Buenos Aires province, Argentina. The region is characterized by intense agricultural activities and it is part of one of the most productive plain in the world. Due to the intensive farming practices a diffuse pollution on the aquatic systems can be identified. Three main vectors that impact the ecological status of water bodies need to be investigated: variation in water quantity, variation in water quality and geomorphology alteration. In this frame, the integration of all the available data, coupled with specific data from appropriate monitoring campaigns is proposed. Particularly, a GIS is developed and an interdisciplinary approach is implemented for mapping water bodies geochemical features and the interactions with the geomorphological context. The watershed is characterized through a DEM, geomorphological, sedimentological, hydrological and hydraulic data, integrated with biological monitoring data for water quality assessment. The aim of the research is to integrate abiotic and biotic data together with all the available information, to identify natural and anthropogenic spatial heterogeneity and ecological status of the watershed. From source to mouth, textural, chemical and petrographical river bed sediments data and water chemical parameters of the main hydrographic network are monitored and analyzed. Geochemical analyses are obtained by an X-ray fluorescence spectrometer, ARL Advant'X series. The integrated GIS-based modeling cascade from catchment and reaches to aquatic habitat is the broad result of the research. The spatial analyses carried out on the available distributed data integrated with the monitoring on site data lead specific results that are recorded in the integrated informative system. The GIS based system can be used for the watershed assessment and to develop spatially distributed mitigation strategies for a sustainable growth environment respectful.

## Geomorphological mapping in Poland

ZWOLINSKI Z.

*Institute of Geoecology and Geoinformation, Adam Mickiewicz University in Poznan, POZNAN, POLAND*

At the beginning of the 21st century, thanks to the growing of geotechnology, it was possible to proceed with the works which started over half a century earlier. Firstly, there were individual works, then, after a few years, long-term works on resuming geomorphological mapping could be taken up within Association of Polish Geomorphologists. This initiative coincided with the implementation of the INSPIRE directive and the actions of Head Office of Geodesy and Cartography resulting from the directive mentioned. These were the favorable conditions for highly professional preparation for modern geomorphological mapping and support from various institutions. The preparation for geomorphological mapping is divided into three stages:

1. a formulation of content assumptions;
2. a formulation of technical standards;
3. a formulation of editorial and technical assumptions.

When all preliminary goals mentioned above are achieved, it will be possible to initiate a systematic nationwide geomorphological mapping and, subsequently, to edit digital geomorphological maps. For Poland's area there should be 1085 such maps (1:50 000 scale). This project is supported by the regulation of the Council of Ministers of the Republic of Poland(2011).

\*\*\*\*\*

## Rainfall intensity, aggregate stability, shear stress resistance as parameters to evaluate soil erosion by water: an experimental study

KEESSTRA S.(1), MARRUEDO ARRIBITA A.(1), LASSU T.(1), SEEGER M.(2)

*(1) Wageningen University, WAGENINGEN, NETHERLANDS ; (2) University of Trier, TRIER, GERMANY*

It is generally assumed there is a relation between raindrop impact on soil surface and aggregate disruption. Depending on the rainfall characteristics, this induces changes in the soil's surface and thus, it is assumed that it leads to changes in aggregate size distribution, aggregate stability and shear strength at the soil's surface. In most studies aggregate stability is seen as a constant parameter over time, however, raindrop impact can have a significant effect on aggregate stability. This study explores the influence of different rainfall intensities on changes in aggregate stability and shear strength of a loamy texture soil from arable land in laboratory rainfall experiments. Furthermore it assesses the hydrology and erosion dynamics on the micro scale as well as the micromorphological changes on the plots surface (rill and crust development) to understand initiation of flow paths.

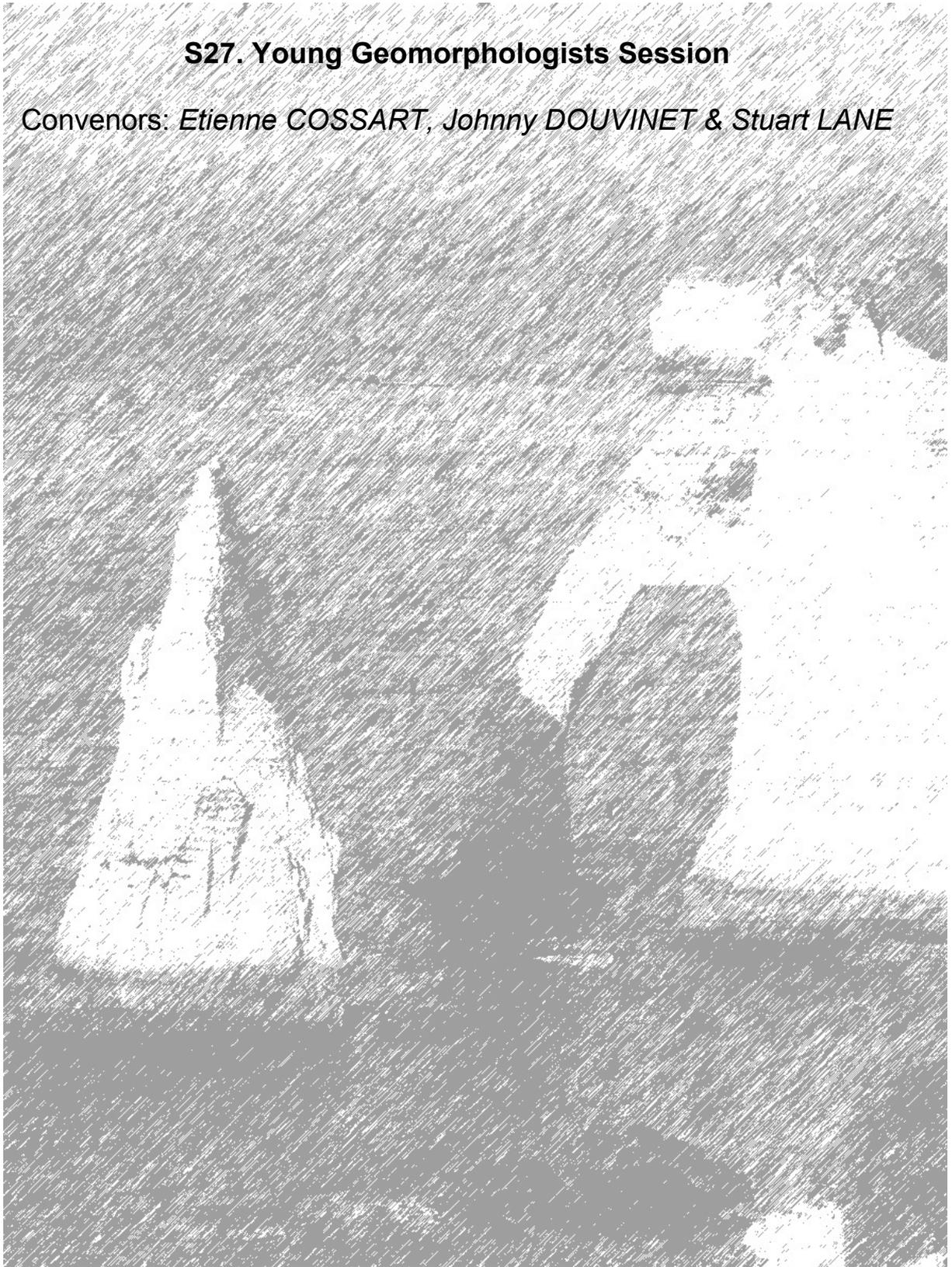
The experimental set up consisted of two experiments in a laboratory rainfall simulator. Each experiment comprised 4 boxes (100cm x 49.5cm) filled with loamy material. Two slope angles, 2.5 and 10-12 degrees were analysed. Rainfall intensity ranging from 30 to 60 mm/h, were used for a period of 5 times 15 minutes (5 repetitions).

The results show that to be able to quantify the complex relationship between the different rainfall intensities and moisture content, Ca cohesive component and aggregate stability, as well as the soil surface roughness changes in time, better suitable methodology is needed. Nevertheless, the results show a clear complex interaction between the analysed components. Thus further research on the influence of different rainfall intensities, slope, soil textural type and crusting processes on the studied variables: Ca cohesive component, moisture content and aggregate stability is recommended. Furthermore, this study showed that the chain method used is not sufficient to assess small scale erosion and deposition processes like observed in this study.



**S27. Young Geomorphologists Session**

Convenors: *Etienne COSSART, Johnny DOUVINET & Stuart LANE*





## **Oral presentations:**

### **Morphometry of talus slopes in the high mountains methodological problems**

LELEN M.

*Pedagogical University of Cracow, CRACOW, POLAND*

Talus slopes are significant elements of the high-mountains landscape as a results of denudation process, especially rocky slope and rockwall erosion. They occurs in different geocological belts. Size, type of longitudinal-profil and development of talus slope are dependent on intensity of geomorphological processes modelling them. Rockwall character is an important factor influencing the formation of the talus slopes. Transfer of weathering debris material from rockwall is due mainly gravity (sometimes with the participation of water, snow and wind). The line of falling of weathering material is various and depends on the rockwall and rocky slope topography. Determination of the exact size of the supply area for talus slopes formation is problematic. It is especially difficult when the remote sensing methods and DTM are used for the studies. So-called „difficult rockwall” with complicated topography and unclear exposure system, require a thorough cartographic analysis and detailed verification in the field. Establishing the direction of transfer of falling debris material requires correlation several factors (exposure, inclination, height, surrounding topography of the rockwall). The problem of determining area from which originates falling debris material do not concern the rockwalls and rocky slopes of the simple topography. Another problems appears when talus slopes extent and its basic morphometric parameters are measured. So-called „easy rockwall” with not complicated topography not impaired additional difficulties determine them. Compact forest (middle sections of the valley) and alpine vegetation (upper sections of the valley), inaccessible terrain or small size surface are main complicating factors. They cause increasing limit of error in morphometric measurements based on remote sensing methods and DTM. The crucial is using proper compilation methods in the studies to minimize measurement error.

\*\*\*\*\*

### **Thermal regime of ground surface in the French Southern Alps: a case study from the Clarée and Ubaye valleys**

PERRIER R.(1), COSSART E.(2), FORT M.(1)

*(1) Université Paris-Diderot, UMR 8586 PRODIG CNRS, PARIS, FRANCE ; (2) Université Paris 1 Panthéon-Sorbonne, UMR 8586 PRODIG CNRS, PARIS, FRANCE*

Permafrost is an important part of the cryosphere and a key indicator of climate change in mountain areas. Actual global warming may induce ground warming and lead to permafrost degradation, which in turn may enhance natural hazards such as rockfall, debris flow or slope instability. Understanding and monitoring permafrost thermal regime becomes a fundamental issue to predict its long term evolution.

Physical processes that control ground temperatures, and thereby permafrost in mountain areas, are highly affected by extreme variability in topoclimatic parameters (altitude, solar radiation), ground material and snow specificities. Therefore multiplication of measurements in various topoclimatic conditions should provide a better understanding of the effect of these factors on ground thermal regime. Studies undertaken on this issue in France for the last decades are rare and restricted to very specific areas. We contribute to expand this research to wider sectors of the French Alps.

We present the results of a two years (August 2010-August 2012) monitoring of thermal regime of ground surfaces by applying continuous measurements of Ground Surface Temperature (GST) using Miniature Temperature dataloggers (MTD). In this contribution, data and analyses from GST are presented for two alpine valleys of the southern French Alps (Clarée, Ubaye). Seven sites have been selected depending on their topoclimatic and geomorphological specificities (rockglaciers, rockfall deposits, talus screes) and have been implemented with 19 MTD (Ibuttons®) measuring temperatures with a 3-hour interval.

Results show that thermal regime is highly dependent on local parameters. In summer, ground surface temperature is influenced by air temperature which itself depends on altitude and solar exposure. In winter, snow duration and height are the major parameters influencing ground temperature as it may isolate ground surface from cold winter air temperature.

**Recent contributions of dendrogeomorphology for the study of mass movements in an Alpine context**

LOPEZ SAEZ J.

