PROGRAM AND ABSTRACTS

15th International Conference on Accelerator Mass Spectrometry

November 15th – 19th, 2021
ANSTO
Sydney, Australia

2021 AMS-15
Local Organising Committee

ANSTO
Fiona Bertuch
David Child
David Fink
Reka Fulop
Mike Hotchkis
Quan Hua
Geraldine Jacobsen
Andrew Jenkinson
Vlad Levchenko
Krista Simon
Andrew Smith

ANSTO
Klaus Wilcken
Alan Williams *
Megan Williams
Bin Yang

ANU
Stewart Fallon

HZDR
Toni Wallner

* Deceased.
The Local Organising Committee acknowledges the invaluable contributions made by Alan Williams to the planning of our AMS-15 conference from the very beginning in mid-2019. Alan sadly passed away in February 2021 after a long battle with cancer. He was the Manager of the AMS Radiocarbon Chemistry Laboratory at ANSTO for many years, tirelessly supporting all students and researchers who worked in his laboratory. Without fail, Alan ensured that radiocarbon sample processing continued without interruptions providing quality graphite targets for AMS analyses on our accelerators.

Alan's efforts to bring this event to the AMS community are greatly appreciated by all members of the Local Organising Committee.

His presence at the 15th International AMS conference will be sadly missed.

2021 AMS-15 International Scientific Advisory Committee (IAC)

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RADIOCARBON DATING SERVICE

	PLENARY	*(INVITED)	APPLICATION	TECHNICAL	POSTER-PLUS
	MONDAY 15th				
7:30 - 7:40	Brett Rowling	Welcome to Country			
7:40 - 7:50	Andrew Peele	Group Executive, Nuclear Science Technlogy, ANSTO			
7:50 - 8:00	Ceri Brenner	Leader, Center for Accelerator Science, ANSTO			
8:00 - 8:10	David Fink	Chairperson, AMS-15, ANSTO			
	BREAK 5 MINS				
8:15 - 9:00	**Andrew Gleadow**	**The Kimberley Rock Art Dating Project – a multi-system approach to dating Aboriginal rock art and landscape evolution in Australia's remote Kimberley region**			
	SESSION 1	**T-5: Advances in sample preparation**		**SESSION 2**	**A-6: Challenges of the nuclear age**
9:00 - 9:45			**9:00 - 9:55**		
	Carracedo	Assessing metal matrices to improve AMS precision for cosmogenic Be-10 applications		Johansen*	Plutonium uptake, dose and source apportioning in wild animals
	Walker	Less is more: optimizing Be-9 carrier addition for AMS analysis of Be-10 at CAMS		Medley	Measurement of Pa-231 for radiological dose assessment from uranium mining
	Fulop	Refinement to the extraction of in-situ cosmogenic C-14		Dorais	U-236/U-238 measurements in uranium ore concentrates at CAMS
9:35 - 9:45		*Group Q&A*			
		BREAK 15 MINS	**9:45 - 9:55**		*Group Q&A*
	SESSION 3	**T-1: Novel AMS systems, components and techniques**			**BREAK 15 MINS**
10:00 - 10:55				**SESSION 4**	**A-1: Earth's dynamic climate**
	Synal*	Low Energy AMS: How to reach 50kyrs with 50 kV	**10:15 - 11:10**		
	He	Development of the low-energy AMS systems at China institute of atomic energy		Dyonisius*	Towards C-14 dating of gases in ice cores – constraining the in situ cosmogenic C-14 production rates by muons
	Freeman	The PIMS project status		Stutz	A data-model comparison on the glacial thinning history of Byrd Glacier, Antarctica
10:45 - 10:55		*Group Q&A*		Braumann	Be-10 moraine chronologies from the Austrian Alps and their correlation with climatic events during the Late Glacial and the Holocene
	SESSION 5	**T-1: Novel AMS systems, components and techniques**	**11:00 - 11:10**		*Group Q&A*
11:00 - 11:45				**SESSION 6**	**A-1: Earth's dynamic climate**
	Yamagata	Development of Ca-41 AMS at MALT, The University of Tokyo	**11:15 - 12:00**		
	Nelson	In-Cathode Activations for Ca-41 Production Cross Section Measurements		Hua	Variability in the Holocene marine radiocarbon reservoir effect for the Tropical West Pacific
	Prasad	Identifying the sources of beam transmission loss of carbon isotopes		McNeil	Evolution of the Great Barrier Reef Halimeda carbonate factory in response to Holocene environmental changes, determined from radiocarbon and nitrogen isotope measurements
11:35 - 11:45		*Group Q&A*		Zeng	A rapid and precise method of establishing age model for coral skeletal radiocarbon to study surface oceanography using coupled X-ray photos and ICP-AES measurement
		BREAK 15 MINS	**11:50 - 12:00**		*Group Q&A*
	SESSION 7	**A-7: Understanding the human story**			**BREAK 15 MINS**
12:00 - 12:55				**SESSION 8**	**A-4: Catastrophic natural events**
	Granger*	Quantitative tests of Al-26/Be-10 burial dating accuracy in archaeology and paleoanthropology	**12:15 - 13:30**		
	Florin	Using stable isotope analysis of archaeological pandanus nutshell to understand past rainfall at Madjedbebe, northern Australia		Brehm*	Detection of solar events by using radiocarbon in tree-rings
	Green	Dating correlated microlayers in engraved, oxalate-rich accretions: new archives of paleoenvironments and human activity from Australian rock art shelters		Park	Δ14C peak (BC660-5) appearing in earlywood and latewood from tree rings close polar area (Finland)
12:45 - 12:55		*Group Q&A*		Haines	Identifying Solar Energetic Particle events of differing magnitudes through increases in C-14 concentrations from high-resolution sampling of Southern Hemisphere tree rings
	SESSION 9	**A-7: Understanding the human story**		Smith	Cosmogenic radionuclides at Law Dome, East Antarctica, as signatures of past Solar storm events.
13:00 - 13:45					
	Webster	Temples through time: a radiocarbon-based chronology for the Bronze to Iron Age temple sequence at Pella (Jordan)	**13:20 - 13:30**		*Group Q&A*
	Hendrickson	A Brief History of Angkor's Iron: Reconstructing multi-scalar chronologies in the Phnom Dek metallurgical landscape,			**BREAK 30 MINS**
	Wu	Radiocarbon dating of the large-scale bronze age burials at Mogou site in Gansu, China			
13:35 - 13:45		*Group Q&A*			
		BREAK 15 MINS			
14:00 - 15:00	**EXHIBITOR NETWORKING SESSION - IONPLUS**				

	PLENARY	*(INVITED)	APPLICATION	TECHNICAL	POSTER-PLUS
		TUESDAY 16th			
8:00 - 8:45	**Joel Pedro**	**From snow pits to a million year ice-core: taking the measure of the planet from Antarctic Ice Sheets and the 1Myr ice core**			
	SESSION 10	**A-3: Living landscapes**		**SESSION 11**	**T-1: Novel AMS systems, components and techniques**
8:45 - 9:30			8:45 - 9:45		
	Malcles	The French Massif-Central, example of a not so inactive intraplate region		Shanks*	Operation and Demonstration of Positive Ion Mass Spectrometry.
	Flatley	A multi-cosmogenic nuclide approach to assess sediment provenance and long-term denudation in the ancient Pilbara region, Western Australia		Shen	A single stage AMS system and its applications at Guangxi Normal University
	Shimizu	A novel in-situ C-14 extraction system for surface exposure dating to reconstruct the past Antarctic ice sheet		Gautschi	Be-10 and Al-26 analysis with the prototype 300kV MILEA system at ETH Zurich
9:20 - 9:30		*Group Q&A*			
		BREAK 15 MINS	9:30 - 9:45		*Group Q&A*
	SESSION 12	**A-1: Earth's dynamic climate**			
9:45 - 10:40					**BREAK 15 MINS**
	Etheridge*	Law Dome 14CH4 measurements confirm revised fossil methane emissions estimates		**SESSION 13**	**T-1: Novel AMS systems, components and techniques**
	Anderson	Antiphase dynamics between cold-based glaciers in the Dry Valleys region and ice extent in the Ross Sea, Antarctica during MIS 5	10:00 - 10:55		
	White	Short duration glacial advances: implications for cosmogenic dating chronologies		Christl*	U-236 analyses with the prototype 300kV MILEA system at ETH Zurich
10:30 - 10:40		*Group Q&A*		Tiessen	Optimizing a cesium-sputter ion source using Lorentz 2E
	SESSION 14	**A-1: Earth's dynamic climate**		Zheng	The status of TOF-E detection system at MALT and its proceedings
10:45 - 11:30			10:45 - 10:55		*Group Q&A*
	Parsons O'brien	Reconstructing Late Pleistocene Atmospheric Radiocarbon using Subfossil New Zealand Kauri (Agathis australis)		**SESSION 15**	**T-1: Novel AMS systems, components and techniques**
	Duxbury	Holocene climate, fire and ecosystem change on Kangaroo Island, South Australia	11:00 - 11:45		
	Adams	The Last Glacial transition and Holocene ecological change in Arthur's Pass National Park, New Zealand.		McIntyre	Sample introduction and interfaces for Positive Ion Mass Spectrometry
11:20 - 11:30		*Group Q&A*		Turney	The New Chronos 14Carbon-Cycle Facility, University of New South Wales, Sydney, Australia
		BREAK 15 MINS		Kutschera	An overview of world-wide AMS facilities
	SESSION 16	**A-7: Understanding the human story**	11:35 - 11:45		*Group Q&A*
11:45 - 12:35					**BREAK 15 MINS**
	Finch*	From radiocarbon dating of mud wasp nests to ages for early Australian rock art		**SESSION 17**	**T-2: Suppression of isobars and other interferences**
	Fernandes	Are radiocarbon dating and Bayesian chronological modelling useful in Classical Archaeology?	12:00 - 12:55		
12:17 - 12:35		*Group Q&A*		Alary*	A Review of the On-line Suppression of Sulfur by Charge Transfer with Nitrogen Dioxide in the Analysis of Chlorine-36 by Accelerator Mass Spectrometry – Hints from Liquid Chromatography Mass Spectrometry
		BREAK 25 MINS		Forstner	The LISEL@DREMS project for isobar suppression by laser photodetachment
				Fenclova	Preliminary tests of Al-26 fluoride target matrix on AMS system
			12:45 - 12:55		*Group Q&A*
					BREAK 5 MINS
		POSTER-PLUS 1			**POSTER-PLUS 2**
13:00 - 13:25			13:00 -13:25		
	Zondervan	C-14 AMS data quality assessment: A key practice at the Rafter Radiocarbon Laboratory		Rugel	Super-SIMS @ DREAMS: status of a challenging initiative
	Hundman	Current Sample Pretreatment Protocols for AMS Radiocarbon Dating by DirectAMS (D-AMS)		Wieser	Cs-135 and Cs-137 detection in environmental samples by AMS
	Gautschi	A new method to graphitize CO2 from atmospheric air for radiocarbon analysis		Hain	First studies on Tc-99 detection using Ion Laser InterAction Mass Spectrometry (ILIAMS)
	Yang	Testing line for processing of dissolved inorganic carbon from water for radiocarbon dating determining the efficacy of trapping carbon dioxide for an automated system		Marchhart	ILIAMS assisted AMS of Sr-90 at VERA
	Regev	A self-made glass ampule cracker, coupled to an EA-IRMS-AGE3		Dorais	Development of Ni-59/Ni-58 measurements at CAMS
13:10 - 13:25		*Group Q&A*	13:10 - 13:25		*Group Q&A*
			BREAK 5 MINS		
		POSTER-PLUS 3			**POSTER-PLUS 4**
13:30 - 13:55			13:30 - 13:55		
	Smith	Graphitisation & measurement of microgram radiocarbon samples at ANSTO.		Kern	Increasing the ionization yield for the detection of U-236 and U-233 by AMS
	Paige	Automated induction heating of quartz for in situ cosmogenic C-14 measurements		Wiederin	Relative Formation Probabilities for Fluoride and Oxyfluoride Anions of U, Np, Pu and Am in AMS Measurements at VERA
	Stutz	Using in situ 1C-14 to unravel complex exposure histories along the David Glacier, Antarctica		Christl	First results from the Zurich Sea Water (ZSW) U-236 intercomparison sample
	Margreiter	Quantification of C-14 in artificially activated reactor graphite via AMS		Wallner	AMS with a 14 million volt accelerator - Mn-53 and Fe-60 with ANU's ENGE
	Crann	Radiocarbon in the environment from the nuclear industry in Canada: a review			*Group Q&A*
13:40 - 13:55		*Group Q&A*	13:40 - 13:55		
			BREAK 5 MINS		
14:00 - 15:00		**EXHIBITOR NETWORKING SESSION - NATIONAL ELECTORSTATIC CORPORATION (NEC)**			

	PLENARY	*(INVITED)	APPLICATION	TECHNICAL	POSTER-PLUS
		WEDNESDAY 17th			
8:00 - 8:45	**Jocelyn Turnbull**	**Dramatic lockdown fossil fuel carbon dioxide decrease detected by citizen science supported radiocarbon observations**			
	SESSION 18	**A-1: Earth's dynamic climate**		**SESSION 19**	**T-1: Novel AMS systems, components and techniques**
8:45 - 9:30			8:45 - 9:45		
	Arazi	I-129 in rainwater along Argentina		Martschini*	Ion Laser InterAction Mass Spectrometry – prospects for AMS without chemistry
	Abascal	I-129 and Cs-137 as dual tracers: From Japan Sea to the Fram Strait		Schiffer	An advanced radio-frequency quadrupole ion cooler for Accelerator Mass Spectrometry
	Qi	Speciation Distribution of Iodine Isotopes (I-127 and I-129) in the North Pacific Ocean		Flannigan	The Isobar Separator for Anions at the A. E. Lalonde AMS Laboratory
09:20 - 09:30		*Group Q&A*			
		BREAK 15 MINS	9:35 - 9:45		*Group Q&A*
	SESSION 20	**A-1: Earth's dynamic climate**			**BREAK 15 MINS**
9:45 - 10:40				**SESSION 21**	**T-1: Novel AMS systems, components and techniques**
	Szidat*	The apportionment of emission sources of atmospheric methane using C-14: capabilities and challenges	10:00 - 10:55		
	Sharma	Radiocarbon based study of fossil fuel CO2 variations across India		Scognamiglio*	Addition of charge state selection after the terminal stripping for reduced background in AMS
	Haines	Anomalous tree-ring identification facilitated by AMS C-14 analysis in subtropical and tropical Australian Araucariaceae samples enables development of a long-term, high-resolution climate reconstruction		Galindo-Uribarri	Ultrasensitive Resonance Ionization Mass Spectrometry of Plutonium
10:30 - 10:40		*Group Q&A*		Callahan	Initial Tests of Accelerator Mass Spectrometry with the Argonne Gas Filled Analyzer (AGFA) and the commissioning of the MONICA detector
	SESSION 22	**A-3: Living landscapes**	10:45 - 10:55		*Group Q&A*
10:45 - 11:30				**SESSION 23**	**T-1: Novel AMS systems, components and techniques**
	Jeromson	The distribution and fractionation of beryllium isotopes in various reactive phases of Antarctic marine sediments	11:00 - 11:45		
	Bailey	Accelerator Mass Spectrometry with Mn-53 at University of Notre Dame		Vockenhuber	Absolute Measurements and AMS - Towards the redetermination of the half-life of Si-32
	Griffin	Slip rates for the Hyde and Dunstan Faults, southern New Zealand, revealed by cosmogenic radionuclide dating		Fifield	Coulomb Explosion of BeO
11:20 - 11:30		*Group Q&A*		Suter	The impact of the break-up of molecules in the stripper on AMS performance
		BREAK 15 MINS	11:35 - 11:45		*Group Q&A*
	SESSION 24	**A-6: Challenges of the nuclear age**			**BREAK 15 MINS**
11:45 - 12:40				**SESSION 25**	**A-7: Understanding the human story**
	Matsuzaki*	Time course profile of Chlorine-36 in Greenland SE dome ice core	12:00 - 12:40		
	Mozafarishamsi	Iodine-129 in Cigar Lake uranium deposits by Pyrohydrolysis and AMS		Wood*	Potential of the petrous part of the human temporal (ear) bone for isotope analysis
	Clark	Actinide Accelerator Mass Spectrometry Development for Environmental Sampling and Neutron Capture Cross Section Measurements		Dighton	Dating the origins and long-term process of olive domestication in the north Jordan Valley: new radiometric data from 5th millennium BCE Pella in Jordan
12:30 - 12:40		*Group Q&A*	12:30 - 12:45		*Group Q&A*
		BREAK 20 MINS			**BREAK 15 MINS**
		POSTER-PLUS 5			**POSTER-PLUS 6**
13:00 - 13:25			13:00 - 13:25		
	Wilkinson	Controls on Be-10 dilution in catchments affected by coseismic landsliding: a 2016 Kaikōura earthquake case-study		Miyairi	Fish habitat study using radiocarbon of otoliths with stepwise dissolution technique
	Zinelabedin	Testing the application of meteoric Be-10/Be-9 ratios on dating calcium sulphate-rich wedges from the Atacama Desert		Johnstone-Belford	Evaluating the Use of Different Tissue Types in the Estimation of Year of Death for Forensic Casework
	Patton	Utilizing meteoric Be-10 to define the mobile-stable regolith boundary within unconsolidated sediment		Lee	In vivo tracking of C-14 thymidine labeled mesenchymal stem cells using ultra-sensitive accelerator mass spectrometry
	Jeromson	Extracting Be-10 and Be-9 from Antarctic marine sediments – a comparison of different extraction techniques		Wood	The potential for radiocarbon to understand the illegal pangolin wildlife trade
	Whitmore	Quantifying the bucket: Quartz purification of 125-63 µm material for in-situ cosmogenic nuclide analysis.		Cherkinsky	AMS C-14 dating of bioapatite: advantage and disadvantage
13:10 - 13:25		*Group Q&A*	13:10 - 13:25		*Group Q&A*
		BREAK 5 MINS			**BREAK 5 MINS**
		POSTER-PLUS 7			**POSTER-PLUS 8**
13:30 - 13:55			13:30 - 13:55		
	Merchel	Be-10 from commercial Be-9 and Al-27 carrier solution – Some measurements		Yang	Investigation of OC and EC fractions of aerosol samples in Sydney area by radiocarbon analysis
	Merchel	An AMS-world without any chemistry? – Untypical measurements of Al-26, Ca-41 and Fe-55		Matley	Late Pleistocene fossil flora of Henty Bridge, Tasmania, and their implications for glacial climate reconstructions
	Kameník	Monitoring of chemical processes for Be-10 and Al-26 AMS target preparation		Reynolds	Usefulness of Stable Polycyclic Aromatic Carbon for dating lake sediments.
	Winkler	The foilstack method for Be-10 analysis at iThemba LABS – first results and intercomparison for field samples		Pachnerova	Radiocarbon dating of charcoals in mother mortars
	Lachner	Optimization of Be-10 beam transport at DREAMS		Burr	A UV-spectrophotometric approach to quantifying Iodine in environmental samples for AMS studies
				Bautista	Sub-annual I-129 environmental record of years 1956-2007 from an ice core in SE Dome Site, Greenland
		Group Q&A			*Group Q&A*
		BREAK 5 MINS			
14:00 - 15:00		**EXHIBITOR NETWORKING SESSION - HIGH VOLTAGE ENGINEERING (HEV)**			

	PLENARY	*(INVITED)	APPLICATION	TECHNICAL	POSTER-PLUS
		THURSDAY 18th			
8:00 - 8:45	**Brian Fields**	**When Stars Attack! AMS Reveals Near-Earth Supernova Explosions**			
	SESSION 26	**T-5: Advanced in sample preparation**		**SESSION 27**	**A-8: Understanding the cosmos**
8:45 - 9:30			**8:45 - 9:45**		
	Fernandes	Tracing metabolic carbon routing in a mice feeding experiment using C-14 at natural abundances		Wallner*	Supernovae and r-process – the extraordinary development of AMS for identifying traces of interstellar origin
	Xiaomei Xu	Graphitization of Samples Containing Sulfur and Chlorine Using the Sealed Tube Zinc Reduction Method for C-14 Analysis on AMS		Chavez Lomeli	Nuclear reaction cross-section measurements using AMS
	Molnár	Application of an automated AGE-CHS unit for water DIC-14 analyses at HEKAL Laboratory		Froehlich	Lead-210: A contaminant in particle detectors for dark matter studies
09:20 - 09:30		*Group Q&A*			
		BREAK 15 MINS	**09:30 - 09:45**		*Group Q&A*
	SESSION 28	**T-5: Advances in sample preparation**			**BREAK 15 MINS**
9:45 - 10:40				**SESSION 29**	**A-6: Challenges of the nuclear age**
	Ginnane*	Refining the Bulk: Ramped Pyrolysis Radiocarbon Dating Enhanced with Parallel Pyrolysis-GC-MS Analysis	**10:00 - 10:55**		
	Biganeh	Experience in commissioning of the radiocarbon dating lab based on Carbosorb method in Tehran		López-lora*	New insights into actinides sources to the Baltic Sea
	Barone	The “Lilliput” experimental set-up at INFN: state of art and future developments		López-Gutiérrez	Atmospheric gaseous and particulate Iodine-129 in Seville (Spain)
10:30 - 10:40		*Group Q&A*		Bautista VII	Seawater I-129/I-127 ratios in the various seas of the Philippines
	SESSION 30	**T-2: Suppression of isobars and other interferences**	**10:45 - 10:55**		*Group Q&A*
10:45 - 11:30				**SESSION 31**	**T-6: Data quality and management**
	Wallner	Reproducibility and accuracy of actinide AMS – lessons learned from precision studies for nuclear data	**11:00 - 11:45**		
	Fu	Study of 10Be/7Be analysis method using Accelerator Mass Spectrometry		Zhong	How far back can radiocarbon date using different materials through comparison with OSL
	Schlomberg	Isobar separation of Si-32 and S-32- Towards the redetermination of the half-life of Si-32		Zhang	Determination of Iodine-129 in twenty soil and sediment reference materials
11:20 - 11:30		*Group Q&A*		Eliades	Be-10, Al-26, Cl-36, Ca-41 and I-129 Data Analysis at KIST
		BREAK 15 MINS	**11:35 - 11:45**		*Group Q&A*
	SESSION 32	**A-1: Earth’s dynamic climate**			**BREAK 15 MINS**
11:45 - 12:40				**SESSION 33**	**T-4: New AMS isotopes**
	Thomas*	Phases of peatland carbon accumulation in the southern mid-latitudes	**12:00 - 12:40**		
	Henriquez	Vegetation, fire and climate change in southwestern South Island (45°S), New Zealand since the Last Glacial Maximum		Hain*	From the U-233/U-236 fingerprint towards an environmental tracer: Tracking down the sources of anthropogenic U-233
				Chamizo	Possibilites of the 1 MV AMS system at the Centro Nacional de Aceleradores (CNA, Seville, Spain) to analyze U-233 in natural samples
12:15 - 12:30		*Group Q&A*	**12:30 - 12:40**		*Group Q&A*
		BREAK 15 MINS			**BREAK 5 MINS**
12:45 - 14:00		**CENTRE FOR ACCELERATOR SCIENCE TOURS**			
13:30 - 14:00		Group Q&A			

	PLENARY	*(INVITED)	APPLICATION	TECHNICAL	POSTER-PLUS
FRIDAY 19th					
8:00 - 8:45	**Jane Willenbring**	**Forging Signatures: Climate’s Limited Role in Shaping and Changing the Earth’s Surface**			
	SESSION 34	**A-2: Water resource sustainability + Sharks**		**SESSION 35**	**A-8: Understanding the cosmos**
8:45 - 9:30			**8:45 - 9:45**		
	Ota	Long term monthly measurements on water dissolved inorganic radiocarbon to understand the seasonal radiocarbon changes in three of Fuji Five lakes, Japan		Feige*	26Al and 10Be in urban and Antarctic micrometeorites
	McDonough	Using radiocarbon and organic carbon characterisation techniques to identify the sources and degradation of dissolved organic matter in groundwater		Koll	Time-Resolved Interstellar Pu-244 and Fe-60 Profiles in a Be-10 Dated Ferromanganese Crust
	Fernandes	Tracking shark spatial mobility patterns using C-14 measurements on vertebrae growth bands		Pavetich	AMS measurements of Zr-93 for astrophysical and nuclear technology applications
9:20 - 9:30	*Group Q&A*				
	BREAK 15 MINS		**9:30 - 9:45**	*Group Q&A*	
	SESSION 36	**A-1: Earth’s dynamic climate**		**BREAK 15 MINS**	
9:45 - 10:40				**SESSION 37**	**A-8: Understanding the cosmos**
	Waterman*	Antarctic mosses reveal high resolution records of local microclimates	**10:00 - 10:55**		
	Goodwin	Using stable isotopes and radiocarbon to extract climate information from grey mangroves with non-annual growth rings		Vivo Vilches*	The performance of Pb-210 AMS radioassay of materials considered for the construction of ultra-low background experiments in Astroparticle Physics
	Patton	Evaluating dO-18 and dC-13 variations within a modern Biggenden Banded snail (Figuladra bayensis) shell using radiocarbon dating: application for past climate reconstruction		Slavkovska	Reaction cross sections 54Fe(n,?)55Fe and 35Cl(n,?)36Cl at keV neutron energies investigated by Accelerator Mass Spectrometry
10:30 - 10:40	*Group Q&A*			Rugel	Holmium-166m measurements with AMS for the ECHo-project
	SESSION 38	**T-6: Data quality and management**	**10:45 - 10:55**	*Group Q&A*	
10:45 - 11:30				**SESSION 39**	**T-5: Advances in sample preparation**
	Salazar	Rethinking the AMS Counting Statistics Theory to Include Overdispersion: Evidence of Non-Poisson distribution in the Radiocarbon Data	**11:00 - 11:35**		
	Tate	Status Report: A Decade of Traditional Radiocarbon Dating Applications by DirectAMS		López-Lora	Advances in actinides radiochemistry at the Centro Nacional de Aceleradores
	Kumar	A long-term performance assessment for AMS measurements at IUAC New Delhi		Tims	236U, 239+240Pu and 137Cs in Gaoyou lake sediment, East China
11:20 - 11:30	*Group Q&A*		**11:25 - 11:35**	*Group Q&A*	
	BREAK 15 MINS			**BREAK 10 MINS**	
	SESSION 40 IN MEMORIAM				
11:45 - 12:15					
	Kutschera	Ken Purser			
	Braucher	Didier Bourles			
	Kieser	Jack Cornett			
12:15 - 13:15	**CLOSING SESSION**				
12:15 - 12:30	**PRIZES, NIM-B INSTRUCTIONS**				
12:30 - 13:00	**AMS-16 BIDS**				
13:00 - 13:15	**THANKS AND FAREWELL**				

The Kimberley Rock Art Dating Project – a multi-system approach to dating Aboriginal rock art and landscape evolution in Australia’s remote Kimberley region

Professor Andrew Gleadow AO FAA[1]
[1]School of Geography, Earth and Atmospheric Sciences, University of Melbourne

Type of presentation: Plenary Presentation

The Kimberley contains one of the greatest concentrations of indigenous rock art in the world, with innumerable sites showing figurative and engraved art of extraordinary richness and beauty. These sites are of great cultural importance and enormous scientific interest, the significance of which to a broader narrative of human origins has been constrained by a lack of dating. The Kimberley Rock Art Dating Project, which began in 2014, is a major research collaboration involving scientists from five different institutions supported by the Australian Research Council and Rock Art Australia in partnership with Balanggarra Aboriginal Corporation and other groups. The project is focussed on developing a deep time framework in which to better understand the art and the people who have lived in this vast region from the Pleistocene to the present day.

Dating rock art in the ancient sandstones of the Kimberley is extremely challenging as the pigments used are mostly devoid of datable constituents. However, bracketing ages can be obtained by dating natural materials that have formed in association with various rock art styles. Four independent dating methods have now been successfully adapted to this purpose. These include cosmogenic radionuclide dating of rock falls and overall landscape evolution rates, radiocarbon dating of minute charcoal particles within mud wasp nests and oxalates in layered rock coatings. Optically stimulated luminescence dating has also been applied to large mud wasp nests, and uranium-series disequilibrium dating to surface mineral accretions. AMS methods have been central to the most successful of these approaches. The project is also providing insights into natural changes to rock surfaces that lead to degradation of the rock art over long periods of time. In this way the project will also help inform future strategies aimed at conservation and preservation of this important part of Australia’s indigenous heritage.

From snow pits to a million year ice-core: taking the measure of the planet from Antarctica

Joel Pedro[1,2]

[1]Australian Antarctic Division, Kingston TAS, Australia, [2]Australian Antarctic Program Partnership, Institute for Marine and Antarctic Studies, University of Tasmania

Type of presentation: Plenary Presentation

The Antarctic Ice Sheet stores a detailed record of climate and atmospheric composition that spans seasonal to orbital timescales. From snow pit studies of monthly variability in the fallout of radio-nuclides, to kilometre-deep ice core studies of the Quaternary glacial cycles, the Antarctic ice sheet is a place to take the measure of the planet.

A network of Antarctic ice cores now provides a continuous record of past climate and atmospheric composition that reaches back 800,000 years. These data demonstrate the close coupling between the carbon cycle and Earth's climate. In particular, providing the clearest known evidence that changes in atmospheric CO2 accompanied and contributed to driving the ice age cycles that dominated climate, sea level and ice sheet variability over this interval. The data also provide important context for current observations: CO2 levels are clearly higher and rising orders of magnitude faster than at any time in the ice core record.

The next frontier in ice core science is to recover a continuous ice core that reaches back well beyond a million years. This 'oldest ice challenge' is significant because between 800,000 years and ca. 1.2 million years there is a major change in the climate state—the Mid Pleistocene Transition (MPT)—during which glacial ice volume declines and the periodicity of glacial cycles quickens from 100,000 years to 41,000 years. Multiple nations have initiated projects to recover the oldest ice in order to test competing hypotheses on the climate, cryosphere and carbon cycle feedbacks involved in this transition. By sampling the MPT climate state and advancing our understanding of the processes involved, we also advance understanding of how these same feedbacks may respond in the future.

I will provide an overview of the Australian Antarctic Program's response to the oldest ice challenge—The Million Year Ice Core Project. Our drilling commences this summer at 'Little Dome C', where radar surveys and modelling indicate that undisturbed 1.5 million-year-old ice is likely present. Our project is collaborating with the European Beyond Oldest Ice Core (BE-OIC) project, who are also drilling in this region. Multiple cores are important to verify that results are not affected by flow disturbance or other artefacts.

Dramatic lockdown fossil fuel carbon dioxide decrease detected by citizen science supported radiocarbon observations

Jocelyn C. Turnbull[1,2,*], Lucas Gatti Domingues[1], Nikita Turton[1]
[1]*Rafter Radiocarbon Laboratory, GNS Science, Lower Hutt, New Zealand, 2CIRES, University of Colorado at Boulder, CO, USA*

Type of presentation: Plenary Presentation

The travel and work restrictions imposed by COVID-19 lockdowns resulted in dramatic changes in fossil fuel CO2 emissions around the world, most prominently in the transportation sector. Yet to date, most estimates of the change in emissions have relied on proxy data, and it is difficult to evaluate emission changes from CO2 measurements alone. Radiocarbon measurements are the gold standard for quantifying recently added fossil fuel CO2 into the local atmosphere, since fossil fuels are devoid of radiocarbon.

We used a novel citizen science campaign to collect grass samples from around New Zealand during the 2020 and 2021 COVID-19 lockdowns, when the highly restrictive lockdowns meant that scientists could not travel to collect samples in a more traditional way. We present the methodology of measuring radiocarbon content of the grass samples and calculating the recently added, local, fossil fuel CO2 mole fraction at the local and time period that the grass grew. We demonstrate that although there are some limitations and caveats of this method, it is possible to control for meteorological and other factors, and infer local fossil fuel CO2 emission changes from the grass data.

Our results from 17 sites in five cities around New Zealand demonstrate dramatic reductions in traffic emissions of 75 ± 3 % during the most severe lockdown restriction period. This is consistent with sparse local traffic count information, and a much larger decrease in local traffic emissions than reported in global aggregate estimates of COVID-19 emission changes. Our results demonstrate that despite nationally consistent rules on travel during lockdown, emission reductions varied by location, with inner city sites dominated by bus traffic showing smaller decreases in emissions than sites dominated by passenger vehicle traffic.

When Stars Attack! AMS Reveals Near-Earth Supernova Explosions

Brian Fields[1]
[1]*University of Illinois Urbana-Champaign, IL, USA*

Type of presentation: Plenary Presentation

Supernova explosions mark the deaths of the most massive stars, and are central actors in galaxy evolution, engines of particle acceleration, and cosmic forges for many of the elements essential for planets and life. Yet these awesome events take a sinister shade when they occur close to home, because an explosion very nearby would pose a grave threat to Earthlings. We will review how AMS measurements of radioisotopes produced by exploding stars can reveal nearby events in the geologic past, and we will highlight isotopes of interest. In particular, geological evidence for live 60Fe has recently been confirmed globally in multiple sites of deep-ocean material, in cosmic rays, and in lunar samples. We will review astrophysical 60Fe production sites and show that the data demand that at least one core-collapse supernova exploded near the Earth over the past few Myr, and explain how debris from the explosion was transported to the Earth as a “radioactive rain.” Deep-ocean and lunar 60Fe measurements thus represent a laboratory for supernova astrophysics, but also with implications for geology, astrobiology, and possibly terrestrial evolutionary biology–possibly including biological extinction events at the end of the Devonian period 360 Myr ago. Finally, we will discuss very recent detections of 244Pu contemporaneous to the 60Fe. The production site of this heaviest of actinides must be rare, thus these surprising data demand either unusual supernovae, or a near-Earth neutron-star merger of the kind recently seen in both light and gravitational radiation as a “kilonova” explosion. We will show that it is possible to distinguish these possibilities through future high-sensitivity AMS measurements of so-called “r-process” radioisotopes including 129I, 93Zr, 107Pd, 135Cs, 236U, 237Np, and 247Cm. These challenging measurements can open a unique new window on the production of the heavy elements, complementary to meteoritic, astronomical, and gravitational-wave measurements.

Forging Signatures: Climate's Limited Role in Shaping and Changing the Earth's Surface

Jane Willenbring[1] , Pedro Val[2]

[1]*Department of Geological Sciences, Stanford University, Stanford, California, US,* [2]*Department of Geology, Federal University of Ouro Preto, Ouro Preto, Brazil*

Type of presentation: Plenary Presentation

How denudation at the Earth's surface affects-and is affected by-climate remains a fundamental question in geoscience because of the influence of silicate weathering on climate and the potential role of climate in shaping landscapes. At the core of this question is a central hypothesis: if surface processes can erode the surface faster than tectonics can uplift topography over the timescale of mountain building, then highly efficient erosional processes which may be modulated by climate can affect mountain height and shape, and could enhance weathering product fluxes to oceans in the process.

In this talk, I'll first provide context for a different (null) hypothesis driven by the observation that the 10Be/9Be ratios in Neogene seawater have been roughly constant, indicating the stability of continental denudation globally. I'll then describe lessons learned and results from in situ-produced 10Be and meteoric 10Be by the cosmogenic nuclide community spanning the last decades. A synopsis of denudation rates and paleo-denudation rates derived from in situ-produced cosmogenic nuclides challenge the signatures of climate-driven geomorphic change in sediments and topography all around us. These past studies and new meteoric 10Be data hold some answers but also create critical, open questions about when and where climatic drivers take a backseat to tectonics.

The 5 MV cosmogenic rock star

Professor Didier Bourlès
26th April 1955 – 1st March 2021

Regis Braucher
CEREGE, CNRS, Collège de France, IRD, INRAE, Aix Marseille Univ., Aix en Provence, France,

Type of presentation: In Memoriam

Before becoming a geochronologist, Didier Bourlès studied physics, completing a doctorate in experimental physics (1981) in Paris. He was a pioneer in performing the first measurements of 10Be using a low-energy (< 3 MV) accelerator mass spectrometer, working with Grant Raisbeck and Françoise Yiou in the CSNSM group at the Tandetron in Gif-sur-Yvette.

In 1982, he became a CNRS researcher at CSNSM. After completing his habilitation in 1988, he spent 2 years as a postdoctoral fellow at the Massachusetts Institute of Technology, in John Edmond ' s Marine Geochemistry Lab. Collaborations initiated at MIT and at WHOI expanded his research horizons, using 10Be as a tool to explore systems ranging from submarine hydrothermal vents to tropical rivers and landscapes. Didier measured 10Be in all sorts of things, from sediments to ice cores, to corals, starfish and mussels. Didier's pioneering contributions during the eighties ranged from discovery of increased 10Be production during geomagnetic reversals and excursions to the development of sequential leaching experiments to extract the authigenic phase from marine sediments, which represents the 10Be/9Be ratio of soluble Be in the ocean at the time of deposition. Authigenic 10Be/9Be ratios remain an effective method for reconstructing paleo-denudation rates and variation in meteoric 10Be production from sedimentary records. In these articles, Didier demonstrated the potential of 10Be/9Be for dating, but he also suggested that the accepted 10Be half-life was likely about 7% too long, an assertion that was confirmed some 20 years. In 1994, Didier received the prestigious CNRS Bronze Medal and in 1998 he moved to CEREGE with a professorship at Aix-Marseille University.

Now in South of France, he was totally dedicated to his teaching duties but also to the development of the ASTER project at CEREGE, struggling with complex time-consuming French bureaucratic constraints, but ultimately establishing a research unit devoted to the measurement of cosmogenic radionuclides. In 2006, the National Cosmogenic Nuclide Laboratory (LN2C, composed of the ASTER AMS facility and the ASCHIM preparation laboratory) was launched, setting the state for innovative and fruitful collaborations worldwide. To increase accessibility to ASTER he worked to develop a French network of sample preparation laboratories. Didier never stopped improving analytical techniques and developing innovative applications of cosmogenic nuclides in geosciences; in 2018, to ensure that the ASTER AMS will remain a top-quality facility, he managed to convince the CNRS as well as local and regional institutions to fund a new magnet to improve 26Al detection limits.

Besides his passion for sciences, Didier had a contagious enthusiasm and always worked in a great and noisy atmosphere (Didier laugh was unique!). Didier's door was always opened and everybody was treated as his equal.

Since 1995, Didier rained a generation of students and scientist with ~20 PhD students, most of them being now involved in research and managing new cosmogenic preparation lab in France or applying "cosmo" in many environmental studies.

References

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Robert John “Jack” Cornett (1954 – 2017)

Robert John “Jack” Cornett
1954 – 2017

Liam Kieser
A. *E. Lalonde AMS Laboratory, University of Ottawa,*

Type of presentation: In Memoriam

Robert John “Jack” Cornett lived and breathed science in all his endeavours. He loved to question, discover, and explore both in the sciences and the outdoors, appropriate for his professional interests in Environmental Chemistry. He took these same attributes to every activity in which he participated, and there were many of these in which he excelled – squash, tennis, kayaking and canoeing, skiing both cross-country and downhill!

With a Ph.D. in Environmental Chemistry from McGill University (Montreal), in 1982, Jack joined the Environmental Research Group at the Chalk River Laboratories of Atomic Energy of Canada. By the early 1990s, he was collaborating with the physicists at the MP tandem there on the AMS analysis of 36Cl and 129I. In 1999, Jack moved to Ottawa to take the position of Director of the Radiation Protection Bureau at Health Canada, applying his radiochemical knowledge to many issues of public health and security. During this time as an Adjunct Professor at the Trent University School of the Environment (Peterborough, Canada), Jack began training students in radiochemical techniques and through his involvement with the Centre for Security Science, Jack championed several projects that advanced the technology and applications of AMS.

After two years as Director General of the Atlantic Science Laboratory of Defence Research and Development, Jack returned to Ottawa as a professor and Tier One Canada Research Chair at the University of Ottawa. There he supervised many graduate students, initiated many programs and served as the Scientific Chair for the organization of the 14th International AMS conference. Unfortunately, several months after that conference, an unusual heart condition took him from us – and we are still trying to catch up with all the programs he started.

Remembering Ken Purser

Ken Purser
1929 – 2018

Prof. Walter Kutschera
University of Vienna, Faculty of Physics, Isotope Physics, , Austria

Type of presentation: In Memoriam

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^{10}Be moraine chronologies from the Austrian Alps and their correlation with climatic events during the Late Glacial and the Holocene

Sandra B. Braumann[1,2], Joerg M. Schaefer[1], Alan J. Hidy[3], Stephanie Neuhuber[1], Markus Fiebig[1]

[1]BOKU University, Vienna, Austria, [2]Columbia University, Lamont-Doherty Earth Observatory, Geochemistry, Palisades, USA, [3]Center for Accelerator Mass Spectrometry, Lawrence Livermore National Laboratory, Livermore, USA

Theme: A-1: Earth's dynamic climate
Type of presentation: Oral Presentation

Late Glacial (LG) moraines in the European Alps, especially those deposited during the Younger Dryas (YD, c. 12.9-11.7 ka), are subject of numerous paleoclimatic studies. Nevertheless, there are still many periods before and after the YD that are controversial in terms of glacier extents and ice dynamics, e.g., the Bølling-Allerød (BA, ca. 14.6–12.9 ka) and the Early Holocene (EH, ca. 11.7–9 ka). At the beginning of the BA, glaciers in the Alps were much more extensive compared to the beginning of the EH. However, the same climatic pattern of rapid temperature increase occurred during both periods, and lead to fast deglaciation. For the period between ca. 12–10 ka, moraine chronologies from different places in the Alps, including data presented in this study, have shown that ice retreat and therefore warming was not steady, but was interrupted by centennial-scale cooling. In contrast, it is still unclear whether ice decay during the BA was fast enough to cause continuous glacier retreat to the highest cirques, or whether glaciers remained larger during that time. To contribute to this question, we mapped LG and EH moraine sequences in a glacial valley of the Austrian Alps, the Jamtal, and applied ^{10}Be surface exposure dating to selected landforms. Fifteen ^{10}Be exposure ages collected along five different moraines suggest the following glacier history: the last major glacier advance occurred during the Little Ice Age (LIA, ca. 1250-1850 CE). Just outboard the historical moraine are two lateral ridges that date to c. 11 ka and that are attributed to Preboreal Oscillation (ca. 11,150–11,300 ka). Boulders from a lateral moraine located c. 100 m higher relative to the EH moraines, indicate a much higher glacier hypsometry in the valley and yield ages that fall into the YD period. A moraine preserved c. 70 m above the YD moraine dates to c. 14.7–14 ka, which overlaps with a centennial-scale cold interval during the BA termed the Older Dryas. The location and age of this moraine indicate that the glacier in this valley was not vanished during the BA, but was even more extensive than during the YD.

Moraine formation ca. 14.7–14 ka is consistent with recent studies from Norway and Scotland (e.g. Ballantyne and Stone, 2012; Wittmeier et al., 2020) and may be correlated with periods of low $\delta^{18}O$ analyzed in Greenland ice cores, so-called "sub-events" (Rasmussen et al., 2014). We note that the moraine age coincides with the Antarctic Cold Reversal (ca. 14.7-12.9 ka) and hypothesize that cooling at that time may have occurred beyond the Southern Hemisphere. More geochronological data of LG moraine sequences are needed for testing this hypothesis.

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Ballantyne & Stone, 2012. Did large ice caps persist on low ground in north-west Scotland during the Lateglacial Interstade? JQS 27, 297-306.
Rasmussen et al., 2014. A stratigraphic framework for abrupt climatic changes during the Last Glacial period based on three synchronized Greenland ice-core records. QSR 106, 14-28.
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129I and 137Cs as dual tracers: From Japan Sea to the Fram Strait

Mr Unai Abascal-Ruiz[1], Dr José María López-Gutiérrez[1,2], Dr Wen Yu[4], Dr María Villa-Alfageme[1,5]

[1]Centro Nacional de Aceleradores (Universidad de Sevilla, CSIC, Junta de Andalucía) , Spain, [2]Dpto. Física Aplicada I, ETSIA, Universidad de Sevilla, Spain, [3]Dpto. Física Aplicada I, Escuela Politécnica Superior, Universidad de Sevilla, , Spain, [4]Laboratory of Marine Isotopic Technology & Environmental Risk Assessment. Third Institute of Oceanography, Xiamen, China, [5]Dpto. Física Aplicada II, ETSI Edificación, Universidad de Sevilla , Spain

Theme: A-1: Earth's dynamic climate
Type of presentation: Oral Presentation

During summer 2017 Chinese icebreaker RV Xuelong sailed from the Sea of Japan to Fukushima Dai-ichi nuclear power plant (FDNPP), Bering Strait and through the Artic Ocean to the Fram Strait and finally to the Nordic Seas. 129I (T1/2 = 15.7 × 106 years) and 137Cs (T1/2 = 30.17 years) were collected in 61 surface stations and 23 profiles in both North Pacific and Arctic Ocean. 129I was measured at the CNA in the University of Sevilla by AMS, and 137Cs results were presented in 1.

It is well known that most of the 129I discharged by the nuclear fuel reprocessing plants (NFRP) of Sellafield and La Hague travels through the North Sea, along the Norwegian coast into the Arctic. However, not many data are available on how this 129I is transported into the Pacific Ocean. In the Pacific, significant amounts of radioactive material, including 129I and 137Cs, have been released to the environment from Fukushima Dai-ichi nuclear power plant (FDNPP) after the tsunami occurred on March 11th, 2011.

Here we use 129I and 137Cs as dual tracers, together with the 129I/137Cs ratio. This study focuses on the Bering Strait, where the releases from FDNPP (Pacific) and European NFRP (Atlantic) converged. FDNPP releases were tracked through the Bering Strait into the Arctic Sea, while NFRP signal tracked the inflow of the Arctic in the Pacific Ocean.

In the Pacific, the concentrations of 129I in the vicinities of Fukushima were updated (9.68·106 - 4.83·107 at·kg-1) in 2017. 129I and 137Cs concentrations over the global fall out reference values were detected in the transect from the Sea of Japan to the Bering Strait. According to the end-member analysis, these values correspond mainly to FDNPP releases, but there is a small contribution of 129I from NFRP in the Bering Sea, associated to a small inflow of the Arctic into the Pacific Ocean. This is confirmed by the 129I/137Cs ratios of the stations inside the strait (2.07-41.07) and in Chukchi Sea and Beaufort Gyre (27.41-567.07).

As expected, 129I logically decreased from the Arctic to the North Pacific Oceans following the NFRP signal. The minimum 129I concentration in both oceans (5.96·105 at·kg-1) was found in the Bering Strait, at 1500 m. It corresponds to the lowest value associated to global fall-out and indicates the low influence of the NFRP in this Arctic region. A distinctive maximum of 137Cs (1 Bq·m-3) was found in the Chukchi and Beaufort Seas indicating the presence of FDNPP, emissions in the Artic Ocean. The 129I/137Cs ratio (2.07-41.07) in Bering Strait values lays among the FDNPP (3.88-26.44) and European NFRP (75.75-1330.1) signal. According to the water circulation time scale in the Pacific this 137Cs signal corresponded to the releases from Fukushima accident in 2011. The tracking of 137Cs and 129I/137Cs signals through the Arctic in the following years could be used to study the dynamics of the Pacific inflow into the Arctic.

1 Huang, D., Lin, J., Du, J. and Yu, T., Environ. Pollut., 256, 113386, 2020.

129I in rainwater along Argentina

Dr. Andres Arazi[1], Dr. Jorge Fernandez Niello[1], Prof. Leslie Keith Fifield[2], Dr. Michaela Froehlich[2], Dr. Stefan Pavetich[2], Dr. Steve Tims[2], Prof. Anton Wallner[2]
[1]Laboratorio Tandar, Comision Nacional de Energia Atomica, , Argentina, [2]Research School of Physics, Australian National University, Canberra, Australia

Theme: A-1: Earth’s dynamic climate
Type of presentation: Oral Presentation

Iodine-129 is a fission product of uranium and hence has a pre-anthropogenic background as well as also being produced and released by atmospheric nuclear weapon tests. However, the major contributors to its inventory are nuclear fuel reprocessing plants in the Northern Hemisphere. In this work we present concentration measurements of 127I and 129I in rainwater samples from several stations along Argentina (latitudes between 25° S and 55° S) for studying the distribution patterns and potential sources of 129I in the Southern Hemisphere. Measured 129I levels, clearly above natural background and nuclear weapon tests, can be explained by the injection of 129I discharged from nuclear fuel reprocessing plants in the Northern Hemisphere into the Southern Hemisphere.

14-CO in Glacial Ice from Law Dome, Antarctica as a Tracer of Changes in Atmospheric OH Abundance from 1870 AD to Present

Andrew Smith4, Dr Peter Neff[1], Vasilii Petrenko[2], David Etheridge[3], Edward Crosier[2], Benjamin Hmiel[2], David Thornton[3], Lenneke Jong[5], Ross Beaudette[6], Christina Harth[6], Ray Langenfelds[3], Blagoj Mitrevski[3], Mark Curran[5], Christo Buizert[7], Lee Murray[2], Cathy Trudinger[3], Michael Dyonisius[2], Jessica Ng[6], Jeff Severinghaus[6], Ray Weiss[6]

[1]University Of Minnesota, Saint Paul, United States, [2]University of Rochester, Rochester, United States, [3]CSIRO, Aspendale, Australia, [4]ANSTO, Kirrawee, Australia, [5]Australian Antarctic Division, Kingston, Australia, [6]Scripps Institution of Oceanography, La Jolla, United States, [7]Oregon State University, Corvallis, United States

Theme: A-1: Earth’s dynamic climate
Type of presentation: Poster

Hydroxyl, OH, is the main tropospheric oxidant and determines the lifetime of methane and most other trace gases in the atmosphere, thereby controlling the amount of greenhouse warming produced by these gases. Changes in OH concentration ([OH]) in response to large changes in reactive trace gas emissions (which may occur in the future) are uncertain. Measurements of 14C-containing carbon monoxide (14CO) and other tracers such as methyl chloroform over the last ≈25 years have been successfully used to monitor changes in average [OH], but there are no observational constraints on [OH] further back in time. Reconstructions of 14CO from ice cores could in principle provide such constraints but are complicated by in-situ production of 14CO by cosmic rays directly in the ice. Recent work in Antarctica and Greenland shows that this in-situ component would be relatively small and can be accurately corrected for at sites with very high snow accumulation rates. A joint US and Australian team sampled and measured firn air and ice at Law Dome, Antarctica (2018-19 season, site DE08-OH, 1.2 m a-1 ice-equivalent snow accumulation), to a maximum depth of 240 m. Trapped air was extracted from the ice using an on-site large-volume ice melting system. Preliminary comparisons of methane measured in the samples to existing ice core records and atmospheric measurements suggest ice core air sample ages spanning from the 1870s to the early 2000s. Firn-air samples from the snow surface to 81 m depth capture air from the early 2000s to present. Analyses of [CO] and halocarbons in the samples show a relatively low and stable procedural CO blank and demonstrate that the samples are unaffected by ambient air inclusion. 14CO analyses in these firn and ice core air samples have been successfully completed. Corrections for in-situ 14CO production, validated against direct atmospheric measurements for the more recent samples, have allowed us to develop a preliminary 14CO history. This history will be interpreted with the aid of the GEOS-Chem chemistry-transport model to place the first observational constraints on the variability of Southern Hemisphere [OH] since ≈1870 AD.

A data-model comparison on the glacial thinning history of Byrd Glacier, Antarctica

Dr Jamey Stutz[1], Dr Shaun Eaves[1,2], Ms Claudia Moore[1,2], Dr. Klaus Wilcken[3], Dr. Kevin Norton[2], Dr Dan Lowry[4]
[1]Antarctic Research Centre, Te Herenga Waka - Victoria University Of Wellington, , New Zealand, [2]School of Geography, Environment and Earth Sciences, Te Herenga Waka - Victoria University of Wellington, , New Zealand , [3]Australian Nuclear Science and Technology Organisation, , Australia, [4]GNS Science, Lower Hutt, New Zealand

Theme: A-1: Earth's dynamic climate
Type of presentation: Oral Presentation

Response of marine based sectors of the Antarctic Ice Sheet (AIS) to projected warming remains a significant uncertainty in sea level rise projections. The aim of this project is to provide understanding of past mechanisms and feedbacks of ice sheet change, and to reduce uncertainty in projections of future change. We extend the satellite record of ice sheet change by targeting strategic locations around the margins of the Ross Ice Shelf, which is responsible for buttressing large sectors of the marine-based West AIS. At these locations, glacial sediments deposited on nunataks adjacent to dynamic ice margins record the transient evolution of ice thickness throughout the Holocene period. Here, we focus on the Byrd Glacier, which drains 10% of the East AIS by area and contributes ~20% of the total mass of the Ross Ice Shelf. At Lonewolf Nunataks along the upper Byrd Glacier, our cosmogenic surface exposure ages constrain (i) past rates of ice thinning; (ii) total magnitudes of ice elevation change; and (iii) the absolute timing of ice discharge and thinning events in these sensitive regions. In this presentation, we will review the existing knowledge of Transantarctic Mountain outlet glaciers and present new data from our 2019-20 season along the upper Byrd Glaciers. Comparing our data to recent regional-scale ice sheet model simulations of the last deglaciation, we observe a distinct time lag between modelled thinning and our data-constrained thinning history. Our new data-model comparison will inform high-resolution, sector-scale numerical glacier model experiments, in which we seek to determine drivers of ice sheet thinning and retreat.

A rapid and precise method of establishing age model for coral skeletal radiocarbon to study surface oceanography using coupled X-ray photos and ICP-AES measurement

Miss Yuning Zeng[1], Professor Yusuke Yokoyama[2], Dr Shoko Hirabayashi[1], Dr Yosuke Miyairi[1], Dr Atsushi Suzuki[2], Dr Takahiro Aze[1]

[1]Atmosphere and Ocean Research Institute, The University of Tokyo, , Japan, [2]Geological Survey of Japan, National Institute of Advanced Industrial Science and Technology (AIST), Tsukuba, Japan

Theme: A-1: Earth's dynamic climate
Type of presentation: Oral Presentation

To discuss 14C variability in corals, a high-precision age model is a critical component of the study. In previous coral-based investigations, coral skeletal bands are often used to establish age model. Summer and winter in each year can be distinguished from the dark and light coral bands on X-ray photo, because dark bands often reflect high-density growth in summer and vice versa.
However, the age model determination based on only coral bands counting may not be able to provide satisfactory precision. For example, Bautista VII et al. (2016) established the age model by coral growth band counting, though it was later testified to shift ~7 years from the actual ages according to their following analysis using X-ray computed tomography (Bautista VII et al., 2021).
Here we propose a rapid and precise method, coupling coral growth band counting using X-ray photo and Sr/Ca measurement using Inductively coupled plasma atomic emission spectroscopy (ICP-AES) to establish precise and high-resolution age model in coral-based study. Sr/Ca is a reliable proxy for sea surface temperature with insensitivity to variations in coral skeletal growth rate (Fallon et al., 2003; Hirabayashi et al., 2013; Kawakubo et al., 2014), so summer and winter (the timing with the highest and lowest temperatures) can be distinguished by peaks in Sr/Ca variation even when using corals with low growth rates.

We used the Porites sp. collected from Kikai Island, Japan. The subsampling of coral powder used in this study was conducted continuously at 400 μm interval along the major growth axis (i.e. 25 samples per year in average). Since our coral was subsampled at a fixed interval, each sample was corresponding to the position on the X-ray photo according to the distance from the top, so each peak in Sr/Ca matched the corresponding year.
Coral Sr/Ca were measured using ICP-AES (iCAP 6300 series, Thermo Fisher Scientific). In ICP-AES measurement, a pre-test was firstly conducted with standard sample Jcp-1 (Okai et al., 2002), to select a proper condition for Sr/Ca measurement using 100-150 μg coral powder.

Sr/Ca values in 1947-1982, which were obtained from this study by ICP-AES, were well correlated with those in Kawakubo et al. (2017) measured by both ICP-MS and LA-ICP-MS (a method which includes more information and has higher accuracy) with a correlation coefficient of 0.9488 ($p < 0.001$, n=72).

Combination of coral growth band counting and Sr/Ca ICP-AES measurement could be a lower-cost and hi-precision alternative for establishing an age model in coral-based study.

Age Offsets between Radiocarbon Sample Materials, and Sedimentation Rate Based Holocene Sea-level Change Captured in Ocean Sediment Cores from Ube City, Yamaguchi Prefecture, Japan

Mr Evan Tam[1,2,3], Dr. Yusuke Yokoyama[1,2,4,5,6], Dr. Yukari Miyashita[3], Dr. Yosuke Miyairi[1]
[1]Atmosphere and Ocean Research Institute, University Of Tokyo, Kashiwa-shi, Japan, [2]Graduate Program on Environmental Sciences, Graduate School of Science, University of Tokyo, Meguro-ku, Japan, [3]Geological Survey of Japan, National Institute of Advanced Industrial Science and Technology, Tsukuba-shi, Japan, [4]Department of Earth and Planetary Science, Graduate School of Science, University of Tokyo, Bunkyo-ku, Japan, [5]Biogeochemistry Program, Japan Agency for Marine-Earth Science and Technology, Yokosuka-shi, Japan, [6]Research School of Physics, The Australian National University, Canberra, Australia

Theme: A-1: Earth's dynamic climate
Type of presentation: Poster

Radiocarbon dating can be applied to many sample materials, but ages achieved from varying sample types from a contemporaneous depositional setting can show age differences of up to several thousand years. The offset between these ages (here after called δage) is well documented, especially for bulk sediment ^{14}C dating (e.g. Raymond and Bauer, 2001), but limited studies have investigated the causes for down core variability in δage. Studies thus far have illustrated that changes in δage can shed light on processes that may alter depositional settings, such as changes in past climate, sea level variability (Ishiwa et al., 2021; Yokoyama et al., 2019), and intensity of monsoon events (Nakamura et al., 2016).

This study examined two shallow ocean sediment cores sourced from the Seto Inland Sea off the coast of Ube city, Yamaguchi prefecture, Japan, sampled within 50m of each other. Both cores were comprised of predominantly silt to silty clay, with limited sections of clay- and sand-based facies. The cores were subsampled for bulk sediment and shell specimens, which were utilized in radiocarbon dating and CNS chemical ratio analyses. Shell based ^{14}C ages from upper ~1.25m of both cores exhibited relatively rapid changes in age from early to late Holocene age (1.2 ka cal AD to 8.2 ka cal BP), whereas downcore sections displayed slower changes in ages from both shell based (7.1 ka cal BP to 8.3 ka cal BP) and bulk sediment based (8.8 ka cal BP to 10.4 ka cal BP) ^{14}C ages. δage values calculated between shell and bulk sediment based ^{14}C ages ranged between 0.7 ka to 2.2 ka, and C/N ratios varied from ~9 to 21.

Relatively slow changes in ^{14}C ages revealed slower sedimentation rates downcore in both cores, in contrast to increased sedimentation rates revealed by relatively rapid changes in upcore ^{14}C ages. Sedimentation rates and their corresponding ^{14}C ages align with sea-level rise and fall associated with the Holocene High Stand (from between ~7 ka to 4 ka; Yokoyama & Purcell, 2021). δage between shell and bulk sediment ^{14}C ages vary in downcore sections, with changes caused by relative increases in ^{14}C sediment ages. These shifts align with increased C/N ratio results, which combined with C/N ratio vs δ^{13}C analyses suggest that changes in δage correlate to periods of increased land-sourced sedimentation. Increases in upcore ages from shell based ^{14}C dating are interpreted as sediment reworking due to shallow ocean bottom erosion. In addition to locally constraining the relative timing of sea transgression and regression during the Holocene High Stand, this study highlights the need to understand changes in the depositional setting to accurately represent ages of deposition.

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AMS RADIOCARBON INVESTIGATION OF THE LARGE AFRICAN BAOBABS OF OUTAPI, NAMIBIA

Prof. Adrian Patrut[1,2], Dr. Roxana T. Patrut[3], Prof. Laszlo Rakosy[3], Dr. Demetra Rakosy[4], Dr. Ileana-Andreea Ratiu[1,2], Dr. Karl von Reden[5]
[1]Babeş-Bolyai University, Faculty of Chemstry and Chemical Engineering, Cluj-Napoca, Romania, [2]Babeş-Bolyai University, Raluca Ripan Institute for Research in Chemistry, Cluj-Napoca, Romania, [3]Babeş-Bolyai University, Faculty of Biology and Geology, Cluj-Napoca, Romania, [4]AG Spatial Interaction Centre, Centre for Integrative Biodiversity Research, Leipzig, Germany, [5]NOSAMS Facility, Woods Hole Oceanographic Institution, Woods Hole, U.S.A.

Theme: A-1: Earth’s dynamic climate
Type of presentation: Poster

The iconic African baobab (Adansonia digitata L.) is endemic to the arid savanna of mainland Africa. In 2005, we initiated an extended research project to clarify several controversial aspects regarding the age, growth and architecture of the African baobab.

Namibia is one of the African countries with the highest number of baobabs, which have different local abundance and distribution in its 12 regions. The highest number and density of baobabs can be found in the Omusati region (26,573 km2), in the north-central part of Namibia. According to a survey, the mean density of baobabs in Omusati is 6.7 trees/ha, which corresponds to a total number of 17.8 million individuals.

Our research in Omusati identified a number of 11 superlative baobabs, with a circumference of over 20 m, out of which 6 are located in and around Outapi, 3 in Onesi and one each in Tsandi and Okahao. The high density of baobabs and the high number of superlative individuals is also due to the large areas with sandy soils, rich in sodium and calcium.

Outapi, located close to the border with Angola, which is the capital of the Omusati region, hosts 6 superlative baobabs in an area of less than 10 km2. The most famous is the Ombalantu baobab, which is part of a national heritage site. Here we present the investigation and the radiocarbon dating results of the 4 largest and oldest baobabs of Outapi, i.e., the Big Baobab of Outapi (girth 31.01 m), the historic Amadhila baobab of Anamulenge (25.33 m), the historic Ombalantu baobab (24.60 m) and the Market Toilet tree (23.05 m). All these superlative baobabs exhibit a closed ring-shaped structure with a false cavity inside. They are all multi-stemmed, with several normal and false stems. The false stems, which emerge from an adjacent normal stem, act as anchors in sandy soils. Thus, the Big Baobab consists of 8 stems, the Amadhila baobab has 11 stems, the Market Toilet tree is composed of 4 stems and the Ombalantu baobab is constructed of 7 stems. These stems may have different ages and belong to several generations. The oldest dated sample had a radiocarbon date of 820 ± 17 BP corresponding to a calibrated age of 780 ± 10 calendar years. It was extracted from the damaged false cavity of the Big Baobab of Outapi. According to the radiocarbon results, the four baobabs exhibit ages between 600 and 850 years. Unfortunately, the historic Amadhila baobab of Anamulenge collapsed and died in April 2021.

Certain wood samples which are radiocarbon dated will be investigated by stable isotope analysis for a climate reconstruction in the area over the past 600-750 years.

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Anomalous tree-ring identification facilitated by AMS 14C analysis in subtropical and tropical Australian Araucariaceae samples enables development of a long-term, high-resolution climate reconstruction

Dr Heather Haines[1,2,3], Dr Jonathan Palmer[1,2,3], Dr Quan Hua[4], Dr Nathan English[5], Dr William Hiscock[3,6], Prof Chris Turney[1,2,3], Dr Christopher Marjo[3,6], Mrs Patricia Gadd[4], Dr Justine Kemp[7], Prof Jon Olley[7]

[1]School of Biological, Earth and Environmental Sciences. The University of New South Wales (UNSW), Sydney, Australia, [2]ARC Centre of Excellence for Australian Biodiversity and Heritage, UNSW Node, Sydney, Australia, [3]Earth and Sustainability Science Research Centre (ESSRC), The University of New South Wales, Sydney, Australia, [4]Australian Nuclear Sciences and Technology Organisation, Sydney, Australia, [5]School of Health, Medical and Applied Sciences & Flora, Fauna and Freshwater Research Group, Central Queensland University, Townsville, Australia, [6]Chronos 14Carbon-Cycle Facility, Mark Wainwright Analytical Centre, University of New South Wales, Sydney, Australia, [7]Australian Rivers Institute, Griffith University, Brisbane, Australia

Theme: A-1: Earth’s dynamic climate
Type of presentation: Oral Presentation

In Australia the majority of tropical and subtropical regions lack long-term instrumental climate records. Paleoclimate reconstructions from tree rings provide one alternative but very few dendrochronological investigations have so far been undertaken. Early assessments of mainland Australian tree species were discouraging due to the high prevalence of anomalous ring boundaries. Some species, however, were seen as more favourable than others including those in the Araucariaceae family which is common along the subtropical-tropical Australian east coast. These trees are longer lived than many other species in the region and contain growth rings known to be annual in nature and responsive to climatic conditions. There is however, a heavy prevalence of anomalous ring boundaries in species from this family which must be accounted for when dating these species.

Here we describe the tree-ring characteristics and growth response from two stands of Hoop pine (Araucaria cunninghamii) trees located in subtropical and tropical Queensland, Australia (regions known for experiencing extreme hydroclimatic events). Confirmation of annual growth driven by moisture sensitivity was determined using radius dendrometers on four trees in Lamington National Park (c. 28º S). Tree cores were collected from both the Lamington stand as well as a stand at Hidden Valley near Paluma, Queensland (c. 19º S). Ring-width assessment showed the presence of false, faint, locally absent, and wedging rings in both sites. Results of bomb-pulse radiocarbon dating of selected single tree rings demonstrated that trees from this species can fall into one of three categories: A – those with locally-absent rings around the circumference of the trees, B – those where false rings were observed, and C – those with many wedging and locally-absent rings. Only trees in the first two categories were able to be included in the master chronologies.

Traditional dendrochronological analysis with age validation by bomb-pulse radiocarbon dating allowed for a robust ring-width chronology from 1805-2014 CE to be developed for the Lamington National Park site. Growth-climate analysis of the master tree-ring chronology determined that the strongest environmental correlation was to wet season drought conditions. The strength of this response was compared to local and regional drought indices as well as to a long-term drought reconstruction. The combined analysis led to the development of a 200-year drought reconstruction for the region which shows influences from both the El Niño Southern Oscillation and the Interdecadal Pacific Oscillation.

Antarctic mosses reveal high resolution records of local microclimates

Dr Melinda Waterman[1], Dr Jessica Bramley-Alves[1], Dr Angelica Casanova-Katny[2], Prof Gustavo Zúñiga[3], Dr Quan Hua[4], Prof Sharon Robinson[1,5]
[1]School of Earth, Atmospheric & Life Sciences, University Of Wollongong, Wollongong, Australia, [2]Facultad de Recursos Naturales, Universidad Católica de Temuco, Temuco, Chile, [3]Facultad de Química y Biología, Universidad de Santiago de Chile, Santiago, Chile, [4]Australian Nuclear Science and Technology Organisation, Lucas Heights, Australia, [5]Securing Antarctica's Environmental Future, Global Challenges Program, University of Wollongong, Wollongong, Australia

Theme: A-1: Earth’s dynamic climate
Type of presentation: Invited Oral Presentation

Introduction
Life in Antarctica is living in the extreme. To survive there, life must be resilient to sub-zero temperatures, high levels of damaging ultraviolet and solar radiation, strong winds and water-limiting environments. In this harsh continent where water is locked up as snow and ice for most of the year, mosses are the dominant plant form. Like many living things, these small plants rely on liquid water to survive. The amount of potential water that is available to drive growth, distribution and survival of Antarctic flora is strongly influenced by the changing climate, especially temperature, precipitation and winds. However, meteorological climate records in most of the biologically diverse regions in Antarctica are sparse and limited to a few decades or less. In these areas, there is an increasing need for local climate proxies. We show that Antarctic moss species can be used as living proxies for local water availability through preserved stable carbon isotopes captured in cellulose.

Methods and Results
Using accelerator and isotope ratio mass spectrometry techniques, we obtained radiocarbon ages and $\delta^{13}C$ signatures along 26 cores of long shoots of moss collected from the Windmill Islands, East Antarctica and South Shetland Islands in the Maritime Antarctic. AMS radiocarbon results showed that these once living cores are up to 500 years old. The five moss species studied grew at different rates; the slowest species grew at less than 1 mm/year while the fastest achieved 8 mm/year. These moss cores provide a high-resolution record, at annual to decadal scales, of their microclimate. Our results also reveal that growth patterns of these Antarctic plants are dependent on local moisture environments. Trends in $\delta^{13}C$ signatures indicate microclimates in these regions are drying.

Conclusion
This work suggests that mosses have considerable potential as climate proxies by providing a temporal and spatial history of microclimate in Antarctica. Applying these measures will allow us to determine which terrestrial sites are at risk of the negative impacts of climate change in order to inform critical conservation efforts in a rapidly changing environment.

Anthropogenic iodine-129 depositions at the Sea of Japan and Pacific sides of the Japanese archipelago, during 2017-2018

Dr Tetsuya Matsunaka[1], Dr. Seiya Nagao[1], Dr. Shinya Ochiai[1], Mrs. Masumi Matsumura[2], Mr. Tsutomu Takahashi[2], Dr. Keisuke Sueki[2], Dr. Kimikazu Sasa[2]
[1]Kanazawa University, Kanazawa, Japan, [2]University of Tsukuba, Tsukuba, Japan

Theme: A-1: Earth’s dynamic climate
Type of presentation: Poster

The investigation of water dynamics change in the Sea of Japan caused by the recent global warming is essential for forecasting the response of ocean circulation with climate change. Anthropogenic ^{129}I (half life = 15.7 million years) produced from the thermal neutron fission, is dominated by release from nuclear fuel reprocessing plants in the Europe and supplied at the Sea of Japan via atmospheric deposition and surface runoff. The long-lived ^{129}I is expected as an oceanic tracer of surface and vertical circulations in the Sea of Japan. This study aimed to illuminate the atmospheric deposition flux of ^{129}I in the Sea of Japan through the monthly monitoring of ^{129}I in precipitation at Nomi located in middle area of the Sea of Japan side of the Japanese archipelago during 2017−2018, by contrasting with the ^{129}I depositions in Tsukuba (Pacific side) about 300 km ESE of Nomi and Hirosaki (Sea of Japan side) (Hasegawa et al., 2017) about 600 km NE of Nomi. Rainwater samples were collected at each station in Nomi and Tsukuba cities using a funnel placed on the buildings of Low Level Radioactivity Laboratory (Kanazawa University) and Tandem Accelerator Complex (University of Tsukuba) on a monthly basis from July 2017 to December 2018. After adding 1 mg of iodine carrier (Woodward old iodine) with an ^{129}I/^{127}I ratio of 1.5×10^{-14} to the filtered 200–500 ml rainwater sample, the iodine was isolated by solvent extraction with CCl_4. The purified iodide was precipitated as AgI by adding $AgNO_3$. The ^{129}I/^{127}I ratio of the AgI targets was measured using the AMS system at the Tandem Accelerator Complex, University of Tsukuba. A terminal voltage of 5 MV and a charge state of 5+ were chosen for acceleration and detection. The measurement ratios were normalized against the S-Purdue (Z94-0597) reference material, which had an ^{129}I/^{127}I ratio of 8.378×10^{-12} and was provided by the Purdue Rare Isotope Measurement Laboratory at Purdue University, USA. Stable iodine (^{127}I) in the rainwater was measured by an ICP–MS. The original ^{129}I/^{127}I ratios and ^{129}I concentrations in the rainwater were calculated using ^{129}I/^{127}I ratio from AMS and ^{127}I concentration from ICP-MS. The overall dissolved ^{129}I concentrations in rainwater varied from 18.3 to 326 nBq/L (mean 129 nBq/L) at Nomi and from 32.7 to 223 nBq/L (mean 134 nBq/L) at Tsukuba. Mean monthly deposition fluxes of ^{129}I during 2017–2018 were in the range 0.144–1.73 µBq/m^2/day at two sites (mean 0.834 µBq/m^2/day at Nomi and 0.488 µBq/m^2/day at Tsukuba), about one-third to one-half of the mean values observed at Hirosaki (1.28 µBq/m^2/day) (Hasegawa et al., 2017). Clear seasonal variations of ^{129}I depositions were found at the Sea of Japan side (Nomi and Hirosaki), with the higher levels being recorded in winter (November to February). These latitude and seasonal dependences revealed that the deposited ^{129}I at the Sea of Japan side was mainly transported by the prevailing northwesterly winter monsoon from higher latitude area of the North Hemisphere.

Antiphase dynamics between cold-based glaciers in the Dry Valleys region and ice extent in the Ross Sea, Antarctica during MIS 5

Mr Jacob Anderson[1], Dr David Fink[2], Dr Toshi Fujioka[3], Professor Gary Wilson[4], Dr Klaus Wilcken[2], Dr Andrey Abramov[5], Dr Nikita Demidov[6]

[1]University Of Otago, Dunedin, New Zealand, [2]Australian Nuclear Science & Technology Organisation, Lucas Heights, Australia, [3]Centro Nacional de Investigación sobre la Evolución Humana, Burgos, Spain, [4]University of Otago & GNS Science, Wellington, New Zealand, [5]Institute of Physicochemical and Biological Problems of Soil Science, Pushchino, Russia, [6]Arctic and Antarctic Research Institute, St. Petersburg, Russia

Theme: A-1: Earth's dynamic climate
Type of presentation: Oral Presentation

During interglacial conditions in Marine Isotope Stage (MIS) 5, outlet and alpine glaciers in the Dry Valleys region, Antarctica, appear to have advanced in response to increased open ocean in the Ross Sea. However, the timing and extent of antiphase behaviour between these glaciers and ice in the Ross Sea is poorly resolved. Here, we report the antiphase behaviour through retreat of a peripheral lobe of Taylor Glacier in Pearse Valley, an area that was glaciated during MIS 5. First, we measured cosmogenic ^{10}Be and ^{26}Al in 3 granite cobbles from thin, patchy drift (Taylor 2 Drift) in Pearse Valley to constrain the timing of retreat of Taylor Glacier. Assuming simple continuous exposure, our exposure ages suggest Taylor Glacier had partially retreated from Pearse Valley no later than 71 ka. Timing of retreat after 71 ka, until the Last Glacial Maximum (LGM), when Taylor Glacier was at a minimum position, remains unresolved. Second, we measured paired ^{10}Be and ^{26}Al depth profiles to ~3 metres in permafrost in proximity to the cobble sampling sites at Pearse Valley and neighbouring Lower Wright Valley. The ^{10}Be and ^{26}Al depth profiles from both sites show no clear exponential attenuation trend which suggest that both deposits are too young for the most recent exposure (≥71 ka for Pearse Valley and LGM – early Holocene for Lower Wright Valley) to alter the profile, and measured nuclide concentrations are essentially dominated by inheritance. Using ^{10}Be depth profile data from Pearse Valley we calculate a maximum age of ~100 ka for surface layer permafrost formation. The cobble exposure-ages and depth profile constrain surface permafrost formation in Pearse Valley to between ~71 – 102 ka, following the retreat of the Taylor Glacier from Pearse Valley. These new data are consistent with geochronology from central Taylor Valley, and suggest changes in moisture delivery over Taylor Dome during MIS 5c and 5a appear to be associated with the extent of the Ross Ice Shelf and sea ice in the Ross Sea. Our ^{26}Al/^{10}Be concentration ratios for all depth profile samples also exhibit relatively constant and suppressed ratios of 4.3 and 5.2 for Pearse and Wright valleys, respectively, indicating that prior to surface permafrost formation, these sediments experienced a significant complex prior exposure history. Assuming a simple burial scenario, the observed ^{26}Al/^{10}Be ratios are equivalent to a total exposure-burial history of ~1.2 Ma, somewhat consistent with the Packard dune field in Victoria Valley. Our new data corroborate antiphase behaviour between outlet and alpine glaciers in the Dry Valleys region and ice extent in the Ross Sea, and imply a causal mechanism with cold-based glacier advance and retreat being controlled by moisture availability and drying, respectively due to ice retreat and expansion in the Ross Sea.

Establishing robust chronologies for two young stalagmites from the tropical south Pacific using radiocarbon

Mr Mohammadali Faraji[1], Dr Quan Hua[2], Dr Andrea Borsato[1], Prof Silvia Frisia[1]

[1] *The University Of Newcstle,* [2]*ANSTO*

Theme: A-1: Earth's dynamic climate
Type of presentation: Poster

In the last couple of decades, speleothems have provided terrestrial paleoclimate reconstructions covering almost all latitudes and a with temporal resolutions varying from seasonal to millennial scales. The most important property of speleothems is their capability to be dated via radiometric methods. The most commonly used dating method is based on U-series disequilibrium. When this method is not applicable, for example, because of multiple sources of 230Th, robust chronologies can be acquired via integrating the counting of annual physical and chemical laminae in two-dimensional maps. This approach may also entail uncertainties related to the exact age of the youngest parts of the speleothem, commonly assumed to be actively growing at the time of removal. An alternative/complementary method for obtaining accurate age models and/or further constrain the age of speleothems that grew in the last circa 100 years is using the radiocarbon "bomb-pulse". However, when comparing the radiocarbon age of speleothems with other contemporaneous terrestrial samples which absorb carbon from atmospheric CO2, speleothems show older than expected ages. That is due to the contribution of 'radioactively dead' carbon, known as Dead Carbon Fraction (DCF), derived from 14C-depleted material from bedrock and aged soil organic matter. Yet, a thorough understanding of DCF variations in speleothems potentially generates reliable chronologies.

Relatively young Tropical Pacific stalagmites are commonly difficult to date with the U-series, and radiocarbon is, potentially, the best dating method. We studied stalagmites Pu17 and Nu16, retrieved from Pouatea and Nurau caves in Atiu, the second largest island from the southern group of the Cook Islands in the South Pacific. Both were studied with the aim to construct robust radiocarbon chronologies and attain information about the hydrogeology of the caves. These caves are expected to provide an excellent opportunity for radiocarbon dating because the rock burden above caves is thin (4 to 8 m), characterized by high porosity, and a limited and patchy soil cover is. This ensures rapid transmission of surface climate parameters into the cave. Rapid transmission of rain signal into the cave reduces the interaction between rainwater and bedrock, thus, minimizing the contribution of bedrock-derived dead carbon, which is crucial for constructing accurate and robust chronologies.

Forty samples from the top portions of Pu17 and Nu16 were analysed for 14C using the VEGA AMS Facility at ANSTO. By modelling the soil carbon pools, we evaluated the age distribution of soil carbon above the cave. Results indicate a young epikarst carbon pool (younger than 22 years) for both Pu17 and Nu16, which translates into less than 4% DCF contribution. Radiocarbon chronologies of the two stalagmites show a sharp and relatively early bomb peak at ca. 1970 CE. The radiocarbon bomb-pulse allows to anchor chemical lamina counting and obtain accurate chronologies for modern speleothem and thus obtain robust paleorainfall records for the climate-vulnerable south Pacific Island communities.

Evaluating δ18O and δ13C variations within a modern Biggenden Banded snail (Figuladra bayensis) shell using radiocarbon dating: application for past climate reconstruction

Mr Nicholas Patton[1,2], Professor James Shulmeister[1,2], Professor Melanie Leng[3,4], Professor Mathew Jones[4], Dr. Quan Hua[5], Dr. Catherine Hughes[5]
[1]University Of Canterbury, Christchurch, New Zealand, [2]University of Queensland, St. Lucia, Australia, [3]British Geological Survey (BGS), Keyworth, England, [4]University of Nottingham, Nottingham, England, [5]Australian Nuclear Science and Technology Organisation (ANSTO), Lucas Heights, Australia

Theme: A-1: Earth’s dynamic climate
Type of presentation: Oral Presentation

Gastropods are utilized to infer paleoclimate variability due to the preservation and incorporation of stable isotopes (δ18O and δ13C) in their aragonite shells. Analyses along the growth axis of larger gastropods have been suggested to contain high-resolution records of local seasonal climate variability and the organism’s biological life cycle. Here a Figuladra bayensis (Biggenden Banded snail) shell was collected shortly after death from Coalstoun Lakes National Park, Queensland, Australia. A total of 200 samples were collected for δ18O and δ13C analyses and an additional 8 radiocarbon dating samples were collected along the growth axis from the apex to the aperture. Results from our work indicates that the Biggenden Banded snail lived ~4.4 years, with evidence of two aestivation (dormant stage) periods during the dry, cool winters. As a result, its growth rate was episodic with the highest rates of ~90 mm/yr occurring shortly after large rain events. The δ18O and δ13C variation in the shell is closely related to total rainfall, diet and physiological changes. To our knowledge this is the highest resolution isotopic and radiocarbon dated study on a modern terrestrial snail, allowing the nuances of the stable isotope record to be more clearly interpreted and therefore used as a palaeoenvironmental proxy.

Evaluation of uranium-thorium dating and radiocarbon measurement potentials using marine mollusks

Dr Shoko Hirabayashi[1], Dr Takahiro Aze[1], Dr Yosuke Miyairi[1], Dr Hironobu Kan[2], Dr Yusuke Yokoyama[1]
[1]Atmosphere and Ocean Research Institute, The University of Tokyo, Kashiwa, Japan, [2]Research Center for Coastal Seafloor, Kyushu University, Fukuoka, Japan

Theme: A-1: Earth's dynamic climate
Type of presentation: Poster

Mollusks incorporate radiocarbon and uranium into their skeleton. Radiocarbon dating of mollusks are widely used in paleoclimatology and archeology, while uranium-thorium (U/Th) dating is generally difficult to provide reliable age using mollusks. However, several recent studies suggested that the U/Th dating potential using marine bivalves in Mediterranean Sea (Rowe et al., 2015), Caspian Sea (Arslanov et al., 2002) and Korea (Cheong et al., 2006). These studies have investigated limited mollusks species and regions. Therefore, the uranium uptake process into mollusks shell and the criteria of choosing the mollusks species for U/Th dating have not been understood.

In this study, we investigated the distribution of radiocarbon and uranium in mollusks, including the calcified opercula of Turbo sazae Fukuda, Turbo marmoratus and Tridacnina sp. collected from Kume Island, Ryukyu region and Chiba, Japan. We measured high-resolution radiocarbon and uranium concentration using single stage AMS (Yokoyama et al., 2019) and laser-ablation ICP-MS in Atmosphere and Ocean research Institute, The University of Tokyo, respectively. Our results showed that uranium in opercula of modern Turbo sazae Fukuda and Tridacnina sp. were unevenly distributed. The uranium concentrated in the center of opercula of Turbo sazae Fukuda and in the hinge and outer layer of Tridacnina sp. Those concentration were 1000 times-less than that in coral skeletons, which are widely used for U/Th dating. The uranium in the calcified opercula of Holocene (1 ka BP) Turbo marmoratus was also unevenly distributed but concentrated area in the opercula was different from that of the modern samples, which suggested exchange uranium after they were deposited. We will also discuss the possibility of U/Th dating and reconstruction of seawater mass mixing based on radiocarbon measurement using mollusks.

Evolution of the Great Barrier Reef Halimeda carbonate factory in response to Holocene environmental changes, determined from radiocarbon and nitrogen isotope measurements

Dr Mardi McNeil[1], Dr Quan Hua[2], Dr Dirk Erler[3], Dr Luke Nothdurft[1], Dr Jody Webster[4], Dr Patrick Moss[5]

[1]Queensland University Of Technology, Brisbane, Australia, [2]Australian Nuclear Science and Technology Organisation, Lucas Heights, Australia, [3]Southern Cross University, Lismore, Australia, [4]The University of Sydney, Sydney, Australia, [5]The University of Queensland, Brisbane, Australia

Theme: A-1: Earth's dynamic climate
Type of presentation: Oral Presentation

The inter-reef Halimeda algal bioherms of the northern Great Barrier Reef (GBR) have accumulated up to 25 m of positive relief and up to four times greater volume of calcium carbonate than the nearby coral reefs during the Holocene. Covering > 6000 km² on the continental shelf, the Halimeda bioherms represent a significant contribution to the development of the northeast Australian neritic carbonate factory and sedimentary archive of post-glacial environmental changes. However, the geochronological record of initiation and development of the Halimeda bioherm carbonate factory throughout the Holocene was poorly constrained and based on very few radiocarbon dates, considering their vast area. Additionally, the main source of nitrogen (N) fuelling the productivity of these biogenic structures had not been traced geochemically, and there was no understanding of any temporal variation.

A total of 63 samples of calcium carbonate Halimeda and foraminifera grains, mollusc shells, and bulk soil were dated by ^{14}C AMS using the VEGA facility at the ANSTO Centre for Accelerator Science. Changes in the terrestrial vegetation community were determined from palynological analysis at the University of Queensland. Nitrogen isotopes were measured on a subset of 27 Halimeda samples using isotope ratio mass spectrometry (IRMS) at the Centre for Coastal Biogeochemistry at Southern Cross University. Using the persulfate-denitrifier method previously developed for foraminifera and coral skeletal material, nitrogen bound within the Halimeda skeletal organic material (SOM) was targeted. This allowed for fossil samples down-core to be analysed, thus providing a 5000-year record of Halimeda δ^{15}N-SOM.

A temporal sequence of facies transitions that record terrestrial and marine environmental changes over a full sea level cycle from the Last Interglacial, to Last Glacial Maximum (LGM) and deglacial, to transgressive estuarine sediments and shallow marine carbonates was reconstructed. Halimeda growth and carbonate deposition had established by 11,143 (+237/-277) cal. yr BP, just ~450 years after the marine transgression. The Halimeda carbonate factory was productive at least 2100 years earlier than Holocene coral reefs in the study area. Our results provide the first direct in-situ measurements of Halimeda bioherm ages from at or near the Holocene/Pleistocene boundary, recording the timing of bioherm initiation in response to post-glacial sea level rise.

The average Halimeda skeletal δ^{15}N-SOM was 6.28 ± 0.26 ‰, consistent with δ^{15}N-NO_3^- from western tropical South Pacific (WTSP) thermocline waters, geochemically validating shelf-break upwelling of an oceanic N source. From 5000 to 2000 cal. yr BP, Halimeda δ^{15}N-SOM decreased by 1-2 ‰, reaching a minima of 5.5 ‰ that persisted for almost 1000 years. The Halimeda δ^{15}N-SOM variation reflects changes in regional climate and intensified El Niño activity and is consistent with other regional climate proxy records at this time. Thus, the inter-reef Halimeda algal bioherms of the GBR are an important carbonate ecosystem that record a >10,000-year near-continuous record of northeast Australian Holocene oceanographic and environmental changes in response to sea level and climatic drivers, potentially filling spatial and temporal gaps not covered by coral and other proxies.

Holocene climate, fire and ecosystem change on Kangaroo Island, South Australia

Miss Lucinda Duxbury[1,2,3], Jonathan Tyler[1,3], Linda Armbrecht[2], Alexander Francke[1], Haidee Cadd[4,8], W. Boone Law[5,6], Atun Zawadzki[7], David Child[7], Patricia Gadd[7], Geraldine Jacobsen[7], John Tibby[7], Kieren Mitchell[2,3]

[1]Department of Earth Sciences, The University Of Adelaide, North Terrace, Adelaide, [2]Australian Centre for Ancient DNA, The University of Adelaide, North Terrace, Adelaide, [3]ARC Centre of Excellence for Australian Biodiversity and Heritage (CABAH), The University of Adelaide, North Terrace, Adelaide, Australia, [4]ARC Centre of Excellence for Australian Biodiversity and Heritage (CABAH), University of Wollongong, Wollongong, Australia, [5]Department of Geography, Environment and Population, University of Adelaide, North Terrace, Adelaide, Australia, [6]School of Biological Sciences, University of Adelaide, North Terrace, Adelaide, Australia, [7]Australian Nuclear Science and Technology Organisation, Sydney, Australia, [8]Chronos 14Carbon-Cycle Facility, Mark Wainwright Analytical Centre, University of New South Wales, Sydney, Australia

Theme: A-1: Earth's dynamic climate
Type of presentation: Oral Presentation

Introduction
Fire has long been a familiar and important part of Australian landscapes. However, anthropogenic climate change has heralded major shifts in fire regimes, negatively impacting ecosystems. These effects are expected to worsen in coming years, but there remain difficulties with projecting fire regime trajectories and their environmental impacts, in part due to a lack of data on centennial to millennial timescales. Uncertainties remain concerning the independent effects of climate and human impact on bushfires, and the long term impacts of fire on both terrestrial and aquatic ecosystems.

Aims
This study aims to address these uncertainties by returning to Lashmars Lagoon, Kangaroo Island, a site of pioneering palaeoenvironmental research in South Australia that has been overlooked in recent decades. Kangaroo Island presents a fascinating case study, due to the putative abandonment of the island by ancient Aboriginal populations ~ 2,500 years ago. As such, it represents a unique opportunity to study the impact of cessation of Aboriginal management practices on ecosystems prior to European invasion.

Methods
We collected a ~ 7.5 metre long sediment core from Lashmars Lagoon, which we expected, from the work of previous studies, to span the past 5,000 years. We are combining multiple traditional and novel palaeoecological and geochemical proxies to infer both fire, catchment and ecosystem variability, augmented by an age model based on Pb-210, Pu isotopic profiling and C-14 dating.

Results
Our preliminary age model determined our core to span the past ~ 7,000 years, an adjustment to previous estimates. Our model is based on the radiocarbon dating of 6 plant macrofossils, 2 pollen samples and 1 shell. The pollen dates concur well with the plant macrofossils. The shell demonstrates an older age than the other samples from a similar horizon, a 'reservoir effect' that is expected from the integration of older carbon into the sample. The model also integrates 15 Pb-210 dates from the uppermost 30 cm, verified by the establishment of a nuclear bomb testing peak from Pu isotopic profiling. The broad peak detected in the Pu profile is also worthwhile of mention. Further interrogation of this phenomenon could be useful to infer certain processes the uppermost sediments, such as bioturbation, lateral leaching of Pu in the sediment or disturbance from the coring process. Overall, the age model indicates a constant rate of sedimentation approximately 1 mm/yr across the entire length of the, a somewhat surprising result given the considerable variation in sedimentology.

Conclusions
The development of a robust age model is integral to the interpretation of environmental, geochemical and climatic proxies at Lashmars Lagoon, South Australia. Importantly, the better constraint of our age model improves certainty around the timing of the human exodus from Kangaroo Island and the resultant discontinuation of Indigenous fire management.

Investigation of OC and EC fractions of aerosol samples in Sydney area by radiocarbon analysis

Dr Bin Yang[1], Dr Melita Keywood[2], Dr Fabienne Reisen[2], Dr A. M. Smith[1], Dr Vladimir Levchenko[1]
[1]Australian Nuclear Science & Technology Organisation, Lucas Heights, Australia, [2]CSIRO Oceans and Atmosphere, Aspendale, Australia

Theme: A-1: Earth's dynamic climate
Type of presentation: Poster-Plus Presentation

Secondary Organic Aerosols (SOA) can be a major component of atmospheric PM.2.5 pollution, emitted from natural and anthropogenic sources. SOA is formed by the oxidation of volatile organic compounds (VOC) which have biogenic and anthropogenic sources. Measurement of the radiocarbon activity of SOA allows to discriminate between these sources, as biogenic sources have a near-modern activity and anthropogenic sources are generally depleted in ^{14} C. As part of the Sydney Particle Study [1,2], aerosol samples were collected on quartz filters using a high volume sampler fitted with a PM2.5 size selective inlet during the summer months of 2011 and autumn months of 2012. In order to estimate the apportionment of the SOA sources, we measured the radiocarbon content of organic carbon (OC) and elemental carbon (EC) fractions, using the novel method described below.

We combusted strips (90 × 35 mm) of the quartz filters strip inside a quartz tube filled with high purity oxygen at ~300 mbar at 375°C to collect the OC fraction and then at 780°C to collect the EC fraction. CO_2 gas produced during each combustion was collected in a cold trap at -170°C, volumetrically measured and transferred into a Micro Conventional Furnaces (MCF) [3] for graphitisation. This method was shown to be reproducible for EC and OC filter densities from the same filter. We processed 25 air filters in this way to produce 50 samples for Accelerator Mass Spectroscopy (AMS) measurement with an average of 58 µg carbon (range 10 µg to 220 µg). Our densities compared well with OC and EC densities obtained using a standard thermal desorption method at CSIRO [2].

We combined the measured radiocarbon activity with sophisticated chemical transport modelling, using the EC tracer method [4] to determine SOA. Levoglucosan was used as a tracer to allow for biomass burning events. Our results suggested that i) biogenic SOA comprised around 50% of the SOA in summer and autumn, ii) higher radiocarbon activities for OC are associated with higher SOA concentrations, supporting the model theory [1] that that biogenic VOCs are an important contributor to SOA in the Sydney airshed, iii) the formation of SOA involves both anthropogenic and biogenic VOC, iv) the lowest EC and OC radiocarbon activities were for summer mornings, indicating high fossil fuel carbon (i.e. vehicle emissions). Afternoons in summer and autumn displayed the highest ratios, indicating low fossil fuel carbon.

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Late Pleistocene fossil flora of Henty Bridge, Tasmania, and their implications for glacial climate reconstructions

Ms Kia Matley[1], Dr Quan Hua[2], Dr Kale Sniderman[3], Associate Professor Andrew Drinnan[1]

[1]University Of Melbourne School of BioSciences , Parkville , Australia, [2]Australian Nuclear Science and Technology Organisation , Lucas Heights , Australia , [3]University of Melbourne School of Earth Sciences , Parkville , Australia

Theme: A-1: Earth's dynamic climate
Type of presentation: Poster-Plus Presentation

The climatic extremes of the last glacial period (approx.100,000 years ago to 12,000 years ago) and in particular the last glacial maximum (LGM, approximately 20,000 years ago) are thought to have exerted a significant influence over the current distribution of mesic forest taxa in southeast Australia. However, limited taxonomic resolution afforded by fossil pollen has meant that the nature of glacial biotic communities remains poorly understood.

In southeast Australia, pollen-based palaeoclimate reconstructions of the LGM suggest a mostly treeless, 'glacial steppe' environment characterised by cold, dry, windy conditions. But phylogeographic evidence suggests that forest taxa persisted widely in southeast Australia, in multiple, disjunct, local refugia. Resolving this apparent conflict is the focus of our study.

Pollen is ubiquitous and virtually indestructible, which makes it remarkably useful for palaeoenvironmental reconstruction, particularly in lacustrine or cave environments where sediments accumulate over timescales of millennia. But despite its widespread use in palaeoecology, pollen-based reconstructions are limited by coarse taxonomic resolution. Pollen of narrow-range species that might be used as ecological indicators, for example, can be difficult or impossible to distinguish from the pollen of geographically widespread, and therefore less informative, taxa.

Plant macrofossils, by contrast, are routinely identified to species level, and a majority of the species that were present at the LGM still exist today. These improvements to the taxonomic precision of palaeobotanical records allow for the use of bioclimatic niche models to quantitatively reconstruct palaeoclimate. Using our understanding of fossil species' modern-day climatic niche, we hope to gain a more nuanced reconstruction of the climate at the time of their deposition.

We sampled for plant macrofossils at a known LGM palynological site in Henty Bridge, Tasmania (Colhoun, 1985). Using the AMS radiocarbon dating facility at ANSTO, we produced a series of dates which indicate that these fossils were deposited at least 10,000 years prior to the LGM, a significant change to what was previously known of the site. Bioclimatic niche modelling of these fossil species suggests that, in the period preceding the LGM, the climate of western Tasmania was cooler than present by at least 2°C. Moreover, our data show clear evidence of species migration in response to changes in climate; some of the species in the Henty Bridge assemblage are today confined to higher elevations.

These results contribute to the globally significant debate around the influence of the Pleistocene climate over the generation and maintenance of terrestrial biodiversity, and also to the increasingly urgent discussion of the degree of sensitivity of Australian plant taxa to changing climate in general.

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Law Dome 14CH4 measurements confirm revised fossil methane emissions estimates

Dr David Etheridge[1,2], Dr Vasilii Petrenko[3], Dr Andrew Smith[4], Dr Peter Neff[3,5], Dr Benjamin Hmiel[6], Dr Cathy Trudinger[1], Dr Edward Crosier[3], David Thornton[1,2], Dr Ray Langenfelds[1], Dr Lenneke Jong[2,7], Dr Christina Harth[8], Dr Blagoj Mitrevski[1], Dr Christo Buizert[9], Dr Bin Yang[4], Professor Ray Weiss[10], Professor Jeffrey Severinghaus[8]

[1]Climate Science Centre, CSIRO Oceans and Atmosphere, Aspendale, Australia, [2]Australian Antarctic Program Partnership, Institute for Marine and Antarctic Studies, University of Tasmania , Hobart, Australia,

[3]University of Rochester, Department of Earth and Environmental Sciences, Rochester, USA, [4]Australian Nuclear Science and Technology Organisation (ANSTO), Kirrawee, Australia, [5]University of Minnesota Twin Cities, Department of Soil, Water, and Climate, Minneapolis, USA, [6]Environmental Defense Fund, New York, USA, [7]Australian Antarctic Division, Kingston, Australia, [8]University of California San Diego, Scripps Institution of Oceanography, La Jolla, USA, [9]Oregon State University, College of Earth, Ocean, and Atmospheric Sciences, Corvallis, USA, [10]Univ California San Diego, La Jolla, USA

Theme: A-1: Earth’s dynamic climate
Type of presentation: Invited Oral Presentation

Methane is a powerful greenhouse gas and has significant roles in the chemistry of the atmosphere. Its global concentration has risen by 240 % since 1750 AD. Atmospheric $^{14}CH_4$ is an independent and potentially unambiguous tracer of fossil CH_4 emissions from anthropogenic and natural geologic sources, however, ^{14}C from nuclear weapons tests and $^{14}CH_4$ from nuclear power plants complicate its interpretation after the late 1950s. Measurements before then rely on air extracted from polar ice and firn. Hmiel et al. (Nature, 2020) measured $^{14}CH_4$ in air extracted from firn and ice in Greenland and Antarctica and found that the natural global fossil CH_4 source is very small (<6 Tg CH_4 /yr). This is inconsistent with bottom-up geological CH_4 emissions estimates (40-60 Tg CH_4 /yr) and implies an upward revision of anthropogenic fossil source emissions, emphasising the need for further measurements.

We present new $^{14}CH_4$ measurements of air extracted from the high accumulation site DE08-OH on the Law Dome ice sheet in 2018/19, including firn air to 81 m depth and large ice samples combined from parallel ice cores to 240 m. Measurements of trace gases confirm that the samples were uncontaminated and only minor corrections are required for sample processing. The correction for cosmogenic in-situ production of $^{14}CH_4$ is very small at DE08-OH due to its high accumulation rate and relatively low elevation. The new $^{14}CH_4$ results compare closely with the previous measurements from the other sites. An atmospheric $^{14}CH_4$ history is reconstructed from inverse modelling of the combined ice and firn data. The pre-industrial $^{14}CH_4$ level is almost identical to that expected from contemporaneous biogenic sources, confirming very minor natural fossil CH_4 emissions. $^{14}CH_4$ decreases to a minimum in about 1940 as anthropogenic fossil methane is emitted followed by an increase during the nuclear era from 1950 to present. The record since the 1950s would allow the evolution of the anthropogenic fossil source to be quantified when improved nuclear $^{14}CH_4$ emissions estimates become available. The larger emissions from anthropogenic fossil sources implied by this result suggests opportunities for methane emissions reductions.

Phases of peatland carbon accumulation in the southern mid-latitudes

Dr Zoë Thomas[1,2], Prof. Chris Turney[1,2], Dr Haidee Cadd[1,2], Dr Heather Haines[1,2], Dr Chris Marjo[1,2], Dr Steffi Carter[3], Dr Paul Brickle[3]
[1]Earth and Sustainability Science Research Centre (ESSRC), School of Biological, Earth and Environmental Sciences, University of New South Wales, Sydney, Australia, [2]Chronos 14Carbon-Cycle Facility, Mark Wainwright Analytical Centre, University of New South Wales, Sydney, Australia, [3]South Atlantic Environmental Research Institute (SAERI), Stanley, Falkland Islands

Theme: A-1: Earth's dynamic climate
Type of presentation: Invited Oral Presentation

Creating high resolution chronologies in sediment sequences is important for understanding past carbon-climate dynamics, including accurately dating the timing of climate events, and calculating carbon accumulation changes through time. Here we present >100 ^{14}C dates from UNSWs high-throughput MICADAS (Turney et al. 2021) that help answer key questions about carbon-climate dynamics in the Southern Hemisphere. Peatlands from the southern mid-high latitudes have an important role in the global carbon budget but are underrepresented in global syntheses due to paucity of data. Developing accurate age-depth models from peat sequences is notoriously difficult. Outliers are common, with peat being susceptible to issues such as root penetration and in-wash of sediment. With careful consideration to site selection (Thomas et al. 2019) and material preparation (e.g. sieving out root and rootlet material), the age-depth models presented here demonstrate stratigraphic integrity with no evidence of significant outliers, providing robust and detailed chronologies to enable a range of scientific questions to be answered.

To better constrain the understanding of southern peatland dynamics, we collected and radiocarbon-dated 25 basal peats from across sub-Antarctic islands of the South Atlantic region, doubling the existing available data. We then collated basal peat radiocarbon ages from >35°S and analysed their temporal and spatial distribution. We find two distinct phases of peat formation, at ~16,000 cal years BP and ~13,000 cal years BP, independent of northern hemisphere peat growth. Well-constrained age models from these regions (including a 6 m peat sequence with 55 ^{14}C dates) show changes in carbon accumulation rates that are consistent with these phases. Potential drivers of these phases include growth disruption via the Antarctic Cold Reversal, and the latitudinal movement of the southern hemisphere westerly winds, with implications for future carbon storage in these under-studied regions.

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Radiocarbon based study of fossil fuel CO2 variations across India

Mr Rajveer Sharma[1,2], Dr. Ravi Kumar Kunchala[1], Mr. Sunil Ojha[2], Dr. Pankaj Kumar[2], Mr. Satinath Gargari[2], Dr. Sundeep Chopra[2]
[1]Centre for Atmospheric Science, Indian Institute Of Technology Delhi, New Delhi, India, [2]Inter University Accelerator Centre, New Delhi, India

Theme: A-1: Earth’s dynamic climate
Type of presentation: Oral Presentation

Radiocarbon is a unique tracer for identifying the fossil fuel CO2 (CO2ff) content in the atmosphere since fossil fuels are depleted in the radiocarbon. The measurement of radiocarbon content in air can easily identify CO2 produced by combustion of fossil fuels. The radiocarbon content of crop plants can also provide the signature of CO2ff of their growing period because plants assimilate atmospheric CO2 for photosynthesis process. The literature indicates that India is the one of the largest CO2 emitter in the world. However, as per literature survey, no radiocarbon-based study of fossil fuel CO2 has been reported about emissions from India. A study has been initiated through present measurements to determine the fossil fuel CO2 variations across major parts of India using radiocarbon measurements in the crop plants.

A variety of samples in the form of leaves and grains of crop plants (wheat, mustard, rice etc.) from various locations in India has been collected for the present study. Radiocarbon measurements were performed using a 500kV Ion accelerator (XCAMS: the compact 14C Accelerator Mass Spectrometer eXtended for 10Be and 26Al) at Inter University Accelerator Centre (IUAC) - Accelerator Mass Spectrometry (AMS) facility with the precision between 2 to 3 per mill and measured 14C/12C ratios were converted into Δ14C values and CO2ff values were calculated using Δ14C values.

The results focus towards the high CO2ff values from the areas having largest coal reserves in India and from the samples collected in the vicinity of highways. The studies were further extended to look into the effect of sampling different plant organs on the CO2ff values which indicate that sampling of wheat grain in place of wheat leave can introduce an error which is slightly higher than the error introduced due to uncertainty in the radiocarbon measurements. The present study emphasizes that radiocarbon measurements can also be used effectively to monitor fossil fuel CO2 concentrations across India in the absence of continuous measurements of CO2.

Radiocarbon-based carbon source apportionment of black carbon and organic carbon in carbonaceous aerosols in Asian outflow

Dr Masao Uchida[1], Hidetoshi Kumata[2], Naoki Kaneyasu[3], Kanako Mantoku[1], Daishi Handa[4], Takemitsu Arakaki[4], Kimitaka Kawamura[5], Yasuyuki Shibata[1]
[1]National Institute For Environmental Studies, Tsukuba, Japan, [2]Tokyo University of Pharmacy and Life Sciences, Tokyo, Japan, [3]National Institute of Advanced Industrial Science and Technology, Tsukuba, Japan, [4]University of the Ryukyus, Nishihara, Japan, [5]Chubu University, Kasugai, Japan

Theme: A-1: Earth's dynamic climate
Type of presentation: Poster

Analysis of radiocarbon in carbonaceous aerosols allows an apportionment of fossil and non-fossil (biomass and biogenic) sources of airborne particulate matter. We measured the ^{14}C content of black carbon (BC), organic carbon and total carbon in PM2.5 and PM10 aerosols collected from 2008 to 2010 at Fukue Island and Cape Hedo on Okinawa Island in the East China Sea to investigate the sources of BC from China and surroundings. We also conducted back-trajectory analyses for each sampling period to ascertain the source regions of BC. The results showed that on average, approximately 60% of the air masses at both sites were delivered from the Asian continent, but results from two sites had no apparent relation to the concentrations or ^{14}C contents of BC. However, the trajectory maps suggest some relationships between BC source regions and ^{14}C content of BC at both sites. Our data from Fukue showed relatively large contributions of biomass burning in mid-winter, and back-trajectory analyses suggest that the source area was as distant as Mongolia or Siberia, which showed a clear difference in aerosol sources for the two sites.

Reconstructing Late Pleistocene Atmospheric Radiocarbon using Subfossil New Zealand Kauri (Agathis australis)

Ms Priyadarshini Parsons O'brien[1], Prof. Chris Turney[1], Dr. Jonathan Palmer[1], Dr. Pavla Fenwick[2], Prof. Alan Hogg[3], Dr. Andrew Lorrey[4], Dr. Quan Hua[5]
[1]Chronos 14Carbon-Cycle Facility, and Earth and Sustainability Science Research Centre, University of New South Wales, Sydney, Australia, [2]Gondwana Tree-Ring Laboratory, Little River, New Zealand, [3]Radiocarbon Dating Laboratory, University of Waikato, Hamilton, New Zealand, [4]National Institute of Water and Atmospheric Research Ltd, Auckland, New Zealand, [5]Australian Nuclear Science and Technology Organisation, Kirrawee, Australia

Theme: A-1: Earth’s dynamic climate
Type of presentation: Oral Presentation

Subfossil New Zealand kauri (Agathis australis) buried in bogs across Northland, New Zealand, provide considerable potential for a continuous high-precision radiocarbon calibration curve that extends across the full range of radiocarbon dating. Kauri currently is a significant contributor to our understanding of calibration in this Southern region. The preserved samples also offer a unique opportunity to reconstruct climate events on multi-millennial timescales with annual resolution and carbon concentration. Here we investigate a key site called Waipu, where 40 subfossil trees have been crossdated to form 5 floating chronologies. These series cover collectively 6000 years and preliminary radiocarbon dating suggests a range of ages from 22,000 to 49,000 years BP. Further radiocarbon dating and crossdating of other kauri tree-ring series using the new RingdateR package and visual inspection has identified other trees that may cross-date. This suggests it may be possible to link the floating Waipu series, forming a continuous chronology.If successful this would form the one of the longest subfossil kauri chronologies, with the help of radiocarbon dating. The Waipu chronology would form a world-class palaeo-archive for the Southern Hemisphere and provide a valuable contribution to future iterations of the international calibration curves.

Reduce, Reuse, Recycle: Curating re-calibrated radiocarbon proxies refine Holocene sea-level curve for crucial far-field region

Mr Hayden Golding[1], Dr Zoe Thomas[2], Dr Kirti Lal[1], A/Prof Kerrylee Rogers[1], Prof Chris Turney[2], Dr Amy Dougherty[1,2,3]
[1]University of Wollongong, Wollongong, Australia, [2]University of New South Wales, Sydney, Australia, [3]GeoInsights, Wollongong, Australia

Theme: A-1: Earth’s dynamic climate
Type of presentation: Poster

The impacts of global mean sea-level rise (GMSLR) are expected to be spatially and temporally complex, highlighting the need for well-informed assessments of future change for coastal communities and cities around the world. Accurate projections of sea-level rise depend on models that consider past climatic, tectonic, and isostatic responses to the transfer of water between the cryosphere and ocean. Records of relative sea-level from tectonically stable, far-field regions have the potential to improve understanding of past meltwater contributions to GMSLR, informing on models. However, these key regions remain under-represented within the global atlas of postglacial sea-levels (e.g., Australia). Despite decades of research from southeast Australia, considerable uncertainty surrounds whether Holocene sea-level stabilised at present levels, fell gradually from a prolonged highstand or experienced multiple small-scale oscillations. This study aims to update the mid- to late-Holocene sea-level curve for southeast Australia by incorporating recently published data and re-analysing previously synthesised sea-level proxies using protocols from the global sea-level atlas. The resulting set of radiocarbon dates were calibrated to sideral years against the Southern Hemisphere calibration (SHCal20) dataset using OxCAL 4.4. Simply re-calibrating and re-analysing the same proxies used to construct the previous sea-level curve, resulted in noticeable shifts in the location and error of each individual indicator. This combined with a twofold increase in the total number of data points has expanded the lower limit of the pre-existing range (+0.5 m) down to contemporary sea level. This new reconstruction primarily aligns with the previous envelope that extends up to a maximum highstand of ~2 m between ~8 to 2 ka followed by a gradual fall to present. Merging disparate and imperfect datasets diffuses the ability to accurately interpret sea-level change. To refine this sea-level reconstruction, each proxy used is objectively critiqued and data with high uncertainties eliminated to produce a curve of higher confidence with a more precise envelope. This is of particular importance as much of the available data originate from localised, geomorphic studies and not specifically gathered to be used for sea-level reconstruction. With 75% of the points removed the curve is reduced to two main proxies, mangrove deposits that capture sea-level rise and tubeworm encrustations that document sea-level fall. Together these proxies exhibit a highstand of ~1.8 m between 7 to 4.5 ka, indicating prolonged meltwater contributions in the mid- to late- Holocene. This is incongruous with current regional models and given that these individual pieces of evidence are scattered along >500 km of coastline, it appears unlikely that they are anomalous. The preservation of these optimal proxies is sparse, highlighting the value of a single, widely distributed proxy that records both rising and falling sea-level. This would aid the construction of curves and data-driven models in other far-field regions to capture subtle variations in relative sea-level highstands.

Regional dependence of Be-10 and Cl-36 variations in rainwater at the Sea of Japan and Pacific sides of Japan

Ms Masumi Matsumura[1], Dr. Kimikazu Sasa[1], Mr. Yuta Ochiai[1], Dr. Tetsuya Matsunaka[2], Dr. Yuki Tosaki[3], Mr. Tsutomu Takahashi[1], prof. Keisuke Sueki[1]
[1]University Of Tsukuba, Tsukuba, Japan, [2]Kanazawa University, Kanazawa, Japan, [3]National Institute of Advanced Industrial Science and Technology (AIST), Tsukuba, Japan

Theme: A-1: Earth's dynamic climate
Type of presentation: Poster

The concentrations of long half lived radionuclides, ^{10}Be (half-life = 1.36 × 10^{6} years) and ^{36}Cl (half-life = 3.01 × 10^{5} years) in rainwater were measured at the Pacific side and the Sea of Japan side, to discuss the regional dependencies of seasonal variation. This study focused on ^{10}Be and ^{36}Cl, which are produced in the upper atmosphere via nuclear reactions between cosmic rays and elements in the atmosphere.
We have collected monthly rainwater samples in Tsukuba city, Ibaraki (36°06'N, 140°06'W) at the Pacific side and in Nomi city, Ishikawa (36°25'N, 136°32'W) at the Sea of Japan side. ^{10}Be and ^{36}Cl were measured with the accelerator mass spectrometry system at UTTAC (K. Sasa et al., 2018). The concentrations of ^{10}Be in rainwaters ranged from (6.6 ± 0.3) × 10^{6} to (5.9 ± 0.6) × 10^{7} atoms L^{-1} at Tsukuba (Jan. 2017 – Dec. 2018), and from (1.9 ± 0.1) × 10^{6} to (4.7 ± 1.2) × 10^{7} atoms L^{-1} at Nomi (Jul. 2017 – Sep. 2019). The concentrations of ^{36}Cl in rainwaters ranged from (1.5 ± 0.7) × 10^{5} to (2.0 ± 0.1) × 10^{6} atoms L^{-1} at Tsukuba, and from (1.2 ± 0.7) × 10^{5} to (2.6 ± 0.7) × 10^{6} atoms L^{-1} at Nomi. The ^{10}Be and ^{36}Cl concentrations showed insufficient correlation (^{10}Be; correlation coefficient $r = 0.3$, $p < 0.2$, ^{36}Cl; $r = 0.2$, $p < 0.6$) at Tsukuba and Nomi, therefore it was confirmed that the variations of ^{10}Be and ^{36}Cl concentrations had different trend between the Pacific side and the Sea of Japan side.
The seasonal variations were derived from the monthly averages of ^{10}Be and ^{36}Cl concentrations (Apr. 2004 – Dec. 2018, at Tsukuba and Jul. 2017 – Sep. 2019 at Nomi). In terms of Nomi, the variation of ^{10}Be had a similar trend with Tsukuba in summer while the ^{10}Be concentration was higher than Tsukuba in winter. The strong north-west wind blows down around the Sea of Japan side in winter, ^{10}Be is produced much in polar atmosphere, hence, the strong wind contains huge ^{10}Be, which makes high ^{10}Be concentration in rainwater at Nomi, similar as ^{7}Be (M. Yamamoto et al., 2006 and J. Masarik et al., 2009). The concentration of ^{36}Cl in winter was also higher than in summer at Nomi, corresponding to the large ^{36}Cl production in the polar regions (J. Masarik et al., 2009). In contrast, ^{10}Be and ^{36}Cl concentration increased in mid-spring at Tsukuba. The strong stratosphere-troposphere exchange occurs around Japan in spring due to the westerly wind. The air mass has high concentrations of ^{10}Be or ^{36}Cl in the stratosphere. It is easy to be transported to the boundary layer. Therefore, high concentrations of ^{10}Be and ^{36}Cl were observed in rainwater at Tsukuba.

Short duration glacial advances: implications for cosmogenic dating chronologies

A/Prof. Duanne White[1], Dr Reka Fulop[2,3], Dr David Fink[2], Dr Toshi Fujioka[2,4], Mr Marcello Blaxell[1], Mr Matt Jeromson[1], Dr Alexandru Codilean[3]
[1]University Of Canberra, , Australia, [2]ANSTO, , Australia, [3]University of Wollongong, , Australia, [4]Centro Nacional de Investigación sobre la Evolución Humana, CENIEH, , Spain

Theme: A-1: Earth's dynamic climate
Type of presentation: Oral Presentation

Cosmogenic nuclides are now the mainstay technique for constraining past ice advances in terrestrial environments. However, limited erosion of bedrock and recycling of older glacial sediments complicates the interpretation of dated records. Where younger deposits or striated bedrock surfaces contain nuclides inherited from previous periods of exposure, cosmogenic dates overestimate deglaciation by tens to hundreds of thousands of years. This is especially problematic in Antarctica, where low erosion rates and cold-based glaciation produce widespread inheritance in erratics or bedrock surfaces. Studies using long-lived nuclides such as Be-10 have identified sites where <5% of erratics are inheritance-free, making it logistically difficult to measure ice sheet retreat.

To address this issue, the short-lived nuclide in-situ C -14 is being applied in Antarctic deglaciation studies. The relatively recent deglaciation across most parts of Antarctica mean inheritance in erratics can be detected by discordant Be-10 and C-14 ages. Bedrock may also be dateable using C-14 if the inherited nuclides decay below measurement uncertainties while ice cover is present. However, both these approaches, particularly direct bedrock dating, make assumptions of the duration of the glacial advance.

To test these approaches we measured C-14 in bedrock surfaces from sites across East Antarctica between Enderby Land (48oE) and Vincennies Bay (107oE). At each site, the true deglaciation age was well established via Be-10 ages on erratics, and in some cases, coincident with the onset of biogenic sedimentation in lake and marine basins. We find that the assumption of a long-duration Last Glacial Maximum (LGM) is not widely met. The two inland sites appear to have been buried long enough to re-set the C-14 signal. However, at least four sites along the East Antarctic coastline displayed bedrock surfaces that were saturated with C-14, despite clearly having been covered by ice during the early Holocene.

These results mean that in-situ C-14 ages must be carefully interpreted, especially when used on bedrock. Bedrock surfaces that provide discrete ages can be used to indicate that deglaciation has occurred since the global Last Glacial Maximum. However, those with saturated surfaces provide equivocal results unless supporting evidence can support the expected duration of the LGM.

Spatial variations of ^{10}Be in surface snow along the inland traverse route of Japanese Antarctic Research Expedition

Dr Kazuho Horiuchi[1], Shinji Kato[2], Kou Ohtani[1], Dr Naoyuki Kurita[3], Shun Tsutaki[4], Fumio Nakazawa[4], Hideaki Motoyama[4], Kenji Kawamura[4], Hirofumi Tazoe[5], Naofumi Akata[5], Keisuke Yamagata[6], Hiroyuki Matsuzaki[6]

[1]Graduate School of Science and Technology, Hirosaki University, Hirosaki, Japan, [2]Hachinohe Office, National Tax Agency, Hachinohe, Japan, [3]Institute for Space-Earth Environmental Research, Nagoya University, Nagoya, Japan, [4]National Institute of Polar Research, Tachikawa, Japan, [5]Institute of Radiation Emergency Medicine, Hirosaki, Japan, [6]Micro Analysis Laboratory, Tandem accelerator (MALT), The University of Tokyo, Bunkyo-ku, Japam

Theme: A-1: Earth's dynamic climate
Type of presentation: Poster

Snow and ice layers in Antarctica have huge and diverse implications on global climatic and paleoclimatic phenomena. They not only are involved in global climate changes but also serve as cryo-archives providing a lot of key information for paleoclimate communities. Cosmogenic ^{10} Be is probably one of such information. Cosmic-ray variations and events, which are of geomagnetic, solar and other celestial origins, have been intensively investigated using temporal ^{10} Be variations analyzed in polar ice cores (e.g. Beer et al., 2012). Temporal ^{10} Be records are also used to evaluate snow accumulation rates of ice cores from inland Antarctica by assuming a fairly constant fallout rate of the nuclide within relatively small fluctuations recording the production signals (e.g. Cauquoin et al., 2015). However, spatial distribution of ^{10} Be in surface snow is scarcely investigated and it was reported only by a few studies (e.g. Berggren, et al., 2013). We here present a data set of ^{10} Be in surface snow samples obtained along the inland traverse route of the 59th and 60th Japanese Antarctic Research Expedition (JARE). The traverse expeditions were conducted between the coastal S16 point (69°02'S, 40°03'E) and the vicinity of the inland Dome Fuji station (77°19'S, 39°42'E). The route is almost straight (precisely arc-like) from north to south and from the foot of the slope (0.6 km in altitude) to the high plateau (up to 3.8 km in altitude). We took fresh snow or fresh drift snow samples in early austral summer (Nov. 12th to Dec. 17th, 2017) in the 59th JARE and in mid-austral summer (Jan. 1st to Jan. 19th, 2019) in the 60th JARE. The samples were then transported in frozen form to Japan. Sample pretreatments were performed at Hirosaki University. Accelerator Mass Spectrometry was employed for the ^{10} Be analysis at Micro Analysis Laboratory, Tandem accelerator (MALT), The University of Tokyo. The ^{10} Be concentrations in the samples varied by an order of magnitude from 3.7×10^3 to 8.6×10^4 atoms/g. Plotted against the latitude, the concentrations show a clear southward increasing trend with an upward inflection point around 75° S (3.5 km in altitude) for the JARE 59th. On the other hand, for the JARE 60th, such a trend is less clear and the concentrations are sometimes significantly higher than those of the 59th JARE north of 75° S. We compared our results with a compiled data set of snow accumulation rates (SAR) from snow stake measurements along the traverse route during the last three decades (Kamiyama et al., 1994; Tsutaki et al., in preparation). The comparison suggests that the ^{10} Be variations observed in the 59th JARE are largely accounted for by variations of the local mean SAR and a possible difference of the ^{10} Be fallout rate between the high plateau and the other areas. On the other hand, higher ^{10} Be concentrations sometimes found in the 60th JARE samples can be interpreted to reflect a seasonal variation of ^{10} Be fallout, which is related to stratosphere–troposphere exchange that may cause a distinct ^{10} Be enhancement in mid-austral summer

Speciation Distribution of Iodine Isotopes (127I and 129I) in the North Pacific Ocean

Mr Yuanzhi Qi[1], Mr. Takeyasu Yamagata[1], Prof. Hisao Nagai[2], Prof. Hiroyuki Matsuzaki[1]
[1]MALT, The University Of Tokyo, Tokyo, Japan, [2]Nihon University, Tokyo, Japan

Theme: A-1: Earth’s dynamic climate
Type of presentation: Oral Presentation

Bulk inorganic 127I and 129I, as well as for iodide and iodate of these two isotopes, were measured in seawater of different depth profiles in the North Pacific Ocean. The bulk inorganic 129I concentrations were 1.16 ~ 1.71 × 107 atoms L-1 in surface waters, and the vertical profiles almost have same trend, which is that the 129I concentration decrease with depth from the subsurface layer, among all study stations. The same trend indicates that atmospheric deposition may be the overwhelming 129I source in the North Pacific Ocean. Compare to subsurface layers, surface seawater always has relative lower bulk inorganic 129I concentrations, implying some loss processes, like inorganic 129I emission and bio-utilization, exist in the surface bound layer of ocean. Based on the measured bulk 129I concentrations, the 129I inventories in the upper layer (to the depth of 800 m) of North Pacific Ocean are 5.0 ~ 9.1 × 1011 atoms m−2. As the thermodynamically stable form of iodine in normal seawater, iodate is the predominant 127I species (35.8 ~ 63.7 µg/L, accounting for 72.6 ~ 97.5% of bulk 127I) in the North Pacific Ocean. However, the 129I/127I ratio in iodide is much higher than which in iodate, indicating that 127I and 129I have different circulation pathway. Besides, due to the exist of eastern subtropical North Pacific oxygen minimum zones (ESTNP-OMZs), the 127I--127IO3- differences in the eastern Pacific Ocean are obvious less in comparison with which in the western Pacific Ocean, at the same time, the differences between 129I-/127I- and 129IO3-/127IO3- also decrease in the eastern Pacific Ocean. The results suggest that in-situ reduction from iodate to iodide occurs in the ESTNP-OMZs.

Speleothem 14C is unlikely to be impacted by wildfire – case studies from Western Australia and Tasmania

Dr Micheline Campbell[1], Dr Liza McDonough[2], Ms Nevena Kosarac[1], Dr Pauline Treble[2,1], Dr Monika Markowska[3], Professor Andy Baker[1,2], Dr Quan Hua[2]
[1]UNSW, Kensington, Australia, [2]ANSTO, Lucas Heights, Australia, [3]Max Plank Institute for Chemistry, Mainz, Germany

Theme: A-1: Earth's dynamic climate
Type of presentation: Poster

Accelerator Mass Spectrometry (AMS) can be used to measure ^{14}C in speleothems (cave formations). AMS derived ^{14}C measurements offer an alternative geochronological method to U-series dating for recently formed speleothems with low U concentrations and insufficient ^{230}Th ingrowth, and where speleothems are impacted by allogenic thorium. However, using ^{14}C for dating speleothems is complicated by variable ^{14}C sources and dilution by ^{14}C-depleted parent rock (dead carbon). Old carbon may be mobilised from soil and decaying organic matter, which can mix with new carbon from root respiration in the vadose zone. These processes and their incorporation in speleothems are non-stationary in time and can be difficult to correct for.

While variable dead carbon is a complication for dating speleothems, hypothetically, a sudden decline in ^{14}C, indicating an influx of old carbon, could be expected to occur after a bushfire. This could be because old carbon previously sequestered in soil and biomass may be mobilised, or there could be a decline in the previous oversupply of biological CO_2 while root respiration is in recovery following tree death. Using speleothems as proxy archives for past fire is an emerging field, and recent research has shown multiple proxies are needed to accurately characterise a fire event. To test the hypothesis that ^{14}C may serve as a proxy for palaeofire, we chose four sites which have experienced bushfires; Crystal, Golgotha, and Yonderup Caves in Western Australia, and Frankcombe Cave in central Tasmania. We used the AMS facilities at the Australian Nuclear Science and Technology Organisation to quantify the ^{14}C content along growth axes for the speleothems from Western Australia. Previously published AMS ^{14}C data for the Tasmanian speleothem were measured at the Australian National University. Crystal and Yonderup Cave speleothems had additional age-constraints of annual laminations.

The Crystal Cave speleothem shows no decline in ^{14}C after an historical fire event. The Yonderup Cave speleothem does show a decline in ^{14}C after a reconstructed fire event, but the decrease is within analytical uncertainty. The Golgotha speleothem ^{14}C shows no change after a documented fire. The Tasmanian speleothem does show a significant decline in ^{14}C during a period where the region experienced successive large bushfires, as recorded in the historical record, but the temporal uncertainty of the measurements is so high (± 15 years), that the decline cannot reliably be attributed to the bushfires.

These case studies provide only limited evidence to support our hypothesis that ^{14}C in speleothems may be a proxy for past fire events. This may be because the response is too short to be observed, sampling resolution is insufficient, or the carbon flux associated with a bushfire is too small relative to the total CO_2 flux in the vadose zone. While this is discouraging for palaeofire researchers, results offer relief to those who use ^{14}C dates to create speleothem chronologies, as it is one less source of uncertainty to consider when correcting ^{14}C ages. Our results may also serve to elucidate the importance of CO_2 source on ^{14}C, and by extension, on $\delta^{13}C$.

Surface distribution of iodine-129 in the southwestern Okhotsk Sea in 2018

Dr. Tetsuya Matsunaka[1], Dr. Seiya Nagao[1], Dr. Mutsuo Inoue[1], Dr. Yukiko Taniuchi[2], Dr. Hiromi Kasai[2], Mr. Tsutomu Takahashi[3], Mrs. Masumi Matsumura[3], Dr. Keisuke Sueki[3], Dr. Kimikazu Sasa[3]
[1]Kanazawa University, Kanazawa, Japan, [2]Japan Fisheries Research and Education Agency, Kushiro, Japan, [3]University of Tsukuba, Tsukuba, Japan

Theme: A-1: Earth’s dynamic climate
Type of presentation: Poster

The investigation of water dynamics change in the East Asian marginal seas such as the Okhotsk Sea and Sea of Japan caused by the recent global warming is essential for forecasting the response of ocean circulation with climate change. Anthropogenic ^{129}I (half-life: 15.7 million years) produced from the thermal neutron fission, is dominated by release from nuclear fuel reprocessing plants in the Europe and supplied at the Okhotsk Sea via atmospheric deposition and surface runoff. To illuminate the availability of ^{129}I as a tracer of surface circulation in the Okhotsk Sea, we investigated the horizontal distribution of ^{129}I in 2018.

Surface seawater samples with a depth 0 m of 1 L were collected at 15 stations in the Okhotsk Sea and Sea of Japan using a bucket during the Wakataka Maru expedition in September 2018 (WK18-09). After adding 1 mg of iodine carrier (Woodward old iodine) with an ^{129}I/^{127}I ratio of 1.5 × 10^{-14} to the filtered 500 ml seawater sample, the iodine was isolated by solvent extraction with CCl_4. The purified iodide was precipitated as AgI by adding $AgNO_3$. The AgI precipitate was then washed with NH_4OH and ultra-pure water, and was dried and loaded into an Al holder with Nb powder. The ^{129}I/^{127}I ratio of the AgI targets was measured using the accelerator mass spectrometry (AMS) system at the Tandem Accelerator Complex, University of Tsukuba. A terminal voltage of 5 MV and a charge state of 5+ were chosen for acceleration and detection. The measurement ratios were normalized against the S-Purdue (Z94-0597) reference material, which had an ^{129}I/^{127}I ratio of 8.378 × 10^{-12} and was provided by the Purdue Rare Isotope Measurement Laboratory at Purdue University, USA. Stable iodine (^{127}I) in the seawater was measured by an inductively coupled plasma–mass spectrometry (ICP–MS). The original ^{129}I/^{127}I ratios and ^{129}I concentrations in the seawater were calculated using ^{129}I/^{127}I ratio from AMS and ^{127}I concentration from ICP-MS.

The dissolved ^{129}I in surface water in the Okhotsk Sea varied from 15.0±0.7 to 26.6±0.8 nBq/L, and was negatively correlated with water temperature ($R^2 = 0.67$) and salinity ($R^2 = 0.68$). This water temperature and salinity-dependent distributions revealed that the dissolved ^{129}I in the area was controlled by mixing of water mass from the Okhotsk Sea surface seawater with cold and lower salinity and the Soya warm current from the Sea of Japan with warm and higher salinity. ^{129}I is considered to be a tracer for the front of the Okhotsk Sea surface water.

The apportionment of emission sources of atmospheric methane using 14C: capabilities and challenges

Prof. Soenke Szidat[1,2], Dr. Thomas Laemmel[1,2], Mr. Christophe Espic[1,2], Mr. Matthias Bantle[1], Dr. Stephan Henne[3], Prof. Dominik Brunner[3], Prof. Markus Leuenberger[2,4]
[1]University of Bern, Dept. of Chemistry, Biochemistry and Pharmaceutical Sciences, Bern,, [2]University of Bern, Oeschger Center for Climate Change Research, Bern, , [3]Empa, Laboratory for Air Pollution / Environmental Technology, Duebendorf, , [4]University of Bern, Climate and Environmental Physics, Bern,

Theme: A-1: Earth’s dynamic climate
Type of presentation: Invited Oral Presentation

Introduction

Methane (CH4) is the second most important greenhouse gas after carbon dioxide (CO2). Radiocarbon (14C) analysis of atmospheric CO2 is a powerful tool for the apportionment of its emission sources and especially for the quantification of fossil CO2 emissions. This story of success may also be expanded to the source apportionment of CH4. However, several circumstances hamper such an approach, e.g. the ~200-times lower ambient CH4 concentrations compared to CO2, the requirement of a bias-free extraction of CH4 from ambient air, missing reference datasets from monitoring stations or interfering 14CH4 emissions of nuclear power plants (NPPs).

Methods

Short-term air samples have been collected biweekly since 2018 at three Swiss sites: the high-alpine research station Jungfraujoch, the tall tower Blosenbergturm in the rural area of Beromünster and an urban site in Bern. We developed a methane preconcentration and purification setup that enables the isolation of CH4 from atmospheric samples for 14C measurements (Espic et al., 2019). With this, we extract pure methane from 50-100 L of ambient air. After oxidation to CO2, samples of ~50 µgC are measured with the gas ion source of our accelerator mass spectrometer MIni CArbon DAting System (MICADAS).

Results

The methane preconcentration and purification setup guarantees a bias-free isolation of CH4 from air, which particularly prevents an interference of CO2. This is mainly achieved by a multi-trap preconcentration, followed by purification using gas chromatography (GC), in which the retention times of both gases differ comfortably by ~4 minutes. The GC also allows the surveillance of this separation for each sample, which is not possible for simplified methane extraction systems that exclude the GC step.

Most of the short-term air samples from Jungfraujoch showed a fraction modern (F14C) for CH4 of ~1.35, which agrees well with few observations at other background sites. Results from Beromünster and Bern revealed larger scattering, however, which indicates an influence from other sources. These may include emissions from fossil and biogenic sources as well as from nearby NPPs. Whereas the first two of which are related to the aims of this project, the last of which unfortunately complicates the 14C source apportionment of CH4 for Switzerland so that further filtering of the data is needed.

Conclusions

- The combination of our methane preconcentration and purification setup with the the MICADAS provides the technical basis for the apportionment of emission sources of atmospheric methane using 14C.
- The high-alpine research station Jungfraujoch is well suited as a reference station of 14CH4 for central Europe.
- Due to the impact from nuclear power plants, the 14C source apportionment of CH4 requires additional filtering of data, for example by analyzing atmospheric transport, to be effective for Switzerland.
- In a recently started project, we aim at a broadened sampling strategy combined with atmospheric inversion models in order to improve the capabilities of 14CH4 measurements.

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The Last Glacial transition and Holocene ecological change in Arthur's Pass National Park, New Zealand.

Mr Patrick Mark Adams[1], Dr David Fink[2], Prof Jamie Shulmeister[3], Dr Craig Woodward[4], Dr Toshiyuki Fujioka[5], Ms Krista Simon[2]
[1]The University Of Queensland, Brisbane, Australia, [2]Australian Nuclear Science and Technology Organisation (ANSTO), Sydney, Australia, [3]University of Canterbury, Christchurch, New Zealand, [4]Iniversity of Wollongong, Wollongong, Australia, [5]Centro Nacional de Investigacion Sobre la Evolucion Humana (CENIEH), Burgos, Spain

Theme: A-1: Earth's dynamic climate
Type of presentation: Oral Presentation

This study improves our understanding of paleo-climate and -environmental change in the high-country South Island New Zealand focusing on formerly glaciated valleys near Arthur's Pass. The area is of importance being positioned under a steep precipitation gradient on the lee side of the Southern Alps. Be-10 exposure ages (n=37) of ice limits, mapped as terminal moraines deposited during the last deglaciation through to late Holocene, span the past 17 000 years.
The glacial record from well-preserved moraine sequences within the valley floor and glacial benches (850 to 1350m) demonstrates an initial post-LGM fast retreat that confirms previous studies (e.g. Shulmeister et al., 2010). Coupled with available in-valley exposure ages from Misery, Dobson and McGrath Moraines (Fink et al, 2017), a comprehensive regional deglacial pattern emerges. The Be-10 ages at Misery Moraines, subject of an early debate supporting a Younger Dryas glacial advance in the Southern Hemisphere (Ivy-Ochs et al. (1999), are re-dated to the Antarctic Cold Reversal (~14-15 ka).
The record in headwater valleys of the Bealey and Otira rivers is largely obscured by slope-processes making conclusive observations relating to glaciation difficult. Consequently, early to middle Holocene moraines ages were not recovered in these valleys in contrast to nearby Dart Valley (Dowling et al., 2021). There is strong evidence at Otira headwall for a Little Ice Age glacial moraine limit. Several non-glacial boulders yield ages of 6.7ka, 4.2ka, 2.2ka and 1.7ka in the over steepened upper reaches of Bealey and Otira valleys that may reflect landslides associated with separate seismic events.

In addition to our glacial chronology, we report on a well constrained record from Lances Tarn (Pb-210, and 37 radiocarbon dates over 4 m core length), a moraine-impounded bog at the saddle of Arthur's Pass. This record spans ~13 000 years and displays post-glacial environmental change. The pollen record indicates typical succession from herb field through to closed forest, similar to other regional records (e.g. McGlone et al., 2004). The onset of Holocene like conditions is observed early c12ka, unlike central and lower South Island (~10ka). The area is influenced by persistent westerly flows through the entire record but with a reduction in flow in Early Holocene between 9.5 and 8.5ka, causing drier conditions in agreement with other records in Tasmania (Mariani and Fletcher, 2017 also in Patagonia (Moreno et al., 2020). There is little evidence of burning until c2.2ka when grass pollen rises sharply and charcoal counts increase, indicating a change in evapotranspiration (drying). Increased fires are evident from the onset of human arrival 750 years ago. The largest change in fire history and sediment transport occurs after European settlement ~ 1850's, when intensive deforestation is evident in the pollen record.

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The potential of using in situ cosmogenic 14CO in ice cores at Dome C to examine the assumption of a constant galactic cosmic ray flux

Dr Vasilii Petrenko[1], Dr. Segev BenZvi[2], **Dr. Andrew Smith[3]**, Dr. Michael Dyonisius[4], Dr. Benjamin Hmiel[5], Dr. Peter Neff[6], Dr. Christo Buizert[7], Dr. Jeffrey Severinghaus[8]

[1]Department of Earth and Environmental Sciences, University Of Rochester, Rochester, United States, [2]Department of Physics and Astronomy, University of Rochester, Rochester, United States, [3]Australian Nuclear Science and Technology Organisation (ANSTO), Lucas Heights, Australia, [4]Physics of Ice, Climate and Earth, Niels Bohr Institute, University of Copenhagen, Copenhagen, Denmark, [5]Environmental Defense Fund, New York, United States, [6]Department of Soil, Water and Climate, University of Minnesota Twin Cities, Saint Paul, United States, [7]College of Earth, Ocean and Atmospheric Sciences, Oregon State University, Corvallis, United States, [8]Scripps Institution of Oceanography, University of California San Diego, La Jolla, United States

Theme: A-1: Earth’s dynamic climate
Type of presentation: Poster

Cosmogenic nuclides produced in the Earth’s atmosphere and at the surface are powerful proxies for important climate processes and drivers. Records of atmospherically-produced 14C and 10Be have been used to reconstruct past solar activity and solar irradiance. 10Be, 14C, 26Al and other nuclides produced in surface rock are widely used in studies of past ice dynamics and extent. All these studies generally assume that the galactic cosmic ray (GCR) flux at Earth is constant in time. However, the available geochemical evidence for GCR flux constancy is complicated by processes that are not fully constrained. As a result, the assumption of a constant GCR flux may be uncertain by 30% or more. Cosmic rays also produce 14C in situ in glacial ice and firn; this 14C then reacts rapidly to form mainly 14CO and 14CO2. Almost all of the 14C produced in the firn layer is lost to the atmosphere via gas diffusion, and in situ 14C only starts to accumulate in the deepest firn (≈95 m at Dome C) where gas exchange with the atmosphere effectively stops. At this depth, all of the in situ 14C production is via interactions with deep-penetrating muons. Such muons are generated by high-energy primary GCRs that are unaffected by geomagnetic and solar modulation. Further, at sites with low snow accumulation such as Dome C, in situ 14CO strongly dominates over trapped atmospheric 14CO in the ice. As a result, 14CO in ice at Dome C would provide a record of the past GCR flux that is virtually free of confounding factors and should allow to constrain any past flux variations to within ≈ 10%. This presentation will provide a brief overview of results from recent studies of in situ cosmogenic 14CO in Greenland and Antarctica, as well as predictions for Dome C under a range of different GCR flux scenarios.

Time course profile of Chlorine-36 in Greenland SE dome ice core

Dr Hiroyuki Matsuzaki[1], Ms. Miwako Toya[1], Dr. Kazuho Horiuchi[2], Dr. Yoshinori Iizuka[3]
[1]MALT, The University Of Tokyo, Tokyo, Japan, [2]Hirosaki University, Hirosaki, Japan, [3]Hokkaido University, Sapporo, Japan

Theme: A-1: Earth's dynamic climate
Type of presentation: Invited Oral Presentation

Chlorine-36 (half life: 3.01E5 yr) is a neutron activated nuclide from Cl-35. In the process of atmospheric nuclear weapon testing held on the ocean, seawater is blew up and Cl-35 in seawater is irradiated by neutron flux, consequently, vast amount of Cl-36 is produced. In the case of nuclear weapon testing on the continent, Cl-36 is considered not to be produced. Produced Cl-36 is transported by the atmospheric circulation and falls down on various sites on the earth including the polar regions. The ice core is a good archive that preserves a time-course records of various atmospheric nuclides including Cl-36. In this study, a time-course record of Cl-36 in Greenland SE-dome ice core was analyzed with high time resolution.

Greenland SE-dome is located at 7.18 deg. North, 36.37 deg West at the altitude 3170 m. The ice core this study analyzed was taken in 2015 and covers years 2015 to 1955 [1, 2]. Concentration of major elements and oxygen isotopic ratio had been analyzed and published [3]. We analyzed Cl-36 from 1956 to 1983 with about half year time resolution or better. A clear peak corresponding to the nuclear weapon testing was observed. The time course profile of our study is quite different from that of Iodine-129 taken from the same ice core previously [4]. I-129 takes its one peak at around the weapon testing and after the peak increases again towards to the present which is due to the operation of the spent fuel reprocessing plant. The peak positions of Cl-36 and I-129 are also different. These observation is considered to reflect the difference of the production processes between two nuclides.

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Towards 14C-dating of gases in ice cores – constraining the in situ cosmogenic 14C production rates by muons

Michael Dyonisius[1,2], Vasilii Petrenko[2], Andrew Smith[3], Benjamin Hmiel[2], Peter Neff[2,6], Bin Yang[3], Quan Hua[3], Philip Place[2], James Menking[4], Sarah Shackleton[5], Ross Beaudette[5], Christina Harth[5], Michael Kalk[4], Heidi Roop[2,6], Bernhard Bereiter[5], Casey Armanetti[4], Christo Buizert[4], Jochen Schmitt[7], Edward Brook[4], Jeffrey Severinghaus[5], Ray Weiss[5], Joseph McConnell[8]
[1]Niels Bohr Institute, Physics Of Ice Climate And Earth, Copenhagen, Denmark, [2]University of Rochester, Dept. Earth and Environmental Sciences, Rochester, USA, [3]Australian Nuclear Science and Technology Organization, Sydney, Australia, [4]Oregon State University, College of Earth, Ocean, and Atmospheric Sciences, Corvallis, USA, [5]Scripps Institution of Oceanography, San Diego, USA, [6]University of Minnesota, Dept. of Soil, Water, and Climate, Minnesotta, USA, [7]University of Bern, Climate and Environmental Physics, Bern, Switzerland, [8]Desert Research Institute, Reno, USA

Theme: A-1: Earth’s dynamic climate
Type of presentation: Invited Oral Presentation

Radiocarbon dating of glacial ice has been a longstanding goal in ice core science. In glacial ice, ^{14}C is incorporated mainly through trapping of ^{14}C-containing atmospheric gases ($^{14}CO_2$, ^{14}CO, and $^{14}CH_4$). However, ^{14}C in ice is also produced in situ, directly in the ice lattice from reactions with secondary cosmic rays. In situ ^{14}C in ice mostly accumulates after bubble close-off (generally at firn depths between 50-120 m) because almost all of the in situ produced ^{14}C in the firn column is lost to the atmosphere via diffusion. The in situ ^{14}C at corresponding close-off depths of most ice core sites is generally dominated by production from deep penetrating muons. Understanding the muogenic ^{14}C production rates is thus important to deconvolve the in situ cosmogenic and atmospheric ^{14}C signals in ice cores. In this study, we use measurements of ^{14}C in ancient ice (>50 kilo-annum before present, ka BP) from the Taylor Glacier ablation site, Antarctica to calibrate the muogenic ^{14}C production rates. We find that literature values are overestimated by factors of 5.7 (3.6-13.9, 95% confidence interval) and 3.7 (2.0-11.9 95% confidence interval) for negative muon capture and fast muon interactions respectively. Furthermore, the partitioning between the in situ ^{14}C species appears to be constant (^{14}CO:$^{14}CO_2$ ratio of 1:2, with small <0.2% contributions from $^{14}CH_4$). Our results allow for future ice core ^{14}C studies to be potentially used for several applications, including absolute dating of gases and improving the ^{14}C calibration curve in periods where high-resolution tree ring data are not available.

Unraveling the process of aerosols secondary formation and dissipation based on cosmogenic beryllium-7 and beryllium-10

Mr Xu-Ke Liu[1,2], Dr Yun-Chong Fu[1,3,4], Prof. Wei-Jian Zhou[1,3,4], Dr Li Zhang[1,4], Mr Guo-Qing Zhao[1,4], Dr Qi-Yuan Wang[1]

[1]Institute Of Earth Environment, Chinese Academy Of Sciences, Xi'an, China, [2]University of Chinese Academy of Sciences, Beijing, China, [3]Xi'an Jiaotong University, Xi'an, China, [4]Xi'an AMS Center, Xi'an, China

Theme: A-1: Earth’s dynamic climate
Type of presentation: Poster

The production and dissipation process of aerosols is extremely complicated, which has a great impact on the environment and human health. For example, the new production process of secondary aerosols (SA) can further deteriorate air quality. However, at present, the accuracy of SA estimation has not been fully recognized, and the measurement process of multiple substances (such as NH4+, NO3- and SO42- for secondary inorganic aerosols, and organic carbon and elemental carbon for secondary organic aerosols) is complicated. Explore other single element tracing methods that may make up for these shortcomings. In addition, it is a more ideal way to focus not only on the SA new production process but also on the aerosol dissipation and removal process. Cosmogenic 7Be and 10Be in the atmosphere are rapidly adsorbed on aerosols after being formed, and their production rate and geochemical properties are relatively stable. We have noticed that the 7Be and 10Be attached to the aerosol will no longer return to the atmospheric storage after being deposited on the surface (except for the effects of resuspended dust, which will be discussed later), and they are not used as precursors for SA formation. Therefore, 7Be and 10Be may provide different aerosol chemical pathways from traditional tracers. In addition, since the production and deposition of 7Be and 10Be are closely related to aerosols, their deposition process can also represent the physical removal process of aerosols (such as the removal process of rainfall and vertical atmospheric movement, etc.). Here, we measured the daily resolution atmospheric 7Be and 10Be in autumn and winter of Xi’an (heavy pollution period in a typical polluted area) by AMS, And it is found that the actual 10Be/7Be ratio obtained after deducting the influence of the resuspended dust in the 10Be can realize the accurate judgment of the atmospheric vertical stability. It is confirmed by SA tracers (such as NH4+, NO3-, and SO42-) and precursors (such as SO2, NO2) that a large amount of SA is formed during these stable periods judged by the 10Be/7Be ratio. The 7Be and 10Be concentration in these stable periods is significantly negatively correlated with the aerosol concentration (R2 › 0.9, P<0.001). Therefore, the SA relative content in aerosols can be estimated by the dilution degree of 7Be and 10Be, reflecting the second generation process of aerosol chemistry. In addition, we also used 7Be and 10Be washout to further quantitatively estimate removal of aerosol by rain and its residence time and based on the change of 10Be/7Be ratio. We found that the rapid dissipation of aerosols in some periods of Xi’an may be caused by the atmospheric vertical movement. In summary, atmospheric 7Be and 10Be will provide a new view angle to study the process of secondary chemical generation and physical elimination of aerosols.

Using in situ 14C to unravel complex exposure histories along the David Glacier, Antarctica

Dr Jamey Stutz[1], Dr. Reka Fülop[2], Dr. Kevin Norton[3], Dr. Andrew Mackintosh[4], Dr. Ross Whitmore[4], Dr. Bin Yang[2], Dr. Andrew Smith[2]

[1]Antarctic Research Centre, Te Herenga Waka - Victoria University Of Wellington, , New Zealand, [2]Australian Nuclear Science and Technology Organisation, Sydney, Australia, [3]School of Geography, Environment and Earth Sciences, Wellington, New Zealand, [4]School of Earth, Environment and Atmosphere, Melbourne, Australia

Theme: A-1: Earth’s dynamic climate
Type of presentation: Poster-Plus Presentation

Understanding the past Antarctic Ice Sheet (AIS) is critical to forecast the impacts of future of the AIS and its contribution to sea level rise. Ice sheet models constrained by geological data provide improved confidence in future projections. Both marine and terrestrial geologic data are required for a robust reconstruction of both the extent and thickness of the AIS. On land, cosmogenic nuclides have transformed the ability to constrain reconstructions of the past AIS through time. High-resolution, low-inheritance chronologies focused on large outlet glaciers provide enhanced understanding on the timing, rate and potential mechanisms driving past ice sheet change. Using the ‘glacial dip stick’ approach at each site, we sample glacial debris and bedrock from the local peak down to the modern ice surface. While field sampling strategies and analytical capability continues to improve, ‘complex’ exposure histories remain a common occurrence in practice. Inheritance, or a signal of cumulative exposure, can arise due to burial by cold-based, non-erosive nature of the AIS. At Mt. Kring along the upper David Glacier, previous studies show a distinct mid-Holocene signal of glacier thinning as well as at least two populations of apparent older glacial thinning events. Here, we use 14C measurements on samples suspected of having an inherited signal. We show that samples with >30 ka 10Be exposure ages indeed carry a mid-Holocene 14C exposure age and improve the existing thinning history. This multi-nuclide comparison approach provides a preliminary data set to bolster previous and emerging studies where complex exposure histories occur around Antarctica.

Using in-situ cosmogenic 36Cl exposure dating of glacial erratics to establish a retreat chronology of the Iller Piedmont Glacier (Southern Germany)

Dominic Hildebrandt[1,4], Florian Hofmann[1,5], Silke Merchel[2,3], Georg Rugel[2], Johannes Lachner[2], Martin Martschini[3], Anke Maria Friedrich[1]

[1]Department of Earth & Environmental Sciences, Ludwig Maximilian University Munich, Ludwig Maximilian University Munich, Munich, Germany, [2]Department Accelerator Mass Spectrometry and Isotope Research, Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany, [3]University of Vienna, Faculty of Physics, Isotope Physics, Vienna, Austria, [4]Present address: Department of Earth Sciences, ETH Zurich, Zurich, Switzerland, [5]Department of Earth Sciences, University of Southern California, Los Angeles

Theme: A-1: Earth’s dynamic climate
Type of presentation: Poster

The dynamic behavior of glacial retreat following the globally diachronous Last Glacial Maximum (LGM) is poorly understood. In the Northern Alpine Foreland, multiple lobes of foreland glaciers produced a complex morpho-sedimentary record. While the reconstructed LGM ice extent is laterally constant in the west, it shows significant variations in the central and eastern parts. We explore how these geological differences relate to local climatic variability and global paleoclimate during a period of rapid climate change in the late Pleistocene.

In this study, we employ cosmogenic ^{36}Cl in limestone to constrain the in-situ exposure age of glacial erratics situated on moraine walls of the Iller Piedmont Glacier. We sampled erratic boulders from three moraine crests previously interpreted to represent the LGM and two post-LGM retreat stands. We measured ^{36}Cl/Cl and Cl-nat of seven samples from all three locations by applying routine chemistry protocols (Merchel et al., 2013) and isotope-dilution AMS measurements using a dedicated ion source for halogenides (Pavetich et al., 2014) at the DREsden AMS facility.

Preliminary results show that the sampled boulder surfaces provide internally consistent, reproducible, and geologically meaningful dates. Field investigations indicate that some of the erratic boulders were affected by chemical weathering, slope processes or human activities after their glacial deposition, thereby influencing the measured in-situ ^{36}Cl concentrations. In order to account for these complexities, we apply appropriate correction factors to obtain more accurate ages and discuss the related uncertainties.

Sample preparation of 14 additional samples was performed at the Laboratory for cosmogenic nuclide extraction at the University of Natural Resources and Life Sciences (BOKU) in Vienna. We will likely present ^{36}Cl/Cl and Cl-nat data of these additional samples measured at the Vienna Environmental Research Accelerator (VERA) at the time of the meeting. The exposure age data elucidate the spatio-temporal patterns of receding glaciers in the Northern Alpine Foreland, and place constraints on climate reconstructions for Central Europe during the late Pleistocene.

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Using stable isotopes and radiocarbon to extract climate information from grey mangroves with non-annual growth rings

Mr Matthew Goodwin[1], DR Danielle Verdon-Kidd[1], Dr Quan Hua[2], Dr Nathan B English[3], Dr Heather Haines[4,5], Dr Kathryn Allen[5,6,7]

[1]School of Environmental and Life Science, University of Newcastle, Callaghan, [2]Australian Nuclear Science and Technology Organisation , Lucas Height, [3]School of Health, Medical and Applied Sciences, Flora, Fauna and Freshwater Research, Central Queensland University, Townsville, [4]Chronos 14Carbon Cycle Facility, School of Biological, Earth and Environmental Sciences, University of New South Wales, Sydney, [5]ARC Centre of Excellence for Australian Biodiversity and Heritage, University of New South Wales, Sydney, [6]School of Geography and Spatial Science, University of Tasmania, Sandy Bay, [7]School of Ecosystem and Forest Sciences, University of Melbourne, Richmond

Theme: A-1: Earth's dynamic climate
Type of presentation: Oral Presentation

Hydroclimate variability in Australia is not well understood prior to the commencement of instrumental climate records in the mid-20th Century. Instrumental climate records can be extended further back in time using proxy data obtained from annual ring forming trees using dendrochronology. However, aside from several exceptions (e.g., Callitris spp.), suitable trees are rare in mainland Australia. Novel techniques such as bomb-pulse radiocarbon dating and stable isotope analysis have made it possible to obtain climate information from trees that do not form annual growth rings. Grey mangroves (Avicennia marina) are the most common mangrove species in NSW, but their growth layers are non-annual. However, grey mangroves are highly sensitive to climate-related variation in freshwater availability and soil salinity. In this study we demonstrate that radiocarbon-based time series of δ18O and δ13C measured from grey mangroves can be used as hydroclimate proxies.

Four grey mangrove stem sections were sampled from dead mangrove trees in the Myall and Hunter River estuaries in NSW, Australia in 2018 and analysed layer-by-layer for δ18O and δ13C using isotope ratio mass spectrometry. Four of the growth layers in each stem including the pith, the outermost layer and two other layers spaced evenly along the selected measurement radius were dated using bomb-pulse radiocarbon dating. A simple age / growth model was prepared for each stem assuming linear growth between the dated layers. Age estimates for all growth layers were truncated to integer calendar years allowing isotope data from the four stems to be averaged into composite δ18O and δ13C series covering the 1962-2016 period. The composite δ18O and δ13C time series were then assessed for similarity with a range of relevant climate variables using Spearman correlation analysis.

Significant correlations were found between δ18O and rainfall, days rain, sea level, vapour pressure, Palmer Drought Severity Index (PDSI) and the El Niño Southern Oscillation (ENSO). Grey mangrove δ18O values appear to reflect the relative proportions of assimilated sea water (δ18O ≈ 0‰ VSMOW) and 18O-depleted fresh water entering mangrove wetlands as rainfall and runoff. Higher δ18O values were observed during known droughts in the 1960's and during the millennium drought, whilst lower δ18O values occurred at the same time as La Niña events in 2010-12, 2007-08, 1998-2001, 1988-89 and 1973-76. The composite δ13C series was positively correlated with temperature, vapour pressure and evapotranspiration, suggesting that grey mangrove δ13C values were primarily influenced by atmospheric moisture demand. The most significant positive δ13C peak occurred at the same time as the intense El Niño drought of 1982/83, and the most significant negative δ13C peak occurred at the same time as the La Niña of 2010-12 that was the wettest 24-month period on record in Australia.

These results demonstrate that stable carbon and oxygen isotope ratios in grey mangroves yield valuable hydroclimate information. Grey mangroves can live for up to 800 years, are widespread along northern Australian and tropical coastlines and could provide important information regarding pre-instrumental climate in regions currently lacking high-resolution centennial scale climate proxy records.

Variability in the Holocene marine radiocarbon reservoir effect for the Tropical West Pacific

Dr Quan Hua[1], Prof Sean Ulm[2], Prof Kefu Yu[3,4], Dr Tara Clark[5,6], Dr Luke Nothdurft[7], Dr Nicole Leonard[6], Prof John Pandolfi[8], Dr Geraldine Jacobsen[1], Prof Jian-xin Zhao[6]

[1]Australian Nuclear Science and Technology Organisation, Lucas Heights, Australia, [2]ARC Centre of Excellence for Australian Biodiversity and Heritage, College of Arts, Society and Education, James Cook University, Cairns, Australia, [3]Guangxi Laboratory on the Study of Coral Reefs in the South China Sea and Coral Reef Research Centre of China, Guangxi University, Nanning, China, [4]Southern Marine Science and Engineering Guangdong Laboratory (Zhuhai), , China, [5]School of Earth, Atmospheric and Life Sciences, University of Wollongong, Wollongong, Australia, [6]School of Earth and Environmental Sciences, The University of Queensland, Brisbane, Australia, [7]School of Earth and Atmospheric Sciences, Queensland University of Technology, Brisbane, Australia, [8]ARC Centre of Excellence for Coral Reef Studies, School of Biological Sciences, The University of Queensland, Brisbane, Australia

Theme: A-1: Earth's dynamic climate
Type of presentation: Oral Presentation

Reliable determination of the marine radiocarbon reservoir effect (e.g., marine radiocarbon reservoir correction (ΔR)) is important for the construction of robust radiocarbon chronologies for marine archives for various research areas including archaeology, palaeoecology, paleoceanography, Quaternary research and climate change studies. In this study, we examined temporal ΔR variability for the South China Sea (SCS) and the Great Barrier Reef (GBR) during the past ~8.1 ka based on ^{14}C analysis of ^{230}Th-dated corals.

Coral samples, including Acropora sp., Cyphastrea sp., Favia sp. and Porites sp., were collected from Xisha (or Paracel) Islands and Yongshu Reef, Nansha (or Pratly) Islands in the SCS; Clerke Island, Gore Island, Haggerstone Island, Alexandra Reef and High Island in the northern GBR; and Great Keppel Island in the southern GBR. A total of 44 unaltered coral samples (based on SEM screening, δ^{234}U and initial ^{230}Th/^{232}Th ratios) were analysed for ^{230}Th and ^{14}C. ^{230}Th dates were determined using a VG Sector-54 thermal ionization mass spectrometer (TIMS) or a Nu Plasma MC-ICP-MS in the Radiogenic Isotope Facility, The University of Queensland, with a precision better than 0.5% (2σ). Subsamples of these dated corals were then taken for radiocarbon analysis using the STAR AMS facility at ANSTO with a typical precision of ~0.3-0.4% (1σ).

Results show large ΔR variations of ~410 yr and ~490 yr for the SCS and the northern GBR at ~5.5-8.1 ka and ~5.5-7 ka, respectively, and a smaller ΔR variability of ~200 yr for the SCS at ~2-3.5 ka. Changes in the sources (or ^{14}C level) of upwelled waters in the Tropical East Pacific, and variations in Pacific-wide and regional/local ocean circulation associated with climate change might be responsible for these observed ΔR variations [1]. The results of our study also indicate the need for regional marine radiocarbon calibration curves for improved radiocarbon dating of marine samples as the observed Holocene ΔR values for the Tropical Pacific are not fully reproduced by recent modelling work using a 3D ocean model [2], which takes into account climate change effects. Ocean circulation changes were included in the model for the period 11.5-50 ka but possibly not considered or not well represented for the Holocene, which might explain the differences between the observed and modelled ΔR values.

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Vegetation, fire and climate change in southwestern South Island (45°S), New Zealand since the Last Glacial Maximum

Dr William Henriquez[1,2]

[1]University Of Melbourne, Melbourne, [2]Victoria University of Wellington, Wellington,

Theme: A-1: Earth's dynamic climate
Type of presentation: Oral Presentation

I report pollen, spore and charcoal records from Lake Von (45°14'S; 168°17'E, 685 m.a.s.l), a small closed-basin lake located in southwestern South Island of New Zealand. These records allow the examination of past vegetation and climate changes during and since the Last Glacial Maximum (LGM). The record indicates dominance of alpine vegetation with cold-tolerant shrubs, herbs and ferns between ~18.0-16.7 ka, followed by a gradual transition toward Coprosma-dominated subalpine vegetation with the local presence of subalpine/montane hygrophilous trees between ~16.7-14.8 ka. These data suggest an early stage with cold and relatively wet conditions between ~18.0-16.7 ka under moderate southern westerly winds (SWW) influence, followed by cold-temperate conditions and a slight increase in precipitation between ~16.7-14.8 ka under strong SWW influence. I observe a rise in vegetation characteristic of alpine environments between ~14.8-12.6 ka at the expense of Coprosma, accompanied by increases in cold-tolerant hygrophilous species and lake levels. This was followed by the increase and dominance of Coprosma between ~12.6-10.8 ka, along with declines in alpine vegetation, cold-tolerant hygrophilous trees and lake levels. I interpret these data as indicating decline in temperatures and enhanced precipitation between ~14.8-12.6 ka under stronger SWW influence, followed by warming and reduced precipitation between ~12.6-10.8 ka under weak SWW influence. Conspicuous increases in Halocarpus and Phyllocladus between ~10.8-7.2 ka, along with increases in drought-resistant conifers and fire activity, suggest a further warming pulse and reduced precipitation under weaker SWW influence. The record shows an increase in the cool-temperate silver beech (Lophozonia menziesii) between ~7.2-3.7 ka, along with the hygrophilous conifer Dacrydium cupressinum and relatively low abundance but with high variability in the warm-temperate tall conifers. Within this multi-millennial-scale interval, I detect low-magnitude centennial-scale decline in Lophozonia menziesii and Dacrydium cupressinum between ~6.0-5.2 and ~4.4-4.1 ka, concurrent with increase in the drought-tolerant Prumnopitys taxifolia. These changes were followed by decline in Lophozonia menziesii and Dacrydium cupressinum between ~3.7-2.9 ka, sustained increase in Lophozonia menziesii, Dacrydium cupressinum and drought-intolerant species between ~2.9-1.9 ka, and a rapid and prominent rise in Fuscospora between ~1.9-0.56 ka. I interpret these data as a decline in temperature and a sustained rise in precipitation between ~7.2-3.7 ka under increased SWW influence. Superimposed upon, and following this multi-millennial climate trend, I detect alternating dry and wet oscillations of millennial- and centennial-scale with low precipitation between ~6.0-5.2, ~4.4-4.1, ~3.7-2.9, and ~1.9-0.56 ka under decreased SWW influence, and wet periods in the intervening intervals suggesting increased precipitation under strong SWW influence. Finally, the records show increased fire activity during the last ~600 years, coeval with a decline in arboreal pollen and rise in vegetation indicative of human disturbance (Māori). The climate trends detected from Lake Von record are coherent with variations of the SWW identified in other terrestrial mid-latitude records, suggesting synchronic and symmetric changes in the SWW during and since the LGM. These results might constitute the best empirical evidence in southern New Zealand to demonstrate high variability of the SWW during and since the LGM

A reinvestigation of lagoon specific local marine reservoir effects in Tongatapu, the Kingdom of Tonga, over the last 3000 years

Dr Naoto Fukuyo[1], Professor Geoffrey Clark[2], Professor Yusuke Yokoyama[1,3]
[1]Atmosphere And Ocean Research Institute, The University Of Tokyo, , Japan, [2]Archaeology and Natural History, College of Asia and the Pacific, The Australian National University, Canberra, Australia, [3]Department of Earth and Planetary Science, Graduate School of Science, The University of Tokyo, , Japan

Theme: A-2: Water resource sustainability
Type of presentation: Poster

Lagoon-specific local marine reservoir effects (ΔRlagoon) were defined in Fukuyo et al. (2020) as the difference between the ^{14} C activity of the open ocean and lagoon-specific values from the same time period to estimate the 14C activity change in the lagoon's freshwater proportion. This study also reported that ΔRlagoon values from fossil bivalves of Gafrarium tumidum excavated from archaeological sites in the Fanga 'Uta Lagoon, located on the north coast of Tongatapu Island, the Kingdom of Tonga. ΔRlagoon values in the lagoon increased linearly from 220 to 370 years between ~2.6 and 0.4 ka. These values suggested that the main cause of ΔRlagoon value increase was the closure of the Fanga 'Uta Lagoon due to relative sea-level (RSL) changes, which caused an influx of radiocarbon depleted water sourced from on-land Tongatapu Pleistocene limestone. However, ΔRlagoon values in Fukuyo et al. (2020) had large errors, and the calibration was conducted before the publication of the latest and more precise calibration data sets ShCal20 and Marine20. Here, we present new 15 ΔRlagoon values from G. tumidum fossils, combine these with the published values from Fukuyo et al. (2020), and recalculate ΔRlagoon using Marine20. Although the newΔRlagoon values were similar between 0.4 ka and 1.2 ka (160 to 170 years), the values increased from 2.6 ka to 1.2 ka (100 to 160 years). Fukuyo et al. (2020) reconstructed RSL changes between 2.6 and 0.4 ka using glacio-hydro-isostatic adjustment (GIA) modeling. The results of GIA modeling suggest RSL decreased sharply after 2.25 ka. This timing aligns with anΔRlagoon increase of approximately 50 years between 1.2 ka and 2.6 ka. In contrast, the absence of RSL change between 0.4 ka and 1.2 ka suggested freshwater influence in the lagoon was similar to the environment, and thus, ΔRlagoon was small. These results were consistent with paleotopographical comparisons reported in Fukuyo et al. (2020) and an archaeological study reported by Clark et al. (2015).

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Groundwater flow system in the Kamikita Plain, Japan, inferred from geochemical tracers including ^{36}Cl

Dr Yuki Tosaki[1], Dr Noritoshi Morikawa[1], Dr Kohei Kazahaya[1], Mr Hitoshi Tsukamoto[1], Mr Tsutomu Sato[1], Dr Hiroshi Takahashi[1], Mr Masaaki Takahashi[1], Dr Akihiko Inamura[1]
[1]*Geological Survey of Japan, AIST, Tsukuba, Japan*

Theme: A-2: Water resource sustainability
Type of presentation: Poster

For intermediate depth disposal of radioactive waste, evaluation of the impacts of long-term phenomena is important including glacial-interglacial sea-level changes (up to about 120-130 m). Because the movement of coastlines results in a shift of the discharge area of a regional groundwater flow system, sea-level changes can considerably affect groundwater flow regimes especially in coastal areas. To study its influence on groundwater flow, we attempt to extract palaeohydrological information from groundwater in a coastal sedimentary basin (the Kamikita Plain, NE Japan), using chemical and isotopic tracers including ^{36}Cl.

The Kamikita Plain is characterized by marine terraces developed widely throughout the plain. Positions of former shorelines corresponding to MIS 1, 5e, 7, and 9 have been reconstructed from the terraces and tephra layers. The difference in the elevations of these terraces indicate that the plain has uplifted with an average rate of 0.1–0.2 mm/yr at least in the late Quaternary period. The gradient of continental shelf is rather gentle in the offshore area of the southern part of the Kamikita Plain. It suggests that the horizontal extension of groundwater flow system during the interglacial-glacial transition is relatively large for the study area.

Based on water chemical composition, groundwater samples obtained from existing boreholes were divided into (1) Ca-HCO_3 type shallow fresh groundwater (>-400 m a.s.l.; Pliocene-Pleistocene aquifers), (2) Na-Cl type deep saline/brackish groundwater (-700 to -1,200 m a.s.l.; Miocene aquifers), and (3) Na-HCO_3 type deep fresh groundwater (-400 to -1,300 m a.s.l.; Miocene aquifers). Stable oxygen and hydrogen isotope ratios are distributed between the local meteoric water line and the value of seawater, indicating the mixing between meteoric water and seawater. Since ^{3}H is detected in about half of the Ca-HCO_3 type shallow fresh groundwater, they were recharged by relatively recent precipitation. The δD values of the Na-HCO_3 type deep fresh groundwater are ~10‰ lower than those of recent precipitation, suggesting that they were recharged in a colder period than the present. The ^{36}Cl/Cl ratios of the Na-Cl type deep saline/brackish groundwaters are comparable to the secular equilibrium value of the aquifer, except for coastal locations. This would indicate that old trapped seawater partly remains in Miocene aquifers of the plain.

The above results show that meteoric groundwater currently flows at a depth shallower than -400 m. During the glacial period, meteoric water reached to a depth of around -1,000 m due to sea level drop. However, old seawater trapped in deep Miocene aquifers are remaining in inland locations. It suggests that the meteoric flushing during the glacial period is rather limited in a sedimentary aquifer system as compared to a fractured rock aquifer system.

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Long term monthly measurements on water dissolved inorganic radiocarbon to understand the seasonal radiocarbon changes in three of Fuji Five lakes, Japan

Mr Kosuke Ota[1,2], Prof Yusuke Yokoyama[1,2], Dr Yosuke Miyairi[1], Dr Shinya Yamamoto[3], Dr Toshihiro Miyajima[1]
Atmosphere and Ocean Research Institute, The University of Tokyo, , Japan, [2]Department of Earth and Planetary Science, Graduate School of Science, The University of Tokyo, , Japan, [3]Mount Fuji Research Institute, Yamanashi Prefectural Government, , Japan

Theme: A-2: Water resource sustainability
Type of presentation: Oral Presentation

The process of water flowing into lakes through precipitation, groundwater, and river varies depending on the region and season. It is important to clarify the details of hydrological cycles for long term in order to know the state of the lake in the future. In this study, we investigated the water pathway of Fuji Five Lakes, Japan by measuring the radiocarbon concentration (Δ^{14} C) oxygen, and hydrogen stable isotopes of precipitation, groundwater, and lake water from 2018 to 2021.

Three out of five lakes, namely lakes Motosu, Shoji and Sai only have temporal inflow and outflow rivers, and the lake water property is defined by inflow of precipitation and groundwater. Therefore, the transportation pathway of water can be quantitatively estimated including the carbon transport process in the hydrosphere. The mass balance of water was then calculated from the groundwater recharge altitude, lake observation data, and the box model of groundwater and lake water Δ^{14} C.

In Lake Motosu, continuous surveys of surface water properties have been conducted, such as vanadium concentration, water temperature and water quality surveys in summer and winter, and vertical surveys of water temperature and water quality throughout the year. They show that precipitation is dominant to govern water property to the lake.

A single stage Accelerator Mass Spectrometer and a wavelength scan cavity ring-down spectrometer at the Institute of Atmosphere and Ocean Research, The University of Tokyo were used for the measurement of ^{14} C, oxygen, and hydrogen stable isotope ratios (δ^{18} O, δD). In addition, the results of the groundwater measurement and the water balance study were combined to provide a comprehensive picture of water exchanges.