*Irstea, SAINT MARTIN D'HERES, FRANCE*

Dendrogeomorphology relies on the capacity of ligneous vegetation to react to external stresses induced by changes in the environment and to register these impacts in the form of either characteristic annual rings or morphological anomalies. By analyzing the radial growth of trees (in the form of one or several abnormally narrow or wide tree rings), their morphology (scars, resumption of apical growth, change of growth axis, tilting, adventitious roots) and their associated anomalies (formation of reaction wood, tangential rows of traumatic resin ducts, modification of the cell structure), past mass movements such as debris flows, landslides, rockfalls, snow avalanches and erosion can be reconstructed with yearly or even monthly precision. In turn, dating these events allows for the assessment of environmental changes and geomorphic processes on a spatial scale. This presentation will focus on the main dendrogeomorphic methods, starting with the Event /Impact/Response concept, and examines the model's evolution, especially in the Alps. Based on recent progresses in the field of dendrogeomorphology, it will also discuss the model's relevance for the study of geomorphic processes with respect to the knowledge and management of natural hazards and risks.

\*\*\*\*\*

**New constraints on landscape sensitivity to glacial-interglacial climate change: A detailed and quantitative record from debris flow deposits in Owens Valley, California**

D'ARCY M., WHITTAKER A., RODA BOLUDA D., ALLEN P.

*Imperial College London, LONDON, UNITED KINGDOM*

The geomorphological evolution of a landscape is controlled by a number of fundamental controls which should be quantifiable, including tectonics, erosion and climate. Fluvial landscapes are known to be sensitive to tectonic boundary conditions; these are recorded geomorphologically and stratigraphically with a response timescale on the order of  $10^{5-6}$  years. Much less is known about how climate controls landscape evolution. Theoretical insights suggest that sediment supply from mountain catchments should be sensitive to climate change, but a lack of observational data means we do not yet know the nature, magnitude or timescale of possible responses. This is very limiting: if we could quantify the independent controls on sediment generation, transport and deposition we may be able to invert observational records (like alluvial fan stratigraphy) to build time-integrated, terrestrial archives of climatic and tectonic history. We provide new insights on landscape sensitivity to climate change from debris flow deposits along the Sierra Nevada front in Owens Valley, California. These deposits have been dated in detail and span the period ~140 ka to present, enabling us to extract a high resolution record of sediment supply and deposition throughout a full glacial-interglacial cycle. By comparison with detailed local palaeoclimate records, we find that alluvial fan stratigraphy is a highly sensitive record of climate change which can also be quantified. We describe new stratigraphic and sedimentological data which reveals the impact of climate change on the catchments, and our data sheds further light on how useful interpretations can be made from (often neglected) debris flow deposits. Furthermore, we document a  $10^4$  year response timescale following climate perturbations, which challenges popular theoretical ideas about the preservation of climatic signals in alluvial fan deposits.

### Study of the spatial interactions in the hydrosedimentary transfers on agricultural watershed

REULIER R., DELAHAYE D., VIEL V., CAILLAULT S., ABDELKRIM B., DAVIDSON R.  
*Université de Caen Basse-Normandie, CAEN, FRANCE*

Erosive runoff is a major cause of land degradation and affects more than one hundred million hectares in Europe. If these processes are well established at the agricultural plot scale, research is shifting towards the dynamics of hydrosedimentary transfers from fields to streams. In hedgerow context, the dynamics are complex because they are constrained by the landscape mosaic induced especially by anthropogenic developments (e.g., hedges, ditches, roads ...). Nevertheless, the analysis of the hydrological role of these linear elements is critical to the good understanding of the watershed functioning. To grasp the role of the man-made networks, knowledge of their localization, their organization, and their induced dynamics is necessary. To this end, two complementary approaches are presented here. First, the revealing of hydrosedimentary transfer with an estimation of sedimentary transfers during different rainfall events will be presented. This expert approach is made possible by field monitoring on a 15 km<sup>2</sup> catchment area (Lingèvres, Calvados). Secondly, this investigation is complete with the use of a simulation by multi-agent programming (NetLogo). NetLogo is particularly well suited for modeling complex systems evolving over time and enables identification of the role of local interactions (played at the hedge, ditch or plot scale) on the evolution of spatial structures at a higher level (group of plots, basin heads ...). This approach, called bottom-up, allows - a better understanding of the behavior of the studied watershed (global) - to obtain of the hydrologic effectiveness indices at the linear scale (local) - to follow dynamics connections (continuity of the hydrological basin from upstream to the stream). The simulations confirm the field observations and provide new spatial analysis indications (linear impacts on hydrological flow, visualization of input points in the network, location of places of behavioral changes flow...).

\*\*\*\*\*

### Morphometric analysis of two calanchi areas in Sicily (Italy) by exploiting high resolution Digital Elevation Models

CARABALLO ARIAS N.(1), CONOSCENTI C.(2), DI STEFANO C.(1), FERRO V.(1)

*(1) Dipartimento di Scienze Agrarie e Forestali, University of Palermo, PALERMO, ITALY ; (2) Dipartimento di Scienze della Terra e del Mare, University of Palermo, PALERMO, ITALY*

In the Mediterranean areas, specifically in Sicily (Italy), irregular rainfalls, strong seasonal changes, scarce vegetation cover and, frequently, outcropping of clayey deposits favor water erosion phenomena. Badland landscapes are the result of severe erosion processes, characterized by steep slopes, sparse vegetation, high drainage density, rapid erosion rates and a shallow or non existing regolith profile. In this investigation we focused on the *calanchi* badland type, consisting of heavily dissected terrain with steep, unvegetated slopes and channels that rapidly incise and extend headwards. This research was carried out in two *calanchi* sites located in Sicily. The geometry of 25 badland channels was characterized in order to verify if relationships, already tested for minor linear erosion landforms (i.e. rills, ephemeral and permanent gullies), could also be verified for these bigger erosion channels. To this aim, two Digital Elevation Models (DEM) were processed in a Geographic Information System (GIS) environment: the first DEM obtained by a LIDAR survey, with 2 m and 0.1-0.2 m of horizontal and vertical resolution; the second DEM obtained by photogrammetry of 840 images captured by a drone, with 0.3 m and 0.05 m of horizontal and vertical resolution. Each channel was divided into segments delimited by transverse sections. Cumulative length and volume of all channels segments were plotted on scatter diagrams showing highly significant power relationships. Additionally, some morphometric attributes of channels segments (length, volume) and sections (depth, width), were combined into two dimensionless groups, already tested for minor erosion landforms, providing measured pairs also highly correlated by power relationships. The results of this experiment confirm that length of erosion channels is sufficient to predict volume of eroded material and evidence a morphological similarity between rill, ephemeral and permanent gullies and *calanchi* landforms.

### **Spatial Correlation between Geomorphological and Subsurface Characteristics: A Case Study of Bantul, Yogyakarta, Indonesia**

NURWIHASTUTI D.(1), NURWIHASTUTI D.W.(1), SARTOHADI J.(2), MARDIATNO D.(2), NEHREN U.(3)

*(1) PhD student at Faculty of Geography, Gadjah Mada University; Department of Geography, State University of Medan, North Sumatra, Indonesia, YOGYAKARTA, INDONESIA ; (2) Faculty of Geography, Gadjah Mada University, YOGYAKARTA, INDONESIA ; (3) Institute for Technology and Resources Management in the Tropics and Subtropics, Cologne University of Applied Sciences, COLOGNE, GERMANY*

Bantul has been experienced by several earthquakes creating severe damages. The last major earthquake caused severe damage occurred on May 27<sup>th</sup>, 2006. The damages in the flat fluvial landform of Bantul had a certain pattern. The damages pattern controlled the subsurface characteristic below the fluvial landform. Understanding the geomorphological and subsurface characteristics of the area is important for earthquake hazard analysis.

Remote sensing and Geographical Information Systems techniques were applied to analyze geomorphological characteristics. Gravity analysis was applied to identify the subsurface structure and the basement depth. While geoelectric analysis was applied to identify groundwater characteristic and sediment depth. Moreover, spatial correlation analysis was used to identify the relationship between the geomorphological and subsurface characteristics.

The results show that fluvial, marine and aeolian landforms have low rock density value based on gravity analysis. These indicate that they were composed by thick unconsolidated material of Quaternary alluvium. While denudational, structural and solutional landforms composed by material of Tertiary rocks have high rock density value. Moreover, the subsurface structure is a asymmetric graben. The sediment depth is varied 3 – 150 m based on the analysis of geoelectric data and drilling data. The thick sediment occupied in the fluvial landform close to the escarpment of Baturagung Range in the eastern part of Bantul. In vice versa, the shallow sediment occupied in the fluvial landform close to the isolated hill and denudational hill in the western part of Bantul. In addition, the water level of groundwater varied 0.30 – 24.5 m. The shallow water table is located in the fluvial, marine and aeolian landforms. While the deep water table is located in the denudational, structural and solutional landforms.

Keywords: spatial correlation, geomorphology, subsurface characteristic

\*\*\*\*\*

### **Geomorphic mapping for environmental management in urban areas (case study of Moscow parks)**

SAMSONOVA S.

*Moscow State University, MOSCOW, RUSSIAN FEDERATION*

Moscow city is one of the biggest megalopolises in Europe, with a population of more than 10 million occupying over 1,000 sq. km of territory. Environmental management is the newest type of land use in Moscow which is represented by the system of protected areas (19 existing and 20 planning). All protected areas in Moscow have administrative borders which do not match with natural landscape borders. All parks are isolated; include pieces of private property and infrastructure. To ensure sustainable development of green areas in Moscow it is necessary to monitor natural landscapes within the boundaries of parks, but also adjacent urban landscapes which are represented by residential areas, roads, industrial zones etc. In order to improve the management at the local level, a specific methodological approach was applied.

The approach is based on geomorphic mapping of urban areas and includes series of maps:

- 1) land use;
- 2) morphomerty (elevation, slopes, aspects, plan and profile curvature);
- 3) streams and watersheds;
- 4) urban landforms (buildings, roads) and it's relation to natural landforms;
- 5) geomorphological zones.

It is strongly recommended to take into consideration geomorphologic features of the territory, its historical and cultural specifics, the land use structure and the influence of neighbouring areas, including technogenic landforms. The method, implemented by the author, combines all these parameters and, thus, provides a complex geomorphic monitoring on protected areas. This research aims to develop recommendatory schemes for city administration in order to improve environmental management and ensure sustainable development of urban protected areas.

### Exploring geomorphic and vegetational features of low energy rivers using Google™ Earth

SEKARSARI P.(1), GURNEL A.M.(1), HENSHAW A.J.(1), ZOLEZZI G.(2)

(1) Queen Mary University of London, LONDON, UNITED KINGDOM ; (2) University of Trento, TRENTO, ITALY

Google™ Earth provides an enormous potential source of information on the character of rivers worldwide over the last decade. This paper describes research that is investigating properties of low energy, single thread river channels and their floodplains in order to assess the variety of characteristics shown by such rivers across Europe as environmental conditions change. There have been many attempts to differentiate characteristic geomorphic features and categorise such river systems (e.g. Schumm, 1985, Nanson and Croke, 1992), and recent work has illustrated that riparian vegetation may also be influential, in addition to the physical properties of sediment and flow regime (e.g. Eaton et al, 2010). By using Google™ earth as a data source, this research has assembled a data set describing both channel dimensions (planform, width, gradient), floodplain and channel geomorphic features, and vegetation structure and extent of approximately 100 European rivers. This data set underpins empirical exploration of interrelationships between river and floodplain properties and riparian vegetation and supports the identification of different low energy river types. Early analyses have already revealed associations between longitudinal channel width variability, planform sinuosity, sediment bar and vegetation structure and reach-averaged hydraulic properties computed with a simple 1-D mathematical model.

#### References

- Eaton, (2010). Channel patterns: braided, anabranching, and single-thread. *Geomorphology* 120, pp 353-364.  
 Nanson, G. C. & Croke, J.C. 1992. A genetic classification of floodplains. *Geomorphology*. Volume 4, pp. 459-486.  
 Schumm, S., 1985. Patterns of alluvial rivers. *Annual Review, Earth and Planetary Sci.*, 13, pp. 5-22

\*\*\*\*\*

### Typology of eolian landforms of South Kharga oasis (Western Desert of Egypt): original evolution models and local specificities of Saharan loess deposits

CREPY M., CALLOT Y.

Laboratoire ArcheOrient (UMR 5133 CNRS - Universite Lumiere Lyon 2, Maison de l'Orient et de la Mediterranee, LYON, FRANCE

The Western Desert of Egypt is the largest area of high aridity in the world. In this kind of environment, wind and eolian dynamics have a great influence on morphogenic processes. The study of eolian dynamics and associated landforms is very important in arid areas where there is human occupation or archaeological sites: eolian landforms can be both a resource (arable land, moisture-retaining places and soil formation) and a constraint (ablation, wind abrasion and sanding up).