The results show that Lake Motosu had the highest Δ^{14} C in January. In this lake, Δ^{14} C was found to increase in winter. No clear seasonal changes were observed in Lake Sai. Isotope ratio in Lake Motosu became lighter in summer.

We will present the three years long record of Δ^{14} C, δ^{18} O, and δD to discuss hydrological cycles for the Fuji Five Lakes.

Using radiocarbon and organic carbon characterisation techniques to identify the sources and degradation of dissolved organic matter in groundwater

Dr Liza McDonough[1,2], Dr Karina Meredith[1], Dr Helen Rutlidge[2,3], Dr Martin Andersen[2,3], Dr Denis O'Carroll[2,3], Mr Phetdala Oudone[2,4], Ms Megan Behnke[5], Dr Christopher Marjo[6], Dr Isaac Santos[7], Dr Robert Spencer[5], Dr Amy McKenna[8], Professor Andy Baker[2,4]

[1]Australian Nuclear Science and Technology Organisation, Lucas Heights, Australia, [2]Connected Waters Initiative Research Centre, Manly Vale, Australia, [3]School of Civil and Environmental Engineering, UNSW Sydney, Australia, [4]School of Biological, Earth and Environmental Sciences, UNSW Sydney, Australia, [5]Department of Earth, Ocean and Atmospheric Science, Florida State University, , USA, [6]Mark Wainwright Analytical Centre, UNSW Sydney, Australia, [7]National Marine Science Centre, Southern Cross University, Coffs Harbour, Australia [8]National High Magnetic Field Laboratory, Florida State University

Theme: A-2: Water resource sustainability
Type of presentation: Oral Presentation

Dissolved organic matter (DOM) plays a significant role in biogeochemical processes, ecological functioning, and carbon cycling. Interactions with the environment over time results in changes to the molecular size of DOM molecules as well as the number and arrangement of their atoms, thereby changing DOM reactivity, functioning and fate. Significant advances have been made in our understanding of surface water DOM sources and degradation throughout the past decade, largely due to the development of ultra-high resolution carbon characterisation techniques such as Fourier-transform ion cyclotron resonance mass spectrometry (FT-ICR MS) which can be linked to changes in radiocarbon (^{14} C) dissolved organic carbon (DOC) content. The sources and degradation of DOM in groundwater, however, remains poorly studied. This is in part due to the typically low (~1 ppm) DOM concentrations in these environments, meaning that in the past, large quantities of water were required for ^{14} C-DOC analyses. The ability to measure ^{14} C in small mass samples on ANTARES allows for a larger throughput of ^{14} C-DOC samples and quicker sample preparation due to lower quantities of water required. Here, we combine ^{14} C-DOC, ^{14} C of dissolved inorganic carbon (DIC), FT-ICR MS, liquid chromatography organic carbon detection, fluorescence and DOC concentrations to identify groundwater DOM sources at three locations in New South Wales. We then determine the changes in DOM character as it ages in groundwater. Sources identified include aged peat with an aromatic character and a young hydrophilic terrestrial source. The young terrestrial source was found to degrade into carboxylic-rich alicyclic molecules with intermediate hydrogen/carbon (H/C) and low to intermediate oxygen/carbon (O/C) ratios in shallow groundwater. In contrast, increasing thermodynamic constraints in deep confined aquifers resulted in an increase in ancient (up to 25,310 ± 600 years before present) low O/C DOM due to the preferential microbial decomposition of more oxidised formulae. We also identify the accumulation of high H/C and heteroatom containing microbial metabolites and biomass in deep highly aged anoxic groundwater. Our results show that the current paradigm of aged, stable DOM occurring in the centre of H/C versus O/C space may be constrained to well-mixed, oxic aquatic environments. In contrast, the oldest DOM appears instead to occur in anoxic aquifers where the most persistent formulae have high H/C and low O/C ratios. Interestingly, these formulae are typically biolabile in aerobic environments.

Testing the potential of Serpulidae tubes as an indicator of past relative sea level at higher latitude coast using shored wave dissipating blocks along the northern Pacific coast of Japan

Mr Kai Leggett[1], Yusuke Yokoyama[1], Yosuke Miyairi[1], Kosuke Ota[1], Naoto Fukuyo[1], Yoshiki Shirahama[2]

[1]The University of Tokyo, Atmosphere and Ocean Research Institute, [2]Advanced Industrial Science and Technology, Geological Survey of Japan, Research Institute of Earthquake and Volcano Geology, Active Fault Research Group

Theme: A-3: Living landscapes
Type of presentation: Poster

Determining the relative sea-level (RSL) is necessary to understand long-term crustal movement, because elevation of paleo-shorelines can indicate vertical displacement during tectonic uplift (eg., Tam and Yokoyama, 2021). Defining the sea-level range represented by each proxy is required to accurately determine RSL. High-resolution dating of the proxy is also required to assess long term RSL change. For high-resolution dating, a suitable sample must be used to minimize the age errors.

In western Japan, dating has been conducted using Pomatoleios krausii (PK), a type annelid which lives around ambient sea-level, as a RSL indicator (Shishikura et al., 2008). However, ^{14} C dating using PK has not been conducted along the Tohoku Pacific coast, northern Japan, due to sample scarcity caused by lower sea surface temperature (SST) despite frequent occurrence of earthquake. Therefore, using alternative proxies is necessary for reconstructing long-term crustal movements along the Tohoku Pacific coast. Hydroides ezoensis (HE) is a calcium carbonate tube forming annelid which lives around ambient sea-level and is widespread along the Tohoku Pacific coast. The reliability of HE as a RSL indicator, especially as a dating sample, must be confirmed for use in reconstructing long-term crustal movements.

Around the Tohoku Pacific coast, vertical mixing between the warm Kuroshio current (KC) and the cold Oyashio current (OC) occurs, where the OC flows underneath the KC. This fluctuation depends on the season, as the KC is dominant at the surface during the summer, and the OC is affective to the water mass near the surface during the winter. The OC is a deep water sourced current and has a relatively low ^{14} C values. Therefore, dating samples influenced by low ^{14} C values from the OC, results in large age uncertainties due to the local reservoir effect. From previous ecological research, HE is known to grow only during the summer (Miura and Kajita, 1983).
Through analysis and comparison of the HE Δ^{14} C with previous research, we examine whether it retains 14C value of the ocean surface during the Tohoku Pacific coast summer. We collected HE calcium carbonate tubes attached to Tetrapods shored at Iwate Prefecture, Tohoku. A total of 18 samples were collected and analyzed for Δ^{14} C using a single-stage accelerator mass spectrometer (AMS) at the Atmosphere and Ocean Research Institute, the University of Tokyo.

Aerial photographs showed that sampled Tetrapods were installed in the 2000s and shored between 2014 and 2016, suggesting that HE became attached to the Tetrapods during this period. The average of Δ^{14} C was compared with previous data during the same period. The results showed that samples were uninfluenced by the OC, indicating that HE retains ^{14} C value only from the ocean surface in summer when the KC prevails. This suggests that HE is suitable for high-resolution ^{14} C dating to reconstruct past RSL, and for nderstanding long-term crustal movements in Tohoku.

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10Be analysis of the rock samples from the lake terrace of a high-altitude lake (Pumoyum Co, south Tibetan Plateau)

Dr Fumiko Nara[1], Dr Takahiro Watanabe[2], Dr Yoko Kokubu[2], Dr Kazuho Horiuchi[3], Professor Liping Zhu[4]

[1]Nagoya University, Japan, [2]Japan Atomic Energy Agency, Japan, [3]Hirosaki University, Japan, [4]Chinese Academy of Sciences, Japan

Theme: A-3: Living landscapes
Type of presentation: Poster

The Tibetan plateau is the largest and the highest (ca. 4,500 m asl on average) plateau in the world. Because of its topographic features, the Tibetan Plateau has played an important role in global climate changes, especially Northern Hemisphere monsoon circulation. Furthermore, the Tibetan plateau is covered highly sensitive area to the Asian monsoonal activity. This means that the Tibetan plateau is an important key area to understand the hydrological response to the climate changes in the Asian region. Lake Pumoyum Co is located on the south Tibetan Plateau (altitude, ca. 5030 m asl; lake surface area, 281 km^2; maximum water depth, ca. 65 m), and a fresh water lake formed by fault activity on the south Tibetan plateau. Precipitation variability in this region is strongly influenced by Indian monsoon activity. Therefore, reconstruction for the past precipitation variability in this region gives us important insight into the past Indian monsoonal activity. The researches on the past climate and precipitation changes during the mid-Holocene using the sediment cores from Lake Pumoyum Co have been carried out. On the other hand, the researches on the past lake volume (lake level) changes are still limited. The lake terraces are developed on the eastern lake shore, and it supposed that the large lake level changes would have happened in Lake Pumoyum Co. The in-situ terrestrial cosmogenic radionuclide (TCN) can be used to estimate the earth surface processes, such as the erosion rate and exposure age dating of rocks. Here we report the results of 10Be values as the TCN of the rock samples from the lake terraces around Lake Pumoyum Co on the Tibetan Plateau. Rock samples were collected on 2009 China-Japan Scientific Research expedition. The ^{10}Be/^{9}Be ratios were measured relative to the ICN 01-5-1 standard (^{10}Be/^{9}Be = 2.709 ± 0.030 × $1/10^{12}$). The concentrations of 10Be were measured by the JAEA-AMS-TONO-5MV (AMS; 15SDH-2, National Electrostatics Corporation) in the Tono Geoscience Center, Japan Atomic Energy Agency. The 10Be concentrations ranged from 3.78-10.8 × 10^{6} (atoms/g), but the ^{10}Be values showed the decreasing trend following to the distance from the lake shore. This result indicates that ^{10}Be values of the rocks at the shore of the Lake Pumoyum Co could be influenced from the erosion rate or tectonic process rather than the exposure date resulting from the past lake level changes.

236U, 239+240Pu and 137Cs in Gaoyou lake sediment, East China

Dr Stephen Tims[1], Dr Yanan Huang[1,2], Dr Michaela Froehlich[1], Prof Shaoming Pan[3], Prof Keith Fifield[1], Mr Dominik Koll[1,4], Dr Stefan Pavetich[1], Dr Zuzana Slavkovská[1], Prof Anton Wallner[1,4]

[1]Australian National University, Canberra, Australia, [2]Sun Yat-sen University, , Zhuhai, China, [3]Nanjing University, Nanjing, China, [4]Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany

Theme: A-3: Living landscapes
Type of presentation: Oral Presentation

The depth distributions of ^{236}U, ^{239}+^{240} and ^{137}Cs have been investigated in a Chinese freshwater lake sediment core. The 14UD accelerator at ANU was used to make AMS measurements of ^{236}U and the plutonium isotopes, and ^{137}Cs was determined in the γ-ray spectrometry laboratories at Nanjing University. Pronounced peaks in the concentrations of all isotopes were identified with the 1963 peak in fallout activity. The ^{236}U/^{239}Pu and ^{239}Pu/^{137}Cs isotopic ratios show potential for use as markers of environmental change in lake conditions over the last 60 years. Results suggest long-term artificial aquaculture may affect radionuclide accumulation in Lake Gaoyou. The core also provides a record of potential contributions from sources other than global fallout, such as the Chinese nuclear weapons test site at Lop Nor (1964-1980) or from the Chernobyl reactor incident (1986). A comparison of the new data with the limited results from other freshwater deposits will be presented.

36Cl and 10Be production rate calibrations in the Pleistocene Ardèche lava flows (eastern edge of the Massif Central, France).

Dr Régis Braucher[1], Dr Guillaume Duclaux[2], Dr Vincent Godard[1], Mr Karime Keddadouche[1], Mr. Georges Aumaître[1]
[1]CEREGE, CNRS, Collège de France, IRD, INRAE, Aix Marseille Univ., Aix en Provence, France,
[2]Université Côte d'Azur, CNRS, Observatoire de la Côte d'Azur, IRD, Géoazur, Valbonne, France

Theme: A-3: Living landscapes
Type of presentation: Poster

In situ produced cosmogenic nuclides have revolutionized geomorphology by allowing quantification of surface processes operating at the Earth's surface. Numerous studies have been dedicated to the calibration of production rates in common target minerals (quartz for^{10} Be, $CaCO_3$ mainly for ^{36} Cl) because these minerals contain the main target elements (O, Si for ^{10} Be, Ca for ^{36} Cl). Most of these calibrations have been performed on geomorphological features (moraines, glacially polished rocks, boulders from landslides) where accurate independent ages are available (mostly from ^{14} C), most of them being younger than 20 ka, minimizing the effects of denudation.

The aim of this project is to work on minerals from basaltic rocks collected in the Ardéche mountains (SE France) on sites already studied and dated by Ar/Ar by Sasco et al (2017). As these well preserved and well exposed lava flows cover a temporal range of 20 to 200 ka, they offer a unique opportunity to calibrate production rates over such a long period and to assess if these long term production rates are in agreement with the ones actually used.

We will present preliminary results obtained on two lava flow surfaces dated at ~30 ka by Sasco et al. (2017) for which ^{36} Cl concentrations have been measured in whole rock. Together with these methodological developments we will also discuss the significance of this region geomorphology, where deeply incised valleys formed within ~300 Ma old basement rocks and tectonic forces have uplifted a plateau above 1400m despite downwearing due to long term denudation processes.

Ref:

Sasco, R., Guillou, H., Nomade, S., et al. 2017. 40Ar/39Ar and unspiked ^{40} K-^{40} Ar dating of pper Pleistocene volcanic activity in the Bas-Vivarais (Ardèche, France). Journal of Volcanology and Geothermal Research, 341, p. 301-314.

A multi-cosmogenic nuclide approach to assess sediment provenance and long-term denudation in the ancient Pilbara region, Western Australia

Ms Alissa Flatley[1], Dr Jan-Hendrik May[1], Dr Toshiyuki Fujioka[2], Dr David Fink[3], Dr Klaus Wilcken[3], Professor Ian Rutherfurd[1]
[1]School of Geography, Earth and Atmospheric Sciences, University of Melbourne, Melbourne, Australia, [2]Centro Nacional de Investigación Sobre la Evolución Humana (CENIEH) , Burgos, Spain, [3]Australian Nuclear Science and Technology Organisation, Sydney, Australia

Theme: A-3: Living landscapes
Type of presentation: Oral Presentation

The Pilbara region is characterized by extremely iron-rich Proterozoic bedrock geology which represents an enormous economic interest for Australia and the reason for extensive open-pit mining in the region. Investigating the role of terrigenous sediment supply is important to provide a baseline value of spatially averaged regional erosion rates across the landscape to help decipher in-channel responses of anthropogenically modified landscapes. In particular, quantifying long-term denudation rates within the region improves our understanding of sediment pathways, residence times and storage within the catchment setting. In this study, cosmogenic nuclides 26Al and 10Be from detrital samples are used to quantify basin-wide erosion rates and sediment flux within the Upper Fortescue River and to understand sediment provenance and its transport process in the area where mining operations are active.

Detailed analysis of catchment morphometric properties and lithology have been combined with multi cosmogenic nuclide (10Be and 26Al) measurements to provide much needed long-term denudation rates for the region, in addition to improving our understanding of first-order controls on catchment wide erosion. Our results indicate that erosion rates within the Upper Fortescue catchments are between 0.94-4.04 m/Ma. This value is similar to channel bedrock erosion rates (2.5 ± 0.8 m/Ma; n = 4), but somewhat higher than mesa summit or alluvial fan surfaces (0.8 ± 0.6 m/Ma; n = 13) in the Pilbara region, previously determined by cosmogenic 53Mn measurements (unpublished data). A two-isotope plot (10Be vs 26Al/10Be) shows that most of our sediment samples plot below the steady-state erosion-exposure island (26Al/10Be = 4.7 - 5.8), indicating a complex exposure history (or perhaps a reduced production rate) despite the shallow and transitory nature of Quaternary deposits in the generally bedrock-controlled landscape.

The apparent offset between bedrock erosion rates (in-channel, mesa plateau) and basin-wide average denudation rates infers that vast areas of iron-rich outcropping rock surfaces in the region are not the major contributor of sediments to the system. We consider two scenarios - i) sediment samples, after an initial exposure on exposed parent rock, experienced episodes of deep burial for a minimum few hundred thousand years, and/or ii) sediments are derived from reworked river bank and floodplain deposits into the channel system following storage at shallow depth for a prolonged period of time. Most of our data can be explained by being sourced from the average depth of 0.5-2 m.

Surprisingly, our cosmogenic nuclide derived erosion rates also show an apparent inverse relationship against average basin slopes. Hence, we explore various interpretations of our data in the context of specific morphometric, lithologic and environmental settings in the Pilbara region, and discuss the contribution of retreating vertical faces (e.g., gully, cliff) as a potential sediment source. Ultimately, this approach thereby contributes to the question whether foundational relationships between underlying morphometric conventions for catchment analyses are appropriate with these ancient, quiescent dryland landscapes.

A novel in-situ C-14 extraction system for surface exposure dating to reconstruct the past Antarctic ice sheet

Mr Yusuke Shimizu[1], Dr. Yusuke Yokoyama[1], Dr. Yosuke Miyairi[1], Dr. Masako Yamane[2]
Atmosphere and Ocean Research Institute, The University of Tokyo , Kashiwa, Japan, [2]Institute for Space-Earth Environmental Research, Nagoya University, Chikusa-ku, Japan

Theme: A-3: Living landscapes
Type of presentation: Oral Presentation

In-situ carbon-14 (C-14) surface exposure dating is a powerful tool to understand the Earth surface processes including reconstruction of past Antarctic ice sheets behavior during the late Quaternary (Hippe et al., 2017). However, the markedly small amounts of in-situ C-14 in quartz hampered the advance of study using this technique until recently (Lifton et al., 2001).

This study developed in-situ C-14 extraction system which heats samples to 1650 ℃ for extracting in-situ C-14 from quartz at Atmosphere and Ocean Research Institute, The University of Tokyo (Yokoyama et al., 2004; Fülöp et al., 2019). Our newly developed in-situ C-14 extraction system consists of three parts: the extraction furnace, the gas cleaning line, and the graphitization port. The new system employed novel heating furnace that requires dramatically short time to raise the target temperature for the experiment.

To test the extraction system performance, we prepared two types of granite samples, namely in-situ C-14 free samples and in-situ C-14 saturated samples. The initial experiments showed the high blank level (1.6 x 10^8 C-14 atoms) and the low extraction efficiency (5.6%).

Each procedural step required the blank test to understand the cause of high background, and the results suggested that several components of the extraction systems were identified as the source of C-14 contamination. After the revision of the apparatus design was made, the new system showed sufficiently low blank level (4.6 x 10^4 C-14 atoms).

The initial extraction system circulated Oxygen-Helium mixed gas during extraction heating to convert released carbon to carbon dioxide. This gas circulation possibly cooled the quartz sample and prevented quartz grains from releasing in-situ C-14. Thus, we improved our heating procedure to increase the extraction efficiency. The extraction furnace was filled with Oxygen-Helium gas before the heated extraction and was kept closed during the heating. The extraction efficiency ranged from 98% to 105% with this new procedure.

These results indicates that the novel system is successfully able to extract in-situ C-14 from sample for surface exposure dating.

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Accelerator Mass Spectrometry with 53Mn at University of Notre Dame

Mr Thomas Bailey[1], Ms Lauren Callahan[1], Mr Adam Clark[1], Dr Philippe Collon[1], Mr Austin Nelson[1], Dr Michael Paul[2], Dr Anton Wallner[3,4]

[1]University Of Notre Dame, Notre Dame, United States, [2]Hebrew University of Jerusalem, Jerusalem, Israel, [3]Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany, [4]Australian National University, Canberra, Australia

Theme: A-3: Living landscapes
Type of presentation: Oral Presentation

A new sensitivity measurement for ^{53}Mn is presented. At the University of Notre Dame's Nuclear Science Laboratory (NSL), an FN Tandem accelerator is used in conjunction with a Browne-Buechner Spectrograph operated in gas-filled mode and various detection systems to perform AMS. A new split-anode ionization chamber, MONICA, went through multiple commissioning runs at the NSL. As part of these commissioning runs, standard material (^{53}Mn/^{55}Mn = $2.53*10^{-10}$) and independently measured samples for ^{53}Mn were analyzed for the first time at the NSL. ^{53}Mn is an isotope of interest in AMS as it can be used as a geological chronometer and be used to study the deposition of interstellar matter on Earth. The low level detection of this isotope is challenging due to its stable isobar of ^{53}Cr and various suppression techniques are required to separate them. Analysis of the results and experimental techniques will be presented for this report.

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Ages of Pleistocene marine terraces in the south coast of Japan using in situ cosmogenic 10Be and 26Al

Prof. Yusuke Yokoyama[1], Dr Atsunori Nakamura[2], Mr Gen Nagano[1], Prof. Hideaki Maemoku[3], Dr Yosuke Miyairi[1], Prof. Hiroyuki Matsuzaki[4]

[1]Atmosphere And Ocean Research Institute, The University Of Tokyo, Kashiwa, Japan, [2]Geological Survey of Japan, National Institute of Advanced Industrial Science and Technology , Tsukuba, Japan, [3]Hosei University, Chiyoda-ku, Japan, [4]MALT, The University of Tokyo, Bunkyo-ku, Japan

Theme: A-3: Living landscapes
Type of presentation: Poster

Marine terraces are formed with the changes in the relative sea level (RSL) that is affected by combined effects of the eustatic sea level (ESL) and the tectonic movements (e.g. uplift, subsidence and isostatic effect). Therefore, determining the ages and the elevations of the marine terraces allows us to reconstruct the ESL and/or the tectonic history (eg., Tam and Yokoyama, 2021).

The southern coast of the Shikoku Island and the Kii Peninsula are located along the Nankai Trough where the Philippine Sea Plate is subducting under the Eurasian plate. There exist relatively well-preserved marine terraces along the coast with the elevation ranges between ca. 50 –100 m. The terraces are regarded as the suitable counterparts to reconstruct uplift history of the south coast of Japan due to this unique tectonic setting. However, the ages of these terraces have been inferred partially using tephrochronology. In this study, we attempted to determine the age of the marine terraces employing terrestrial in-situ cosmogenic radionuclides (TCN), 10Be and 26Al. This is the first age estimation of the marine terraces in Japan using TCN, allowing us to determine the uplift rates and the seismic history of the region.

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Bomb-pulse radiocarbon dating as a method for verifying atmospheric CO2 uptake during carbonate precipitation

Dr Kari Finstad[1], Dr Megan Smith[1], Dr Gregory Dipple[2], Dr Georges Beaudoin[3], Dr Naomi Marks[1], Dr Roger Aines[1]
[1]Lawrence Livermore National Laboratory, Livermore, United States, [2]University of British Columbia, Vancouver, Canada, [3]Université Laval, Quebec City, Canada

Theme: A-3: Living landscapes
Type of presentation: Poster

Precipitation of carbonate minerals is one of the most stable methods for removing carbon dioxide (CO2) from the atmosphere. Carbon mineralization occurs passively during the alteration of ultramafic rocks as cations (Mg2+ and Ca2+) are released and react with dissolved bicarbonate (HCO3-) to precipitate carbonate minerals. This process has been observed occurring naturally in numerous ultramafic settings, and previous studies have confirmed that actively precipitating systems incorporate modern atmospheric CO2 by measuring F14C > 1. There is a lot of interest in harnessing carbon mineralization as a CO2 sequestration strategy, however a method to account for carbon uptake is necessary. Here we report on our efforts to determine if bomb-pulse radiocarbon dating can be used to quantify atmospheric carbon sequestration and determine rates of precipitation during carbon mineralization.

We first validated our method by analyzing carbonate samples with known dates of precipitation at three time-points along the bomb curve. Two out of the three samples produced results within one year of the known sample precipitation date. We hypothesize that the sample which did not produce the expected result had an additional biological influence, as indicated by the d13C value. Samples from a suite of different ultramafic environments were then analyzed to further explore the applicability of this method, including a banded travertine to determine if calculating a rate of precipitation was possible. We conclude that bomb-pulse radiocarbon dating can be used to quantify the incorporation of modern atmospheric carbon during precipitation in certain environments, but calculating a rate of precipitation will be challenging and requires additional study. Careful sample selection is required, as is an understanding of local carbon cycling at individual sites.

Controls on 10Be dilution in catchments affected by coseismic landsliding: a 2016 Kaikōura earthquake case-study

Dr Clare Wilkinson[1], Dr Tim Stahl[1], Katie Jones[2,3], Dr Toshiyuki Fujioka[4,5], Dr David Fink[5], Dr Kevin Norton[2]

[1]University Of Canterbury, Christchurch, New Zealand, [2]Victoria University of Wellington, Wellington, New Zealand, [3]GNS Science, Lower Hutt, New Zealand, [4]Centro Nacional de Investigación sobre la Evolución Humana (CENIEH), Burgos, Spain, [5]Australian Nuclear Science and Technology Organization (ANSTO), Menai, Australia

Theme: A-3: Living landscapes
Type of presentation: Poster-Plus Presentation

The 2016 Mw 7.8 Kaikōura earthquake triggered tens of thousands of landslides across the northern Canterbury and southern Marlborough regions in the South Island of Aotearoa New Zealand. The influence of landslides generated by this earthquake on sediment generation, transport and deposition in stream networks has varied across the region and through time — some catchments show significant and near-immediate responses while others show little to no change despite the extensive landsliding. We measured 10Be concentrations in detrital quartz sands over a two-year period in the Conway River catchment, which has a total area of ~475 km2 and had ~13 M m3 of new landslide material liberated from hillslopes during the 2016 Kaikōura earthquake. Samples for 10Be analysis were collected at the rangefront of the Seaward Kaikōura Mountains and near the catchment outlet on three sampling campaigns between 2017-2018. We also carried out a similar sampling regime in the nearby Hurunui catchment, which was unaffected by the 2016 Kaikōura earthquake. Measured 10Be concentrations were converted to basin wide mean denudation rates using accepted GIS-based elevation and shielding programs. Our results indicate that apparent catchment-wide erosion rates in the Conway River (i) did not change through time, (ii) have remained similar to basin mean erosion rates for the Hurunui, (iii) overlap with the range of values for exhumation rates of the region (from previously published low-temperature thermochronology data), and (iv) are influenced in part by selection of grain size. We also compared our 10Be concentrations for the Conway catchment to values derived by modelling mean landslide 10Be concentrations constrained by local production rates, detailed mapping of all landslides across the catchment, area-volume scaling, and landslide-channel connectivity estimates. Our modelling estimates show that the mean 10Be concentrations derived from landslide sediment would have been sufficient to dilute pre-earthquake catchment-wide 10Be values by up to a factor of 3. We explore various landscape and landslide parameters that may explain the mismatch between measured and modelled 10Be and ascertain that the combination of storage, site specific channel connectivity, and landslide geometries/failure mechanisms likely exert first-order controls on in-situ 10Be concentrations following such a large catchment-wide disturbance event. We conclude that using fluvial quartz grains to characterise catchment response to landsliding and the mass balance of earthquakes, is subject to a number of factors that are highly site-specific.

Discordant 26Al/10Be ratios as an indicator of bedrock plucking: case studies from northern Australia

Dr Toshiyuki Fujioka[1], Dr Jan-Hendrik May[2], Dr David Fink[3], E. Prof Gerald Nanson[4]
[1]CENIEH, Burgos, Spain, [2]University of Melbourne, Melbourne, Australia, [3]ANSTO, Sydney, Australia, [4]University of Wollongong, Wollongong, Australia

Theme: A-3: Living landscapes
Type of presentation: Poster

With the number of multi cosmogenic nuclide data from detrital samples increased, it becomes apparent that discordant ^{26}Al/^{10}Be ratios are not exception but common. Traditionally, depressed ^{26}Al/^{10}Be ratios, below the nominal production ratio of 6.8, have been interpreted as prior burial. However, in northern Australia, such scenario is highly unlikely as the region is subject to intensive annual floods and therefore river channels normally lack long-term sediment storage. Another possible interpretation for lower ^{26}Al/^{10}Be ratios is non-steady state erosion, such as stochastic bedrock plucking. Such interpretation has an important implication to the sediment source and production mechanism, and therefore to the basin-wide erosion rate approach that assumes a steady-state erosion at sediment source. In this study, we measured ^{10}Be and ^{26}Al concentrations from three different waterfall sites in northern Australia with contrasting lithological and physical characteristics, in an attempt to capture depleted ^{26}Al/^{10}Be ratios. Our results indicate that ^{26}Al/^{10}Be ratios from two sandstone-dominated sites show consistently lower values (4.3-6.1), consistent with non-steady erosion interpretation, whereas data from a quartzite-dominated site (5.9-6.9) are indistinguishable from steady-state interpretation. Detrital samples collected downstream at each site indicate the similar trend as respective bedrock sites, implying that sediments are largely derived from the waterfall bedrock surfaces. In this paper, we discuss the results in the context of lithological difference and physical erosion mechanism between the sites.

Fish habitat study using radiocarbon of otoliths with stepwise dissolution technique

Dr Yosuke Miyairi[1], Prof. Yusuke Yokoyama[1], Prof. Toshi Nagata[1]
[1]Atmosphere and Ocean Research Institute, The University of Tokyo, 5-1-5 Kashiwanoha, Kashiwa-city, Japan

Theme: A-3: Living landscapes
Type of presentation: Poster-Plus Presentation

Fish habitats have been studies using instrument loggers tagged directly. Yet, their life-long migration histories are often difficult to reconstruct due to various obstacles including size of instruments and low recovery rates after catch and release. Chemical traces including radiocarbon, however, likely can overcome these problems to fill the gap of our scientific knowledge (eg., Larsen et al., 2017). Spatial variation of radiocarbon in North Pacific ocean is particularly large and hence we selected the area to demonstrate for proof of concept. Radiocarbon in the Pacific deep water depleted its values significantly since the water aged after isolation from the surface, thus depth information of water can be deduced. Surface variation of radiocarbon concentration can be found where different water masses meet. Off Japan is a such location where radiocarbon depleted Oyashio cold current (Δ^{14}C = －50‰) and radiocarbon less depleted Kuroshio warm current(Δ^{14}C = 50 to 70‰) is converged（Larsen et.al., 2017）.

Since otoliths of fish are recorded mainly by DIC in ambient seawater (eg., Kubota et al., 2015; Hane et al., 2020), analyzing the radiocarbon concentration for the calcium carbonate contained in the otoliths provides information of seawaters where the fish migrates. The otoliths of the western Pacific roughy (Hoplostethus japonicus) caught in Suruga Bay (Shizuoka prefecture) were treated by a stepwise dissolution method using phosphoric acid (Barr et al., 1993; Yokoyama et al., 2000), and carbon dioxide was extracted to make graphite. Each graphite samples converted from CO_2 extracted in step from the otoliths and analyzed using a single-stage accelerator mass spectrometer at the Atmosphere and Ocean Research Institute of the University of Tokyo (Yokoyama et al., 2019). The results show that radiocarbon concentrations in the otoliths are gradually decreased, indicating that the depth of habitat of the analyzed individuals gradually shifted from deep to shallow water.

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How far back can radiocarbon date using different materials through comparison with OSL

Ms Jiemei Zhong[1], Dr Xiaolin Xu[1], Dr Xianmei Huang[1], Prof Zhongping Lai[1]
[1]*Institute Of Marine Sciences, Guangdong Provincial Key Laboratory Of Marine Biotechnology, Shantou University, Shantou,, China*

Theme: A-3: Living landscapes
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Radiocarbon (C-14) dating has been accepted as a reliable and widely applicable dating method extensively applied in the field of archaeology and Quaternary geology. It is claimed that the C-14 dating limit can be up to 50-60 cal ka BP, based on ideal dating materials. However, it is argued that in practice the limit could be much lower (e.g., 25-35 cal ka BP). Recently, the results of the comparison between the optically stimulated luminescence (OSL) dating and C-14 have been published substantially. In this paper, we present an overview of the C-14 dating range using different materials to explore the upper limit of C-14 dating through comparison with OSL dating. It is demonstrated that the practical upper limit of C-14 dating is ~25-35 cal ka BP, regardless of dating various materials, including inorganic carbon, organic carbon, organic matter, or even plant remains. It's therefore suggested that radiocarbon ages greater than ~25-35 cal ka BP should be taken by caution. This severe underestimation could be due to modern carbon contamination.

Radiocarbon age offsets of plant and shell in the Holocene sediments from the central part of Sanriku coast, Northeast Japan

Dr. Toshimichi Nakanishi[1], Dr. Yuichi Niwa[2], **Prof. Wan Hong[3]**
[1]Museum of Natural and Environmental History, Shizuoka, Japan, [2]Keio University, Tokyo, Japan, [3]KIGAM, Daejeon, South Korea

Theme: A-3: Living landscapes
Type of presentation: Poster

To identify the chronological and spatial changes of the marine reservoir effect in the East Asia, the radiocarbon ages of pair samples of marine shells and terrestrial plants were measured from same horizons of Holocene sediment cores. This research project began in 2010 with a research on the Korean coast, and has established with research grants from the Japan Geographic Data Center, the National Research Council of Science & Technology of Korea and the Japan Society for the Promotion of Science. After explaining the outline of this research project in the southwest Japan [1-4] and the Korean Peninsula [5-7], a case study conducted in the Sanriku Coast of Tohoku region is introduced using three sediment cores [8-9]. The changes in depositional environment had been mainly associated by the sea-level rise during the last deglacial period. The reservoir ages of therty-seven pairs were obtained from the transgressive lag to delta front facies. The average value during 2000–9,000 cal BP was 420 ± 150 years within 100 ± 90 to 720 ± 60 years. The chronological change in the reservoir effect was consistent with the previous results in the Korean Peninsula and Southwest Japan such as the Hakata Bay, Oita Plain, Sukumo Plain and Miyazaki Plain. These relatively large variability of reservoir ages would reflect the sensitivity of the marine reservoir effect under the environment of warm Kuroshio and cold Oyashio Currents. This study was partially funded by the Japan Society for the Promotion of Science Kakenhi grant number JP18H01310.

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Rapid carbon accumulation in soil rapidly forming in the Southern Alps of New Zealand

Mr Eron Raines[1], Quan Hua[2], Anthony Dosseto[1], Claire E. Lukens[3], Julie R. Deslippe[4], Kevin P. Norton[5]

[1]Wollongong Isotope Geochronology Laboratory, School of Earth, Atmospheric and Life Sciences, University of Wollongong, Wollongong, Australia, [2]Australian Nuclear Science and Technology Organisation, Lucas Heights, Australia, [3]School of Natural Sciences, University of California , Merced, United States of America, [4]School of Biological Sciences, Victoria University of Wellington, Wellington, New Zealand, [5]School of Geography, Environment and Earth Sciences, Victoria University of Wellington, Wellington, New Zealand

Theme: A-3: Living landscapes
Type of presentation: Poster

Biota contribute 3-7 orders of magnitude more potential energy to landscapes than climate or tectonics alone. This potential energy is quantified as the system's net primary productivity (NPP), i.e., the net gain of photosynthetically sourced carbon. The effects of biological energy on landscape evolution is likely highly non-negligible, yet, has proven difficult to properly quantify in the past. Current methods for quantifying NPP vary in accuracy and can involve careful and costly study over the course of many years. The associated costs are often prohibitive for geomorphic studies. Therefore, NPP is not a commonly included measurement made in such studies. While relating biological to geomorphic processes in rapidly forming soils could help increase the predictive ability of current geomorphic models, a more suitable method for quantifying NPP is required to make this possible.

Here, we present a novel method combining uranium and carbon isotopes that can be used for quantifying soil NPP. The study was carried out on a rapidly forming, New Zealand soil. The uranium isotope composition of the soil was used to derive a soil age of 178 years. Given the soil's age, the soil production rate is 1.7 mm yr-1 which is one of the most rapid every quantified. Geomorphic models fail to predict such rapid soil production by a factor of ~2. Carbon-14 (14C) was also isolated from the same soil and quantified by AMS. The 14C measurements allow for the soil organic carbon (SOC) mean residence time (MRT) to be calculated. Utilizing a commonly employed biogeochemical model, the MRT allows for the calculation of the concentration of SOC as a function of time. In the rapidly forming soil, we measured a SOC content of 536 g-C m-1. Employing MRT and SOC to calculate the expected age of soil yielded a predicted soil age of 408 years. The discrepancy in MRT predicted age and the observed soil age indicates that the biogeochemical model fails to predict the rate of carbon accretion in the rapidly forming soil by a factor of ~2.

The work presented here is the first biogeochemical characterization of a soil forming more rapidly than current geomorphic models can accurately determine. Both the observed soil NPP and the soil formation rate exceed current model predictions. It is possible that a causal relationship exists, however, further co-characterization of biological energy input rates and soil formation rates is needed to test this hypothesis

Small scale wetland based sedimentary environmental change during the Holocene on the Konsen Plateau, eastern Hokkaido, Japan based on TOC and flowcytometry-pollen radiocarbon dating

Ren Tsuneoka[1], Yusuke Yokoyama[1], Kosuke Ota[1], Yosuke Miyairi[1], Reisuke Kondo[1], Minoru Yokochi[2], Kazuhiro Kaneko[3], Takashi Inoue[4], Norio Kito[5], Kyota Uemura[6], Mari Sumita[7], Arata Momohara[8], Hiroko Fujita[9]

[1]Atmosphere and Ocean Research Institute, The University of Tokyo,, [2]Graduate School of Global Food Resources, Hokkaido University,, [3]Graduate School of Agriculture, Hokkaido University,, [4]Research Faculty of Agriculture, Hokkaido University,, [5]International and Regional Studies, Hokkaido University of Education, , Japan, [6]College of Humanities and Sciences, Nihon University,, [7]GEOMAR Helmholtz Centre for Ocean Research Kiel, Germany, [8]Faculty of Horticulture, Chiba University,, [9]The Field Science Center for Northern Biosphere, Hokkaido University,

Theme: A-3: Living landscapes
Type of presentation: Poster

Widespread peatland and wetland distribution is common in eastern Hokkaido, Japan. However, few studies of paleoenvironmental transition history in small alluvial lowland wetland systems located on the Konsen plateau have been conducted. A major obstacle is the reconstruction of a robust age model. Bulk radiocarbon dating, generally used for determining age of peat, must be employed with caution in selection of samples since peat and wetland sediments contain both plant remains at the time of sedimentation and various organic materials such as roots that are mixed from the layer above after sedimentation (Shinozaki, 2013). Radiocarbon dating on macrofossils and marker tephra provide accurate ages, but they cannot always be found from wetland sediments. On the other hand, pollen fossils show accurate radiocarbon dates (e.g. Brown et al., 1992). In this study, we measured radiocarbon from pollen fossils contained in a sediment core taken from a wetland of Chanai region on the Konsen Plateau, eastern Hokkaido, Japan. This study marks the first use of pollen to measure radiocarbon concentrations of peat by using flowcytometry, which allows for substantially more efficient pollen screening compared to conventional methods. To reconstruct paleoenvironments, we conducted high resolution elemental analysis on samples to interpret the origin of the wetland sediments and their decomposition rate.

Tephra stratigraphic analysis of the core indicates that the transition to a wetland setting occurred between ca. 7.5-2.5 ka. Bulk radiocarbon dates suggest that the core sample preserved mostly continuous sediments from about 5.0 ka to the present. Results from elemental analysis showed that Total Organic Carbon (TOC) fluctuated between 20 and 40% at 90 to 60 cm below surface (cmbs), and between 40 and 50% at 40 to 5 cmbs, with a peak of 53% at 36 cmbs. The resulted carbon and nitrogen (C/N) ratios were about 14-20 between 90 and 40 cmbs, and were about 25 in the upper 40 cm of the core, with a sharp rise around 40 cmbs. Since C/N ratios decrease with the decomposition of peat (Kondo et al., 1997), this sharp rise suggests the changes in sedimentary preservation status occurred around this depth. We will further examine the transition of sedimentary environment in the wetland together with the results of radiocarbon dating using pollen fossils purified by newly developed flowcytometry system.

Testing the application of meteoric Be-10/Be-9 ratios on dating calcium sulphate-rich wedges from the Atacama Desert

Ms Aline Zinelabedin[1], Dr. Benedikt Ritter[1], Dr. Steven Binnie[1], Dr. Svenja Riedesel[2], Prof. Tony Reimann[2], Prof. Tibor Dunai[1]
[1]Institute of Geology and Mineralogy, University of Cologne, Cologne, Germany, [2]Institute of Geography, University of Cologne, Cologne, Germany

Theme: A-3: Living landscapes
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Subsurface wedges are common geomorphological features in periglacial environments and typically associated with polygonal patterned grounds on the surface. Polygonal patterned grounds are also observed surface expressions on Mars suggesting similar wedge structures and formation conditions in the Martian subsurface. Wedges in periglacial environments show a characteristic vertical lamination being the product of cryogenic processes in the subsurface. These geomorphological features similarly occur in arid to hyperarid environments, such as in the Atacama Desert, where haloturbation and salt heave mechanisms are suggested to control wedge-polygon formation. X-ray diffraction and x-ray fluorescence analyses of the wedges from the Atacama Desert revealed various calcium-sulphate phases as potential drivers for wedge-growth activity. The wedge formation is linked to varying water activity resulting in hydration- and dehydration-induced phase transitions of calcium-sulphate phases. In combination with crystallisation pressures of (re-)precipitating salts from infiltrated solutions, these salt dynamics lead to considerable volumetric changes in the deposits and result in a stress increase in the subsurface. The stress releases upward and expresses in a microtopographic signature of the surface, such as the polygonal patterned ground.

The subsurface-wedge activity in the Atacama Desert is strongly dependent on the occurrence of water of unknown state and volume. Geochronological data of calcium-sulphate wedges are crucial to temporally resolve the wedge formation and potentially use the wedge-polygon system as a palaeoclimate indicator. We test the application of cosmogenic nuclide dating on calcium sulphate-rich wedges from the Atacama Desert by using meteoric ^{10}Be/^{9}Be ratios. During wedge formation surface material is assumed to be transported through open soil fractures into the subsurface and deposited as alternating layers. Once the sediment is deposited, the meteoric ^{10}Be/^{9}Be ratio is only dependent on the radioactive decay of ^{10}Be, which allows us to constrain the time duration between numerous wedge samples. We also apply post-infrared infrared stimulated luminescence (post-IR IRSL) dating on the subsurface-wedge material to confirm the obtained meteoric ^{10}Be/^{9}Be data and possibly determine individual deposition ages. Our post-IR IRSL results of coarse-grain feldspars extracted from calcium-sulphate wedges indicate multiple phases of wedge formation during the Pleistocene.

The distribution and fractionation of beryllium isotopes in various reactive phases of Antarctic marine sediments

Mr Matthew Jeromson[1], Dr. Toshiyuki Fujioka[2], Dr. David Fink[3], Dr. Alix Post[4], Ms. Krista Simon[3], Dr. José Tonatiuh Sánchez-Palacios[5], Mr. Marcello Blaxell[1], Dr. T Gabriel Enge[6], Dr. Klaus Wilcken[3], Dr. Duanne White[1]
[1]University Of Canberra, Canberra, Australia, [2]Centro Nacional de Investigación sobre la Evolución Humana (CENIEH), Burgos, Spain, [3]Australian Nuclear Science and Technology Organisation, Sydney, Australia, [4]Geoscience Australia, Canberra, Australia, [5]Murdoch University, Perth, Australia, [6]Research School of Earth Sciences, Australia National University, Canberra, Australia

Theme: A-3: Living landscapes
Type of presentation: Oral Presentation

Beryllium isotopes, ^{10}Be and ^{9}Be, in Antarctic marine sediments are increasingly being applied as paleoenvironmental proxies and indicators of past ice shelf extent. The evidence base for interpreting meteoric-^{10}Be concentrations and ^{10}Be/^{9}Be ratios has largely been derived from examining their spatial distribution in modern depositional environments, or by correlation with other proxies in paleo-records, such as diatom abundance.

Meteoric-^{10}Be is geochemically adsorbed onto sediment grains in the reactive phase during transport from the atmosphere to deposition on the seafloor. Unlike meteoric-^{10}Be, ^{9}Be is both available within the reactive phase after crustal weathering and native within mineral lattice in significant quantities. The complexity in fixing and preserving the Be isotopes onto grain surfaces leads to uncertainties in selecting the chemistry methods to consistently extract the reactive phases of ^{10}Be and ^{9}Be in different sediments. This gap in understanding the physical behaviour and geochemical forms of reactive Be in Antarctic sediments limits their utility in reconstruction of paleoenvironmental conditions.

We conducted a sequential leach procedure on three homogenised sediment grab samples from the front of the Amery Ice Shelf that span a range of water masses. Using different chemical reagents, from very weak to very strong, five phases of Be isotope signatures were extracted sequentially, including : i) water soluble, ii) amorphous oxides leached by 0.5M HCl, iii) crystalline oxides leached by 1M NH_2OH-HCl in 1M HCl, iv) organic leached by 0.01M HNO_3 and H_2O_2, and v) mineral/residual phase dissolved by HF– with the water through to organic leach making the reactive phase. We found that the amorphous and crystalline oxide phases contained the largest fraction of ^{10}Be, about 90% of total ^{10}Be, with the remaining 10% being in the mineral/residual phase. For ^{9}Be, the oxide phases contained only 10-30%, the majority of ^{9}Be being in the residual phase. The water-soluble and organic chemical treatments were inefficient in extracting any significant reactive Be. This distribution has been observed in other deep marine and continental riverine sediments. However, the proportional distribution of the two isotopes between the amorphous and crystalline oxides differed for our Antarctic sediments compared to those other studies. While reactive ^{9}Be was close to equally split across the two oxide phases, 80% of reactive ^{10}Be was located within the amorphous phase, with the remainder within the crystalline oxide phase.

The difference in fractionation provides evidence for different sources of each isotope and different processes affecting their deposition. ^{9}Be is sourced primarily from the Earth's crust and is likely segregated into the different fractions during the process of subglacial chemical weathering. Open water ^{10}Be is processed in the water column, where interaction with biogeochemical processes likely segregates it into the more labile phases. These findings inform decisions regarding the selection of procedures for efficient and reproducible extraction of meteoric-^{10}Be, and for understanding the processes that drive the source and distribution of different isotopes around ice shelf systems.

The French Massif-Central, example of a not so inactive intraplate region

Dr Oswald Malcles[1], Dr Vernant Philippe[2], Dr Jean-François Ritz[1], Dr David Fink[3], Msc Gaël Cazes[4]
[1]Geosciences Montpellier, CNRS, Montpellier, France, [2]Geosciences Montpellier, University of Montpellier, Montpellier, France, [3]Australian Nuclear Science and Technologie Organisation, Sydney, Australia, [4]CENOTE, Nimes, France

Theme: A-3: Living landscapes
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Plate tectonic theory postulates that intraplate areas are geodynamically inactive regions, active geologic and seismic deformations being concentrated along more or less narrow areas: the plate boundaries. The tectonic plates are supposed rigid, allowing stress transfer from one boundary to another. Therefore, no deformation is expected within the intraplate regions.

True inactivity of intraplate areas is however refuted by evidences of active deformation. Many cases of intraplate earthquakes are known as for instance the lake Muir earthquake in 2018 (Mw = 5.3), the Botswana earthquake in 2017 (Mw= 6.5) or the New-Madrid sequence in 1811-1812 (4 events with Mw > 7).
Recent propositions tend to decouple plate tectonics dynamic from intraplate earthquakes (e.g. [1]). In this case, the processes generating the stresses are local (e.g. fluid migration) or transient (e.g. GIA) and therefore long-term intraplate deformations are unlikely to happen.

Significant intraplate deformations are however easily recognizable at the earth surface using the topography. Indeed, an important regional relief (Mountains) is the first evidence of earth surface long-term deformation and examples can be found for almost each intraplate region, for example: the Appalachians mountains (Northern America), the Great Dividing Range (Australia) or the Guiana highlands (Southern America). The origins of these topographic features are highly debated and almost every explanation has been given: tectonic stress, past tectonic frontier with old relief, dynamic topography, etc.
In many cases, the lack of absolute dating precludes the determination of the landscape evolution rates leading to inaccurate and sometimes physically unsound geomorphologic models.

Using the example of the French Massif-Central, we study if the long-term surface processes (erosion and sedimentation) can be responsible for intraplate deformation.
Quantification of the surface erosion and incision rates were performed using Terrestrial Cosmogenic Nuclides (TCN), mainly 10Be and 26Al. Using both mean watersheds derived denudation rates (covering the last ~ 15 ka) and long-term incision rates using endokarstic infilling (covering the last ~ 5 Ma) we show, despite local variations due to specific morphology and possible climatic variations, that the region is affected by significant erosion (s.l.) with a mean denudation rate of ~ 60 m/Ma of and an incision rate of ~ 90 m/Ma. Given the current ~ 300 m depth of the valleys, we conclude that this mountainous region is the consequence of a Plio-Quaternay uplift and therefore that intraplate area can be associated with active long-term processes leading to consequent finite deformation.
First order numerical model addresses the question of driving processes and show that a combination of thermal isostasy and erosion driven isostatic adjustment can explain both long-term uplift rate and distributed volcanic activity of the area.
Such relatively constant long-term uplift is expected to be at the origin of long-term stress concentrations and therefore intraplate earthquakes could be associated with low-frequency seismic cycles modulated by transient or local processes.

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Tracking shark spatial mobility patterns using 14C measurements on vertebrae growth bands

Dr Yota Harada[1], Dr Johan Gustafson[2], Dr Quan Hua[3], Dr Philip M. Riekenberg[4], Dr Axel Steinhof[5], **Dr Ricardo Fernandes**[6,7,8]
[1]Biogeochemistry Research Center, Japan Agency for Marine-Earth Science and Technology, Yokosuka, Japan, [2]Coastal and Marine Research Centre, Southport , Australia, [3]Australian Nuclear Science and Technology Organization, Kirrawee, [4]NIOZ, Royal Netherlands Institute for Sea Research, Department of Marine Microbiology and Biogeochemistry, Den Hoorn, Netherlands, [5]Max-Planck Institute for Biogeochemistry, Jena, Germany, [6]Max Planck Institute for the Science of Human History, Jena, Germany, [7]University of Oxford, Oxford, United Kingdom, [8]Masaryk University, Brno, Germany

Theme: A-3: Living landscapes
Type of presentation: Oral Presentation

Information on shark spatial mobility patterns is crucial to understand their feeding ecology and to identify prospective marine protected areas essential for their conservation. In this respect, radiocarbon can make a useful contribution by exploring spatial variations in marine radiocarbon reservoir effects. Here, we report data for seven sharks (1× scalloped hammer head, 1× tiger shark, 2× great hammer head, 3× great white shark) found dead off the Brisbane coastal region in Australia between 2016 and 2019. To examine temporal variations in dwelling areas and feeding habits, separate growth band samples were taken from a vertebra of each specimen for AMS 14C measurements, for carbon and nitrogen stable isotope analyses of bulk collagen, and nitrogen stable isotope analysis of single amino acids. Here we show considerable variability in 14C values among the different specimens and across time for each specimen which is indicative of individual spatial mobility patterns. We will discuss the use of novel Bayesian approaches to map temporal dwelling areas for each specimen by comparing shark vertebrae 14C results with the spatial distribution of surface marine radiocarbon levels effects . This has the potential of offering a new research tool for conservation purposes.

Utilizing meteoric 10Be to define the mobile-stable regolith boundary within unconsolidated sediment

Mr Nicholas Patton[1,2], Professor James Shulmeister[1,2], Dr. Toshiyuki Fujioka[3,4], Dr. David Fink[4], Krista Simon[4], Dr. Klaus Wilcken[4]
[1]University of Canterbury, Christchurch, New Zealand, [2]University of Queensland, St. Lucia, Australia, [3] Centro Nacional de Investigación sobre la Evolución Humana (CENIEH), Burgos, Spain , [4]Australian Nuclear Science and Technology (ANSTO), Lucas Heights, Australia

Theme: A-3: Living landscapes
Type of presentation: Poster

Understanding the physico-chemical properties of soil profiles are fundamental to evaluate long-term landscape evolution in response to climate, tectonic and human activities. The thickness of the mobile regolith; the portion of the soil profile that is experiencing down slope movement, is a key parameter controlling soil production and erosion rates on hillslopes. However, delineating the interface between the mobile and stable boundary is difficult, specifically in thick (>1 m) unconsolidated sediment profiles. In this study we evaluate the utility of in situ and meteoric 10Be depth profiles to define the mobile-stable regolith boundary at the Cooloola Sand Mass coastal dune fields, Australia. Our results indicate a fairly uniform profile for in situ 10Be concentrations, suggesting the profile is largely dominated by inheritance thus not appropriate for this application. In contrast, meteoric 10Be concentration displays a humped profile, where the concentration significantly increases near the boundary of A(E)- and B-horizons. This observation is largely consistent with the qualitative field observation of the mobile-stable boundary. Despite these positive outcomes, however, it is still uncertain whether the observed meteoric 10Be soil profile reflects the mobile-stable boundary or other changes in physiochemical characteristics (e.g., bulk density, bioturbation, zone of illuviation). Consequently, work is being undertaken to test this approach on other dunes of varying ages (0.5, 2, 5, and 10 ka) in the same area that represent different soil maturity stages and thus variable degrees of physical/chemical evolution of soil profiles. If successful, the development of this new method will be utilized to quantify the mobile regolith layer, which can then be used to create mass balance models of soil erosion and deposition in landscape evolution studies. It will control an important, previously difficult to define parameter in soil production and erosion studies.

14C dating correction method for tectonically active complex deep marine environments at cold seep vents off Eastern Japan: Seawater DIC acquisition by Calpyptogena sp. Bivalves

Mr Kazuhiro Yagasaki[1], Dr. Juichiro Ashi[1], Prof. Yusuke Yokoyama[1], Dr. Stephen Obrochta[2], Dr. Yosuke Miyairi[1], Dr. Shin'ichi Kuramoto[3]

[1]Atmosphere And Ocean Research Institute, The University of Tokyo, Tokyo, Japan, [2]Department of Earth Science, Akita University, Akita, Japan, [3]Japan Agency for Marine Earth-Science and Technology (JAMSTEC), Yokohama, Japan

Theme: A-4: Catastrophic natural events
Type of presentation: Poster

Shells and corals are often used as proxies for sea surface temperature reconstructions in paleoclimatology. These species utilise the dissolved inorganic carbon (DIC) in seawater making it suitable for analysing ocean circulation through the measurement of radiocarbon 14C. It is also possible to estimate the age of the shell through analysing the growth increments within the shells and radiocarbon 14C dating. Yet correction models in deeper marine environment remains complicated due to the multiple variables that must be considered, which include problems such as carbon sinks, ocean current flux and dead carbon effect from seafloor vents.

This study proposes a correction method at a depth of 600m at the Daini Tenryu Knoll off Tokai, Japan, which is a renowned region for recurrent M8 class earthquakes that occur very 100-150 years. Due to the regular tectonic activity and the presence for rich methane hydrate layers below the seafloor (Ashi et al., 2002, Otsuka et al., 2015), the fault regions are common with cold seep vents, which accommodate various sized colonies of Calyptogena sp. bivalves. We propose a novel method towards developing such a correction model in this complex environment and to determine if the Calyptogena sp. is affected by the methane from beneath the seafloor or from biogenic origins. Radiocarbon age of seawater DIC depth profiles and bivalve shell measurements conducted using a Single-Stage Accelerated Mass Spectrometer (AMS) (Yokoyama et al., 2007).

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A revised age estimate for the mid-Holocene eruption of Mount Hudson (H2) using a high-resolution radiocarbon chronology

Mr Panayiotis Panaretos[1,2], Dr Paul Albert[3], Dr Zoë Thomas[1,2], Dr Chris Turney[1,2], Dr Charles Stern[4], Dr Gwydion Jones[3], Dr Alan Williams[5,6], Dr Victoria Smith[7], Dr Alan Hogg[8], Dr Christina Manning[9]

[1]Chronos 14Carbon-Cycle Facility, Mark Wainwright Analytical Centre, University of New South Wales, Australia [2]Earth and Sustainability Science Research Centre (ESSRC), School of Biological, Earth and Environmental Sciences, University of New South Wales, Australia [3]Department of Geography, Faculty of Science and Engineering, Swansea University, UK [4]Department of Geological Sciences, University of Colorado, USA [5]EMM Consulting Pty Ltd, NSW, Australia [6]ARC Centre of Excellence for Australian Biodiversity and Heritage, School of Biological, Earth and Environmental Sciences, University of New South Wales, Australia [7]Research Laboratory for Archaeology and History of Art (RLAHA), University of Oxford, UK [8]Carbon Dating Laboratory, School of Science, University of Waikato, New Zealand [9]Department of Earth Sciences, Royal Holloway University of London

Theme: A-4: Catastrophic natural events
Type of presentation: Poster

Cryptotephra deposits (microscopic volcanic ash) are important geochronological tools that can be used to synchronize records of past environmental change. Here we report a distal cryptotephra from a Holocene peat sequence (Canopus Hill) in the Falkland Islands, in the South Atlantic. Using a high-resolution radiocarbon chronology and geochemical analysis (major- and trace-element) of individual volcanic glass shards, we provide a robust correlation between this cryptotephra and the large mid-Holocene explosive eruption of Mt. Hudson in Patagonia, Chile (H2; ~3.9 ka cal BP). While the commonly cited age for the H2 eruption is 3600 BP; ~3.9 ka cal yr BP, this is derived from 14C ages of bulk organic soil, sediment and peat deposits bracketing the tephra in South America. To better constrain the age of the H2 eruption, we derive a chronology from the peat sequence using a Bayesian deposition model from radiocarbon analysis of terrestrial plant macrofossils. Our age model dates the H2 tephra to 4265 ± 65 cal yr BP, suggesting that the eruption occurred slightly earlier than previously reported. The refined age and new geochemical reference dataset will facilitate the identification of the H2 tephra in other distal locations. We recommend future studies search for its presence across the sub-Antarctic islands and Antarctic Peninsula as a potentially useful chronological marker. Finally, this study improves our knowledge of the dispersion of volcanic ash from Mt. Hudson, allowing us to better understand the eruptive frequency and risks associated with the Hudson volcano.

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Cosmogenic radionuclides at Law Dome, East Antarctica, as signatures of past Solar storm events.

Dr Andrew Smith[1], Dr Mark Curran[2,3], Dr David Fink[1], Dr Michael Dee[4], Dr Margot Kuitems[4], Dr Vladimir Levchenko[1], Dr Andrew Moy[2,3], Dr Andrea Scifo[4], Dr Krista Simon[1], Dr Klaus Wilcken[1]
[1]ANSTO, Lucas Heights, Australia, [2]Australian Antarctic Division, Kingston, Australia, [3]Australian Antarctic Program Partnership, Institute for Marine and Antarctic Studies, Hobart, Australia, [4]Centre for Isotope Research, University of Groningen, Groningen, Netherlands

Theme: A-4: Catastrophic natural events
Type of presentation: Oral Presentation

This project investigates evidence for increased atmospheric production of cosmogenic radionuclides in ice core records at Law Dome, East Antarctica, during three extreme events. These events are the Carrington Event (CE) of 1859 AD [1], the largest solar storm of modern times, and two recently discovered cosmic radiation events of even greater magnitude, the Miyake Events (ME) of 774/5 AD [2] and 993/4 AD [3]. Our intention is to determine ^{14}C, ^{10}Be and ^{36}Cl profiles, with the highest sub-annual temporal resolution to date, across these events to determine whether or not all three events are manifestations of the same phenomena. Understanding the frequency, origin and magnitude of these events is essential for future-proofing modern communication infrastructure against such high magnitude radiation impacts from space. Identification of the events also provides an independent check on the Law Dome ice chronology.

New annual Δ^{14}C measurements in tree rings, in combination with earlier published data, show that the ME774 and the ME993 events occurred in close proximity to the point of maximum activity of the 11-year solar cycle [4]. Although it did not leave any radiocarbon signature, the CE1859 event was already known to have occurred around the point of maximum activity of the solar cycle from sunspot records.

Ice samples for ^{10}Be and ^{36}Cl analysis are derived from ice cores drilled near the summit of Law Dome, East Antarctica. This is the first time these radionuclides have been measured at the same site for these events, allowing a direct comparison of ME774, ME993 and CE1859 under similar transport conditions. Both ME samples were taken from sections of core where the amount of available ice was limited, and the CE samples were taken from a section where more ice was available. AMS measurements involved some method development at ANSTO, measuring both ^{10}Be and ^{36}Cl in the same samples, with sample sizes challenging for the ME samples. Preliminary ^{10}Be results at annual resolution spanning 30 years allowed an exact location of the events. We have clearly identified the expected ME774 and ME993 ^{10}Be peaks, which were ~ 4 years and ~ 2 years, respectively, within the error of when the layer-counted DSS ice core chronology had suggested. Accordingly, a further set of ^{10}Be samples at sub-annual seasonal resolution have been taken to better define the fine structure and amplitude of the signal but are currently not processed. We will also prepare a set of ^{36}Cl AMS targets from the sub-annual ice core samples and the initial annual survey samples. No discernible ^{10}Be peak or ^{36}Cl peak was found for CE1859 at annual resolution.

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Detection of solar events by using radiocarbon in tree-rings

Mr Nicolas Brehm[1], Dr Marcus Christl[1], Dr Florian Adolphi[2], Prof Raimund Muscheler[3], Prof Hans-Arno Synal[1], Florian Florian Mekhaldi[3], Mrs Chiara Paleari[3], Dr Timothy Knowles[4], Mr Emmanuelle Casanova[4], Dr Lukas Wacker[1]

[1]ETH Zürich, Zürich, Switzerland, [2]Alfred Wegener Institute for Polar and Marine Research, Bremerhaven, Germany, [3]Lund University, Lund, Sweden, [4]University of Bristol, Bristol, UK

Theme: A-4: Catastrophic natural events
Type of presentation: Invited Oral Presentation

The Sun irregularly expels large amounts of energetic particles into the interplanetary space and towards Earth which can be observed as so-called solar proton events (SPE). These large amounts of energetic particles can cause major damages to satellites and could even disrupt sensitive electronic systems at ground level. This rises the questions how often strong SPEs occur. Since sattalite observations of SPEs are limited to the last few decades, cosmogenic radionuclides are the most reliable tool to detect and study SPEs multiple millenia back in time.
The production rate of cosmogenic nuclides, such as radiocarbon, is primarily dependent on the incoming flux of highly energetic galactic cosmic rays (GCR). When the sun expels large amounts of highly energetic particles into the interplanetary space cosmogenic radionuclide production can suddenly be increased. There are findings of sharp increases in several radionuclide records (10Be, 36Cl, 14C) within less than one year, which can be attributed to SPEs.
Until now, only three strong SPEs could confidently be detected by using cosmogenic radionuclides. Analyzing annual 14C concentrations in tree-rings from Switzerland, Germany, Ireland, Russia, and the USA we discovered rapid increases in atmospheric 14C. The ~2% increases of atmospheric 14C recorded for both events exceed all previously known 14C peaks but after correction for the slowly varying geomagnetic field, they are comparable to the largest event of this type discovered so far at 775 CE. These strong events serve as accurate time markers for the synchronization with floating tree-ring and ice core records and provide critical information on the previous occurrence of extreme solar events which threaten modern infrastructure. Such sudden increases in radionuclide production also have the potential to be used to synchronize not precisely dated cosmogenic radionuclide records (e.g. 10Be and 36Cl in ice core records) with precisely dated records (14C in tree-ring records).

Holocene activity of the strike-slip faults revealed by sediment cores and ground penetrating radar profiling, the northern area of the Izu Peninsula, central Japan

Dr. Haruo Kimura[1], Prof. Toshimichi Nakanishi[2], Ms. Mei Yukawa[1], Mr. Takashi Hosoya[3], Dr. Wan Hong[4]
[1]Central Research Institute Of Electric Power Industry, Abiko, Japan, [2]Museum of Natural and Environmental History, Shizuoka, Shizuoka, Japan, [3]Chuo Kaihatsu Corporation, , Japan, [4]Korea Institute of Geoscience & Mineral Resources, Daejeon, Republic of Korea

Theme: A-4: Catastrophic natural events
Type of presentation: Poster

The Mjma=7.3 1930 Kita-Izu earthquake ruptured the N-S trending Kita-Izu fault zone, which was also called as the Tanna fault zone. The fault zone is located in the Izu Peninsula, northern tip of the Izu-Bonin-Mariana arc, and it consists of many sinistral strands and some conjugate dextral ones. The Sagiriko fault located to the south of the Kita-Izu fault zone also consists of N-S trending strands and conjugate ones. The Tanna fault zone and a N-S trending strand of the Sagiriko fault were ruptured during the 1930 earthquake, but Holocene activity of the conjugate E-W trending strands of the fault have not been revealed. We analyzed the near-surface structure profiled by ground penetrating radar (GPR) and accelerator mass spectrometry (AMS) radiocarbon ages of drill cores to estimate Holocene activity on the main strand of the Tanna fault, which caused the largest surface displacement in the fault zone during the 1930 earthquake, and one of the E-W trending strands of the Sagiriko fault, which have been reported no deformation during the earthquake. In order to detect detailed location of the fault trace on the surface, we first carried out aerial photograph interpretation and field observation before the drilling and GPR surveys. The drilling sites were arrayed near the Tanna fault and the Sagiriko fault, respectively. The GPR surveys were conducted along the arrays of the drilling sites. The GPR profiling data were collected by common-offset modes using pulseEKKO PRO GPR systems manufactured by Sensors and Software Inc., and we also carried out wide-angle measurements to estimate the electromagnetic wave velocity used in the time-to-depth conversion of the GPR sections. We interpreted several horizons showing local subsidence and past seismic events on the final depth-converted GPR sections of the Tanna and the Sagiriko faults, respectively. The horizons were dated by AMS radiocarbon ages of plant fragments and organic soil samples in the drilled cores. The chronology was confirmed by tephra layers such as the Kawago-daita pumice and Aira-Tanzawa ash. The horizons explained the Holocene activity of the E-W trending strand of the Sagiriko fault as well as the main strand of the Tanna fault. This work was started as a research project funded by the Izu Peninsula UNESCO Global Geopark. This study was partially funded by the Japan Society for the Promotion of Science Kakenhi grant numbers 15K01255 and 18K03768.

Identifying Solar Energetic Particle events of differing magnitudes through increases in 14C concentrations from high-resolution sampling of Southern Hemisphere tree rings

Dr Heather Haines[1,2,3], Prof Chris Turney[1,2,3], Dr Jonathan Palmer[1,2,3], Dr Zoë Thomas[1,2,3,4], Dr William Hiscock[3,4], Mrs Juee Vohra[3,4], Dr Kathy Allan[2,5], Dr Brendan Buckley[6], Asst Prof Ana Carolina Barbosa[7], Dr Christopher Marjo[3,4]

[1]School of Biological, Earth and Environmental Sciences, The University of New South Wales (UNSW), Sydney, Australia, [2]ARC Centre of Excellence for Australian Biodiversity and Heritage, UNSW Node, Sydney, Australia, [3]Earth and Sustainability Science Research Centre (ESSRC), The University of New South Wales, Sydney, Australia, [4]Chronos 14Carbon-Cycle Facility, Mark Wainwright Analytical Centre, University of New South Wales, Sydney, Australia, [5]School of Geography, Planning, and Spatial Sciences, University of Tasmania, Hobart, Australia, [6]Lamont-Doherty Earth Observatory, Columbia University, Palisades, USA, [7]Department of Forest Sciences, Federal University of Lavras, Lavras, Brazil

Theme: A-4: Catastrophic natural events
Type of presentation: Oral Presentation

Solar Energetic Particle (SEP) events cause increases in 14C concentrations in tree rings which are measurable at high resolution time scales. Known as Miyake events, two large 14C excursions in AD 774-775 and 993-994 have been identified in numerous tree-ring chronologies by laboratories around the world. These events generally are not observed in the standard 5-10 year resolution noted in most long-term tree-ring series. Annual ring analysis is required to pick up these short-term excursions. However, undertaking annual AMS 14C dating can be costly, time consuming, and, depending on the method, requires larger sample volumes than may be available. The Chronos 14Carbon-Cycle Facility at the University of New South Wales employs a Mini CArbon DAting System (MICADAS) which allows for high throughput of samples with only 10mg of wood needed to produce a full sized 1000µm graphite cathode using the Chronos cellulose preparation methods. This small sample requirement provides an ideal opportunity to search for SEP events using high-resolution dating.

In order to confirm our abilities to identify SEP events we have examined Manoao colensoi (New Zealand Silver Pine) samples from Oroko Swamp and observe both Miyake events in this species. Due to the ability for the MICADAS to process small samples sizes and the desire to better understand the seasonality of SEP events, we sampled the 6-year periods, AD 772-777 and 991-996, as sub-annual slices creating between 2 and 4 samples per annual ring. These slices were cut to 5-10mg in size and in the majority of cases 1000µm graphite cathodes could be prepared that were suitable for radiocarbon analysis. For seven cathodes smaller amounts of graphite were produced ranging from 559-848µm of graphite. However, detailed analysis at Chronos has determined that samples of this size produce reliable dates comparable to full sized cathodes. The results from this subsampled study helps to confine these events seasonally in the Southern Hemisphere.

Based on positive results identifying these large SEP events in Southern Hemisphere samples, we attempted to identify a smaller SEP event, the Carrington 1859 event, which had only been identified in Northern Hemisphere tree-ring samples. Here we again sampled the Oroko Swamp M. colensoi rings as well as Athrotaxis seleganoides rings from Tasmania, Australia, Callitris intratropica rings from the Northern Territory, Australia, Pinus merkusii rings from Thailand, Pseudotsuga menziesii rings from Vietnam, and

Cedrela odorata rings from Brazil. A core from each site was sampled from 1857-1861 again using sub-annual ring sampling to represent possible seasonal varaibility. The Carrington SEP event occurred on September 1-2, 1859 which, with the exception of C. odorata, falls at the very start of the growing season for each of these tree species. Our results represent the ability of locating this small SEP event from across a range of locations and species in the Southern Hemisphere.

Radiocarbon ages and tsunami deposits in laminated mud layers from the Lake Harutori, Pacific coast of Hokkaido, Northeast Japan

Dr Toshimichi Nakanishi[1], Dr Futoshi Nanayama[2], Prof. Yasuo Kondo[3], Dr Keitaro Yamada[4], Mr Keisuke Sakai[5], Dr Tatsuhiko Yamaguchi[6], Dr Kiyoyuki Shigeno[7], Dr Kota Katsuki[8], Dr Hirokuni Oda[2], Prof Wan Hong[9]

[1]Museum Of Natural And Environmental History, Shizuoka, Shizuoka, Japan, [2]Geological Survey of Japan, Tsukuba, Japan, [3]Faculty of Science and Technology, Kochi University, Kochi, Japan, [4]Research Centre for Palaeoclimatology, Ritsumeikan University, Kusatsu, Japan, [5]Graduate School of Human Development and Environment, Kobe University, Kobe, Japan, [6]National Museum of Nature and Science, Tokyo, Tsukuba, Japan, [7]Meiji Consultant Co. Ltd., Sapporo, Japan, [8]Estuary Research Center, Shimane University, Shimane, Japan, [9]Geochemical Analysis Center, Korea Institute of Geoscience & Mineral Resources, Daejeon, Republic of Korea

Theme: A-4: Catastrophic natural events
Type of presentation: Poster

In order to identify the chronological changes of the marine reservoir effect (MRE) in the Northeast Japan, the radiocarbon ages of terrestrial plants and marine shells were measured from two sediment cores obtained from the Lake Harutori, Northeast Japan [1-2]. This lake is located where the one of the greatest MRE were detected in East Asia, which faces on the Oyashio cold current. This drilling site locates in a tectonic active region in the southwestern Kuril arc associated by the oblique subduction of the Pacific Plate under the Okhotsk Plate [3]. Based on analyses of lithology, molluscan and diatom assemblages, and radiocarbon dating, we interpreted five sedimentary units in order of decreasing age: fluvial sediments, transgressive tidal flat, transgressive lagoon, deltaic lagoon sediments and artificial fills. The lagoon sediments consisted of laminated mud layers with terrestrial plant and marine shell fragments. They were intercalating 28 event deposits by 22 sand layers of tsunamis and 6 volcanic ashes [1-2]. The structure was clearly imaged by a core scanning of a computed tomography (CT) and X-ray fluorescence (ITRAX). The reservoir ages were obtained from the transgressive tidal flat to deltaic lagoon sediments in the last 9,000 years. The chronological change of MRE was correlated with the patterns from the other coastal area in Southwest Japan [4-7] and South Korea [8-10]. The core scanning of CT and ITRAX was performed under the cooperative research program of Center for Advanced Marine Core Research, Kochi University (Accept No. 18B061, 19A056, 20A063). This study was partially funded by the Japan Society for the Promotion of Science Kakenhi grant number JP18H01310.

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Slip rates for the Hyde and Dunstan Faults, southern New Zealand, revealed by cosmogenic radionuclide dating

Mr Jonathan Griffin[1,2], Prof. Mark Stirling[2], Dr Klaus Wilcken[3], Mr David Barrell[4], Krista Simon[3]

[1]Geoscience Australia, Canberra, Australia, [2]University of Otago, Dunedin, New Zealand, [3]ANSTO, Sydney, Australia, [4]GNS Science, Dunedin, New Zealand

Theme: A-4: Catastrophic natural events
Type of presentation: Oral Presentation

Reverse faulting in Otago, southern New Zealand, accommodates distributed tectonic convergence on the eastern side of the Australia-Pacific plate boundary. Paleoearthquake records from some of the faults in the region show highly variable earthquake recurrence times, and this work is focused on providing longer term context to these records. We use 10Be cosmogenic radionuclide dating of alluvial fan surfaces to characterise late Quaternary slip rates on two significant faults within the system, the Hyde and Dunstan faults. We determine a slip rate of 0.29 mm/yr (0.24 – 0.37 mm/yr at 95% confidence) for the Hyde Fault since 115 ka and a slip rate of 0.17 mm/yr (0.15 – 0.23 mm/yr 95% confidence) for the Dunstan fault since 320 ka. The lower rate for the Dunstan Fault, which has greater total displacement and is closer to the plate boundary, supports a hypothesis of migration of the deformation front eastward from the plate boundary. Both faults show deviations from a constant linear slip rate through time, with slip rates varying by a factor of 2 – 4 over timescales of 15 – 80 kyr. Increases in slip rate are out of phase on the two faults, supporting a hypothesis that strain is shared within the fault system over timescales on the order of 10s – 100s kyr; however, neither fault shows evidence for long periods of seismic quiescence.

Evaluating the effectiveness of bomb-pulse dating in the investigation of forensic anthropological human remains.

Miss Eden Johnstone-belford[1], Professor Soren Blau, Professor Stewart Fallon
[1]*Monash University, Melbourne, Australia*

Theme: A-5: Advancing human health
Type of presentation: Poster-Plus Presentation

Introduction:
When human remains are discovered, the identification of the decedent is the initial aspect of the forensic medical investigation. The determination of year of death can provide vital information in the identification of the decedent, by either including or excluding missing persons to whom the remains may belong. In cases of skeletonised, or badly decomposed remains, estimating the year of death can be difficult, due to high rates of variation in decomposition due to taphonomic factors. Bomb pulse dating, a technique which is unaffected by external factors, directly compares levels of 14C within human tissues to atmospheric levels, and can provide an estimate of the year of death.

Methodology:
This study measured the 14C content in samples of hair, nail and puparia collected from donors at the Australian Facility for Taphonomic Experimental Research (AFTER). A total of 14 hair, 11 nail and 13 puparia samples were collected from 18 donors whose bodies were placed outdoors on the ground surface between 2016-2018. All donors were born between 1924-1957, and died between 2016-2018, with a mean age at death of 76.
Sample analysis was undertaken at the Radiocarbon Dating Laboratory at the Australian National University (ANU). Hair and nails were de-fatted using a mixture of dichloromethane and methanol (2:1), before undergoing an ABA pre-treatment involving 0.1 M HCL (30 mins), 0.1 M NaOH (1 hour), and 0.1 M HCL (30 mins). The nail samples required a second defatting treatment before drying could occur. Puparia were physically cleaned to remove dirt and debris, before a 30-minute 0.1 M HCL soak.

Pre-treated samples were placed into quartz tubes containing an oxidation agent (CuO) and silver, and torch sealed under vacuum, before being combusted for 6 hours at 900C. Graphitisation was then carried out, followed by measurement by the accelerator mass spectrometer at the ANU radiocarbon dating laboratory (followed published standard procedures). All data is background subtracted using 14C free coal, corrected for □13C and reported as F14C.

Results and Conclusion:
All samples were found to contain 14C levels consistent with modern post 1950 levels. Of all the samples, 71% produced a calibrated YOD range which encompassed the actual YOD, and all samples contained 14C concentrations that were within 4 years of the atmospheric concentrations at the known year of death.

The nail samples provided the most accurate year of death estimations, with 91% correctly predicting YOD. Hair samples were also highly accurate, with a 79% correct prediction rate. Both hair and nails were found to have a lag time of 0-1 years.
Puparia was found to have the highest levels of 14C, and as such, were the least consistent with the actual YOD. However, while only 46% contained 14C levels consistent with atmospheric levels at the time of death, all puparia samples provided YOD estimates which were within 4 years of the actual year of death.
Based on the results of this study, hair, nail and puparia should be considered as useful samples to obtain accurate estimates for YOD using bomb pulse dating.

In vivo tracking of ^{14}C thymidine labeled mesenchymal stem cells using ultra-sensitive accelerator mass spectrometry

Dr Gwan-Ho Lee[1], Mr Min‑ Seok Oh[1,2], Mr Seul‑ Gi Lee[2], Prof C‑ Yoon Kim[2], Dr Jong Han Song[1], Prof. Hyung Min Chung[2], Dr Byung‑ Yong Yu[1]
[1]Korea Institute Of Science And Technology, Seoul, South Korea, [2]Konkuk University, Seoul, South Korea

Theme: A-5: Advancing human health
Type of presentation: Poster-Plus Presentation

Therapeutic effects of stem cells have been established but confirmation of the safety and the efficacy of stem cells is still required. This requires development of methods for quantification of stem cells that after introduction into the test organism. Commonly used methods for quantifying administered stem cells to organs are limited, with problems including limited sensitivity and damage to cells by the materials used during the labeling process.

To overcome these problems in particular, we radiolabeled the DNA of human stem cells (AD-MSCs) grown in vitro with a trace amount of ^{14} C thymidine with low radioactivity (5 nCi/mL, 24.2 ng/mL) that would have minimal effects on the properties and function of the stem cells.

We additionally demonstrate the utility of both liquid scintillator counter (LSC) and accelerator mass spectrometry (AMS) in investigating the distribution and quantification of radioisotope labeled adipocyte derived mesenchymal stem cells (AD-MSCs) after intravenous (IV) transplantation. The high sensitivity of AMS enabled quantification down to the single ^{14} C-labeled AD-MSCs cell level in various tissue while it was found that the sensitivity of LSC was below that of AMS. For LSC, AD-MSCs were only detected in the lung with the highest number of cells existing within the organ at 4 hr post-transplantation. This sharply decreased over time with little to no trace left by 72 hr. In contrast, AMS was able to detect a small number of cells located in all other tested organs but difficult to quantify larger numbers such as the lung's case due to over-detection. At 4 hr post-transplantation, the number of AD-MSCs per mg located in the spleen and liver was 19 ± 8 and 14 ± 1, respectively. And even lesser amounts or single cells were detected in the heart and kidney (1 ± 0 infused cells number/mg) while no cells were detected in the brain. This approach can show the results of a vital pattern of distribution for stem cells such as MSCs which is essential for both research and therapeutic purposes.

The potential for radiocarbon to understand the illegal pangolin wildlife trade

Dr Rachel Wood[1], Ms Erin Barr, Dr Stewart Fallon
[1]*Australian National University, Australia*

Theme: A-5: Advancing human health
Type of presentation: Poster-Plus Presentation

The eight species of pangolin found in Asia and Africa are the only truly scaly mammals, and the worlds most illegally traded animal. Between 2000 – 2019 an estimated 895,000 pangolins were taken from the wild, primarily for the trade in pangolin scales for use in Traditional Asian Medicine, and the trade appears to be increasing (Challender, et al., 2019). The IUCN has noted that research is required into life history and ecology, and trade trends. Basic information required for demographic models, such as life span, is not yet known, and there is currently no way to ascertain how long it takes pangolins to reach the Asian market following capture. This pilot project aimed to establish whether radiocarbon dating of scales could be used to examine how quickly pangolin scales grow, how scale growth is related to the age of the animal, and thus whether radiocarbon could be used to aid study of pangolin demographics and the wildlife trade.

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Tracing metabolic carbon routing in a mice feeding experiment using 14C at natural abundances

Dr Ricardo Fernandes[1,2,3], Dr Axel Steinhof[4]
[1]Max Planck Institute for the Science of Human History, Jena, Germany, [2]University of Oxford, Oxford, United Kingdom, [3]Masaryk University, Brno, Czech Republic, [4]4. Max-Planck Institute for Biogeochemistry, Jena, Germany

Theme: A-5: Advancing human health
Type of presentation: Oral Presentation

Metabolic routing knowledge is essential to understand how food nutrients are incorporated into consumer tissues. Pertinent information can be obtained using controlled feeding experiments and appropriate tracers. In this respect, stable isotope studies have been a valuable source of information although isotopic fractionation may, in some cases, impose limitations when interpreting obtained results. It thus becomes advantageous to explore the use of radiocarbon as tracer since its concentration values can be corrected for fractionation effects. Although enriched 14C has been used previously in controlled feedings experiments here we explore its use by using two protein sources (terrestrial vs. aquatic protein) at natural 14C abundances that differ significantly. These protein sources were fed in varying fixed ratios to mice individuals from five separate dietary groups. Hair keratin samples were taken after c. 3 months into the experiment and radiocarbon measurements performed on these and on food sources. The measurements allowed us to quantify the amounts of carbon from different macronutrients (proteins, carbohydrates, lipids) that are incorporated into hair keratin. We will present these results and discuss not only the implications that these have for the study of nutrition physiology but also for the use of stable isotope methods for dietary reconstruction and for aquatic dietary radiocarbon reservoir effect corrections in chronological projects.

236U/238U measurements in uranium ore concentrates at CAMS

Corinne Dorais[1], Scott Tumey[1], Naomi Marks[1], Gregory Brennecka[1]
[1] *LLNL, Livermore, United States*

Theme: A-6: Challenges of the nuclear age
Type of presentation: Oral Presentation

Uranium ore concentrate (UOC), the refined uranium product that is subsequently enriched for use in reactors and weapons, is one of the nuclear materials most frequently targeted for theft and trafficking. In the event that questioned UOC is recovered, nuclear forensic analyses are conducted to assist in provenance assessment. Such investigations rely on multiple forensic signatures that provide complementary information about the origin and processing history of a sample. One such signature that is still being developed is the 236U/238U ratio of a sample. Generally considered to be an anthropogenic isotope, 236U is also produced naturally at ultra-trace levels via neutron capture on 235U. Variation in the natural 236U/238U ratio, which has been shown to range from 10-14 to 10-10, is thought to be controlled by factors that affect the production or moderation of neutrons in the ore body such as ore grade, deposit age, the amount of certain trace elements present, and water content. However, because 236U is present at such low concentrations in natural materials, AMS is the only technique with the sensitivity to measure this ratio. Recently, the Center for Accelerator Mass Spectrometry (CAMS) at Lawrence Livermore National Laboratory (USA) made upgrades to the heavy element beamline, including the installation of a new 15º bending magnet, in an effort to further suppress 235U, which is up to 1011 times more abundant than 236U and can interfere with the 236U measurement. Details of the new 236U/238U measurement setup at CAMS along with preliminary results from a suite of UOC samples will be presented.

Actinide Accelerator Mass Spectrometry Development for Environmental Sampling and Neutron Capture Cross Section Measurements

Mr Adam Clark[1], Mr Thomas Bailey[1], Ms Lauren Callahan[1], Mr Austin Nelson[1], Dr Philippe Collon[1], Dr Michael Paul[2]
[1]University Of Notre Dame, South Bend, United States, [2]The Hebrew University of Jerusalem, Jerusalem, Isreal

Theme: A-6: Challenges of the nuclear age
Type of presentation: Oral Presentation

The detection of anthropogenic actinide isotopes in the environment has proven critical for monitoring releases from accidents or reprocessing facilities but has also led to unexpected signatures of stellar production. At the University of Notre Dame's Nuclear Science Laboratory, progress towards broadening our accelerator mass spectrometry (AMS) capabilities from I-129 to the actinides has been made. Following the implementation of a two microchannel plate time-of-flight system, measurements of uranium ores have been performed. Details highlighting the key developments towards a reliable measurement technique, the projected detector system limitations, a comparison of previously measured material, and preliminary results from a small subset of the "Ewing collection" of minerals and rocks housed at the University of Notre Dame will be presented.

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AMS measurements of C-14, Cl-36, and Pu-239/240 samples taken in a small facility

Mr Marco Michel[1], Mr André Filby[2], Dr Stefan Heinze[1], Mr Raphael Margreiter[1], Dr Erik Strub[1]

[1]*University Of Cologne, Cologne, Germany,* [2]*Gesellschaft für Anlagen- und Reaktorsicherheit (GRS) gGmbH, Berlin, Germany*

Theme: A-6: Challenges of the nuclear age
Type of presentation: Poster

Introduction

In Germany, the release of nuclear facilities from regulatory control is commonly addressed by demonstrating that possible contaminations with radionuclides are below the clearance values as given in the German Radiation Protection Ordinance. For certain radionuclides, those clearance levels are very low, e.g. 1 Bq/g for the unrestricted release of C-14. Such a limit might be a challenge for conventional decay counting techniques, especially regarding weak beta emitters like C-14 and Cl-36. Also, Pu-240 poses a challenge because it can practically not be distinguished from Pu-239 by alpha spectrometry since the respective alpha energies are very similar. However, for the release of a bigger nuclear facility from regulatory control, this poses no problem: it is good practice to define nuclide vectors, i.e. assuming a fixed composition of different radionuclides. Typically, these nuclide vectors contain some easily detectable nuclides like Co-60 as reference nuclides. The quantification of the radionuclides is then derived from the measurement results of these reference nuclides.

Contrary, in the case of so-called small facilities, like radiochemistry laboratories, the operational history might be unclear and/or a broad range of different radionuclides might have been utilized. In such cases, it might also be challenging to derive a common nuclide vector and it might be necessary to quantify radionuclides that are difficult to measure.

Also in such cases, AMS (accelerator mass spectrometry) is probably not the obvious choice for an analytical technique. However, this work aimed to demonstrate that AMS is able to provide valuable information for the release of small facilities from regulatory control. For this case study, a radiochemistry laboratory in Cologne, Germany was chosen. It was known that C-14, Cl-36 as well as Pu-240 had been handled openly in this lab. There were no apparent contaminations, i.e. no alpha/beta contaminations that could be detected using a hand-held radiation monitor. In total, 10 concrete samples were taken out of the walls and the floors of the facility and processed for the subsequent AMS measurements.

Methods

C-14 was directly measured without chemical separation by coupling an elemental analyzer to AMS. The measurement of the radionuclides Cl-36 and Pu-239/240 required chemical processing. Cl-36 was separated based on the separation procedure developed at the University of Cologne for the AMS measurement. This procedure was modified for the separation from concrete samples. Also, a modified approach was developed based on the separation procedure developed by Hoo. All AMS measurements were performed at the CologneAMS facility.

Results and Conclusion

An increased C-14 content was detected in 2 of 10 samples; this correlates with the rooms in which C-14 was openly handled. Increased Cl-36 values and traces of Pu-239/240 were found in all samples. All of the specific activities are well below the values for unrestricted clearance as given in. Nevertheless, the data correlates with locations in the laboratory in which corresponding radiochemical work was carried out. We conclude that AMS measurements might contribute to reconstruct operational history and/or to define nuclide vectors during decommissioning of a small facility.

Atmospheric gaseous and particulate Iodine-129 in Seville (Spain)

Dr. José María López-Gutiérrez[1,2], Mr. Juan Ignacio Peruchena[2,3], Dr Guillermo Manjón[1]

[1]Universidad de Sevilla, Sevilla, Spain, [2]Centro Nacional de Aceleradores (Universidad de Sevilla, CSIC, Junta de Andalucía) , Sevilla, Spain, [3]Consejo Superior de Investigaciones Científicas, Sevilla, Spain

Theme: A-6: Challenges of the nuclear age
Type of presentation: Oral Presentation

The origin of atmospheric 129I in the Northern Hemisphere is, nowadays, clearly linked to the emissions of the nuclear fuel reprocessing plans (NFRP) of Sellafield and La Hague. It is well known that these plants have released high amounts of 129I in both liquid and gaseous forms. Most part of the liquid discharges travel from both plants to the North Sea and then to the Arctic along the Norwegian coast. However, the impact of 129I liquid discharges is already evident in the whole North Atlantic Ocean. On the other hand, gaseous discharges, although much lower than liquid ones, distribute quickly over the Northern Hemisphere. In the last years, there has been a discussion on the origin of atmospheric 129I in Europe. Last studies carried out in Norther Europe seem to show that the formation of sea spray is the main responsible of the 129I in aerosols, as shown for example in Denmark [1]. In this work, 129I/127I ratios agree well with the ones measured recently in the North Sea. This and other evidence show that the North Sea surface is responsible for the presence of 129I in Danish aerosols. This result is compatible with previous results obtained for Northern and Central Europe.

In this work, we present weekly results for the 129I concentrations and 129I/127I ratios measured in the air of Sevilla (Spain) during the year 2013. Both magnitudes were determined independently by Accelerator Mass Spectrometry on polypropylene filters in order to determine them on particulate iodine. Also, 129I concentrations were measured in charcoal filters, that give information on gaseous iodine. Results show that the presence of 129I in the gaseous form is much more important than the particulate form. Particulate 129I concentrations are typically in the order of 104 at/m3 while gaseous 129I concentrations are at least one order of magnitude higher. 129I/127I ratios in particulate iodine are in the order of 10-9-10-8, and they are being currently determined in gaseous iodine. The origin of this 129I is not so clear as in Northern Europe, Surface North Atlantic water at mid latitudes has been shown to present isotopic ratios of 10-10 to low 10-8 recently [2], slightly lower than the ones measured in our work. However, no clear correlation between western wind origin in Sevilla during the periods of high 129I concentration.

Apart from this, there seems to be a correlation between gaseous and particulate 129I, which could reveal a common origin at least in a fraction of it or changes of physical form on the way from the source to the city.

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Characterisation of Reactor Graphite with Ion Beam Techniques

Martina Gwozdz[1], Timm-Florian Pabst[1], Max Steffan[1], Gereon Hackenberg, Klaus Eberhardt[3], Stefan Heinze[1], Susan Herb[1], Markus Schiffer[1], Alexander Stolz[1], Erik Strub[2], Alfred Dewald[1]

[1]Insititute of Nuclear Physics, University of Cologen, , Germany, [2]Division of Nuclear Chemistry, University of Cologne, , Germany, [3]Institute for Nuclear Chemistry, Johannes Gutenberg University Mainz, Germany

Theme: A-6: Challenges of the nuclear age
Type of presentation: Poster

Activated graphite, e.g. from graphite moderated reactors contains several radioactive isotopes like ^{14}C, ^{36}Cl, or ^{3}H. For the final disposal of such material a quantitative characterization is demanded. We are aiming for a system which enables automated measurements using the AMS technique with gaseous samples, especially for the isotopes ^{14}C, ^{36}Cl, and ^{3}H. The aimed system should provide a high sample throughput as well as the possibility of sample dilution in cases of high activity.

Therefore, for ^{14}C, a new gas-interface was built which uses two syringes for the transport of the sample gas into the ion source and separate reservoir for blank gas which can be used for the dilution. An advantage over the already established procedure using Liquid Scintillation Counting (LSC) is that the setup at the CologenAMS does not need elaborate chemical sample preparation. Additionally the LSC method is less sensitive with 2·10E-4 Bq/g whereas the AMS technique can be used down to 3·10E-9 Bq/g [1].

For the measurement of the tritium concentration, we expanded our ion source test bench. A 100 kV accelerator stage with a carbon stripper foil in the centre was installed along with an additional 90° analysing magnet and a silicon detector. This will allow efficient and accurate characterisation of the activity in reactor graphite material, which is foreseen to be stored in repositories like the e.g. mine Konrad where activity limits have to be considered.

In this contribution we will present the layout of our systems as well as the stage of realization.
Supported by BMBF under contract number 15S9410B.

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Chlorine-36 and Iodine-129 Inventories in Difficult-to-return Zone in Fukushima

Prof. Keisuke Sueki[1,2], Mr. Yuki Ohta[1,2], Mr. Hiroki Yokoyama[1,2], Mr. Yuta Ochiai[1,2], Mr. Seiji Hosoya[1,2], Dr. Maki Honda[1,2,3], Dr. Yukihiko Satou[1,2,3], Dr. Tetsuya Matsunaka[2,4], Mr. Tsutomu Takahashi[2], Ms. Masumi Matsumura[2], Prof. Kimihiko Sasa[1,2]

[1]Graduate School of Pure and Applied Science, University of Tsukuba, Tsukuba, Japan, [2]Accelerator Mass Spectrometry Group, Tandem Accelerator Complex, University of Tsukuba, Tsukuba, Japan, [3]Japan Atomic Energy Agency (JAEA), Tokai-mura, Japan, [4]Low Level Radioactivity Laboratory, Institute of Nature and Environmental Technology, Kanazawa University, Wake, Nomi, Japan

Theme: A-6: Challenges of the nuclear age
Type of presentation: Poster

The Fukushima Daiichi Nuclear Power Plant (FDNPP) accident in March 2011 released a large amount of radionuclide. It is necessary to clarify where and how much of chlorine-36 and iodine-129, which have a long half-life and are thought to have long-term effects, are accumulated in the soil. In particular, the investigation of iodine-129 is very important for understanding the extent of the effect of iodine-131 released at the time of the accident. Chlorine-36 has been reported by Miyake et al. [Miyake 2015], iodine-129 has been reported in an attempt to reproduce the amount of iodine-131 inventory [Miyake 2012, Muramatsu 2015]. In this study, we evaluated the accumulation of chlorine-36 and iodine-129 in areas strongly contaminated with radioactive cesium around the nuclear power plant and its northwestern area, which are still designated as difficult-to-return areas. The anarized samples were the soil around the nuclear power plant collected from 2008 to 2009 before the accident and the soil up to 5 cm from the surface layer collected in Okuma-machi, Futaba- machi, and Namie- machi from 2013 to 2016. The dried sample was sieved by 2 mm and then pulverized by a ball mill. It was placed in a U8 container and measured gamma-ray with a Ge detector, part of it was thermally hydrolyzed for iodine-129, and the other part was extracted with dilute nitric acid to extract the inorganic chloride component and measured chlorine-36. Both chlorine-36 and iodine-129 were determined by isotope ratio using the AMS course of the 6MV tandem accelerator at the University of Tsukuba. Stable chlorine was quantified using ion chromatography and stable iodine was quantified using ICP-MS. From the analysis of 31 points, ratios of ^{36}Cl/Cl were obtained from 1.38×10^{-13} to 1.00×10^{-11}. By evaluating the natural background before the accident as $(4.10 \pm 0.17)\times10^{-13}$, ^{36}Cl derived from the accident could be evaluated. Based on this, the accumulated amount of inorganic ^{36}Cl was determined, and 0.007-6.10 mBq/m² was obtained. When compared with ^{137}Cs, it was found to be as small as 10^{-9}. However, it has been found that the presence forms of chlorine in soil are considered to be inorganic and organic, and the amounts thereof are almost the same. From the analysis of 44 points of ^{129}I in soils, the results of ^{129}I specific activity in the range of 1.13-105 mBq/kg were obtained. Since this was 0.38±0.19 mBq/kg before the accident, it could be evaluated that iodine-129 was contaminated by the accident at all points. In comparison with ^{137}Cs, the ratio was large at a short distance from the nuclear power plant, but it was constant at 2.3×10^{-7} at the distance of 13 km or more to the northwest. It was possible to evaluate the degree of contamination of chlorine-36 and iodine-129 in difficult-to-return area by comparing with the data before the accident. The amount of iodine-131 inventory from the obtained amount of iodine-129, it became possible to estimate the effect of iodine-131 at the time of the accident.

Chlorine-36 deposition at Tsukuba, Japan, after the Fukushima Daiichi Nuclear Power Plant accident

Dr Kimikazu Sasa[1], Mr Yuta Ochiai[1], Dt Yuki Tosaki[2], Dr Tetsuya Matsunaka[3], Mr Tsutomu Takahashi[1], Mrs Masumi Matsumura[1], Prof Keisuke Sueki[1]

[1]University of Tsukuba, Tsukuba, Japan, [2]National Institute of Advanced Industrial Science and Technology, Tsukuba, Japan, [3]Kanazawa University, Nomi, Japan

Theme: A-6: Challenges of the nuclear age
Type of presentation: Poster

Many radionuclides were released to the environment during the Fukushima Daiichi Nuclear Power Plant (FDNPP) accident in Japan in March 2011, including ^{36} Cl (half-life 3.01 × 10^5 yr), and were transported in the atmosphere and deposited over large areas. However, there have been few studies of the ^{36} Cl release from the FDNPP, and the actual amounts released and deposited have not been accurately quantified. ^{36} Cl is a β-particle emitter (β decay 0.7092 keV, 98.1%; electron capture 1.1422 keV, 1.9%) and is difficult to quantify by radioactivity measurements with gas-flow detectors or liquid-scintillation counters. However, accelerator mass spectrometry (AMS) is suitable for ^{36} Cl measurements, with a detection limit of ~1 × 10E–6 Bq/kg (Sasa et al., 2018). Miyake et al. (2015) analyzed soil samples from around the FDNPP and confirmed that ^{36} Cl/Cl ratios in soils had risen by factors of 2–60 after the accident. However, no reports concerning atmospheric ^{36} Cl were available, and it was not clear how ^{36} Cl was transported or deposited. Matsumura et al. (2018) reported temporal variations of ^{129} I in rainwater at Tsukuba from March 2009 to October 2014, with ^{129} I concentrations in March 2011 being ~1000 times those of preceding months. It is expected that ^{36} Cl and ^{129} I would behave similarly in the environment as both are halogens, and a comparison of depositions of the two should therefore elucidate the dynamics of ^{36} Cl deposition following the FDNPP accident. Concentrations of ^{36} Cl in rainwater samples collected monthly at Tsukuba, Japan, during the period January 2010 to September 2011, were determined by accelerator mass spectrometry at the University of Tsukuba and used to calculate depositions. In March 2011, the monthly deposition of ^{36} Cl was (1.03 ± 0.02) × 10E–4 Bq /m², 18 times higher than the average for March in previous years. Monthly ^{36} Cl deposition was strongly correlated with that of ^{129} I (r = 0.7) and ^{137} Cs (r = 0.8) measured in the same rainwater samples from April to August 2011. The total amount of ^{36} Cl released by the FDNPP accident was estimated to be (1.4 ± 0.2) × 10^8 Bq based on the ^{36} Cl/^{129} I deposition ratio of March 2011.

Determination of I-129/I-131 in surface soils related to the Fukushima Daiichi Nuclear Power Plant accident

Dr Kimikazu Sasa[1], Mrs Masumi Matsumura[1], Dr Tetsuya Matsunaka[2], Mr Tsutomu Takahashi[1], Dr Yukihiko Satou[3], Dr Norikazu Kinoshita[4], Prof Hiroyuki Matsuzaki[5], Prof Keisuke Sueki[1]

[1]University of Tsukuba, Tsukuba, Japan, [2]Kanazawa University, Nomi, Japan, [3]Japan Atomic Energy Agency, Tokai, Japan, [4]Shimizu Corporation, Koto-ku, Japan, [5]The University of Tokyo, Bunkyo-ku, Japan

Theme: A-6: Challenges of the nuclear age
Type of presentation: Poster

Total amounts of radionuclides discharged into the atmosphere were estimated to be 8.1 GBq for ^{129}I (half-life 1.57 × 10^7 y) (Hou et al., 2013) and 120 – 200 PBq for ^{131}I (half-life 8.02 d) (Chino et al., 2011) released from the Fukushima Daiichi Nuclear Power Plant (FDNPP) accident. Although the accident-derived ^{131}I in soil extinguished in a few months, the long-lived ^{129}I can be used as a tracer to retrospectively infer the level of ^{131}I. The ^{129}I/^{127}I ratio for the prepared AgI sample including iodine carrier with an ^{129}I/^{127}I ratio of 1.8 × 10E–13 was measured using AMS at the MALT, The University of Tokyo. The ^{129}I/^{127}I ratios and ^{129}I concentrations in surface soils were calculated using the ^{127}I concentration obtained from an inductively coupled plasma-mass spectrometry and the ^{129}I/^{127}I ratio obtained from the AMS, and by subtracting the ^{127}I and ^{129}I contents of the background during the sample preparation. Pre-accident levels of ^{129}I concentration were estimated to be (2.7 ± 1.4) × 10^8 atoms/g at Fukushima. We determinated the ^{129}I/^{131}I atomic ratio in surface soils of Fukushima area for reconstruction of the ^{131}I deposition using the long-lived ^{129}I, which has same behavioral response with ^{131}I in the environment. For this purpose, we investigated the concentrations of ^{129}I among 5-cm-long surface soils in and around Fukushima area, which were measured for ^{131}I immediately after the accident by gamma-ray spectrometry (Kinoshita et al., 2011). Average ratio of ^{129}I/^{131}I was estimated to be 26.0 ± 5.7 as at March 11, 2011. The correlation coefficient (R^2) is 0.98 between concentrations of ^{129}I and ^{131}I in surface soils at Fukushima. We also found the deference of ^{129}I/^{131}I ratios depending on the locations. It is thought to be due to reflect differences related to emission sources from the FDNPP. Previous studies has reported the ^{129}I/^{131}I ratios of 31.6 ± 8.9 (Miyake et al., 2012), 26.1 ± 5.8 (Miyake et al., 2015), and 21 (Muramatsu et al., 2015) in surface soils. The calculations for ^{129}I/^{131}I ratios by the ORIGEN2 code resulted 31.4 for the Unit 1 reactor, 21.9 for the Unit 2 reactor, and 20.8 for the Unit 3 reactor (Nishihara et al., 2012). Our result of 26.0 ± 5.7 for ^{129}I/^{131}I ratio was consistent with previous studies and the estimates by the ORIGEN2 code.

First evidence of plutonium and uranium fallout on a Southern Ocean Island (Macquarie Island, 54°S, 158°E)

Dr Krystyna Saunders, Mr David Child, AD Griffiths, JJ Harrison, Dr Mike Hotchkis, G Motta, SJ Roberts, A Zawadzki

Theme: A-6: Challenges of the nuclear age
Type of presentation: Poster

Plutonium and uranium concentrations and isotopic signatures may be used to trace the changing patterns and locations of nuclear testing activities and the resulting spatial distribution of fallout. Virtually nothing is known about the fallout distribution of plutonium and uranium in the Southern Ocean region. Although only 10% of the atmospheric nuclear weapons detonations between 1945 and 1980 were conducted in the Southern Hemisphere, atmospheric transport meant that it received a much larger proportion of fallout – about one third of the total inventory. Lake sediment and peat records from the few remote sub-Antarctic islands in the Southern Ocean provide unique and undisturbed archives for investigating fallout histories, and an opportunity to bridge the spatial gap between the Southern Hemisphere mid-latitudes, where records show mixed regional and global signatures, and Antarctica, where global signatures dominate.

Here, we present the first nuclear weapons testing fallout history for a sub-Antarctic island using a lake sediment core from Macquarie Island. Macquarie Island is nearly equidistant from Tasmania, New Zealand and Antarctica at 54°S, 158°E. It has an area of 120 km2 and lies just north of the Polar Frontal Zone in the core belt of the Southern Hemisphere westerly winds, which dominate the climate of the Southern Hemisphere mid-high latitudes.

A 54.0 cm sediment core was collected from a small lake on the western edge of the Macquarie Island plateau. It was sampled at 0.5 cm increments, dated using 210Pb (ages calculated using the constant flux, constant sedimentation model) and 14C, and scanned with micro x-ray fluorescence and hyperspectral (400-1000 nm) core scanners to identify stratigraphic and geochemical variations through time.

The core spanned ca. 2000 years, with the upper 18.0 cm dating back to ca. 1900 based on 210Pb dating. Plutonium and uranium fallout isotopes 239Pu, 240Pu, 241Pu and 236U were measured on this part of the core. The profile demonstrated the onset of nuclear weapons testing at 12.0-12.5 cm (late 1940s based on 210Pb dating) with a 240/239Pu atom ratio of 0.24. This coincides with ratios typical of US testing in the Pacific Proving Grounds, which were the dominant source of global fallout at the time. Concentrations of all isotopes sharply increased between 12.5-9.5 cm and peaked at 9.5-10.0 cm, which, based on 210Pb dating corresponds to ca. 1963. In the late 1950s and early 1960s, there was a change to a lower 240/239Pu atom ratio of 0.17 coinciding with the shift from US testing dominating global fallout to that of the former Soviet Union. A replicate sediment core from another lake on Macquarie Island is currently being analysed to verify these findings, as well as records from other sub-Antarctic islands, with the aim of tracing the changing patterns and locations of nuclear testing activities and resulting spatial distribution of fallout in the mid-late 20th century.

First results from the Zurich Sea Water (ZSW) U-236 intercomparison sample

Dr Marcus Christl[1], Dr. Arne Bratkič[6], Prof. Núria Casacuberta[1], Dr Maxi Castrillejo[1], Dr Elena Chamizo[2], Dr Laura Fantozzi[7], Dr Karin Hain[3], Dr Joze Kotnik[5], Dr Mu Lin[4], Dr Mercedes López-Lora[2], Dr Jixin Qiao[4], Prof Hans-Arno Synal[1], Dr Anne-Marie Wefing[1]

[1]ETH Zurich, Laboratory of Ion Beam Physics, Zurich, Switzerland, [2]Centro Nacional de Aceleradores, Universidad de Sevilla, Seville, Spain, [3]Faculty of Physics, University of Vienna, Vienna, Austria, [4]Technical University of Denmark, Department of Environmental Engineering, Roskilde, Denmark, [5]Jozef Stefan Institute, Department of Environmental Sciences, Ljubljana, Slovenia, [6]University of Liège, Chemical Oceanography Unit, Liège, Belgium, [7]National Research Council of Italy, Water research institute, Verbania, Italy

Theme: A-6: Challenges of the nuclear age
Type of presentation: Poster-Plus Presentation

During the Fenice11 expedition to the Tyrrhenian Sea in 2011 several samples totaling more than 350L seawater were collected in for 236U/238U analyses at ETH Zurich. Due to a chain of unfortunate circumstances the sample labels were not readable any more when they arrived at LIP (ETH Zurich). We decided not to discard the seawater but instead to prepare a large volume intercomparison sample for 236U.

All samples collected in 2011 were pumped through 0.45µm filters into a 400L plastic tank and then slightly acidified to pH3. After homogenization the seawater was filled into 35 ten liter plastic cubitainers. One or two cubitainers were sent out to each lab that intended to participate in the intercomparison study. The labs were asked to apply their standard sample processing procedures. The AMS labs were primarily asked to provide information on the 236U/238U ratio and (if possible) on the 236U and 238U concentrations of the sea water sample.

So far, several batches of the ZSW intercomparison samples were processed in four different chemistry labs and measured on four different AMS systems. While all four AMS labs returned information on the 236U/238U ratio of the intercomparison sample and most of them provided 236U and 238U concentrations, some additionally reported 233U/238U ratios and shared their results on Pu-, Am-, and Np-isotopic composition of the seawater sample.

While not all participating labs have yet reported their results this contribution intends to present the current status of the intercomparison study. A preliminary analysis shows that the different AMS labs reported very consistent results on the U-isotopic composition of the sea water sample. A preliminary consensus value for the 236U/238U ratio and the 236U and 238U concentrations will be presented. Also the results for the other actinides will be presented but the number of contributing labs is still too small for providing a consensus value.

The fact that the ZSW has been characterized by many different AMS labs makes the ZSW sample a valuable internal standard for quality control for the analysis of anthropogenic U-isotopes in seawater.

Forensic research on the year of birth by human teeth sequential sampling in the range of 14C peak

Miss YiHsien Lin[1], **Prof. Xiaohong Wu[1]**
[1]*School Of Archaeology And Muselogy, Peking University, Beijing, China*

Theme: A-6: Challenges of the nuclear age
Type of presentation: Poster

The sequential dentine samples is a potentially powerful method for studying the early life histories of individuals. Enamel and dentine grow incrementally, and the isotopic composition of the tissues on different time scales (daily to yearly) remains in the tooth. Except for the wisdom teeth (the third molars), the permanent dentition of humans are fully developed when they are about 12 years old. Therefore, the teeth completely record the period of rapid growth in the early life of humans. However, the incremental growth structure of dentine is full of complexity. Current methods, such as horizontal cross-section sampling of half or quarter of a tooth from which inorganic minerals have been removed, have the risk of mixing multiple growth layers or containing unwanted cementum or secondary dentine. These methods also need to destroy most of the teeth. A new method with low destructiveness and relatively simple experimental procedures was published recently, which can reduce sample loss, increase resolution in time series, and improve the accuracy of age-alignment between different individuals. This new experimental protocol allowed us to perform sequential sampling of small samples (cylindrical samples with a diameter of 1 mm) on 2 mm wide longitudinal slices of teeth, as well as inferring the corresponding developmental age of the sequential samples from the average growth rate of dentine. The teeth from 5 individuals with known ages were collected. Small samples were taken in sequence of dentine based on the difference in the growth rate of different anatomical parts of the tooth. The dentine collagen were graphitized and the measurements of radiocarbon dating were performed on compact accelerator mass spectrometry at PKU. Radiocarbon dating results of the dentine sequential samples from the first molar tooth gave more accurate age within 1-2 years difference, comparing with the known birth year of one dividual. The radiocarbon dating results from the second premolar teeth were not matched with the known ages of the individuals. The differences between the age of measurement and known age are about 1-20 years. It can be concluded that the radiocarbon dating of the first molar or the second molar with the sequential sampling can be applied to study the birth year of human individuals in order to solve the forensic questions.

Iodine-129 in Cigar Lake uranium deposits by Pyrohydrolysis and AMS

Mr Hamed Mozafarishamsi[1,3], Ian D. Clark[1,3], Liam Kieser[2,3], Matthew N. Herod[1,3]
[1]Department of Earth and Environmental Sciences, University of Ottawa, 25 Templeton St,, Ottawa, Canada, [2]Department of Physics, University of Ottawa, 25 Templeton St, Ottawa, Canada, [3]A. E. Lalonde AMS Laboratory, University of Ottawa, 25 Templeton St, Ottawa, Canada

Theme: A-6: Challenges of the nuclear age
Type of presentation: Oral Presentation

129I is a spontaneous fission product in the Cigar Lake uranium deposits, northern Saskatchewan, Canada, can be measured using accelerator mass spectrometry (AMS). It can provide useful information on its mobility in the natural geosphere as an analogue to a nuclear waste repository. The iodine was extracted from rock samples and then measure by AMS. Extracting iodine from rock samples for inductively coupled plasma mass spectrometry (ICP-MS) and AMS analysis can be done using several methods. Of these, pyrohydrolysis is the most widely used.

Here we use pyrohydrolysis with an alkaline solution to trap the iodine released from the sample during combustion. We used two different trap solutions with varying concentrations. These solutions were NaOH (0.4M, 0.3M, 0.2M, 0.1M, and 0.05M) and Tetramethylammonium hydroxide TMAH (1.5%, 1% and 0.5%). Also, we used NaHSO3 (0.02M) as a reducing agent. Iodine recovery is quantified using iodine-125 as a yield tracer. We observed that TMAH 1.5% has the highest Recovery (84%) and TMAH 1%, and 0.5% had slightly lower recoveries (83% and 81%). On the other hand, for NaOH solutions, NaOH 0.4M, NaOH 0.3M, and NaOH 0.2M had the highest recoveries (80%), but NaOH 0.1M and NaOH 0.05M had lower recoveries of 76% and 68%. The rock samples were also mixed with vanadium pentoxide (V2O5) as an oxidizing agent to aid in sample combustion. We examined different ratios of V2O5/sample by weight (0, 0.25, 0.5, 1, 2, 3, 4, and 5) and observed increased recoveries with increased V2O5. We obtained the highest Recovery of 88% for a V2O5/sample mass ratio of 5.

By using TMAH 0.5% as a trap solution and using ratio of three for V2O5/sample, the iodine was extracted from rock samples. An iodine recovery of about 85%-95% was obtained through pyrohydrolysis method. 127I was measured with ICP-MS and 129I was measured with AMS. Along a ~450m rock profile at Cigar Lake study site, the 129I concentration ranged from 1.2E+08 atoms/kg in low uranium concentration area to 1.4E+13 atoms/kg in high uranium concentration zone. The 127I concentration varied from 77ppm to 850ppm in the same profile.

Keywords: Iodine-129; Accelerator mass spectrometry (AMS); Uranium; Pyrohydrolysis

Measurement of Pa-231 for radiological dose assessment from uranium mining

Mr Peter Medley[1,2,3], Dr. Stephen Tims[2], Dr. Michaela Froehlich[2], Dr. Andreas Bollhöfer[4], Prof. Keith Fifield[2], Mr. Dominik Koll[2], Dr. Zuzana Slavkovská[2], Prof. Anton Wallner[5]

[1]Environmental Research Institute of the Supervising Scientist, Darwin, Australia, [2]Australian National University, Canberra, Australia, [3]Queensland Health, Brisbane, Australia, [4]Bundesamt für Strahlenschutz, Freiburg, Germany, [5]Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany

Theme: A-6: Challenges of the nuclear age
Type of presentation: Oral Presentation

Naturally occurring radionuclides in the environment lead to a natural background exposure from ionising radiation to people. Industrial processes, such as the operational and post-remediation phases of uranium mining, can lead to increased release above natural background levels of these radionuclides into the environment. The movement and partitioning of these radionuclides in environmental systems can lead to bioaccumulation in organisms. Traditional indigenous land rights exist on many former mine sites in Australia where traditional owners may exercise their rights such as hunting and gathering. The bioaccumulation of radionuclides in traditional food items on former mine sites can therefore lead to an increased exposure to people from ionizing radiation.

The Ranger Uranium Mine in the Alligator Rivers Region (ARR) of the Northern Territory of Australia ceased all mining and milling operations in January 2021. Mine site remediation is taking place with the intention to release the former mine site to traditional owners. Detailed information on biological uptake of naturally occurring radionuclides is needed to undertake a radiological dose assessment for people intending to collect food from the site. Protactinium-231 is one of the radionuclides that have the potential to be released through uranium mining activities and to bioaccumulate in organisms. Uptake of Pa-231 has been modelled using analogue elements but has not previously been directly measured in the ARR.

AMS is the only suitable technique capable of achieving the low limits of detection required to measure Pa-231 in natural environmental samples. We have developed new, safer radiochemical methods to prepare the Pa-233 isotopic tracer and for extraction of Pa from biological samples. We report on methods development for Pa-231 at the ANU, measured activity concentrations of Pa-231 in traditional food items from the ARR and implications for potential doses from ionizing radiation to people.

New insights into actinides sources to the Baltic Sea

Dr Mercedes López-lora[1], Mats Eriksson[1], Grzegorz Olszewski[2], Elena Chamizo[3], Per Törnquist[1], Håkan Pettersson[1], Marie Karlsson[1], Patric Lindahl[4], Victoria Lérida[3], José María López-Gutiérrez[3]

[1]Linköping University, Linköping, Sweden, [2]University of Gdańsk, , Poland, [3]Centro Nacional de Aceleradores, Sevilla, Spain, [4]Swedish Radiation Safety Authority, , Sweden

Theme: A-6: Challenges of the nuclear age
Type of presentation: Invited Oral Presentation

The Baltic Sea is a semi-enclosed and shallow sea with an increased accumulation of radioactive materials compared to open oceans. The main sources of artificial radionuclides to this marine environment are: i) fallout coming from atmospheric nuclear weapon testing (1945-1980), ii) fallout coming from Chernobyl accident (1986), iii) liquid releases form Sellafield and La Hague nuclear reprocessing facilities transported through the North Sea, iv) authorized radioactive discharges occurring during the routine operation of nuclear installations in the Baltic Sea region and v) possible leakages from the multiples radioactive wastes dumping sites within this marine region [1]. Because of the specific situation and characteristic of this marine environment, the Baltic Sea is one of the most studied areas regarding the distribution of radioactive radionuclides. However, radionuclides such us 233U, 236U and 237Np, possibly only mensurable by AMS, have been scarcely studied and their sources to the Baltic Sea remain unknown. Recent studies have revealed the still open question about 236U sources to the Baltic Sea [2].

The aim of this work is the study of actinides (i.e. 233U, 236U, 237Np and Pu isotopes) from a series of samples (i.e. seawater, sediments, seaweed and biota) collected from different regions at the Baltic Sea in order to get better insights into their input sources to this oceanic environment. Two study areas are included here: i) an area close to Gothenburg, which has not been previously studied even though radioactive wastes were dumped there in 1964, and ii) the Tvären Bay, directly impacted by the liquid releases from Studsvik Nuclear Plant whose actinides isotopic composition have not been documented. We have found out that: i) there are not significant evidences of possible leakages from the dumped wastes at the Gothenburg area; and ii) our results from Tvären clearly indicate an important contribution of Studsvik releases, especially for 236U, 239Pu and 240Pu. Dated sediment cores from Tvären Bay have been used to study the historical releases. Furthermore, the study of the isotopic composition of Pu in those sediments is extended to the most minor Pu isotopes, 241Pu and 244Pu.

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Plutonium uptake, dose and source apportioning in wild animals

Dr Mathew Johansen[1], David P. Child[1], Michael A.C. Hotchkis[1]
[1]ANSTO, Lucas Heights, Australia

Theme: A-6: Challenges of the nuclear age
Type of presentation: Invited Oral Presentation

Plutonium contamination from nuclear explosions and accidental releases can be found in every environmental system on earth. High yield weapons tests resulted in global fallout, while other releases have a local or regional impact. Addressing concerns over potential impacts of Pu to living organisms presents a challenge because its relatively high dose potential and complex uptake mechanisms require the measurement of extremely small quantities. Highly sensitive analyses are also required to distinguish the Pu from different sources (e.g., local releases vs general fallout).

Following the 2011 Fukushima accident, concern was expressed about Pu releases from the mixed oxide reactor fuels. The use of Accelerator Mass Spectrometry (AMS) enabled us to quantify and compare Pu taken up by local biota (earthworms and wild boar) near the accident site to uptake at a site near Nagasaki Japan, where Pu had been dispersed by the 1945 nuclear weapon detonation. Results revealed that the uptake of Pu was greater in biota near Nagasaki where >90% was sourced from the weapon detonation (vs from global fallout), whereas near Fukushima, >90% of Pu in biota was from global fallout and <10% from the accident. In both cases, the local sources can be distinguished from global fallout using their isotopic signatures. Whereas 240Pu/239Pu isotopic ratios are typically used to distinguish such sources, we have found that the 241Pu/239Pu ratio can be a more powerful signature of source term. 241Pu/239Pu ratios are particularly effective in distinguishing global fallout from nuclear power releases with a difference of >100 compared to a factor of <3 for 240Pu/239Pu ratios.

Pu was dispersed in Australia by the British nuclear testing conducted in the 1950s-60s. At Maralinga in the arid desert of South Australia, a complex history of contamination resulted from seven nuclear detonations as well as hundreds of non-fission tests. The use of AMS enabled us to quantify Pu distribution in mammal tissues of bone (83%±6%), muscle (10%±9%), liver (6%±6%), kidneys (0.6%±0.4%) and blood (0.2%). Results included Pu uptake rates for a wide range of biota, including kangaroos, reptiles and invertebrates, important for environmental and human food chain evaluations.

Ongoing uptake of Pu also occurs in marine biota at the Montebello Islands, Western Australia, where nuclear tests were conducted from 1952-56. Each test (one from a ship and two on land) produced a distinct Pu isotopic signature, which was used to determine their respective Pu dose impacts. The high sensitivity afforded by the VEGA Actinide analysis capability at ANSTO allowed for the inclusion of protected marine species in the study, including flatback sea turtles, using small, non-lethal skin punches. Pu released during the local tests is the dominant source in the tissues of local fish, reptiles and crustaceans and sea cucumbers. However, dose rates to local biota, including the sea turtles that nest on contaminated beaches, are relatively low today compared with doses in the decade following the tests.

Preparation and Characterization of a Charcoal Reference Material for the Determination of Atmospheric Iodine

Mr Jacob Brookhart[1], Mr. Michael Glaser[1], Dr. Alonzo Martinez[1], Mr. John Olson[1], Ms. Rachael Roenfeldt[1], Dr. Darin Snyder[1], Dr. Matthew Watrous[1]
[1]*Idaho National Laboratory, Idaho Falls, United States*

Theme: A-6: Challenges of the nuclear age
Type of presentation: Poster

Activated charcoal is a well-known effective absorber of gaseous iodine and is routinely employed in environmental sampling. Post collection processing for iodine isotope ratio mass spectrometry can be challenging if sample preparation does not include a sampling media combustion step. One gap in an analysis protocol is the absence of a charcoal matrix reference material for method development and quality control use for analysis.

Preparing a suitable laboratory reference material can be challenging due to the granular nature of the collection media and the high partition coefficients for molecular and alkyl iodides. Air flow heterogeneity across charcoal grains during sampling efforts negatively impacts aliquot uniformity and is a difficult parameter to control. In preparing a reference material corresponding to lesser amounts of iodine, representative sampling becomes troublesome.

The Idaho National Laboratory has established a method for producing an iodine on charcoal laboratory standard which is tunable for iodine content. Acceptable aliquot uniformity has been achieved through sampling design and sampler air flow analysis of variance. The media produced has been characterized for total iodine concentration and 129I / 127I ratio by ICP-MS and AMS. A reference material corresponding to 100 hours of exposure time has been found to have a total 127I concentration of 0.059 ± 1.9% µg 127I / g charcoal with 129I / 127I atom ratio of 4.1 x10-8 ± 2.1% at the 95% confidence level.

Proof of suitability of Ca-41 as a reference isotope for the characterization of reactor concrete

Richard Spanier[1], Matthias Dewald[1], Björn Dittmann[1], Stefan Heinze[2], Markus Schiffer[2], Susan Herb[2], Claus Müller-Gatermann[2], Gereon Hackenberg[2], Alexander Stolz[2], Alfred Dewald[2], Raphael Margreiter[3], Erik Strub[3], Marco Michel[3], Klaus Eberhardt[4]

[1]Gesellschaft Für Anlagen- Und Reaktorsicherheit (grs) Ggmbh, Cologne, Germany, [2]Institute for Nuclear Physics, CologneAMS, University of Cologne, Cologne, Germany, [3]Department of Nuclear Chemistry, University of Cologne, Cologne, Germany, [4]Institute for Nuclear Chemistry, Mainz, Mainz, Germany

Theme: A-6: Challenges of the nuclear age
Type of presentation: Poster

In the field of nuclear waste management, reference nuclides are important for the radiological characterization of the radioactive material. Commonly used reference nuclides are e.g. Co-60 or Eu-152 because they can be easily quantified by gamma ray spectrometry. In case of Co-60 the relatively short half-live of 5.3 a might be a major disadvantage as decommissioning works might take place on a longer timescale. Thus, it is not very well suited if longer storage and control is needed. Another disadvantage in the case of reactor concrete is that they are generated by neutron irradiation of Co-59 or Eu-151, respectively, which both are contained only as trace elements with an unknown level of homogeneity.

This research project therefore investigated the suitability of Ca-41 as a reference isotope for the characterisation of reactor concrete, e.g. originating from the bio-shield of a nuclear power station. For this purpose, several samples of concrete material were irradiated with thermal neutrons with different doses at the Mainz TRIGA reactor. The irradiated samples were then measured by gamma spectroscopy and the Ca-41 was chemically extracted as CaF to produce a sputter target for the AMS measurement. Subsequently the Ca-41 concentration was determined at the 6MV TANDETRON AMS set-up, “CologneAMS”, of the University of Cologne.

We will report on the results with respect to sensitivity and precision obtained so far.

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Quantification of C-14 in artificially activated reactor graphite via AMS

Mr Raphael Margreiter[1], Dr. Matthias Dewald[2], Ms. Martina Gwozdz[3], Dr. Stefan Heinze[3], Prof. Dr. Alfred Dewald[3], Prof. Dr. Klaus Eberhardt[4], PD Dr. Erik Strub[1]

[1]Division For Nuclear Chemistry, University Of Cologne, Germany, [2]Gesellschaft für Anlagen- und Reaktorsicherheit (GRS) gGmb, Germany, [3]Institute of Nuclear Physics, University of Cologne, Germany, [4]Institute for Nuclear Chemistry, Johannes Gutenberg University, , Germany

Theme: A-6: Challenges of the nuclear age
Type of presentation: Poster-Plus Presentation

Introduction

There are currently 250.000 Mg activated reactor graphite around the globe without a well-defined disposal path [1]. A relevant subgroup of this material is the roughly 1000 Mg reactor graphite in Germany, largely from the prototype reactors AVR (Jülich) and THTR-300 (Hamm-Uentrop). The disposal of this material is as of now still an unresolved challenge. The still ongoing research presented here tries to address some of the difficulties and to open a possible path toward an orderly disposal procedure, mainly by investigating the possible application of the CologneAMS system for precise quantification of C-14 in reactor graphite.

Methods

The main challenge of measuring activated graphite samples with AMS are the relatively high C-14 concentrations compared to the routine measurements for carbon dating. In the ongoing project, this is addressed by the development of a dedicated gas system, consisting of a conventional elemental analyzer and a gas dilution system, which is directly coupled to the AMS ion source [2]. To obtain accurate results with this system, it must be extensively tested using samples with elevated C-14 concentration. This work describes the production, the preparation, and the measurement of the corresponding samples.

We chose three materials to obtain defined C-14 concentrations by irradiating with thermal neutrons. Two of the three materials chosen for our studies are graphite blocks originally intended for uses within the AVR prototype reactor itself, namely as reflector material (sample K) and thermic shielding (sample S). The third graphite sample was part of the shielding material for a low-level measuring station in the nuclear chemistry division at the university of cologne (sample G).

Each of the three samples underwent neutron activation at the TRIGA II research reactor in Mainz, Germany, 3 hours, 10 minutes, and 1 minute respectively. This resulted in a variety of samples with C-14/C-12 ratios ranging from 10-13 up to 3*10-10. The samples were also analyzd by means of γ-measurements for the detection of trace amounts of short- and long-lived impurities in the material.

Results and Discussion

First measurements of the samples with the AMS gas system were performed using solid dilutions of the materials. This showed that this technique opens a way to measure samples with elevated C-14 covering at least 4 orders of magnitude. The main challenge is to avoid not only contaminations of the AMS system but also reservoir effects in different part of the gas system, possibly leading to cross-interferences when measuring samples with different C-14 concentrations. In the next step, the irradiated samples will be used to demonstrate the equivalency of the solid dissolution and gas dilution and for the development of a procedure to enable fast routine measurements of irradiated reactor graphite.

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Radiocarbon in the environment from the nuclear industry in Canada: a review

Mrs Carley Crann[1], Dr. Felix Vogel[2], Professor Michael Pisaric[3]

[1]A.E. Lalonde AMS Laboratory, Ottawa, Canada, [2]Climate Research Division, Environment and Climate Change Canada, Toronto, Canada, [3]Department of Geography and Tourism Studies, Brock University, St Catherine's, Canada

Theme: A-6: Challenges of the nuclear age
Type of presentation: Poster-Plus Presentation

Applications of radiocarbon analysis since the industrial revolution must take into consideration the anthropogenic sources of carbon isotopes. However, there is no simple correction factor to apply since anthropogenic carbon emissions vary across space and time and can either contribute to a depletion in the 14CO2 signature (eg. burning of fossil fuels), or an enrichment in the 14CO2 signature (eg. from the nuclear industry). About 15%of Canada's electricity comes from nuclear power and the CANDU reactor design emits higher levels of 14CO2 than the boiling reactor design. Monitoring of stack emissions from CANDU reactors started in the 1980s. Here we review the sources and history of nuclear 14CO2 emissions and emissions monitoring data around nuclear facilities in Canada, as well as the publicly available 14C data on environmental samples (air, tree ring, vegetation) from the modern age. From this review, we identify key spatial and temporal gaps in the datasets that may be filled by tree ring measurements.

Reproducibility and accuracy of actinide AMS – lessons learned from precision studies for nuclear data

Prof. Anton Wallner[1,2], Marcus Christl[3], Michael A.C. Hotchkis[4], Joerg Lippold[5], Michaela Froehlich[2], L. Keith Fifield[2], Peter Steier[6], Stephen Tims[2], Stephan Winkler[1]
[1]Helmholtz-Zentrum Dresden-Rossendorf (HZDR), Dresden, Germany, [2]The Australian National University, Canberra, Australia, [3]Laboratory of Ion Beam Physics, ETH Zurich, Zurich, Switzerland, [4]Australian Nuclear Science and Technology Organisation (ANSTO), Sydney, Australia, [5]Ruprecht-Karls-Universität Heidelberg, Institut für Umweltphysik, Heidelberg, Germany, [6]VERA Laboratory, Faculty of Physics, University of Vienna, Austria

Theme: A-6: Challenges of the nuclear age
Type of presentation: Poster-Plus Presentation

Actinide detection has grown into an important discipline for environmental and geological sciences, for oceanography, e.g. as monitors of anthropogenic activities, but also in nuclear (astro)physics. Consequently, AMS measurements of actinides have become routine at many facilities. In particular, applications in nuclear (astro)physics continue to challenge the present limits in accuracy and abundance sensitivity of actinide detection.

Presently, there is a major ongoing effort in experiment and theory to better understand cross sections at thermal and higher neutron energies. These activities are motivated by the urgent need for improved and highly accurate nuclear data for optimised designs of advanced reactor concepts, nuclear fusion reactors, or next generation nuclear power plants (Gen IV) and accelerator driven systems (ADS). One example is the cross-section value for 235U neutron-capture at thermal energies: serving as a so-called thermal constant, this quantity is believed to be known to better than 1%. Despite its importance, direct measurements are rare (only two older data exist for thermal energies) and exhibit large uncertainties, thus its knowledge is based on indirect information.

For these applications, accurate actinide data are required, e.g. with uncertainties better than 2-3% for capture reactions. The combination of activation and subsequent AMS detection offers a powerful and complementary tool to measure these cross sections. However, this method had been applied only very recently for measurements on actinides. Importantly, adding an independent technique to established methods helps also to identify unrecognized systematic uncertainties in the existing nuclear database.

Several uranium and thorium samples had been irradiated with neutrons of energies between sub-thermal and 22 MeV at seven different neutron-producing facilities. These samples were then analysed at different AMS facilities: at the Vienna Environmental Research Accelerator (VERA), at ANSTO's ANTARES, at ETH's TANDY and at HIAF (ANU). These facilities cover terminal voltages for actinide AMS between 0.3 and 4 MV.

We present systematic investigations of nuclear data from a series of neutron-irradiated samples that were obtained by AMS. Long-lived reaction products that were measured include Th-229, Pa-231,233, U-233,236 and various Pu isotopes. Some irradiated samples were directly pressed into sample holders. Some samples were dissolved and spiked with well-known amounts of one or more reference isotopes, relative to which the radionuclides were quantified.

To achieve the highest accuracy, we compared the results from repeated measurements at the different facilities. We also had to take into account the measurement reproducibility of the individual facilities; an uncertainty component that represents unknown uncertainties beyond counting statistics and other known systematic uncertainties. A comparison of these data provides the present limits in the measurement accuracy of heavy-ion AMS.

Seawater 129I/127I ratios in the various seas of the Philippines

Dr Angel Bautista VII1, Ms. Sophia Jobien Limlingan[1], Ms. Mary Margareth Bauyon[1], Mr. Remjohn Aron Magtaas[1], Mrs. Eliza Enriquez[1], Mr. Jeffrey Munar[2], Mr. Edwin Dumalagan, Jr.[2], Dr. Haruka Kusuno[3], Dr. Caroline Marie Jaraula[2], Prof. Fernando Siringan[2], Prof. Hiroyuki Matsuzaki[3]
[1]Philippine Nuclear Research Institute (DOST-PNRI), Quezon City, Philippines, [2]University of the Philippines - Marine Science Institute (UP-MSI), Quezon City, Philippines, [3]Micro Analysis Laboratory Tandem Accelerator (MALT), The University of Tokyo, Tokyo, Japan

Theme: A-6: Challenges of the nuclear age
Type of presentation: Oral Presentation

Introduction
Iodine-129 is a long-lived radioactive isotope produced as a fission product in human nuclear activities (HNAs) such as nuclear accidents, nuclear fuel reprocessing, concentration of weapons-grade nuclear material, and nuclear weapons testing. Previous measurements of 129I in coral cores from the West Philippine Sea (WPS) have shown elevated levels compared to those observed from the Pacific Ocean side of the Philippines (Bautista et al., 2016, 2021). For this reason, we wanted to look at the current 129I levels in seawater in the WPS compared to the Pacific Ocean and the rest of the country to understand better the possible sources, implications, and applications of the elevated 129I in the WPS.

Materials and Methods
A total of 79 surface seawater samples were collected over the course of three years from the West Philippine Sea, Philippine Rise, the Tubbataha Area in the Sulu Sea, and several other areas across the country. Iodine was extracted from the samples via multi-stage solvent extraction procedures and then analyzed for 129I and 127I via Accelerator Mass Spectrometry (AMS) and Inductively Coupled Plasma Mass Spectrometry (ICP-MS) in MALT, The University of Tokyo.

Results and Discussion
The average 129I/127I ratios in the WPS have been found to occur at around 2.4 to 3.7 x 10-11, which is at an average of 9.1%, 29.9%, and 13.3% higher than those observed in the Philippine Rise, Sulu Sea, and in the other areas studied, respectively. The seawater samples have also shown location-based variation, suggesting that the elevated 129I in the WPS comes from sources located along the prevailing currents.

Conclusions
Using data from all over the Philippines, we demonstrate that the elevated 129I level in the WPS initially detected in corals has been sustained and isolated in the WPS. Results suggest a regional source for the 129I in the WPS. Moreover, this study is proof that, since 129I is elevated in the WPS, it can be used as a quantitative oceanographic tracer for the complicated circulation and water mass mixing in the WPS, South China Sea, and other neighboring bodies of water.

Sources and reserves of artificial radionuclides (237Np, 239,240Pu, 241Am) in soils of Changbai Mountain

PHD Chunping Huang[1,2], Prof Zhiyong Liu[2], **Prof. Yongjing Guan[1]**, Mr Deyu Wang[1,2], Mr Shenzhen Wang[1,2], Mr Shaohan Sun[1]
[1]Guangxi University, Nanning, China, [2]Soochow University, Suzhou, China

Theme: A-6: Challenges of the nuclear age
Type of presentation: Poster

Changbai Mountain, as the highest mountain system in Northeast Asia, has attracted much attention to its ecological changes. Artificial radionuclides in the surface environment are an important part of the assessment of environmental radioactivity risk. In this paper, artificial radionuclides (237Np, 239,240Pu, 241Am) in Changbai Mountain were measured by ICP-MS for the first time, and 137Cs were measured by anti-Compton HPGe. The results indicated that 137Cs activity ranges from 3.124 to 17.98 mBq/g, 237Np activity ranges from 0.318 to 4.016 mBq/kg, 239+240Pu activity ranges from 0.345 to 3.122mBq/g, and 241Am activity ranges from 0.479 to 1.096mBq/g, such high specific activity was very rare in samples from other regions in China. The 240Pu/239Pu (0.172-0.256) and 237Np/239Pu (0.136-0.584) atom ratios in our research samples show that the Pu and Np is from global fallout. The deposition characteristics of cesium, plutonium and neptunium were fitted by convective- dispersion equation model. By calculation, the accumulated inventory of 137Cs, 237Np, 239+240Pu is consistent with the global settlement value.

Sub-annual I-129 environmental record of years 1956-2007 from an ice core in SE Dome Site, Greenland

Dr Angel Bautista VII[1], Ms. S.J. Limlingan[1], Ms. M. Toya, Dr. Y. Miyake[3], Dr. K. Horiuchi[4], Prof. H. Matsuzaki[2], Dr. Y. Iizuka[5]
[1]Philippine Nuclear Research Institute (DOST-PNRI), , Philippines, [2]Micro Analysis Laboratory Tandem Accelerator (MALT), The University of Tokyo, Tokyo, Japan, [3]RIKEN Nishina Center for Accelerator-Based Science (RNC), Saitama, Japan, [4]Graduate School of Science and Technology, Hirosaki University, Aomori, Japan, [5]Institute of Low Temperature Science, Hokkaido University, Sapporo, Japan

Theme: A-6: Challenges of the nuclear age
Type of presentation: Poster-Plus Presentation

Introduction
Iodine-129 in ice cores can be used to reconstruct the historical impact of human nuclear activities transported through the atmosphere. Furthermore, this information can be used as an age marker to confirm ice core chronologies and as a tracer to better understand environmental processes. Here we show 129I levels in an ice core from SE-Dome, Greenland, for years 1956-2007 at a time resolution of ~ 4 months, the most detailed record to date.

Materials and Methods
The ice core analyzed in this study was drilled at the SE-Dome site (67.18°N, 36.37°W; 3,170 masl; Figure 1), 185 km north of Tasiilaq, Greenland. The total length of the ice core is 73.4 meters, which corresponds to the years 1956.1 to 2007.5. Subsampling at 0.5 m intervals, resulting in a total of 149 ice core samples. Iodine was extracted from the samples via CCl4 and NaNO2 solvent extraction followed by AgI precipitation and analysis for 129I and 127I via Accelerator Mass Spectrometry (AMS) and Inductively Coupled Plasma Mass Spectrometry (ICP-MS) in MALT, The University of Tokyo.

Results and Discussion
Results revealed 129I bomb peaks in 1959, 1962, and 1963, associated with tests performed by the former Soviet Union one year prior, in its Novaya Zemlya test site. All 129I bomb peaks were observed in winter (1958.9, 1962.1, and 1963.0), while tritium bomb peaks were observed in spring or summer (1959.3, 1963.4, and 1964.6). These results indicate that 129I and tritium bomb peaks can be used as annual and seasonal age markers for these years. Furthermore, 129I signals from nuclear fuel reprocessing and the Chernobyl Accident are recorded in the ice core. Comparisons with other published records of 129I in natural archives such as coral and sediment cores showed that 129I signals could also be used as common age markers and tracer for different types of records available in varying latitudes.

Conclusions
Iodine-129 record in the SE-Dome ice is the most detailed historical reconstruction of atmospheric 129I to date. Results show prominent seasonal bomb peaks that can be used as age markers. Common nuclear reprocessing and accident signals found in the SE-Dome ice core and other published records of varying archive types (e.g., coral and sediment cores) suggest the potential of using 129I to tie up and relate 129I records of different types of natural archives, which are exclusively available in varying latitudes in the world.

Traces of the Fukushima accident pollution on India and the Arabic Sea

Dr Alexandru Razvan Petre[1], Dr Mihaela Enachescu[1], Dr Catalin Stan-Sion[1], Dr Doru Gheorghe Pacesila[1]
[1]*Horia Hulubei National Institute For R&d In Physics And Nuclear Engineering (ifin-hh), Magurele, Romania*

Theme: A-6: Challenges of the nuclear age
Type of presentation: Poster

We continue with this AMS experiments to establish the pollution outspread from the Fukushima Nuclear Accident (FNA) in 2011, that released radioactive nuclei into the atmosphere and into the ocean waters. Water samples were collected repetitively between 2014 -2019 from rivers of India and from the China Sea and the Arabian Sea and they were measured for the 129I concentration. AMS measurements of seawater samples from Shanghai had an average concentration 1.3 x 10 7 atoms/L and those collected from Disneyland Hong Kong 1.5 x 10 7 atoms/L. These results are in accordance with the measurements of Liu et al [2016. Sci. 365 Rep. Doi: 10.1038/srep 36611] for seawater of the East Chinese Sea values (0.73 - 3.99) x10 7 atoms/L. Such low concentrations are proofs that no contribution from the Fukushima accident is present. Probably, it is the consequence of the seawater flow blocking towards the China Sea and Yellow Sea produced by the Kuroshio Current. As a result, the actual baseline of 129I concentration for the China Sea is 1.5 x10 7 atoms/L and it is unaffected by the Fukushima accident.

However, the atmospheric outspread from the Fukushima accident 2011 was found in water samples from the rivers in India (Ken River and Gange River) and from the Arabian Sea (offshore Goa). The Ken River, is considered to have one of the most pure and unpolluted water in India. It is nestled in the Panna Tiger Reserve, a prime tiger-land in the Vindhyan Hills. The measured 129I concentration was 1.8 x 10 8 atoms/L, which is an increased value but similar with that of the Arabian Sea (3.15 x 10 8 atoms/L) in samples collected periodically at 300 m out in the ocean from the Sinquerim Beach, overlooking the Arabian Sea. The averaged value of measured of the 129I concentration was 3.15 x 10 8 atoms/L.

Water samples collected from both locations were influenced by the atmospheric transport from the nuclear pollution sources. The big reprocessing nuclear power plant (NRPP) Tarapur (19.85N 72.7E) in the Maharashta State of India is at a distance of about 680 km from this location and its contribution cannot be neglected. The Gange River at Varanasy (25.17N 226 82.57E) located in the central India, at a distance of only 372 km from the Tarapur NRPP. The measured radio iodine concentration for the Gange River was 9.94 x 10 7 atoms/L and 2.54 x 10−9 for the isotope ratio. In spite of the smaller distance to the NRPP, this measured concentration is about two times lower than that of the Ken River.

An actual baseline can be assigned for both the continent and the sea water of India at the value (1-2) x 10 8 atoms/L for the 129I concentration, which is ten times higher than the 129 I concentration in the China Sea.

Ultratrace determination of 99Tc in the seawater by low energy AMS

Mrs Mosammat Khan, Barbara Francisco, Xiaolei Zhao, Liam Kieser, Ian Clark

Theme: A-6: Challenges of the nuclear age
Type of presentation: Poster

The ultrarace determination of 99Tc by AMS is challenging due to the presence of the 99Ru isobar and lack of a stable Tc isotope for ratio measurement. An effective sample preparation method and carefully prepared targets offer an opportunity to achieve low detection limit for the measurement of 99Tc by 3MV-AMS system with the sufficient reduction of 99Ru. In this study, a chemistry methodology was developed to produce 99TcF5– with sufficient suppression of 99Ru5– to allow correction with 101Ru such that measurements down to femtogram (fg) levels of 99Tc are possible. An ICP-MS approach using a prepared standards over a range of 99Tc concentrations has been followed to allow 99Tc-AMS measurement without a stable Technetium isotope. Depending on the sample preparation, a linear correlation of 99Tc concentration has been obtained by improving the sample preparation chemistry to produce the FeOxHy precipitate carrying the 99Tc. Using targets made up of (99Tc)FeOxHy mixed with FeF3, which we find to produce a more stable current than the traditionally used PbF2. The 99Ru background was significantly reduced to □1 fg with the lower detection limit of 99Tc, < 1 fg in the unit of “fg 99Tc per mg of FeOxHy precipitate” using +2 ions in the ionization chamber. This method is anticipated to allow the analysis of 99Tc in environmental samples such as seawater/groundwater and soil.

A Brief History of Angkor's Iron: Reconstructing multi-scalar chronologies in the Phnom Dek metallurgical landscape, Cambodia.

A/Prof. Mitch Hendrickson[1], Dr. Quan Hua[2], Dr. Shuhui Cai[3], Dr. Lisa Tauxe[4], Dr. Stéphanie Leroy[5], Dr. Kaseka Phon[6]

[1]University Of Illinois At Chicago, , United States, [2]ANSTO, , Australia, [3]State Key Laboratory of Lithospheric Evolution, Institute of Geology and Geophysics, Chinese Academy of Sciences, , China, [4]Scripps Institution of Oceanography, UCSD, , USA, [5]LAPA-IRAMAT Saclay, CNRS, , France, [6]Royal Academy of Cambodia, , Cambodia

Theme: A-7: Understanding the human story
Type of presentation: Oral Presentation

Iron was an essential commodity in the rise of Angkor, the largest and most influential state in mainland Southeast Asia between the 9th to 13th centuries. Multidisciplinary research around Phnom Dek in northern Cambodia revealed an extensive metallurgical landscape spanning over 1300 years of production activity and a dramatic increase in the scale of smelting correlating with the expansion of the Khmer Empire. Extensive AMS radiocarbon dating of in-slag charcoals from across the Phnom Dek region and materials recovered from furnaces and occupation at the site of Tonle Bak are used here to reconstruct the multi-scalar chronologies of production (furnace, mound, site, region) during this important time in Southeast Asian history. By integrating geomagnetic intensity data from furnace bases, we demonstrate that it is possible to identify temporal differences between 'contemporary' smelting sites within a single mound. At the scale of the slag mound and site we posit that the terminal use relates to ritual while the regional pattern indicates the Khmer state's desire to increase production and improve access to iron resources needed for temples, warfare and daily life.

Are radiocarbon dating and Bayesian chronological modelling useful in Classical Archaeology?

Dr Ricardo Fernandes[1,2,3], Dr Jesús Torres-Martínez[4], Dr Philippe Sciau[5], Dr Christian Hamann[6], Dr Manuel Fernández-Götz[7]

[1]Max Planck Institute for the Science of Human History, Jena, Germany, [2]University of Oxford, Oxford, Germany, [3]Masaryk University, Brno, Czech Republic, [4]IMBEAC, Universidad Complutense de Madrid, Madrid, Spain, [5]Center for Materials Elaboration and Structural Studies - French National Centre for Scientific Research, Toulouse, France, [6]Leibniz-Laboratory for Radiometric Dating and Isotope Research, Kiel, Germany, [7]School of History, Classics & Archaeology, University of Edinburgh, Edinburgh, United Kingdom

Theme: A-7: Understanding the human story
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The oppidum site of Monte Bernorio in northern Spain was likely laid under siege and destroyed by Augustus' legions during the course of the Cantabrian Wars (29 and 19 BCE). These wars constitute the last stage in the gradual annexation of the Iberian Peninsula by Rome and of its transition from the Iron Age into the Roman period. Located within Monte Bernorio were burial deposits containing cremated human remains mixed with partial fragments of artefacts and animal bones suggesting the symbolic practice of Pars pro toto (part taken for whole).

To investigate the chronology of burial practices at Monte Bernorio and potential links to the siege event we employed Bayesian modelling of available chronological evidence: stratigraphic sequence, typological dating, coin dating, written records, and radiocarbon measurements on animal and plant remains. Modelling results revealed intricate burial practices, with the transfer of animal bone remains from older graves into more recent ones and the start of the site preceding the timing of the siege. One of the graves contained partial fragments of a Terra Siggilata bowl of Italian origin; established from measurements of elemental composition. It was likely acquired during the siege given that the first exports of Italian Terra Siggilata took place in c. 30 BCE. Its deposition in a grave in a fragmentary state, although in line with the Pars pro toto practice observed for other graves at Monte Bernorio, might have also symbolized the destruction of the Roman enemy. It is possible that the use of the burial site intensified during the siege but given the small number of analysed graves it is not possible to confirm this.

The Monte Bernorio case study illustrates how the integration of multiple sources of chronological evidence can be integrated within a Bayesian framework to better understand the temporal development of complex social phenomena.

Chronological modelling of radiocarbon data from the Torres Strait to understand occupation, settlement, and cultural change.

Ms Lauren Linnenlucke[1,4], Professor Ian McNiven[2,4], Associate Professor Fiona Petchey[3,4], Distinguished Professor Michael Bird[1,4], Distinguished Professor Sean Ulm[1,4]
[1]James Cook University, Cairns, Australia, [2]Monash University, Melbourne, Australia, [3]University of Waikato Radiocarbon Laboratory, Waikato, New Zealand, [4]ARC Centre of Excellence for Australian Biodiversity and Heritage, , Australia

Theme: A-7: Understanding the human story
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The Torres Strait presents a unique case study in Australian archaeology where people settled an archipelago between two mainlands, creating a thriving maritime seafaring culture. Using 221 AMS radiocarbon dates, we examine initial occupation and settlement patterns in the first example of Bayesian chronological modelling applied to the Torres Strait as a whole, as opposed to the individual assessment of sites. This holistic approach uses data from 49 archaeological sites to develop a more holistic understanding of when people moved to, and between, islands throughout the archipelago. Existing human migration theories focus on movement of people between c.2500 and 4000 years ago; however, with a culture dating back at least 9000 years, this new chronological modelling enables us an opportunity to rethink how chronology informs our current understanding of key cultural adaptions relating to societal change and the onset of ritual activities.

Dating correlated microlayers in engraved, oxalate-rich accretions: new archives of paleoenvironments and human activity from Australian rock art shelters

Dr Helen Green[1], Dr Damien Finch[1], Prof Andrew Gleadow[1], Ms Jenna Hoy[1], Dr Vladimir Levchencko[2], Ms Cecilia Myers[3], Ms Pauline Heaney[4], Dr Robyn Pickering[5]
[1]The University Of Melbourne, Melbourne, Australia, [2]Australian Nuclear Science and Technology Organisation, Lucas Heights, Australia, [3]Dunkeld Pastoral Company, Kununurra, Australia, [4]Lettuce Create, Brisbane, Australia, [5]The University of Cape Town, Cape Town, South Africa

Theme: A-7: Understanding the human story
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Distinctive, dark coloured, glaze-like mineral accretions, often found in rock shelters around the world, offer important opportunities for radiocarbon dating of associated rock art.

The mineralogy of these accretions is dominated by well-crystallised calcium oxalate and sulphate minerals, most commonly whewellite and gypsum, with significant occurrences of phosphates in some samples. The accretions are typically several millimetres thick and characterised by distinctive internal laminations that exhibit regular stacked undulations giving a stromatolitic appearance under the microscope. Together with other apparently microbial features observed under the SEM, these features provide strong support for a microbiological origin for these oxalate-rich accretions. Risks surrounding contamination and open system behaviour, previously limiting the application of radiocarbon dating to these accretions, are addressed by the well-crystallised nature of the oxalates and the preservation of fine laminar features within their internal stratigraphies. In a case study from the north Kimberley region of north-western Australia, we demonstrate the use of sample characterisation and chemical pre-treatment techniques to pre-screen for evidence of open system behaviour and address potential contamination. The results provide stratigraphically consistent sequences of radiocarbon dates in mm-scale laminated accretions, with correlations between distinctive patterns in the layer sequences visible in rock shelters up to 90 km apart. This demonstrates that pre-screened samples offer opportunities to reliably date rock art, particularly symbolic markings commonly engraved into these relatively soft deposits and suggests their synchronised formation is not entirely shelter specific but broadly controlled by variations in regional environmental conditions. Consequently, these accretions also offer potential as paleoenvironmental archives, with radiocarbon dating of layers in nine accretions indicating four, approximately synchronous growth intervals covering the last 43 ka.

Dating the origins and long-term process of olive domestication in the north Jordan Valley: new radiometric data from 5th millennium BCE Pella in Jordan

Ms Anne Dighton[1], Dr Stephen Bourke[2], Quan Hua[3], Geraldine Jacobsen[3]

[1]School of Social Science, The University Of Queensland, Brisbane, Australia, [2]The Pella Project, NEAF, Archaeology, SOPHI, A14, University of Sydney, Sydney, Australia, [3]Australian Nuclear Science and Technology Organisation, Lucas Heights, Australia

Theme: A-7: Understanding the human story
Type of presentation: Oral Presentation

This paper reports on 20 new 5th millennium calBC dates from the archaeological site of Pella in Jordan. The sampled strata straddle the chronological interface between the Late Neolithic and the Early Chalcolithic periods (around 4600/4500 calBC), a critical period in the development of horticulture in prehistory, where movement from early human-olive interaction to intensified manipulation of the olive occurs.

Although there is ongoing debate concerning the region(s) in which the earliest manipulation of the olive occurred, there is little argument that the foothills of the Jordan Valley are among the earliest. Considerable work in the 1990s exploring one of the earliest centres of olive exploitation at Teleilat Ghassul in the south Jordan Valley made clear that the second half of the 5th millennium BCE was the era of intensive engagement with the olive in the southern Valley flatlands. Pollen analysis suggested an earlier genesis in the northern Valley foothills, where investigations since the 2000's targeted the first half of the 5th millennium calBC for intensified exploration. After much archaeological material-cultural proxy data, and significant macrobotanical datasets had been accumulated, the final element was direct dating of olive endocarps drawn from across the frontier eras (late 6th through late 5th millennium BCE) of olive manipulation.

This presentation will present the 20 new dates determined using the VEGA AMS Facility at ANSTO, and briefly discuss their significance for the ongoing analysis of the process of olive domestication in the Jordan Valley, underlining the long-term and gradualist process at work. The impact of the move from ad hoc engagement with wild fruit in the 6th millennium calBC, manipulation of select wild trees in the first half of the 5th millennium calBC, and the active propagation of desired traits in cultivated groves, towards the end of the 5th millennium calBC will also be discussed.

From radiocarbon dating of mud wasp nests to ages for early Australian rock art

Dr Damien Finch[1], Professor Andrew Gleadow[1], Professor Janet Hergt[1], Dr Helen Green[1], Dr Vladimir Levchenko[2], Ms Pauline Heaney[3]
[1]University of Melbourne, Melbourne, Australia, [2]Australian Nuclear Science and Technology Organisation, Sydney, Australia, [3]Rock Art Australia, Melbourne, Australia

Theme: A-7: Understanding the human story
Type of presentation: Invited Oral Presentation

Northern Australia is home to some of the richest rock art provinces in the world. It has long been thought that the oldest of the rock art still visible today may date back to the Pleistocene period, more than 11,000 years ago. Until recently, after more than 30 years of research, there were only one or two quantitative, radiometric, age determinations to support this view. Importantly, there was certainly insufficient data to say when some of the oldest, very distinctive, styles of rock art were created and there were no age estimates at all for the oldest style of figurative rock painting.

Here, we report on the development of radiocarbon dating methods to provide the first estimates of the ages spanned by the two earliest styles of painted rock art in the Kimberley region in northwest Australia. Mud wasp nests overlying, or underlying rock art were dated to provide maximum and minimum age constraints for rock art motifs.

Radiocarbon dating of fossilised mud that sits exposed on rock shelter walls for millennia poses many challenges. The sources of carbon in the nest when it is built need to be identified so that the relationship between the age of the nest, and the age of the carbon in it, is well characterised. As the nest ages, organic and inorganic components will undergo different taphonomic processes that need to be identified to determine if the fossilised nest behaves as a closed system for carbon and to understand which sources of carbon will be preserved. Mineral accretions commonly develop on all exposed surfaces in these rock shelters, including old wasp nests, so the mineralogy of these and any aeolian contamination such as ash and pollen needs to be understood so that appropriate treatments can be designed to remove any such contamination. Wasp nests gradually weather away so the older nests are small and have very low carbon concentrations. Many samples yield less than 10μg of carbon, challenging the limit of what is possible to measure reliably, so pretreatment methods must be optimised to maximise yield while minimising the risk of contamination.

Here we review the methods used to address these challenges. We then report on the results of the dating program, so far, including the first chronometric estimates for the two earliest periods in the stylistic sequence of painted Kimberley rock art. We show that both periods date back to the terminal Pleistocene with evidence of the oldest art painted at the end of the Last Glacial Maximum, around 17,000 years ago.

Influence of the radiocarbon calibration curves on the chronology of Inca

Prof. Andrzej Rakowski[1], Dr. Jacek Pawlyta[1], Dr. Dominika Sieczkowska[1,2], Prof. Mariusz Ziółkowski[2], Dr. Jose Bastante[3]
[1]Silesian University Of Technology, , Poland, [2]Centre for Andean Studies,, Warsaw, Poland, [3]National Archeological Park of Machupicchu, Peru

Theme: A-7: Understanding the human story
Type of presentation: Poster

The chronology of Machupicchu was traditionally associated with the period attributed to the reign of Pachacuti Inca Yupanqui. Within the scheme on the so-called historical chronology, proposed by John H. Rowe in 1945, the ascension to power of Pachacuti Inca took place around 1438 AD and the construction of Machupicchu began by 1450 - 1460 AD. There are several radiocarbon-dated samples that may help to try to understand the chronology of the construction of llaqta of Machupicchu, Chachabamba, and Choqesuysuy. The sites have been interpreted as being part of the contemporary Late Horizon Inca landscape. However, all the sites are located in the Andes where the influence of the Northern and Southern Hemisphere for the atmospheric radiocarbon radioactivity is to be investigated and discussed for different periods. The influence will probably reflect both regional and global climatic changes in the region. Here we present how different mixing of Intcal13/SHcal13 and Intcal20/SHcal20 radiocarbon calibration curves influences the chronology of all three sites.

Mortar dating: A new procedure in the Zagreb Radiocarbon Laboratory

Dr Andreja Sironić[1], Alexander Cherkinsky[2], Damir Borković[1], Suzana Damiani[3], Jadranka Barešić[1]
[1]Ruđer Bošković Institute, Zagreb, Croatia, [2]University of Georgia, , United States, [3]Academy of Fine Arts, University of Zagreb, Zagreb, Croatia

Theme: A-7: Understanding the human story
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Mortar can be dated by radiocarbon dating of binder carbonates created during mortar hardening. However, the most prominent problem in mortar dating is selecting the carbonates from binder without impurities used in mortar production that lead to overestimated ages. To this day there is no consensus on the unique way of sample preparation that would always provide the true date. At the Zagreb Radiocarbon Laboratory, Croatia, we established a procedure for graphite preparation form AMS radiocarbon dating of mortar that we find simple and cost-effective. The 14C activity of graphite samples prepared in the Zagreb Radiocarbon Laboratory is measured at the Center for Applied Isotope Studies (CAIS), University of Georgia, Athens, USA.

The basis of the procedure is collection of mortar particle fraction 32 - 63 μm which is hydrolyzed by H3PO4 and CO2 fractions are collected after 3, 10, 30 s and until the end of reaction. The rule was established that the first fraction is the reliable for date of mortar, and it should not exceed 20 % of total CO2 yield. Applying this rule, for some samples the collection of CO2 fractions has to be repeated, either by prolonging the periods, or slowing the reaction by lowering temperature of acid at fixed (the same) time periods.

In order to validate the procedure two laboratory mortars containing 26 % and 48 % of binder carbonate (Šustić et al. 2012) were prepared and yielded 97.7 ± 0.3 pMC and 100.6 ± 0.3 pMC, respectively. In addition, seven original archeological mortars were used to test the method. For five archeological samples the expected age of samples was estimated by the sample provider, one sample true date was estimated from two charcoal samples associated with the sample formation and one sample true date was obtained from a tombstone with engraved date of death. Two laboratory and five archaeological samples showed acceptable results, justifying the applicability of the proposed procedure. However, two archaeological samples sampled from an altar in a cave showed a14C higher than 100 pMC, suggesting that these mortars were still active, leading to conclusion that mortars from caves, due to specific conditions during mortar hardening, are not representative for radiocarbon dating.

Šustić, I., Barešić, J. & Šipušić, J. (2012) Determination of hardened binder initial composition. Zement - Kalk - Gips international, 65 (10), 70-78.

Potential of the petrous part of the human temporal (ear) bone for isotope analysis

Dr Rachel Wood[1], Ms Katherine Dunn, Dr Hannah James, Prof Stewart Fallon
[1]*Australian National University, Australia*

Theme: A-7: Understanding the human story
Type of presentation: Invited Oral Presentation

Tooth enamel contains a valuable strontium isotope record which archaeologists and forensic scientists often use to establish where a person did (or did not) spend their childhood. However, tooth enamel rarely survives cremation. In periods where cremation is common, our understanding of mobility is therefore limited and interpretations biased towards individuals from particular burial practices. The petrous (ear) bone may capture an isotopic record at multiple points during life. The otic capsule of the petrous (ear) bone is thought to form before the age of two and not remodel. The otic capsule is surrounded by other dense bone, and this by spongy bone, each with different remodeling rates. The bone often survives cremation and retains its strontium isotope ratio through the burning and later diagenesis processes, and may provide an alternative for isotopic analysis of enamel. This project aimed to confirm remodeling of the petrous bone with radiocarbon. It found that the otic capsule did not remodel after childhood, but that limited and substantial amounts of remodeling occurred in the cortical and spongy bone respectively.

Precise radiocarbon dating using Miyake event

Prof. Andrzej Rakowski[1], Prof. Marek Krąpiec[2], Dr. Jacek Pawlyta[1], M.Sc. Damian Wiktorowski[2]
[1]Silesian University Of Technology, Gliwice, Poland, [2]AGH, University of Sciences and Technology, Kraków, Poland

Theme: A-7: Understanding the human story
Type of presentation: Poster

Miyake et al. (2012, 2013 and 2014) described a sudden increase of radiocarbon (14C) concentration in annual tree rings of Japanese cedar (Cryptomeria japonica) and Hinoki cypress (Chamaecyparis obtusa) between AD 774 and 775 and between AD 993 and 994.

Due to the characteristic of the sharp increase in radiocarbon concentration that occurs in Miyake event, and due to the global character of this event, it is possible to use it for accurate dating of annual tree rings, using radiocarbon method. In practice, linking the relative dendrochronological dating and radiocarbon analysis of annual growth rings is possible by useing the “Wiggle matching” technique to precisely determine the calendar age of samples of pine from the floating pine chronology (2U_02A) for central Poland. Absolute dating chronology 2U_02A is covering 227 years, determined on the basis of 50 individual sequences, and is of great importance for archaeology of the early Middle Ages. This is particularly important for the polish history, as during the period covered by this chronology, evolutionary changes occurred, such us the transition from tribal organization to state organization and the emergence of a series of fortified towns, for which dendrochronology dating without pine standard is difficult. So far, summarized standard curves for pine in Poland date back from the present to 1106 AD for Gdańsk Pomerania (Zielski 1997) and 1091 AD for Lesser Poland (Szychowska-Krąpiec 2010) and does not include the Xth century AD.

The procedure is divided into three phases. In the Phase I, four samples, each contain five consecutive annual rings, were selected from the floating chronology 2U_02A. The results of wiggle-matching are presented on Figure 3. Taking into account position of the first ring dated with the radiocarbon method, it is possible to determine the period represented by the curve 2U_02A for the years 860-180 (±10) cal. AD. In the Phase II, five samples of annual tree rings were selected and measured to compare with the curve representing radiocarbon concentrations for the period AD 986 – 1013. The results are presented in Figure 4. In the last Phase III, which is planned, around 25 annual ring samples, covering the period between AD 985 – 1010, will be measured and compared with the curve form Miyake et al. (2013, 2015).

Quantitative tests of 26Al/10Be burial dating accuracy in archaeology and paleoanthropology

Prof. Darryl Granger[1], Dr. Lan Luo[1], Professor Marc Caffee[1]
[1]*PRIME Lab, Purdue University, United States*

Theme: A-7: Understanding the human story
Type of presentation: Invited Oral Presentation

The precision of burial dating with 26Al and 10Be has greatly increased due to the development of isochron methods together with improvements in 26Al measurements by AMS. The burial dating method is becoming widely applied, and has been particularly impactful for dating in archaeology and human evolution, where many sites were previously undatable. In many cases burial dating confirms pre-existing notions of the site's antiquity, but in others the burial dates are significantly older than previously assumed. Given the often highly contentious nature of research in human evolution, this has raised important questions about the accuracy and reliability of the burial dating method in general, and the isochron method in particular.

Here we compare results from multiple independent dating methods at a variety of sites in archaeology and human evolution to quantitatively assess burial dating accuracy. We focus on sites with pre-existing radiometric dating and/or paleomagnetic stratigraphy. Burial ages are calculated accounting for uncertainties in production rates, production rate ratios, and decay constants. For this comparison we analyze only isochron burial ages, which are more robust against outliers and have higher precision than simple burial ages.

We find that in all cases where there is careful stratigraphic control the isochron burial dating method agrees within expected uncertainty with independent bracketing ages from paleomagnetism and U-Pb dating of cave flowstones, confirming previous comparison with 40Ar/39Ar in bracketing volcanic flows. Cases where burial dating disagrees with other work can be explained by independent stratigraphic re-analyses showing previously unrecognized unconformities or intrusions that affected earlier interpretations.

We conclude that the isochron burial dating method is accurate to approximately within calculated uncertainties Internal checks , including goodness-of-fit and the calculated value of postburial production rates, can be used to validate assumptions in the method and bolster confidence in the reliability of the results. Older-than-expected isochron burial ages at archaeological sites must therefore stimulate a re-evaluation of early human evolution and migration, including the earliest hominin migration into Asia.

Radiocarbon dating of charcoals in mother mortars

Dr Katerina Pachnerova Brabcova[1], Mr Pavel Simek[1], Mr Tomas Krofta[1], Dr Vaclav Suchy[1], Dr Pavel Kundrat[1], Dr Petr Kozlovec[2], Ms Kristyna Kotkova[2], Dr Anna Fialova[2], Dr Jan Valek[2], Dr Ivo Svetlik[1]
[1]Nuclear Physics Institute of the CAS, Praha, Czech Republic, [2]Institute of Theoretical and Applied Mechanics of the CAS, Praha, Czech Republic

Theme: A-7: Understanding the human story
Type of presentation: Poster-Plus Presentation

Radiocarbon dating of historical mortars remains challenging due to the complex processes that take place during mortar maturation, which, if not reflected, lead to misleading rejuvenation or ageing of the results. Organic remains embedded in the mortars, such as wood charcoals, seeds, microbiotas, wood, or bones, are also available for dating; however, such samples are often perceived as unsuitable for the possibility of yielding older age which differs from the age of the mother mortar. A typical example frequently mentioned in the literature is the problem of so-called “old wood” based on the fact that even very old trees can be used as fuel for burning limestone, resulting in the embedded charcoals being older than the mortars.

This work adds to the determination of how reliable such organic inclusions can be for radiocarbon dating, with special attention paid to wood charcoals. For the analysis, we have collected 192 charcoal samples from seven different historical castles and churches located throughout the Czech Republic. The chosen architectural objects meet the following criteria: i) known age documented in written sources and optimally also obtained through other dating method or complemented with radiocarbon dating of samples other than mortar samples; ii) known history of repairs and maintenance; iii) the age falling into the period before the erratic wiggles of the 14C calibration curve in the early modern period — before 1650 AD. In the context of the Czech Republic history, it resulted in the selection of early to late medieval objects. The occurrence of charcoals varied significantly from object to object, ranging from 0.003 to 0.033 charcoals per m2.

The samples were carefully examined, cleaned under an optical microscope and treated with an acid-base-acid procedure. About 10% of the samples dissolved completely, thus reducing the final number of the charcoal samples. The surviving samples were then combusted and finally graphitized using metallic zinc as a sole reduction agent. Accelerator mass spectrometry (AMS) measurements were performed using the MICADAS instrument by the Hertelendi Laboratory of Environmental Studies in Debrecen, ATOMKI, Hungary or the MILEA instrument by the Nuclear Physics Institute, Czech Republic. The AMS results were compared with the known age of the castles.

The first results did not confirm the extended use of very old wood for burning limestone, as most of the analysed charcoals were not older than the mother mortars. On the contrary, several samples were found to be younger. The sources of charcoal contamination during the long-term exposure when embedded in the mortars, as well as the possibility of its removal, are discussed in this contribution.

Radiocarbon dating of historical iron products with accelerator mass spectrometry

Dr Toshio Nakamura[1], Mr Koichi Eto[2], Mr Takao Fujimoto[3], Mr Tetsuya Yamada[4], Prof Tsutomu Saito[5], Prof Masayo Minami[1]
[1]Nagoya University, Nagoya, Japan, [2]Eto Sword Refreshing, Fukuoka, Japan, [3]Sword Judgment Expert, Pieter Lodewijk Takstraat, The Neterlands, [4]Gangoji Institute for Research of Japanese Property, Minami Hijitsuka, Japan, [5]National Institute of Japanese History, Sakura, Japan

Theme: A-7: Understanding the human story
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The age of ancient iron artifacts can be measured by using carbon component contained in metal iron that was included during the iron producing or iron reprocessing stages. To extract carbon from iron artifacts in a form of CO2, a quartz tube has been used for metal iron combustion at the temperature of 1000°C for about 15 hours. We tested the quartz tube combustion method successfully of metal iron in a fine flake condition of almost 1mm in size. Almost 87 % recovery in average for 24 standard iron material was attained when metal iron weight is about 25% of CuO used as an oxidizer. The CO2 of about 1mg carbon was changed to graphite and 14C dated with the HVE 14C-AMS system at Nagoya University.