In Kharga Oasis, which receives less than one millimeter of mean annual rainfall, there are many contemporary cultivated fields and villages, thanks to deep wells in the Nubian Sandstone Aquifer System. During Antiquity (from the beginning of Persian domination to late Roman times), this area was already affected by hyper-aridity and wind effects: archaeologists from the IFAO (Institut Français d'Archéologie Orientale) have revealed that the water resource was artesian and that some remains of buildings in the south of Kharga oasis present architectural features related to defence against wind abrasion or sanding up. Moreover, many remains of ancient fields or buildings are located on top of yardangs composed of eolian sediment.

This work in Kharga oasis attempts to identify specific aspects of eolian dynamics and their Holocene evolution, especially from 2500BP to the 21th century. The first results show that:

Some thick fine-grained deposits, previously thought to be playa-deposits are Saharan loess deposits which had been used as arable land during Antiquity. The relation between this kind of deposit and artesian springs or cultivated fields is highlighted.

Some eolian forms, barchans for example, do not follow a classic evolution model.

Several deposition and ablation phases occurred during the Holocene. Ablation and deposition were very rapid.

Eolian sediment is very important for agriculture, and fields function as sediment traps.

## **Poster presentations:**

### **Tectonic sway on alluvial fan trilogy at Himalayan foothills**

*MANDAL S.(1), SARKAR S.(2), BOSE P.K.(2)*

*(1) ASUTOSH COLLEGE, KOLKATA, INDIA ; (2) JADAVPUR UNIVERSITY, KOLKATA, INDIA*

Similar evolutionary history of 3 Quaternary alluvial fan systems spread over a linear distance of ~100 km at immediate south of the Mountain Front Thrust of Eastern Himalayas manifests neotectonics at the aftermath of the orogeny. DEMs delineate fans of 5 different generations within each of the 3 fan systems, belonging to the Rivers Tista, Chel and Neora-Murti. The 3 fan systems shrank over time and apices of their constituent fans tended to shift upslope, although the active river channels incise deeply through the systems. Diversion of axes and overall increase in slope, tilt, as well as convexity of the fans through time evinces influence of tectonism rather than climatic shift to aridity on evolution of the fan systems. Progressive increase in maximum clast size and enhanced contribution from successively older formations in the massflow fan facies are in good agreement with sediment source uplift. Preferred concentration of SSD structures along the fan contacts traced over a distance in excess of 100kms further elicits the tectonic effect.

On the other hand, either upheaval of the piedmont or significant enhancement of water discharge caused deep incision of the presentday channels through the fan systems and formation of unpaired terraces on their banks. Topographic profile and the basement configuration reconstructed from known gravity anomaly data documents a basement depression along the axial lineament of which runs the Tista on the piedmont. On both flanks of the depression other rivers show overwhelming tendency to incise deeper as well as to migrate closer towards the Tista. Rapid downward migration of the Tista presumably dragged the water table down towards the valley axis and compelled the rivers on the valley flanks to swerve sharply towards the Tista digging deeper simultaneously to reach the inclined water table. This tectonically induced incision and migration, however, stopped effectively sometime before 1962 in case of two rivers, viz., the Mahananda and Chel.

\*\*\*\*\*

### **Identifying complex internal architecture in debris flow and lahar deposits using ground penetrating radar**

*STARHEIM C.(1), GOMEZ C.(1), DAVIES T.(1), OWENS I.(1), HADMOKO D.S.(2), WASSMER P.(3), LAVIGNE F.(4)*

*(1) University of Canterbury, CHRISTCHURCH, NEW ZEALAND ; (2) Universitas Gadjah Mada, YOGYAKARTA, INDONESIA ; (3) Université de Strasbourg, STRASBOURG, FRANCE ; (4) Université Paris 1 Panthéon-Sorbonne, PARIS, FRANCE*

Debris flows and lahars help shape many mountain and volcanic landscapes around the world, yet current understanding of their flow and deposition processes has been largely restricted by the nature and unpredictability of events. One approach used to circumnavigate these inherent limitations has been to focus research on the interpretation of post-event deposits using conventional stratigraphy, sedimentology, and geomorphology. As channel bank exposures, erosional outcrops, and depositional surfaces are most easily accessed during forensic survey of deposits, findings typically over-represent the longitudinal profile of deposits, with comparatively few studies comprehensively examining the internal architecture of deposits parallel and perpendicular to the flow path. Recognizing this, the present study integrates ground penetrating radar (GPR) surveys, geospatial data, and forensic field observations to investigate debris flow and lahar deposits at high spatial resolutions along their longitudinal and transverse axes. Although corroborative evidence from GPR surveys and field observations frequently verified the presence of primary stratigraphic deposit features (e.g. inversely graded beds), GPR imagery exposed additional sub-surface architecture that was not readily discernible using only field-based visual observations. Distinctive deposit sub-units identified with GPR imagery were thought to reflect individual flow surges and/or discrete flow events. Findings from ancillary analyses of lahar video imagery and modelled debris flow deposition patterns are discussed in an effort to further explain the internal architectural features identified in this study. As well as demonstrating the need for continued investigation of deposit architecture using non-traditional techniques, these findings are expected to generate improvements to post-event deposit interpretations.

### The use of a rain simulator as an infiltrometer at Kinshasa (D.R. Congo)

MAKANZU IMWANGANA F.(1), MOEYERSONS J.(2), NTOMBI M.(3)

(1) *Laboratoire de Géomorphologie et Télédétection, Centre de Recherches Géologiques et Minières (LAGEOT/CRGM), KINSHASA, CONGO (THE DEMOCRATIC REPUBLIC OF THE)* ; (2) *Division of Geomorphology and Remote Sensing, Royal Museum of Central Africa, TERVUREN, BELGIUM* ; (3) *Département des Sciences de la Terre (Géographie-Géologie), Faculté des Sciences, Université de Kinshasa, KINSHASA, CONGO (THE DEMOCRATIC REPUBLIC OF THE)*

The partial contribution of different soil uses to the alimentation of mega-gullies has been studied in Kinshasa. The water infiltration envelope for several soil uses on slopes varying between 5 and 10° has been defined. A rainfall simulator of the sprinkler type (KULeuven) has been used as an infiltrometer. The circular impluvium of this apparatus has a diameter of ±3 m.

The envelope is established by measuring the time between the start of the constant artificial rain intensity and the moment that a runoff runnel goes 10 cm beyond the impluvium border. This procedure is followed on the same site in three impluvia with the same soil use. The rainfall intensity varies for every impluvium. The envelope is the power trend line through the three points in a graph with logarithmic scale where the Y-axis indicates the applied rainfall intensity ( $\text{mm h}^{-1}$ ) and the X-axis the time to runoff (seconds). On every impluvium a ring infiltrometer has been used to measure the hydraulic conductivity of the soil at his initial state of water content.

The tested soils are sands (mean  $D_{10}$  of  $100\mu\text{m}$ ) and show a mean recalculated hydraulic conductivity of  $354 \text{ mm h}^{-1}$  and a mean bulk density of  $12.7 \text{ kN m}^{-3}$ . Runoff generation varies considerably from one soil use to another. Earthen roads and other hard bare surfaces quickly produce runoff. The other soil uses with vegetation generate retarded runoff. Generally speaking, time to runoff is proportional to the degree of vegetation soil cover and inversely proportional to the bulk density of the soil. There are two particularities: loose bare sands colonized by a thin layer of lichen and grass-plots with a root mat (*Paspalum notatum sp.*). Both quickly produce runoff and join the group of the bare and compacted surfaces. The other soil uses are rather weak runoff generators and can only significantly contribute to the alimentation of gullies in the case of exceptional rains.

Keywords: gully, infiltrometer, rainfall simulator, runoff, soil use

\*\*\*\*\*

### Spatial distribution of beach ridges in the Intra-Americas Seas islands: a supervised manual investigation using Google Earth

GESCON A.L., COOPER J.A.G., JACKSON D.W.T.  
*University of Ulster, COLERAINE, UNITED KINGDOM*

Beach ridges landforms are still under debate about their formative process. If along the tropical coasts we can observe occasionally one or two beach ridge landforms, when they occur in wide plains they are easily identifiable.

This work considers the beach ridges of the islands in the Intra-Americas Seas. Using Google Earth it aims to identifying and describing almost all the beach ridge plain sites.

We used a human-supervised approach to identify and characterize beach ridges landforms and plains on Google Earth available images in 2012. This kind of work can be done because the shape of beach ridges can be well defined on remote sensing imagery material by a human observer.

Not only were the position of all beach ridge sites and their number recorded, but also other qualitative and quantitative elements that can be observed on the imagery, like the distance from the reef, the vegetation cover or the approximate percent of building cover over the plains.

The number of beach ridge plains in this area is significantly greater than what was expected. More than 100 beach ridge sites were identified and almost 200 other possible sites. In the Bahamas where more than 100 possible sites were identified there is no literature about modern beach ridges to our knowledge.

This work represents a first attempt to identify and characterize the beach ridges in these areas at a very high spatial resolution. The quantitative and qualitative observations were discussed in each context to isolate some beach ridges categories for the Intra-Americas Seas geographical area.

### **A methodological framework for the spatial decision support of the management of coastal wetlands**

ZOUVA C.(1), GAKI-PAPANASTASSIOU K.(2)

(1) Department of Geography and Regional Planning, Faculty of Rural and Surveying Engineering, National Technical University of Athens, ATHENS, GREECE ; (2) Department of Geography - Climatology, Faculty of Geology and Geoenvironment, National & Kapodistrian University of Athens, ATHENS, GREECE

Coastal wetlands, such as lagoons and deltas, considering their geomorphology and ecological status, are complex and sensitive environments, directly threatened by climate change. It is important to develop methodologies and models with modern technological tools for their effective vulnerability assessment and management against the rise of the sea level. Therefore, understanding and interpreting this problem is important and necessary today, not only for practical reasons but also for the challenge to the theoretical framework. The aim of this paper is to summarize the theoretical background of this issue, stressing the gaps and then, propose a new methodology by using G.I.S. and Fuzzy Logic. This will help decision-makers in the effective management of coastal wetlands that are at risk from the future sea-level rise. The proposed methodology examines the variables which are related to the problem by forming a geodatabase and making an initial classification of the coastline. These variables will be transformed into fuzzy sets, expressing the uncertainty input in the system. The appropriate membership functions will be proposed and the parameters will be ranked according to weights, so that the decision makers will be able to compare different vulnerable regions in coastal wetlands in a flexible and non data-driven manner. The discussed approach will be applied in a typical coastal wetland of continental Greece, in order to validate its efficiency.

\*\*\*\*\*

### **Interaction of tectonic, karstic and sedimentary processes in Early Pleistocene deposits (central Ebro Basin, NE Spain)**

GIL H., SORIANO M.A., LUZÓN A., PÉREZ A., POCOVÍ A.

Universidad de Zaragoza, ZARAGOZA, SPAIN

Sediments and deformation structures of the oldest alluvial Quaternary deposits located in the central Ebro Basin are analysed. Miocene continental detrital deposits, evaporites and carbonates filled this zone. Quaternary detrital materials, mainly alluvial, covered partially the former. In this context, the Early Pleistocene deposits correspond to gravel bars of braided fluvial system with high availability of water. Interbedded aeolian sands and, less frequently, lutites deposited in small lakes, are present. Vertical and lateral relations show a clear interaction between these environments. These materials were deposited during the Matuyama chron, with reverse polarity, as paleomagnetic data obtained from samples indicate.

These deposits show deformation structures with varied genesis and scale. Faults and fractures are frequent and affect to gravel and sand. Their main trends are NNE-SSW and NW-SE being consistent with the regional stress field and with the fracturation of the Miocene substratum. This may indicate a structural control of the deformation in Quaternary materials. Moreover, structures with rounded, tubular and synform morphologies disrupting the Pleistocene sediments are observed. The sediments can be either structured or unstructured and the deformation can be syn- and post-sedimentary. Collapse, subsidence and suffosion are the main processes involved in their generation. These structures are interpreted as related to karstification of evaporites at depth. In addition, karstification caused the existence of subsiding areas where an increase of sediment rates, development of diverse sub-environments and modification of environments location took place. At the same time, karstification generated sedimentary accommodation space and facilitated the preservation of fine deposits (as for instance aeolian dunes) that, in other circumstances, will be easily eroded by the activity of the gravel braided river.