One of the famous iron artifacts in Japan is Japanese sword, owned traditionally by samurai, a Japanese warrior, and used during battles. At the present time, Japanese swords are one of excellent art collections, and many fake swords exist in the market. Traditionally, Japanese sword has been authenticated by experts based on visual outlook of them and judged real ones out of fakes. A more scientific method was required for judging the original sword. We have analyzed several iron flakes of about 1mm in size collected from Japanese swords in the course of grinding and re-sharpening them. The analyzed swords were believed to have produced in the 2nd century and after, by the name of the manufacturer inscribed on the surface of the sword, and/or by the traditional judgment by experts. The obtained 14C dates for the sword samples were calibrated with IntCal20 and compared with the authorized production dates by visual analysis. The 14C ages were almost consistent with the judgments. We consider that 14C dating is a useful tool to certificate the visual judgment of the swords by experts and to accept existing historical documents about them.

In addition, iron rust samples are commonly excavated from archeological sites in Japan and in foreign countries. We have tested four rust nail samples form archeological sites in India, to collect carbon component successfully by the quartz tube in the same way as pure metal iron. The nail samples were covered by rust on the surface, but the samples should contain metal portion, because they were attracted by the magnetic filed. The carbon content of the rust nails was from 0.2 to 0.5 % in weight ratio. We are going to get their 14C ages soon.

Radiocarbon dating of the large-scale bronze age burials at Mogou site in Gansu, China

Prof. Xiaohong Wu[1], Miss YiHsien Lin[1], Miss Yan Pan[1], Prof. Ruilin Mao[2], Prof. Hui Wang[3]
[1]School Of Archaeology And Muselogy, Peking University, , China, [2]Institute of Archaeology in Gansu Province, Lan Zhou, China, [3]Fudan University, Shanhai, China

Theme: A-7: Understanding the human story
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Mogou site is located in the U-shaped mountain area at North-west bank of Tao Valley, on the northeastern edge of the Qinghai-Tibet Plateau, with 2200 meters high in altitude. The site was excavated since 2008 and more than 1600 burials were found in 8000 square meters. The excavation of this cemetery provides very important new information for the study of eastern and western cultural communication along the Hexi corridor, and also provides important clues for the exploration of the origin and development process of nomadic culture in northwest China. Most of the individuals were buried in the ground directly and some are cremated. The tombs were arranged in rows from northeast to southwest, with the tombs facing northwest. The tombs were in two types, vertical cavity with or without partial chamber. Most of the bombs are only with one chamber. Double chamber tombs are relatively few. The traces of door were found at most of the chambers. Most of simple vertical cavity tombs are buried by one person. There are only a small number of single burial found in tombs with chamber. Usually 2 ~ 3 or more than 10 people buried together, including adults and children in the tombs with chamber. The skeletons in the inner part of the chambers were mostly disturbed, which gave the clue that the individuals were not burials together at one time. Most of the artifacts found with burials were pottery, with relatively few tools, and the skeletons were often decorated with bone, stone and copper. The earthenware are the jars in red clay and gray clay, with double ears, abdominal ears, tiny neck, drum belly etc. Some amphorae with the trend of saddle mouth were found. Lot of the evidences were found for the two different cultural sets of artifacts coexist in the same burial. More than 120 bone samples were collected from the burials, according to the types of tombs, single burial or multi burial, style of artifacts, spatial arrangement, et al. The bone sample were treated following the protocol of the gelatin extraction after pretreatment and graphitization. The radiocarbon measurements were carried out by compact AMS at PKU. Finally, about 50 radiocarbon dating ages were produced and calibrated by OxCal V4.2, calibration curve 2020. The modelling calculation by Bayesian statistics analysis produced the time range of the burials as the first stage from 1648-1562 BC to 1418-1369 BC, the second stage from 1546-1498 BC to 1277-1229 BC. The results shows that the two groups of people with different cultures came to this area at different time and met, stayed along for about hundreds years. The chronological results laid solid foundation for the further research of livelihood, environmental effects, cultural or biological exchange and communication with the two different groups of people.

Single-year radiocarbon dating of Japanese tree rings of the 9-10th century including the 946CE eruption of the Baitoushan Volcano.

Dr. Minoru Sakamoto[1,2], Dr. Takumi Mitsutani[3], Dr. Fuyuki Tokanai[4]

[1]*National Museum of Japanese History, Sakura, Japan,* [2]*The Graduate University for Advanced Studies, Sakura, Japan,* [3]*Nara National Research Institute for Cultural Properties, Nara, Japan,* [4]*Yamagata University, Kaminoyama, Japan*

Theme: A-7: Understanding the human story
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After the discovery of the rapid increase in atmospheric ^{14}C concentration at 775CE, known as the Miyake event, radiocarbon dating of tree rings is intensively promoted to certify the event and to find similar behaviors. As a result, a large amount of single-year radiocarbon ages of the 8th-century corresponding to the 775CE event and of around 1000CE corresponding to the subsequent 993CE event were accumulated. The IntCal20 calibration curve contains these data, however, single-year radiocarbon data of the 10th century still seems to be inadequate. Therefore we conducted single-year radiocarbon dating of Japanese tree rings of the 9-10th century to confirm the fine structure of ^{14}C concentration.

The wood of Japanese cypress (Chamaecyparis obtusa) was provided by Iida City, Nagano, Japan. Dendrochronological age determination resulted in the range of 795-1055CE (t=9.2) matching with the master chronology for central Japan. Plate-like bleaching of the butt end of the tree rings was carried out to obtain cellulose of single-year. Graphitization and AMS radiocarbon measurement was performed by YU-AMS.

The radiocarbon ages of the single-year cellulose were mainly located above the IntCal20 calibration curve. The period includes the 946CE eruption of the Baitoushan (Changbaishan) volcano located on the border between China and North Korea, as determined by ^{14}C spike matching based on the Miyake event. Previous attempts of ^{14}C wiggle matching for this eruption had not been very successful, suggesting instability in the calibration curve. Additional accumulation of the radiocarbon ages of tree rings of this period is also needed.

Temples through time: a radiocarbon-based chronology for the Bronze to Iron Age temple sequence at Pella (Jordan)

Dr Lyndelle Webster[1], Dr Stephen Bourke[2], Ms Anne Dighton[3], Dr Quan Hua[4], Dr Geraldine Jacobsen[4]
[1]Austrian Academy Of Sciences, Vienna, Austria, [2]University of Sydney, Sydney, Australia, [3]University of Queensland, Brisbane, Australia, [4]ANSTO, Kirrawee DC, Australia

Theme: A-7: Understanding the human story
Type of presentation: Oral Presentation

The sequence of temples at Tabaqat Fahil (Pella) is among the largest and best-preserved in the southern Levant. Its six phases of architecture – exposed in recent decades by the University of Sydney – exemplify the longevity of sacred precincts and documents how temple designs and cult practices developed over time. Pella offers a unique chance to investigate these structures with up-to-date approaches and techniques, since many parallel examples were exposed in the early–mid-20th century (e.g. Megiddo, Shechem and Beth Shean). Pella's six consecutive temple phases are particularly well-suited to AMS radiocarbon-based dating with a Bayesian approach.

Samples for 14C dating were collected throughout the seasons of excavation, and a substantial dataset developed in collaboration with ANSTO and other partner institutions. This paper will present an analysis of the presently available data, comparing the results of a 14C-based chronology with the traditional dating of each phase, and exploring implications for wider chronological issues.

Using stable isotope analysis of archaeological pandanus nutshell to understand past rainfall at Madjedbebe, northern Australia

Dr Anna Florin[1,2,3], Dr Patrick Roberts[4,2,3], Assoc. Prof. Ben Marwick[5], Nicholas R. Patton[6], Prof. James Shulmeister[6,7,3], Prof. Catherine E. Lovelock[8], Linda A. Barry[9], Dr Quan Hua[9], May Nango[10], Djaykuk Djandjomerr[10], Prof. Richard Fullagar[11], Assoc. Prof. Lynley A. Wallis[12], Prof. Andrew S. Fairbairn[2,3,4], Prof. Chris Clarkson[2,3,4,11]

[1]St John's College, University Of Cambridge, Cambridge, United Kingdom, [2]School of Social Science, University of Queensland, Brisbane, Australia, [3]ARC Centre of Excellence for Australian Biodiversity and Heritage, Wollongong, Australia, [4]Department of Archaeology, Max Planck Institute for the Science of Human History, Jena, Germany, [5]Department of Anthropology, University of Washington, Seattle, USA, [6]School of Earth and Environment, University of Canterbury, Christchurch, New Zeaand, [7]School of Earth and Environmental Sciences, University of Queensland, Brisbane, Australia, [8]School of Biological Sciences, University of Queensland, Brisbane, Australia, [9]Australia Nuclear Science and Technology Organisation, Lucas Heights, Australia, [10]Gundjeihmi Aboriginal Corporation, Jabiru, Australia, [11]Centre for Archaeological Science, School of Earth, Atmospheric and Life Sciences, University of Wollongong, Wollongong, Australia, [12]11Griffith Centre for Social and Cultural Research, Griffith University, Nathan, Australia

Theme: A-7: Understanding the human story
Type of presentation: Oral Presentation

Archaeological research provides a long-term perspective on how humans live with various environmental conditions over tens of thousands of years. However, to do this, archaeologists rely on the existence of local and temporally comparable environmental proxies, which are often not available. Our research at Madjedbebe, a ~65,000-year-old archaeological site on Mirarr country in northern Australia, developed an on-site proxy for past rainfall from pandanus nutshell, a remnant of ancient meals eaten at the site. This talk will discuss how we can use ancient food scraps, such as pandanus nutshell, to document past rainfall and what the results of this research mean for communities living at Madjedbebe in the past.

Δ14C peak (BC660-5) appearing in earlywood and latewood from tree rings close polar area (Finland)

Dr Junghun Park[1], Dr. Joonas Uusitalo, Dr. Wan Hong[1], Dr. G. Park[1], Dr. K. S. Sung[1], Laura Arppe[1], Samuli Helama[1], Harri Mäkinen[1], Pekka Nöjd[1], Markku Oinonen[1]

[1]Kigam, Daejeon, South Korea

Theme: A-8: Understanding the cosmos
Type of presentation: Oral Presentation

Since annual Δ^{14} C graph can mean special thing like M12, 993/4 CE and ~BC660, the causes and the detail procedures are surveyed. We focused BC 660 Δ^{14} C peak and collected tree rings in the area (Finland) close polar. Tree rings on this area can respond to extreme solar proton events (SPE) faster than other areas, so we respect information about detail procedure and intensity of ~BC660 event. The tree rings were divided into earlywood and latewood and precisely measured. Measured data were compared with air simulation results using new estimated troposphere and stratosphere ratio and carbon oxidation time. Timing and intensity of SPE were estimated and what the cause of longer increase time of ~BC660 event is two serial SPE became more reliable from the analysis.

26Al and 10Be in urban and Antarctic micrometeorites

Dr Jenny Feige[1], Alessandro Airo[1,2], Dirk Berger[1], Dennis Brückner[3], Matthew Genge[4], Ingo Leya[5], Fatemeh Habibi Marekani[1], Niko Klingner[6], Johannes Lachner[6,7], Jörg Nissen[1], Beate Patzer[1], Nicolas Schley[1], Andreas Schropp[3], Scott Peterson[8], Christof Sager[1], Martin Suttle[9], Reto Trappitsch[10], Joachim Weinhold[1]
[1]Technische Universität Berlin, Berlin, Germany, [2]Museum für Naturkunde, Berlin, Germany, [3]Deutsches Elektronen-Synchrotron DESY, Hamburg, Germany, [4]Imperial College, London, United Kingdom, [5]Universität Bern, Bern, Switzerland, [6]Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany, [7]Universität Wien, Vienna, Austria, [8]University of Minnesota, Minneapolis, United States of America, [9]Natural History Museum, London, United Kingdom, [10]Brandeis University, Waltham, United States of America

Theme: A-8: Understanding the cosmos
Type of presentation: Invited Oral Presentation

Roughly 100 tons of extraterrestrial material released from asteroid collision events or cometary sublimation enter the Earth’s atmosphere each day. Part of this material reaches the Earth’s surface as micrometeorites (MMs) – mostly submillimetre-sized spherical melted droplets. For more than a century MMs were collected only in remote environments such as deep-sea sediments or Antarctic firn and ice. However, since 2017 significant numbers of MMs have been recovered from urban areas, particularly the rooftops of buildings. In contrast to MMs originating from slow-accumulating environments that can have terrestrial ages of millions of years, cosmic spherules recovered from rooftops are not older than the buildings themselves and are therefore the youngest MMs ever collected.

The study of the irradiation histories of MMs provides an important step towards identifying the nature and origin of their parent bodies. During their million-year-long space journey on spiral trajectories to Earth, these small interplanetary particles are exposed to cosmic radiation producing long-lived radionuclides such as ^{26}Al and ^{10}Be. Since the number of cosmogenic nuclides increases with the time the MMs reside in interplanetary space, it is possible to estimate from which heliocentric distance in the Solar System they originated. However, the very small amounts of a few million atoms of the radionuclides within a MM decrease after deposition on Earth, i.e., with increasing terrestrial age. Hence, urban MMs, with insignificant terrestrial ages, provide for the first time the opportunity to measure the highest possible concentrations of long-lived radionuclides within MMs.

We analyzed the ^{26}Al and ^{10}Be content of six urban MMs and, for comparison, six Antarctic MMs (which have terrestrial ages up to 780 kyr). These MMs with sizes of 90-500 µm were dissolved and, after stable carrier addition, ^{26}Al and ^{10}Be were chemically extracted and measured by accelerator mass spectrometry (AMS) at the Vienna Environmental Research Accelerator (VERA), Austria. The data was compared to results from numerical simulations calculating ^{26}Al and ^{10}Be concentrations in micrometeoroids using various orbital parameters, compositions, and irradiation profiles.

The ^{26}Al/^{27}Al and ^{10}Be/^{9}Be measurement results were significantly above the chemistry blank values, except for the smallest (90 µm) Antarctic MM. Conversion to ^{26}Al and ^{10}Be concentrations yield values between 10^4 and 10^7 atoms per sample. Based on the comparison of the ^{26}Al and ^{10}Be concentrations with the theoretical data we generally favour carbonaceous chondrite objects as the parent bodies of the MMs orbiting with several eccentricities within our Solar System.

Our results are influenced by the following assumptions: no pre-irradiation within the parent body, no mass loss during atmospheric entry, average carbonaceous or ordinary chondrite composition, no significant terrestrial ages, and no uncertainty in the production rates for ^{26}Al and ^{10}Be. Besides the use of additional methods such as mineralogical and isotope geochemical analysis, better statistics of long-lived radionuclides within MMs may help to constrain some of these assumptions.

AMS measurements of Zr-93 for astrophysical and nuclear technology applications

Dr Stefan Pavetich[1], Anton Wallner[1,2], Keith Fifield[1], Michaela B Froehlich[1], Shlomi Halfon[3], Yanan Huang[4], Dominik Koll[1], Martin Martschini[5], Michael Paul[6], Zuzana Slavkovská[1], Asher Shor[3], Johannes H Sterba[7], Moshe Tessler[6], Steve G Tims[1], Leo Weissman[3]

[1]Research School of Physics, The Australian National University, , Australia, [2]Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany, [3]Soreq Nuclear Research Center, Yavne, Israel, [4]School of Marine Sciences, Sun Yat-sen University, Zhuhai, China, [5]University of Vienna, Faculty of Physics, VERA Laboratory, Vienna, Austria, [6]Racah Institute of Physics, Hebrew University, Jerusalem, Israel, [7]TRIGA Center Atominstitut, Technische Universität Wien, Vienna, Austria

Theme: A-8: Understanding the cosmos
Type of presentation: Oral Presentation

The radionuclide ^{93}Zr with a half-life of (1.61±0.05) Myr [1] plays an important part in stellar nucleosynthesis and nuclear technology. In stellar environments it is predominately produced by neutron capture on stable ^{92}Zr in the slow neutron capture process (s-process). Neutron capture cross sections in the keV range are the key parameters to model this process. They are of particular importance in the Zr-mass range as this is the transition area between two components of the s-process taking place in two different stellar environments. Back on Earth, ^{93}Zr is produced in significant amounts in reactors as a high yield fission product of the nuclear fuel and by neutron capture on stable ^{92}Zr, which is used in the cladding of nuclear fuel rods.

Despite their importance, experimental data on neutron capture cross sections of ^{92}Zr at thermal, epithermal, and stellar energies, suffer from large uncertainties. The combination of neutron activations and AMS presents an alternative method to online time-of-flight (TOF) measurements for the determination of these cross sections. The main challenges in AMS of ^{93}Zr are the interference from the stable isobar ^{93}Nb and the production of reference material. The high particle energies available at the Heavy Ion Accelerator Facility (HIAF) are ideal to tackle the first challenge. Additionally, by using ZrF_4 as sample material and extracting ZrF_5^-, the Nb background is reduced by ≃2 orders of magnitude compared to the use of ZrO_2 samples and extraction of ZrO- beams. Using the 13+ charge state and particle energies of ≃190 MeV ^{93}Zr/Zr background levels in the 10^{-12} range are regularly achieved at HIAF.

Zirconium oxide powders were irradiated at the reactor of the Atominstitut in Vienna with thermal and epithermal neutrons, and a ZrO_2 pellet was irradiated at the Soreq Applied Research Accelerator Facility with keV neutrons produced by the ^{7}Li(p,n) reaction on the Liquid-Lithium Target. These samples were converted into ZrF_4 and their ^{93}Zr content was measured at HIAF. Preliminary results for the cross sections seem significantly higher than the most recent values from literature [2,3] (TOF and compilation respectively) but they still suffer from a large uncertainty in the nominal ratio of the AMS reference material that was used. Currently a new more precise reference material, produced via fission of ^{235}U, is being characterised.

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Holmium-166m measurements with AMS for the ECHo-project

Dr Georg Rugel[1], Sebastian Berndt[2], Christoph E. Düllmann[2,3,4], Holger Dorrer[2], Oliver Forstner[5,6], Tom Kieck[2,7], Johannes Lachner[1], Silke Merchel[1,8], Carlos Vivo-Vilches[1], Anton Wallner[1], Klaus Wendt[7]

[1]Accelerator Mass Spectrometry and Isotope Research, Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany, , Germany, [2]Department of Chemistry, Johannes Gutenberg University, Mainz, Germany, [3]GSI Helmholtzzentrum für Schwerionenforschung GmbH, Darmstadt, Germany, [4]Helmholtz Institute Mainz, Mainz, Germany, [5]Friedrich-Schiller-University Jena, Jena, Germany, [6]Helmholtz Institute Jena, Jena, Germany, [7]Institute of Physics, Johannes Gutenberg University, Mainz, Germany, [8]Isotope Physics, Faculty of Physics, University of Vienna, Vienna, Austria

Theme: A-8: Understanding the cosmos
Type of presentation: Oral Presentation

The Electron Capture in ^{163}Ho experiment (ECHo) aims at measuring the mass of the electron neutrino by analysing the EC spectrum of the long-lived radionuclide ^{163}Ho (T_1/2 = 4570 a) with a metallic magnetic calorimeter (MMC). For the determination of a reasonable upper limit for the neutrino mass it is mandatory to keep the contamination with the long-lived radionuclide ^{166} mHo (T_1/2 = 1132.6 a) nine orders of magnitude below the ^{163}Ho content. The ion-implantation of ultra-pure ^{163}Ho into a MMC for the experiment is carried out by the RISIKO (Resonance Ionization Spectroscopy in KOllinear geometry) mass separator. The separation from ^{166} mHo, however, cannot be guaranteed to such low levels as needed in this project, it can only be estimated. Here we present our approach to determine the corresponding low isotopic ratio with accelerator mass spectrometry (AMS). Of course, this requires the formation of negative ions, where we find the highest negative ion yield for the anion HoO_2^-. For first tests, stable ^{165} Ho was implanted by RISIKO into various different metal foils and we studied the overall Ho detection efficiency for our setup. We will present first results and estimates of the expected detection limit for the ^{166} mHo/^{163}Ho isotope ratio.

Radio-impurity measurements for a Dark Matter Sodium Iodide Detector

Ms Ferdos Dastgiri[1], Dr Zuzana Slavkovska[1], Dr M.B. Froehlich[1], Dr M. A. C. Hotchkis[2], Mr Dominik Koll[1], S. Merchel[1,3,4], Dr Stefan Pavetich[1], Dr S. G. Tims[1], Professor Keith Fifield[1], Dr Anton Wallner[3,1]

[1]Australian National University, Canberra, Australia, [2]Australian Nuclear Science and Technology Organisation, Sydney, Australia, [3]Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany, [4]Faculty of Physics, University of Vienna, Vienna, Austria

Theme: A-8: Understanding the cosmos
Type of presentation: Poster

The first dark matter detector is being built in the Stawell gold mine in south-eastern Australia, as the southern hemisphere arm of an international collaboration SABRE (Sodium Iodide with Active Background Rejection). This experiment employs ultra-low background sodium iodide (NaI) detectors placed in highly shielded vessels across both hemispheres. The aim is to confirm or refute annual modulation claims attributed to dark matter particles by the DAMA/LIBRA collaboration at the Laboratori Nazionali del Gran Sasso in Italy. This requires the lowest possible concentration of radio-contaminants that can be achieved, to minimise the potential for radiation signals that can mimic dark matter particles signals.

We report on the techniques employed for the detection of potentially problematic contaminants in the NaI material from which the crystals will be grown. We focus on the establishment of the measurement techniques of ^{40}K and ^{210}Pb at the Australian National University and ANSTO.

For the measurement of ^{40}K, Inductively Coupled Plasma Mass Spectrometry (ICP-MS) was used to measure the concentration of ^{39}K, and from the well-known natural abundance ratios of ^{39}K/^{40}K, the concentration of ^{40}K was inferred. The challenges associated with measuring ultra-precise levels of ^{39}K, and the techniques of minimising the introduction of potassium in the sample preparation will be discussed.

210-Lead was measured using AMS. The ^{210}Pb concentration in the NaI powder is very low, which necessitates that large amounts (~ 1kg) of the powder need to be processed to result in sufficient atoms for an AMS measurement. This low concentration requires the additions of a Pb-carrier (~ 1mg), which itself needs to contain minimal ^{210}Pb. Several lead materials have been investigated and will be reported. In addition, we will discuss the different lead compounds and cathode materials used to optimise the beam current and minimise the background.

Other contaminants of potential interest such as ^{3}H, ^{232}Th and ^{238}U; especially those identified in DAMA/LIBRA and other NaI detectors will be presented.

Reaction cross sections 54Fe(n,γ)55Fe and 35Cl(n,γ)36Cl at keV neutron energies investigated by Accelerator Mass Spectrometry

Dr Zuzana Slavkovska[1], Prof. Anton Wallner[1,3], R. Reifarth[2], L. Bott[2], B. Brückner[2], P. Erbacher[2], Prof. Keith Fifield[1], Dr Michaela Froehlich[1], K. Göbel[2], K. Al-Khasawneh[2], Mr Dominik Koll[1], Johannes Lachner[3], Dr Silke Merchel[3,4], Dr Stefan Pavetich[1], M. Reich[2], G. Rugel[3], B. Thomas[2], S. G. Tims[1], M. Volknandt[2], M. Weigand[2]

[1]Research School of Physics, The Australian National University, , Australia, [2]Institute of Applied Physics, Goethe University, Frankfurt, Germany, [3]3Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany, [4]4Faculty of Physics, University of Vienna, Vienna, Austria

Theme: A-8: Understanding the cosmos
Type of presentation: Oral Presentation

Typical neutron energies for the astrophysical s-process follow the Maxwell-Boltzmann distribution in the keV energy range. Neutron capture cross sections highly relevant for modelling the s-process can be experimentally determined by using the Time-of-Flight (ToF) method [1] or by the activation technique. If the reaction product is a long-lived radionuclide (t1/2 ~ yr -100 Myr), the cross section can be determined by activation with a quasi-stellar neutron distribution (typically kT = 25 keV) and a subsequent accelerator mass spectrometry (AMS) measurement of the reaction product [2]. Comparison of a number of such neutron capture cross sections shows a systematic bias, i.e. AMS data being lower than the ToF data [3, 4].

To investigate this discrepancy, we repeated experiments for two reactions that allow for highly precise AMS data: Maxwellian-averaged cross sections for the reactions 54Fe(n,γ)55Fe and 35Cl(n,γ)36Cl were investigated with dedicated activations at the Frankfurt Neutron Source (FRANZ) in Germany [5] and AMS measurements at two independent facilities. Analogously to previous activations, a quasi-stellar neutron spectrum of kT = 25 keV was produced via the 7Li(p,n) reaction, but at a different neutron-producing facility. Furthermore, to complement existing ToF and AMS data, an additional neutron activation of 54Fe and 35Cl at a proton energy of 2 MeV was performed, yielding data in the not-yet explored kT = 90 keV region.

The irradiated metallic Fe foil and NaCl pellet (both of natural isotopic composition) were chemically processed and converted to AMS targets (Fe2O3 and AgCl) together with non-irradiated blanks. The subsequent AMS measurements of both radionuclides, 36Cl and 55Fe, were performed at two complementary AMS facilities, the Heavy Ion Accelerator Facility (HIAF) at the Australian National University [6] and at the Helmholtz-Zentrum Dresden-Rossendorf (HZDR) in Germany [7]. AMS allows a direct measurement of the 55Fe/54Fe and 36Cl/35Cl conversion ratios that result from the irradiation. The cross section is then deduced from the isotope ratio and the neutron fluence, which is determined using Au monitor foils.

The new experiment was designed to produce highly accurate data and, owing to the two independent AMS measurements, it minimizes unrecognized sources of uncertainties in the AMS technique. The new preliminary data obtained in this work seem to confirm the previous AMS results. Consequently, the systematic discrepancy between AMS and ToF data remains unresolved.

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The Initial Exploration for 26Al Chronology in Ferromanganese Crust

Dr Kejun Dong[1], Ying Hu[1], Lifeng Cui[1], Ms. Jiaqi Zhang[1], Prof. Sheng Xu[1]
[1]*Institute of Surface Earth System Science, School of Earth System Science, Tianjin University, Tianjin, China*

Theme: A-8: Understanding the cosmos
Type of presentation: Poster

The dating techniques of 10Be/9Be has widely been used in study on the chronology of marine sediments with the development of accelerator mass spectrometry (AMS). However, some controversial topics were still remained due to the influence of isotope fractionation, palaeomagnetic intensity variations and measurement sensitivity etc. The deep-sea ferromanganese crust (DSFC) is a natural archive for recording of the history of the earth evolution, as one of the most common authigenic assemblages in marine sediments. An initial exploration for 26Al chronology in DSFC was proposed by using AMS measurement of 10Be and 26Al. The experimental protocol will focus on previous research and the corresponding relationship of isotopic ratios of Al and Be, discuss and explore the possibility of 26Al chronology based on the DSFC samples analysis and linear contrast with 10Be and 10Be/9Be. The experimental strategy and program will be detailed in this contribution.

The performance of Pb-210 AMS for the radioassay of materials considered for the construction of ultra-low background experiments in Astroparticle Physics

Dr Carlos Vivo-Vilches[1,2], Benjamin Weiser[1,2], Dr Xiaolei Zhao[3,4], Dr Barbara B.A. Francisco, Prof. Razvan Gornea[1], Prof. William E. Kieser[3,4]
[1]Department of Physics, Carleton University, Ottawa, Canada, [2]Arthur B. McDonald Institute, Kingston, Canada, [3]A. E. Lalonde AMS Laboratory, Ottawa, Canada, [4]Department of Physics, University of Ottawa, Ottawa, Canada

Theme: A-8: Understanding the cosmos
Type of presentation: Invited Oral Presentation

One of the most important tasks in the design and construction of ultra-low background experiments is the radioassay of the materials used. This requires the selection of the materials and enables the calculation of expected detector background. The ASTREA project (Accelerator mass spectrometry Survey of Trace Radionuclides for Experiments in Astroparticle physics) addresses AMS radioassay challenges for a few rare event experiments. Some examples are nEXO, which is searching for neutrinoless double beta decay; and NEWS-G and DarkSide, which are attempting to directly detect dark matter. This project, led by the André E. Lalonde AMS Laboratory (AEL-AMS) at the University of Ottawa, is performed in collaboration with Carleton University, Queens University and University of Alberta.

The main focus of the project is screening Pb-210 in various detector construction materials, with emphasis on low background copper and high-performance polymers. We have studied the possibility of using 2 different materials for the AMS measurements: lead fluoride (PbF2) and lead oxide (PbO) targets, producing respectively (PbF3)- and (PbO2)- ions on the LE side. In both cases, the 210Pb/206Pb blank ratio is in the 1e-14–1e-13 range. Measurements on 1-2 g Kapton films have established upper limits in the range 850-2500 mBq/kg at 90% C.L.

Future ASTREA activities will focus on the Pb-210 assay in acrylic, which is considered for future low background dark matter detectors. Previous best results, obtained in 2014 by γ-counting 2 kg of acrylic, have established an upper limit for the Pb-210 concentration of 0.3 mBq/kg. Our proposed method, using AMS, should provide a limit of detection in the 0.01-0.1 mBq/kg range.

Other important study looks at the Pb-210 contamination in the electroformation process of the copper for the NEWS-G and nEXO detectors. For the Pb-210 concentration in the copper, we estimate a limit of detection in the 0.3-1.0 mBq/kg range.

Time-Resolved Interstellar Pu-244 and Fe-60 Profiles in a Be-10 Dated Ferromanganese Crust

Mr Dominik Koll[1,2], Prof. Dr. Anton Wallner[1,2], Dr. Michael Hotchkis[3], Mr. David Child[3], Prof. Dr. Keith Fifield[1], Dr. Michaela Froehlich[1], Mr. Michi Hartnett[1], Dr. Johannes Lachner[2], Dr. Silke Merchel[1,2,4], Dr. Stefan Pavetich[1], Dr. Georg Rugel[2], Dr. Zuzana Slavkovska[1], Dr. Stephen Tims[1]

[1]Research School of Physics, Australian National University, Canberra, Australia, [2]Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany, [3]Australian Nuclear Science and Technology Organisation, Sydney, Australia, [4]Faculty of Physics, University of Vienna, Vienna, Austria

Theme: A-8: Understanding the cosmos
Type of presentation: Oral Presentation

More than 20 years have passed since the first attempts to find live supernova Fe-60 (t1/2 = 2.6 Myr) in a deep-sea ferromanganese crust [1]. Within these 20 years, strong evidence was presented for a global influx of supernova dust into several geological samples around 2 Myr ago. Recently, a much younger continuous influx was found in Antarctic snow and in deep-sea sediments [2-4] and an older peak around 7 Myr in deep-sea crusts [5,6].

The long-lived isotope Pu-244 (t1/2 = 80 Myr) is produced in the astrophysical r-process similarly to most of the heaviest elements. Although the production mechanism is believed to be understood, the astrophysical site is heavily disputed. Most likely scenarios involve a combination of rare supernovae and neutron star mergers. The search for Pu-244 signatures in samples with known Fe-60 signatures allows to test for either common influx patterns or independent Pu-244 influxes disentangled from stellar Fe-60. Accordingly, this information provides a unique and direct experimental approach for identifying the production site of the heavy elements.

Very recently and first reported in the AMS-14 conference, the first detection of interstellar Pu-244 was published [6]. This was only feasible by achieving the highest detection efficiencies for plutonium in AMS ever reported [7]. The achieved time resolution of 4.5 Myr integrates over the supernova influxes and is therefore not high enough to unequivocally show a correlated influx pattern of Fe-60 and Pu-244.
Based on this progress, we are now aiming to measure highly time-resolved profiles of Fe-60 and Pu-244 in the largest ferromanganese crust used so far. Results on the characterization of the crust including cosmogenic Be-10 (t1/2 = 1.4 Myr) dating and a 10 Myr profile of interstellar Fe-60 including the confirmation of the 7 Myr influx will be presented along with first data on interstellar Pu-244.

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Using 14C of tree rings to study CO2 emissions from fossil sources in Beijing

Dr Qingzhang Zhao[1], **Ming He**[1], Wenhui Zhang[1], Yijun Pang[1], Hongyu He[1], Jingjing Jia[2], Aiguo Li[2], Pan Hu[1]
[1]*China Institute of Atomic Energy, , ,* [2]*Institute of Atmospheric Physics, Chinese Academy of Sciences, ,*

Theme: A-8: Understanding the cosmos
Type of presentation: Poster

The study of fossil fuel-derived CO2 is important to understanding urban carbon emissions，which can help us to devise strategies to reduce emission. Using accelerator mass spectrometry to measure 14C of cedar tree rings near Beijing's North Fourth Ring Road, the emission trends of large burned fossil sources during the process of Beijing's urbanization were analyzed and studied. The results show that the concentration of 14C has a decreasing trend, and is positively correlated with the burning of a large number of fossil fuels in the economic and social development. Because burning large amounts of 14C-free fossil fuels emits CO2 and dilutes the concentration of CO2 in the atmosphere. This study lays a foundation for further research on the tracer application of 14C in the environment.

Keywords: fossil fuel-derived CO2; accelerator mass spectrometry;

A compact ECR ion source using a 2.45 GHz solid-state microwave generator for generating carbon ion beam

Prof. Hiroyuki Kitagaawa[1]

[1]*Institute for Space-Earth Environment Research, Nagoya, Japan*

Theme: T-1: Novel AMS systems, components and techniques
Type of presentation: Poster

At the Institute of Space-Earth Environmental Research, Nagoya University, A compact electron cyclotron resonance (ECR) ion source using a 2.45 GHz solid-state microwave generator for generating carbon ion beam has been developed on a trial basis. The plasma chamber volume is about 40 ml, and the 2.45 GHz microwave is introduced to the plasma chamber from a solid-state microwave generator with a maximum output of 200 W through small antennas with coaxial cables giving transverse-electromagnetic mode of transmission. The compact ECR is installed to a beam injection system; an Einzel lens, XY steer and injection faraday cup, 90◦ dipole magnet, which were made by modifying a part of the HVEE 14C AMS and General Ionex AMS system. A series of experiments and simulations for optimization of carbon isotope measurement will be discussed toward the practical use of stable carbon isotope and radiocarbon analyses.

A simple gas ionization chamber design for low energy ions measurements.

Prof. Hongtao Shen[1,2], Shulin Shi[1], Junsen Junsen Tang[1], Li Wang[1], Yingge Wang[1,3], Guofeng Zhang[1]
[1]Guangxi Normal University, Guilin, China, [2]Guangxi key laboratory of nuclear physics and technology, Guilin, China, [3]Sino-French Institute of Nuclear Engineering and Technology,Sun Yat-sen University, zhuhai, China

Theme: T-1: Novel AMS systems, components and techniques
Type of presentation: Poster

A simple single anode gas ionization chamber (GIC) design for low energy ions was developed for the small accelerator mass spectrometer (GXNU-AMS) at Guangxi Normal University. This detector consists of a 50nm silicon nitride window, an anode, a Frisch grid, and a cathode. To find optimal measurement conditions and to characterize the detector performance in the low energy, the test experiments have been performed with ions of 3H and 14C in the energies range from 15keV to 250 keV, and the dependence of energy resolution and charge output per unit particle energy of the projectile is investigated and parametrized. As a result, Tritiums below 20 keV were measured with a resolution better than 3 keV, radiocarbons below 50 keV were measured with a resolution better than 10 keV, and good linearity of the particle energy and detector signal was found in the energy range between 50 and 250keV. Also, the low energy performance of GIC is compared to that of the Surface Barrier Detector and proves that GICs are more suitable for measuring ions at extremely low energy, which meets the requirements for 3H and 14C measurements at GXNU-AMS.

A single stage AMS system and its applications at Guangxi Normal University

Prof. Hongtao Shen[1,2,3], Shulin Shi[1], Junsen Tang[1], Li Wang[1], Guofeng Zhang[1], Mingji Liu[1], Professor Kimikazu Sasa[2], Professor Ming He[4], Yiwen Bao[4], Professor Jiang Shan[1]

[1]Guangxi Normal University, Guilin, China, [2]University of Tsukuba, Tsukuba, Japan, [3]Guangxi key laboratory of nuclear physics and technology, Guilin, China, [4]China institute of Atomic Energy, Beijing, China

Theme: T-1: Novel AMS systems, components and techniques
Type of presentation: Oral Presentation

GXNU-AMS, a compact 14C accelerator mass spectrometer, jointly developed by the Chinese Institute of Atomic Energy and Guangxi Normal University was installed and commissioned in Guangxi Normal University. Without the traditional mode of SF6 pressure tank, The terminal of the system was designed as an open insulated high voltage platform, which reduces the construction size of the traditional accelerator to be about 2.5×4.5 square meters. Helium gas stripping was used to eliminate the interference of molecular ions, and the maximum operating voltage was 230KV. At present, the measurement accuracy of the instrument is 0.5%, and the measurement sensitivity is 14C/12C≈5×10-15 (measurement background is 45,000 years), which can meet the measurement requirements in the fields of life sciences and archaeology. In this paper, the experimental conditions and the lowest possible energy of GXNU-AMS were discussed, as well as several interesting application studies in GXNU-AMS group were presented.

Keywords: status; GXNU-AMS; 14C; low energy

Absolute Measurements and AMS - Towards the redetermination of the half-life of ^{32}Si

Matthias Schlomberg[1], **Dr Christof Vockenhuber[1]**, Hans-Arno Synal[1], Dorothea Schumann[2], Mario Veicht[2], Ionut Mihalcea[2], Anton Wallner[3]
[1]ETH Zurich, , Switzerland, [2]PSI, , Switzerland, [3]HZDR/ANU, Australia

Theme: T-1: Novel AMS systems, components and techniques
Type of presentation: Oral Presentation

AMS usually relies on relative measurements, i.e., measurements of unknown isotopic ratios of samples relative to well-known standard materials. In the case of ^{32}Si no such standard material is available; even worse its half-life of about 150 years is still not well known despite several independent measurements over the past decades.

The determination of the half-life of long-lived radionuclides requires two absolute measurements, the activity concentration (Bq/g) and the atom concentration (at/g) of the radionuclide, respectively, both having their own challenges and can result in (often unknown) systematic errors. In the past, AMS has been used for the latter, however, given the complex AMS instrument these measurements require some extra effort. All relevant changes to the measured isotopic ratios must be well understood. In particular fractionation effects in the ion source and during the stripping process in the tandem accelerator can have a significant effect especially at large mass differences. These can be monitored with stable isotopes, luckily silicon has three stable isotopes, ^{28} Si, ^{29} Si and ^{30} Si. Additionally, losses to the radionuclide in the detection setup must be quantified. We aim for a simple absorber setup for isobar separation of ^{32}Si from ^{32}S, details are presented in another contribution to this conference.

In this presentation, we concentrate on the challenges of the absolute measurement of ^{32}Si for the half-life measurement within the SINCHRON collaboration with partners from PSI, CHUV, PTB, ANU and ETH. Results of dedicated charge state distribution measurements and the strategy for an absolute AMS measurement are presented.

Addition of charge state selection after the terminal stripping for reduced background in AMS

Grazia Scognamiglio[1], Matthias Klein[1], Dirk Mous[1]
[1] *High Voltage Engineering Europa B.V., Amersfoort, The Netherlands*

Theme: T-1: Novel AMS systems, components and techniques
Type of presentation: Invited Oral Presentation

Fragments from injected molecules, which undergo charge exchange in the second acceleration stage of tandem accelerators, are an important contribution to the measurement background in AMS systems. The latest sub-MV AMS machines designed by High Voltage Engineering Europa B.V. are equipped with vacuum insulated accelerators featuring charge state selectors (CSS) in the terminal [1]. The CSS consists of a magnetic or electrostatic deflector that selects a specific charge state after the stripper, filtering out background contributions originating from charge exchange processes in the high-energy acceleration section.

The effectiveness of the CSS method has been demonstrated on the ^{14}C-dedicated 4102Bo-AMS system, which is equipped with a tandem accelerator operating at 210 kV terminal voltage. After the stripping process in the accelerator, ions in the 1+ charge state have the highest yield and are selected for the AMS measurement. Along ^{14}C, isobaric $^{12}CH_2$ and ^{13}CH molecules are injected into the accelerator and break-up in the stripper. A fraction of ^{12}C and ^{13}C molecular fragments undergoes 2+ → 1+ charge exchange in the second acceleration stage and increases the $^{14}C/^{12}C$ background to the mid to high 10^{-15} level, depending on the molecule content in the ion beam. A magnetic CSS in the accelerator terminal suppresses other charge states than 1+, removing these background contributions and enabling the measurement of a $^{14}C/^{12}C$ blank ratio in the 10^{-16} regime.

Following the results obtained with the ^{14}C-dedicated system, HVE will apply the CSS method also to the multi-element 4103Bo-AMS system based on a 300 kV terminal voltage vacuum-insulated accelerator. The CSS is added to improve the measurement background especially for actinide AMS. Actinide measurements use the 3+ charge state but suffer the interference of 4+ molecular fragments that charge exchange to 3+ in the high-energy acceleration stage. The CSS removes the ions in the 4+ charge state, thereby preventing the 4+ → 3+ charge exchange processes responsible for the dominant class of background.

In this presentation, we will discuss the design and the measurement results obtained at the ^{14}C-dedicated 4102Bo-AMS system and the design of the new 300 kV tandem accelerator for the multi-element 4103Bo-AMS system.

[1] European Patent EP 18177774.9.

An advanced radio-frequency quadrupole ion cooler for Accelerator Mass Spectrometry

Dr Markus Schiffer[1,2], Oscar Machhart[2], Susan Herb[1], Martin Martschini[2], Robin Golser[2], Erik Strub[3], Tibor Dunai[4], Alfred Dewald[1]
[1]University of Cologne, Institute for Nuclear Physics, , Germany, [2]University of Vienna, Faculty of Physics, Isotope Physics, , Austria, [3]University of Cologne, Institute for Nuclear Chemistry, , Germany, [4]University of Cologne, Institute for Geology and Mineralogy, , Germany

Theme: T-1: Novel AMS systems, components and techniques
Type of presentation: Oral Presentation

Ion Laser InterAction Mass Spectrometry (ILIAMS) has demonstrated an extraordinarily high isobar suppression capability for a variety of radionuclides which are important for accelerator mass spectrometry. It uses selective laser photodetachment of decelerated ion beams in a gas-filled radio-frequency quadrupole (RFQ) cooler for the suppression of interfering isobars [1]. Furthermore, the admixture of O_2 gas (≈3%) to the helium buffer gas has revealed an even higher isobar suppression, larger than 10^5 in the case of $^{90}Sr/^{90}Zr$, at the Vienna Environmental Research Accelerator (VERA), without the use of a laser.

Therefore, we started to develop a RFQ cooler designed for the deceleration and trapping of ion beams with high beam emittance like heavy molecular anions, e.g. $^{90}SrF_3$. The system will be finally used at the Cologne 6 MV accelerator after commissioning and test measurements at VERA. The ion cooler will use gas reactions with the option of adding a laser in a later phase.

The new RFQ design intends to solve technical challenges by a self-aligned structure with the possibility of readjustment without breaking the vacuum. The vacuum chamber of the RFQ can be opened at the top for easy maintenance and for changes in the experimental setup. This allows changes of the quadrupole itself, like the installation of higher-order multipole segments at the entrance of the radio-frequency device providing higher acceptance for divergent ion beams. Based on the design of the injection unit of ISOLTRAP [2] an elliptical injection electrode was developed that should increase the theoretical transmission in comparison to ring or conical electrodes. It will also allow to slow down the ions far away from the central region where the buffer gas is leaking out of the RFQ trough the central aperture.

A new and easy to manufacture guide field assembly was developed to reduce the electric multipole order, which is naturally induced by inclined DC electrodes. For this purpose, diagonally split cylindrical electrodes are capacitively coupled to a core rod that is carrying the RF signal. Consequently, only low DC voltages are needed to create a gradually changing potential in longitudinal direction. This design is a simplification of the diagonally split hyperbolical RF electrode assembly of BECOLA [3]. In this contribution, we will compare different guiding field structures by the calculation of multipole expansion coefficients.

Additionally, a remote-controlled radio-frequency resonance tuning and impedance matching system for heavy radionuclide applications will be presented, which is able to drive the RFQ with frequencies in the range of 1 MHz with RF peak-to-peak voltages of 250 V.

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[2]A. Kellerbauer et al., Buffer gas cooling of ion beams, NIM A 469 (2001) 276–285.
[3] B.R. Barquest et al., RFQ beam cooler and buncher for collinear laser spectroscopy of rare isotopes, NIM A 866 (2017) 18-28.

An overview of world-wide AMS facilities

Prof. Walter Kutschera[1]

[1]*University of Vienna, Faculty of Physics, Isotope Physics, , Austria*

Theme: T-1: Novel AMS systems, components and techniques
Type of presentation: Oral Presentation

The current review will attempt to cover the world-wide spread of AMS facilities, reflecting the tremendous success of AMS to explore our environment at large.

Accelerator Mass Spectrometry (AMS) started in earnest in 1977, when physicists at three nuclear physics laboratories in North America (Berkeley, McMaster, Rochester) realised almost simultaneously that accelerators can be used to measure extremely low abundances of long-lived radioisotopes by ‘counting atoms rather than decays‘.

After early AMS experiments with existing accelerators, including cyclotrons, linear accelerators and tandem accelerators, it was quickly realised that tandem accelerators are best suited for AMS of 14C and a few other radioisotopes. The chief reason is the complete absence of the interference from the isobar 14N, because nitrogen does not form stable negative ions. Therefore, with very few exception (e.g. the ATLAS linear accelerator at Argonne National Lab), tandem accelerators became the dominant accelerator type for AMS.

The field of AMS benefitted greatly from the early development of dedicated AMS facilities, pioneered by the late Ken Purser. Eventually the field developed from a handful AMS facilities in the early 1980s to a world-wide total of ~150 in 2021. Originally, AMS at existing tandem accelerators and dedicated AMS facilities manufactured by High Voltage Engineering Europe (HVE) and by National Electrostatics Corporation (NEC) dominated the field. Later, intense ion-beam studies of the AMS group at the ETH Zuerich, partly in collaboration with NEC, allowed a considerable reduction of the terminal voltage from 3 MV to eventually 0.2 MV. This resulted in a laboratory-size AMS facility called MICADAS (Mini Carbon Dating System), which is now being manufactured by the spin-off company Ionplus.

Although 14C is by far the most-used radioisotope in research with AMS, many other radioisotopes in the half-life range from a few years to 100 million years (~40) are of interest for AMS studies in a multitude of different fields, examplified by the versatile program of the AMS-15 Conference. A number of these radioisotopes (e.g. 10Be, 26Al, 36Cl, 41Ca, 129I, and some of the actinide isotopes) can nowadays almost be considered ‘routine‘ ones, but there are quite a few rarely used radioisotopes which require special techniques to reduce the interference from stable isobars. The VERA lab has successfully developed the Ion Laser InterAction Spectrometry (ILIAMS) system to allow for yet difficult-to-measure radioisotopes like 90Sr, 135Cs, and 182Hf (Martschini et al., this meeting). ILIAMS also opens up new possibilities for low-energy accelerators to measure 36Cl by complete suppression of 36S.

One purpose of the current review is to present a complete list of all AMS facilities around the world, to the best of the author’s knowledge. For this I am thankful for the information provided by Henri van Oosterhout (HVE), Mark Sundquist (NEC), and Hans-Arno Synal (ETHZ). Comments and corrections for the list of AMS facilities are welcome and will be considered in the paper for the proceedings of the conference.

Be-10 and Al-26 analysis with the prototype 300kV MILEA system at ETH Zurich

Mr Philip Gautschi[1], Dr Marcus Christl[1], Dr Christof Vockenhuber[1], Dr Arnold Müller[1,2], Dr Sascha Maxeiner[1,2], Prof Hans-Arno Synal[1]
[1]ETH Zurich, Zurich, Switzerland, [2]Ionplus AG, Dietikon, Switzerland

Theme: T-1: Novel AMS systems, components and techniques
Type of presentation: Oral Presentation

The construction of a new Multi Isotope Low Energy Accelerator system (MILEA) was finalized at the LIP, ETH Zürich in 2018. As a compact low energy AMS system with a maximal terminal voltage of 300 kV, it is optimized for high overall beam transport and efficiency [1]. It consists of a MICADAS type negative Cs sputter ion source [2], followed by an achromatic electrostatic analyser (ESA)-magnet pair on the low energy (LE) side. The accelerator uses a 300kV solid state power supply and is equipped with a He-stripper. On the high energy (HE) side the system consists of two magnets with an ESA in between. The detection system consists of nine Faraday cups for current measurements and a two-anode gas ionization chamber (GIC), which can be optionally equipped with a gas absorber cell.

For routine Be-10 measurements at MILEA samples are prepared from BeO powder, mixed with Niobium (~1:1 molar) and then pressed into Al sample holders. The molecule BeO- is extracted and injected into the stripper at a positive terminal voltage of 220 kV. This terminal voltage was selected based on systematic transmission measurements into the 1+ and 2+ charge state for stripping energies between 50keV and 120keV. On the HE side the 2+ charge state is selected and 9Be2+ is measured as positive current (up to 5 pμA) in an offset Faraday cup. Boron isobar separation is achieved with a 75 nm Si3N4 degrader foil setup and a two anode GIC. The second HE magnet removes potentially interfering Be-9 ions [3] and ensures for achromatic beam transport of Be-10 into the GIC.

For Al-26, samples are prepared as AlO powder, mixed with Cu, and pressed into Cu sample holders. On the LE side masses 27 and 26 (Al-27 and Al-26) are injected sequentially into the stripper channel at a positive terminal voltage of 280 kV. On the HE side the 2+ charge state is selected and Al-27 is measured in an offset faraday cup (up to 0.3 pμA). The separation of 26Al2+ from its m/q interference 13C1+ is achieved by a gas filled absorber cell, placed directly in front of the GIC where the carbon ions are stopped due to their 50% lower energy [4].

This contribution presents the setup and parameters currently used at LIP for routine Beryllium-10 and Aluminium-26 measurements with MILEA, including their respective performance parameters such as blank levels, stability, linearity and overall efficiency.

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Coulomb Explosion of BeO

Prof. Keith Fifield[1], Prof Martin Suter[3], Dr Michaela Froehlich[1], Mr Dominik Koll[1], Dr Stefan Pavetich[1], Dr Zuzana Slavkovska[1], A/Prof Stephen Tims[1], Prof Anton Wallner[1,3]

[1]The Australian National University, Canberra, Australia, [2]Laboratory of Ion Beam Physics, ETH, Zurich, Switzerland, [3]Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany

Theme: T-1: Novel AMS systems, components and techniques
Type of presentation: Oral Presentation

Molecular negative ions used in AMS, most notably BeO-, may undergo so-called “Coulomb explosion” when they are dissociated in the stripper. In this process, both components of the molecule are stripped to positive ions while still at molecular separation. They therefore repel each other, and the Coulomb potential energy is converted into kinetic energy of their relative motion. Somewhat counter-intuitively, this can lead to a significant spread in energy after the second stage of acceleration with implications for transmission.

The situation is most extreme for foil stripping, which strips the two components to higher average charge states, but it is also present for gas stripping (see Nottoli et al., and Suter abstract to this conference).

We have made a series of measurements of this phenomenon using foil, gas+foil, and gas-only stripping of BeO- using the 14UD accelerator at the ANU operating at a terminal voltage of 8.6 MV. Energy distributions of 9Be2+, 3+, 4+ and 16O5+ ions were measured under different stripper conditions. These measurements will be presented and discussed in terms of a model of the Coulomb explosion process.

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Development of 41Ca-AMS at MALT, The University of Tokyo

Mr Takeyasu Yamagata[1], Mr. Hironori Tokuyama[1], Ms. Miwako Toya[1], Mr Lezhi Wang[1], Mr Li Zheng[1], Prof Hiroyuki Matsuzaki[1]
[1]MALT, The University Of Tokyo, Yayoi 2-11-16, Bunkyo-ku, Japan

Theme: T-1: Novel AMS systems, components and techniques
Type of presentation: Oral Presentation

The long-lived radionuclide ^{41}Ca (half-life 1.03 x 10^{5} y) is important for the environmental assessment of nuclear waste from decommissioning of nuclear facilities. Currently, Femto-isotopes such as ^{10}Be, ^{26}Al, ^{36}Cl, and ^{129}I are measured using the 5UD Pelletron accelerator, National Electrostatics Corp., at MALT, The University of Tokyo. In this study, we developed a new AMS system of ^{41}Ca at MALT.
We chose CaF_2 for the chemical composition of the ^{41}Ca-AMS target, and the dried CaF_2 precipitation ware packed in a cathode with a 1.5 mm diameter. The 300nA of CaF_3 - beam was extracted from the MC-SNICS ion source. $^{41}CaF_3$ - (m.w.98) and $^{40}CaF_3$ - (m.w.97) were injected sequentially into the accelerator by the jumping method. We selected the charge state of 5+, which has a high charge fraction (3%) and a relatively low ^{41}Ca/^{40}Ca background. The counts of $^{41}Ca^{5}$ + were measured by the 2 plates gas ionization chamber. From the spectrum from the GIC, no significant interference of isobar as ^{40}K was investigated, although it might be only measured the standard sample and the reagent blank before, several unknown signals were investigated. The calibration curve was obtained from 10^{-12} to 10^{-10} with good linearity. The background of ^{41}Ca/^{40}Ca in our system was obtained 2 x 10^{-13}. The background was increased by the scattering component from unknown ions.

Development of the low-energy AMS systems at China institute of atomic energy

Prof. Ming He[1], Dr. Yiwen Bao[1], Dr. kangning Li[1], Dr. Qubo You[1], Dr. qingzhang Zhao[1], Wenhui Zhang[1], Shengyong Su[1], Pan Hu[1]
[1]*China Institute Of Atomic Energy, Beijing, China*

Theme: T-1: Novel AMS systems, components and techniques
Type of presentation: Oral Presentation

With the development of technologies, the AMS systems are developing towards the miniaturization with the low terminal voltage. Two systems with the terminal voltage of less than 300kV have been developed at China institute of atomic energy (CIAE). One of the device is a kind of single stage AMS system with a working voltage of 230kV. Based on the system, the measurement methods of C-14 and H-3 hve been developed. C-14 measurements with precision of 0.4% and a background level of 0.2pMC have been achieved. The sensitivity of H-3/H=1×10exp(-15) is obtained. Another system is a kind of tandem AMS system with the terminal voltage of 300kV. This system have high mass resolution which is used for heavy nuclides measurement. Based on this system, the measurement methods of I-129 and actinides have been developed. The results show that the transmission efficiency of the system have been improved greatly, meanwhile the sensitivity are comparable or even better than other big AMS system (terminal voltage >1MV). The transmission efficiency for I-129 measurement with the system is 60% and sensitivity of I-129/I<1×10exp(-13) have been achieved. The transmission efficiency for Acitnides measurment with the system is 25%, the detection limitation for Pu-239 is 0.1fg and the sensitivity for U-236 is U-236/U<1×10exp(-13). the measurement methods of Al-26 and Ca-41 with this AMS system are under developing.

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Identifying the sources of beam transmission loss of carbon isotopes

Dr Gurazada Prasad[1], Dr Alexander Cherkinsky[1]
[1]*University Of Georgia, Athens, United States*

Theme: T-1: Novel AMS systems, components and techniques
Type of presentation: Oral Presentation

The continuous decrease of 12C beam transmission through the accelerator with increasing injection current is well known. For high enough beam currents, the post acceleration 13C+/12C+ ratio of a sample is no longer a constant due to a greater loss of 12C+ beam current, which is detrimental for online d13C estimation, as reported by some NEC 250 kV SSAMS facilities including ours. Factors such as beam emittance, space charge at the ion source and scattering at the gas stripping column of the accelerator are thought to contribute to the changes in beam transmission. In this study we attempt to identify the sources of transmission-loss by looking at all three isotopes of carbon.

The two extreme cases are 1) very high beam currents of 12C and 2) practically no beam case of 14C through the accelerator. Our earlier analyses of SSAMS data showed that 12C transmission steadily decreased until 85µA of injected current, and then dropped rapidly for higher currents. We also found that even the 13C+/12C- ratio decreased steadily where - and + signs refer to pre and post-acceleration currents respectively. The 14C+/13C+ ratio of a sample did not change with the beam current and therefore did not affect the accuracy of pMC measurements.

In the current study, we examined the 14C+/12C- ratios on SSAMS. The 14C data of OXII standards from several runs were analyzed. We have indeed found that 14C+/12C- ratio is not a constant for a given sample, but decreases linearly with the 12C- beam. The rate of decrease varies across runs due to operating conditions, but typically ~1% for a 10µA change in 12C-. This is very interesting because 14C being a rare isotope, its transmission is not expected to be affected during acceleration. This observation implies that for low to moderately high beam currents, steady decline in transmission is not due to scattering effects at the stripping column but likely due to ion-source effects. The beam emittance of the ion-source, which is a measure of beam width and divergence may have a decisive effect on beam transmission that needs further investigation.

On the other hand, the sudden drop in the beam transmission of 12C above 85µA appears to occur only during acceleration. While scattering due to argon gas is the most likely cause, any effects of space charge due to charge exchange collisions might also need consideration.

In effect, we observed a steady decrease in beam transmission for all three isotopes with increasing 12C beam. The important end note is that even though both 13C and 14C showed the beam dependence, they both underwent the same rate of decrease and the ratio 14C+/13C+ remained unchanged over the range of beam currents observed (70-100 µA of 12C-).

In-Cathode Activations for 41Ca Production Cross Section Measurements

Mr Austin Nelson[1], Thomas Bailey[1], Lauren Callahan[1], Adam Clark[1], Dr. Philippe Collon[1]
[1]*University Of Notre Dame, Notre Dame, United States*

Theme: T-1: Novel AMS systems, components and techniques
Type of presentation: Oral Presentation

^{41}Ca ($t_{1/2}$ = 9.94 x 10^4 yrs) is an important stellar radionuclide and its production in the early Solar System from various irradiation scenarios can help determine the viability of models of early stellar processes. Information on the production of ^{41}Ca is limited, as several production cross sections have minimal or no experimental data. A novel reaction technique has been under development and recently tested at the Nuclear Science Lab at the University of Notre Dame. This technique utilizes an in-cathode reaction method, which means that natural Ca material is pre-packed into an ion source sample holder (cathode) before being irradiated. The activated sample is then placed directly into the ion source to be sputtered and its concentration of ^{41}Ca/^{40}Ca is measured using Accelerator Mass Spectrometry. This method bypasses the chemistry steps that would be necessary with other reaction activation techniques. We will report our initial findings and the viability of this method using the reaction ^{40}Ca(^{3}He, 2p)^{41}Ca, and compare total cross section measurements, at various energies, with previous experimental cross section data and TALYS predictions.

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Integration of Absolute Cathode Position Encoding and Digital Indexing Control for use with MCSNICS Ion Sources

Mr Sean McNamer[2], **Dr Thomas Donoclift[1]**, Stewart Freeman[1], Richard Kitchen[1]
[1]SUERC, Glasgow, United Kingdom, [2]NEC, ,

Theme: T-1: Novel AMS systems, components and techniques
Type of presentation: Poster

The SUERC AMS Laboratory has incorporated the use of new cathode wheel indexer controllers that are capable of interfacing with an optical, absolute positional encoding ring. The optical encoder and digital indexer controller work together to minimise indexing failures on our 134-multi-cathode SNICS ion sources, that would otherwise result in human intervention and delays to sample batch running. The absolute encoding ring utilises a diffraction grating that rotates with the cathode sample wheel. This encoded ring is then paired with a fixed sensor head that contains an analysing grating, a detector array, and a light source. The detector array can infer rotation direction, speed, and angular position of the encoded ring and thus determine the cathode wheel position. This information is used to recover from indexing failures without having to “home” the cathode wheel. The digital indexer controller functions more efficiently than the traditional indexer controller units and significantly speeds up indexing operations. The digital indexer controller unit also features a programmable micro controller with updatable firmware via a USB connection. This allows useful movement operations and new features to be included in firmware updates as and when they are needed.

Ion Laser InterAction Mass Spectrometry – prospects for AMS without chemistry

Dr Martin Martschini[1], Johannes Lachner[1,2], Oscar Marchhart[1], Silke Merchel[1], Alfred Priller[1], Peter Steier[1], Alexander Wieser[1], Robin Golser[1]
[1]University of Vienna, Faculty of Physics - Isotope Physics, VERA Lab, Vienna, Austria, [2]Helmholtz-Zentrum Dresden Rossendorf, Dresden, Germany

Theme: T-1: Novel AMS systems, components and techniques
Type of presentation: Invited Oral Presentation

Laser photodetachment and molecular dissociation processes of anions provide unprecedented isobar suppression factors of $>10^{10}$ for several established AMS isotopes like ^{36}Cl [1] or ^{26}Al [2] and give access to new AMS isotopes like ^{90}Sr [3], ^{135}Cs [4] or ^{182}Hf [5] at environmental levels. Five years ago, a setup for Ion-Laser InterAction Mass Spectrometry (ILIAMS) was coupled to the Vienna Environmental Research Accelerator (VERA) five years ago. Its potential and applicability as a new means of isobar suppression in AMS has since been explored at this state-of-the-art 3 MV tandem facility [6]. Over this time, ILIAMS has been proven to meet AMS requirements regarding efficiency, reliability and robustness with a typical reproducibility of results of 3%.

The benefits of the ILIAMS technique are in principle helpful for any AMS machine, irrespective of attainable ion beam energy. ILIAMS exploits differences in electron affinities (EA) within elemental or molecular isobaric systems neutralizing anions with EAs smaller than the photon energy. Alternatively, these differences in EA can also facilitate anion separation via chemical reactions with the buffer gas, although the possibility of reverse reactions may cause some plateau effect not observed with laser photodetachment. In order to achieve the required ion-laser interaction times or ion-gas collision energies, the anion beam is decelerated to almost thermal energies within a gas-filled radiofrequency quadrupole.

Since isobar suppression via ILIAMS is so efficient, there is often no need for any further element separation in the detection setup. Hence, highly-populated charge states can be selected after the accelerator, which in combination with 100% efficient ion detection in an ionization chamber more than compensates for transmission losses in ILIAMS, which are on the order of 20-50%. Thus, counting statistics with ILIAMS are typically similar or better than with conventional AMS means, e.g. 500 cts of ^{26}Al in a 10 min run on a sample with 26Al/Al = 10^{-12}.

Recent test measurements also demonstrated that, owing to the virtually complete suppression of isobars, ^{26}Al (extraction of AlO^-) and ^{41}Ca (extraction of CaF_3^-), can be measured directly from stony meteorite samples as little as 1-2 mg without doing any chemical sample preparation [7]. There is also potential for ILIAMS measurements of terrestrial cosmogenic ^{26}Al in in-situ-dating quartz originating from high altitudes. Last but not least, ^{36}Cl may even become accessible without the need for sulfur reduction by chemical treatment and, maybe, without accelerator at all.

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[7] Merchel et al., this meeting

Isobaric Molecules Suppression by a Surface Stripper for the AMS System with Ion Energy below 50 keV: A Numerical Study

Dr Akihiro Matsubara[1], Dr Natsuko Fujita[1], Prof. Dr. Kenji Kimura[1]
[1] *Japan Atomic Energy Agency, , Japan*

Theme: T-1: Novel AMS systems, components and techniques
Type of presentation: Poster

The technology for downsizing AMS systems has approached a stage in the development of ^{14} C-AMS systems with a footprint below 2 m × 2 m (ion energy below 50 keV without a tandem accelerator). One of the challenges is to overcome high background which is attributed to poor vacuum conditions originated from a gas stripper used to destroy interference isobaric molecules such as $^{12}CH_2$, ^{13}CH. As the system scale is reduced, the position of the gas stripper becomes closer to a magnetic filter. As a result, it is difficult to maintain the pressure of the filter low enough to prevent various collisional processes inside the filter.

A novel stripper technique based on ion–surface interactions, which would be termed “surface stripper”, was proposed as a gas free stripper [1]. Under grazing angle incidence of ions on a single crystal surface, the ions can be specularly reflected by a repulsive planer potential of the first atomic plane. During the reflection, the ions interact with surface electrons and atoms, which may result in charge transfer and dissociation of those isobaric molecules. In addition, the specular reflection not only ensures suppression of the large angle scattering, but also is of advantage to avoid damage to the crystal surface or the surface stripper.

We numerically estimated the suppression efficiency of the surface stripper in the case of the grazing incidence of the ^{13}CH with energy of tens of keV onto a single crystal surface. The present study is focused on the effect of the collision with the surface electrons on the dissociation. The energy distribution of the surface electrons along the trajectory was derived using a local density approximation. In addition, the model involves a softening of the C-H bond due to the electrostatic screening by the surface electrons. The obtained survival probability of ^{13}CH falls to below $1/10^{12}$ at which the level is required for the practical use. This suggests the sufficient dissociation capability of the surface stripper.

[1] A. Matsubara, et al., Nucl. Instr. Meth. Phys. Res. B 437 (2018) 81-86.

Low Energy AMS: How to reach 50kyrs with 50 kV

Prof. Hans-Arno Synal1, Daniele De Maria[1], Lukas Wacker[1], Sascha Maxeiner[2], Andreas Herrmann[2]
[1]ETH Zurich, Zurich, Switzerland, [2]Ionplus AG, Dietikon, Switzerland

Theme: T-1: Novel AMS systems, components and techniques
Type of presentation: Invited Oral Presentation

The technical evolution of Accelerator Mass Spectrometry (AMS) instrumentation over the last ten years has boosted research with radioactive tracers in global environment. The by far most important AMS nuclide is radiocarbon. Here, dedicated high performing instruments like the MICADAS system will cover the needs of a wide user community to get reliable isotopic ratio measurements with uncertainties in the range of 10 - 20 radiocarbon years. In many cases, not the instrumental capabilities are the dominating source of final uncertainties, but rather the external sample handling and preparation process. Although such instrumentation fulfils the user needs, there is still a potential to further develop the measurement technology to finally build instruments which are even more compact, less expensive, more user friendly, and maybe tailored to specific application needs. In collaboration with Ionplus AG we have set-up a miniaturized version of a radiocarbon detection system called LEA (Low Energy AMS). It follows basic MICADAS design principles but operate at a terminal voltage of 50 kV only. A prototype system has been finalized in 2019 and performance measurements have been conducted. Initial results of these experiments are presented.

Nuclear reaction cross-section measurements using AMS

Prof. Efrain Chavez Lomeli[1], Dr. Luis Acosta, Dra. Libertad Barrón-Palos, Fis Arcadio Huerta, Dr Daniel J. Marín-Lámbarri, Dra Carmen G. Méndez, Dr. Santiago Padilla, Dra. María G. Rodríguez-Ceja, Dr. Vijay R. Sharma, Dra. Corina Solís
[1]*Instituto De Fisica. UNAM, Coyoacán, México*

Theme: T-1: Novel AMS systems, components and techniques
Type of presentation: Oral Presentation

Introduction
We describe the use of AMS technique as a tool to measure nuclear reaction cross sections at the AMS (Accelerator Mass Spectrometry) at the LEMA (Laboratorio Nacional de Espectrometrometría de Masas con Aceleradores) facility at IFUNAM (Instituto de Física, Universidad Nacional Autónoma de México).
The 28Si(d,alpha)26Al, 9Be(n,gamma)10Be and the 14N(n,p)14C nuclear reactions are presented as examples.

Methods:
The irradiation of targets both in accelerator facilities and nuclear reactors are described.
Sample preparation, before and after the irradiation is also described.
AMS measurements of 10Be, 14C and 26Al are described.
Data analysis and the extraction of absolute cross sections are described.

Results.
Raw data as well as the deduced final cross sections for the selected nuclear reactions are shown.

Conclusions:
Success, advances and perspective for future work are presented for the selected nuclear reactions as well as other in process.

Operation and Demonstration of Positive Ion Mass Spectrometry.

Dr Richard Shanks[1], Prof Stewart Freeman[1], Dr Cameron McIntyre[1], Dr Mark Sundquist[2], Mr Kenny Kearney[2], Mr Allan O'Connor[2], Mr Mike Mores[2], Mr Richard Kitchen[2], Mr Thilo Hauser[2], Dr Matthieu Cavellier[3], Mr Arun Annaluru[3], Mr Vincent Bertrand[3]

[1]Scottish Universities Environmental Research Centre, Glasgow, United Kingdom, [2]National Electrostatic Corp., Madison, USA, [3]Pantechnik S.A., Bayeux, France

Theme: T-1: Novel AMS systems, components and techniques
Type of presentation: Invited Oral Presentation

Positive ion mass spectrometry (PIMS), was first demonstrated at the Scottish Universities Research Centre (SUERC) in 2014. In 2018 a prototype PIMS systems, co-developed with and manufactured by National Electrostatics Corp. (NEC) and Pantechnik, was installed at SUERC. Shortly after installation, the electron cyclotron resonance (ECR) ion source was upgraded to the Pantechnik Microgan capable of producing up to 1mA $^{12}C^{+}$.

PIMS combines an ion source producing a positively charged carbon beam and a simple reaction cell to supress ^{14}C interferences. The objective of the PIMS project is to measure ^{14}C with comparable performance to conventional graphite AMS, directly from CO_2. PIMS allows direct integration and automation of sample processing interfaces, such as Elemental Analyser (EA), autosamplers, stable Isotope Ratio Mass Spectrometry (IRMS), etc., with performance competitive to conventional techniques that require sample graphitisation.

Operation and performance, such as background, memory, sample through-put, precision and accuracy of the PIMS system will be demonstrated and discussed.

Optimization of the LLNL/CAMS gas-accepting ion source and 1 MV compact AMS for natural abundance radiocarbon analysis.

Taylor Broek[1], Ted Ognibene[1], Karis McFarlane[1], Kimber Moreland[1], Thomas Brown[1]
[1]*Lawrence Livermore National Laboratory-Center for Accelerator Mass Spectrometry, Livermore, United States*

Theme: T-1: Novel AMS systems, components and techniques
Type of presentation: Poster

The Lawrence Livermore National Laboratory-Center for Accelerator Mass Spectrometry (LLNL/CAMS) 1 MV AMS system was recently repurposed from a biomedical AMS instrument to a natural abundance 14C spectrometer. The system is equipped with a gas-accepting hybrid ion source capable of measuring both solid (graphite) and gaseous (CO2) samples, however, routine radiocarbon (14C) measurements are currently only conducted with graphite. Here we describe ongoing experiments intended to establish and optimize 14CO2 measurement capabilities at natural abundance levels. This optimization encompasses two simultaneous efforts to: 1) maximize the production of C- ions from CO2 gas and 2) limit the influence of scattered ions in the AMS beamline, with the ultimate objective of producing radiocarbon data comparable in both accuracy and precision to those generated from solid samples. We optimized ionization efficiency by adjusting CO2 concentration, flow rates, and target design and reduced angular scattering through modifications to the beamline and changes to operational parameters. As configured, we currently achieve >8% conversion of CO2 to C-, resulting in approximately 250 ± 50 14C counts/ µgC from modern (OX I) gas samples. We validate our current capabilities using background materials and standards of known 14C abundance. Finally, we compare results from solid and gaseous samples derived from splits of CO2 generated from a soil incubation experiment.

Project for Development of a Downsized AMS System based on the Surface Stripper Technique

Dr Natsuko Fujita[1], Dr Akihiro Matsubara[1], Dr Kenji Kimura[1], Dr Yoko Saito-Kokubu[1]
[1]*Japan Atomic Energy Agency, Gifu, Japan*

Theme: T-1: Novel AMS systems, components and techniques
Type of presentation: Poster

Over the last decade, significant technological advances were made to downsize the AMS systems. The state of the art technology has reached a stage in development of ^{14}C-AMS systems with a footprint below 2 m × 2 m [1]. The toughest hurdle for further downsizing is to overcome low transmission and high background caused by collisional processes with a stripper gas used to destroy interference isobaric molecules such as $^{12}CH_2$, ^{13}CH.

A novel stripper technique based on specular reflection of fast ions on a single crystal surface, so called “surface stripper”, was proposed as a gas free stripper [2]. During the reflection, the ions interact with surface electrons and atoms. This may result in dissociation of those isobaric molecules. A numerical study to evaluate the survival probability of the isobaric molecule in the surface stripper has suggested the sufficient isobar suppression capability of the surface stripper for the practical use [3].

Japan Atomic Energy Agency has started a project for developing a prototype downsized AMS system (with the footprint of the system is 1.9 m × 1.9 m) based on the surface stripper technique. Although the system configuration using an ion source, magnets, and detectors is similar to that in conventional systems, there is no tandem accelerator as well as a gas stripper. The ion acceleration is provided in the ion source (maximum ion energy 40 keV). As the element of the surface stripper, a single crystal is placed between injection and analyzing magnets. The most remarkable feature of the system is that the post stripper beam line can be rotated horizontally as a unit (from the analyzing magnet to the rare detection) around the reflection point on the crystal surface so that the reflected ions can be analyzed. For proof-of-principle experiments, we have planned two steps: (1) Observation of the specular reflection and the dissociation by using a compact electrostatic analyzer located just behind the stripper, and (2) Demonstration of ^{14}C measurement, along with the experimental confirmation of the isobar suppression capability of the surface stripper.

[1] H.-A. Synal, et al., Nucl. Inst. and Meth. B 294 (2013) 349.
[2] A. Matsubara, et al., Nucl. Instr. Meth. Phys. Res. B 437 (2018) 81-86.
[3] A. Matsubara, et al., submitted to the AMS-15 conference.

Rethinking the AMS Counting Statistics Theory to Include Overdispersion: Evidence of Non-Poisson distribution in the Radiocarbon Data

Dr Gary Salazar[1,2], Prof. Soenke Szidat[1,2]
[1]*University Of Bern, Dept. of Chemistry, Biochemistry and Pharmaceutical Sciences, LARA Laboratory, Bern Bern, Switzerland , Bern, Switzerland,* [2]*University of Bern, Oeschger Center for Climate Change Research, Bern, Switzerland*

Theme: T-1: Novel AMS systems, components and techniques
Type of presentation: Oral Presentation

Introduction
The Poisson distribution is the most fundamental principle for the counting statistics of Radiocarbon and other rare isotopes using AMS. It has been the golden standard for estimating the variance of the measurement for every single Radiocarbon publication. AMS Radiocarbon inherited this uncertainty estimation from radioactivity-decay counting methods. Nevertheless, as far as we know, the Poisson hypothesis has actually never been tested. If the Poisson model is true then the standard deviation of the whole population of AMS counts per cycle should be the root square of the mean counts per cycle (μ) as: σ pois = √μ.
Methods
In this work, we applied non-Poisson counting statistics models that account for overdispersion (σ counts > √μ) to our historical data from the analysis of samples and standards. These models were the quasipoisson, and the negative binomial I and II; and their standard deviation of the counts is defined as σ = D√μ where D is the dispersion parameter. The counts per cycle were queried from our database for each cycle of every pass. The query and analysis was done automatically using a script written in the R language. The statistics models were fitted with Generalized Linear Model packages of the R program. The counts were corrected for systematic drift or random current jumps from one pass to the other. The correction was done by multiplying the counts of each cycle by the global current mean divided by the mean current of the respective pass.
Results
We discovered that, even though the correction for systematic effects, only a small fraction of our data (15%) presented Poisson-like distributions with D value of 1.0-1.1. The rest of the data presented D values of 1.1 to 3.0. Most of the standards that presented Poisson distribution were blanks. Monte Carlo simulations showed that the reason of the non-Poisson behavior was, in part, due to the scatter of the beam current within a pass. When the current oscillates or it is noisy, then the mean C14 counts is rather non-stationary. The Monte Carlo results were in agreement with the real data. The expanded counting statistics relative error was calculated as σ counts,rel=D/√Nt where Nt is the total counts. This allowed us to calculate an expanded quoted error. We also calculated the conventional quoted error using the Poisson relative counting error. The χ2 was calculated as the square of the ratio of the relative standard error of the passes ratios divided by the Poisson relative error. The average χ2 for all the standards and samples for a span of 1 year was 1.2±0.3.
Conclusion
Our average χ2 is quite acceptable; therefore, we think that it is not possible that all our data is somehow misleading. Rather, we conclude that the sputtering of the target causes the beam current to oscillate, to scatter and to become noisy. This makes the mean of the C14 counts to drift and to oscillate, thus many samples present non-Poisson distributions. Probably the same happens to other AMS instruments.

Sample introduction and interfaces for Positive Ion Mass Spectrometry

Dr. Cameron McIntyre[1], Dr. Richard Shanks[1], Prof. Stewart Freeman[1,3], Andrew Tait[1], Doug Hamilton[2], Issaku Kohl[2], Taylor Graham[2], Kenny Kearney[3], Allan O'Connor[3], Richard Kitchen[3], Thilo Hauser[3], Mark Sundquist[3]
[1]Scottish Universities Environmental Research Centre, East Kilbride, United Kingdom, [2]Thermo Fisher Scientific, Bremen, Germany, [3]National Electrostatics Corp., Middleton, USA

Theme: T-1: Novel AMS systems, components and techniques
Type of presentation: Oral Presentation

Positive Ion Mass Spectrometry (PIMS) is a new technique for the analysis of 14C. The system analyses CO2 using an Electron Cyclotron Resonance Ion Source (ECRIS) and therefore requires apparatus for the introduction of samples as gas. A collaboration between Thermo Fisher Scientific (TFS), National Electrostatics Corp. (NEC) and the Scottish Universities Research Centre (SUERC) has been formed to integrate instruments into the PIMS system.

The integrated instruments includes the NEC Automated Gas Ampoule Transfer Equipment (AGATE) system, a TFS Elemental Analyser (EA), a TFS GasBench and a TFS Isotope Ratio Mass Spectrometer (IRMS). These instruments are interfaced to a PIMS system via a Gas Sample Handling (GSH-NEC) system. This is designed to provide comprehensive quantitative elemental and isotopic analysis for a range of samples. Using this combination of instrument, analyses such as %C, %N, C/N ratio, 13C, 15N, 14C are possible for both solid and liquid, organic and inorganic samples. The PIMS system along with TFS instrumentation will be used to provide high precision and accuracy.

This package is currently being commissioned at SUERC and the initial architectural and operational aspects of the system will be introduced and discussed.

Super-SIMS @ DREAMS: status of a challenging initiative

Dr Georg Rugel[1], René Ziegenrücker[1], Johannes Lachner[1], Carlos Vivo-Vilches[1], Axel D. Renno[1], Anton Wallner[1], Michael Wiedenbeck[2]
[1]Accelerator Mass Spectrometry And Isotope Research, Helmholtz- Zentrum Dresden-Rossendorf, Dresden, Germany,
[2]Helmholtz-Zentrum Potsdam, Deutsches GeoForschungsZentrum , Potsdam, Germany

Theme: T-1: Novel AMS systems, components and techniques
Type of presentation: Poster-Plus Presentation

At the DREAMS (DREsden AMS) facility [1,2] we are implementing a so-called Super-SIMS (SIMS = Secondary Ion Mass Spectrometry) device [3] for specialized applications. The system combines the spatial resolution capability of a commercial SIMS (CAMECA IMS 7f-auto) with AMS capability, which should suppress molecular isobars in the ion beam allowing for the quantification of elemental abundances down to ~ E-9 - E-12. This would be more than an order of magnitude improvement over traditional dynamic SIMS (e.g. [4,5]). We aim to use this for the highly sensitive analysis of geological samples in the context of resource technology.

In the present setup, high efficiency transmission in the low-energy ion optics segment remains a challenge, as the beam needs to traverse two existing magnet chambers without deflection, where no steering or lens elements are available over a flight distance of 4 m. We have now improved the low-energy injection just after the ion beam exits the 7f-auto, upgrading the steerers directly after the SIMS and by adding a beam intensity attenuator. This provides both more stable conditions for instrument tuning and simplifies transition between measurements of the beam intensity in Faraday cups and the gas ionization chamber. Regarding the measurement of C, N and O in silicon, we found that a simple Wien-filter using permanent magnets for the primary Cs-sputter beam significantly reduces the background at the detector, as the 7f-auto uses a Cs_2CO_3 source – rather than metallic Cs – for the generation of the primary positive Cs beam.

Once the remaining issues associated with ion beam-path are fully addressed, we will still need to tackle the issue of establishing suitable, well characterized reference materials needed for our first suite of resource and geoscience applications (e.g., halides in naturally occurring sulphide minerals). We present ongoing developments and results, as well as plans for extending to other matrices and isotope systems.

[1] S. Akhmadaliev et al., NIMB 294 (2013) 5. [2] G. Rugel et al. NIMB 370 (2016) 94. [3] J. M. Anthony, D. J. Donahue, A. J. T. Jull, MRS Proceedings 69 (1986) 311-316. [4] C. Maden, PhD thesis, ETH Zurich 2003. [5] S. Matteson, Mass Spectrom. Rev., 27 (2008) 470.

The impact of the break-up of molecules in the stripper on AMS performance

Mr Martin Suter[1], Arnold Milenko Müller[1], Hans-Arno Synal[1], Marcus Christl[1], Philip Gautschi[1], Sascha Maxeiner[2], Keith Fifield[3]
[1]Ion Beam Physics, ETH Zurich, Zurich, Switzerland, [2]Ionplus AG, Dietikon, Switherland, [3]Research School of Physics, The Australian National University, Canberra, Australia

Theme: T-1: Novel AMS systems, components and techniques
Type of presentation: Oral Presentation

When negative molecular ion beams are injected into an AMS system, the molecules break up in the stripping process in the terminal of the accelerator. If both fragments of the molecule are in positive charge states, the Coulomb force pushes them apart. Even though the resulting kinetic energy is only in the 10 eV range, the effect on the beam can be significant, because it is not energies but velocities that must be added. The transverse component of the break-up then leads to an angular spread and the longitudinal component causes an energy spread. This effect can cause significant beam losses during the transport to the final detector. This break-up process is called Coulomb explosion and was studied intensively in the period between 1975-1990 (Gemmel 1980). Already in 1983 Middleton mentioned that the Coulomb explosion of BeO in a stripper foil can lead to significant beam losses in 10Be AMS. He recommended to use a combination of gas stripping at low pressure followed by carbon foil stripping to get better transmission. However, measurement at the AMS facility Aster (Nottoli 2015) demonstrated that the effect of the coulomb explosion is also significant with gas stripping. In these experiments, measured beam profiles developed pronounced tails and the observed beam size was a factor of 2-3 times wider compared to that of atomic beams. An effective beam width of more than 10 mm was seen in the focal plane of the high energy magnet which is larger than the size of the detector entrance. Data are meanwhile available from low energy AMS, Vterm <1 MV, which also show a significant beam size enlargement in the sub-MeV range, leading to beam dimensions of ~10 mm (Gautschi, this Conference). Because the energy spread of the beam induced by the coulomb explosion enlarges the beam width, related transmission losses can be reduced by appropriate ion optics e.g. with an achromatic mass spectrometer at the high energy side of the accelerator. The size of Faraday cups, apertures and detector windows must also be optimized for best transmission.

Ways of modeling the effect of this Coulomb explosion have been investigated. Based on the bond length of BeO molecules, the Coulomb energy can be estimated for the various charge combinations of the two fragments. Under the assumption of an isotropic orientation of the molecules, the effect on the beam profile can be derived. Using the equation of motion, the separation of the fragments in time can be calculated. Foil and gas stripping lead to completely different processes. In gas stripping, the Coulomb energy is determined by the charges of the two fragments created in the single collision that breaks up the molecule. In foil stripping, by contrast, multiple collisions occur within the foil before the two fragments separate, and the mean charge of fragments within the foil is the important parameter. For thinner foils, the fragments continue to separate outside the foil, and this also plays a role.

The New Chronos 14Carbon-Cycle Facility, University of New South Wales, Sydney, Australia

Prof. Chris Turney[1], Dr Zoë Thomas[1], Dr Lorenna Becerra-Valdivia[2], Dr Jonathan Palmer[1], Dr Heather Haines[1], Dr Haidee Cadd[3], Professor Lukas Wacker[4], Professor Andy Baker[5], Associate Professor Martin Andersen[6], Dr Geraldine Jacobsen[7], Dr Karina Meredith[7], Ms Khorshed Chinu[8], Dr William Hiscock[1], Ms Juee Vohra[1], Dr Christopher Marjo[1,8]

[1]Chronos 14Carbon-Cycle Facility, University Of New South Wales, Sydney, Australia, [2]Oxford Radiocarbon Accelerator Unit, Oxford, UK, [3]University of Wollongong, Wollongong, Australia, [4]Laboratory of Ion Beam Physics, ETH Zurich, Zurich, Switzerland, [5]School of Biological, Earth and Environmental Sciences, University of New South Wales, Sydney, Australia, [6]School of Civil Engineering, University of New South Wales, Sydney, Australia, [7]Australian Nuclear Science and Technology Organisation (ANSTO), Lucas Heights, Australia, [8]Mark Wainwright Analytical Centre, University of New South Wales, Sydney, Australia

Theme: T-1: Novel AMS systems, components and techniques
Type of presentation: Oral Presentation

The Chronos 14Carbon-Cycle Facility is a new radiocarbon laboratory at the University of New South Wales, Australia. Built around an Ionplus 200 kV MIni-CArbon DAting System (MICADAS) Accelerator Mass Spectrometer (AMS) installed in October 2019, the facility was established to address major challenges in the Earth, Environmental and Archaeological sciences. Here we report an overview of the Chronos facility, the pretreatment methods currently employed (bones, carbonates, peat, pollen, charcoal, and wood) and results of radiocarbon and stable isotope measurements undertaken on a wide range of sample types. Our measurements on international standards, known-age and blank samples demonstrate that the facility is capable of measuring 14C samples from the Anthropocene back to nearly 50,000 years ago. Future work will focus on improving our understanding of the Earth system and managing resources in a future warmer world.