### **Lake Allos: a 12,000 year reference record of past climate-Human-environment interactions in the Mediterranean French Alps**

*BRISSET E.(1), MIRAMONT C.(2), GUITER F.(2), TROUSSIER T.(2), ANTHONY E.(3), ARNAUD F.(4)*

*(1) CEREGE/IMBE Aix-Marseille University, AIX EN PROVENCE, FRANCE ; (2) IMBE - Aix-Marseille University, AIX EN PROVENCE, FRANCE ; (3) CEREGE - Aix-Marseille University, AIX EN PROVENCE, FRANCE ; (4) EDYTEM, CHAMBÉRY, FRANCE*

Lake Allos lies in a cirque in the southern French Alps at an altitude of 2200 m. A 15 m-long core down to the lake substratum was obtained in 2011 and multiproxy analyses conducted on core sedimentology, geochemistry, and palynology, supported by a relevant age-depth model (22 <sup>14</sup>C AMS ages). Preliminary sedimentological observations of thin sections under the scanning electron microscope show: (1) millimetre to centimetre-thick detrital graded-bed layers that may be attributed to detrital inputs by rivers flowing into the lake; (2) clayey laminae containing poorly sorted detrital particles deposited during spring ice-melting of the lake; (3) homogeneous matrix-supported layers indicating recurrent intra-lake sediment destabilization between ca. 8000 and 3000 cal. BP.

These facies suggest four main palaeoenvironmental phases. From 12,000 to 10,500 cal. BP, organic-poor sediment indicates seasonal detrital inputs probably associated with glacier retreat in the Allos catchment. Organic matter content increases after 10,500 cal. BP with mainly biogenic laminations of algae and terrestrial micro-remains, whereas detrital layers are less frequent up to 9000 cal. BP. These conditions indicate a phase of forest colonization and stable soils probably due to efficient sediment retention on slopes. Detrital layers become more and more frequent after 6300 cal. BP, and their thickness has increased since 2500 cal. BP, signaling a phase of slope instability and forest retreat due probably to climate deterioration and/or increasing human pressure through deforestation and pastoralism.

These multi-proxy analyses and the reconstructed sediment dynamics will subsequently be discussed in the light of the pollen record that is currently being established, thus enabling elucidation of anthropogenic and/or climatic controls on Lateglacial/Holocene sedimentation.

\*\*\*\*\*

### **Geomorphology of Sylhet City, Bangladesh - for Sustainable Urban Planning**

*HAQUE N., SHAMSUZZAMAN ..., RAHMAN M.A., EKRAM A.R., UDDIN N., HASAN F.*

*Geological Survey of Bangladesh, DHAKA, BANGLADESH*

Sylhet is one of the oldest cities in the north-eastern part of Bangladesh. People are living here from ancient period but now experiencing rapid growth and unplanned expansion of the city. The city has been expanding rapidly without taking consideration of geomorphological parameters. Rapid urbanization without planning compelled to face the area with various geo-hazard problems. The present study has been carried out to provide geomorphological map and related information of the city area and probable use of the map units which may help to future city planning.

Geomorphologically, the area has been classified into two broad units - Fluvial and Hilly units. Fluvial unit is sub-divided into twelve units. Hilly unit is sub-divided into four units. Total mapped area is about 160 sq. km. Among the area, flood plain and natural levee comprises about 40%, backswamp about 15%, Piedmont about 13%, alluvial fan about 10%, level hill about 9% and other 13%. Average height of the area is about 18.856 AMSL. Northern part of the area is characterized by low bounded hillocks which are 30 to 70 meters high. Slope of the area is toward the south direction. Minimum slope is 0.5 degree in floodplain and maximum is 25 degree in hill slope region. The Surma river produces the main drainage system of the area but average drainage density is low.

Each geomorphic unit has some potential uses. Some units are suitable for residential and some may be used for recreation and industrial purposes. Analyses of some data show that different unit faces different geo-hazard problem such as flood, bank erosion, flash flood, land slide, rill and gully erosion etc. The outcome of the study may play key tools for planners and decision makers for sustainable development of the city area and also as a model for other urban area of Bangladesh. Maps may also be used as base map of hazard vulnerability assessment of the area.

### **Assessing the impact of the pipeline on the swamp geosystems**

ADAMA.

*INSTITUTE FOR WATER AND ENVIRONMENTAL PROBLEMS SIBERIAN BRANCH OF THE RUSSIAN ACADEMY OF SCIENCES, BARNAUL, RUSSIAN FEDERATION*

The interaction of a gas pipeline with a range of environments have different repercussions both for a gas pipeline and for the surrounding environment. In this paper, the problem of the interaction between the gas pipeline and wetlands in the south of Western Siberia is considered. The swamp under study is an oxbow swamp located on the terrace above the floodplain of Chumysh River, a large right tributary of the Ob. The swamp area is about 40 km<sup>2</sup>, it stretches for 5 km from north to south and up to 6.5 km from east to west. Based on a study, the peculiarities of the interaction of engineering construction and swamp geosystems were revealed, the dynamics was assessed, and the forecast of geomorphic processes development was made. The forecast of the swamp impact on the gas pipeline was done.

\*\*\*\*\*

### **Modelling sediment transport: Evaluating the effects of spatially refined input data**

WERB S., DELGADO J.M., BRONSTERT A.

*University of Potsdam, POTSDAM, GERMANY*

Hydrological models working at the meso-scale are often based on a lower degree of spatial information. Giving consideration to computation times, the larger the modelling domain, the less information of individual hillslope components can be accounted for. However, the spatial representation of soil and vegetation patterns can have considerable effects on partially connected sediment delivery towards the channel system.

The spatially semi-distributed model WASA-SED (**W**ater **A**vailability in **S**emi-**A**rid Environments – **SED**iments) uses a bottom-up aggregation scheme. In this study it is applied to simulate sediment transport at the Isábena catchment (445 km<sup>2</sup>) in the Central Spanish Pyrenees. This catchment includes a large system of badlands these being one of the major sediment sources, driving the severe siltation of the downstream Barasona reservoir.

Improved data availability of climate and hydrological data as well as the spatial information of land-use patterns provided by high resolution satellite data such as Rapid Eye images may improve simulation efficiency. Different parameterisations of the model are used for independent simulations in order to understand the effect of spatially refined input data. As a result improved calibration techniques can be applied. It is to be evaluated how a refined spatial resolution of input data affects the efficiency of water and sediment transport.

### Sedimentary environment of Hwajinpo lake using diatom analysis

GO A.(1), TANAKA Y.(1), KASHIMA K.(2)

(1) *Kyung Hee Univ., SEOUL, SOUTH KOREA* ; (2) *Kyushu Univ., FUKUOKA, JAPAN*

Lake Hwajinpo is located on the eastern coast of Korea, Gosung-gun, Gangwon-do. This study reconstructed sedimentary environment of Hwajinpo and its surroundings and presumed sea-level changes during the Holocene using radiocarbon dating and diatom analysis from core samples. The undisturbed core samples were taken at the inner lake and the outer lake of Lake Hwajinpo, named HJP01 and HJP02 respectively.

HJP01 is located at the delta margin by the tributary sedimentation. The numbers of freshwater and freshwater-brackish water species was increased gradually from the bottom to upper of the core, according to the expansion of the delta. The relative marine regression, the environmental change from high salinity environment (marine – brackish water) to low salinity (freshwater) was observed in the core.

In contrast to HJP01 site, HJP02 site is affected by the sea-level change directly. According to the result of diatom analysis, the brackish lagoon environment was formed surrounding ca. 4,000yrBP. However, the relative marine regression started since about 3,200yrBP because the number of marine and brackish water species reduced gradually. After then the lake environment was presumably disappeared and the HJP02 site was completely dried up since 2,500yrBP through 1,450yrBP, because the diatom frequency of this period became very poor. Since 1,450yrBP, HJP02 recovered aquatic environment, however it was separated from lake water from Lake Hwajinpo by the coastal ridge along the lake, and has continuously deposited peat bogs till now.

\*\*\*\*\*

### I just can't put my finger on it! Understanding coastal lagoon systems from remotely sensed data - A case-study comparison from Denmark and Argentina

SANDER L., KABUTH A.K.

*University of Copenhagen, Department of Geosciences and Natural Resource Management, KOBENHAVN, DENMARK*

*"You can only discover what you have already imagined"*

(Gastón Bachelard)

Quote seen in "Museum of Man and the Sea", Puerto Madryn, Argentina

How much geomorphology and process understanding can we get out of SRTM and Landsat data when it comes to coastal lagoon systems? Holocene sea-level fluctuations shaped the world's coastlines as we know them today. Sediments and surface morphology tell and conserve a part of these developments on accreting coasts and in marginal marine environments, like lagoons or marshes. Most modern coastal lagoons formed in embayments after the rapid post-glacial sea-level rise stabilized in the mid Holocene and barrier spits and beach ridges started to develop.

In the BRIDGES project (2011-2014) we attempt to reconstruct coastal evolution and sea-level history for a Danish site from lagoon sediments and associated beach ridges in an environment of Holocene relative sea-level drop.

In Denmark, high-resolution digital elevation models (DEM) are available for this purpose as are orthophotos and maps with an overall high temporal coverage. This allows a fine-tuned GIS-based interpretation of landforms, coastal dynamics and the processes that create them, even before setting foot out of the door.

We compare this situation with a similar case from Argentina where our interpretation of the evolution of a mesoscale lagoon system is primarily dependent on readily-available low-resolution geospatial data. We present the results from an SRTM- and Landsat-based mapping of inter- and supratidal environments, barrier systems, cliffs and dune fields, which we complement with an on-site correction and GPS survey data. This allows us to quantify our error and touch upon the potential of these datasets for primary site assessment in geomorphology, lagoonal research, and sea-level studies.

**Characteristics of loam deposits as indicators of their sedimentary environment in the Late Glacial, example from Nowy Targ-Orava Basin, southern Poland**

CHMIELOWSKA D.

*Institute of Geography, Pedagogical University of Cracow, KRAKOW, POLAND*

This project aims to determine the origin of the 2 m thick loamy deposits underlying peatbogs in the intramontane Nowy Targ-Orava Basin, southern Poland. Relatively unpermeable, these deposits allowed the development of the largest and most valuable natural peatland complex in southern Poland, protected as Natura 2000 area. Since the oldest peat deposits were dated at  $8960 \pm 80$  years BP, the underlying loams must have been deposited under the periglacial conditions that typified the area in the Late Glacial. This study focuses on the detailed analysis of textural and structural characteristics of the loams to determine their origin and aid reconstruction of the environmental conditions that existed in the basin before the onset of peatbog formation. Earlier hypotheses assumed these are allochthonic deposits associated with long-distance aeolian transport. Although macroscopic analysis of loam profiles suggested a uniform structure, microscopic analysis revealed the presence of varied material. Grain-size distribution of the loams and characteristics of quartz grains (roundness and surface matting) were analyzed in 30 samples to infer about general transport conditions and its duration. The abundance of broken, new and non-rounded quartz grains, a result of the destruction of larger grains, excludes long-distance or prolonged transport by wind assumed earlier. Some quartz grains within the loam samples are typical of flysch sandstones occurring in the periphery of the basin, which suggests weathering origin and local transport. On the other hand, the presence of shiny, rounded grains may be associated with fluvial deposition by sediment-laden rivers flowing from the Tatra Mountains into the foreland depression of the Nowy Targ-Orava Basin. The results are preliminary, however, this variability of the loam deposits suggests their origin may be polygenetic.

\*\*\*\*\*

**Hydric properties of carbonates accumulation horizons in Chalky Champagne (NE of Paris Basin, France)**

LINOIR D., THOMACHOT-SCHNEIDER C., FRONTEAU G., MALAM ISSA O., BARBIN V.

*Groupe d'Etude sur les Géomatériaux et les Environnements Naturels, Anthropiques et Archéologiques EA3795 (GEGENAA), Université de Reims Champagne-Ardenne, REIMS, FRANCE*

In Chalky Champagne, discontinuous carbonate accumulation horizons may affect the top of a quaternary cryoturbated paleosol. They mainly seem originated from polyphased pedogenesis. Observations of microscopic neoformed needle shaped calcite also suggest a biological origin related to the presence of fungal.

Even if the assumptions concerning their genesis become clearer over time, many questions still remain about these Chalky Champagne carbonate horizons and especially with regard to the consequences they can have on water transfers.

In order to highlight the potential impact of these pedogenic horizons on soil water transfers, different methods usually employed in the laboratory to characterize natural and artificial building materials (water and mercury porosimetry, capillary absorption and drying) were adapted to study three vertical profiles of a site with carbonate accumulation horizons. Infiltrometry measurements performed on the field permit to verify that results obtained in the laboratory have significance with hydric compartment into the profiles.

Results showed that carbonate accumulation horizon do not be likely to slow water transfers contrary to what is generally proposed in the literature.

### **Application of terrestrial digital photography and free computer software in generating digital terrain models and geomorphological analysis**

MAJEWSKI K.

*Pedagogical Univeristy of Cracow, CRACOW, POLAND*

Dissemination of digital photography in the twenty-first century significantly facilitated geomorphological documentation. Nowadays terrestrial digital photography does not have to be used only to illustrate geomorphologic forms and processes. There are some free computer applications allowing the generation of a cloud of points from a set of non-metric photos without the need for knowledge of photogrammetry. Point cloud can then be used for generating digital surface models including digital terrain models. The accuracy of such a model is naturally not as high as in terrain models obtained with for example Terrestrial Laser Scanning. On the other hand, method of creating digital terrain models on the basis of terrestrial digital photography is distinguished by lower costs, higher simplicity and higher rate of generation than other more popular methods.

The research aimed to evaluate the capabilities of using terrestrial digital photography in geomorphological studies as exemplified by the studies in Polish Carpathians. During the field work in the Gubalowskie Foothills and the Beskid Wyspowy Mountains photographs of natural and anthropogenic landforms were taken. Then, there were generated digital models of landslides, stream channels and quarries on the basis of photographs. There were analyzed landforms of various sizes, shapes and land cover types. There were applied two free computer applications for terrain modeling: Microsoft Photosynth and Autodesk 123D. Examples of the application of created models in morphometric analysis and geomorphological mapping were carried out with GIS and CAD software.

The results of the research indicate that digital terrain models generated on the basis of terrestrial digital photography can be useful in geomorphological analysis, especially when top accuracy is not demanded. Application of this method of generating digital terrain models is particularly relevant for the study of relatively small areas and individual landforms.

\*\*\*\*\*

### **Research on the relationship between alluvial fans and the mountain uplift in Northwestern China based on GIS technique**

LI S.(1), ZHANG K.(2)

*(1) Department of Geoscience, Sun Yat-sen , GUANGZHOU, CHINA ; (2) Department of Geoscience, Sun Yat-sen, GUANGZHOU, CHINA*

In recent years, more and more technology was applied to the study of geomorphology. In this paper, the geomorphological features of the alluvial fans in Northeast margin of the Tibetan Plateau have been analyzed with RS, GIS and etc. Based on the tectonics and geomorphological features, we found that the Helan Mountain underwent a strong tectonic activity in Eocene, the mountain uplifted and the Yinchuan Basin sank. As the closer to the fault, the more obviously the mountain uplifted, the uplifting in western sector was weaker than the eastern one. Alluvial fans at Helan Mountain have larger size, bigger width to length ratio, and bigger fan angle than others, also, the fan slopes are steeper, and the feet of the mountain are more bending. As to Luoshan Mountain, the research shows that in the Quaternary, Luoshan Mountain, where there is no basin in front of, uplifted intensively, alluvial fans at Luoshan Mountain have steep slopes and small width to length ratio. The feet of the mountain are straighter relatively. Research on alluvial fans at basins reveals how alluvial fans are affected by faulted basins, with statistical analysis methods, it is found that the more the Piedmont Basin sinks, the bigger the radio of catchment area to the fan area is, the more obviously the fan cross-section bends, and the larger the width to length radio the fan has. Besides, the later uplift is, the straighter the foot of the mountain results. and the spacing of the ravine and the width of the fan is shorter than others. The geomorphologic features of the fan are influenced by both tectonic uplifting and isostatic uplifting of the mountain: the more intense tectonic activity is, the steeper the slope of the fan is, the smaller the fan area exhibits. At the end of the isostatic uplifting, the height difference will be stable, the area increase seldom by the increased catchment areas. With the fan area increase, a new alluvial fan form in the direction away from the mountain.



## ALPHABETICAL INDEX OF PRESENTING AUTHORS

- AALTO, 687, 988  
ABAZOVIC, 850  
ABRAHAMI, 219  
ABU GHAZLEH, 362  
ACHYUTHAN, 971  
ADAM, 1198  
ADAMSON, 367  
AGATOVA, 411  
AGATOVA, 186  
AGHAJANY, 610  
AGUILAR, 279  
AKCAR, 1157  
AKKOPRU, 214  
ALAM, 910  
ALCAYAGA SALDIAS,  
 740  
ALDIGHIERI, 586  
AL-DOAAN, 1107  
ALEIXO, 1135  
ALHO, 1099  
ALLEN, 521  
ALMEIDA  
CAVALCANTE, 990  
ALMODARES, 1073  
ALVAREZ DE  
BUERGO, 300  
ALVES, 975  
ALVIOLI, 1079  
AMADEU, 760  
AMIT, 950  
ANDERS, 1090, 1110  
ANDRÉ, 524  
ANDREO, 325  
ANGEL, 1052  
ANGHEL, 831  
ANIKINA, 458  
ANSAN V., 165  
ANSBERQUE C., 205  
ANTHONY, 880  
ANTONELLI, 751  
AQUINO, 1144  
ARA JO-GOMES, 430  
ARAÚJO, 860, 889  
ARINGOLI, 476  
ARISANTY, 879  
ARNAUD, 734  
ASCIONE, 192  
ASCIONE A., 204  
ASEVEDO, 652  
ASHMORE, 447  
ASLAN, 279  
ASMARYAN, 1133  
ATIF, 705  
ATTAL, 261  
AUBAULT, 443  
AUDEMARD, 195  
AUDISIO, 799  
AUDRA, 317, 328  
AUGUSTIN, 452, 710  
AUTHEMAYOU, 222  
BAARTMAN, 251, 1076  
BACANI, 1125, 1174  
BACENETTI, 1183  
BACHRI, 609  
BADYUKOVA, 896  
BAEWERT, 1054  
BAIBATSHA, 421  
BAIONI D., 167  
BAKER V., 138  
BALKE, 886  
BALLAIS, 583, 584  
BALLESTEROS, 317,  
 337, 374  
BALME M., 169  
BALTHAZAR, 689  
BALYAN, 211, 240  
BANDYOPADHYAY,  
 488, 699  
BANERJEE, 302  
BAOLI, 966  
BARBOUX, 1095  
BARCHI M., 182  
BARKWITH, 1072  
BARONI, 386, 396  
BARR, 1011, 1057  
BARRETT A., 162  
BARROS, 219  
BARTLEY, 445  
BARTZ, 407  
BARYSHNIKOV, 403  
BASTOS, 559  
BATHRELLOS, 1022  
BÄTZ, 602, 772  
BAUZYS, 621  
BAWA, 984  
BAYRAKDAR, 1062  
BAZHENOVA, 282  
BEACH, 439  
BEAN, 995, 996  
BEBERMEIER, 424  
BECHT, 390  
BECKERS, 926  
BEERTEN, 479  
BELL, 625, 650  
BELLETTI, 774  
BELLIN, 193  
BELLOTTI, 415, 899  
BELYAEV, 824  
BEN FRAJ, 949, 1173  
BENACCHIO, 1100  
BENAICHOUCHE, 1075  
BENAZZOZ, 945  
BENEDETTI, 347  
BENITO, 374, 377  
BENNIA A., 147  
BERA, 806  
BERENQUER, 1006  
BERNAL, 994  
BERNARDIE, 514  
BERNATEK, 642  
BERTHET, 761  
BERTHLING, 1006, 1028  
BERTI, 215  
BERTI, 195  
BERTOLDI, 757, 810  
BERTRAND, 1125  
BESN, 802  
BESSIN, 273  
BETARD, 541, 594  
BEUZEN, 427  
BEYLICH, 746, 829  
BEZERRA F., 204  
BHATTACHARJEE, 696  
BHATTACHARYA  
SOMA, 185  
BIALY, 555  
BIEJAT, 939  
BIERMAN, 276, 280,  
 1023  
BINI, 410, 1181  
BIOLCHI, 259  
BIRHENJIRA, 588  
BISWAS, 905  
BKHAIRI, 375  
BLANCO-CHAO, 895  
BLINOVA, 531  
BLÖTHE, 281  
BLUE B., 144  
BOARDMAN, 435, 637  
BOCCALI, 615, 638  
BOCIC, 323  
BODIN, 1043, 1045, 1099  
BOGAARD, 620, 684  
BOIVIN, 778  
BOLLATI, 1022  
BOLLOT, 645, 654  
BOLTRAMOVICH S.,  
 150  
BONACHEA, 498, 667  
BONNET, 288  
BONTHIUS, 998  
BORGEAUD, 603  
BÖSE, 341  
BOSSI, 682  
BOSSON, 1054, 1064  
BOUAKLINE, 865  
BOUMEAZA, 589  
BOUQDAOUI, 590  
BOURENANE, 1171  
BOURGES, 414  
BOURKE, 941  
BOURKE (, 171  
BRACCHI, 924  
BRANCIER J., 152  
BRANDOLINI, 559, 675  
BRARDINONI, 826, 1039  
BRAVARD, 987  
BRIANT, 379  
BRIDGLAND, 365  
BRIERLEY, 787  
BRILL, 873  
BRISSET, 472, 833, 1197  
BRISTOW, 389, 963  
BROCARD, 295  
BROOKS, 388, 743  
BROOThAERTS, 436,  
 750  
BRUNIER, 688  
BRUSCHI, 385  
BRUXELLES, 1038  
BRYSON, 1089  
BUCALA, 463, 641  
BUCCI, 198  
BUFFIN-BELANGER,  
 786  
BULTEAU, 867  
BURKOW, 1070  
BURNINGHAM, 923  
BURSZTYN, 302  
BUSNELLI, 1018  
BUZJAK, 533, 1174  
BYUN, 1143  
CALISE, 356  
CALLANAN, 412  
CALVET, 277  
CALVET, 199  
CAMIZ, 225, 232  
CAMMERAAT, 940  
CAMPANA, 775  
CANIL, 499  
CAPPADONIA, 301, 531  
CARABALLO ARIAS,  
 1191  
CARBONEL, 329  
CARDOSO-LANDA,  
 622, 1145  
CARLING P.(, 138  
CAROZZA, 378, 405, 978  
CARPENTER, 893  
CARTIER, 884  
CARVALHO ARAUJO,  
 653  
CARVALHO VIEIRA,  
 661  
CASADO, 780  
CASTALDINI, 473  
CASTALDINI D., 213  
CASTANET, 368, 379  
CASTELLANOS, 986  
CAVIEZEL, 252  
CELARINO, 996  
CENDRERO, 448  
CERDAN, 1073  
CERMINARO, 719  
CEVCON, 872, 1195  
CHABROL, 406  
CHAKRABORTTY, 476  
CHAKRABORTY, 1001  
CHAMPAGNAC J., 175  
CHAMPAGNAC J.D.,  
 210  
CHAPUIS, 750, 1069  
CHAUDHURI, 920  
CHAUSSE, 423  
CHEDEVILLE, 325  
CHELLI, 623  
CHEN, 497, 691, 804,  
 865  
CHENG, 683  
CHERNOV, 702  
CHHABRA, 683  
CHIODI, 732  
CHIROL, 563  
CHITU, 649  
CHMIELOWSKA, 1200  
CHOI, 883  
CHRISTOL, 344  
CHUDANICOVA, 773  
CIAMPALINI, 763, 1071  
CIANCIO, 460  
CICCACCI, 200  
CIUREAN, 666  
CLAPUYT, 1118  
CLARKE, 747, 771  
CLAUDE, 1163  
CLAUDIN, 959, 1069  
CLEMENTE SALAS,  
 906  
CLIFFORD N., 143  
COCO, 1170  
COE, 357  
COLANGELO, 253  
COLLANTES, 491, 507  
COLON S., 212  
COMANESCU, 547  
COMITI, 1051  
CONCEICAO, 283  
CONCEIÇÃO, 1162  
CONESA-GARCÍA, 811,  
 1107