The PIMS project status

Prof. Stewart Freeman[1], Richard Shanks[1], Cameron McIntyre[1], Tom Donoclift[1], Mark Sundquist[2], Kenny Kearney[2], Allan O'Connor[2], Richard Kitchen[2], Mike Mores[2], Thilo Hauser[2], Matthieu Cavellier[3], Arun Annaluru[3], Vincent Bertrand[3], Doug Hamilton[4], Issaku Kohl[4], Taylor Graham[4]

[1]Scottish Universities Environmental Research Centre, United Kingdom, [2]National Electrostatics Corp., USA, [3]Pantechnik S.A., France, [4]Thermo Fisher Scientific,

Theme: T-1: Novel AMS systems, components and techniques
Type of presentation: Oral Presentation

The academic and commercial project to develop and exploit positive ion mass spectrometry (PIMS) analysis of long-lived radionuclides continues. Further instruments are being constructed following the establishment of radiocarbon measurement on a prototype that is competitive with established techniques. Design revisions include the removal of ion analysis between the plasma ion source and the chemical reaction cell that both removes molecular interferences to ^{14} C detection and by negatively ionising the transmitted particle beam also permits the subsequent elimination of the interfering atomic isobar. Essentially the gas cell is now also used to control the space charge of the multi-milliamp ion source output in addition to filtering the beam. Tests on the prototype instrument show that this does not raise measurement background, but the cell thermal loading needs management. Moreover, new hardware has been built to maintain the optimum flow of analyte gas into the plasma source and to make the PIMS instrumentation compatible with usual radiocarbon analysis laboratories' workflow; sealed glass ampoules of cryogenically focussed CO_2 samples may now be automatically processed, and without the performance compromise of alternative mass spectrometry. Finally, Thermo Fisher Scientific company has newly joined the project. Suites of their technologies that are complimentary to PIMS, including multi-element stable isotope mass spectrometry and coupled handling of organic and inorganic materials are being integrated. The vision is of an automated laboratory technology package combining the disparate usual analyses for best performance, high productivity and cost savings.

The status of TOF-E detection system at MALT and its proceedings

Mr Li Zheng[1], Mr Takeyasu Yamagata[1], Mr Hiroyuki Matsuzaki[1]
[1]*The University Of Tokyo, Japan*

Theme: T-1: Novel AMS systems, components and techniques
Type of presentation: Oral Presentation

Accelerator Mass Spectrometry (AMS) is the most sensitive technique for the measurement of ^{236}U. A Time of Flight-Energy (TOF-E) detection system is the most appropriate technique to discriminate ^{236}U from ^{238}U, ^{235}U and other interferences. Micro Analysis Laboratory, Tandem Accelerator (MALT) aims to improve the sensitivity of ^{236}U/^{238}U from 3×10^{-10} to 10^{-13} with the installation of TOF-E detection system.

Due to only 0.4% of energy difference of ^{236}U and ^{235}U and 0.8% of energy difference of ^{236}U and ^{238}U, it is difficult to clearly identify them by gas ionization chamber (GIC). However, with their distinct velocity difference among ^{235}U, ^{236}U and ^{238}U, it is sufficient to separate ^{236}U from ^{235}U and ^{238}U even in naturally occurring ^{236}U sample using flight time technique. Currently, MALT has acquired starting timing signal and stopping timing signal using two identical Microchannel Plates (MCPs). Additionally, a silicon surface barrier detector (SBD) is also scheduled to the determination of stopping timing and energy with its fast time response and higher energy resolution. In order to achieve higher sensitivity of uranium AMS, several TOF-E detection configurations will be set and optimized.

Prior to the construction of realistic TOF-E detection system, a (Geometry and Tracking version 4) Geant4 Monte Carlo simulation of TOF-E detection system has been completed. several detection configurations with three thicknesses of carbon foil as secondary electron device have been simulated. From simulation results, it shows that the thickness of carbon foil is one key factor to efficiency and time resolution. The thinner the carbon foil, the better efficiency and time resolution. Adopting the setting of a MCP as starting timing detector and SBD as stopping timing detector and energy detector with 2.4 meters of flight path and 3 ug/cm^2 of carbon foil, flight time difference of ^{236}U and ^{235}U, and ^{236}U and ^{238}U are 3 ns and -6 ns, respectively, and the full width at half maximum (FWHM) of ^{235}U, ^{236}U and ^{238}U are nearly identical, 1 ns. The simulation results have demonstrated that the above setting is adequate to identify ^{236}U from ^{235}U, ^{238}U.

SBD can be set as energy detector with its higher energy resolution and at same time as stop timing detector with its fast time response. The time response and energy reconstruction of SBD has been simulated by using Garfield simulation. The uranium energy reconstruction with Pulse height spectrum is needed to compare with the following realistic experiment.

Simulation can offer useful information to experiment.The related experiments are under proceeding and uranium AMS will be measured by using this TOF-E detection system.

U-236 analyses with the prototype 300kV MILEA system at ETH Zurich

Dr Marcus Christl[1], Philip Gautschi[1], Dr Arnold Milenko Müller[1,2], Dr Sascha Maxeiner[1,2], Prof Hans-Arno Synal[1]

[1]*ETH Zurich, Laboratory of Ion Beam Physics, Zurich, Switzerland,* [2]*Ionplus AG, Dietikon, Switzerland*

Theme: T-1: Novel AMS systems, components and techniques
Type of presentation: Invited Oral Presentation

Compact, low energy accelerator mass spectrometry (AMS) has evolved over the past years as one of the most sensitive, selective, and robust techniques for the analysis of light and heavy and long-lived radionuclides. Particularly the analysis of actinides in environmental samples profited a lot from the technical advances in compact AMS.

In this contribution we discuss the setup and the analytical capabilities of the compact prototype AMS system MILEA for 236U and Pu-isotope analyses. The prototype MILEA system has been developed and installed at ETH Zurich in 2018/2019. Meanwhile, evolved MILEA versions have become commercially available by the ETH Zurich spin off company Ionplus. The prototype MILEA system has been optimized for low background and highly efficient analyses of light and heavy long-lived radioisotopes.

A special setup for AMS of U-isotopes has been developed that allows the sequential measurement of three isotopic ratios (236U/238U, 233U/238U, and 235U/238U) using fast bouncing mode for 238U. The system provides an abundance sensitivity at the order of 10-13 in the mass range of the actinides and thus allows determining the 236U/238U ratio in samples with U from anthropogenic and natural sources. Efficiency tests show that the MICADAS-type ion source provides a maximum ionization efficiency of almost 3% for UO- and PuO- extracted from a sample matrix containing a mix of Fe-oxide and Nb powder. First routine analyses of 236U/238U were carried out in small volume (<2L) sea water samples containing about 5µg natural U. The samples provided average 238U3+ currents of up to 2 nA on the high energy side and 236U/238U ratios were determined with an overall uncertainty level of 2%.

Our results show that the ETH Zurich MILEA system allows highly efficient and background free determination of anthropogenic 236U/238U ratios of ≥10-10 in small (1-2 L) sea water samples. Overall uncertainties of a few percent can be reached and are dominated by counting statistics. The very good abundance sensitivity further allows accessing the expected range of natural U-isotopes (233U/238U and 236U/238U) which are estimated to be in the 10-13 – 10-14 range with small to negligible background corrections.

Ultrasensitive Resonance Ionization Mass Spectrometry of Plutonium

Dr Alfredo Galindo Uribarri[1]
[1]*Oak Ridge National Laboratory, Oak Ridge, United States*

Theme: T-1: Novel AMS systems, components and techniques
Type of presentation: Oral Presentation

The monitoring and quantification of actinides such as thorium, uranium, and plutonium at ultra-low levels is a challenge in many fields of science: neutrino physics, dark matter searches, nuclear astrophysics, environmental science, etc. These fields are pushing the limits of conventional techniques for ultra-trace analysis, demanding more sensitive and more efficient techniques. Ultra-trace analytical techniques such as Accelerator Mass Spectrometry (AMS) have been used to measure the abundance of 244Pu in deep-sea reservoirs on Earth. However, this technique using Cs-sputtering sources has relatively low efficiency for actinides.

Resonance ionization mass spectrometry (RIMS) is one of the most sensitive techniques for ultra-trace analysis of long-lived radionuclides such as the isotopes of actinides. In RIMS, ions are formed by stepwise resonant absorption of two or three photons through allowed atomic levels to photoionization. The multistep resonance process is extremely selective for the specific element of interest. Thus, in comparison with the commonly used mass spectrometry techniques RIMS is superior in suppressing the isobaric interferences in the subsequent mass separation and promises high detection efficiencies and thus high sensitivities.

The Holifield Radioactive Ion Beam Facility (HRIBF) at Oak Ridge National Laboratory (ORNL) provided beams of Radioactive Ion Beams for over 15 years. The two fields of research – AMS and RIBs – complement each other in techniques. With a setup consisting of a Resonant Ionization Laser Ion Source (RILIS), a mass spectrometer based on a radioactive beam platform and a single counter detector (Channeltron) we performed sensitivity studies in Pu. We present the studies of efficient resonance ionization schemes for ultra-trace analysis of Pu isotopes by RIMS. We have identified several highly efficient three-step resonant ionization schemes for Pu. The total efficiency of the method was investigated and a total efficiency above 50% was reached. These unique outstanding results compare very favorably with the efficiencies obtained in AMS for actinides and is an order of magnitude improvement over the previously reported laser ionization efficiency for Pu. We describe the experimental setup, and a path forward to apply this technique for ultrasensitive analytical work of actinides and potential applications.

Universal Interface for Online Measurements of 13C and 14C Concentrations in CO2

Ms Melina Wertnik[1,2], Dr. Caroline Welte[1,2], Dr Lukas Wacker[2], Philip Gautschi[2], Dr. Negar Haghipour[1,2]
[1]ETH Zurich Biogeoscience Group, Zurich, Switzerland, [2]ETH Zurich Laboratory for Ion Beam Physics, Zurich, Switzerland

Theme: T-1: Novel AMS systems, components and techniques
Type of presentation: Poster

Combined $\delta^{13}C$ and $^{14}C/^{12}C$ measurements are a staple ingredient for carbon cycle studies, biogeoscience and paleoclimatology because together they provide information not only about the source (e.g. marine or terrestrial) and sink but also about time (e.g. age mixtures). For organic samples ^{13}C and ^{14}C can be measured concurrently by using a commercially available Elemental Analyser – Isotope Ratio Mass Spectrometer (EA-IRMS) system coupled with the ETH Zurich Accelerator Mass Spectrometer (AMS)[1]. Here, the CO_2 from the EA is first introduced to the IRMS and then split for introduction into the AMS. However, the existing system is limited to sample materials that can be processed in an EA.

Here we present an update to our universal gas interface for ^{14}C analysis[2] which allows simultaneous $\delta^{13}C$ measurements independent of the source material (e.g. carbonates, cracker samples, etc.). The samples are converted to CO_2 that is collected in a syringe and diluted with Helium to a concentration of 4%, ensuring reproducible conditions for subsequent measurements. The CO_2 -helium gas mixture is then fed over two separate capillaries into the Gas Chromatography (GC)-inlet of the IRMS as well as the gas ion source of the AMS for simultaneous $\delta^{13}C$ and $^{14}C/^{12}C$ analysis.

The performance of the proof of concept for simultaneous $\delta^{13}C$ and $^{14}C/^{12}C$ analysis will be demonstrated on various representative standard materials.

[1] C. P. McIntyre et al., 'Online 13C and 14C Gas Measurements by EA-IRMS-AMS at ETH Zürich', Radiocarbon, vol. 59, no. 3, pp. 893–903, Oct. 2016, doi: 10.1017/rdc.2016.68.
[2] L. Wacker et al., 'A versatile gas interface for routine radiocarbon analysis with a gas ion source', Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms, vol. 294, pp. 315–319, Jan. 2013, doi: 10.1016/j.nimb.2012.02.009.

Usefulness of Stable Polycyclic Aromatic Carbon for dating lake sediments.

Mr William Reynolds[1], Dr Timothy Cohen[1], Dr Samuel Marx[1]
[1]*University Of Wollongong/CABAH, Wollongong, Australia*

Theme: T-1: Novel AMS systems, components and techniques
Type of presentation: Poster-Plus Presentation

1. Introduction

Lake sediments are useful for reconstructing past changes in the environment and climate. Analysis of a one meter sediment core from Table Top Swamp near Darwin showed conditions 35,000 to 18,000 years ago were perhaps half as dry as today. Rising sea levels at 9,000 years ago caused rainfall at the site to increase (as the coastline and moisture source moved closer to the study site). As a result the swamp became semi-permanent, the dominance of trees increased and fire became more frequent.

In addition to providing this broad story of rainfall variability over the past 35,000 years, the study site has the potential to provide finer scale information. However the ability to tease out more information is limited by the resolution of the age model. One of the barriers to deriving a more accurate chronological framework is the behavior of materials previously used for radiocarbon dating. Ages derived from charcoal and humins show these materials move around in the sediment post-deposition. They are also liable to post-depositional alteration due to weathering and biological activity which may affect their 14C concentration. Plant macro-fossils and lumps of charcoal are often the preferred materials for radiocarbon dating. But these were absent from our sediment. So we explored the alternative method of isolating black carbon from sediment by hydrogen pyrolysis.

2. Methods

In hydrogen pyrolysis samples are mixed with a molybdenum catalyst then heated to 500° C in the presence of hydrogen pressurized to ten Mpa. This gets rid of the younger, more labile organic components leaving behind black carbon or Stable Polycyclic Aromatic Carbon (SPAC). SPAC is composed of clusters of eight or more aromatic carbon rings. Because it is highly chemically stable it is presumed to give radiocarbon ages which are close to the age of the sediment. With the support of a generous AINSE grant we dated SPAC from a variety of depths.

3. Results

Disappointingly, all the results clustered in a tight range around 7,000 years.

4. Conclusion

This means the SPAC itself was moving up and down through the sediment and mixing in the process returning an average age for the sediment. This pattern contrasts with the increase in age with depth shown by OSL techniques. The alternating wet and dry seasons experienced at Table Top Swamp cause the water table to fluctuate with the seasons. The evidence suggests SPAC is being moved through the sediment profile as the water table fluctuates. The take-home message is that the SPAC technique of isolating charcoal for radiocarbon dating may not be appropriate to apply to sites where the water table fluctuates seasonally.

A method for background correction in 10Be detection: evaluation of indirect isobaric interference by 7Be generated at the entrance window of a gas counter

Dr Yuki Matsushi[1], Dr Hiroyuki Matsuzaki[2]
[1]Kyoto Univ, Gokasho, Uji, Japan, [2]The University of Tokyo, Yayoi, Bunkyo-ku, Japan

Theme: T-2: Suppression of isobars and other interferences
Type of presentation: Poster

This report presents a method of background correction for isobaric interference by 10B in 10Be accelerator mass spectrometry with 4.8 MV terminal voltage and 10Be3+ ion counting at Micro Analysis Laboratory, Tandem Accelerator, The University of Tokyo. The detector used here is a gas counter with an absorber cell (5 cm in length) filled with 12 kPa of N2 gas, which is separated by a Havar foil of 5.6 µm in thickness at the entrance and 3.0 µm-thick polypropylene film at the outlet. Signals of injected 10Be3+ were detected by two anode plates aligned in the main ionization chamber filled with of 6 kPa of flowing P-10 gas (90% Ar and 10% CH4), to plot the events on a 2D spectrum of loss and residual energies. By this configuration, tail of 10B signals can be clearly separated from the 10Be events, but the counts are enhanced by interposition of 7Be generated from reaction of 1H(10B, 7Be)4He due to hydrogen attached on the surface of the entrance Havar window. As the number of 7Be events should be proportional to the counts of 4He and/or 10B events, we can evaluate the interference via a statistical analysis for correlations between counting data for the multiple regions of interest on the 2D spectra. Here we propose a procedure for accurate background correction and demonstrate the validation using standards, chemical blanks, and natural samples with different 10Be/9Be isotopic ratios.

A Review of the On-line Suppression of Sulfur by Charge Transfer with Nitrogen Dioxide in the Analysis of Chlorine-36 by Accelerator Mass Spectrometry – Hints from Liquid Chromatography Mass Spectrometry

Dr Jean-François Alary[1], Dr. Lisa M. Cousins[1], Erin L. Flannigan[2], Dr. Gholamreza Javahery[1], Prof. William E. Kieser[1,2]
[1]Isobarex Corp., Vaughan, Canada, [2]University of Ottawa, Ottawa, Canada

Theme: T-2: Suppression of isobars and other interferences
Type of presentation: Invited Oral Presentation

The range of isotopes that can be measured in Accelerator Mass Spectrometry (AMS) is in large part determined by the ability of the technique to eliminate interfering stable isobars either in the ion source or by dE/dx separation in foils or gases, using a gas ionization detector or a gas-filled magnet. In the case of the detection of chlorine-36 by small AMS systems, attempts at selectively suppressing sulfur via ion-molecule reactions have been made using the electron transfer reaction $S^- + NO_2 \rightarrow S^0 + NO_2^-$, exothermic by 0.2 eV. The equivalent reaction involving a chlorine anion is endothermic by 1.34 eV [Dunkin et al, Chem. Phys. Letters 15 (1972) 257-259]. Unfortunately, energy conditions found in classical AMS systems do not allow this suppression reaction to occur with appropriate efficiency.

We discuss the various approaches that were tried to enable this specific suppression reaction in the low energy line of an AMS system, where it would be most useful. We review results obtained initially with a charge exchange canal, then an early Radio Frequency Quadrupole (RFQ) system, the Isobar Separator for Anions (ISA), both tested at the IsoTrace laboratory in Toronto, and a more advanced ISA currently operated at the A. E. Lalonde AMS Laboratory, University of Ottawa. Comparing these three systems, which operate over an energy range from ~1 eV to 1 KeV, illustrates the different phenomena governing the suppression reaction of sulfur, as well as the transmission of chlorine anions towards the tandem accelerator. A comparison is also made with conditions found in Liquid Chromatography Mass Spectrometry (LC-MS), another RFQ-based technique [Douglas, J. Am. Soc. Mass Spectrom. 9 (1998) 101–113].

These results are reinterpreted considering the most recent results obtained at A. E. Lalonde. Notably, the degree of thermalization of anions on their passage through the device is extensively discussed. The transition from non-thermal to near-thermal conditions appears to be essential to accomplish the sulfur suppression reaction to the degree required for AMS determination but entails a cost in the transmission of chlorine anions unless appropriate precautions are taken. Lessons learned over the multi-decade development of LC-MS systems, in which ions are transferred efficiently between thermal and non-thermal zones (albeit at generally lower energy levels), can be applied to improve transmission of chlorine anions through the ISA. The approach also improves markedly the transmission of molecular anions such as SrF_3^-, of great interest in the determination of other rare isotopes, by reducing their fragmentation during their passage through the ISA.

AMS with a 14 million volt accelerator - Mn-53 and Fe-60 with ANU’s ENGE

Prof. Anton Wallner1’[2], Prof. LK Fifield[1], Michaela B. Froehlich[1], Dominik Koll[1,2], Guy Leckenby[1,3], Martin Martschini[1,4], Stefan Pavetich[1], Stephen G. Tims[1], Dorothea Schumann[5], Zuzana Slavkovská[1]

[1]The Australian National University, Canberra, Australia, [2]Helmholtz-Zentrum Dresden-Rossendorf (HZDR), Dresden, Germany, [3]present address: University of British Columbia, TRIUMF, Vancouver, Canada, [4]present address: University of Vienna, Faculty of Physics, VERA Laboratory, Vienna, Austria, [5]Biology and Chemistry, Paul Scherrer Institute (PSI), Villigen, Switzerland

Theme: T-2: Suppression of isobars and other interferences
Type of presentation: Oral Presentation

AMS at ANU’s Department of Nuclear Physics and Accelerator Applications is based on a 14UD tandem accelerator. The 14UD has demonstrated exceptional accelerator performance over more than 3 decades of AMS, e.g. by running regularly above 14 MV. Sadly, but perhaps inevitably, a number of similar nuclear physics facilities have been lost to closure due to aging equipment and high operational costs. The aim of this paper is to showcase the actual performance and potential of an indeed older but definitely not obsolete AMS facility, demonstrating the continuing need for specialised high-energy systems.

The measurement program at the Heavy Ion Accelerator Facility (HIAF) has always been strong on environmental, safeguards and geological research. Several nuclear astrophysics projects were also added over the past 10 years as a major research topic. This system operates with particle energies between ~24 MeV (actinides) and >200 MeV (e.g. ^{53}Mn, ^{93}Zr).

The focus here will be on the AMS performance utilizing HIAF’s unique setup of high particle energies combined with an ENGE split-pole spectrograph that has been converted into a gas-filled magnet (GFM) as a means for providing an efficient reduction of isobaric background. ANU’s ENGE has been in use as a GFM now for more than 20 years, first for ^{32}Si and then for ^{53}Mn in geology. However, more recently, a set of additional isotopes has been added and to support these projects a new flexible multi-anode ion chamber was constructed:

- ^{60}Fe: this isotope – mainly of interest to astrophysics, e.g. the search for recent nearby Super-nova explosions – has become one of the dominant isotopes within ANU’s measurement program. Background-free measurement (equivalent to ^{60}Fe/Fe<3×10^-^{17}) has been demonstrated.
- ^{53}Mn: more difficult to measure than ^{60}Fe, this nuclide is of interest to nuclear astrophysics as well as for geological applications. Both applications require a measurement sensitivity that challenges even HIAF’s present capabilities.
- Other nuclides measured with the ENGE include ^{32}Si, ^{59}Ni and ^{93}Zr. In addition, ^{10}Be and ^{26}Al, both extracted as oxides, achieve lower background or higher measurement efficiency when using the ENGE, as already demonstrated at other facilities, e.g. TU Munich and PRIME lab.

The potential of the ENGE for isobaric suppression and more generally HIAF’s measurement sensitivity and accuracy will be exemplified using ^{60}Fe and ^{53}Mn. We will give an overview of recent research activities, ongoing discussions on the half-life values, standard materials used and we will summarize ANU’s performance parameters of the above mentioned other isotopes.

Backgrounds and blanks in I-129 measurements at the Australian National University

Prof. Keith Fifield[1], Dr Michaela Froehlich[1], Mr Dominik Koll[1], Dr Stefan Pavetich[1], Dr Zuzana Slavkovska[1], A/Prof Stephen Tims[1], Prof Anton Wallner[1,2]
[1]The Australian National University, , Australia, [2]Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany

Theme: T-2: Suppression of isobars and other interferences
Type of presentation: Oral Presentation

Although the AMS measurement of 129I is straightforward in principle due to the absence of a stable isobar, an inter-laboratory comparison exercise conducted more than 20 years ago (Roberts et al. 2000) indicated that there could be issues with both the chemistry and AMS of this isotope. In particular, there were clearly unidentified sources of AMS background at some laboratories. We are not aware that these issues have subsequently been fully resolved.

Recently, the number of 129I measurements at the ANU has been increasing, and it was considered timely to explore in rather more detail the questions of backgrounds and blanks at our facility. Specifically:

a) To date, Woodward iodine, which has an 129I/127I ratio of ~2x10-14, has been the lowest ratio material available and hence is widely used as carrier. We have made repeated measurements of this material in order to define its ratio more accurately. A number of other iodides have also been studied with a view to identifying lower-ratio material. In the event, 8 different iodides of varying provenance proved to have remarkably similar ratios, all of which were an order of magnitude higher than the Woodward iodine.

b) Any backgrounds are likely to be due to 127I7+ and 128Sb7+ ions. Hence, we are studying the extent to which 127IH2-, 127ID- and 128SbH- ions are produced in the ion source and injected into the accelerator along with 129I-.

c) Since our processing blanks have been consistently higher than our historical Woodward iodine material, we are making a series of measurements of the 129I content of the various chemicals used in sample processing. This includes the Woodward iodine carrier that we are using, which is from a different batch than the historical material.

Measurements are performed at a terminal voltage of 11 MV with nitrogen gas stripping, the 7+ charge state is selected, and the 88 MeV 129I7+ ions are detected in a gas-ionisation detector with an energy resolution of 1.3%.

These questions on background and blanks are, however, essentially independent of the available particle energies, and thus are also relevant for smaller AMS systems.

References

M.L. Roberts and M.W. Caffee, Nucl. Instr. Meth B172 (2000) 388-394

Benchmarking 10Be2+ ion detection against 10Be3+ method at ANSTO

Dr Klaus Wilcken[1], Krista Simon[1], Sam Micallef[1]
[1] *ANSTO, Lucas Heights, Australia*

Theme: T-2: Suppression of isobars and other interferences
Type of presentation: Poster-Plus Presentation

It has been demonstrated that low background high efficiency measurement of 10Be can be achieved with 2+ charge state using 3 MV accelerator [1]. The method is advantageous because transmission to 2+ charge state at 3.0 MV is roughly 60% and nearly double what is achieved with 3+ ions using 5-6 MV accelerators and Ar stripper gas. Increased measurement efficiency translates into improved precision and sensitivity.

Typically, AMS facilities measure samples from a range of satellite sample preparation laboratories. Different procedures and laboratory settings often lead into varying 10B rates from the prepared BeO targets. Therefore it is desirable that the employed AMS method can accommodate samples with varying 10B rates without negatively impacting the 10Be measurement.

To benchmark the 10Be2+ methodology against our routine 10Be3+ method, based on 6.0 MV acceleration voltage and standard passive Ar absorber cell [2], we evaluated the impact of increasing B concentration to the measurement background with both methods. Ion detection for 10Be2+ ions was done with standard gas ionisation detector preceded by SiN-foil stack to stop the 10B ions. To optimise the achievable background and its sensitivity to varying B-rates different accelerator voltages between 3 and 5 MV were evaluated.

References:
[1] P. Steier et al. / International Journal of Mass Spectrometry 444 (2019) 116175
[2] K. Wilcken et al./ Nuclear Inst. and Methods in Physics Research B 455 (2019) 300–304

Chemical removal of sulphur from AgCl and AgBr for 36Cl measurements at ANSTO

Ms Krista Simon[1], Dr Klaus Wilcken[1], Ms Archana Amatya Joshi[1]
[1]Australian Nuclear Science And Technology Organisation, , Australia

Theme: T-2: Suppression of isobars and other interferences
Type of presentation: Poster

Measurements of 36Cl on the 6MV tandem accelerator (SIRIUS) at ANSTO began in 2016, and since then over 1000 groundwater and rock samples have been processed and measured. The challenge with the sample preparation for 36Cl is to keep the 36S rates consistently low to minimise the impact to the 36Cl ion detection. This is generally achieved by precipitating sulphate as BaSO4 before a final precipitation as AgCl. We tested a range of methods for their efficacy, ease of use and consistency in keeping the 36S rates low.

For measurement, the AgCl is backed in a bed of AgBr, but the sulphur rate of commercially available AgBr can vary significantly between batches. Preparing AgBr in house can produce very low sulphur rates [1,2]. Alternatively, we have achieved similarly low 36S rates by treating commercially available AgBr in 1M HNO3 for >24 hours.

References:
[1] M. Martschini et al. / Nuclear Instruments and Methods in Physics Research B 294 (2013) 115 – 200
[2] S. Hosoya et al. / Nuclear Inst. and Methods in Physics Research B 438 (2019) 131–135

Current dependency of isotope ratio measurements at the Trondheim 1 MV AMS

Dr Martin Seiler[1], Prof. Pieter Meiert Grootes[1], Dr. Helene Svarva[1], Dr. Marie-Josée Nadeau[1]
[1]The National Laboratory for Age Determination, NTNU, Trondheim, Norway

Theme: T-2: Suppression of isobars and other interferences
Type of presentation: Poster

A current dependency of isotope ratio measurements is often seen in accelerator mass spectrometry. It presents an obstacle when increasing currents to yield higher precision and throughput or measuring samples with different current outputs. It can be observed when measuring carbon, as there are two abundant isotopes of which the abundance ratio can be measured with great accuracy in Faraday cups. For other elements, a current dependency is often difficult to determine due to the limited precision in counting rare isotopes. Nevertheless, such an effect can lead to imprecise normalization of unknown samples, especially when the currents of the standards do not cover the full current range of the unknowns.

Based on data of the carbon measurements, we estimated the fractionation for beryllium by correcting for effects caused by different masses and energies of the nuclides, as well as different intensity of the ion beam. For comparison, we prepared a set of ^{10} Be samples with different BeO-Nb mixing ratios to yield different Be ion currents under similar ion source conditions. In addition, we varied the Cs flux in the source to test the influence of ion source conditions and increase the current range covered by this test.

Our ^{10} Be/^{9} Be data, especially for increasing currents, is affected by the intense ^{10} B beam that partially hits the detector. While the separation of the ^{10} Be and ^{10} B counts in a 2-dimensional ΔE-Eres spectrum works well, the dead time caused by the boron reduces the efficiency of the ^{10} Be detection causing an additional component of the current dependency of the ^{10} Be/^{9} Be ratio. We will present the data both for carbon and beryllium showing the change in measured ratio for varying currents as well as our calculations.

Development of 59Ni/58Ni measurements at CAMS

Corinne Dorais[1], Scott Tumey[1], Alan Hidy[1]
[1]*LLNL, Livermore, United States*

Theme: T-2: Suppression of isobars and other interferences
Type of presentation: Poster-Plus Presentation

Nickel-59 is a long-lived radioisotope (t1/2=76,000a) with applications in nuclear security, dosimetry, and cosmochemistry. However, the measurement of 59Ni via AMS is made difficult by the presence of isobaric 59Co. Cobalt and Ni share very similar chemical behavior and are therefore difficult to fully separate using traditional sample purification chemistry. Furthermore, Co can be found in many components of the AMS ion source, target holders, and sample packing materials, in which Co cannot be removed via chemistry. Recent work at the Center for Accelerator Mass Spectrometry (CAMS) at Lawrence Livermore National Laboratory (USA) has focused on developing a method of measuring 59Ni/58Ni on our 10MV FN tandem accelerator. In order to minimize the Co background, new ion source components have been made from materials low in Co. Additionally, a variety of materials have been investigated for target holders and sample packing. Results of these modifications will be presented along with measurement setup, charge state selection, and measurement challenges.

This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under contract DE-AC52-07NA27344. We thank the U.S. Department of Energy's National Nuclear Security Administration, Office of Defense Nuclear Nonproliferation Research and Development, for financial support.

Initial Tests of Accelerator Mass Spectrometry with the Argonne Gas Filled Analyzer (AGFA) and the commissioning of the MONICA detector

Miss Lauren Callahan[1], Dr Philippe Collon, Dr Michael Paul, Dr Melina Avila Coronado, Dr Birger Back, Mr Thomas Bailey, Mr Adam Clark, Mr John Greene, Dr Heshani Jayatissa, C.L. Jiang, Dr Yoav Kashiv, Mr Austin Nelson, Dr Richard Pardo, Dr David Potterveld, Dr K. Ernst Rehm, Dr Rudra Sahoo, Robert Scott, Dr Dariusz Seweryniak, Dr Ivan Tolstukhin, Richard Vondrasek, Dr Anton Wallner
[1]*University Of Notre Dame, South Bend, United States*

Theme: T-2: Suppression of isobars and other interferences
Type of presentation: Oral Presentation

As the scope of Accelerator Mass Spectrometry (AMS) expands, there is an increased need to research isobaric separation in the medium-heavy mass region. Existing AMS facilities are limited in their ability to separate medium to heavy radioactive nuclei of interest from their neighboring stable isobars, as such measurements require higher energies than available in most facilities. The Argonne Tandem Linac Accelerator System (ATLAS) at Argonne National Laboratory (ANL) can accelerate isotopes to the energies required for the separation of high mass isobars, and the Argonne Gas-Filled Analyzer (AGFA) setup at ATLAS, specifically designed to study heavy, rare isotopes, has the necessary magnetic rigidity to facilitate their measurement. AGFA was commissioned to perform AMS measurements in November, 2019, and successfully separated the stable isobars 92Zr and 92Mo. This measurement demonstrated that this setup can be used successfully for AMS measurements. Since that time, MONICA, an 8-anode ionization chamber that measures both energy loss and position with two sets of split anodes, has been developed to aid in the study of AMS at AGFA and has undergone four commissioning runs at the Nuclear Science Laboratory at the University of Notre Dame utilizing Si, Fe, Zr, and Mn beams. This report will present the 11/2019 AGFA AMS run and the subsequent commissioning runs of the MONICA detector. This work was supported by the U.S. Department of Energy, Office of Nuclear Physics, under Contract No. DE-AC02-06CH11357. This research used resources of ANL's ATLAS facility, which is a DOE Office of Science User Facility.

This work is supported by the National Science Foundation, Grant No. NSF PHY-2011890 and Israel Science Foundation, Grant No. 876/19.

Investigation of target materials for low energy accelerator mass spectrometry of 26Al

Dr Kejun Dong, Mrs Jiaqi Zhang, Prof. Sheng Xu
[1]*Institute of Surface Earth System Science, School of Earth System Science, Tianjin University, , China*

Theme: T-2: Suppression of isobars and other interferences
Type of presentation: Poster

Aluminum-26 accelerator mass spectrometry (AMS) technique has been widely applied in many scientific fields. At present, most laboratories routinely use Al_2O_3 as the target material from which Al- is extracted. However, the lower Al- ion beam current limits the measurement sensitivity. In this study, a series of surveys on Al- ion beam current, conductive agent, and interference background were carried out based on previous research and the low-energy AMS system of Tianjin University. The results show that AlN as a potential target material to replace Al_2O_3 is worth further study, and Mg element is still one of the main interference factors for low-energy ^{26}Al-AMS.

Investigation of the beam trajectory and beam profile development in the 135° gas-filled magnet at the AMS device for medium mass isotopes at the Cologne University

Ms Susan Herb[1], Mr. Gereon Hackenberg[1], Dr. Markus Schiffer[1], Dr. Stefan Heinze[1], Prof. Dr. Alfred Dewald[1]
[1]*University Of Cologne, Cologne, Germany*

Theme: T-2: Suppression of isobars and other interferences
Type of presentation: Poster

First 53Mn and 60Fe test measurements revealed that improvements of our AMS set-up at the FN tandem accelerator should be made to enable the measurement of lower levels isotopic ratios of 10^(-13) and 10^(-16.) Therefore, we aim to improve the isobar separation of the high energy mass spectrometer as well as its transmission.

For a better understanding of the ion beam behavior inside a gas-filled region of a magnet, the development along the flight path inside the magnet was investigated. The beam profile and position along the ion paths was measured in the dispersive direction (x-axis) with dedicated silicon pin diode detector arrays at 4 different locations. In addition, the two-dimensional profile (x/y) was measured at the exit of the magnet. For the measurement inside the magnet, a 60Ni background taken from a 60Fe blank at an initial energy of 100 MeV was injected and particles were verified with the detector arrays. Thereby, we also investigated the effect of using nitrogen to helium as fill-gas.

The measured data was used to test and improve our in-house developed Monte-Carlo simulation code. The code simulates the ion transport in a gas filled magnet taking into account continuous energy loss and successive charge changing collisions as well as angular and energy straggling. The first version of the code was designed for nitrogen gas and was now adapted for helium. The comparison of the calculated and the measured beam trajectories revealed that the gas density effect influencing the ion charge has to be considered [1].

The contribution will report on details of the conducted measurements and compare it with the calculations. Ongoing developments of the simulation code will be discussed.

[1] Betz, 1972, Reviews of Modern Physics, 44.

Isobar separation of ^{32}Si and ^{32}S - Towards the redetermination of the half-life of ^{32}Si

Mr Matthias Schlomberg[1], Dr Christof Vockenhuber[1], Prof Hans-Arno Synal[1], Dr Dorothea Schuman[2], Dr Ionut Mihalcea[2], Mario Veicht[2], Prof Anton Wallner[3]
[1]ETH Zurich, , Switzerland, [2]PSI, , Switzerland, [3]HZDR/ANU, , Australia

Theme: T-2: Suppression of isobars and other interferences
Type of presentation: Oral Presentation

The ^{32}Si is a cosmogenic, long-lived radionuclide with potentially interesting applications for dating the recent past. However, its half-life of about 150 years is still not known with sufficient precision despite several independent measurements over the past four decades. The SINCHRON collaboration with partners from PSI, CHUV, PTB, ANU and ETH aims at a comprehensive redetermination of the half-life of ^{32}Si.

The Laboratory of Ion Beam Physics (LIP) at ETH Zurich will perform the AMS measurements using the 6 MV-Tandem facility for the determination of the number of ^{32}Si atoms in the samples used for the activity measurement. In addition to the challenge of performing an absolute measurement without having standards available, ^{32}Si must be separated from its intense isobar ^{32}S. We developed a method based on a passive gas absorber in front of a gas ionization detector that allows us the detection of ^{32}Si by stopping the isobar ^{32}S at 30 MeV. However, background from light recoils from the absorber material and deviations of the stopping power at low energies still pose challenges.

An overview of the SINCHRON project will be presented. The setup and the obtained data will be discussed with respect to an absolute measurement.

Optimization of 10Be beam transport at DREAMS

Johannes Lachner[1], Georg Rugel[1], Konstanze Stübner[1], Carlos Vivo-Vilches[1], Stephan Winkler[1], Anton Wallner[1]
[1]*Helmholtz-Zentrum Dresden-Rossendorf (HZDR), Dresden, Germany*

Theme: T-2: Suppression of isobars and other interferences
Type of presentation: Poster-Plus Presentation

^{10} Be measurements at DREAMS take up a large fraction of the AMS beam times at the 6MV accelerator at the ion beam center of HZDR. Currently, they are undertaken at a terminal voltage of 4.5 MV [Rugel et al., NIMB 2016]. Here, we investigated potential benefits from a change in accelerator terminal voltage in order to increase the efficiency of ^{10} Be counting.
Presently, after the stripping in Ar gas in the accelerator, Be2+ ions are directed towards a 1 µm thin SiN foil placed after the analysing magnet on the high-energy side that helps to suppress the ^{10} B interference by differential energy loss and separation in an electrostatic analyser. After passage through the absorber foil the mean charge state of Be ions is increased and the 4+ charge state is selected and transported to the detector. In this mode of operation, losses of ^{10} Be ion beam intensity on the way from the low-energy side of the system to the detector are dominated by these two charge exchange processes [Arnold et al., NIMB 2010].
However, there is only limited data for the recharge behaviour of Be in a stripper gas at energies relevant for the measurements at DREAMS [Hofmann et al., NIMB 1987; Niklaus et al., NIMB 1994]. For an argon gas stripper, Niklaus et al. [NIMB 1994], suggest lower terminal voltages for optimal transmission of ^{10} Be2+. On the other hand, an increase of the overall energy of the Be2+ beam after the accelerator will certainly allow for a higher Be4+ yield after the passage through the absorber foil.
In contrast to the original data by Niklaus et al. [NIMB 1994], we found that increasing the terminal voltage to ≥ 5MV does not reduce the yield of the Be2+ charge state after the accelerator.

As a further recharge to the 4+ charge state is conducted in a foil after the analysing magnet it is desirable to hit the foil with the highest available energy/velocity to have optimal stripping of Be2+ to the naked ion. Thus, the efficiency of ^{10} Be measurements can indeed be improved by increasing the terminal voltage, both at DREAMS and at other AMS facilities of a similar size that are using the absorber method with a charge exchange from 2+ to 4+ for isobar suppression.
We present data on the performance of the system at higher beam energies documenting an increase in overall detection efficiency by 25%. Under these conditions the interfering isobar ^{10} B is still well separated, and no additional interferences (e.g. from nuclear reactions) appear in our spectra.

Preliminary tests of 26Al fluoride target matrix on AMS system

Ms Kateřina Fenclová[1], Tomas Prasek[1], Dr Marcus Christl[2], Mr Philip Gautschi[2], Dr Christof Vockenhuber[2]
[1] *Department of Nuclear Chemistry, Czech Technical University in Prague, Prague, Czech Republic,*
[2] *Laboratory of Ion Beam Physics, ETH Zürich, Zürich, Switzerland*

Theme: T-2: Suppression of isobars and other interferences
Type of presentation: Oral Presentation

The performance of the fluoride materials using a superhalogenide ion AlF4- extracted from Na3AlF6 based target materials for 26Al/27Al measurements was tested on the 0.3 MV MILEA AMS. Routine AMS measurements of 26Al/27Al are often performed by using Al2O3 target samples and extracting the negative Al-ions from the ion source. In that case, a 26Mg isobar is suppressed as magnesium does not form sufficiently stable negative ions. However, the intensity of the Al- currents is significantly lower compared to molecular ions like AlO-, which cannot be generally used for analysis due to the formation of the molecular isobar 26MgO-.
In this study, a fluoride matrix utilization for 26Al measurements was investigated initially in a caesium sputtering ion source and low energy side of the HVE Tandetron system at NPI Rez, Czech Republic, and subsequently on the MILEA AMS system at ETH Zürich. The AlF4- current was used to evaluate the performance of the respective samples. Additives as PbF2 were tested to increase the extracted ion currents and samples containing MgF2 were used to investigate the presence of isobaric ions and the ionization efficiency of AlF4- was determined by recording the 27Al2+ current on the high energy side. The signals of 26Al2+ were investigated with the gas ionization detector. It was realized that aluminium fluoride matrix provides significantly more intense ion beam of AlF4- ion than Al- and AlO- from Al2O3 matrix but possible interferences from magnesium and cathode material were identified.

Progress of laser photo detachment experiment at MALT

Dr Yasuto Miyake[1], Mr Takeyasu Yamagata[2], Prof. Hiroyuki Matsuzaki[2]
[1]Riken, , Japan, [2]MALT, The University of Tokyo, , Japan

Theme: T-2: Suppression of isobars and other interferences
Type of presentation: Poster

A laser photo detachment (LPD) method for Accelerator Mass Spectrometry (AMS) systems is developing at Micro Analysis Laboratory Tandem accelerator, The University of Tokyo (MALT). LPD is a method of neutralizing negative ions by interacting with a laser and a negative ion beam. Neutralization of negative ions occurs when the electron affinity (EA) of the atoms in the negative ion is lower than the energy of the laser photon. Therefore, if the laser energy is appropriately selected, only the targeted ions can be separated. For example, the isobaric compound of ^{36} Cl (T1/2 = 3.01×10^{5} y) is a stable nuclide ^{36} S. The EA of Cl is 3.61 eV, while the EA of S is 2.08 eV. Thus, if a laser with a wavelength of 532 nm (hν = 2.33 eV) is used, only S can be selectively neutralized and separated from Cl.

The test bench beamline for the LPD experiment at MALT was constructed, which consists of a negative ion source, an analyzing magnet, a negative ion cooler, an electrostatic deflector, a laser system, and a detection system such as a FC. The negative ion beam produced by the ion source with the energy of 22 keV is mass analyzed and then interacts with the laser in the ion cooler. The laser is a 20 W continuous wave laser ,and its wavelength is 532 nm. After passing through the ion cooler, negative ions are deflected and measured as current by the FC. On the other hand, neutralized particles are separated without being deflected.
In this study, we report recent progress of the LPD experiment of Cl and S, the change in the suppression of S by the laser when He is introduced as a buffer gas, and the change in the transmission efficiency.

Relative Formation Probabilities for Fluoride and Oxyfluoride Anions of U, Np, Pu and Am in Accelerator Mass Spectrometry Measurements at VERA

Mr Andreas Wiederin[1,2], Robin Golser[1], Michael Kern[1], Karin Hain[1], Martin Martschini[1], Aya Sakaguchi[3], Peter Steier[1], Akihiko Yokoyama[4]
[1]University of Vienna, Faculty of Physics, Isotope Physics, Vienna, Austria, [2]Vienna Doctoral School of Physics, University of Vienna, Vienna, Austria, [3]University of Tsukuba, Faculty of Pure and Applied Sciences, Tsukuba, Japan, [4]Kanazawa University, Institute of Science and Engineering, Kanazawa, Japan

Theme: T-2: Suppression of isobars and other interferences
Type of presentation: Poster-Plus Presentation

Fluoride molecular anions have emerged as a potential alternative to oxides for the extraction of actinides for AMS [1, 2]. Research at the Vienna Environmental Research Accelerator (VERA) in this respect has focused on mixing samples prepared as oxides in Fe_2O_3 with PbF_2 for in situ fluoridization during the sputter process. In this context, the relative formation probabilities for a range of (oxy-)fluoride molecular anions of the actinides uranium, neptunium, plutonium, and americium have been systematically investigated. This data helps to identify isobaric contaminations for those elements.
A first application is monitoring the production of the unwanted byproduct ^{236}U in the irradiation of Th foils with ^{7}Li ions, which is considered for the production of ^{236}Np, a potential isotopic spike for ^{237}Np. Exploring these relative formation probabilities is an important step towards the separation of U and Np isobars via selective photodetachment or reactive gases in the Ion Laser InterAction Mass Spectrometry (ILIAMS) ion-cooler [3,4].

Test samples were prepared by drying a well-known amount of ^{236}U, ^{237}Np, ^{242}Pu and ^{243}Am spike solution with 300 µg Fe (as nitric solution), ignition, and mixing with PbF_2 in a mass ratio of 1:9. The required instrumental setups, spanning a mass range from 306 u to 338 u, were scaled from the closest pilot beam ($^{238}UF_5^-$ and $^{238}UF_2O_2^-$) by adjusting only the electrostatic components of VERA to allow for fast switching. The formation probability for each molecular anion $AnF_{\square}O_{\square}^-$ (An standing for the respective actinide) was determined relative to AnF_5^-. The remaining material from an irradiation experiment previously measured at VERA in oxide form was mixed with PbF_2 and the distributions of the molecular anions for the trace masses 237 (co-produced ^{237}Np) and 236 were compared to the spiked samples.

The distribution of the molecular anions was found to be element-specific for U, Np, Pu and Am. With progressive consumption of fluorine, the formation ratios shifted towards lower fluorides and oxyfluorides. Lower mixing ratios (1:4.5) with PbF_2 had a similar effect, while increased ratios (1:18) did not affect the distribution significantly. In sufficiently short (<2.5h) measurements, the molecular anion formation ratios for mass 236 obtained for samples irradiated at the RIKEN Nishina Center are well compatible with Np. This result indicates that ^{236}Np was successfully produced in the irradiation and chemically separated at the University of Tsukuba. The investigation has also revealed that Uranium can be suppressed by one order of magnitude compared to Np by extracting them from the AMS target as UF_4^- and NpF_4^-. Due to the large difference in formation probabilities, these two molecules are of particular interest for the development of the in-flight separation of ^{236}U and ^{236}Np with ILIAMS.

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Study of 10Be/7Be analysis method using Accelerator Mass Spectrometry

Dr Yun-Chong Fu[1,2,3], Dr Li Zhang[1,2], Prof. Wei-Jian Zhou[1,2,3], Mr Guo-Qing Zhao[1,2], Mr Xu-Ke Liu[1,2,4]

[1]Institute Of Earth Environment, Chinese Academy Of Sciences, Xi'an, China, [2]Shaanxi Key Laboratory of Accelerator Mass Spectrometry Technology and Application, Xi'an, China, [3]Xi'an Jiaotong University, Xi'an, China, [4]University of Chinese Academy of Sciences, Beijing, China

Theme: T-2: Suppression of isobars and other interferences
Type of presentation: Oral Presentation

The 10Be/7Be ratio is a sensitive tracer for the study of atmospheric transport, particularly with regard to stratosphere-troposphere exchange. Measurements with high accuracy and efficiency are crucial to 7Be and 10Be tracer studies. Full stripping method of 7Be have been carried out by few larger AMS. However, for low energy AMS that is difficult to obtain efficient full stripping Be, the method of 7Be measurement using non-fully stripping is few reports, which is more widely applicable for all AMS. Firstly, the preparation procedures of rain samples that is suitable for 7Be and 10Be by AMS measurement at same target have been established. 7Be analysis has been performed to by full stripping method, which completely removed 7Li due to its electronic structure, using more homogeneous Si3N4 as a secondary stripping film, and same way for 10Be. 7Be/9Be background was less than 2×10-16. On the other hand, study for non-full stripping method to 7Be has been analyzed by AMS. The magnitude of suppression for isobaric 7Li has been discussed at each stage, and another interference 14N were found and analyzed. Due to the full stripping method was not used, it makes for it possible to analyze 7Be with lower energy AMS, which is ultra-low efficiency to obtain 7Be4+. The non-full stripping method is generally method for 7Be analysis especially for low energy AMS. In addition, we discussed quality control and data calibration methods. A preliminary study of environment applied was carried out using 7Be and 10Be by 3MV AMS. The ratio of 10Be/7Be and concentration of 10Be and 7Be of rainwater collected in Xi'an have been obtained.

The foilstack method for 10Be analysis at iThemba LABS - first results and intercomparison for field samples

Dr. Stephan R. Winkler[1], Dr. Vela L. Mbele[1], Ms. Rivoningo R. Khosa[1], Dr. Lee B. Corbett[2], Prof. Paul R. Bierman[2], Dr. Alan Hidy[3], Dr. Tom Brown[3], Dr. Tebogo V. Makhubela[4], Prof. Jan D. Kramers[4], Dr. Stephen Tooth[5]

[1]TAMS Department, iThemba LABS, Johannesburg, South Africa, [2]Department of Geology, University of Vermont, Burlington, USA, [3]Lawrence-Livermore National Laboratory, , USA, [4]Dept. of Geology, University of Johannesburg, Johannesburg, South Africa, [5]Geography & Earth Sciences, Aberystwyth University, Aberystwyth, United Kingdom

Theme: T-2: Suppression of isobars and other interferences
Type of presentation: Poster-Plus Presentation

Beryllium-10 is an important isotope for the AMS system at iThemba LABS in Johannesburg because of demand for cosmogenic radionuclide dating methods in the national, regional, and international earth science and paleosciences community. Rather than being designed as one system, the AMS system at iThemba LABS has been set up over several phases based on an existing tandem accelerator, which usually poses challenges implementing the best measurement approach for any given isotope. The injector-side features an in-house built multi-sample cesium sputter ion source, similar to systems employed at CAMS/Lawrence Livermore National Laboratory and Purdue Rare Isotope Measurement Laboratory. The ion source is followed by an in-house built electro-static analyzer and an (in-house built) analyzing magnet, with NEC's multi-beam switching electronics system applied to our own insulated magnet chamber. The accelerator is a pelletron-refurbished HVEC Model EN tandem, and the high-energy beam line is modified by addition of a switching magnet beam-line from a typical setup delivered by NEC for 5 MV tandem accelerators. Unfortunately using the gas absorber cell employing Havar windows (as was delivered) requires higher energies, usually requiring the 3+ charge state and relatively high terminal voltage, which, for the purpose of AMS operations, are not currently delivered reliably enough by our tandem accelerator. Recently it has been shown that low-stress silicon nitride membranes can be used as absorber foils for full stopping of Boron-10 with a particle energy as low as 6 MeV for the measurement of Beryllium-10 [Steier, et al., 2019]. This allows for the use of the 2+ charge state, avoiding the charge state losses of the post-stripping method used with accelerators capable of similar or lower terminal voltage elsewhere, albeit at the expense of allowing some background from nuclear reactions. We implemented this method in lieu of the gas absorber cell, thus utilizing from the efficiency gain from using the 2+ charge state. In order to investigate the impact of Boron-10 interference and to devise a background correction formalism we conducted experiments using our own ultra-low-Beryllium-10 phenakite-based carrier, and a dilution series of deliberately added Boron-10. We present data which demonstrate good performance of the system on standards and the dilution series samples, and 14 comparison measurements with results obtained at CAMS/LLNL, with all the comparison samples having been prepared at University of Vermont for a landscape evolution study in South Africa. The independent AMS measurements results from the two laboratories are in excellent agreement. A correlation analysis for the two data sets yields a Pearson's r of 0.9993, with slope (1.009+/-0.017) and offset fully consistent with cross-calibration between the laboratories. The mean difference between the laboratories' results for individual samples is just 1.7%, in line with the AMS uncertainty given by the laboratories.

The Isobar Separator for Anions at the A. E. Lalonde AMS Laboratory

Erin L. Flannigan[1], Dr. Jean-François Alary[2], Dr. Lisa M. Cousins[2], Dr. Gholamreza Javahery[2], Dr. William E. Kieser[1,2]
[1]University Of Ottawa, Ottawa, Canada, [2]Isobarex Corp., Vaughan, Canada

Theme: T-2: Suppression of isobars and other interferences
Type of presentation: Oral Presentation

Accelerator Mass Spectrometry (AMS) of isotopes with abundant negative ion-forming isobars often requires the use of large accelerators to achieve high sensitivity measurements. The Isobar Separator for Anions (ISA) is a radiofrequency quadrupole (RFQ) reaction cell system that provides selective isobar suppression of many of these isotopes in the low energy system, prior to injection into an accelerator. The ISA can then facilitate the measurement of these ions using smaller accelerators. A commercial version from Isobarex Corp. (Vaughan, Ontario, Canada) has been installed into a separate Research Line of the 3 MV tandem accelerator system at the A. E. Lalonde AMS Laboratory, University of Ottawa.

The Research Line consists of a Cs+ Sputter Ion Source that produces a 20-35 keV anion beam, which is energy and mass analyzed before injection into the ISA. The ISA includes a DC deceleration region, a combined cooling and reaction cell, and a DC re-acceleration region. The deceleration region reduces the beam energy to a level at which the RFQ cell can capture and contain the ions. The cell is filled with an inert cooling gas that has been experimentally selected to further reduce the ion energy and therefore facilitate charge exchange or other chemical reactions between the interfering isobar and the reaction gas, as well as enabling the highest transmission of the isotope of interest. A reaction gas, chosen to preferentially react with the interfering isobar, is also contained within the cell. RFQ segments along the length of the cell create a potential well, which limits the divergence of the traversing ions. DC offset voltages on these RFQ segments maintain a controlled ion velocity through the cell. After exiting the cell, the wanted ions are re-accelerated prior to injection into the tandem accelerator for conventional AMS analysis.

Here we present ISA characterization for best achieved sulfur suppression and chlorine transmission. These tests use NO_2 as the reaction gas due to its well-known exothermic reaction with sulfur anions but endothermic reaction with chlorine anions [1]. Helium was selected as the cooling buffer gas, as it provided the best chlorine transmission of ~50% through the ISA column. Over six orders of magnitude reduction of sulfur-36 to chlorine-37 has been observed. Using the sulfur suppression from the ISA and the degree of dE/dx separation for 12 MeV ions in the detector offered by the 3MV-AMS system, a chlorine-36/chlorine-37 abundance sensitivity of ~$7x10^{-15}$ was achieved.

The ISA will be used to measure chlorine-36 samples and its applications will soon be extended to additional isotopes involving, for example, the suppression of $^{90}ZrF_3{}^-$ and $^{135}BaF_2{}^-$/$^{137}BaF_2{}^-$ in the measurements of $^{90}SrF_3{}^-$ and $^{135}CsF_2{}^-$/$^{137}CsF_2{}^-$, respectively.

[1] D.B. Dunkin et al. Chemical Physics Letters 15 (1972) 257.

The LISEL@DREMS project for isobar suppression by laser photodetachment

Dr Oliver Forstner[1], Mr. Vadim Gadelshin[2], Mr. Dominik Studer[2], Prof. Klaus Wendt[2], Dr. Kurt Stiebing[3]
[1]University Of Jena, Jena, Germany, [2]University of Mainz, Mainz , Germany, [3]University of Frankfurt, Frankfurt, Germany

Theme: T-2: Suppression of isobars and other interferences
Type of presentation: Poster

LISEL@DREAMS (Low energy Isobar SEparation by Lasers at DREsden Accelerator Mass Spectrometry) is a recent project to widen the applications of AMS by extending the range of measurable (radio-) nuclides. AMS has proven to be a versatile tool capable of detecting a large number of long-lived radionuclides at the ultra-trace level – i.e. isotope ratios down to 10^-16. However, being a mass spectrometric method, it is limited by the presence of strong isobaric background. To overcome this imitation, we propose to remove the isobars already at the low-energy side by laser photodetachment. This method allows to selectively neutralize isobars by laser radiation, leaving the ions of interest intact. First studies were performed at the University of Vienna within the ILIAS project and gave promising results for the easier to be measured low-mass AMS isotopes Al-26 and Cl-36. Within the LISEL@DREAMS project this method will be for the first time applied to an AMS facility based on a 6 MV tandem accelerator. This should allow to measure all isotopes from around Z=50 up to the actinides. The first isotopes to be addressed with the new method will be Mn-53 and Fe-60. Both are currently only measurable at AMS facilities with more than 10 MV terminal voltage (after closure of the tandem accelerator lab of the LMU and TU Munich in Garching/Germany currently only available at the ANU in Canberra/Australia). The tunable Ti:Sapphire laser system is currently developed at the University of Mainz. Further on we foresee to apply this method to other rare isotopes, making LISEL@DREAMS a versatile machine for “all” isotopes. This will subsequently widen the applications and also the user community.
The required spectroscopic data especially for molecular anions will be gathered at the low-energy electrostatic storage ring FLSR at the University of Frankfurt. It has recently been upgraded with a source for negative ions and commissioning with lasers is currently taking place.
LISEL@DREAMS is a project funded by the German Federal Ministry of Education and Research BMBF.

Matrix-assisted production of actinide molecular anions for AMS

Dr Barbara Francisco[1], Dr Xiaolei Zhao[1]
[1]*University Of Ottawa, Ottawa, Canada*

Theme: T-3: Ion sourcery
Type of presentation: Poster

The multiple probable oxidization states of actinide elements can lead to their molecular anions to result in complicated yield patterns from a Cs+ sputter ion source. For actinides AMS, two methods can be practiced in order to concentrate the yields into just one or two anion species. The present common practice has been to deprive the availability of oxygen in the sputter targets, so that the mono-oxide anions are produced with good or applicable ionization efficiencies. However, this method requires the typical 860-type Cs+ sputter ion sources to be operated with relatively high Cs+ fluxes, a condition that not all such sources in use can be operated with a lasting stability. On the contrary, with low Cs+ fluxes, good or applicable ionization efficiencies can also be achieved for producing element-specific poly-atomic oxide, oxyfluoride, or fluoride anions of actinides, if the sputter targets are aided with dominantly oxidizing or fluorinating matrices. We describe a systematic study of such phenomena using ZnO and FeF_3 to form the respective oxidizing and fluorinating matrices. It was found that using element-specific polyatomic atomic fluoride anions and $FeOxHy+FeF_3$ sputter targets, not only all rare actinides could be measured with low detection limits matching those by mono-oxides, but also with the available ionization efficiencies fully utilized within a shorter time. In addition: sample chemistry is simplified without the need for high temperature calcination; the lack of triply charged hydride ions and mono-isotopic fluorine help in achieving better $^{236}U/^{238}U$ abundance sensitivity using just one large analyzing magnet in the high energy system of AMS; scatter interferences of $^{232}ThF_6^-$ to $^{231}PaF_6^-$ detection, and $^{238}UF_4^-$ to $^{237}NpF_4^-$ & $^{239}PuF_4^-$ detection, are naturally lower by an order of magnitude because Th and U molecular anions are concentrated into ThF_5^- and UF_5^-; and finally, measurement background is two orders of magnitude less sensitive to any long-lasting ion source memories. In conclusion, the use of element-specific poly-atomic fluoride anions and $FeOxHy+FeF_3$ sputter targets is a viable alternative approach to actinides AMS, especially when low-output Cs+ sputter ion sources are used.

Key Words: actinides AMS; matrix-assisted sputtering; FeF_3 matrix; poly-atomic fluoride anions; ionization efficiency; detection limits; Cs+ sputter ion source memory effects;

Negative ionisation efficiencies for 10Be, 26Al and Pu with MC-SNICS at ANSTO

Klaus Wilcken[1], David Child[1], Dr. Michael Hotchkis[1], Michael Mann[1], Krista Simon[1], Dominik Koll[2,3], Prof. Anton Wallner[2,3], Thilo Hauser[4], Richard Kitchen[4]
[1]ANSTO, Lucas Heights, Australia, [2]Australian National University, Canberra, Australia, [3]HZDR, Dresden, Germany, [4]National Electrostatic Corporation, Middleton, USA

Theme: T-3: Ion sourcery
Type of presentation: Poster-Plus Presentation

Low overall detection efficiency for actinides and cosmogenic isotopes (Al, Be) is the limiting factor affecting precision and sensitivity for applications where the amount of available sample material is small and/or rare isotope concentration is low. Due to low ionisation efficiencies for these isotopes it is not uncommon that more than 99% of the rare isotopes in the sample do not contribute to the statistical precision of the measurement. Optimising ion transmission and detection efficiency in the AMS measurement offers some room for improvement but these avenues are already close to their theoretical limits.

On the other hand, optimising the performance and operation of the negative ion Cs-sputter sources has significant scope for improvement but is challenging. One often needs to compromise between competing requirements, for example, maintaining high sputtering rate to allow expedient consumption of the sample material but at the same time keeping the source insulators clean for longevity. The lack of a well-understood theoretical model for the negative ionisation process adds to the engineering challenges.

Negative ionisation efficiencies above 30% have been demonstrated for radiocarbon [1] but remain often more than an order of magnitude lower for Be, Al and actinides. This is sometimes taken to be an inherent limitation of the technique, rather than a challenge to be addressed.

Here we present details of the modified MC-SNICS sources at ANSTO, including engineering modifications that have improved longevity and stability. With attention to a combination of ion source running conditions, sample masses and sample binders the total efficiency for Pu measurements was increased up to 1.5%, corresponding to a negative ionisation yield of 4%. For Al- and BeO- negative ion source yields are 0.2% and 3%, respectively.

References:

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Optimizing a cesium-sputter ion source using Lorentz 2E

Mr Collin Tiessen[1], Dr. William Kieser[1], Dr. Xiaolei Zhao[1]
[1]*University of Ottawa, Ottawa, Canada*

Theme: T-3: Ion sourcery
Type of presentation: Oral Presentation

The cesium-sputter negative-ion source is a fundamental component of accelerator mass spectrometry studies. Improvements in ion current and output emittance allow for higher precision measurements and potential for new applications. The High Voltage Engineering Europa SO-110C ion source has been modeled using Integrated Engineering Software's Lorentz 2E ion trajectory simulation software. This software includes the mutual space charge interactions between the incoming cesium ions from their production in the ionizer and the outgoing negative ion beam from the target (cathode). Simulations examined the effects of changing the geometry of various source components, electrode potentials, ion currents, position of the target and negative ion mass.

The simulations demonstrated that, as the cesium current is increased, the cesium beam broadens by its own space charge repulsion. This affects its focusing and distribution on the sample material. It is important that the cesium cover the outer proportions of the sample well for best usage of the material and stability of the outgoing negative ion beam. Changes in geometry and electrode potentials can mitigate this effect.

Informed by these simulations, experiments at the A.E. Lalonde Accelerator Mass Spectrometry Laboratory (Lalonde) recessed the target in incremental 1 mm steps (targets were translated away from the ionizer along the axis of symmetry). Custom target bases were machined to facilitate these recesses without the need to modify the target pressing procedure. The abundant isotopes were measured using the post-accelerator offset Faraday Cups and rare isotopes at the gas ionization detector to compare outputs at various settings.

These tests were first run at routine ^{14}C measurement settings (6 kV target-ionizer potential difference, 115 °C cesium oven temperature) on graphite blanks. At these settings, a target recess of 1 mm gave the most stable output with the highest usage of sample material.

A second experiment, using targets made from a ^{10}Be standard, expanded this study by increasing the cesium oven temperature (and hence cesium current) incrementally from 130-140 °C, while also varying the target-ionizer potential difference (4-11 kV). This multi-dimensional study gave several promising settings, resulting in the most precise measurement of ^{10}Be performed to date at Lalonde.

A demonstration of key simulations and a comparison with experimental results will be presented.

Potential ways to increase C- from CO2-fed sputter ion sources

Dr John Vogel[1]
[1] *Univ Of California, ukiah, united states*

Theme: T-3: Ion sourcery
Type of presentation: Poster

The CO2-fed ion source was first proposed at the Third AMS Symposium in 1984. At the same gathering, the chemical method of reducing CO2 to a fullerene on fine iron powder was also presented. This latter method has been the mainstay of 14C AMS sample preparation to the present day, despite the numerous advantages of the gas sample approach. A number of laboratories built prototype gas-fed sources in the 1990's after Middleton showed his improved gas source in 1989. Oxford, especially, had an active measurement program in the 90's using CO2, but by 2004 it became clear that ion currents from CO2 were routinely 5-15 µAmps from actual samples, although "tank" gas occasionally produced 25 µA. Detailed analyses of the CO2-fed ion source continued, but many AMS labs, especially those having MICADAS equipment, resigned themselves to their lower-than-desired ion current and proceeded with their small sample science programs. At the last AMS meeting, I proposed that there were two ionization processes at work in the sputter ion source: surface ionization which should limit solid samples to 30 µA of C- (at Icathode = 1 mA); and volume ionization from sputtered neutral C atoms scattering off neutral, excited cesium with up to 100 µA available from recessed samples. Very large currents (300 - >400 µA) result from the volume ionization remaining active to an immersion lens located a few mm in front of the sample. The cross sections for this ionization can be calculated from equations given in my AMS-14 paper. They are in the hundreds of Å2, many of orders of magnitude greater than electron attachment or even surface ionization. I had shown in an earlier paper that other sputtered elements could compete with carbon for the Cs atoms of the desired excited state to depress C-. Oxygen particularly competes with carbon for the most plentiful Cs excited state, Cs(5d), having 62% higher cross section than carbon at this energy. The near-Gaussian cross sections reverse dominance, however. by exciting the Cs to the Cs(7s) state from the Cs(5d) with a 1359 nm laser. A competition model gives 50% more C- at that state.This is for the volume ionization only. I am uncertain how to calculate the surface ionization of gas. In his 1989 paper, Middleton said that CO gave. marginally more C- current than did CO2, but the problem of reduction was probably not worth it. This may merit revisiting, considering that the present sources are operated differently from his. He used a CaCO3 heated source of CO2, without He carrier, and the samples were generally bigger than those of today. A recent theoretical chemistry paper compared binding of CO, CO2 and CH4 to a. titanium surface and showed that while one oxygen was removed from both CO ,and CO2, the CO carbon remained on the surface while the CO2 carbon became more tightly bound to a lower level of Ti atoms.

Pulsed operation of a SNICS ion source - ionization efficiency and ion output

Dr Martin Martschini[1], Alfred Priller[1], Peter Steier[1], Robin Golser[1]
[1]*University of Vienna, Faculty of Physics - Istope Physics, VERA Lab, Vienna, Austria*

Theme: T-3: Ion sourcery
Type of presentation: Poster

Accelerator mass spectrometry (AMS) aims at highly efficient and fast detection of minute amounts of radioisotopes and thus crucially depends among others on the attainable negative ion output from a cesium sputter ion source. Generations of scientist have thus experimented with variations of sputter matrix composition, ion source settings and other ion sourcery magic to achieve the best performance of their AMS ion sources.

In 2020, Blahins et.al. [1] reported strong ion current enhancement for negative ions when operating their Peabody Scientific Model PS-120 in a pulsed mode. They switched the cathode voltage with 10Hz repetition rate and a duty cycle of 10% between the standard operating value of −3 kV and an idle value of −200V, primarily with the aim to make their cathodes last longer during experiments with pulsed lasers.

At the Vienna Environmental Research Accelerator VERA, we have subsequently investigated possible ion output enhancement factors for C^-, C_4^-, Al^-, AlO^-, CaF_3^- and SrF_3^-, by a pulsed operation of one of our NEC-MC-SNICS II ion sources under AMS-conditions. The cathode voltage was switched periodically between −5 kV for regular sputtering and a reduced value of −800 V with a Behlke GHTS-60A High Voltage Push-Pull Switching Unit. A pulse generator allowed variation of both the repetition rate (1-10Hz) and the duty cycle (5-90%).

When operating the ion source with regular AMS settings such that a $^{12}C^-$ output of 30-40 μA DC was obtained, all of the above ion species showed a peak ion current in pulsed mode similar to the DC ion current of that species. A study of ionization efficiency of Al^- from Al_2O_3 sputter targets likewise revealed no enhancement of ionization efficiency by pulsing the source. However, current enhancement of up to 400% for C^- and especially C_4^- were observed in pulsed mode when strongly reducing the cesium supply to the source. Presumably, longer Cs accumulation times enhance the ion current only in a state of cesium scarcity in the source. Since these are unfavorable and unusual conditions in AMS, no benefits for AMS could be identified.

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Radiocarbon measurement of CO2 from carbonate minerals using a gas ion source with an open split interface

Mr Brett Longworth[1], Mr Joshua Burton[1], Dr. Simon Pendleton[1], Mr. Joshua Hlavenka[1], Ms. Sydney Moser[2], Dr. Mark Roberts[1], Dr. Mark Kurz[1]
[1]Woods Hole Oceanographic Institution, Woods Hole, United States, [2]University of Ottawa, Ottawa, Canada

Theme: T-3: Ion sourcery
Type of presentation: Poster-Plus Presentation

We have developed a method for measurement of radiocarbon in carbonate minerals as CO2 gas via a NEC MCSNICS hybrid sputter gas ion source (HGIS). The method uses helium as a carrier gas to displace CO2 from sample vials to an open split, where a glass capillary samples the mixture for delivery directly to the HGIS. This method skips the gas transfer and quantification steps used in a closed inlet HGIS system, simplifying sample measurement. Samples larger than 10 mg carbonate can currently be measured. Results from measurements of consensus standards (TIRI-I, IAEA C2, and an internal modern shell standard), and samples from a marine core (40-115 pMC) show that the method agrees well with traditional AMS measurement of the same samples as graphite, and that the method error is less than 1.5 pMC. We discuss advantages and disadvantages of continuous flow sample introduction, and the effect of reduced precision on calibrated age-depth models produced using gas-source data.

135Cs and 137Cs detection in environmental samples by AMS

Mr Alexander Wieser[1], Mr Johannes Lachner[2], Mr Dorian Zok[3], Mr Martin Martschini[1], Mr Peter Steier[1], Mr Alfred Priller[1], Mr Robin Golser[1]

[1]University of Vienna, Faculty of Physics - Isotope Physics, Vienna, Austria, [2]Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany, [3]Leibniz University Hannover, Institute of Radioecology and Radiation Protection, Hannover, Germany

Theme: T-4: New AMS isotopes
Type of presentation: Poster-Plus Presentation

The isotopic ratio ^{135}Cs/^{137}Cs can be used to assign sources of anthropogenic cesium input, as a geochemical tracer, or for modifying anthropogenic radionuclide dispersion models. The long-lived ^{135}Cs is also of interest in stellar nucleosynthesis models, where ^{134}Cs is an important s-process branching point, defining the ^{134}Ba/^{136}Ba ratio as both those nuclides are shielded from the r-process. ^{135}Cs is a pure beta-emitter with a low end-point energy and a long but not very well known half-life around 2.3 Ma. Therefore, ^{135}Cs is hard to detect via radiometric methods. Mass spectrometry on the other side has to deal with the isobaric interferences ^{135}Ba and ^{137}Ba for Cs detection.

The new method of Ion Laser InterAction Mass Spectrometry (ILIAMS) at the Vienna Environmental Research Accelerator (VERA) overcomes this problem by exploiting differences in the electron affinities of CsF_2^- and BaF_2^-. There, the ion beam is cooled and overlapped with a 532 nm laser beam of 10W power in a He buffer gas filled radiofrequency quadrupole. Ions like BaF_2^- with a detachment energy lower than the photon energy of 2.33 eV are efficiently suppressed by photodetachment, while CsF_2^- ions with a detachment energy higher than the photon energy remain unaffected. With this approach an isobar suppression of more than 10^6 was achieved for BaF_2^-, while reaching a CsF_2^- transmission of 40% through the RFQ ion cooler. A $^{133}CsF_2^-$ current on the order of 50 nA from a mixed Cs_2SO_4 and PbF_2 - matrix is extracted from the MC-SNICS ion source and measured in the 3+ charge state on the high-energy side with an accelerator transmission of 30%. In order to improve the yield for CsF_2^- and keep cross-contamination in the ion source between samples low, we investigated and present the results of two sputtering processes: Rubidium sputtering and negative ion production without external sputter agent.

We achieved reproducible detection of ^{135}Cs and ^{137}Cs in an in-house reference material with an isotopic ratio of $^{135}Cs/^{137}Cs \approx 2.5$. Further, first environmental samples showing the ^{135}Cs/^{137}Cs signature of the nuclear accidents in Chernobyl and Fukushima were measured at VERA and compared to values obtained by ICP-QQQ-MS by Zok et al. [1] at the Leibniz University of Hannover. The ILIAMS assisted AMS measurements at VERA reach blank levels of $^{135}Cs/^{133}Cs \approx 6 \cdot 10^{-12}$ and $^{137}Cs/^{133}Cs \approx 3 \cdot 10^{-12}$.

Monitoring mass 136 throughout a measurement, where only stable barium and cerium are present, shows that at these levels there is no contribution to the background from insufficient isobar suppression so that the limitation for the AMS blank level is cross contamination in the ion source. We aim to reduce this blank value by at least two orders of magnitude to perform measurements of environmental samples also far from directly contaminated sites.

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Developing the measurement method of Sr-90 using AMS

Prof. Ming He[1], Dr. qingzhang Zhao[1], Dr. wenhui Zhang[1], jiancheng Liu[1], Pan Hu[1], hongyu He[1], Dr. Kangning Li[1]
[1]*China Insttitute Of Atomic Energy, Beijing, China*

Theme: T-4: New AMS isotopes
Type of presentation: Poster

90Sr is the major fission produce of uranium and plutonium and is interest in the environmental and health areas. In order to carry out 90Sr measurement with AMS, the methods of 90Sr measurement have been carried out at CIAE.

SrF2 is selected as target material, the procedures of preparation of SrF2 have been developed, The SrF2 sample mixed with five times its weight of PbF2 was pressed into holders and molecular negative ion of SrF3- is used for extracting from ion source.

SrF3- with beam current of about 200nA is extracted from the ion source. After passing through electrostatic analyzer and injection magnet, SrF3- is send to tandem accelerator which worked at terminal voltage of 11MV. Carbon foil is used as stripper at the terminal. A 90∘double focusing high energy analyzing magnet is used to selects 90Sr9+ with a the stripping probability of 25%. By means of the switching magnet, the particles were transported further to the Q3D spectrometer which have three dipolar magnets. In order to suppress the isobaric interference of 90Zr, the □E-Q3D method is used. The ΔE-Q3D system consists of the Q3D magnetic spectrometer with an absorber placed at its entrance, which is used to absorb part of the ions' energy, and a four-anode gas ionization chamber at the center of its focal plane. When isobars with the same energy pass through the absorber, their energy losses are different, then the Q3D magnetic spectrometer can separate isobars due to their different residual energies. Silicon nitride (Si3N4) membranes with a thickness of 1μm was used as the absorber and the ions of 90Sr20+ with a stripper possibility of 25% were selected by Q3D spectrometer. The results show that the optimum magnetic field value of 90Sr is 25 Gs larger than that of 90Zr, indicating that the residual energy of 90Sr is about 0.86% higher than that of 90Zr. According to the size of ionization chamber entrance window and the ion beam spot, the interference background of 90Zr can be reduced by 6 times after setting the Q3D magnetic field to the optimal magnetic field of 90Zr.

After separating with Q3D magnetic spectrometry, the 90Sr and part of 90Zr enter the gas ionization chamber. The chamber is used to further identify 90Sr and 90Zr by using their different energy loss. Four anodes and a cathode are used to identify 90Sr and 90Zr. A suppression factor of 6000 for 90Zr was obtained with the detector alone by application of appropriate gates on these five signals. By implementing the techniques described above, the Sensitivity of 90 Sr/Sr= 9.2×10exp(-13) has been obtained.

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First studies on ^{99}Tc detection using Ion Laser InterAction Mass Spectrometry (ILIAMS)

Johanna Pitters[1,2], Fadime Gülce[1], **Karin Hain**[1], Martin Martschini[1], Markus Schiffer[3], Robin Golser[1]

[1] University of Vienna, Faculty of Physics, Isotope Physics, , Austria, [2]Vienna Doctoral School in Physics,
[3] University of Cologne, Institute for Nuclear Physics, Germany

Theme: T-4: New AMS isotopes
Type of presentation: Poster-Plus Presentation

Technetium-99 ($t_{1/2} = 2.1 \cdot 10^5$ a) is an anthropogenic isotope released by nuclear waste reprocessing, from global fallout and nuclear medicine. Owing to its high solubility, it can serve as a tracer for water transport processes. The detection of ^{99}Tc in environmental samples presently requires Accelerator Mass Spectrometry (AMS) at the largest AMS-facilities in order to adequately suppress the strong interference from the isobar ^{99}Ru. In our project, we aim at measuring ^{99}Tc at the 3-MV facility VERA (Vienna Environmental Research Accelerator) using laser photodetachment at our unique setup ILIAMS (Ion Laser InterAction Mass Spectrometry) for isobaric suppression (Martschini et al., this meeting). Access to ^{99}Tc measurements at low terminal voltage will open a whole range of applications in fields such as oceanography and nuclear waste repositories.

To make ^{99}Tc accessible, chemical sample preparation, ion source output and laser photodetachment all require optimization. We have already developed a chemical sample preparation method using liquid-liquid-extraction and separation with a TEVA column which is able to suppress Ru in sea water and peat-bog samples by a factor 10^{-4}. For an effective isobaric suppression of Ru by laser photodetachment, a negative ion system had to be found, where the electron affinities favor a neutralization of Ru by the laser while Tc is unaffected. In a test series with fluoride and oxide ions, we have found that this is the case for the molecular system TcF_5^- / RuF_5^-. RuF_5^- is suppressed by five orders of magnitude by a 532 nm laser while TcF_5^- is hardly affected. To ensure the formation of penta-fluorides in the ion source, a Nb_2O_5 matrix in which Tc is embedded, is mixed with PbF_2 (about 1:10 by weight) as a fluorine donor. All in all, we are optimistic about reaching a blank level of some 10^6 atoms per sample through the combined effects of Ru-suppression in the sample preparation method, ion source and laser photodetachment.

As there is no stable Tc isotope, a normalization to an isotopic Tc spike material, i.e. ^{97}Tc ($t_{1/2} = 4.2 \cdot 10^6$ a), or a stable reference isotope of another element needs to be established. Unfortunately, due to the high background from ^{97}Mo, a normalization to ^{97}Tc has so far not been possible. Instead, we are normalizing to the ^{93}Nb current, as NbF_5^- is not detached by the 532 nm laser. The chemical recovery is monitored using a ^{95m}Tc spike ($t_{1/2}$ = 61 d, provided by the University of Cologne) and gamma-spectrometry. This way, we have recently shown that varying fractions of Tc are lost during calcination at temperatures around 400°C. By reducing the temperature to 300°C, higher Tc yields could be more reproducibly obtained. In the near future, we plan tests with heating under argon atmosphere for reducing the oxygen content of the AMS target. This is expected to increase and stabilize the production yield for both, NbF_5^- and TcF_5^-, and thereby improve the normalization.

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From the U-233/U-236 fingerprint towards an environmental tracer: Tracking down the sources of anthropogenic U-233

Karin Hain[1], Robin Golser[1], Xiaolin Hou[2], Johannes Lachner[1,3], Mu Lin[2], Maria Meszar[4], Jixin Qiao[2], Aya Sakaguchi[5], Peter Steier[1], Michael Wagreich[4], Gabriele Wallner[6], Andreas Wiederin[1], Janis Wolf[1]

[1]University of Vienna, Faculty of Physics, Vienna, Austria, [2]Technical University of Denmark, DTU Environment, Roskilde, Denmark, [3]Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany, [4]University of Vienna, Department of Geology, Vienna, Austria, [5]University of Tsukuba, Faculty of Pure and Applied Sciences, Tsukuba, Japan, [6]University of Vienna, Department of Inorganic Chemistry, Vienna, Austria

Theme: T-4: New AMS isotopes
Type of presentation: Invited Oral Presentation

Recently, the atomic ^{233}U/^{236}U ratio was proposed as a superior oceanographic tracer as the ^{233}U/^{236}U signature allows to distinguish environmental emissions of civil nuclear industry from weapons fallout [1] and uranium (U) behaves conservatively in sea water. In this previous work, the ratios detected in representative compartments of the environment affected either by releases of nuclear power production or by weapons fallout differ by one order of magnitude and varied between $0.1\cdot10^{-2}$and $3.7\cdot10^{-2}$. Significant amounts of ^{233}U were only released in nuclear weapons fallout, either produced by fast neutron capture on ^{235}U or directly by ^{233}U fueled devices. For tracer applications, a careful characterization of the principal sources of ^{233}U including the contribution from natural production is required.

The ^{233}U/^{236}U ratios were analysed in samples from different locations, partly time-resolved or of well-known age to be able to narrow down the time span of the maximum ^{233}U release. Samples comprised air filters from 1961-1965 collected in Austria, i.e. the period of maximum deposition of global fallout, two time-resolved sediment cores from the Baltic Sea and sediment from the urban layered archaeosphere in the underground of Vienna (Austria). In addition, a depth profile of ^{233}U/^{236}U in a water column located in the Northeast Pacific Ocean was also analysed. This sampling station is assumed to be less affected by tropospheric fallout from a suspected ^{233}U fueled device (Nevada Test Site, 1955). Whenever possible, the ^{233}U/^{236}U data were directly compared to other isotopic signatures and/or mono-isotopic makers, such as ^{240}Pu/^{239}Pu or ^{241}Am, respectively.

The Baltic Sea sediment core confirms a maximum deposition of ^{233}U around 1954/1955 [2]. This finding is supported by the rather low ^{233}U/^{236}U ratios (below $0.5\cdot10^{-2}$) on the air filters from Vienna indicating a comparatively low ^{233}U deposition during global fallout maximum. Values of around 0.1 were measured for the maximum of the ^{233}U/^{236}U ratio in the Baltic Sea sediment. The isotope ratios including ^{233}U/^{236}U found in a layer of the Vienna underground material which was assigned to the 1960s, clearly point to atmospheric atomic bomb fallout. The ^{233}U/^{236}U ratios in the upper part of the Pacific water column showed very stable values of $(1.33\pm0.13)\cdot10^{-2}$ which are in good agreement with the published value for global fallout [1].

The new data confirms the previous result that the maximum releases of ^{233}U happened before the global fallout maximum in 1963. The consistently high ratios found in the Pacific Ocean indicate at least a contribution from thermonuclear explosions to the global inventory of ^{233}U. The unexpectedly high ^{233}U/^{236}U values in the Baltic Sea show the necessity to systematically identify the global and local ^{233}U input sources. Nevertheless, our preliminary data indicate that the ^{233}U/^{236}U ratio serves as a potential marker for the on-set of the Anthropocene, even in the rather demanding urban environment.

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ILIAMS assisted AMS of ^{90}Sr at VERA

Oscar Marchhart[1,2], Dag Hanstorp[3], Maki Honda[1,4], Johannes Lachner[1,5], Martin Martschini[1], Alfred Priller[1], Peter Steier[1], Alexander Wieser[1,2], Robin Golser[1]

[1]*University of Vienna, Faculty of Physics – Isotope Physics, Vienna, Austria,* [2]*University of Vienna, Faculty of Physics & VDSP, Vienna, Austria,* [3]*University of Gothenburg, Department of Physics, Göteborg, Sweden,* [4]*Japan Atomic Energy Agency, Tōkai-mura, Japan,* [5]*Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany*

Theme: T-4: New AMS isotopes
Type of presentation: Poster-Plus Presentation

The long-lived fission product ^{90}Sr is produced in the nuclear fuel cycle or in nuclear weapon tests with a high yield of 4%. It is very mobile in the environment and due to its chemical similarities to calcium is easily incorporated in the body, e.g. in bones or in teeth, following ingestion or inhalation. With a half-life of T1⁄2=28.90 years [1] its uptake and retention in the human body poses potential health risks. ^{90}Sr also has significant potential as an environmental tracer.