CONOSCENTI, 1128  
CONWAY S.J., 165  
COOMBES, 599, 897  
CORATZA, 536, 542  
CORDEIRO SANTOS, 611  
CORDIER, 366  
CORENBLIT, 779  
CORNET T., 163  
CORNU, 978, 1180  
COROMINAS, 629  
CORONA, 643, 1160  
CORREA, 1083  
COSSART, 628  
COSTA, 236, 610, 840  
COSTARD, 1033  
COTTON, 786  
COUTO E., 209  
COUTO E., 208  
COUTURIER, 491  
CRADDOCK R., 159  
CREACH, 492  
CREMA, 682  
CREMON, 999  
CREPY, 428, 1193  
CROKE, 249, 753  
CSILLAG, 290, 1164  
CUCCHI, 332  
CUPPER, 410  
CUREBAL, 299  
CUROY, 892  
CYFFKA, 792  
CZECHOWSKI L., 169  
D'AGATA C., 151  
D'ARCY, 1190  
DA SILVA SOUSA, 1145  
DA SILVEIRA FONTES, 992  
DADSON, 1087  
DADSON S., 144  
DAIMARU, 457  
DAMIANO, 1110  
DANDURAND, 318  
DANIEL, 976  
DANIELSEN, 446  
DAQUDI, 579, 587  
DAS, 487, 703  
DAS MAJUMDAR, 885  
DAVID, 706  
DE, 514, 672  
DE BELIZAL, 241  
DE BRUE, 450  
DE BUERGO, 303  
DE GOUVEIA SOUZA, 917  
DE LUIZ ROSITO LISTO, 512  
DE OLIVEIRA, 752  
DE OLIVEIRA MAGALHEES, 505  
DE VET, 964  
DE VET S., 159  
DE WAELE, 310, 318, 319  
DEBNIK K., 166  
DECAULNE, 830, 1008  
DEFFONTAINES, 182  
DEFIVE, 428, 1045  
DEGIOVANNI, 810  
DEGIOVANNI S., 176  
DELANNOY, 413, 418  
DELGADO, 689  
DELGADO BLASCO, 1101  
DELINÉ, 630  
DELLA SETA, 282, 671  
DELMAS, 285, 350  
DELUIGI, 1152  
DEMERS, 783  
DENNISTON, 337  
DEPRET, 730  
DESRUELLES, 154, 401  
DEVATY, 820  
DEVI DATT D., 185  
DEVOTO, 625  
DEWEZ, 1098  
DHORDE, 913, 1102  
DI LUDOVICO, 515  
DIAS, 348, 646  
DIAS ALVES PORTELA, 1111  
DICKSON, 847  
DIETZE, 938, 1153  
DIEZ-HERRERO, 376, 500  
DINH, 814  
DIXON, 789, 833  
DLUZEWSKI, 940  
DOBROWOLSKI, 332  
DOETTERL, 598  
DOMINGUEZ-CUESTA, 475, 1137  
DONADIO C., 146  
DONADIO C., 153  
DONNARUMMA, 255  
DOOLITTLE, 439  
DORANTI-TIRITAN, 289  
DOSHIDA, 670, 671  
DOUDJE, 807  
DOUVINET, 1072  
DOWNS, 754, 823  
DRAEBING, 1055  
DRAMIS, 389  
DREJZA, 890  
DUBININ, 929  
DUFRECHOU, 1105  
DUMITRIU, 749  
DUPERRET, 191  
DURAN, 869  
DUSKOVA, 478  
DWIGHT, 1040  
DYKES, 299  
DZANA, 998  
EBERT, 272, 1130  
ECHELARD, 1097  
ECKARDT, 950, 951, 962  
ECKERT, 1151  
ECOCHARD, 571  
EFE, 214  
EGOZI, 742  
EICHEL, 612  
EISANK, 624, 1140  
EISENBERG, 974  
EKASSI ONDOUA, 806  
EKINCI, 540  
EL ABDELLAOUI, 580  
EL GHACHI, 1183  
EL TALIBI, 877  
ELHABAB, 196  
ELIAS Z., 212  
ELINEAU, 846  
ELMIMOUNI, 905  
ELVERFELDT, 384  
EMBABI, 947  
EMBLETON-HAMANN, 451  
ENZEL, 372, 953, 958  
ERHARTIC, 529, 550  
ERSAN, 513  
ERTEK, 417  
ESCHBACH, 802  
ESKOLA, 1024  
ETIENNE, 264, 890  
ETTINGER, 1088  
ETZELMULLER, 1034, 1133  
EVANS, 1005  
EWERTOWSKI, 1011, 1044  
FACINCANI, 801  
FAIVRE, 402  
FARINES, 273  
FAUST, 375, 943  
FEDOROVA, 901  
FERK, 254  
FERNANDES, 622, 647, 651, 664, 677, 703, 975  
FERNANDEZ, 455, 872, 912, 1103  
FERNANDEZ MAROTO, 644  
FERRAZ M., 135  
FERRY, 225  
FERRY M., 186  
FICHAUT, 849  
FILIZOLA, 762, 987  
FINLAYSON, 690  
FITZSIMONS, 183  
FLAUX, 347, 351  
FLOOD, 878  
FLUGEL, 290  
FLUGEL T.J., 176  
FONSECA, 397  
FONTANA, 927  
FORD, 323  
FORGET, 446  
FOROUTAN.(., 192  
FORT, 268, 638  
FOUACHE, 412  
FOUCHER, 823, 832  
FRANK, 1091  
FRANKL, 440  
FRANKL A., 149  
FRANZINELLI, 999  
FRAUSTO MARTINEZ, 334  
FRENCH J., 146  
FRESSARD, 645, 665  
FREY, 748  
FRYIRS, 743  
FUBELLI (., 197  
FUCHS, 673, 827  
FURDADA, 487  
FURLANI, 856  
FURLANI S., 136  
FURQUIM, 608  
FURUICHI, 983  
GABARROU, 961  
GABRIEL, 852  
GAERTNER-ROER, 1036  
GAGARIN, 1033  
GAKI-PAPANASTASSIOU, 511, 805  
GAL, 1111  
GALANI, 570  
GALANIN, 953, 1017  
GALANTI, 674  
GALIA, 728  
GALILEA, 471, 472  
GALVE, 329  
GAMBIN, 409  
GAMBOA-ROCHA, 803  
GANCE, 1098  
GAO, 393, 769  
GARCÉS-ESCAMILLA, 464  
GARCIA, 250  
GARCIA-GOVEA, 973  
GARCIA-MELENDEZ, 1112, 1143  
GARCIA-RUIZ, 444  
GARCÍA-RUIZ, 266  
GARDENT, 1008, 1059  
GARES, 248  
GARGANI, 264  
GARGANI J., 167  
GARLAN, 924  
GARNIER, 370, 977  
GAUCI, 534, 858  
GAUTIER, 688  
GAY, 822  
GEBICA, 346  
GEIGER, 1025  
GENET, 525  
GENTI, 216  
GERMANOSKI, 275  
GHAHROUDI TALI, 1113  
GHANBARI, 489  
GHATAK, 221, 986  
GHEDHOUJ r., 211  
GHEORGHIU, 1028  
GHILARDI, 370, 414  
GHINOI, 661  
GHIRALDI, 536, 1144  
GHOMSI, 497  
GHOSH, 287, 608  
GHOSH P., 187  
GIACHETTA, 274  
GIARME, 898  
GIARDINO, 486, 553  
GIBEAUT, 870  
GIL, 1196  
GILCHRIST, 449  
GILES, 348, 813, 1081  
GILYAZOV, 756  
GINESU, 281  
GIOIA, 216  
GIORDANO, 551  
GIULIANO, 1095  
GIUSTI, 309, 552  
GLAIS, 423  
GO, 1199  
GOB, 737  
GODARD V., 203  
GODLEWSKA, 459, 1018  
GODOY, 540  
GOIRAN, 405  
GOLDIN, 1051  
GOLOSOV, 1166  
GOMES, 480, 1131  
GOMEZ, 1118, 1135  
GOMEZ-GUTIERREZ, 1109, 1142  
GOMEZ-PUJOL, 894  
GONCALVES, 330  
GONNET, 429

GONTIJO-PASCUTTI, 217  
GONZALEZ-AMUCHASTEGUI, 465  
GONZÁLEZ-AMUCHASTEGUI, 551  
GONZALEZ-DIEZ, 624  
GONZALEZ-VILA, 918  
GORI, 184  
GORUM, 623  
GOSLIN, 882  
GOSWAMI, 779  
GOSWAMI U., 213  
GÖTZ, 1050  
GOURNELOS, 674  
GOURRONC M., 161  
GRANJA, 884  
GRANT G., 137  
GRAY, 529  
GRECU, 352, 794  
GREEN, 868  
GREENWOOD, 793  
GRIFFITHS, 537, 562, 1169  
GRIMAUD J., 177  
GRUNERT, 664  
GUERRA, 383  
GUERREIRO, 336  
GUI, 668  
GUIDEZ, 594  
GUILLÉN-MARTÍN, 231  
GUILLOCHEAU, 287  
GUILLOU, 1007  
GUIMARAES S., 148  
GUIZER, 342  
GUNDIM SILVA, 722  
GUNS, 824  
GUPTA, 687  
GURGEL S.P.D.P., 209  
GURNELL, 785, 795  
GUSAROV, 742  
GUSMAROLI, 785  
GUTIERREZ, 189  
HACHEMI, 581  
HADMOKO, 230, 242  
HAEDKE, 1137  
HAHM, 598  
HAJDUKIEWICZ, 797  
HALIUC, 394  
HALLOT, 741  
HAMED, 948  
HANEBUTH, 927  
HAQUE, 1197  
HARBOR, 220, 291, 1010  
HARNISCHMACHER, 468  
HARRISON, 1009, 1024  
HART, 877, 1132  
HARTVICH, 715  
HATTANJI, 324, 603  
HAYAKAWA, 1117  
HECKMANN, 678, 1120  
HENAFF, 706  
HENGESH, 181  
HEQUETTE, 871  
HERGET, 373  
HERMUCHE, 1127  
HERNÁNDEZ MORENO, 552  
HERNANDEZ-CRUZ, 469  
HERNY C., 160  
HESSE, 938  
HETU, 352  
HEYMAN, 727  
HEYVAERT, 426  
HIGGITT, 572, 692  
HILGER, 827  
HIRE, 197  
HIRSCH, 1019  
HO?UB, 1132  
HOBGEN, 822  
HOBLEA, 533  
HOFFMANN, 444  
HONG, 267  
HOOKE, 460, 777, 805  
HORACIO, 796  
HOSSAIN, 977  
HOUBRECHTS, 767, 796  
HOUDE-POIRIER, 358  
HOWARD A., 163  
HRADCKI, 628  
HU, 699  
HU X., 189  
HUANG, 307, 308, 693  
HUBER, 604  
HUDSON, 435  
HUGHES, 735, 1012  
HUGUET, 1015  
HURST, 631  
HUSEIN, 879, 961  
IBISATE, 650, 781  
IKEDA, 1065  
ILIES, 524  
INBAR, 240, 469  
INCZE, 466  
INKPEN, 523  
INKPEN R., 140  
IOANA-TOROIMAC, 809  
IOSIF, 548  
IRENE, 470, 544  
IRIMUS, 549, 672  
ISKANDARSYAH, 899  
ISLAMI, 1171  
ISOGAI, 651  
ITO, 351  
ITURRIZAGA, 504, 1017  
IWAFUNE, 494  
IWASHITA, 1077  
JACOB, 384  
JAILLET, 333  
JAIN, 972  
JAKUBINSKY, 709  
JAMES, 387  
JAMET, 346  
JARMAN, 1007, 1061  
JARRETT, 413  
JARRY, 322  
JAVIER, 840, 1141  
JEANSON, 886  
JENSEN, 825  
JIMENEZ-SANCHEZ, 319, 420  
JOARDAR, 477  
JOHN, 357  
JOHNSON, 729  
JOLICOEUR, 892  
JOMELLI, 974  
JONES, 372, 478  
JOUBERT, 690  
JOYCE, 230, 544  
JUGIE, 782  
JUIGNER, 903  
KACPRZAK, 634  
KADEREIT, 354  
KAIN, 897, 1119  
KALE, 971  
KAN, 838  
KARALIS, 711  
KARIYA, 639  
KARYMBALIS, 814, 912  
KASHIRO, 471  
KASPRZAK, 1042  
KASSE, 943  
KATSUKI, 964  
KAZHOKINA V., 151  
KEESSTRA, 762, 1185  
KEILER, 248  
KEMP, 991  
KENCH, 839  
KENNEDY, 894  
KERMODE, 770  
KERVYN, 233, 234  
KEZOVIC, 199  
KHABIDOV, 562  
KHANCHOU, 797  
KHEZRI, 327  
KHOMCHANOVSKI, 901  
KHOUAKHI, 916  
KIM, 358, 535, 695, 717  
KING, 1016  
KIRCHNER, 530  
KIRKBY, 593, 758  
KLIMES, 626, 1064  
KLIMES J., 206  
KLOESCH, 734  
KNOX, 331  
KNIGHT, 1016, 1049  
KOBYLKIN, 360, 450  
KODAMA, 900  
KOKHAN, 928  
KOLODYNSKA-GAWRYSIAK, 468  
KONAN, 580  
KORUP, 247  
KOSTRZEWSKI, 709, 716  
KOTAPALLI, 431  
KOTHIERINGER, 440  
KRAUSHAAR, 482  
KROMUSZCZYNSKA O., 161  
KULL, 502  
KUMAR A., 188  
KURASHIGE, 792  
KUTOGLU, 496  
KUZUCUOGLU, 425  
LABAZUY, 243  
LABUZ, 883, 1134  
LADEIRA, 294  
LADEIRA F.S.B., 177  
LAHA, 992  
LAHIRI, 995  
LAHITTE, 241, 1128  
LAIGRE, 371, 376  
LAJCZAK, 343, 723  
LAMBERET, 747  
LAMBIEL, 1055, 1176  
LANCASTER, 948, 965  
LANCZONT, 416  
LANDEMAINE, 737, 831  
LANE, 769, 1103  
LANGSTON, 277  
LANS, 304  
LANTUIT, 1031  
LAQUINA, 473  
LARSEN, 437  
LASTOCHKIN A., 145  
LATOCHA, 442, 563  
LATRUBESSE, 969  
LAURETI L., 140  
LAUTE, 640, 826  
LAVARINI, 218  
LAVIGNE, 229, 244  
LE BOUTEILLER, 759  
LE COEUR, 462, 1037  
LE COZANNET, 388  
LE DEIT L., 162  
LE DREZEN, 429  
LE ROY, 1013  
LEDUC, 733  
LEHMKUHL, 944  
LEIGH, 425, 445  
LELEN, 1189  
LEMCKERT, 878  
LEZOVIC, 634  
LEONARD, 278  
LEONELLI, 597  
LESCURE, 415  
LESENCIUC, 718  
LESPEZ, 462, 783  
LETORTU, 846  
LI, 680, 1201  
LI Y., 187  
LIANG H., 210  
LIBERATOSCIOLI, 677  
LIEBAULT, 729, 763  
LIEDERMANN, 698  
LIGUORI, 333, 900  
LILLEØREN, 1056, 1062  
LIM, 718  
LIMA, 632  
LIMBER, 853  
LIN, 495, 616, 870, 1127  
LIND, 979, 1112  
LINDOSO, 1000  
LINOIR, 1200  
LIRO, 755  
LISENBY, 991  
LISSAK, 659, 684  
LIU, 215, 451, 539  
LOCKOT, 907  
LOCZY, 436  
LOMBARDO, 662  
LOPEZ SAEZ, 642, 1190  
LÓPEZ-GRANADOS, 154  
LOUREIRO, 893  
LU, 392, 829  
LU H., 196  
LUGERI, 538, 569, 574  
LUKENS, 593  
LUZ, 447  
LYGIN, 909, 915  
M. RÉMILLARD, 353  
MA, 253, 394  
MACHACEK, 1109  
MADDY, 1078  
MAGDIEL LYDIA, 881  
MAGILLIGAN, 780  
MAGKLARA, 915  
MAGNIN, 1035  
MAILLARD, 713, 1175  
MAIRE, 300  
MAJEWSKI, 1201

MAKANZU  
IMWANGANA, 582, 1195  
MAKHINOV, 714  
MAKHNATOV, 331  
MALET, 678  
MALIK, 501  
MALTSEV, 1121  
MAMADOU, 963  
MANDAL, 1194  
MANDLIER, 839  
MANI, 249  
MANYARI, 794  
MAQUAIRE, 631, 914  
MARCAL, 354, 976  
MARCATO, 640  
MARCHESE, 933  
MARCHESINI, 1087  
MARGOTTINI, 636  
MARIE, 904  
MARINO, 849  
MARQUIS, 730, 753  
MARREN, 776, 1019  
MARSTON, 494  
MARTEL, 1078  
MARTIN, 609, 1026  
MARTINEZ-GUTIERREZ, 201  
MASHUKOV, 350  
MASSELINK, 723, 876  
MASSON E, 145  
MASSUANGANHE, 881  
MATERAZZI, 627  
MATIAS, 868  
MATLAKHOVA, 377  
MATOS FIERZ, 917  
MAY, 874, 969, 1162, 1166  
MAYAMBA AIME, 1106  
MAZUREK, 349, 1085  
MBATCHOU  
MBATCHOU, 627  
MBEUGANG  
TCHEUBONSOU, 288  
MCDOWELL, 815  
MCINTOSH, 221  
MCLEAN, 841  
MEADOWS, 391  
MEDEIROS, 507  
MEGHRAOUI, 193  
MEIKLEJOHN, 1034  
MELELLI, 532  
MELIS, 427  
MELLO, 224, 361  
MELUN, 791  
MENAD W., 152  
MENANTEAU, 260, 441  
MENENDEZ-DUARTE, 602  
MERCIER, 834, 1010  
MERGILI, 1086  
MERIAUX, 188  
MESHKOVA, 970, 993  
MESSENZEHL, 655  
MESSERLI, 1165  
METTRA, 727  
MEYER, 486  
MIASNIKOV, 604  
MICALLEE, 923  
MICCADEI, 681  
MICHELETTI, 619, 1104  
MICHOUD, 1114  
MICU, 629, 641  
MIGON, 310, 1138  
MILAN, 255, 266  
MILEVSKI, 454, 479  
MINDRESCU, 1013  
MIRABELLA F., 202, 203  
MISIURA K., 164  
MIZUNO, 618  
MOEINI, 1176  
MOHR, 1089  
MOLIN, 201  
MOLNAR, 728  
MONDY, 1075  
MONTANE, 500, 744  
MONTEIRO, 292  
MONTERO, 989  
MONTREUIL, 903  
MOORE J.M., 164  
MOORMAN, 1097  
MORAES, 506  
MORAIS, 793  
MORALES, 200  
MOREAU, 345  
MORETTI, 911  
MORGAN, 838  
MORGAN A., 171  
MORGENSTERN, 1032  
MORHANGE, 401  
MORISSETTE, 867  
MORITA, 663  
MOSES, 851  
MOTTE, 422  
MOTTERSHEAD, 850  
MOURALIS, 421  
MOYA, 660  
MOZZI, 368, 426  
MUELLER, 828  
MUGNIER, 1020  
MUJIA FOFACK, 503  
MULAS, 668  
MUNIZ, 1002  
MUNRO, 959  
MUNYIKWA, 1158  
MURAKAMI, 504  
MURILLO GARCIA, 498  
MURILLO GARCIA, 673  
MURUJ, 403  
MWELWA, 984  
MYKHNOVYCH, 710  
N. BARRETO, 293  
NACHON, 170  
NADAL JUNQUEIRA VILLELA, 596  
NADAL ROMERO, 712, 1104  
NAEIMINEZAMABAD, 954, 1081  
NAGARALE, 489  
NAGUMO, 695  
NAMDEO, 711  
NANSON, 767  
NAPARUS, 589  
NARDINI, 1083  
NARTEAU, 1082  
NASCIMENTO, 355  
NAUMENKO, 353, 1136  
NAVARO, 560  
NAYLOR, 600, 861  
NAZAROV, 834  
NEDELEA, 1179  
NEHME, 320  
NEMETH, 233, 541  
NERY, 680  
NESCI, 422, 537  
NEUBERGOVA, 461  
NEVSKY V., 139  
NEXER, 289  
NG, 618, 985  
NGO, 583  
NGUYEN, 419  
NGUYEN XUAN, 334, 1178  
NIAGSU, 643  
NIANG, 584  
NICOLAE LERMA, 909  
NICOLL, 739  
NICULITA, 676, 1172  
NIELSEN, 925  
NIKAM, 812, 815  
NINFO, 1101, 1142  
NISHII, 647, 1053  
NIWA Y., 181  
NIZ, 516  
NKOUATHIO, 236  
NKURUNZIZA, 646  
NOMIKOU, 235  
NORMAN, 845  
NORMANDEAU, 932  
NOTEBAERT, 369  
NOWACKI, 408  
NUNES, 853  
NUNES PATUCCI, 809  
NURWIHASTUTI, 1192  
O'DONNELL, 791  
OGAMI, 804  
OGUCHI, 263, 522, 1126, 1136  
OLDKNOW, 800  
OLIVA, 301, 343, 1040  
OLIVEIRA, 291, 611, 665, 756, 761, 1141  
OLLERHEAD, 891  
OLLIER C., 178  
ORFORD, 887  
ORKHONSELENGE, 345  
OSINTSEVA, 502  
OSORNO, 535  
OUCHI, 1074  
OUERCHEFANI, 385  
OWCZAREK, 508, 1037  
OZDEMIR, 1121  
OZER, 581, 588  
PAGANELLI, 931  
PAILLOU, 941  
PAIN, 945  
PALACIO-PRIETO, 543  
PALAMARA, 932  
PALOMBA, 648  
PAN, 280, 307, 960  
PANEK, 630  
PANI, 1170  
PANIN, 366  
PANIZZA, 547, 579, 585  
PANYUSHKINA, 406  
PAPATHOMA-KOEHLE, 509  
PAPPALARDO, 854  
PAQUIER, 898  
PARDESHI, 449  
PARISE, 330, 633  
PARK, 902, 911  
PARON, 569  
PARROT, 637, 741, 1129, 1130  
PARRY, 659, 1178  
PARTELI E., 172  
PASCHOAL, 458  
PASCULLI, 1086  
PASTRE, 365  
PASUTO, 648  
PATEAU, 461, 582  
PAVANO F., 207  
PAVLOPOULOS, 931  
PAVLOVA, 952, 1050  
PAWLIK, 599  
PEDERSON, 278  
PEDROSA, 918  
PEETERS, 790  
PEIXOTO, 784  
PELACANI, 820  
PELLEGRINI, 418, 1119  
PENG, 311, 312  
PENIDO, 574  
PEREIRA, 532, 554, 666, 1184  
PEREZ FILHO, 751, 754  
PEREZ-ALBERTI, 854, 857  
PÉREZ-ALBERTI, 859  
PERKINS, 939  
PERRIER, 1041, 1189  
PERRIN, 335  
PERRY, 841  
PERSENDT, 1122  
PERSOIU, 371, 378, 816  
PERUCCA, 198  
PETERSEN, 808  
PETROVIC, 1108  
PETSCHKO, 679  
PEULVAST, 275, 416  
PHARTIYAL, 1053  
PIACENTINI, 663, 1179  
PIANA, 369  
PICA, 538, 543  
PIEPADE, 930  
PIJET-MIGON, 474  
PILLANS B., 184  
PINHEIRO, 1085  
PIOTROWSKA, 572  
PIRAZZOLI, 929, 930  
PIRAZZOLI, 183  
PITLICK, 749  
PLACZKOWSKA, 716  
PLATONOVA, 1180  
POEPPL, 714  
POIRAUD, 395  
POLVI, 788  
POP, 832  
PRASICEK, 1139  
PRATOMO, 570  
PRICE, 442  
PROCTER, 229  
PROMPER, 510  
PSUTY, 875  
PULUNGAN, 596  
PURDUE, 404  
QI, 303, 313  
QU N HERV, 1102  
QUENEHERVE, 1090  
RAAB, 342, 411, 601  
RABASSA J., 175, 178  
RACHLEWICZ, 1012  
RACZKOWSKA, 1060  
RACZKOWSKA, 267  
RAGARU, 861  
RAJ, 344  
RAJIB, 606  
RAMAGE, 1046