The established method to measure ^{90}Sr is decay counting. However, this is time consuming, as the ingrowth of ^{90}Y over a period of two weeks is needed due to ^{90}Sr being a pure and low-energy beta emitter. The main challenge in ^{90}Sr detection with mass spectrometric methods is the interference of isobars, i.e. ^{90}Zr and ^{90}Y. Limits of detection of mass spectrometric methods such as ICP-MS, RIMS and conventional AMS are all above or close to the radiometric detection limit of 3 mBq.

The new Ion Laser InterAction Mass Spectrometry (ILIAMS) technique [2,3] at the Vienna Environmental Research Accelerator (VERA) overcomes the isobaric problem. ILIAMS achieves near complete suppression of isobars via element selective laser photodetachment in a gas-filled radio frequency quadrupole ion guide. The technique exploits differences in the electron affinities (EA) between the isotope of interest and its isobars by neutralizing anions with EAs below the photon energy while leaving anions with EAs above the photon energy unaffected. Additionally, chemical reactions with the buffer gas may enhance separation.

The Sr samples are produced as SrF_2 and mixed with PbF_2, which allows the extraction of an intense SrF_3^- ion beam [4]. Using a 532 nm continuous wave laser at 10 W and a He+O_2 mixture, with an oxygen content of 3%, as buffer gas, ILIAMS achieves a suppression of ZrF_3^- and YF_3^- vs. SrF_3^- of >10^7 at 35% ^{90}Sr transmission through ILIAMS. Extraction of SrF_3^- from the ion source and elemental separation in an ionization chamber leads to an additional ^{90}Zr suppression of 10^5. The overall ^{90}Sr detection efficiency is 0.4‰; a blank level of ^{90}Sr/Sr = $(4.5\pm3.2)\times10^{-15}$ is reached. This corresponds to a more than tenfold improved detection limit of <0.1 mBq, i.e. 10^5 atoms of ^{90}Sr in a 1 mg Sr sample. Measurements of samples from an in-house dilution series with ^{90}Sr/Sr ratios ranging from 10^{-11} to 10^{-14} prove the linearity of this technique. First tests on different environmental samples - from bone to soils - were successful, showing no influence on the detection limit on "real" samples.

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Measurement of plutonium in surface corals by Accelerator Mass Spectrometry

Prof. Huijuan Wang[1], **Prof Yongjing Guan[1]**, Mr. Xiayu Zhan[1,2], Prof Ming He[2], Dr. Qingzhang Zhao[2], Mr. Jingyu Mai[1], Mrs. Chunping Huang[1], Prof Xianggao Wang[1], Prof Zhiyong Liu[3], Mr. Mario De Cesare[4]
[1]Guangxi Key Laboratory for Relativistic Astrophysics, School of Physical Science and Technology, Guangxi University, Nanning, China, [2]China Institute of Atomic Energy, Beijing, China, [3]School for Radiological and Interdisciplinary Sciences (RAD-X), Collaborative Innovation Center of Radiological Medicine of Jiangsu Higher Education Institutions, Jiangsu Provincial Key Laboratory of Radiation Medicine and Protection, Soochow University, Suzhou, China, [4]Department of Diagnostic Methodologies and Measurement Techniques, CIRA, Italian Aerospace Research Centre,, Capua, Italy

Theme: T-4: New AMS isotopes
Type of presentation: Poster

In order to measure the activity concentration and source of Pu around Weizhou land in Beibu Gulf, China, plutonium isotopes in the different surface coral species were determined using accelerator mass spectrometry at CIAE. The activity concentration of 239Pu in the coral is determined to be in the range of 1.56–24.92 mBq/kg. The results indicate that different coral species have different 239+240Pu activity concentrations, this may depend on the different Pu absorption capacity of coral species. The 240Pu/239Pu atom ratios in the samples range from 0.173 to 0.225, indicating that the main source of plutonium in this area is global fallout while the contribution of PPG is about 30%.

Possibilites of the 1 MV AMS system at the Centro Nacional de Aceleradores (CNA, Seville, Spain) to analyze 233U in natural samples

Dr Elena Chamizo[1], Dr. Mercedes López-Lora[2], Dr. Marcus Christl[3]
[1]Centro Nacional de Aceleradores (CNA) (Universidad de Sevilla. Junta de Andalucía. Consejo Superior de Investigaciones Científicas), Seville, Spain, [2]Department of Health, Medicine and Caring Sciences (HMV), Linköping University, Linköping, Sweden, [3]Laboratory of Ion Beam Physics, Institute for Particle Physics and Astrophysics, ETH Zürich, Zürich, Switzerland

Theme: T-4: New AMS isotopes
Type of presentation: Oral Presentation

^{233}U has recently been put in the limelight of interesting AMS radionuclides. The reason is the potential of the ^{233}U/^{236}U atom ratio to unravel anthropogenic U sources. The measurement of ^{233}U by AMS is challenging due to its extremely low abundance in the environment. For example, the reported ^{233}U/^{238}U atom ratios in surface seawater are at the level of 1E-11 (i.e. 10^5 atoms/L), and published ^{233}U/^{238}U values in sediments are above 1E-10. The achievement of such low ratios by AMS is usually hampered by: i) chemical contamination of the samples with ^{233}U, and ii) background effects caused by the presence of either ^{232}Th and/or the naturally occurring U isotopes ^{234}U and ^{235}U. In this work we explore the possibilities that the 1 MV compact AMS system at the Centro Nacional de Aceleradores (CNA, Seville, Spain), offers to analyse ^{233}U in natural samples. In contrast to other AMS facilities used for ^{233}U determinations, the CNA AMS system is limited by its ion-beam design. On the low energy side, neighbouring masses are suppressed solely by a sector magnet. On the high energy side, scattered molecular fragments are filtered out making use of a sector magnet and an electrostatic analyser. He is used as a stripper gas, causing additional scattering process on the acceleration tubes. The achievement of ^{233}U/^{238}U atom ratios at the level of 1E-11 entails a thorough set up of the instrument in connection with a deep knowledge of the ^{232}Th, ^{234}U and ^{235}U background effects, and the use of different proxies to correct them. Another key point is the radiochemistry applied to the samples, which must be aimed at suppressing ^{232}Th from the U fraction specially in the case of soils and sediments. At the CNA, existing radiochemistry methods have been adapted to measure ^{233}U in ^{232}Th-rich matrixes, and the background effects caused by ^{232}Th, ^{234}U and ^{235}U have been evaluated. A series of IAEA reference materials, soils and sediments, have been studied at CNA, and the obtained ^{233}U/^{238}U and ^{236}U/^{238}U ratios were compared to the results of duplicate sample analysis performed at the 600 kV Tandy AMS facility at ETH Zurich that offers significantly lower abundance sensitivity for actinide analyses. As we will demonstrate, the overall technique applied at CNA (radiochemistry plus AMS method) provides a ^{233}U/^{238}U detection limit of roughly 2E-11 in sediment samples, which is mostly conditioned by ^{234}U and ^{235}U scattered molecular fragments.

Sm-146 – Feasibility studies to re-date the chronology of the Early Solar System

Dr Stefan Pavetich[1], Keith Fifield[1], Michaela B Froehlich[1], Dominik Koll[1], Zuzana Slavkovská[1], Attila Stopic[2], Steve G. Tims[1], Anton Wallner[1,3]
[1]The Australian National University, Canberra, Australia, [2]ANSTO, Sydney, Australia, [3]Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany

Theme: T-4: New AMS isotopes
Type of presentation: Poster

AMS measurements of long-lived radionuclides can make significant contributions to the understanding of the temporal evolution of our early solar system. Samarium-146 has a half-life in the order of 100 Myr and decays via emission of α-particles into stable ^{142}Nd. Due to different geochemical behaviour and the radioactive decay of ^{146}Sm, the Sm-Nd isotopic system can serve as a chronometer for the early solar system and planetary formation processes. The half-life of ^{146}Sm, which provides the time scale for this clock, is in dispute. The most recent and notably precise measurements for the half-life are (103±5) Myr (adopted from [1,2]) and (68±7) Myr [3] and differ by more than 5 standard deviations. In addition to potentially resolving this discrepancy, developing AMS for ^{146}Sm might provide the means to study stellar nucleosynthesis on the proton rich side of the chart of nuclei and serve as radiometric tracer for geosciences.

Due to the extremely challenging task of separating ^{146}Sm from its stable isobar ^{146}Nd, to date the only AMS measurement of ^{146}Sm was performed at Argonne National Laboratory with energies in the order of ~880 MeV. At the Heavy Ion Accelerator Facility at ANU, the possibility to measure ^{146}Sm at energies of 200-250 MeV is being explored. Different sample materials, molecular negative ion beams and detector setups are investigated. So far, the lowest Nd backgrounds, from commercially available sample material without additional Nd separation were achieved using SmO_2 - beams extracted from Sm_2O_3 samples.

In order to explore the limits of the Sm detection capabilities, Sm_2O_3 samples were irradiated with thermal neutrons in the reactor at ANSTO to produce the shorter lived ^{145}Sm (t1/2 = (340±3) d [4]) via ^{144}Sm(n,γ)^{145}Sm. The production of ^{145}Sm is easier and faster and the challenges in measuring ^{145}Sm via AMS are very similar to those measuring ^{146}Sm. In addition, ^{145}Sm has the potential to serve as a tracer for future reference materials for AMS measurements of Sm.

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Status report on AMS Measurements of Plutonium Isotopes using the 1MV Tandetron Accelerator at IFIN-HH

Dr Doru Gheorghe Pacesila[1], PhD Iuliana Stanciu[1,2], Dr Mihaela Enachescu[1], Dr Alexandru Razvan Petre[1], Dr Marian Virgolici[1], PhD Andreea Serban[1,3], Dr Florin Albota[1], Mr Ionuz Erhan[1], Dr Viorel Fugaru[1], PhD Decebal Iancu[1,3], Dr Vasile Mosu[1]
[1]Horia Hulubei National Institute For R&d In Physics And Nuclear Engineering (IFIN-HH), Magurele, Romania, [2]Physik Department E68, Technische Universität München, München, Germany, [3]Faculty of Physics, University of Bucharest, Bucharest, Romania

Theme: T-4: New AMS isotopes
Type of presentation: Poster

The Accelerator Mass Spectrometry is the most sensitive measurement method that allows us to determine 239, 240, 244Pu radioisotopes from environmental samples with extremely low isotopic concentrations. By measuring Plutonium isotopes, we focus our research activity on two main directions, monitorization of environmental nuclear pollution and nuclear astrophysics.
This report gives an overview regarding the progress that was made in the determination of Plutonium isotopes at IFIN-HH, and it starts with the studies performed for the transport and measurement of actinides using the 1MV Tandetron Accelerator. The 238U and 232Th isotopes were used as pilot beams for the determination of ion transport parameters, after which the isotopic ratios of 239Pu/242Pu, 240Pu/242Pu and 244Pu/242Pu were measured by using the new Plutonium Standard ColPuS. The results obtained for the isotopic ratios agrees with the consensus values of the standard reported in [B.A. Dittmann, et al., ColPuS, A new multi-isotope plutonium standard for Accelerator Mass Spectrometry, Nucl. Instr. Meth. B 438 (2019) 189–192]. In addition, the radiochemical separation recoveries of Uranium and Thorium using UTEVA and TEVA resins are presented, for this purpose being used an Agilent ICP-MS system (Inductively Coupled Plasma Mass Spectrometry).
Finally, it is provided a short overview of the molecular interferences challenges that are encountered when measuring Plutonium isotopes.

µGraphiline, fully automated graphitization line

Prof. Andrzej Rakowski[1], Dr. Konrad Tudyka[1,2], Dr. Jacek Pawlyta[1], M.Sc. Aleksander Kolarczyk[2], M.Sc. Sebastian Miłosz[2], Kacper Kłosok[1]
[1]Silesian University Of Technology, , Poland, [2]miDose Solution, Zabrze, Poland

Theme: T-5: Advances in sample preparation
Type of presentation: Poster

Currently, the most commonly used measurement technique, due to the possibility of making measurements in samples with masses of about 1 mg of carbon, is the AMS technique. The preparation of samples for measurement consists of their purification, combustion to obtain CO2 and subsequent reduction to atomic carbon in the presence of Fe.

The design of a line for graphitisation of carbon dioxide samples for radiocarbon dating, along with the results of acceptance tests, have been presented in scientific articles (Krąpiec et al. 2018, Wiktorowski et al. 2020). Currently, within the Innovation Incubator 4.0 project, a prototype of an automatic line for graphitisation of samples, is being developed, which will allow to significantly reduce the time needed to prepare samples for measurement. The result of this project is expected to be a commercial device for automatic graphitisation of samples.

^{10}Be from commercial ^{9}Be and ^{27}Al carrier solution – Some measurements

Silke Merchel[1,2], Régis Braucher[3], Johannes Lachner[1,2], Georg Rugel[2]
[1]University of Vienna, Faculty of Physics, Isotope Physics, Vienna, Austria, [2]Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany, [3]CEREGE, Aix Marseille Univ., CNRS, Collège de France, IRD, INRAE, Aix en Provence, France

Theme: T-5: Advances in sample preparation
Type of presentation: Poster-Plus Presentation

In the DREsden Acclerator Mass Spectrometry (DREAMS) chemistry laboratory, we see elevated but constant ^{10}Be/^{9}Be levels (1.2-2.0x10^{-15}) when using a customised ^{9}Be carrier [1]. In satellite and DREAMS laboratories unexperienced researchers and students are performing their own chemical separation, but the “human influence” is unlikely the sole explanation. Different levels of processing blanks as a function of the preparation laboratory are well-known also at other AMS facilities [2]. In our constant approach lowering processing blank levels for ^{10}Be/^{9}Be we have investigated two potential ^{10}Be sources: ^{9}Be and ^{27}Al carrier solutions.

Beryllium-9 carrier solutions are obvious ^{10}Be sources and commercial and customised ones from minerals were already investigated earlier [3]. Inspired by numerous users asking for ^{9}Be carrier analysis, we have compiled all (new) results from different AMS facilities. Remarkably, ^{10}Be/^{9}Be varies in the range of 1-10x10^{-15} from batch to batch (LOT) of the same company, very likely related to production date [4]. Currently, Australian Chemical Reagents and LGC provide carriers with the lowest intrinsic ^{10}Be/^{9}Be. For AMS users not affording a customised ^{9}Be carrier, we advise buying larger quantities of commercial carriers to guarantee long-time low ^{10}Be/^{9}Be and saving precious AMS time from analysing new batches.

Another potential source for elevated and varying ^{10}Be/^{9}Be in processing blanks are Al carrier solutions (added to processing blanks) when performing ^{10}Be/^{26}Al projects. According to [5] commercial aluminium contained ^{10}Be in the range of 4-10x10^{7} ^{10}Be atoms/g(Al). Nowadays, laboratories use 0.5-3.0 mg Al for processing blanks, which would yield into 4-10x10^{5} ^{10}Be atoms/blank increasing the ^{10}Be/^{9}Be ratio to 6-10x10^{-15}.

We asked in-situ dating researchers to provide their Al solutions. To differentiate between ^{10}Be from Al and other sources (contamination in the chemistry laboratory or the ion source) we used a “basic standard-addition approach”: For each Al solution, two AMS targets containing ~300 µg ^{9}Be and either 1 mg ^{27}Al or 3 mg ^{27}Al were prepared. After minimal chemistry (hydroxide precipitation, cation exchange, $Be(OH)_2$ precipitation, washing, drying, ignition, mixing with Nb) samples were measured at DREAMS.

Todays’ Al solutions are lower in ^{10}Be compared to the Al investigated by [5]. None of our results is higher than 3.55x10^{-15}, however, the two processing blanks without any Al have ^{10}Be/^{9}Be ratios of 1.2-1.7x10^{-15}, which is in the same range as 12 out of 14 samples from ACROS, MERCK, ROTH and Traceselect, but 2-3 times higher than the machine blank. This means ~5x10^{4} ^{10}Be atoms/sample are added from chemicals-consumables-materials or laboratory air-dust.
For more quantitative results about the ^{10}Be concentration of Al carriers and to identify the main sources of the ^{10}Be contribution for the processing blanks, additional experiments with larger amounts of Al (10-50 mg) and chemicals are needed.

Acknowledgments: Thanks to ASTER, DREAMS, Trondheim, VERA colleagues for ^{10}Be data, and ANU, AWI, BOKU, CENIEH, CSFK, U Bratislava, U Jerusalem, U Potsdam colleagues for carrier solutions.

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129I in sediment cores from the Celtic Sea by AMS through a microwave digestion process

Ms Victoria Lérida-Toro[1], Mr Unai Abascal-Ruiz[1], Dr María Villa-Alfageme[1,4], Dr Santiago Hurtado[4], Dr Jessica Klar[5], Dr Natalie Hicks[6], Dr José María López-Gutiérrez[1,2]

[1]Centro Nacional de Aceleradores (Universidad de Sevilla, CSIC, Junta de Andalucía), Spain, [2]Dpto. Física Aplicada I, ETSIA, Universidad de Sevilla ,Spain, [3]Dpto. Física Aplicada I, Escuela Politécnica Superior, Universidad de Sevilla ,Spain, [4]Dpto. Física Aplicada II, ETSI Edificación, Universidad de Sevilla , Spain, [5]Université de Perpignan UPVD - CEFREM, France, [6]School of Biological Sciences, University of Essex, UK

Theme: T-5: Advances in sample preparation
Type of presentation: Poster

The impact of the radioactive contamination in aquatic systems is often recorded in sediments. These, depending on their biogeochemical behaviour, they can give detailed information on the history of the discharges from the sources and the environmental processes related to the transportation of the radionuclides to the sediment. For long-lived radioisotopes as Iodine-129, only high sensitivity techniques as Accelerator Mass Spectrometry are able tocan measure its concentration at environmental levels.

To determine Iodine-129 in environmental samples, radiochemical methods are needed. In sediments, iodine can be associated to inorganic or organic matter and it presents several chemical forms. Therefore, a procedure designed to extract these different species from the matrix is necessary, together with a clean and little time-consuming radiochemical method.

In this work, two sediment cores from the Celtic Sea (core A and core I) have been analysed to determine the Iodine-129 concentration. While core I was a sandy sediment, core A was muddy and it had a high proportion of organic matter. For this reason, a conventional microwave digestion method was adapted for an optimum iodine extraction from the organic fraction. The performance of the different options considered for the iodine extraction will be shown in this work. Results show concentrations between 0.19 x 10^12 at/kg and 7.16 x 10^10 at/kg for core A and between 0.28 x 10^12 at/kg and 2.40 10^12 at/kg for core I. Despite an apparent diffusion in the deep layers, depth profiles accurately reproduced Sellafield discharges. The Iodine-129 concentrations will be compared to the Cesium-137 concentrations to calculate isotopic ratios in the cores and subsequently in the Sellafield nuclear fuel reprocessing discharges.

A new method to graphitize CO2 from atmospheric air for radiocarbon analysis

Mr Philip Gautschi[1], Dr Lukas Wacker[1], Prof Hans-Arno Synal[1]
[1]*Lip, Eth Zurich, , Switzerland*

Theme: T-5: Advances in sample preparation
Type of presentation: Poster-Plus Presentation

The concentrations of carbon dioxide (CO2), that is an important greenhouse gas, are increasing radpidly in the athmosphere since the industrialization. The anthropogenic emissions of 14C free CO2 from fossil fuels, such as coal, oil or gas, reduces the 14C to 12C ratio in the atmosphere [2]. When the background 14CO2 level is well known, even the local surplus of anthropogenic CO2 can directly be calculated from locally measured CO2 concentration and 14CO2 abundance [3].

A new simple and fast method to prepare samples for radiocarbon measurements of atmospheric CO2 has been developed and tested. Atmospheric air is collected in air sampling bags (5 L per sample) at site. The bags are transported to the laboratory, where CO2 is isolated from the remaining air with a modified molecular sieve trap (220 mg Zeolite 13X) which is implemented in the automated graphitization line (AGE3) [4]. Using the AGE3, the CO2 is then graphitized in a fully automated way and subsequently measured by accelerator mass spectrometry (AMS). Compared with other techniques [5] this new method avoids the use of caustic sodium hydroxide (NaOH) for sampling in the field. Neither does it require liquid nitrogen for CO2 separation.

The presented method was intensively tested and characterized. Cross contamination between consecutive samples has been calculated to be as low as 1.1±0.3‰ and a blank level of 0.0016±0.004 F14C were found. A programmable air loading box to collect and graphitize up to seven air samples at a time without the need of manually changing bags ensure reliable and repeatable results. A four-month set of radiocarbon measurements on local atmospheric CO2 proves the applicability of the new method.

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A new UV-Oxidation set up for AMS radiocarbon analysis of small dissolved organic carbon in marine and freshwater samples

Dr Negar Haghipour[1,2], Dr Maarten Lupker[2], Dr Lukas Wacker[1], Prof. Timothy Eglinton[2]
[1]Laboratory of Ion Beam Physics, ETHZ, Zurich, Switzerland, [2]Geological Institute, ETHZ, Zurich, Switzerland

Theme: T-5: Advances in sample preparation
Type of presentation: Poster

Radiocarbon measurements of dissolved organic carbon (DOC) is a powerful tool in global carbon cycle studies in the ocean and river systems. The main challenge of UV-Oxidation (UVox) methods is to obtain sufficient DOC with low blanks required for high precision 14C measurement specially in sea water samples. Another disadvantages of currently used UVox methods in the most of laboratories is that only one sample can be oxidized at the same time.

Here we present a UV-Oxidation system with 12 quartz reactors where multiple water samples can be oxidized simultaneously in a compact setup which significantly reduces the processing time. In comparison to the other laboratories no vacuum line is connected to this new UVox setup. To test the oxidation efficiency, reproducibility and blank assessment we used different reference materials and sample type. Here we discuss the preliminary results from the performance of UVox extraction line and compare the data with oxidation methods currently being used in other laboratories.

A sample preparation system for Tritium and Radiocarbon at the GXNU Laboratory

Prof. Hongtao Shen[1,2], Junsen Tang[1], Shulin Shi[1], Li Wang, Guofeng Zhang[1]
[1]Guangxi Normal University, , China, [2]Guangxi key laboratory of nuclear physics and technology, Guilin, China

Theme: T-5: Advances in sample preparation
Type of presentation: Poster

A very simple system for preparing Tritium and Radiocarbon sample was established for the small accelerator mass spectrometer (GXNU-AMS) at Guangxi Normal University. This sample preparation system consists of three units: crusher unit, purification unit, and collection unit, all of the main structure is made of quartz glass. A series of 3H and 14C preparation experiments were carried out to verify the reliability of the system. The recovery rates of tritium and graphite obtained were more than 80%. The carbon and H2O content in samples were linearly fitted to the gas pressure in the measurement unit of the system. The results showed an obvious linear relationship, indicating that the reliability of the sample preparation system can meet the requirements of 3H and 14C-AMS. A batch of standard samples, Reactor graphite samples, and dead graphite samples made by this system was performed with AMS measurement. The results showed that the beam current of 1H- and 12C- for each sample was greater than 15uA and 40uA, respectively, which could meet the requirement of AMS measurement. The measurement results of blank samples indicate the stability of the sample preparation system, and the tritium and carbon pollution introduced during the sample preparation processes were less than 5×10-16 and 2 × 10-15 respectively. The results show that the simple sample preparation system established is a compact, low-pollution, and efficient system, which meets the requirements for 3H and 14C measurements.

A self-made glass ampule cracker, coupled to an EA-IRMS-AGE3 system

Dr Lior Regev[1], Eugenia Mintz[1], Lilia Goffer[1], Prof. Elisabetta Boaretto[1]
[1]*Weizmann Institute of Science, Rehovot, Israel*

Theme: T-5: Advances in sample preparation
Type of presentation: Poster-Plus Presentation

A glass ampule cracker is a common device in radiocarbon laboratories in order to extract gaseous samples. However, the growing popularity of the EA-AGE3 system (an elemental analyzer, coupled to the 3rd generation of automatic graphitization equipment, made by IonPlus company) makes the use of a tube cracker a rare occasion. Yet, when dealing with special sample pretreatments, such as step-combustion procedures, there are hardly any alternatives to using a tube cracker. Our laboratory uses an EA-IRMS-AGE3 system (also coupled to an isotope ratio mass spectrometer) for the past three years. As we would like to measure $\delta^{13}C$ values of our gaseous samples, we designed a tube cracker that will connect to the elemental analyzer and enable us to transfer the gaseous CO_2 from the tube through the IRMS and into the AGE3 for graphitization. By connecting the cracker device to the EA through the quartz bridge between the combustion and reduction columns of the EA, we exploit the EA helium flow, water drying tube, and CO_2 adsorption column, as well as the system's synchronized workflow with the IRMS and AGE3 instruments. The device is almost exclusively built of catalog parts of Swagelok, with mainly one custom-made component (the connector to the EA). We present the working procedure, some efficiency and background level results, and what is needed to build your own device.

A UV-SPECTROPHOTOMETRIC APPROACH TO QUANTIFYING IODINE IN ENVIRONMENTAL SAMPLES FOR AMS STUDIES

Professor G. S. Burr[1], Professor Hiroyuki Matsuzaki[2], Professor A. J. T. Jull[3,4], Professor Sofia Ya Hsuan Liou[1]

[1]National Taiwan University, Department of Geosciences, Taipei, Taiwan, [2]University of Tokyo, The University Museum, MALT AMS Laboratory, Bunkyo-ku, Tokyo, Japan, [3]University of Arizona, Geosciences Department, Tucson, USA, [4]Isotope Climatology and Environmental Research Centre, Institute for Nuclear Research, Debrecen, Hungary

Theme: T-5: Advances in sample preparation
Type of presentation: Poster

We report on a UV-spectrophotometric approach to measure total iodine extracted from a variety of environmental sample types. For seawater samples, the iodine extraction method we use follows several basic steps: 1) dissolved iodate is reduced to iodide; 2) iodide is oxidized to dissolved iodine; and 3) dissolved iodine is extracted in a separatory funnel using an organic solvent (Burr et al. 2020). Organic solvents like carbon tetrachloride and chloroform are often used for iodine extraction because they readily dissolve iodine and are immiscible with water. However they are also known carcinogens, so we have begun to use hexanol ($C_6H_{14}O$) as a relatively benign alternative. Hexanol is also an organic solvent (an alcohol) that readily dissolves iodine and is immiscible with water. The end product of our extraction procedure is nearly pure iodine dissolved in hexanol. At relatively large concentrations in the solvent (> a couple hundred µg/L) dissolved iodine imparts color to the solution: purple in the case of carbon tetrachloride or chloroform, and brown in the case of hexanol. Iodine also produces distinct peaks in the UV spectra of these solvents, a fact that has been studied for more than a century. This feature has been exploited to quantify tiny amounts (1 µg/g) of iodine dissolved in ethanol (Kljubin et al. 2016). UV-spectrophotometry is non-destructive and the sample can be recovered after analysis. A final step in AMS target preparation is to add silver or silver nitrate to the solution, to precipitate iodine as silver iodide. We provide examples that show how iodine spectra can be used to quantify the amount of total iodine in a variety of sample types, monitor the progress of successive extractions with the solvent, and ensure complete conversion of iodine to silver iodide with the addition of silver.

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Advances in actinides radiochemistry at the Centro Nacional de Aceleradores

Dr Mercedes López Lora[1], Elena Chamizo[2], Grzegorz Olszewski[3], Isabelle Levy[4], Victoria Lérida[2], Mats Eriksson[1]
[1]Linköping University, Linköping, Sweden, [2]Centro Nacional de Acleradores, Sevilla, Spain, [3]University of Gdansk, , Poland, [4]International Atomic Energy Agency, , Monaco

Theme: T-5: Advances in sample preparation
Type of presentation: Oral Presentation

The Centro Nacional de Aceleradores (CNA, Sevilla, Spain) has hosted since 2005 a 1MV multi-elemental AMS system allowing the analysis of an assorted group of traditionally targeted AMS radionuclides, being among them the actinides. The measurement techniques for Pu isotopes (i.e. 239Pu, 240Pu, 241Pu), 236U and 237Np have been implemented, consolidating this facility for actinide measurements, and, very recently, the possibilities of this system for 233U analysis have been explored [1]. A key part has been the development of radiochemical procedures meeting the requirements of the CNA 1 MV AMS system which features a compact design. Important efforts have been devoted in order to develop simple and reliable methods allowing the sequential extraction of Np, U and Pu fractions from marine samples in order to analyze 239Pu, 240Pu, 241Pu, 236U and 237Np by AMS at our facility. 237Np has been specially challenging because of the limitations imposed by the lack of a long-lived isotopic tracer to control both radiochemical procedure and AMS analysis. A new simplified method for the sequential extraction of U, Pu and Np from small-volume seawater samples (<10L) was successfully set up at the CNA [2]. This procedure is based on the use of 242Pu as tracer for both Pu and Np, and the U and Np+Pu final purified fractions are extracted using TEVA® and UTEVA® resins. To expand the target matrixes to sediments and seaweed and include 233U among the measurable U isotopes, the former procedure has been adapted and tested during the last few years. The necessity of enhancing the removal of Th from the U fraction to analyze 233U forced the introduction of an additional TEVA® resin in the procedure. The pretreatment step was modified to quantitively recovering U, Pu and Np when solid samples are prepared. These modifications will be discussed and the results for reference materials provided by the International Atomic Energy Agency will be presented and evaluated.

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AMS 14C dating of bioapatite: advantage and disadvantage

Dr Alexander Cherkinsky[1], Dr. Gurazada V. Ravi Prasad[1], Mrs Hong Sheng[1]
[1] *University of Georgia, Athens, United States*

Theme: T-5: Advances in sample preparation
Type of presentation: Poster-Plus Presentation

Since the early days of radiocarbon dating, the analysis of bone material has been a problem due to frequent discord between the dates of the bone material and associated charcoal, and/or between different fractions isolated from a single bone. Recent publications show that such problems still exist and suggest that they are caused by both the poor preservation of collagen and the difficulties in removing contaminants from the bone extracts used for dating.
Most methods of bone preparation for 14C dating used today are designed to extract and purify (with varying degrees of success) a fraction of the organic residue. In general, the goal of these methods is to isolate collagen or some individual compounds such as protein or amino acids of collagen. However, for poorly preserved bones, the problem becomes acute, as they often do not even have collagen for AMS dating. The mineral fraction does not usually undergo microbiological decomposition, hydrolysis, denaturation, and dissolution over millennium scales, so that only exceptional conditions do. Quantities sufficient for analysis survive into the Pleistocene, the exception is permafrost condition where collage could be well preserved for the tens and even hundred thousand years. However, it may be exposed to isotopic exchange with environmental carbonates. The problem thus becomes one of separating the diagenetic carbonates without destroying the bioapatite.

We have used the technique of treating with the weak acid with periodical evacuation and re-pressurization of bone sample to remove the secondary carbonates. Then pretreated samples were treated with 100% phosphoric acid to recover of CO2 from bioapatite. carbon dioxide was graphitized using iron catalyst and radiocarbon concentration was measure using 0.5MV NEC tandem pelletron AMS system. We also compare the mineral and organic fractions for bones and teeth of different ages and differing degrees of preservation.

The obtained results have shown that preservation of the original mineral carbon depends on the conditions of the environment in which bone and tooth samples were buried. The samples, which have been buried in wet environments with ground water saturated by carbonates, usually have been enriched with 14C from isotopic exchange with environmental carbonates. Depletion of 14C of bone bioapatite deposited in the caves and in the limestone is also possible. However the results for the samples from arid, semi-arid and non-carbonate environments are in a good agreement with the dates on other materials.

We demonstrate that that proper pretreatment of bone and tooth samples permits the separation of diagenetic carbonates from bioapatite, as long as the carbon in these samples has not degraded completely. Both bone or tooth tissue can be used for paleodietary studies and radiocarbon dating with taking in account of the environmental condition of the burials.

An AMS-world without any chemistry? – Untypical measurements of ^{26}Al, ^{41}Ca and ^{55}Fe

Silke Merchel[1,2], Robin Golser[1], Johannes Lachner[2], Oscar Marchhart[1], Martin Martschini[1], Georg Rugel, Anton Wallner[2], Diana Walther[3], Alexander Wieser[2]
[1]University of Vienna, Faculty of Physics, Isotope Physics, Vienna, Austria, [2]Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany, [3]VKTA – Strahlenschutz, Analytik & Entsorgung Rossendorf e. V., Dresden, Germany

Theme: T-5: Advances in sample preparation
Type of presentation: Poster-Plus Presentation

AMS measurements typically are lasting minutes to hours, but are usually preceded by time-consuming (typically days to weeks of) chemical preparation. Both, physicists and chemists are dreaming of an AMS-world without any chemistry.

Some of our earlier studies have already proven AMS being reasonable, fast and easily accessible for ^{7}Be [1] and ^{41}Ca [2] analysis if largely reducing radiochemical separation. However, to our knowledge there are only a few cases completely omitting wet chemical separation, e.g., ^{10}Be/^{9}Be in a Be mineral (phenakite) [3] and ^{14}C/^{12}C by laser-ablation AMS of stalagmites and corals [4]. Here, we focus on two new examples for "Instrumental" AMS (IAMS) at the DREsden AMS (DREAMS) facility and the Vienna Environmental Research Accelerator (VERA):

First, a pilot study to quantify ^{55}Fe ($t_{1/2}$ =2.76 a) in steel from a reactor vessel of a nuclear power plant by IAMS was validated (after radiochemical separation) by liquid scintillation counting (LSC) and AMS [5]. DREAMS reaches an uncertainty <10% at the 1 kBq $g(Fe)^{-1}$ level within 10 min measuring unprocessed steel chips. The background (<3 Bq $g(Fe)^{-1}$) is limited by the short measurement time. IAMS for analysing ^{55}Fe from neutron-capture production is reasonable and fast compared to other analytical methods.

Secondly, the ILIAMS set-up at VERA (Martschini et al., this meeting) allows to determine ratios of ^{26}Al ($t_{1/2}$ =0.7 Ma) to ^{27}Al and ^{41}Ca ($t_{1/2}$ =0.104 Ma) to ^{40}Ca in stony meteorites by IAMS. The nearly complete suppression of isobars, i.e., $^{26}MgO^{-}$, when extracting AlO^{-}, and $^{41}KF_3^{-}$ when extracting CaF_3^{-}, make pressure digestion (HF/HNO_3), ion exchange and precipitations unnecessary. Most stony meteorites contain ~1% Al, mainly in the form of Na-rich-Ca-poor plagioclase ($(Na,Ca)(Si,Al)_4O_8$)). Additional sources for >1% Ca are pyroxene ($CaMgSi_2O_6$) and phosphates (mainly apatite: $Ca_5(PO_4)_3Cl$)) [6]. IAMS has been performed using 1-2 mg representative powder of the previously-investigated chondrite Dhurmsala [7], either pure, mixed with Fe or PbF_2 powder.

For IAMS of ^{26}Al, AlO^{-} currents from Dhurmsala were - independent of mixing with Fe or pure - about 2% of Al_2O_3 (Fe) ones. At ^{26}Al/^{27}Al of ~$1.3x10^{-10}$ statistical uncertainties of 3% are reached within 15 min sputtering while cathodes last several hours. IAMS data at VERA - in the presence of about 15% Mg - are comparable to earlier (chemical processing) AMS results at DREAMS and ETH Zurich.

For IAMS of ^{41}Ca, very stable CaF_3^{-} currents from Dhurmsala are ~5% of chemically-processed CaF_2 ones (each mixed with PbF_2). At ~$1x10^{-11}$ ^{41}Ca/Ca, count rates of 1 min^{-1} sputtering time are reached. IAMS data measured in the presence of about 1‰ K at VERA are comparable to earlier (chemical processing) AMS results at ANU, DREAMS and ETH Zurich.

The major uncertainty for both nuclides, originating from the current differences of standards and samples, will be addressed soon.

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ANSTO Radiocarbon Laboratory: developments to meet the needs of our community

Ms Fiona Bertuch, Mr Alan Williams, Dr Bin Yang, Mr Tan Nguyen, Mr Simon Varley, Dr Geraldine Jacobsen, Dr Quan Hua
[1] *ANSTO, Lucas Heights, Australia*

Theme: T-5: Advances in sample preparation
Type of presentation: Poster

The radiocarbon chemistry laboratories in the Centre for Accelerator Science at the Australian Nuclear Science and Technology Organisation (ANSTO) have a role providing support to AMS measurements for government organisations, industry, and academia in Australia and overseas. Over recent years the radiocarbon laboratories at ANSTO have expanded to support projects that address unique challenges which include environmental issues, the sustainable management of water resources, climate variability, ecological studies, and research into Indigenous heritage. The increase of work in these areas has seen a growing demand for processing samples of groundwater, rock art, ice cores, tree rings and Antarctic mosses.

Here we will present an update of our procedures for processing a diverse range of sample types. We will also describe developments such as an automated dissolved organic carbon (DIC) extraction system for water samples, and our automated AAA pretreatment system.

We will also outline our range of graphitisation systems which include a set of 24 Fe/H2 graphitisation units, 6 microconventional furnace (MCF) Fe/H2 graphitisation lines, a laser heated furnace (LHF) graphitisation system, and an Ionplus AGE-3 graphitisation system (owned by UNSW). Our MCF and conventional graphitisation lines have been designed to handle and reliably produce graphite targets containing as little as 5 µg and 10ugC of carbon (respectively), making the graphitisation of minute carbon samples from rock art and ice cores possible.

Application of an automated AGE-CHS unit for water DIC-14 analyses at HEKAL Laboratory

Dr Mihály Molnár[1], Róbert Janovics[1], Virág Gergely[1], Dávid Sóvágó[1], Balázs Áron Baráth[1], Gergely Orsovszki[2], Mihály Veres[2], Anita Molnár[2]
[1]INTERACT Centre, Institute for Nuclear Research, Debrecen, Hungary, [2]Isotoptech Zrt, Debrecen, Hungary

Theme: T-5: Advances in sample preparation
Type of presentation: Oral Presentation

keywords: water, DIC, radiocarbon, automated, graphitization

The aim of this study was to demonstrate overall performance of an Automated Graphitization Equipment (AGE-III, IonPlus) and its Carbon Hydrolyses unit (CHS) for dissolved inorganic carbon (DIC) C-14 AMS analyses at HEKAL AMS Facility (Debrecen, Hungary). The AGE-CHS system was not specified for water DIC preparation that's why we applied a small modification on the sample tray block of the CHS unit. The modified sample tray block was able to handle 40 ml septa sealed glass vials, the proper size for 20 ml water samples (Septa-Co.).

After the small mechanical modification of the tray block, the AGE-CHS system became capable to handle water samples for DIC-14 preparation, using its original sampling and sample preparation system and software, provided by the IonPlus AG manufacturer. In AGE-CHS unit, the sample processing steps are tuneable in the driving software, according the desired applications. Comparing the regular carbonate preparation protocol of AGE-CHS unit, we have applied a bit longer He flushing time (5 mins) before acid addition and a bit longer sample transport/focusing time (5 mins) when the liberated CO2 is transferred from the reaction vial to the zeolite trap of the AGE system.

In this study we have tested the ultimate performance of the AGE-CHS for water DIC-14 analyses, including: C yield, different sample sizes, memory effect, cross contamination, process blank level and repeatability using multiple, parallel real water DIC samples and IAEA-C1 and -C2 standard reference material. The performance of the AGE-CHS unit was rather same (or even better) than the off-line, manual sample processing we routinely apply for water DIC-14 analyses at HEKAL.

The research was supported by the European Union and the State of Hungary, co-financed by the European Regional Development Fund in the project of GINOP-2.3.4-15-2020-00007 “INTERACT”. Prepared with the professional support of the Doctoral Student Scholarship program of the co-operative doctoral program of the Ministry of Innovation and Technology financed from the National Research, Development and Innovation found. This work was carried out in the frame of a János Bolyai Research Scholarship (to Mihály Molnár) of the Hungarian Academy of Sciences.

Assessing metal matrices to improve AMS precision for cosmogenic 10Be applications

Dr Ana Carracedo[1], Dr Derek Fabel[1], Dr Richard Shanks[1]
[1] *Scottish Universities Environmental Research Centre, Glasgow, United Kingdom*

Theme: T-5: Advances in sample preparation
Type of presentation: Oral Presentation

The precision of cosmogenic 10Be measurements by AMS (~2% sample-to-sample reproducibility) presents a limitation when applied to Quaternary geoscience problems. To facilitate efficient sample sputtering in the ion source, BeO is dispersed in a matrix of a conductive metal. The homogeneity of this mixture and the sample matrix properties influences beam current stability and can cause measurement scatter. Optimising ion beam current stability may improve measurement accuracy. Here we investigate the effects of different metals (Nb, Fe, Mo) on current stability and measurement reproducibility. The metals were added in solid and solution form to different stages of the Be precipitation process. Mixtures of both BeO and Be(OH)2 were pressed and analyzed using the 5MV Pelletron at SUERC. In a preliminary assessment we can report that the targets containing Be(OH)2 generated high currents and that Fe matrices couple well with the ion source generating particularly stable AMS currents.

Atmospheric deposition of 10Be in Altzomoni rain.

Dr Carmen Grisel Méndez García[2], Dr Santiago Padilla[1], Dr Corina Solís[1], Dr Rocko García[3]

[1]National Autonomous University Of Mexico, , Mexico, [2]Cátedras Conacyt, Benito Juárez, Mexico, [3]Centro de Ciencias de la Atmósfera, , México

Theme: T-5: Advances in sample preparation
Type of presentation: Poster

Altzomoni (Mexico) is located in the Izta-Popo Zoquiapan National Park, between the Iztaccihuatl (5286 m a.s.l) and Popocatepetl (5462 m a.s.l) volcanoes. Altzomoni is approximately 60 km away from Mexico City.
In this work, the radiochemical procedure for the measure of 10Be in small rainfall samples was established. 10Be concentrations were determined in rainfall collections during the rainy seasons of 2017and 2018. The 10Be concentrations of annual rainfall collections for the period of sampling range from 1.91 x 107 to 5.44 x 107 atoms L-1, and the corresponding fallout values were between 1.9 x 105 and 9.8 x 105 atoms cm-2 y-1 which are significantly lower than those reported in the Southern Alps mountain (9-19 x 106 atoms cm-2 y-1).

Cleaning efficiency of cellulose pre-treatment of modern trees

Dr Helene Svarva[1], Professor Pieter Meiert Grootes[1], Dr. Martin Seiler[1], Dr. Marie-Josée Nadeau[1]
[1]*National Laboratory For Age Determination - Ntnu, Trondheim, Norway*

Theme: T-5: Advances in sample preparation
Type of presentation: Poster

The AMS radiocarbon measurement of single ring and sub-annual tree-ring samples demands that the cellulose preparation method be time-efficient, effective in removing contamination, and have high enough yields for wood in different states of preservation. The pre-treatment of wood into hemicellulose allows fast processing with generally good results. However, when a very high accuracy is needed, for instance when measuring sub-annual samples over the bomb spike, the more elaborate extraction of alpha-cellulose, which is the most stable of the polymers that comprises wood cellulose, might be required. We explored the addition of a 17.5% sodium hydroxide step to the base-acid-base-acid-bleach (BABAB; Němec et al. 2010) cellulose preparation. This should dissolve and allow the extraction of the low-weight polymer fractions in the hemicellulose. This extra step was tested on whole ring samples and on samples of early-wood and late-wood in a Scots pine tree (Pinus sylvestris L.). It increases efficiency in removing bomb-contaminated fractions from modern pre-bomb tree rings compared to the standard BABAB extraction of hemicelluloses. It is therefore suitable for the pretreatment of modern samples where a high accuracy is required with moderate effort. For subfossil wood, the extraction yields using this preparation method depend heavily on the state of cellulose preservation in the sample. We here compare the results and yields of different variations of this method, including the use of solvents.

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Combustion and reduction method of methane gas sample for radiocarbon measurement using an automatic reduction system

Dr Kilho Sung[1], Prof Wan Hong[1], Mr Ki Seok Sung[2]
[1]Korea Institute of Geoscience and Mineral Resources (KIGAM), , South Korea, [2]Carbon Analysis Lab. (CAL), , South Korea

Theme: T-5: Advances in sample preparation
Type of presentation: Poster

Methane has been a major sample for AMS radiocarbon measurement since the gas is known one of causes of the global warming [1-4]. Not only atmospheric methane, but also biproduct methane of bioindustries. For the atmospheric methane measurement, large size of air should be treated to obtain proper amount of carbon for AMS measurement with reasonable statistic precision. In many cases, atmospheric methane samples are measured using gas ion source with CO_2 form after combustion process because of the limitation of carbon size. However, since the industrial methane samples are mostly high purity methane, sufficient carbon can be obtained from small size of sample. And graphite is preferred rather than gas sample.

A simple and fast procedure to convert methane to graphite was developed using an automatic reduction system in KIGAM AMS Lab [5]. Biproduct methane gas was collected from a production process of a food industry, in which starch is produced from corn. The methane sample was purified cryogenically, and mixture gas of 1 mg of the methane and oxygen was reacted at 600°C in a quartz reaction tube with the volume of 8.72 ml of the reduction system. The combustion process was completed within roughly three hours. CO_2 gas was purified cryogenically, and reduced to graphite with H_2 gas and Fe catalyst in the same tube. Finally, 0.69 mg of graphite was obtained with reduction yield of 91 %. The graphite was measured with 1 MV AMS at KIGAM. The raw material, corn, and methane were measured to be 101.07 ± 0.44 pMC and 99.24 ± 0.44 pMC, respectively. For the methane measurement with high content from industrial process, graphite could be obtained with the simple treatment process. The precision of the measurement was better than gas measurement.

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Current Sample Pretreatment Protocols for AMS Radiocarbon Dating by DirectAMS (D-AMS)

Mrs Brittany Hundman[1], Tye Lacey[1], Alyssa M Tate[1], Jonathan Adler[1], Jonathan Heile[1], Dr. Ugo Zoppi[1], Dr. James C. Chatters[2]
[1]Directams, Bothell, United States, [2]Applied Paleosciences, Bothell, United States

Theme: T-5: Advances in sample preparation
Type of presentation: Poster-Plus Presentation

Both physical and chemical pretreatment are implemented at DirectAMS to remove exogenous carbon and/or isolate the carbon fraction of interest for radiocarbon dating by AMS. Since the primary offer of a fundamental Acid-Base-Acid pretreatment for organics, DirectAMS has incrementally implemented pretreatment protocols for materials routinely recovered from a variety of contexts. The methods described are the current pretreatment protocols for plant matter, charcoal, wood, alpha-cellulose extraction, shells and other carbonates, fractions of sediment, fraction of bone, keratinous materials, and textiles and other human-worked objects.

Effect of conservation on radiocarbon ages of wood

Dr Irka Hajdas[1], Ms Monika Isler[2], PD Dr. Urs Leuzinger[3], Ms Roswitha Schweichel[3], Dr. Rouven Turck[2], Ms Karin Wyss[1]
[1]Laboratory of Ion Beam Physics, ETH Zurich, Zurich, Switzerland, [2]Institute for Archaeology, University of Zurich, Zurich, Switzerland, [3]Amt für Archäologie Thurgau, Frauenfeld, Switzerland

Theme: T-5: Advances in sample preparation
Type of presentation: Poster

Numerous objects of cultural heritage are preserved to prevent their degradation. Conservation treatments are not always well documented and pose a potential obstacle to accurate dating of the material. The resulting offsets in radiocarbon ages cannot always be detected, especially when no information on expected ages and /or alternative dating is available. Most of the conservation materials produced in the 20th and 21st centuries are based on fossil carbon, therefore, they include 14C free components. The problem of an unknown treatment history is the following: the spectrum of conservation materials is wide at the same time the treatment of radiocarbon samples is standardized. Here we present results of various standard treatments applied to well-dated wood, which was preserved with various conservation materials such as polymer Arigal C, Polyethylene glycol (PEG), Ethanol-Ether, and sugar. An offset is observed between the archeological age and the radiocarbon age for most standard cleaning procedures, which highlights the necessity for the identification of the components present in the samples prior to treatment. We present results of infrared spectroscopy obtained on some of the remaining material, which clearly shows the contaminants present in the 'cleaned' sample or cellulose. Our results highlight the importance of monitoring the purity of the samples, with the FTIR instrument being an essential part of 14C laboratory equipment.

Experience in commissioning of the radiocarbon dating lab based on Carbosorb method in Tehran

Dr Omidreza Kakuee[1], Dr Masoume Sharbatdaran[1], **Dr Ali Biganeh[1]**, Dr Hamidreza Moazemi[1], Mr Yashar Vosoughi[1], Mr Magid Elahi[1], Mr Sadegh Khaleghi[1]
[1]*Nuclear Science and Technology Research Institute, Tehran, Iran*

Theme: T-5: Advances in sample preparation
Type of presentation: Oral Presentation

Introduction

The only available electrostatic accelerator in Iran is a 3 MV Van de Graff accelerator, which was installed in the early 1970s. Various ion beam analysis techniques, including PIXE, RBS, RBS-Channeling, ERDA, PIGE, NRA, and IBIL are being conducted with Microbeam at the laboratory. It partially fulfills analysis requirements of environmental, archaeological, and biomedical samples. By the way, the machine suffers from low emittance, high environmental radiation, and reliability issues due to its age.

However, there is a strong need for more sophisticated mass and elemental analysis for advanced applied research. This includes C-14 dating and ion beam analysis with a focused ion beam at high lateral resolution. Analysis of aerosol samples, distribution of trace elements in biological samples, single ion irradiation of cells, analysis of historical manuscripts and paintings, identification of counterfeit objects are some of the social demands for this facility. To overcome the above-mentioned deficiencies, establish capacity building and develop human resources, Iran is determined to promote and develop ion beam analytical techniques and archaeological dating under the supervision of IAEA as a TC project. For this purpose, a tandem accelerator facilitated with AMS is considered for procurement.

No doubt, C-14 dating is expected to provide reliable data on the archaeological wealth of more than 7000 years' Persian civilization. Unfortunately, there is no active C-14 dating lab in the country. To establish a network and knowledge transfer to potential stakeholders and to explore Iranian cultural heritage by local sources, increased human capacity to perform radiocarbon analysis, and increased ability to get involved in scientific investigations, a C-14 dating lab based on carbosorb methods was commissioned and reported in this work.

Methods

This report describes the experience in commissioning of the radiocarbon dating lab based on carbosorb method in Tehran. Its purpose is to: (a) validate the predefined procedures, (b) introduce the relevant commissioning equipment, and (c) report on significant experiences on sample preparation.

The procedure of the sample preparation for carbosorb method includes acid-base degreasing, carbon isolation, oxidizing, and purification of the radiocarbon, followed by chemical conversion to a compound suitable for C-14 dating was achieved. The measurements on prepared standard, blank, test sample, and background counting would be reported.

Results

The homemade radiocarbon dating equipment and vacuum line have been installed. Statistical analysis, calibration, and interpretation of the results for age determination were achieved. Technical procedure of the Carbosorb dating method, data evaluation, and interpretation were available. In brief, the routine use of C-14 dating based on the carbosorb method including sample preparation, analysis, and age determination is available.

Conclusion

The lab would be used for human resource development and determining the authenticity of cultural heritage objects and materials. No doubt, transfer of skills and expertise of pioneering lab as well as hands-on training on radiocarbon dating methods and validation of the procedures is necessary to achieve the goals.

Acknowledgment

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Exploration of Beryllium Calcination Condition for the High-Resolution 10Be Analysis of Cosmic Ray Events

Kayo Kanzawa[1], **Fusa Miyake[1]**, Kazuho Horiuchi[2], Ryuji Fujimori[1], Takeyasu Yamagata[3], Hiroyuki Matsuzaki[3]
[1]Nagoya University, Nagoya, Japan, [2]Hirosaki University, Hirosaki, Japan, [3]University of Tokyo, Tokyo, Japan

Theme: T-5: Advances in sample preparation
Type of presentation: Poster

High-resolution analyses of cosmogenic 10Be in polar ice cores have been performed to investigate the past cosmic ray events. For such high-resolution 10Be analyses in ice core sample, we introduced a new beryllium calcination system to convert Be(OH)2 to BeO at the Institute for Space-Earth Environmental Research (ISEE), Nagoya University. We explored the several conditions to prepare BeO samples with low 10B background, i.e., a calcination in the air, vacuum, and oxygen conditions. We also tested the calcination temperature from 240℃ to 730℃, and we confirmed sufficient BeO− beam current was obtained from these samples. Although it has been expected that Be(OH)2 is not completely converted to BeO at lower temperature less than 400℃, the results suggest that the BeO samples for the AMS measurement can be obtained at such a lower temperature.

Extracting 10Be and 9Be from Antarctic marine sediments – a comparison of different extraction techniques

Mr Matthew Jeromson[1], Dr. Toshiyuki Fujioka[2], Dr. David Fink[3], Dr. Alix Post[4], Ms. Krista Simon[3], Dr. José Tonatiuh Sánchez-Palacios[5], Mr. Marcello Blaxell[1], Dr. T Gabriel Enge[6], Dr. Klaus Wilcken[3], Dr. Duanne White[1]

[1]University Of Canberra, , Australia, [2]Centro Nacional de Investigación sobre la Evolución Humana (CENIEH), Borgus, Spain, [3]Australian Nuclear Science and Technology Organisation, Sydney, Australia, [4]Geoscience Australia, Canberra, Australia, [5]Murdoch University, Perth, Australia, [6]Research School of Earth Sciences, Australia National University, Canberra, Australia

Theme: T-5: Advances in sample preparation
Type of presentation: Poster-Plus Presentation

Application of meteoric-^{10} Be (M^{10} Be) in sediments and soils from diverse geomorphic settings has been active for many decades. In some cases, M^{10} Be is normalized by the reactive ^{9} Be from the same sediment sample. Given the complexities in geochemical pathways that M^{10} Be is incorporated in the reactive mineral phase of such sediments, very different Be isotope chemistry extraction techniques have been developed. Measurement of M^{10} Be and the reactive phase of ^{9} Be in coastal Antarctic marine sediments has increasingly become promising as a paleo-proxy for the presence (or absence) of past ice shelves, and/or sub-glacial meltwater discharge from grounded outlet glaciers draining the ice sheet. However, published works select different methods to chemically leach Be isotopes from the reactive phase of Antarctic marine sediment and few studies have quantitively compared the efficacy of different leaching recipes. This is problematic because comparisons of ^{10} Be/^{9} Be ratios across different Antarctic sites assumes the same chemical fractionation of Be isotopes regardless of the leaching method.

We examined three large-volume sediment grabs from near the Amery Ice Shelf front in East Antarctica that represent a range of grainsize and environmental conditions. For Be extraction, homogenised materials from each of the three samples were treated with four different leaching procedures, 1–3 targeting the reactive phase: 1) 6M HCl; 2) 0.5M HCl followed by 1M hydroxylamine hydrochloride in 1M HCl; 3) 0.04M hydroxylamine hydrochloride in 25% acetic acid solution 4) a total extraction dissolving in HF, HNO_3 , and $HClO_4$. We also selected one grab to assess the effect of grainsize within the following fractions: <38 um, 38–63 um, 63–90 um, 90–125 um, and >125 um. Each fraction was leached with 6M HCl for 24 hours at room temperature.

We found that both the 6M HCl and the 1M hydroxylamine procedures leached the same amount of ^{10} Be as the total extraction, while the 0.04M hydroxylamine treatment leached only two thirds. Interestingly, the 6M HCl and the 0.04M hydroxylamine procedures leached the same relative proportion of ^{9} Be to ^{10} Be, and thus gave the same ^{10} Be/^{9} Be ratio, while the 1M hydroxylamine procedure leached relatively more ^{9} Be in relation to ^{10} Be, resulting in a lower ^{10} Be/^{9} Be than the other two methods. As shown in previous studies, our results indicate that Be-isotope concentrations varied inversely with grainsize, in our case increasing 4-fold from coarsest to finest fractions, critically showing that the ^{10} Be/^{9} Be ratio remained constant across all grainsizes. Hence, grainsize can be normalised by applying the reactive ^{10} Be/^{9} Be ratio.

We conclude that differences in leaching procedures, can lead to significant variations in efficiencies in extracting Be isotopes from the reactive phase of sediment, whereas the ^{10} Be/^{9} Be ratio appears to remain the same. This study highlights the importance of careful method selection and its consistent application to allow for comparison between studies and more robust interpretation.

First status report on 10Be and 26Al sample preparation techniques at the IHEG, CAGS AMS laboratory (Xiamen, China)

Prof. Hui Zhang[1,2,3], Shenghua Liu[1,2,3], Bo Yu[1,2,3], Manli Zhang[1,2,3], Qingzhang Zhao[4], Ming He[4], Shan Jiang[4]
[1]Institute Of Hydrogeology And Environmental Geology, Chinese Academy Of Geological Sciences, Shijiazhuang, China, [2]Key Laboratory of Groundwater Sciences and Engineering, Ministry of Natural Resources, Shijiazhuang, China, [3]Key Laboratory of Quaternary Chronology and Hydro-Environmental Evolution, Chinese Academy of Geological Sciences, Shijiazhuang, China, [4]China Institute of Atomic Energy, Beijing, China

Theme: T-5: Advances in sample preparation
Type of presentation: Poster

The Institute of Hydrology and Environmental Geology (IHEG), CAGS organized a research group engaged in radionuclides analysis and dating by AMS in 2015, then purchased its first multi-element AMS facility (1MV, HVEE) in 2017. Unfortunately, this facility has not been installed yet. The 10Be and 26Al sample preparation laboratory spent the better part of 2020 establishing pretreatment protocols, and streamlining sample processing, included optimizing extraction and purification of quartz, ion exchange chromatography methods, minimizing backgrounds. Here, we present an overview of sample processing protocols and results from measured standards, reference, and blank materials.

Graphitisation & measurement of microgram radiocarbon samples at ANSTO.

Dr Andrew Smith[1], Dr Quan Hua[1], Mr Simon Varley[1], Mr Alan Williams[2], Dr Bin Yang[1]
[1]ANSTO, Lucas Heights, Australia, [2]Deceased, 9th February 2021, ,

Theme: T-5: Advances in sample preparation
Type of presentation: Poster-Plus Presentation

The Centre for Accelerator Science (CAS) at ANSTO has been providing radiocarbon analyses for the user community and internal projects for two and a half decades. Early on, there was a need to develop the measurement capability for samples containing just tens of micrograms of carbon [1, 2]. We have continued to develop this capability since.

At first effort was directed at optimising our ‘conventional’ graphitisation furnaces [3]. These have a minimum reaction volume of ~ 2.5 mL and reduce CO_2 to graphite over an Fe catalyst at 600 °C in an excess of hydrogen. CAS operates a bank of 24 conventional furnaces which provide for the bulk of our sample graphitisation for samples containing > 5 µg of carbon.
In 2003 we began developing a novel, miniaturised graphitisation furnace which used a focused infrared laser to heat the Fe catalyst in a quartz crucible, with the temperature measured indirectly by infrared thermometry [4]. The prototype unit had an internal reaction volume of ~0.5 mL including pressure transducer and the two subsequent furnaces ~ 0.3 mL. These small volumes allow a higher initial pressure for small amounts of CO_2 , improving the efficiency of conversion to graphite. Efficient trapping of the water vapour produced during the reaction and careful selection of the catalyst are also key to optimising graphitisation of small samples [5, 6]. By localising the heated region within the reaction volume, the addition of extraneous carbon is minimised in these furnaces and samples containing just 1-2 µg of carbon are routinely prepared. The laser heated furnaces (LHF) are preferred for processing the very small samples derived from our ^{14}C in situ program [7].

The fabrication approach developed for the LHF was adapted to a new type of miniaturised furnace we call micro-conventional furnaces (MCF) [8]. These furnaces have a minimum reaction volume of ~ 0.9 mL with a small tube furnace to heat the catalyst. Variable temperature cold traps have been developed to optimise sample processing with samples as small as 5 µg of carbon routinely prepared. The MCF are used extensively in conjunction with ^{14}C measurements of CO, CO_2 and CH_4 derived from ice core and firn air samples.

We present an overview of micro-sample graphitisation and measurement at CAS.

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Graphitization of Samples Containing Sulfur and Chlorine Using the Sealed Tube Zinc Reduction Method for 14C Analysis on AMS

Dr Xiaomei Xu[1], Connor J. Mateer[1], Hector Martinez De La Torre[1]

[1] *Department of Earth System Science, University of California Irvine, , United States*

Theme: T-5: Advances in sample preparation
Type of presentation: Oral Presentation

The method of graphitization by sealed tube zinc reduction of sample CO2 to filamentous graphite has been shown to provide reliable 14C measurements using AMS with low backgrounds and high precision, and over a wide range of sample sizes (1 mgC to <15 µgC) [1-3]. One advantage of this method is that graphite can be stored inside of the tube until the AMS 14C measurements can be performed. We report here an additional advantage of the method – to be able to graphitize samples containing Sulfur (S) and Chlorine (Cl).

It's well documented that it's problematic for Sulfur (S) contained organic samples in graphitization using the H2 reduction method because S can interfere with the graphitization, thus S is considered "poison" to the H2 reduction graphitization. Very often silver is added to combustion of organic samples, especially samples formed in reduced environment to remove S as Ag2S. If S content is high additional separation step is needed to ensure complete S removal before graphitization.

We have investigated graphitization of various C sizes of samples with up 21.5%S, such as methionine (C5H11NO2S), without separating S beforehand. For a full size sample of 0.7-0.9 mgC, the S amount can be as high as 0.48 mgS in combustion. Graphitization of pure 1mgC-aminio acids with various amount of NaCl added has also been investigated and shown successful graphitization up to 100mg NaCl added in combustion with Pyrex glass tube. During the sealed tube Zn reduction graphitization, S and Cl are expected to form ZnS and ZnCl2 respectively, and do not interfere with the graphite forming. Silver is not needed in combustion of all organic samples, which reduces the cost and C blank in the process. The graphite produced from S and Cl contained samples perform well in the ion source of our AMS at UCI, in terms of beam currents and precision.

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Improvement in analysis of dissolved organic radiocarbon in seawater: Evaluation method of accuracy

Dr Shigeyoshi Otosaka[1], Mr Hyunduck Jeon[1], Mr Yunxuan Hou[1], Prof Yusuke Yokoyama[1], Yosuke Miyairi[1], Mr Takahiro Aze[1], Dr Takahiro Watanabe[2], Prof Hiroshi Ogawa[1]
[1]The University of Tokyo, Kashiwa, Japan, [2]Japan Atomic Energy Agency, Toki, Japan

Theme: T-5: Advances in sample preparation
Type of presentation: Poster

Accurate ^{14}C analysis in oceanic dissolved organic carbon (DO^{14}C) in seawater gives us useful information on the timescale of biogeochemical cycle of dissolved organic matter (DOM) in the ocean. However, due to the difficulty of analyzing DO^{14}C, an easier-to-use and safer analysis system has been required. We have established a method for DO^{14}C analysis combining decomposition of DOM with low pressure mercury lamp and accelerator mass spectrometry. This method greatly reduces the heat generation during the UV irradiation, and it enables us preprocess seawater samples more easily and safely than the previous method. In addition, with the sample volume ranging between 0.5 and 1 L, it is possible to decompose DOC with high efficiency (> 95%) without adjusting the sample volume. Since dilution is unnecessary, it also contributes to reduction of blanking due to dilution process. In order to evaluate the performance of such an analytical system, it is necessary to prepare an artificial DOM sample in which a certified reference material having a known ^{14}C isotopic ratio is dissolved in pure water and analyze it in the same manner as the actual sample. We also prepared the artificial samples using IAEA-C7 and -C8 (oxalic acid) reference materials dissolved in pure water and confirmed that the 14C isotope ratio analyzed by this method agrees with the recommended value. However, when the experiment was carried out by dissolving the same reference materials in a solution containing chloride (at similar salinity as seawater), a slightly lower ^{14}C isotopic ratio was obtained as compared with the experiment using pure water. We considered that plastic/rubber parts in the system were decomposed by chlorine generated by UV oxidation of chloride in sample, and contamination by a small amount of petroleum derived carbon reduced ^{14}C isotopic ratio. Although it is needed to reduce the number of plastic parts in the system and to suppress the production of such "background carbon" by using a durable material, it is difficult to eliminate them completely. We thus propose to guarantee the accuracy of the ^{14}C analysis data by conducting DO^{14}C measurement of a standard sample aqueous solution containing salt, monitoring the status of the DO^{14}C analysis system, and correcting the results as necessary. The method to evaluate the reliability of DO^{14}C is feasible only with solid reference material which can be stored at room temperature and DOM free artificial seawater which is easily available. Therefore, this method is promising as a standard method for accelerating oceanic DO^{14}C research.

Increasing the ionization yield for the detection of U-236 and U-233 by AMS

Mr Michael Kern[1], Dr. Karin Hain[1], Tomáš Prášek[2], Dr Peter Steier[1], Andreas Wiederin[1], Prof. Dr. Robin Golser[1]
[1]University Of Vienna, Faculty Of Physics - Isotope Physics, Vienna, Austria, [2]Czech Technical University in Prague, Faculty of Nuclear Sciences and Physical Engineering, Prague, Czech Republic

Theme: T-5: Advances in sample preparation
Type of presentation: Poster-Plus Presentation

The limiting factor for actinide measurement by Accelerator Mass Spectrometry (AMS) is the total detection efficiency (TDE, sample to particle detector), which is strongly dependent on the ionization yield (IY) for anions in the ion source. Normally, uranium is extracted as UO^-, which results in an IY of about 10^{-3}. Fluorine-rich molecules with exceptionally high electron affinity produce strong anion currents by Cs-sputtering in the presence of excess fluorine reactants like PbF_2. Previous research suggested UF_5^- extraction from metal U mixed with PbF_2 powder [1].

At the Vienna Environmental Research Accelerator (VERA) we investigated whether and how much PbF_2 admixture could enable sufficient U-fluoride anions extraction from a Fe_2O_3 matrix with embedded traces of U-oxides. For this, in-house U standard Vienna-KkU [2] solution was co-precipitated with Fe-hydroxide and calcined to UO□ in Fe_2O_3 (U:Fe = 1:30, weight ratio). Vienna-KkU-D30 is representative for environmental samples [3]. Three materials based on Vienna-KkU - each mixed with PbF_2 in variable ratios - were tested:

I. Dry Vienna-KkU-D30
II. Fe solution (~200 µg Fe per sample, U:Fe = 1:30, weight ratio) added to Vienna-KkU solution and dried up, followed by calcination.
III. Co-precipitation of UF_4 (Vienna-KkU solution) with NdF_3 (U:Nd = 1:18, weight ratio) [4].

UO□F□ formation from each mixture and its IY was analyzed using VERA's first mass separator. The TDE of U, isotope ratios $^{236}U/^{238}U$, $^{233}U/^{238}U$ and the fingerprint $^{233}U/^{236}U$ [5] of all mixtures were determined using the entire AMS set-up at VERA.

UF_5^- was the most efficiently extracted UO□F□ ion for all the mixtures but the absolute IY for UF_5^- was limited by other UO□F□ ions in UO□ based materials. The optimal mixing ratio of Vienna-KkU-D30 powder with PbF_2 (I.) was 1:9 by weight ratio. It showed five times higher TDE for U than optimal UO^- extraction. Individually dried and calcined material (II.) with PbF_2 showed a TDE more than twice as much as by UO^- extraction. The UF_4 based mixture (III.) showed a TDE of up to ten-fold compared to UO^-, however, individual sub-milligram NdF_3 preparation was not yet possible. Methods I. III. were checked for reproducibility by comparing the isotope ratios of all the mixtures to the Vienna-KkU consensus value [2]. Materials I and II (both U-oxides) showed $^{236}U/^{238}U$ within 1-σ of Vienna-KkU. Samples prepared as UF_4 (III.) showed surprisingly high $^{236}U/^{238}U$, which might be explained by reagent contamination.
To validate method II. an aliquot of an air filter sample analyzed previously by UO^- was used. $^{236}U/^{238}U$ ratios were confirmed using UF_5^- extraction. Besides higher IY, UF_5^- extraction also seems advantageous for isobaric background suppression ($^{232}ThH^{3+}$, $^{235}UH^{3+}$).

In conclusion, the extraction of U as UF_5^- combined with sub-milligram Fe preparation (high PbF_2 mixing ratios) compared to UO^- extraction allows shorter measurement times and/or lower statistical uncertainty or using smaller sample amounts.

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Initial results from a new, fully automated in situ cosmogenic 14C extraction, purification, and graphitization system at PRIME Lab

Nathaniel Lifton[1,2], Jim Wilson[3], Alexandria Koester[1], Marc Caffee[2]

[1] *Purdue University, Depth Earth, Atmospheric, and Planetary Sciences, West Lafayette, United States,*

[2]*Purdue University, Dept Physics and Astronomy, PRIME Lab, West Lafayette, United States,* [3]*Aeon Laboratories, LLC, Tucson, United States*

Theme: T-5: Advances in sample preparation
Type of presentation: Poster

Extracting in situ cosmogenic ^{14}C (in situ ^{14}C) from quartz is a challenging endeavor: minute quantities of ^{14}C must be extracted and purified from quartz samples while maintaining scrupulous isolation from ubiquitous atmospheric/organic ^{14}C. These extraction and purification procedures are ripe for automation, as they are time-consuming, and labor-intensive when done manually. Lifton et al. (2015) presented results from the initial automated in situ ^{14}C extraction and purification systems at the Purdue Rare Isotope Measurement Laboratory (PRIME Lab), reconfigured and retrofitted from our original glass systems at the University of Arizona. While these automated systems increased throughput and reproducibility over our original purely manual systems, they also required manual transfer of sample gas between separate extraction, purification, and (manual) graphitization systems. Ultimately they proved less reliable than hoped, pointing to limitations in the retrofitting of Lifton's original designs.

We thus recently purchased and installed a customized Carbon Extraction and Graphitization (CEGS) system from Aeon Laboratories, LLC, modified to accommodate our two individually vacuum-pumped tube furnaces. The largely stainless-steel system (except for specific sections requiring glass or fused-quartz components) incorporates more reliable valves and improved actuator designs, as well as a more reliable and efficient liquid nitrogen distribution system. The new system, controlled by a flexible and extensible modular software package written in C# (developed by Aeon), follows a similar procedure to that of Lifton et al. (2015), using a degassed $LiBO_2$ flux to dissolve the quartz sample in an ultra-high-purity oxygen atmosphere. However, al sections of the new system are connected, so that one can extract all evolved carbon species as CO_2 from a quartz sample, purify and precisely measure the resulting gas yield, and convert the CO_2 to graphite for AMS analysis – all without human intervention. We will present baseline results from the now fully operational system, including process blanks and analyses of established intercomparison materials, for both single-use high-purity aluminum oxide and reusable Pt/10%Rh sample boats.

Lifton, N., Goehring, B., Wilson, J., Kubley, T., and Caffee, M., 2015, Progress in automated extraction and purification of in situ ^{14}C from quartz: Results from the Purdue in situ ^{14}C laboratory: Nucl. Inst. Meth. Phys. Res. B, 361, 381–386, doi:10.1016/j.nimb.2015.03.028.

Lead-210: A contaminant in particle detectors for dark matter studies

Michaela Froehlich[1], Silke Merchel[1,2,3], Zuzana Slavkovská[1], Ferdos Dastgiri[1], Leslie Keith Fifield[1], Michael Hotchkis[4], Dominik Koll[1], Stefan Pavetich[1], Stephen Tims[1], Anton Wallner[1,3]

[1]Research School of Physics, The Australian National University, Canberra, Australia, [2]Faculty of Physics, University of Vienna, Vienna, Austria, [3]Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany, [4]Australian Nuclear Science and Technology Organisation, Sydney, Australia

Theme: T-5: Advances in sample preparation
Type of presentation: Oral Presentation

The DAMA/LIBRA (DArk Matter/Large sodium Iodide Block for RAre processes) is a very low background NaI(Tl) detector array that has been running for two decades in the Gran Sasso underground laboratory in Italy. It gives a robust annual modulation signal in the 2 to 6 keV region that may be due to dark matter [1]. In order to verify this result with higher sensitivity, the SABRE (Sodium iodide with Active Background REjection) experiment [2] is being developed. Radioimpurities such as ^{40}K, ^{238}U, ^{210}Pb and ^{232}Th, either intrinsic to the detector material or surface contamination, provide a fundamental limit to the sensitivity of SABRE. Therefore, it is crucial to characterise this background for improved identification of any additional signal above it.

Here, we focus on ^{210}Pb (half-life of 22.2 years) as its beta decay to ^{210}Bi contributes to the low-energy "dark matter" spectra [3]. Lead-210 measurements are usually performed using alpha -, beta - or gamma counting depending on the sample size and concentration [4]. However, in recent years, the interest and therefore developments to measure ^{210}Pb using accelerator mass spectrometry (AMS) has increased [5], [6].

From a chemical point of view, we need to optimise the Pb extraction of ~1 mg of stable Pb carrier through precipitations and ion exchange chromatography using about a kilogram of NaI. This is not trivial and methods using two different resins, i.e., 1x8 anion exchange resin and Sr® resin, have been tested. It is also essential that the stable Pb carrier and any material and chemical product in use should contain as little ^{210}Pb as possible. Hence, several materials have been investigated including a piece from a 16th century roof and radiation shielding blocks as a source of Pb carrier. Furthermore, we studied PbO and PbF_2 samples to identify the optimal negative-ion beam and the suitability of using either Fe_2O_3 or NaF as bulk material for the AMS target to reduce the stable Pb content. AMS measurements related to this work have been made using the 14UD pelletron accelerator at the Australian National University and the 1 MV VEGA accelerator at the Australian Nuclear Science and Technology Organisation.

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Less is more: optimizing 9Be carrier addition for AMS analysis of 10Be at CAMS

Ms Alianora Walker[1,2], Alan J. Hidy[1], Susan R. Zimmerman, Scott J. Tumey[1], Tom Brown[1], Sandra M. Braumann[3], Roseanne Schwartz[3], Joerg M. Schaefer[3]
[1]Lawrence Livermore National Laboratory, Livermore, United States, [2]San Jose State University, San Jose, United States, [3]Columbia University, Lamont-Doherty Earth Observatory, Palisades, United States

Theme: T-5: Advances in sample preparation
Type of presentation: Oral Presentation

We conducted a series of experiments on the CAMS-LLNL (Center for Accelerator Mass Spectrometry, Lawrence Livermore National Laboratory) 10-MV model FN tandem Van de Graaf accelerator and modified high-intensity cesium sputter source to determine the ideal 9Be carrier mass to use for 10Be targets analyzed with our system. CRONUS-A quartz was dissolved then split to prepare targets identical in 10Be content, but with variable 9Be (10-250 µg). For handling purposes, and to control density of 10Be atoms in targets, samples were bulked with Fe or Al carrier to replace the reduced 9Be. Packing experiments were performed with oxide-Nb mixtures to determine volume-equivalent masses needed to keep each target packed to a consistent depth. Our experiments show a maximum ~40% increase in 10Be counts for samples prepared with 75 µg vs. 250 µg 9Be (typical) after 25 minutes of sputtering. This result is substantiated by increased total 10Be counts observed on targets analyzed to exhaustion, implying significant gains in total system efficiency with the lower carrier mass. Multiple low-level (~104 atoms 10Be/g) quartz samples were prepared using both the typical and lower 9Be carrier amounts and analyzed under normal AMS operational conditions. In each case, significantly better counting statistics were achieved with the lower 9Be mass while reproducing the 10Be concentration obtained from the typical-mass duplicate. Similar improvements were also observed in targets prepared with lower carrier from an external sample prep lab (Columbia University).

Collectively, our results indicate that optimal measurement efficiency for 10Be AMS targets analyzed at CAMS is obtained using 75 µg 9Be carrier and replacing the reduced mass with ~230 µg Fe. We recommend adding Fe carrier during the final hydroxide precipitation step prior to calcination. For this work, we sourced our Fe from an ICP standard purchased from Alpha Aesar that was tested to be sufficiently 10Be-free. However, an implementation where Fe is harvested from the digested quartz sample itself (anion column reject) and later reintroduced to the sample is being explored and may be an elegant alternative to using commercial carrier since most quartz has sufficient Fe content for this purpose. This reduction in per-sample 9Be carrier mass—by a factor of 3.3x—offers substantial benefits to both analysis quality and cost (higher analyzed 10Be/9Be ratios, better counting statistics, shorter run times, longer-lasting expensive carrier bottles) without modification to established AMS operations for 10Be analysis at CAMS. Based on these results, 10Be targets prepared with anywhere between 75 and ~250 µg 9Be is acceptable for submission to the CAMS user facility for analysis.

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Monitoring of chemical processes for 10Be and 26Al AMS target preparation

Dr Jan Kameník[1], Prof. Jan Kučera[1]
[1] *Nuclear Physics Institute Of The Czech Academy Of Sciences, Husinec-Řež, Czech Republic*

Theme: T-5: Advances in sample preparation
Type of presentation: Poster-Plus Presentation

The first AMS laboratory in the Czech Republic has been under construction since 2018. Since mid-2021, it hosts a multi-isotope low energy AMS system MILEA (Ionplus AG, Switzerland) and several chemical laboratories. For optimization of chemical procedures for target preparation prior to ^{10}Be and ^{26}Al AMS measurement, methods for monitoring of Be and Al behavior during chemical procedures were proposed. For monitoring of beryllium, radioactive ^{7}Be, a gamma-ray emitter with a half-live of 53.2 days, was employed as a tracer. For aluminium, a suitable radioactive tracer is unavailable. Therefore, its monitoring was based on determination of Al by instrumental neutron activation analysis (INAA).

All experiments were performed in an established radiochemical laboratory. Carrier free ^{7}Be tracer was obtained from a proton irradiated metallic Li target using ion-exchange separation with cation exchange resin. The Li target originated from a fast neutrons generator operated by Nuclear Physics Institute (NPI). Aluminum was determined in separated aliquots by INAA based on gamma-spectrometric determination of ^{28}Al radionuclide with a half-live of 2.2 min formed during irradiation of stable ^{27}Al with thermal neutrons from research reactor LVR15 (operated by Centrum výzkumu Řež).

Two established methods for Be and Al targets preparation were selected for testing of separation of both elements from precipitation and solid specimens. The first method was based on a combination of precipitation steps with ion-exchange chromatography separation by strongly acidic cation and strongly basic anion exchange resins [1,2]. The second method utilized extraction-chromatography separation using a combination of WBEC and AC resins (Triskem International, France) [3] without the need of the precipitation steps. The test indicated that both methods were able to separate Be and Al fractions well. The most critical part in term of separation yields were precipitation steps for both Be and Al. About 50% and 65% of original Be and Al was lost, respectively. Perhaps better control of pH can help in increasing of the overall separation yield. Chromatographic processes were efficient, some improvements could be expected from better control of the flow rate. It was confirmed that the proposed monitoring can help in optimization and development of new chemical procedures for preparation of ^{10}Be and ^{26}Al AMS targets.

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Niobium and Rhenium: Improved Binders for AMS

Dr Thomas Woodruff[1], Dr. George Jackson[1]
[1]*Prime Lab, West Lafayette, United States*

Theme: T-5: Advances in sample preparation
Type of presentation: Poster

In 2017 PRIME Lab began using a gas filled magnet (GFM) system for the measurement of 26Al. This enabled injection of the more prolific AlO- ion as opposed to Al-. Along with these higher beam currents came a lowering of the achievable blank. However, source memory was a much larger problem for 26Al versus 10Be. We have since switched to Nb as a binder for both Al2O3 and BeO. The reduction in source memory for 26Al was substantial and we now routinely run a machine blank with a ratio less than 1E-15 26Al/27Al even after measuring unknown samples with ratios greater than 1E-11 26Al/27Al. We have also begun using all Nb targets periodically during 36Cl runs to eliminate buildup of 36Cl source memory.

Another refractory metal introduced into our process is Re, used as a binder for CaF2. We found that using Re increased currents by 31% over Ag and we now routinely measure currents over 500 nA CaF-. This has increased performance for both our biomedical and extraterrestrial 41Ca programs.

Optimization of sample preparation method for 10Be AMS measurement

Dr Chaolu Yi, Dr Xingfang Ding, Professor Feng Xian, Professor Kejun Dong, Dr Yunzhong Fu, Professor Kexin Liu

Theme: T-5: Advances in sample preparation
Type of presentation: Poster

Higher Beam currents are expected during 10Be/9Be measurements by accelerated mass spectrometry. The last two steps for Be sample preparation include the burning of Be(OH)2 to obtain BeO and then niobium power is added and mixed with the BeO to increase ion beam current. However, the burnt BeO is flaky and a little bit hard to be ground to power so that they cannot mixed evenly. In this study, we present a method of sample preparation which would increase beam current for Be measurement so as to decrease the measurement errors. After Be(OH)2 gel was prepared, we added a little bit niobium powder into the gel and mixed them evenly. After burning in a muffle furnace, Niobium was oxidized into Nb2O5, and Be(OH)2 was dehydrated into BeO. They eventually became a fluffy, evenly white powder. Finally a little bit niobium was added into the white powder. The results of 10Be measurements show that the average of beam currents extracted from BeO mixed with both niobium powder and Nb2O5 were 2.5~4.6 times higher than those mixed only with niobium powder or with Nb2O5. These indicate that the mechanism for high beam current is the homogeneousness of BeO produced by expanded Nb2O5 powder.

The content of the abstract mainly comes from a Chinese patent, A method to increase beam current for Be measurement. Series: 201910175697.9. Authority date：2021-6-30. Inventor: Chaolu Yi.

Performance of Micro graphitization versus Gas Ion Source on the EnvironMICADAS at HEKAL Laboratory

Dr Mihály Molnár[1], Róbert Janovics[1], István Major[1], Katalin Hubay[1], Botond Buró[1], Tamás Varga[1], Titanilla Kertész[1], László Rinyu[1], Anita Molnár[2], Gergely Orsovszki[2], Mihály Veres[2], A.J. Timothy Jull[1,3], Virág Gergely[1]

[1]INTERACT Centre, Institute for Nuclear Research, Debrecen, Hungary, [2]Isotoptech Zrt., Debrecen, Hungary, [3]University of Arizona AMS Laboratory, Tucson, United States

Theme: T-5: Advances in sample preparation
Type of presentation: Poster

keywords: MICADAS, AMS, radiocarbon, gas ion source, micro graphite

The aim of this study was to compare the ultimate performance of sealed tube graphitization (Zn-method) and gas ion source (GIS) based methods for micro-sample analyses on the EnvironMICADAS AMS of the HEKAL AMS facility (Debrecen, Hungary). To accomplish this purpose both methods, which are routinely used in HEKAL have been tested in the range of 10–100 ug carbon content. To exclude the side effects caused by the possible contamination by the chemical pretreatment and combustion of such small samples, all micro-samples of this tests have been produced by splitting large CO2 gas from combusted samples (containing 1 mg C) and large amount of radiocarbon free fossil CO2 borehole gas without any chemical preparation.

Advantages of the micro-graphitization (Zn-method) relative to gas ion source application are the higher number of total counts and better statistics on the same sample. Memory effect in the ion source is negligible in case of micro-graphite AMS analyses. Full magazines with up to 40 samples could run for tens of hours without any personal assistance in the EnvironMICADAS. Losing of samples due to pure ion current and/or bad target quality is very rare when micro-graphites are measured. Drawbacks of the solid graphite based analyses are the higher and mass dependent blank level which strongly limits the measurable maximum age (C-14 detection limit). The mass dependent blank level requires careful planning of the magazines including a proper number of blanks and normalization samples (Oxa-2) in the same mass range as the actual set of samples.

In case of micro-graphites 1-10 pMC average background level can be reached depending the sample size (10 -100 ug C). The lower C amount the higher blank level, which show exponential rise below 20 ug C sample amount. The available precision for modern samples varies between 0.5% to 2% depending the sample size (10 to 100 ug C). Available ion current shows a linear correlation to the sample size, about 0.1 uA/ ug C on the high energy side. Figure of Merit factor of the micro-graphite analyses shows similar performance compared to the GIS analyses, in cases when the worse detection limit allows the application of graphite-based analyses.

The research was supported by the European Union and the State of Hungary, co-financed by the European Regional Development Fund in the project of GINOP-2.3.4-15-2020-00007 “INTERACT”. This work was carried out in the frame of a János Bolyai Research Scholarship (to Mihály Molnár) of the Hungarian Academy of Sciences.

Preparing wood samples: when you´re on the woodway trying to find a unique preparation method

Dr Susanne Lindauer[1], Dr Johannes Tintner-Olifiers[2], Dr. Niels Bleicher[3], Dr. Hannes Knapp[1], Dr. Ronny Friedrich[1], Prof. Dr. Roland Schwab[1]
[1]Curt-engelhorn-centre Archaeometry, Mannheim, Germany, [2]Natural Resources and Life Sciences Vienna, Vienna, Austria, [3]Competence Centre for Underwater Archaeology and Dendrochronology, Zurich, Switzerland

Theme: T-5: Advances in sample preparation
Type of presentation: Poster

Usually, when preparing wood samples of either species, cellulose, especially alpha-cellulose, as the outcome is thought to be the most reliable part of the sample for radiocarbon dating. We noticed that some samples used as blank samples in our laboratory do not work well after cellulose pretreatment – if they still contain cellulose at all - and rather end up with a finite age instead of being radiocarbon dead. Hence we started a test comprising of different wood blank samples as well as some younger species to get an idea about systematic shifts due to pretreatment method chosen. Here, we present outcomes of a range of different pretreatments from rather harsh alpha-cellulose and very soft pretreatment with diluted acids and base steps. The most problematic wood to date, however, is waterlogged wood. Therefore, we included some of these kind of samples in our test as well. All younger wood samples were cross-dated via dendrochronology prior to radiocarbon dating. To understand the sometimes surprising outcomes we checked the samples with a microscope and in more detail with a Scanning Electron Microscope (SEM) as well as Fourier-Transform Infrared Spectroscopy (FT-IR) hoping to understand the samples better.

In conclusion it can be said that to use a sample as process blank in the lab the range of useful sample preparation steps for this sample needs to be determined first. As the data shows it is of no use to prepare a sample for cellulose extraction if the cellulose is badly preserved and then leads to erroneous ages.

Quality assurance and control data for cosmogenic Be-10 sample preparation in the CosmIC laboratory at Imperial College London

Dr Dylan Rood[1], Dr Keir Nichols[1], Mrs Anna Rood[1], Mr Alexander Seal[1], Dr Klaus Wilcken[2]
[1]Imperial College London, London, United Kingdom, [2]ANSTO, Lucas Heights, Australia

Theme: T-5: Advances in sample preparation
Type of presentation: Poster

Quality assurance and control (QA/QC) are sacrosanct for accelerator mass spectrometry (AMS) sample preparation laboratories. However, quantitative data necessary to assess QA/QC is rarely published for cosmogenic nuclide sample preparation laboratories around the world. Here, we compile and report QA/QC data for the first 5 years of Be-10 sample preparation operations in the CosmIC laboratory at Imperial College London, United Kingdom. Our QA/QC data include: 1) inductively coupled plasma - optical emission spectroscopy (ICP-OES) assay data for mineral purity, carrier concentration, beryllium yield, and beryllium purity; 2) AMS data for ion beam current, carrier blanks, laboratory process blanks, and measured isotope ratio versus precision; and 3) nuclide concentration data for replicate samples. These results serve to verify and benchmark our current Be-10 sample preparation methods and data quality. In turn, our QA/QC data set the bar for future development and improvements in the CosmIC laboratory and other cosmogenic isotope sample preparation laboratories globally.

Quantifying the bucket: Quartz purification of 125-63 µm material for in-situ cosmogenic nuclide analysis.

Dr Ross Whitmore[1], Dr Kevin Norton[2], Dr. Luisa Ashworth[2], Dr. Andrew Mackintosh[1]
[1]Monash University, Clayton, Australia, [2]Victoria University of Wellington, Kelburn, New Zealand

Theme: T-5: Advances in sample preparation
Type of presentation: Poster-Plus Presentation

Quartz purification is a necessary and critical step to producing robust and reproducible results in terrestrial cosmogenic nuclide studies. Previous quartz purification work has centred on coarse sample material (1 mm-500 µm) and is anecdotally effective down to ~250 µm. The success of these purification procedures is evident by the large amount of peer reviewed research published each year using the quartz/10Be system. However, even though quartz is ubiquitous in the environment not all rocks contain quartz grains/crystals sufficiently large to be purified with these relatively aggressive procedures. When very-fine quartz is purified this way, it tends to be totally digested.

We tested HCl/HF purification on very-fine sand (125-63 µm), using two 10% HCl leaches to remove oxide forming minerals and phyllosilicates, followed by one 2.5% HF leach and six subsequent 1% HF leaches to remove quartz overgrowths. In addition to this quartz purification test we also quantify major element, 9Be and 10Be removal through the leaching process. For the analysis we retained each post-leach acid supernate and collected a 1 g subsample of the rinsed and dried quartz.

Our results show that more than 99.9% of the meteoric 10Be is removed by the first 10% HCl leach with 10Be removal plateauing after the first 1% HF leach. We also document that Al is pervasive in these very-fine-grained samples and that removing it is more challenging than removing meteoric 10Be. Additionally, our data suggest a correlation between reduced Al and increased 9Be ion-beam strength when the sample is being measured in an accelerator mass spectrometer. Ultimately, this quartz purification method is robust and reliable for removing major elements, meteoric 10Be, and 9Be from material between 125 µm and 63 µm in size.

Refinement to the extraction of in-situ cosmogenic C-14

Dr Reka-Hajnalka Fulop[1,3], Dr Smith Andrew[1], Dr Bin Yang[1], Dr Duanne White[2], Dr Alexandru T. Codilean[3]

[1]Ansto, Menai, Australia, [2]University of Canberra, Canberra, Australia, [3]University of Wollongong, Wollongong, Australia

Theme: T-5: Advances in sample preparation
Type of presentation: Oral Presentation

In situ C-14 is an important addition to the cosmogenic nuclide toolkit. Its relatively short half-life - 5730 years - as compared to the longer-lived cosmogenic nuclides, means that it is substantially more sensitive to short term variations in process rates or more suitable at investigating recent exposure events. In-situ C-14 used in combination with Al-26 and Be-10 is also particularly well suited to studying the relatively short timescales that characterize fluvial sediment transfer and storage.

Despite the above, the extraction of in-situ C-14 from geological samples is still problematic, with recent laboratory intercomparison studies showing considerable overdispersion in both intra and inter laboratory comparisons of standard materials. The discrepancies between laboratories have been attributed to several factors, including the quality of some intercomparison materials, however, clear consensus on the matter is yet to be reached.

Here we present results of in-situ cosmogenic C-14 analyses in the Cronus-A and Cronus-R laboratory intercomparison materials and various samples obtained using the ANSTO/UOW in-situ C-14 extraction system, that suggest the presence of carbon containing minerals within these materials. Our results indicate that quartz separates need a different purity measurement that what would normally be acceptable for cosmogenic Be-10 and Al-26 analyses. Further, we do not observe a bias in results on those samples that underwent froth-floatation to remove feldspars, however applying a final 50% HF etch will result in removal of unwanted minerals. Based on analyses on fluid inclusions we adopted cycled in-vacuo 600oC pre-cleaning for samples and observe improvements in reproducibility for material in the 212-500 micron grainsize range.

Refining the Bulk: Ramped Pyrolysis Radiocarbon Dating Enhanced with Parallel Pyrolysis-GC-MS Analysis

Dr Catherine Ginnane[1], Dr Sebastian Naeher[1], Dr Jocelyn Turnbull[1,2], Mr Andy Phillips[1], Dr Albert Zondervan[1]
[1]GNS Science, Lower Hutt, New Zealand, [2]CIRES, University of Colorado at Boulder, Lower Hutt, New Zealand

Theme: T-5: Advances in sample preparation
Type of presentation: Invited Oral Presentation

Ramped pyrolysis oxidation accelerator mass spectrometry (RPO-AMS) has been recently established at the Rafter Radiocarbon Laboratory. This technique improves on bulk radiocarbon measurements for difficult-to-date sediments and soils, including Antarctic detrital sediment, where the depositional age is often obfuscated by the presence of reworked carbon associated with detrital sediment. By exploiting the thermochemical stability of distinct organic carbon pools present in a sample, younger, more labile authigenic carbon corroborating sediment deposition can be separated from older, more refractory components characteristic of detrital material. Radiocarbon measurements of these carbon fractions provide a more reliable chronology of deposition.

RPO-AMS presents a step change in radiocarbon measurement, providing an intermediate technique between bulk and compound-specific radiocarbon analysis. More accurate information is obtained relative to bulk sediment dating without the cost and major technical challenges associated with compound-specific radiocarbon dating. The traditional RPO-AMS technique requires radiocarbon measurement of multiple CO_2 aliquots obtained at a series of pyrolysis temperatures. The youngest age obtained from the series is assumed to be the limiting age representative of deposition. The requirement for multiple radiocarbon measurements can still be cost prohibitive for comprehensive downcore dating. As the limiting age predominantly coincides with the most labile, lower temperature fractions, it has become more common practice to conservatively date only the lower temperature aliquot(s) to obtain a depositional age.

In order to provide evidence to confirm this assumption that the lower temperature aliquots represent deposition, we have coupled ramped pyrolysis radiocarbon dating with pyrolysis-gas chromatography-mass spectrometry (Py-GC-MS) as a novel application for carbon source identification. The Py-GC-MS is configured to mimic the conditions of the RPO-AMS system, thereby identifying the compound classes present in each aliquot taken at equivalent temperatures and allowing discernment of the desired fractions indicative of deposition. For example, in early results, the presence of short chain n-alkanes indicated marine carbon deposition in more labile, low temperature fractions. Higher temperature aliquots were comprised of older, diagenetically stable aromatic carbon structures that skewed the bulk age from the depositional age.

By combining Py-GC-MS identification with RPO-AMS, the most suitable temperature aliquot comprised of carbon compounds representative of deposition can be selected for radiocarbon dating, thereby shortening run times and reducing measurement costs to achieve more reliable, substantiated comprehensive downcore chronologies.

The development of these RPO-AMS and Py-GC-MS techniques is particularly useful in ongoing climate change research where determining accurate sediment chronologies can elucidate interpretations of polar ice movement and carbon cycle dynamics. Comparisons of RPO-AMS measurements with bulk sediment radiocarbon measurements in the Antarctic has improved chronologies by several hundreds to thousands of years, thereby clarifying inconsistencies in the timing and mechanism of deglaciation events.

Re-treatment of Cervus elaphus bone material in Gliwice Radiocarbon Laboratory using ultrafiltration

Dr Fatima Pawełczyk[1], Professor Magdalena Niedziałkowska[2], Professor Sławomira Pawełczyk[1], Professor Natalia Piotrowska[1], PhD Student Maciej Sykut[2]
[1]Silesian University Of Technology, Institute of Physics, Gliwice, Poland, [2]Polish Academy of Sciences, Mammal Research Institute, Białowieża, Poland

Theme: T-5: Advances in sample preparation
Type of presentation: Poster

Preparation of bones for radiocarbon dating is still quite a challenge for researchers. The methods are being tested and improved, to obtain better and better results and to verify the previous ones. In this work, a set of collagen samples, extracted in 2018 from Cervus elaphus bones and antlers from various sites in Europe, was subjected to re-treatment using ultrafiltration in Gliwice Radiocarbon Laboratory. The samples tested had a wide range of ages, from older than 40 000 14C years BP to modern. The material prepared in this way was subjected to the measurement of C/N atomic ratios and radiocarbon dating using the AMS technique. Also, the stable isotopes (δ13C and δ15N) values were determined. A compilation of the obtained results is presented in this work.

Review of water DIC-14 analyses at HEKAL via a case study: sampling-storage-preparation

Anita Molnár[1], Róbert Janovics[2], László Palcsu[2], Virág Gergely[2], István Futó[2], Mihály Veres[1], Péter Molnár[3], János Országh[3], Dr Mihály Molnár[2]
[1]Isotoptech Zrt, Debrecen, Hungary, [2]INTERACT Centre, Institute for Nuclear Research , Debrecen, Hungary, [3]Public Limited Company for Radioactive Waste Management (PURAM), Pécs, Hungary

Theme: T-5: Advances in sample preparation
Type of presentation: Poster

Keywords: water, DIC, radiocarbon, storage, preparation

The aim of this study was to investigate the overall performance, stability and reliability of the applied water sampling, sample storage and preparation protocols for dissolved inorganic carbon (DIC) C-14 AMS analyses at HEKAL AMS Facility (Debrecen, Hungary). For this purpose we have selected a study site in Southern Hungary (Mecsek Mountains), where deep groundwater monitoring wells are operated routinely. Several different sampling methods, sample conservation techniques and storage conditions have been investigated on real groundwater samples. Some of the wells had rather old (<2 pMC) DIC and some of them had moderate C-14 age (10-20 pMC).
We have investigated the effect of adding sodium-iodine (KI) based conservation, the type/quality of the sampling bottles and their cups and different storage conditions. In the course of the test sampling/analyses, multiple parallel DIC samples were collected from 5 different monitoring wells. Some of the samples have got KI addition as a conservation step, others did not got any added chemicals during sample collection. Conservated and pure DIC samples were stored in refrigerator (at 12 C degree) between the sampling time and sample preparation for C-14 analyses, while a control group of the same samples were stored at room temperature. We have tested the stability of the samples by repeated DIC-14 analyses after 2 weeks and more than 1 month storage, for all type of samples. Some bottles have been opened twice, for the 1st and 2nd analyses, while others were kept closed for more than 1 month. Repeated DIC sampling and preparation from the same wells showed the internal reproducibility of the applied methods. Accidental leaking of the bottle cups were also studied, as a possible source of random error during sample storage. In this study we analyse all the observed effect and they potential on influencing the final DIC-14 results.
The research was supported by the European Union and the State of Hungary, co-financed by the European Regional Development Fund in the project of GINOP-2.3.4-15-2020-00007 “INTERACT”. Prepared with the professional support of the Doctoral Student Scholarship program of the co-operative doctoral program of the Ministry of Innovation and Technology financed from the National Research, Development and Innovation found. This work was carried out in the frame of a János Bolyai Research Scholarship (to Mihály Molnár) of the Hungarian Academy of Sciences.

Sample processing improvements for actinide analysis in low level samples

Mr David Child[1], Mr Robert Chisari[1], Dr Michael Hotchkis[1], Ms Archana Amatya Joshi[1]
[1]*ANSTO, Lucas Heights, Australia*

Theme: T-5: Advances in sample preparation
Type of presentation: Poster

A review of the performance statistics of actinides samples measured on the VEGA AMS facility at the Centre for Accelerator Science, ANSTO indicated that inadequate yield was being achieved on a particular subset of samples, namely plutonium isotopic measurements on chemistry blanks, and on low level “clean” low matrix samples (e.g. swipes and filters) when using our routine method [1]. Absolute yields of AMS targets are difficult to ascertain due to the use of isotopic dilution analysis since measurements yield only relative ratios, and variations in ion source output and ionisation efficiency between targets make it hard to compare absolute count rates. The measured count rates of plutonium isotopes in these samples however were routinely <50% of comparable calibration and tuning materials however leading us to conclude that there was a yield issue. Additionally, development was desired on a simplified processing method for multi-actinide extraction and isolation including U, Np, Pu and Am isotopes.

An investigation was conducted into the chemical loss of Pu in blanks and low matrix samples during processing as well as to determine the efficacy of a proposed multi-actinide extraction method. This investigation was able to successfully reproduce the systematic loss of Pu during ion-exchange extraction chromatography which was correlated to a lack of iron in the sample matrix and its utility as a redox agent for fixing Pu during separation. A revised sample processing method was then developed and tested, confirming an increase in Pu yield >90% for all sample types including blanks and low matrix materials using this revised method. This method employed a streamlined, single pass through utilising paired Eichrom UTEVA/TEVA pre-packed resin cartridges. Additionally >80% yield was achieved on a series of tests samples for U, Np, and Am tracers when employing this revised ion exchange separation method.

This revised method will be presented along with data demonstrating the improved performance of this method.

1. Johansen, M.P., et al., Differentiating Fukushima and Nagasaki plutonium from global fallout using ^{240}Pu/^{239}Pu atom ratios: Pu vs. Cs uptake and dose to biota. 2021. 754: p. 141890.

Significant loss of Be-10 from quartz previously treated for in-situ C-14 extraction

Dr Marcus Christl[1], Dr Olivia Steinemann[1], Prof Susan Ivy-Ochs[1]
[1] *ETH Zurich, Laboratory of Ion Beam Physics, Zurich, Switzerland*

Theme: T-5: Advances in sample preparation
Type of presentation: Poster

For the extraction of in-situ produced cosmogenic 14C from quartz with the ETH Zurich extraction line about 5 g of sample material are heated to 1650°C in an atmosphere of 200 mbar He (with 10% O2 and a defined amount of CO2 carrier gas) for three hours [1]. During routine operation of the in-situ 14C line the CRONUS A intercomparison material (ICM) is regularly processed and analyzed for 14C for quality control.

In this study we tested whether the residual quartz, i.e. the quartz sample after being processed in the in-situ 14C extraction line, still can be reliably analyzed for its 10Be content. Visual inspection of quartz samples after in situ 14C extraction indicates they are not fully melted. In our experiment, we extracted 10Be from two CRONUS A samples after they had been processed in the in-situ 14C extraction line, and from one untreated CRONUS A sample applying standard 10Be preparation methods. While the 10Be concentration measured in the untreated CRONUS A ICM agreed very well with the reported value of (3.42±0.10)x107 at/g [2] the two samples that had previously been processed in the in situ 14C extraction line yielded (1.22±0.20) x107 at/g and (2.95±0.40)x107 at/g, respectively.

Our results clearly indicate that some 10Be is lost during sample processing in the in-situ 14C extraction line. The variability of 10Be losses (14% and 65%) indicates that they do not occur under reproducible conditions. Attempts to find the missing 10Be in one of the cleaning columns further downstream in the in-situ 14C extraction line were not successful so far. We currently do not have a robust explanation for the observed behavior. We assume that not all Be is transferred to BeO (melting point >2500°C) while heating but some stays present as Be (melting point: 1287°C). Beryllium may escape as volatile compounds or as stray atoms that are volatilized coincidentally with other elements or compounds.

Further investigations are still ongoing but our results provide strong evidence that quartz samples previously processed for in-situ 14C extraction cannot be used for 10Be analysis any more due to an uncontrolled loss of 10Be before a 9Be carrier can be added. We note that this probably has a negligible effect on routine 10Be-target preparation procedures which involve a heating step to much lower temperatures (600-1000°C) when converting the Be-hydroxide into its oxide form. At this stage the samples are spiked with a 9Be carrier and their isotopic ratios would not be affected by any loss of Be.

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[2] F.M. Phillips et al., Quat. Geochron., 31 (2016) 119-154

Testing line for processing of dissolved inorganic carbon from water for radiocarbon dating determining the efficacy of trapping carbon dioxide for an automated system

Dr Bin Yang[1], Mr Alan Williams[2], Mr Tan Nguyen[1], Mr Simon Varley[1], Mr Peter Freeman[1]
[1]Australian Nuclear Science and Technology Organisation, New Illawarra Road, Lucas Heights, Australia,
[2]Deceased, ,

Theme: T-5: Advances in sample preparation
Type of presentation: Poster-Plus Presentation

ANSTO's radiocarbon capability experiences a high demand for processing groundwater samples for studies in water resource sustainability. Currently water samples are processed manually using extraction of DIC by acidification of the water and sparging with high purity helium gas (He), then cryogenic trapping of the CO_2 with recirculation of the He carrier gas to effect complete trapping of the CO_2. This method is based on that of McNichol et al. [1].
In order to increase our capacity to extract the dissolved inorganic carbon (DIC), we are developing an automated DIC extraction system. To develop this system and test that efficacy of redesigned traps to completely capture the CO_2 without recirculation of the carrier gas, a manual test DIC line was set up to sparge acidified water with He. This line operates at ambient pressure (1 bar) and is filled with He. CO_2 gas is recovered from 50ml of the water sample by adding 5ml of 85% of phosphoric acid inside a 250ml reaction vessel. The He carrier gas is sparged at a flow rate of 30ml/min and then passed through two water traps to remove water; and two CO_2 traps to collect CO2 gas. Complete recovery of CO_2 is determined by passing the He flow through a CO_2 analyser to verify there is no presence of residual CO_2 gas. By using a temperature controller which was designed in-house the temperature of both the water trap and the CO_2 trap can be adjusted from -170°C to -60°Cwhich optimises the trapping temperature. We found that the best trapping temperatures for H_2O and CO_2 are -110°C and -160°C, respectively. The CO_2 trapping efficiency of our system is over 99%, this was tested by trapping a CO_2/He gas mixture containing 1mg C of CO_2 gas. The CO_2 gas is then transferred into a storage vessel until all samples on the system are processed. The CO_2 is then manually transferred to break seals for purification of the CO_2 by heating to 600°C over CuO and Ag wire. The test line has also been tested with groundwater samples.
Based on the test, we are going to construct an automated DIC line in which all manual valves in the testing line will be replaced by automated valves to be controlled by computer. In addition, the water samples selector and circulation loop were designed by refer the report [2]. The system will enable the automated processing of 10 samples within 10 hours.
References:

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The “Lilliput” experimental set-up at INFN: state of art and future developments

Dr Serena Barone[1,2], Vera Bernardoni[3,4], Giulia Calzolai[1], Massimo Chiari[1], Federica Crova[3,4], Alice Forello[3,4], Lucia Liccioli[1], Franco Lucarelli[1,2], Silvia Nava[1,2], Gianluigi Valli[3,4], Roberta Vecchi[3,4], Mariaelena Fedi[1]

[1]Istituto Nazionale Di Fisica Nucleare, sezione di Firenze, Florence, Italy, [2]Università degli studi di Firenze, Florence, Italy, [3]Istituto Nazionale Di Fisica Nucleare, sezione di Milano, Milan, Italy, [4]Università degli Studi di Milano-Bicocca, Milan, Italy

Theme: T-5: Advances in sample preparation
Type of presentation: Oral Presentation

In the last few years, minimising the invasiveness of the analysis has been one the most relevant research topics in the field of radiocarbon, when it is applied both to Cultural Heritage and to environmental contexts. At INFN-LABEC in Florence, we built up a new experimental set-up, aiming at reducing the necessary mass of graphite for the 14C concentration measurement. Indeed, we are now able to deal with samples of few tens of µg of carbon, while the typical masses collected at the end of the “large” graphitization process are about 700 µg.

We installed new graphitization reactors, reducing their volumes to favour the graphitization reaction by increasing the collected pressure. New reactors were equipped with a small quartz tube used as the “hot” part and a silver cold finger. We also designed and assembled dedicated ovens and small Peltier-based devices, used to reach the temperature needed to trigger the reaction and to trap the unwanted water produced during the graphitization reaction, respectively. Moreover, we installed new miniature pressure gauges, sensitive to low pressures, and we assembled a home-made data acquisition system based on an Arduino board.

As far as the optimization of the AMS measurements in the Tandem accelerator, we performed “Lilliput” beam runs using different operating conditions, especially considering the sputtering ion source and the injection timings of the three carbon isotope masses into the accelerator tube.

The preliminary tests on the new “Lilliput” experimental set-up were successful and nowadays small. samples are routinely measured, especially in the field of Cultural Heritage, e.g. on charcoals, papyri and bone collagen collected from challenging contexts.

Our next goal is to assemble a new set-up at INFN Milan, specifically built for environmental analysis. This new set-up will allow us to reconstruct the emitting sources of the PM carbon fractions. This information is important to collect data on fossil fuel combustion, biomass burning, and natural contributions to the total burden of carbonaceous aerosol in the atmosphere so as to monitor their effects on health and environment.

10Be, 26Al, 36Cl, 41Ca and 129I Data Analysis at KIST

Dr John A Eliades[1]
[1]*Korea Institute of Science and Technology, Seoul, South Korea*

Theme: T-6: Data quality and management
Type of presentation: Oral Presentation

For AMS measurement, Be and Al are prepared in a form that is highly insulating (BeO and Al2O3), while AgI and AgCl compounds are volatile AMS targets. In order to increase cathode conductivity and stabilize (and in some cases increase) negative ion beam current production during sputtering, all of the materials are mixed with a second agent (ex. Ag powder) at KIST. This leads to some variability in quality, especially when end users with little or very intermittent experience prepare their own cathodes, or when sample material is very limited. Typical problems include unstable "spikey" cathodes that produce sudden bursts of large current during analysis and cathodes that do not produce current for the entirety of the analysis time. The AMS system can also experience intermittent instability during analysis, adversely affecting data quality if these data are included in the results. Considering that each cathode is analyzed for three, 10-minute "runs", with each run divided into twenty, 30 second "block" intervals (30 min total analysis time), data can still be salvaged if poor quality blocks are excluded.

The KIST 6MV AMS system manufacturer (HVE Europa) software produces a "result file" that summarizes the "run" data for all cathodes, automatically calculating average isotope ratios and uncertainties based on all runs recorded. The software also produces individual run "result" files that provide all data from each block of the measurement. This talk describes an internal Visual Basic program that is used to analyze the raw data from each result file. It uses the block data to determine if there was a spurious period in the data acquisition. As the rare radio-isotope produces only several to several thousand counts in 30 mins, the stable isotope beam currents (typically in the range 1 μA to 10 μA) are monitored for inter-block beam stability using both the high energy beam stability and the accelerator injection current to high energy current ratio stability. Inter-run Isotope ratio stability and other system conditions are also monitored. Finally, overall cathode current during the entire 30 min period is monitored. The program calculates averages and uncertainties both for the full set of data collected and for the data less flagged points, and provides the analyst with a quick graphical interface to plot data for visual inspection. Data flagging will be discussed, along with examples of data that have been discarded based on monitoring flags.

A Comparison of 14C/12C Data Quality Measured via Gas and Graphite Targets from an “off the shelf” MICADAS-AMS

Jennifer Walker[1], Brett Walker[1], Simon Fahrni[2], Xiaomei Xu[3]
[1]University of Ottawa, Ottawa, Canada, [2]Ionplus AG, Dietikon, Switzerland, [3]University of California Irvine, Irvine, United States

Theme: T-6: Data quality and management
Type of presentation: Poster

Comparisons of achievable graphite vs. gas ^{14}C accuracy and precision were reported >10 years ago from a prototype Mini Carbon Dating System (MICADAS) system (Wacker et al. 2010; Christl et al. 2013). Today, >30 MICADAS instruments have been produced with many improvements. This study evaluates the performance and precision of an “off the shelf” MICADAS, specifically for sample sizes <100 µgC. Modern carbon (MC) and dead carbon (DC) standards were combusted in large quantity (~4 mgC), cryogenically purified on a vacuum line, and split in size-series for gas and graphite measurements. Analyses were completed at Ionplus AG on a recently assembled MICADAS equipped with a hybrid Cs sputter source, Gas Interface System (GIS) and Elemental Analyzer (EA). Graphite was produced at UC Irvine using the small sealed-tube Zn method (Walker and Xu, 2019). Performance of the EA gas peripheral was assessed using standards weighed into pre-baked (300°C/2h) tin capsules. Background corrections were made following the methods of Santos et al. (2007).

Gas samples gave on average ~0.3 µA ^{12}C+/µgC (~7.5 µA maximum for >30 µgC). Each titanium cathode allowed 15 minutes of measurement time before exhaustion, with NIST Oxalic Acid I totaling 44,000 counts. The internal error of 30-50 µgC samples measured via EA or ampules was roughly equivalent (±6.3-7.3‰). However for 6-15 µgC gas samples, the ampule cracker outperformed EA analysis with an internal error of ±7.5-9.1‰ vs. ±10.2-19.9‰, respectively. Both methods had ~0.1 µgC of DC blank. However, the EA MC blank was >4x higher than the GIS cracker (0.4 µgC) due to the addition of tin carbon during sample encapsulation. The resulting propagated error on EA and ampule cracker ~5 µgC samples was ±32.3‰ and ±18.6‰, respectively.

Graphite sample currents averaged ~0.13 µA ^{12}C+/µgC, but had much higher maximum current yields (50 µA ^{12}C+ for samples >500 µgC). Due to longer analysis times and higher carbon ionization efficiency, total counts were much higher compared to gas. NIST Oxalic Acid I averaged ~2700 ^{14}C counts/µgC and full size samples (>500 µgC) totaled >1 x 10^6 counts within 45 minutes, without target exhaustion. The internal error for samples >150 µgC was ±1.5‰, while samples sizes of ~40, 10, and 5 µgC, had internal errors of ±3.1‰, ±5.1‰, and ±8.1‰ respectively, thus outperforming gas analyses. However, the estimated MC and DC blanks of 0.5 and 0.7 µgC, resulted in propagated errors of ±9.8‰, ±35.2‰ and ±80.1‰. Therefore, while graphite measurements allow for improved counting statistics, the multi-step graphitization procedure introduced more extraneous carbon, thereby decreasing achieved precision.

These tests show for sample sizes <50 µgC (assuming total extraneous carbon additions are ≤1 µgC) precision is controlled by the cleanliness of sample preparation, and not MICADAS measurement precision. Our presentation will discuss in more detail the balance between accuracy and precision, the need for size-matched standards and reducing uncertainties.

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A long-term performance assessment for AMS measurements at IUAC New Delhi

Dr Pankaj Kumar[1], Ms Deeksha Khandelwal[1], Ms Leema Saikia[1], Dr. Pavitra V. Kumar[1], Mr Rajveer Sharma[1], Mr. Sunil Ojha[1], Mr. Satinath Gargari[1], Dr. Sundeep Chopra[1]
[1]*Inter-university Accelerator Centre, New Delhi, India, , India*

Theme: T-6: Data quality and management
Type of presentation: Oral Presentation

A 500kV ion Accelerator based Accelerator Mass Spectrometer (AMS) system was established in 2015 at Inter-University Accelerator Centre (IUAC), New Delhi, India (14C Lab Code: IUACD) and is being extensively used routinely for 14C, 10Be and 26Al measurements. The AMS System is backed by three automated graphitization equipment (AGE), a carbonate handling system (CHS) in graphitization laboratory and appropriate clean laboratory for the chemical processing of samples in case of 10Be and 26Al measurements. In view of increasing demand, the facility is being more extensively used for 14C dating than other applications.

It is imperative to assess, monitor and establish the consistency of performance of AMS measurements over time since its inception. An attempt, therefore, has been made to evaluate the short- and long-term performance of 14C measurements with the AMS set-up at IUAC, New Delhi, in terms of reproducibility, accuracy, precision and calculation of random machine error (RME) in a routine laboratory environment using International Atomic Energy Agency (IAEA) secondary standards (C1-C9) and chemical blanks in each session. A comparison of the analytical figures of merit between short- & long-term usages of the AMS facility is presented through a rigorous statistical approach highlighting the importance of the measurements and evaluation of primary standards, secondary standards, blanks, and replicates in each of the experiments.

An analysis of a decade of radiocarbon secondary-standard AMS with two spectrometers

Prof. Stewart Freeman[1], Elaine Dunbar[1], Brian Tripney[1], Philippa Ascough[1], Derek Fabel[1], Pauline Gulliver[1], Cameron McIntyre[1], Philip Naysmith[1], Nicola Russell[1], Richard Shanks[1], Sheng Xu[1,2]
[1]Scottish Universities Environmental Research Centre, United Kingdom, [2]Tianjin University, China

Theme: T-6: Data quality and management
Type of presentation: Poster

Nearly 7000 individual graphite preparations of two radiocarbon international intercomparison materials have been measured on the SUERC tandem and single-stage accelerator mass spectrometers in the last ten years. The results are first and foremost used for quality control and quality assurance in routine random sample measurement, but given the power of the large dataset produced they can also be employed to elucidate subtle inter-spectrometer variance and longitudinal effects.

C-14 AMS data quality assessment: A key practice at the Rafter Radiocarbon Laboratory

Albert Zondervan[1], Jocelyn Turnbull[1], Cathy Ginnane[1], Margaret Norris[1], Rafter Radiocarbon Team[1]
[1]*GNS Science, New Zealand*

Theme: T-6: Data quality and management
Type of presentation: Poster-Plus Presentation

The Rafter Radiocarbon Laboratory, in operation since 1951, transitioned from decay counting to AMS in the second half of the 1980s. In the decades since, many improvements were made to sample preparation and carbon-isotope measurement techniques. The most significant of these were an upgrade of the Cs-sputter source (year = 1996) and the charging system of the tandem accelerator (2000), a shift to fast isotope-beam switching and new data acquisition system (2006), complete replacement of the AMS system (2010), introduction of elemental analysis for organic samples (2010), replacement of the graphitisation system (2012), CO_2 extraction from air for high-precision $\Delta^{14}C$ analysis (2012), development of high throughput capacity for modern tree ring samples via accelerated solvent extraction (2017), selective combustion of organics through ramped pyrolysis (2020), and establishment of pretreatment protocols for tiny macrofossil samples (2020). Development projects currently underway are adding a dedicated graphitisation system to facilitate more reliable preparation for < 0.3 mg C samples and an overhaul of vacuum pumping on all sample preparation lines.

Following a review in 2015 of mission-vision-values, the laboratory's main purpose is to support New Zealand geosciences research and international collaborations that benefit New Zealand society. In practice, this means that our focus is less on profitability (competition on price, fast turnaround analyses) and more on value with an emphasis on quality and promotion of laboratory involvement in research collaborations contributing to appropriate sample selection and laboratory methodology, suitable calibration, and interpretation of results.

Generally, our approach to data quality is (i) that the reported error on each C-14 analysis should capture all sources of uncertainty, not just the Poisson counting error, and (ii) that these must be quantified from repeated analyses in order to minimize the risk of bias, i.e. loss of accuracy. We tune XCAMS, our present AMS system, on a graphitisation blank and IAEA-C6 sucrose. Oxalic-acid-I remains our primary standard and every batch measurement on ≤ 40 cathodes contains at least 6 of those. We use a few key radiocarbon inter-comparison materials repeatedly, to ascertain deviations from and non-Poisson scatter around their consensus value. Their results (mean, variance) over a period of 6—12 months allow us to determine the residual, i.e. non-Poisson uncertainty, specific to each sample type and size.

IAEA-C1 carbonate is used to blank correct solid carbonate and dissolved inorganic carbon samples. Wood from a Kauri tree from a well-preserved fossil forest (MIS 7) is used for blank-correcting results on all organic samples according to preparation. No correction is applied for the machine blank as this is incorporated in the process blank corrections. Contamination of the surface of cathodes prepared from materials with $^{14}C/C < 10^{-14}$, presumably by absorption of ^{14}C-modern CO_2, is easily recognisable during data reduction. Blanks are characterised separately for samples < 0.3 mg C.

We will present results for all control materials, to highlight dependencies on date of preparation, preparation method, and sample size.

Determination of Iodine-129 in twenty soil and sediment reference materials

Dr Luyuan Zhang[1,2,3], Ms. Miao Fang[1], Mr. Tong Zhang[1,4], Ms. Huan Jiang[1,4], Dr. Mengting Zhang[1,4], Dr. Xiaolin Hou[1,2,3]

[1]State Key Laboratory of Loess and Quaternary Geology, Shaanxi Key Laboratory of Accelerator Mass Spectrometry Technology and Application, Xi'an AMS Center, Institute Of Earth Environment, Chinese Academy Of Sciences, Xi'an, China, [2]Center for Excellence in Quaternary Science and Global Change, Chinese Academy of Sciences, Xi'an, China, [3]Open Studio for Oceanic-Continental Climate and Environment Changes, Pilot National Laboratory for Marine Science and Technology (Qingdao), Qingdao, China, [4]Xi'an Institute for Innovative Earth Environment Research, Xi'an, China

Theme: T-6: Data quality and management
Type of presentation: Oral Presentation

^{129}I in soil and sediments are paid increasing attention for the purpose of environmental radioactivity monitoring, and understanding the historic nuclear activities and their impacts. Accurate measurement of ^{129}I is vital, which greatly increases the requirement of various certified reference materials (CRMs). However, only few CRMs with low level of ^{129}I are available for accurate determination of ^{129}I in samples remote from nuclear sites and facilities. Here, this work investigated the concentrations of ^{129}I and ^{127}I, and ^{129}I/^{127}I atomic ratios in twenty Chinese soil and sediment CRMs commercially available, as well as one in-house soil standard material (XASTD), with high-temperature pyrolysis combustion in coupling with ICP-MS and accelerator mass spectrometry (AMS) measurements. This study presents that ^{129}I concentrations in the twenty CRMs and one laboratory soil standard range from 0.31×10^6 atoms/g to 34.7×10^6 atoms/g, which were 1-4 orders of magnitude lower than those reference materials in use. For accurate measurement of ^{129}I, the effect of salinity content in the samples on iodine current intensity of AMS measurement is firstly discussed. Significant salinity effect could occur when high-salinity sample is analysed, which is mainly due to the formation of abundant strong oxidant during the pyrolysis process, resulting in iodine existing as iodate instead of iodide. And finally, an analytical procedure was recommended for the low- and high-salinity soil and sediment samples. In summary, these reported data of the CRMs and the laboratory in-house control soil standard material would broaden the group of available reference materials, be useful for method development of low-level ^{129}I samples, interlaboratory comparison and short- and long-term quality control, as well as extend ^{129}I applications in geological, environmental and nuclear sciences.

MAG-C63: a tree-ring standard for AD 1586

Dr Alex Bayliss[1], Dr Michael Dee, Mr Robert Howard, Dr Daniel Miles, Mrs Cathy Tyers, Dr Lukas Wacker
[1]*Historic England, , United Kingdom*

Theme: T-6: Data quality and management
Type of presentation: Poster

Standard materials are fundamental for accurate radiocarbon dating, but must be available in sufficient quantities for all AMS facilities worldwide to use as required.

MAG-C63 is a beam removed from the Great Tower at St Mary Magdalen College, Oxford during repair works in the 1960s. It is 20 feet long, by 12 inches square and weighs over a metric tonne. It has been securely dated by ring-width dendrochronology as spanning AD 1480-1609, and has been purchased in its entirety by Historic England.

The ring selected for use as a tree-ring standard is that for AD 1586. It is 2.76mm in diameter, and sufficiently close to the outside of the timber that dissection in quantity is feasible, yet far enough from the outside of the timber to minimise the potential for contamination.

Whole rings (earlywood and latewood) have been dissected by professional dendrochronologists, each sample being split across the ring so that it contains approximately equal amounts of earlywood and latewood. Each sample weighs approximately 50mg.

We estimate that MAG-C63 will supply 40,000 such samples. These will be made available to the community on a cost-recovery basis by Historic England over the coming years.

Status Report: A Decade of Traditional Radiocarbon Dating Applications by DirectAMS

Alyssa M Tate[1], Jonathan Heile[1], Dr. Jason Giacomo[2], Dr. Ugo Zoppi[1]
[1]DirectAMS, Bothell, United States, [2]University of California, Davis, Davis, United States

Theme: T-6: Data quality and management
Type of presentation: Oral Presentation

DirectAMS debuted as an affordable, high-throughput radiocarbon dating service at AMS-12 in 2011. A dedicated pretreatment laboratory has been in operation since 2012 in conjunction with an NEC 1.5SDH-1 Compact Pelletron Accelerator Mass Spectrometer installed in 2006. Over 60,000 14C radiocarbon dating targets have been measured over the last decade. The status of the laboratory and performance from routinely measured standards, reference, and blank materials are presented.

The design of the new radiocarbon intercomparison, GIRI

Prof. Marian Scott[1], Mr Philip Naysmith[2], Professor Gordon Cook[2]
[1]University Of Glasgow, United Kingdom, [2]SUERC, United Kingdom

Theme: T-6: Data quality and management
Type of presentation: Poster

Introduction

Given the complexity of the radiocarbon dating process, the diversity of materials being dated, the continued technical developments, GIRI (the Glasgow international radiocarbon intercomparison) is the next development of the series of inter-comparisons to support continuing quality assurance.

Methods

As a result of the needs to deliver accurate and precise measurements but also as part of general, good laboratory practice, including laboratory benchmarking and quality assurance, the 14C community has previously undertaken a wide-scale, far reaching and evolving programme of global inter-comparisons, to the benefit of laboratories and users alike (Scott et al, 2018). GIRI has been designed to continue this programme and to meet a number of objectives, including the most fundamental one, to provide an independent assessment of the analytical quality of the laboratory/measurement and an opportunity for a laboratory to participate and improve (if needed).
The principles that we followed in the creation of GIRI are to provide.

A) A series of unrelated individual samples, spanning the dating age range
B) Some linked samples to earlier inter-comparisons to allow traceability
C) Some known age samples, to allow independent accuracy checks
D) A small number of duplicates, to allow independent estimation of laboratory uncertainty
E) Two categories of samples, bulk and individual to support laboratory investigation of variability.

All of the GIRI samples are natural (wood, peat and grain), some are known age, and overall their age spans approx. >40,000BP to modern. Sample materials include: humic acid, whalebone, grain, some single ring dendro-dated samples, some wood samples spanning a number of rings (10 rings), and a background wood sample.

We have designed the study with two groups of samples. The first group is typical of the samples provided in previous intercomparisons, where the volume of material being provided is sufficient to make, at most, a very small number of repeat measurements. The second group of samples will provide a quantity of material, sufficient to allow AMS labs to run multiple measurements in different wheels/batches.
The purpose of including the first group of samples is to allow each laboratory to quality check (once consensus values and uncertainties have been defined) their laboratory operation at the time of analyses (so a classical round robin trial). The second group of samples provides laboratories with well-characterised materials which can function as secondary standards, to be run routinely and thus allow assessment of within-laboratory variability.

Results

Analysis of the GIRI results will have several strands. Ultimately, we wish to define consensus values for all the samples and a quantified uncertainty supporting a more in-depth evaluation of laboratory performance and variability.

Conclusions

The radiocarbon dating community inter-comparison programme has been running for more than 30 years and has evolved over time in line with the changing technology. This paper presents the most recent intercomparison (GIRI) and its design.

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A new AMS facility MILEA at the Nuclear Physics Institute in Řež, Czech Republic

Prof. Jan Kučera[1], Dr. Sascha Maxeiner[2], Dr. Arnold Müller[2,3], Assoc. Prof. Mojmír Němec[4], Prof. Jan John[4], Dr. Ivo Světlík[1], Dr. Dagmar Dreslerová[5], Dr. Jan Kameník[1], Dr. Kateřina Pachnerová-Brabcová[1], Dr. Josef Tecl[1], Joël Bourquin[2], Andreas Herrmann[2], Dr. Simon Fahrni[2]

[1]Nuclear Physics Institute of the Czech Academy of Sciences, Husinec-Řež, Czech Republic, Řež 130, Husinec-Řež, Czech Republic, [2]Ionplus AG, Dietikon, Switzerland, [3]ETH Zurich, Zurich, Switzerland, [4]Czech Technical University in Prague, Faculty of Nuclear Sciences and Physical Engineering, Prague, Switzerland, [5]Institute of Archaeology of the Czech Academy of Sciences,, Prague, Czech Republic

Theme: T-7: Facility Reports
Type of presentation: Poster

Introduction

Developments and applications of accelerator mass spectrometry (AMS) for determination of long-lived naturally occurring and man-made radionuclides at ultra-trace levels are continuously increasing. Simultaneously, new AMS systems are being designed, produced and installed. We briefly describe a new Multi-Isotope Low-Energy AMS (MILEA) system, which was developed in a collaboration of Ionplus AG and ETH Zurich, Switzerland. It combines the established ion source technology and the vacuum insulated accelerator of MICADAS (upgraded to 300 kV) with the well-proven concept of the high energy spectrometer layout of the ETH “TANDY” instrument. At the back-end, an improved low-noise ΔE-Eres gas ionization detector provides outstanding separation and identification of interfering particles.

Methods

Here, we report experience of the first installation of MILEA outside Switzerland for a newly established AMS laboratory within a consortium of the Nuclear Physics Institute (NPI) of the Czech Academy of Sciences (CAS), Faculty of Nuclear Sciences and Physical Engineering of the Czech Technical University in Prague and the Archaeological Institute Prague of CAS. This first Czech AMS laboratory is located at NPI, Řež. The consortium has been established to deal with a project “Ultra-trace isotope research in social and environmental studies using accelerator mass spectrometry”, acronym RAMSES. The presented MILEA system is designed but not limited to for determination of ^{10}Be, ^{14}C, ^{26}Al, ^{41}Ca, ^{129}I, U, Pu and other actinoides. The performance of this next generation multi-isotope AMS facility is given in terms of factory- and on-site acceptance tests for the radionuclides ^{10}Be, ^{14}C, ^{26}Al, ^{129}I, ^{236}, ^{233}U for most of the following parameters: transmissions from the injector to the detector, abundance sensitivity, a stable/radioisotope blank ratio, simple and overall sample scatter of the radioisotope/stable isotope ratios. In the acceptance tests, well known or in-house standards and blanks were used.

Results and discussion

All measured parameters satisfied the needs of RAMSES project and will be discussed in this paper.

Acknowledgement

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A new cosmogenic nuclide dating laboratory in CENIEH, Spain

Dr Toshiyuki Fujioka[1], Ms Leticia Miguens Rodríguez[1], Mr Javier Iglesias Cibanal[1], Dr Fernando Jiménez Barredo[1], Dr María Isabel Sarró Moreno[1], Prof Josep María Parés[1]

[1] *CENIEH, Burgos, Spain*

Theme: T-7: Facility Reports
Type of presentation: Poster

Centro Nacional de Investigación sobre la Evolución Humana (or National Research Centre on Human Evolution, CENIEH) is located in Burgos, northern Spain. The centre is dedicated to human evolution research worldwide, including Atapuerca, a world heritage archaeological site where the oldest human fossil in Europe to date have been discovered. To support the needs of characterising geological and sedimentological context of archaeological sites, the institute also features a wide range of geological analysis (e.g., Laser diffraction grain size analyser, XRD, XRF, Raman Spectroscopy, SEM, Micro CT, Digital mapping and 3D analysis) and geochronology laboratories (including palaeomagnetism, OSL, ESR and U-series). In 2020, a new cosmogenic nuclide dating research line has initiated to strengthen the existing geochronological capabilities in the centre, particularly, at timescales of early-mid Pleistocene and beyond. To date, we have established a procedure for routine quartz separation and ^{10}Be-^{26}Al extraction. Current projects include ^{10}Be-^{26}Al burial/isochron dating of cave deposits, fluvial terraces and artefacts in the context of archaeological and landscape evolution research. In this paper, we present a general setup of the laboratory, its capacity and current projects as well as future prospective.

Accelerator Mass Spectrometry at Purdue University PRIME Lab

Prof. Marc Caffee[1,2], Dr. Greg Chmiel[1], Dr. George Jackson[1], Prof. Darryl Granger[2], Prof. Nat Lifton[1,2], Dr. Lan Luo[1], Prof. Paul Muzikar[1], Dr. Thomas Woodruff[1]
[1]Department of Physics and Astronomy, Purdue University, West Lafayette, United States, [2]Department of Earth, Atmospheric, and Planetary Sciences, Purdue University, West Lafayette, United States

Theme: T-7: Facility Reports
Type of presentation: Poster

The Purdue Rare Isotope Measurement Laboratory (PRIME Lab) is a dedicated AMS research facility measuring ^{10}Be, ^{14}C, ^{26}Al, ^{36}Cl, ^{41}Ca, and ^{129}I. PRIME Lab is an NSF facility providing measurement and sample preparation services and expertise to the US NSF community. In addition to performing AMS measurements of the radionuclides ^{10}Be, ^{14}C, ^{26}Al, ^{36}Cl, and ^{129}I in terrestrial materials we provide chemical extraction techniques for these radionuclides. PRIME Lab measurements address many scientific issues, including polar ice sheet stability, landform evolution, solar activity, and human evolution. We also perform AMS measurements of extra-terrestrial materials for NASA researchers, obtaining cosmic ray exposure ages of meteorites and investigating lunar regolith processes. For extra-terrestrial samples we measure ^{10}Be, ^{26}Al, ^{36}Cl, and ^{41}Ca; we anticipate running ^{129}I in meteorites in the near future. We are looking forward to measuring radionuclides in Hayabusa and Osiris returned samples.

The PRIME Lab accelerator is an FN accelerator that has been upgraded with a pelletron charging system. The low-energy transport system has a high-intensity ion source for AMS; the sample changer is our own design and holds 64 cathodes. The high-energy transport system consists of an analysis magnet and a switching magnet. A Wien filter is between the analysis magnet and switching magnet. There are two AMS beam-lines: a 45° port (R45) off the switching magnet and a 30° port (R30) off the switching magnet. The R45 beamline has two Wien filters and a gas-filled-magnet (GFM) detector system. The R30 beamline has a 15° ESA and a dE/dx detector.

Be-10 (injected as BeO-), ^{14}C (C-), ^{26}Al (AlO-), ^{36}Cl (Cl-), and ^{41}Ca (CaF-) are all measured using the GFM system on the R45 beamline. Iodine-129 (I-) measurements are made on the R30, although we occasionally measure ^{14}C (+3) on this beamline. Pure gas stripping is used for Be charge state (+3) and I (+5) and foils are used for Al (+7), Cl (+8), and Ca (+8). We are currently experimenting with combined gas/foil stripping for Al. Preliminary measurements indicate a higher transmission.

Much of our recent work has focused on continued improvements in ^{26}Al measurements. The GFM has produced substantial improvements in ^{26}Al measurement precision. Before the GFM we injected Al- and typical currents were .5 to 2 μA. With the GFM we now inject AlO-, MgO- is also injected but the GFM suppresses Mg in the detector. The Al currents measured at the high-energy cup are variable, but range from 5 to 15 μA. We have also made improvements for Al in the ion source. Using Nb as a binder for Al cathodes results in less ion source memory; typical backgrounds are < .5 x 10^{-15}. We are also experimenting with gas plus foil stripping for Al; preliminary measurements indicate increased yield. The GFM has enabled measurements of ^{26}Al that were previously not possible some years ago, it is likely that additional development will produce additional improvements.

This work has been funded primarily by NSF and NASA.

Actinides AMS Sample Processing Capability at ANSTO – A tour by poster

Mr David Child[1], Dr M.A.C. Hotchkis[1]
[1]*ANSTO, Lucas Heights, Australia*

Theme: T-7: Facility Reports
Type of presentation: Poster

Designing and developing sample processing facilities for processing of samples for actinides analysis poses some unique challenges. Facilities for actinide research need to be tailored to specific application areas, sample composition for each area of research may contain isotopic ratio mixtures and isotopic concentrations incompatible with the sensitivity requirements and background/blank levels of adjacent projects. This is due to the widely varying sample compositions related to the source of the actinides, for example age dating of nuclear materials compared to safeguards analysis of uncontaminated swipe samples.

The Actinides AMS capability at ANSTO's Centre for Accelerator Science is operated by a small research group focussed on providing support for government, academic and industry users, and stakeholder projects. These facilities have been designed with versatility in mind, specialising on provision of high sensitivity analyses for low activity samples and projects to support the greatest breadth of applications.

The current range of research applications supported include:
Environmental occurrence and distribution of anthropogenic actinides
- Actinides bomb pulse dating and tracing – geomorphology
- Radioecology - biological uptake of nuclear activities environmental release

Non-proliferation and monitoring
- Nuclear Safeguards – swipe sample monitoring and wide area environmental sampling
- Nuclear Forensics - nuclear material characterisation and dating
- Environmental monitoring – emergency response, contamination monitoring, baseline studies

Actinides from astrophysical events

The Actinides AMS chemistry laboratory has been purpose built for low level environmental actinides sample preparation, in particular for high sensitivity low abundance actinides isotope (^{233}U, ^{236}U, ^{239}Pu, ^{240}Pu, ^{241}Pu, ^{244}Pu), allowing for segregation of "dirty" operations (unpacking and handling of dried environmental materials) to progressively cleaner environments whilst still allowing for aggressive sample destruction and dissolution. To achieve this a range of specialised sample preparation components and configurations have been employed to allow for a wide range of sample types (swipes/filters, soils/sediments, biota, water, minerals) with elimination of possibility of sample crosstalk, dust and external atmospheric ingress and contamination. This is especially important given the potential for high dynamic ranges of isotopic concentrations between consecutively handled research projects.

To support research applications unable to be handled in the AMS Actinides laboratory, partnered facilities with capability to process active materials are utilised to pre-treat samples and deliver subsamples suitable for handling in the low-level AMS laboratories.
We present here the methodologies, processes and backgrounds achieved to deliver high sensitivity actinide samples for a range of applications and give the current status of the Actinides AMS capability.

ANU SSAMS Update 2021

Prof. Stewart Fallon[1], Dr Rachel Wood[1], Ms Rebecca Esmay[1], Mr Eric Usher[1]
[1]*The Australian National University, Canberra, Australia*

Theme: T-7: Facility Reports
Type of presentation: Poster

The NEC Single Stage Accelerator Mass Spectrometer at the Research School of Earth Sciences, Australian National University was installed in January 2007. Over the years many modifications have been performed. For example, a newly designed extractor lens, helium stripping and increased vacuum pumping. This presentation highlights the changes to the NEC SSAMS over the past 14 years highlighting increases in transmission, a discussion of instrumental background, online d13C measurement and sample throughput.

ASTER report status and upgrades.

M. Karim Keddadouche[1], **Dr Régis Braucher[1]**, Mr. Georges Aumaître[1], Dr. Vincent Godard[1]

[1] *CEREGE, CNRS, Collège de France, IRD, INRAE, Aix Marseille Univ., Aix-en-Provence, France*

Theme: T-7: Facility Reports
Type of presentation: Poster

ASTER (CEREGE, Aix en Provence, France) is a HVEE 5MV AMS in operation since 2007 within the LN2C (Laboratoire National de Nucléides Cosmogéniques, French national facility for cosmogenic nuclides). ASTER measures in routine around five thousand samples per year dispatched between ^{10} Be, ^{36} Cl and ^{26} Al. Initially delivered with the HVEE SO-110B, ASTER has been upgraded in 2016 with the SO-110-C head source slightly increasing the output currents for ^{27} Al- and ^{9} BeO-. This source is now used for all ^{10} Be and ^{26} Al measurements while the previous source is dedicated to ^{36} Cl. We will present several tests and performances of the SO-110-C and how it is operated to ensure high quality routine measurements (high level and stable current) with a minimum cleaning procedure.

In December 2019, a new line incorporating a gas-filled magnet was installed. Despite the progress made by the new source, this upgrade will be used to further improve the overall efficiency of ^{26} Al measurements by producing at least an order of magnitude higher negative ion beam in the ion source by injecting AlO- rather than Al-. Since the isobaric interfering MgO- is also produced, separation of these isobars becomes imperative. This new beamline thus endowed a multi-anode gas ionization chamber (GIC) and a 120 degrees (450 mm radius) gas-filled magnet (GFM) to reduce the initial intensity of Mg combined to realize this preliminary test. Due to the pandemic situation this extension is still under development but preliminary tests will be presented.

We would like to dedicate this work to our late colleague and friend Didier Bourlès († 26/04/1955 – 01/03/2021).

Automated induction heating of quartz for in situ cosmogenic 14C measurements

Miss Cody Paige[1], Dr. John Gosse[1], Mr. Jim Wilson[2], Dr. Liam Kiesler[3], Dr. Maarten Lupker[4]
[1]Dalhousie University, Halifax, Canada, [2]Aeon Laboratories, Tuscon, USA, [3]A. E. Lalonde Laboratory, Ottawa, Canada, [4]ETH Zurich, Zurich, Switzerland

Theme: T-7: Facility Reports
Type of presentation: Poster-Plus Presentation

A new C-14 extraction line laboratory at Dalhousie University (DCELL) builds on recent innovations from other labs and introduces two additional features to improve process blank levels and reproducibility. DCELL is an automated, ultra-high vacuum stainless steel extraction system that uses induction heating to extract C-14 from quartz. A 10-kW induction furnace is used to heat cleaned fine quartz sand in one or more platinum tubes within a sapphire combustion chamber so that masses >5 g may be possible. Heating is controlled with two system-integrated pyrometers with overlapping temperature ranges (200-1500°C and 800-2300°C). The pyrometers are safely positioned 30 cm from the induction coil for an off-axis sensing with a radius of ~2 mm on the surface of the tubes. Tests with different platinum boat geometries inside a test sapphire tube (ID 3 cm) appear to suggest that Pt-tubes are optimal. Safe ramp speeds of 50°C/s and platinum boat surface temperatures of >1600°C were achieved (STP, no quartz) with less than 25% of available power. While tests are required to verify the complete transformation of quartz to cristobalite for carbon diffusion from the quartz, DCELL may be able to achieve the complete extraction in less than 1 hour at temperatures above the commonly cited 1650°C threshold. The released gasses are purified to CO2 using an automated process through a stainless steel line which uses only metallic fittings (no carbon-bearing seals, only copper gaskets in conflat fittings and copper tips in the pneumatically operated valves). Liquid nitrogen variable temperature traps, an optional quartz bead heater, an Ag-Cu furnace, and helical LN trap are all automated, and system parameters are logged during the complete run. We will report results of induction furnace experiments to determine if there is any real improvement in sample throughput rate, process blank, and experiment reproducibility.

Efficient radiocarbon measurements on marine and terrestrial samples with a single stage Accelerator Mass Spectrometry at the Atmosphere and Ocean Research Institute, University of Tokyo

Prof. Yusuke Yokoyama[1], Dr Yosuke Miyairi[1], Dr Takahiro Aze[1], Dr Chikako Sawada[1], Ms Yuka Ando[1], Ms Satomi Izawa[1], Ms. Yoshiko Ueno[1], Dr Shoko Hirabayashi[1], Dr Naoto Fukuyo[1], Mr Kosuke Ota[1], Mr Yusuke Shimizu[1], Ms. Yuning Zeng[1], Mr Ren Tsuneoka[1], Ms. Kozue Ando[1], Professor Toshi Nagata[1]

[1]*Atmosphere And Ocean Research Institute, The University Of Tokyo, , Japan*

Theme: T-7: Facility Reports
Type of presentation: Poster

Nine years anniversary has just past in August 2021 since the first scientific measurement with a single stage Accelerator Mass Spectrometry (National Electrostatic Corporation, YS-AMS) at the Atmosphere and Ocean Research Institute (AORI), University of Tokyo in 2013 was conducted. Stable running conditions has been maintained and the average annual operation hours is reached 7732 hours/year for the last five years that allowed us to measure as much as 2912 samples/year (excluding numbers of standard samples). Newly developed inhouse automated vacuum line, auto-weighing system, and auto-target pressing system have increased the numbers of sample throughput dramatically and measured samples in total excluding standards have reached 14,000 to date. Precision for 14C/12C measurements on standard samples are reached better than 0.1 % due to improvement of operation software system as well as increased numbers of measurement of standards per run.

Other in house developed apparatuses including the flowcytometry based pollen purification system and in-situ produced 14C extraction system from quartz enable us to measure various range of samples from marine and terrestrial environments with the size from several microgram to milligram of carbon.

Facility Report : ANSTO's 6 MV NEC SIRIUS accelerator – an update since AMS 14 Ottawa.

Prof. David Fink[1], Dr Reka Fulop[1], Dr Toshiyuki Fujioka[2], Mr Steve Kotevski[1], Ms Krista Simon[1], Dr Klaus Wilcken[1]
[1]Ansto, , Australia, [2]CENIEH , , Spain

Theme: T-7: Facility Reports
Type of presentation: Poster

ANSTO's SIRIUS tandem accelerator is a customised 6 MV tandem accelerator manufactured by NEC and commissioned in 2015. It is a shared AMS and IBA instrument described in detail in Pastuovic et al (2015). Initial AMS performance data for cosmogenic isotopes 10Be, 26Al and 36Cl was presented at the Ottawa AMS14 Conference (Wilcken et al 2019).
The AMS spectrometer consists of a 134 sample-wheel MC-SNICS Cs sputter source, a 45-degree spherical ESA (R=300 mm) and a double focusing insulated injection magnet (R=1000 mm, ME=20, vacuum gap = 70 mm). Two stripper gases (typically Ar and He) and thin foils are selectable in the terminal, and the selected charge state is focussed by an in tank electrostatic quadruple triplet positioned in the high energy column section. The high-energy section consists of two identical ME=176 analysing magnets (R=1270 mm) feeding two independent beam line transport systems, one for AMS and the other IBA. The AMS setup includes a post-stripper or energy degrader ladder, a 45-degree spherical ESA (R=3810 mm, gap = 30mm) and two magnetic quadrupoles. A choice of 3 AMS beam lines selectable by a ±30 degree switcher magnet provides options for dedicated radionuclide detection of 10Be (absorber cell), 36Cl and 26Al (multi-anode ionization counter), and an 8 m long TOF setup for future 129I and U-isotope measurements.

A suite of sample geochemistry preparation laboratories, including a dedicated laboratory for preparation of in-situ 14C samples (Fulop et al 2019) and an ice-core storage facility, provide AMS targets of 10Be (meteoric), 10Be, 26Al 14C and 36Cl (in-situ). The cosmogenic chemistry extraction laboratories host many visiting students and researchers to prepare samples and participate in AMS measurements. A wide variety of earth science applications in landscape evolution, sediment transport, tectonics, polar ice sheet stability, Quaternary geochronology supporting paleoclimate research change, solar variability and archaeology are supported. Ancillary facilities at ANSTO provide high precision elemental analyses (eg 9Be and 27Al) using a variety of techniques (ICP-OES, ICP-MS, AA, SEM, and XRF).

We present details of recent data on routine AMS accelerator performance, reproducibility and linearity with various AMS standards, transmission, sample throughput, background reduction, and some improvements in sample chemistry methods .

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Improvements for ultra-microscale radiocarbon measurements at NIES-TERRA

Dr Masao Uchida[1], Kanako Mantoku[1], Toshiyuki Kobayashi[1]
[1]*Earth system division, National Institute For Environmental Studies, Tsukuba, Japan*

Theme: T-7: Facility Reports
Type of presentation: Poster

In our AMS facility (NIES-TERRA), the NEC 5MV tandem Pelletron AMS (15SDH-2) have been used for various environmental studies since 1996. For past 10 years, we have made improvements such as installation of a type of MC-SNICS II ionizer, reconstruction of beam lines and exchanges of related electric instruments . With this renovation, we have developed method for ultra-microscale radiocarbon analysis with development of new graphitization systems and their improved protocol. In this conference, we report validations of ultra-microscale radiocarbon measurements to 1 μgC in improved AMS system and newly developed preparation methods.

Introduction of Interactive Remote Monitoring at SUERC

Dr Brian Tripney[1], Mr Andrew Tait[1]
[1] *Scottish Universities Environmental Research Centre (SUERC), East Kilbride, United Kingdom*

Theme: T-7: Facility Reports
Type of presentation: Poster

SUERC has implemented remote control of routine and experimental NEC spectrometer operations. Through secure tunnelling, a dedicated laptop for each spectrometer can execute parts of the AccelNET suite and communicate remotely with the underlying database: instrument control pages are accessible and changes to the run list can be effected in DMAN. X-forwarding facilitates the use of abc for data reduction upon the large remote dataset, allowing the operator to evaluate data quality mid-run, while screen-sharing is employed to provide flexible access options. AccelNET's read-only html output (formerly the predominate form of remote monitoring) remains accessible for 'casual' progress checking by non-operators.

While there are limitations to each technology used, these changes to our setup and operating procedures have had positive effects both for operators, and upon the smooth delivery of sample data.

LEMA FACILITY IN THE DETERMINATION OF METEORIC 10Be

Dr Carmen Grisel Méndez García[2], Dr Santiago Padilla[1], Dr Corina Solís[1], Dr Efraín Chávez[1], Gerardo Rojas[1], M.C Karen Gaitán De Los Ríos[1], Dr. Luis Acosta[1]
[1]National Autonomous University Of Mexico, Coyoacán, Mexico, [2]National Council for Science and Technology, Benito Juárez, Mexico

Theme: T-7: Facility Reports
Type of presentation: Poster

The National Laboratory of Mass Spectrometry (LEMA for its acronym in Spanish) is an AMS facility inaugurated in 2013. It is based on a 1 MV High Voltage Europe Engineering isotope separator. Since its foundation, LEMA has carried out numerous analyses in the study of 14C, which has been mainly used to date geological and archeological samples.
More recently, a significant effort has been made to open new lines of research.
The AMS system at LEMA has been optimized to measure the cosmogenic radionuclide 10Be. Several radiochemical procedures of extraction of this radionuclide have been analyzed and improved in different samples.
10Be is a cosmogenic radionuclide produced by spallation reactions between high-energy cosmic radiation and some atmosphere elements, mainly nitrogen and oxygen. Its long half-life (T1/2=1.39×106 y) makes it an element of great interest in environmental and geophysical sciences studies

The studies of meteoric 10Be have been applied extensively to many different systems in the last decades. Its study in rain waters, surface firns, ice cores, and particulate matter samples provides essential information about its production and distribution in the atmosphere. It can also be used as a tracer of climatic events. For example, meteoric 10Be associated with the aerosols can be used as a tracer of interactions in the lower Stratosphere, upper Troposphere, the air exchange between both atmospheric layers, and the deposition processes of Earth surface.

The information obtained from the analysis of the meteoric 10Be production is a powerful tool to increase the knowledge about past environmental and climatic changes due to being able to be used as tracer operating over time scales up to 107 years.

In this work, the preliminary results of the meteoric 10Be in particulate matter, rain, and snow samples, as well as the characterization of the process of extraction and measurement of this radioisotope with the AMS technique at the LEMA, Mexico facility, are presented.

Performance for Low Energy AMS measurement of 10Be at Tianjin University

Dr Kejun Dong, Prof. Yunchao Lang, Prof. Sheng Xu
[1]*Institute of Surface Earth System Science, School of Earth System Science, Tianjin University, Tianjin, China*

Theme: T-7: Facility Reports
Type of presentation: Poster

The AMS system with a nominal voltage value of 500 kV at Tianjin University was installed in 2017. The facility is now in routine operations after the initial testing and commissioning phase. As the most challenging nuclide, 10Be has completed the measurement and analysis of more than 500 samples from different scientific fields. However, the measurement method of ^{10} Be has to be optimized and developed due to the accelerator terminal voltage must be operated at the maximum limit value of 600 kV for each experiment. As a result, a series of measures have been taken in order to further optimize the ^{10} Be measurement method and reduce the risk to the equipment during the experiment. In this contribution, the experimental setup and corresponding performance improvements will be briefly introduced.

Present status of the YU-AMS system and its operation over the past 10 years

Dr Mirei Takeyama[1], Mr Toru Moriya[1], Dr Hisako Saitoh[2], Dr Hiroko Miyahara[3], Dr Motonari Ohyama[4], Dr Hirohisa Sakurai[5], Dr Fuyuki Tokanai[1,5]

[1]Center for Accelerator Mass Spectrometry, Yamagata University, Kaminoyama, Japan, [2]Department of Legal Medicine, Graduate School of Medicine, Chiba University, Chiba, Japan, [3]Humanities and Sciences / Museum Careers, Musashino Art University, Kodaira, Japan, [4]Botanical Gardens, Tohoku University, Sendai, Japan, [5]Faculty of Science, Yamagata University, Yamagata, Japan

Theme: T-7: Facility Reports
Type of presentation: Poster

In 2009, Yamagata University (YU) installed a compact ^{14} C accelerator mass spectrometry (YU-AMS) system and an automated graphitization line (AGL I) in Yamagata Research Institute located in Kaminoyama City. The AMS system is based on a 0.5 MV Pelletron accelerator (CAMS) developed by National Electrostatics Corporation. This AMS system was the first AMS system installed in a university in northern Japan (Tohoku–Hokkaido region). In March 2014, a second automated graphitization line (AGL II) and a second ion source on the AMS system were installed. AGL II consists of an elemental analyzer (EA, Vario MICRO cube, Elementar) and a glass vacuum line. It has the same graphitization process as the previously installed AGL I except for the procedure of stable isotope ratio mass spectrometer (IRMS) measurement. The AGL works as follows. A sample whose ^{14} C content is to be measured is packed in a tin capsule. The packed sample is then set in the autosampler in EA, where it is automatically combusted at 1150 °C. In this process, N_2 , O_2 , and CO_2 are generated. The CO_2 gas is transferred to a cryogenic CO_2 -trapping system, consisting of 20 identical glass lines. The trapped CO_2 is finally reduced to graphite at 630 °C using hydrogen and an iron powder catalyst. The collection of CO_2 and the addition of H_2 used for CO_2 reduction are automatically conducted. An additional ion source can be used for subsequent measurement by setting samples in a chamber and evacuating the chamber while the other source is being used for AMS measurement. Hence, this system can shorten the total measurement time.

Approximately 2,000 samples are measured per year using the system. The facility is capable of treating more than 3,000 samples per year. The samples most commonly measured using the YU-AMS system over the last 10 years (2010–2020) were wood (~70%). The second and third most commonly measured samples were charcoal and soil, respectively, which were mainly extracted from historical remains. The long-term stability of the YU-AMS system has been routinely assessed by measuring the IAEA-C7 standard sample. The average ^{14} C activity for IAEA-C7 measured using the system is 49.52 ± 0.11 pMC (percent modern carbon), which is in good agreement with the consensus value of 49.53 ± 0.12 pMC. Using the YU-AMS system, we have been carrying out studies in various fields such as archaeology, environmental science, geology, and space and earth sciences. Recently, we have also been expanding our research into the field of forensic medicine. In this conference, we will report on the present status of the YU-AMS system and its operation over the past 10 years.

Real-world long-term performance of the MICADAS-type AMS system at CEZA

Dr Ronny Friedrich[1], Dr Susanne Lindauer[1], Robin van Gyseghem[1], Elena Dimitrakopoulos[1], Matthias Hänisch[1], Dr. Bernd Kromer[1]
[1]*Curt-Engelhorn-Center Archaeometry, Mannheim, Germany*

Theme: T-7: Facility Reports
Type of presentation: Poster

The Curt-Engelhorn-Center Archaeometry (CEZA) located in Mannheim, Germany has been operating a MICADAS-type AMS system for 12 years. The main applications are focused towards archeological science but also climate and environmental research are part of the scientific issues investigate with 14C there. Back then this system was the first commercially available MICADAS for radiocarbon-dating applications. Here we present the full record of all quality control standards displaying the stability and performance of the AMS system over the entire period of operation. We will also provide insights into the routine operation and reliability of the system.

Status report of JAEA-AMS-TONO: research and technical development in the last four years

Dr Yoko Saito-Kokubu[1], Dr Natsuko Fujita[1], Dr Takahiro Watanabe[1], Dr Akihiro Matsubara[1], Ms Chika Ishizaka[1], Mr Masayasu Miyake[2], Mr Tomohiro Nishio[2], Mr Motohisa Kato[2], Ms Yumi Ogawa[2], Mr Masahiro Ishii[3], Dr Kenji Kimura[1], Mr Akiomi Shimada[1], Mr Nobuhisa Ogata[1]
[1]Japan Atomic Energy Agency, Toki, Gifu, Japan, [2]PESCO Co., Ltd., Toki, Gifu, Japan, [3]Beam Operation Co., Ltd., Takasaki, Gunma, Japan

Theme: T-7: Facility Reports
Type of presentation: Poster

The JAEA-AMS-TONO facility at the Tono Geoscience Center, Japan Atomic Energy Agency has an accelerator mass spectrometer (JAEA-AMS-TONO-5MV) with a 5 MV Pelletron™ accelerator (15SDH-2, National Electrostatics Corp., US). The JAEA-AMS-TONO-5MV has been used to measure radiocarbon (^{14}C) in geological samples since the installation at 1997 . In this past decade, the spectrometer enabled us to use a multi-nuclide AMS of ^{14}C, beryllium-10, aluminium-26 and iodine-129, and we have recently been proceeding test measurement of chlorine-36. In-house projects mainly utilize the spectrometer to determine the age of geological samples in studies into long-term geological stability as a basic research and development related to the geological disposal of high-level radioactive waste. In addition, the spectrometer is also available to the JAEA's common-use facility program, which is shared use of the AMS for researchers belonging to other research organizations. In response to an increase of samples, we installed a state-of-the-art multi-nuclide AMS with a 300 kV Tandetron™ accelerator (4103Bo-AMS, High Voltage Engineering, Europa B.V., Netherlands) in 2020. Recently, we are driving the development of techniques of isobar separation in AMS and of sample preparation. Ion channeling is applied to remove isobaric interference and we are building a prototype AMS based on this technique for downsizing of AMS. The small sample graphitization for ^{14}C has been attempted using an automated graphitization equipment (AGE3, Ionplus, Switzerland) equipped with an elemental analyzer (Vario Micro cube, Elementar Analysensysteme GmbH, Germany) .

Status report of the Radiocarbon and Mass Spectrometry Laboratory in Gliwice, Poland

A/Prof. Natalia Piotrowska[1], Dr Marzena Kłusek[1], A/Prof. Danuta J. Michczyńska[1], A/Prof. Adam Michczyński[1], Dr Fatima Pawełczyk, A/Prof. Sławomira Pawełczyk, Dr Jacek Pawlyta[1], A/Prof. Andrzej Rakowski[1], A/Prof. Barbara Sensuła[1], Dr Konrad Tudyka[1]

[1]*Silesian University of Technology, Institute of Physics-CSE, Division of Environmental Isotopes, Gliwice, Poland*

The Gliwice Radiocarbon Laboratory was established in 1967 by Prof. Włodzimierz Mościcki, a pioneer in the ^{14}C measurements with gas proportional counters. Since then, the unit instantly developed and at present is officially distinguished in the University structure as the Radiocarbon and Mass Spectrometry Laboratory, a part of the Division of Environmental Isotopes at the Institute of Physics – Centre for Science and Education. Another unit within the Division is a Luminescence Dating Laboratory, and both lab teams naturally cooperate to solve scientific questions in various disciplines: Earth and environmental sciences, physics, and archaeology. The present human potential of the Laboratory are 12 permanent employees, including 9 persons in the scientific positions and 3 technicians.

The equipment of Laboratory fills the space area of ca. 400 m². Fully furnished chemical preparation rooms are equipped with fume boards, water demineralisers, analytical and micro- balances, ultrasonic baths, lyophiliser, microscope etc.
Most important equipment is:
1. AMS Laboratory (responsible: Natalia Piotrowska):
-Automated graphitisation equipment AGE-3 (IonPlus AG)
-VarioMicro EA for combustion of organic samples
-Manual tube cracker for CO_2 introduction
-Vacuum line for carbonate decomposition and CO_2 purification
-AMS MICADAS (IonPlus AG) spectrometer scheduled to be installed in 1st quarter of 2022

2. LSC Laboratory (responsible: Adam Michczyński):
-Two Quantulus 1220 spectrometers
-Two ICELS spectrometers
-Prototype multi-chamber scintillation spectrometer for rapid measurements of low radioactivities
-Vacuum lines for sample combustion and conversion to benzene
-Oxygen-flow line with two ovens: two-zone oven Czylok PRS-50, infra-red oven Behr IRF-10 for stepped-combustion

3. Mass Spectrometry Laboratory (responsible: Jacek Pawlyta):
-Continuous-flow IRMS IsoPrime for HCNO isotope composition determination
-Elemental analyser EuroVector EA3000 for analysis of solid samples with combustion or pyrolysis
-MultiFlow device for preparation of water and carbonate samples

In addition, the field sampling equipment is available: Wardenaar and Russian (instorf) coring devices for sediment sampling and drills for tree-ring coring. The LINTAB equipment for tree-ring width measurement was recently upgraded with a new microscope.

At present state the Radiocarbon and Mass Spectrometry Laboratory carries out yearly ca. 400 radiocarbon dates and a similar number of stable isotope determinations, for the research projects in cooperation with national and international teams and external orders.
Most important projects carried out in the Laboratory:
1) Centre for Isotope Methods CEMIZ (designed to AMS spectrometer installation); leader: Natalia Piotrowska
2) Laboratory for Research and Analysis of Working Conditions of Industrial Professions; leader: Adam Michczyński
3) Archives of Spatial and Temporal Evolution of environmental Contamination related to mining and smelting activities in Upper Silesia, Poland; leader: Jarosław Sikorski
4) Abrupt increase of radiocarbon concentration due to high Sun activities in VIII and X century AD based on measurements in annual tree rings; leader: Andrzej Z. Rakowski
5) Chronology of the Inca expansion in Cordillera de Vilcabamba (Peru); leader: Andrzej Z. Rakowski
6) Multi-proxy investigations and advanced methods of determining numerical time scales in the reconstruction of the evolution of inland dunes in Poland during the end of the last glaciation; leader: Piotr Moska
7) Smaller research and commercial projects: ca 30/year

Status report of the Tsukuba 6 MV multi-nuclide AMS system: Progress in iodine-129 AMS

Ms Masumi Matsumura[1], Dr Kimikazu Sasa[1], Dr Aya Sakaguchi[1], Dr Tetsuya Matsunaka[2], Mr Tsutomu Takahashi[1], Prof Keisuke Sueki[1]

[1]University Of Tsukuba, Tsukuba, Japan, [2]Kanazawa University, Kanazawa, Japan

Theme: T-7: Facility Reports
Type of presentation: Poster

The 6 MV Pelletron tandem accelerator (model 18SDH-2 Pelletron, NEC, USA) has been utilized for various researches at the University of Tsukuba, Tandem Accelerator Complex (UTTAC) since 2016 (K. Sasa et al., 2015). The rare-particle detection system on the 6 MV Pelletron tandem accelerator (Tsukuba 6 MV multi-nuclide AMS system) was developed for high-sensitivity detections of ^{10}Be, ^{14}C, ^{26}Al, ^{36}Cl, ^{41}Ca, and ^{129}I (K. Sasa et al., 2018), and also expected to measure other radioisotopes such as ^{90}Sr (K. Sasa, et al., 2021). The background of the system for isotopic ratio of ^{10}Be, ^{14}C, ^{26}Al, ^{36}Cl, ^{41}Ca, and ^{129}I show $\leq 2\times10^{-15}$, $\leq 2\times10^{-16}$ (Graphite), $\leq 1\times10^{-16}$, $\leq 3\times10^{-15}$, $\leq 3\times10^{-15}$, $\leq 2\times10^{-14}$, respectively. The total experimental beam time and AMS measuring time of the 6 MV Pelletron tandem accelerator are approximately 6,130 hours and 3,800 hours, respectively, since 2016. The total number of AMS measuring samples is approximately 3,570. The Tsukuba 6 MV multi-nuclide AMS system has been applied to environmental researches, for example, ^{10}Be in rainwater samples, ^{36}Cl in rainwater, ice core and soil samples, and ^{129}I in rainwater, riverwater, soil, seawater and coral samples (A. Sakaguchi et al., 2018). In 2020, we have measured the certified materials of ^{129}I, the Standard Reference Material® 3230, Level Ⅰ and Level Ⅱ, provided from the National Institute of Standards and Technology (NIST, USA). They were normalized by using Purdue-2 STD (Z94-0596) with an ^{129}I/^{127}I ratio of 6.5400×10^{-11} (P. Sharma et al., 1997) (the value was revised in 2014 (M. Caffee, Purdue University, Private communication)), which was provided by the Purdue Rare Isotope Measurement Laboratory (PRIME Lab) at Purdue University, USA. The nominal ^{129}I/^{127}I ratios are $(4.920 \pm 0.062) \times 10^{-10}$ and $(0.985 \pm 0.012) \times 10^{-12}$, for NIST 3230- Level Ⅰ and Level Ⅱ, respectively. The two samples after sputter-cleaning for 1 or 5 min. were measured in each run. The measured values of Level Ⅰ are approximately 10% lower than the nominal one. The resulting ratio and standard deviation (1σ) of the precision are $(4.361 \pm 0.058) \times 10^{-10}$ (1.3%) and $(0.909 \pm 0.065) \times 10^{-12}$ (7.1%), respectively. We will report current status, memory effect and performance of ^{129}I measurement for the Tsukuba 6 MV multi-nuclide AMS system. In addition, we will introduce a development plan for the iodine-129 standard reference materials at UTTAC in this presentation.

Status report on Laboratory of Radiocarbon Dating, The University Museum, The University of Tokyo, Japan

Dr Takayuki Omori[1], Dr Hiromasa Ozaki[1], Mr Kohei Yamazaki[1], Mr Ayao Kanesawa[1], Ms Fumina Minamitani[2], Prof Minoru Yoneda[1,2]
[1]The University Museum, The University of Tokyo, 7-3-1, Hongo, Bunkyo, Japan, [2]Graduate School of Frontier Sciences, The University of Tokyo, 5-1-5, Kashiwa, Japan

Theme: T-7: Facility Reports
Type of presentation: Poster

0.5 MV compact Accelerator Mass Spectrometry (CAMS) system (1.5SDH-1, NEC), customized for museum exhibitions, was installed in the Laboratory of Radiocarbon dating at the University Museum, the University of Tokyo (LRD.UMUT) in 2014. The CAMS in the exhibition space has welcomed more than one hundred thousand visitors and supported chronological research and academic projects. More than five years after the laboratory was renewed as an AMS facility, the 14C data accumulation and facility improvements proceeded. This paper provides current laboratory status and measurement performance.

As a small group, LRD.UMUT achieved more than ten thousand measurements with optimized sample preparations and stable AMS operations. Primary applications focus on archaeology, anthropology, and earth sciences that handle various types of materials. The chemical laboratory is ready for comprehensive approaches, from conventional pretreatments to improved chemical treatments, such as ABOx-Stepped combustion, Carbonate Density Separation (CarDS), and Ultrafiltration, including sample screenings using FT-IR, XRD, and EA. The preparation of an AMS target is available from the standard 1 mgC to less than 100 μgC, for small samples operating in an original remote and automation EA-based system. The efficiency of the target preparation is two thousand samples/person in a year, and the data stability increased more than manual preparations. The AMS system, comprised a solid-state ion source (MC-SNICS) and a 0.5 MV accelerator, maintains a measurement error of less than ±0.3%, keeping a low background around 0.1 pMC. The stable measurements are due to the power supply and temperature control for each component, resulting in success with little changes in conditions, even after a long time of measurement (several days).

We summarize here the general procedures for 14C dating on LRD.UMUT, as well as quantitative comparisons regarding the schemes for the optimization and stability measurements.

The new 300 kV multi-nuclide AMS system at the Tono Geoscience Center, Japan Atomic Energy Agency

Dr Natsuko Fujita[1], Mr Masayasu Miyake[2], Dr Akihiro Matsubara[1], Dr Yoko Saito-Kokubu[1], Mr Erickson Columna[3], Dr Matthias Klein[3], Dr Grazia Scognamiglio[3], Dr Dirk Mous[3], Mr Akiomi Shimada[1], Mr Tsuneari Ishimaru[1]
[1]Japan Atomic Energy Agency, Gifu, Japan, [2]PESCO Co., Ltd, Gifu, Japan, [3]High Voltage Engineering, Europa B.V., Amersfoort, Nederland

Theme: T-7: Facility Reports
Type of presentation: Poster

In the Tono Geoscience Center, Japan Atomic Energy Agency, investigation of deep underground environments for R&D program related to the geological disposal of High-Level Radioactive Waste (HLW) has been performed by using various dating systems including an AMS system. In response to the increasing demand for our AMS measurements especially from a newly established R&D program supporting development of technology for geological disposal of HLW, a state-of-the-art multi-nuclide AMS system was installed.

This system is equipped with a 300 kV AMS (4103Bo-AMS), namely “JAEA-AMS-TONO-300kV”, manufactured by High Voltage Engineering, Europa B.V., Netherlands. The system has capability to measure four nuclides: carbon-14, beryllium-10, aluminium-26 and iodine-129. JAEA-AMS-TONO-300kV is featuring the SO-110C ion source, a low energy spectrometer with electrostatic analyzer (ESA) and injection magnet with fast sequential isotope injection, tandem accelerator which maximum voltage is 300 kV, a high energy analyzer comprised of one ESA and two analysis magnets which degrees are 90 and 120, and an ionization chamber with a gas cell. The system footprint is 6.9 m x 5.0 m. The system structure and features, as well as the results of performance test will be presented.

This installation was carried out by a contract with the Ministry of Economy, Trade and Industry of Japan as part of its R&D supporting program titled “Establishment of Advanced Technology for Evaluating the Long-term Geosphere Stability on Geological Disposal Project of Radioactive Waste (Fiscal Year 2020)”.

The status report on MALT-AMS system and application studies

Dr Hiroyuki Matsuzaki[1], Mr. Hironori Tokuyama[1], Ms. Yoko S. Tsuchiya[1], Mr. Takeyasu Yamagata[1], Ms. Miwako Toya[1], Dr. Yasuto Miyake[2]
[1]MALT, The University Of Tokyo, Tokyo, Japan, [2]RIKEN, Wako, Japan

Theme: T-7: Facility Reports
Type of presentation: Poster

MALT (Micro Analysis Laboratory, Tandem accelerator, The University of Tokyo) is an ion beam analysis facility consist of a negative ion source, injection analysis system, a 5MV tandem accelerator, a high energy analysis system, and 5 beam courses. Among various beam analysis techniques, AMS (Accelerator Mass Spectrometry) is regarded as most important. Since the beginning of the operation of MALT (1993), AMS of various nuclides had been developed and used for application studies.

The accelerator is a Pelletron 5UD type tandem accelerator provided by National Electrostatics Corporation (nec) which generated 5 MV at the maximum. The ion source is 40-cathodes MC-SNICS. The sequential injection system and multi-