RAMIREZ, 1082  
RAMIREZ NUNEZ, 457  
RAMOND, 694, 1152  
RAMONELL, 740, 1000  
RAMOS, 1173  
RAMOS PEREIRA,  
1157  
RAMOS-PEREIRA, 390  
RANDAZZO, 888  
RANGEL, 561  
RAPISARDI, 560  
RÄPPLE, 778  
RASHIDOV, 238  
RAVEL, 251, 391, 506  
RAZAFIMBELO, 906  
RAZAK, 1096  
REBER, 1164  
REDIN VESTENA, 755  
REED, 891  
REGAMEY, 782  
REGARD, 194, 857, 858  
REGMI, 517  
REGNAULD, 888  
REHBEIN, 456  
REINFELDS, 1058, 1126  
REN, 308, 954  
RENOUARD, 336  
REPKINA, 896  
RESTREPO, 989  
REULIER, 1140, 1191  
REVELLINO, 1181  
REYNARD, 546  
REZENDE, 481  
RIBOLINI, 1038, 1108  
RICCI, 232  
RICCIONI DE MELOS,  
283  
RICHARDS, 252, 635  
RICHARDS K., 137  
RICHARDSON, 286  
RIEDLER, 633  
RIEGL, 837  
RIFFEL, 274  
RINALDI, 787, 808  
RIQUIER, 694  
RIXHON, 260, 265  
RIZZETTO, 1129  
ROBINSON, 855  
ROBITAILLE, 392  
ROCHA, 359, 798  
RODRIGUES, 438, 545,  
700, 1182  
RODRIGUEZ GARCIA,  
292  
RODRIGUEZ  
RODRIGUEZ, 554,  
1027  
RODZIK, 717  
ROHMER, 847  
ROJAN, 731, 1066  
ROMANO, 424, 510  
ROMERO RUIZ, 239  
ROSCA, 1091  
ROSKIN, 455, 949  
ROSSATO, 1025  
ROSSETTI, 194  
ROSSI, 1151  
ROSSKOPE, 555  
ROSU, 564  
ROTIGLIANO, 662, 681  
ROUSSEAU, 732, 1080,  
1084, 1105  
ROUSSEL, 1063  
ROUSSELIN, 1124  
ROVERA, 860, 1052  
ROY, 459, 972  
RUALT, 910  
RUDAZ, 1124  
RUDOY A., 139  
RUIZ-VILLANUEVA,  
1071  
RUNGE, 973, 983  
RUTHERFURD, 788  
RUZ, 882  
RYSIN, 720  
SAAD A.Z.E., 148  
SAEMUNDSSON, 616  
SAHA, 490  
SAHANI, 585  
SAIJO, 463  
SAITO, 1131  
SALEEM, 856  
SALIT, 696  
SALOMON, 407  
SALVATORE, 679  
SAMINPANYA, 309  
SAMPAIO, 223  
SAMSONOVA, 1192  
SAMYN, 1028  
SANCHEZ, 293  
SANDER, 914, 1199  
SANDERSEN, 190  
SANDRIC, 619  
SANKARAN, 191  
SANTOS CORREA,  
1113  
SANTOS M., 208  
SANTOS-GONZALEZ,  
1020, 1021  
SAPOVAL, 848  
SARDINHA, 744  
SARIKAYA, 226, 1158  
SARMA J.N., 153  
SASS, 760  
SATDAROV, 757  
SATO, 644  
SATPATI, 467  
SAVINI, 926  
SAWABE, 639  
SAYAGO, 441, 955  
SAYED, 919  
SCAPOZZA, 356, 1065  
SCATENA, 601, 993  
SCHARF, 276  
SCHIAVONE, 1056  
SCHILLEREFF, 254  
SCHMELTER, 1150  
SCHMIDT F., 160  
SCHMITT, 736, 1120  
SCHOENEICH P., 135  
SCHROTT, 1035  
SCHULTE, 373  
SCHWEIGSTILLOVA,  
313  
SCORPIO, 774  
SCOTTI (, 190  
SCUDERI, 946  
SEAR, 777  
SEBE, 944  
SECHI, 419  
SEELIGER, 402  
SEJOURNE, 1032  
SEKARSARI, 1193  
SELCUK BIRICIK, 715  
SELLIER, 530  
SEMBRONI, 285  
SEONG, 1159  
SEPEHR, 1074  
SEPPI, 1021  
SÉRGIO BERNARDES  
LADEIRA, 295  
SERRANO, 542, 1049  
SERRANO MUELA, 721  
SHAH-HOSSEINI, 871  
SHAO, 692  
SHI, 284, 702  
SHIMAZU, 799  
SHRODER, 635  
SHTOBER-ZISU, 324  
SHUTTLEWORTH, 438,  
565  
SIDDIQUI, 499  
SIL, 470  
ŠILHÁN, 632  
SILINSKI, 885  
SILVA, 220, 467, 474,  
481, 649, 704, 1084  
SIMONSON, 311  
SIMOU E., 207  
SINHA, 367, 985  
SKARPICH, 758  
SLATER, 739  
SLATTERY, 719, 731  
SLAYMAKER, 383, 1015  
SLEE, 1041, 1057  
SLOWIK, 773  
SMITH, 821, 1100  
SMITH-ADAO, 770  
SMITHERS, 837  
SMOLIKOVA, 453, 653  
SMOLKOVA, 360  
SMOLSKA, 712  
SOLDATI, 493, 675  
SONG, 522  
SONNEVELD, 453  
SORIANO, 957  
SOSA-GONZALEZ, 997  
SOUZA, 573, 713, 813,  
895  
SOUZA MARTINS, 294,  
1172  
SOUZA VALLADARES,  
1138  
SPATTI, 748  
SPIZZICHINO, 667  
SRIDHAR, 738  
STARHEIM, 1117, 1194  
STARKEL, 250, 271  
STAUB, 1066  
STAUCH, 947  
STEINMANN, 408  
STEPANCIKOVA, 224  
STEPHAN, 866, 908  
STEPHENS, 534, 655  
STEPHENSON, 855  
STEVAX, 988  
STEWARTSON, 768  
STOATE, 595  
STOCK, 431  
STOCKER-  
WALDHUBER, 1014  
STOFFEL, 485, 607  
STONE, 965  
STORANI, 800  
STOUT, 789  
STROHMEYER, 1043  
STROMSOE, 828  
STRONG, 951  
STRZELECKI, 859, 1009  
STUIVER, 845  
STURMOVA, 466  
SUANEZ, 866, 907  
SULTANA, 830  
SURIAN, 759  
SUWA, 615  
SUZUKI, 495, 508  
SVOBODOVA, 452  
SWIRAD, 848  
SWITZER, 261, 842  
SZABO, 768  
SZEFLER, 1169  
TAAOUATI, 902  
TÁBOŘÍK, 652  
TAKEZAWA, 496  
TAL, 733  
TALLÓN-ARMADA, 404  
TAMURA, 263  
TANAKA, 359  
TANANAIEV, 701, 821  
TANARRO, 1123  
TAPETE, 521  
TARRAGONI, 511  
TATUI, 908  
TAVARES, 272  
TAVER, 326  
TCHINDJANG, 512, 545  
TEFOGOU, 526, 654  
TEIXEIRA, 1177  
TELLEZ, 575  
TEMME, 1059, 1060  
TEMMERMAN, 600  
TEMOVSKI, 320  
TEOUGAM, 776  
TERRY, 259, 262  
TERUGGI, 1182, 1184  
TESTA, 550, 564  
THAKRE, 811  
THOMAZ, 454  
THOMMERET, 790,  
1153  
THOURET, 235, 238  
TIAN, 698  
TIE, 1058  
TILLMANN, 869, 1160  
TIUMENTCEVA, 956  
TOBLER, 485, 1023,  
1096  
TODA, 605  
TOMCZYK, 561  
TONELLI, 321  
TOROK, 525  
TRAVALINI, 889  
TRENHAILE, 852  
TRINDADE, 265, 904  
TRIPATHI, 218  
TRIVELLATO, 480  
TROIANI F., 205  
TRUEMAN, 607, 1079  
TSANAKAS, 515  
TSODOULOS, 217, 1165  
TUNNICLIFFE, 738,  
1031  
TURCONI, 697  
TURKINGTON, 605  
TURNER, 775  
UNDE, 490  
UNJAH, 539  
URBAN, 1039  
URDEA, 1036  
USMANOV, 420, 1106  
UTASSE, 493  
VALCARCEL, 1005

VALE, 819  
VALENTE, 697, 916  
VALKANOU, 223  
VAN ASCH, 660, 676  
VAN DE WIEL, 1134  
VAN DE WIEL M., 136  
VAN DER BEEK, 271  
VAN DER WAAL, 784  
VAN GORP, 1076  
VAN NIEULAND, 430  
VAN VLIET-LANOE,  
874  
VAN WYK DE VRIES,  
231, 243  
VANACKER, 247  
VANARA, 322  
VANDARAKIS, 409  
VANDYCKE S., 206  
VÁQUEZ-TARRÍO, 795  
VATNE, 735  
VAUDOR, 1150  
VEIT, 942  
VELLA, 509  
VERDUM, 565, 595  
VERONESI, 1149  
VERSTRAETEN, 386,  
962  
VESPREMEANU-  
STROE, 875, 1044

VIEIRA, 997  
VIEIRA GOMES, 477  
VIEL, 720, 819  
VIETZ, 448  
VILANO, 361  
VILIMEK, 626  
VILLAÇA GOMES, 621  
VITAL, 925  
VOELKEL, 464, 597  
VOICULESCU, 1061  
VOUNDI, 503  
WACHECKA-  
KOTKOWSKA, 341,  
1177  
WAINWRIGHT, 1088  
WALKER, 443  
WALSH, 262, 1001  
WANG, 803, 928, 1026  
WANG W., 170  
WARAGAI, 523  
WASSMER, 617  
WAWRZYŃIAK, 771  
WERB, 1198  
WERREN, 488  
WHITE, 321, 553, 887  
WHITFIELD, 781  
WIBOWO, 242, 722  
WICKRAMASOORIYA,  
505, 571

WIEDERKEHR, 812  
WILCOCK D., 143  
WILLIAMS, 942, 1077  
WINKELBAUER, 606  
WINOWSKI, 876  
WIRSIG, 1159  
WISTUBA, 620  
WITEK P., 168  
WLOSINSKA, 1139  
WOOD, 994  
WU, 393  
WYZGA, 746, 772  
XIE, 513  
XU S., 149  
YAIR, 284, 937  
YAN, 704, 957  
YAN W., 155  
YANG, 222, 349, 691,  
693, 705  
YESILYURT, 1027  
YOON, 417, 955  
YOSHIDA, 239  
YOUNG, 851, 913  
YU, 395, 970, 1063  
YURY, 286  
YURY E., 168  
ZAGÓRSKI, 335, 873  
ZAHERI, 327  
ZAIDAN, 670

ZANONER, 1014, 1042  
ZARROCA, 328  
ZAWIEJSKA, 798  
ZERBONI, 312, 355  
ZEZERE, 492  
ZÉZERE, 1149  
ZHANG, 396, 701, 880,  
937, 946, 960, 1070  
ZHANG S., 202  
ZHAO, 700, 952  
ZHENG, 956  
ZHIJIU c., 147  
ZHIROVA, 150  
ZHIZHONG, 919  
ZHOU, 617  
ZIEGLER, 990  
ZINI, 326  
ZITOUNI, 587  
ZIZIOLI, 669  
ZOMENI, 387  
ZORN, 475, 549  
ZORRIASATEYN, 736  
ZOU, 958  
ZOU X., 166  
ZOUVA, 1196  
ZWOLINSKI, 825, 1185

## **IAG EXECUTIVE COMMITTEE (2009-2013)**

### **President**

Prof. MICHAEL CROZIER (New Zealand)

### **Vice-Presidents**

Prof. DAVID DUNKERLEY (Australia)  
Prof. ERIC FOUACHE (France)  
Prof. PIOTR MIGON (Poland) - Working Groups Officer

### **Secretary General**

Prof. MORGAN DE DAPPER (Belgium)

### **Treasurer**

Prof. FRANCISCO GUTIÉRREZ (Spain)

### **Publications Officer**

Dr. SUNIL KUMAR DE (India)

### **Co-opted members**

Dr. BIANCA CARVALHO VIEIRA (Brazil)  
Prof. DAVID HIGGITT (Singapore) - Public Relations Officer  
Prof. YOSHIMASA KURASHIGE (Japan)  
Prof. LOTHAR SCHROTT (Germany/Austria)  
Prof. MAURO SOLDATI (Italy) - Young Geomorphologists Training Officer  
Prof. MOHAMMED UMER (Ethiopia) †  
Prof. ASFAWOSSEN ASRAT (Ethiopia)  
Prof. XIAOPING YANG (China)  
Prof. ZBIGNIEW ZWOLINSKI (Poland) – Webmaster

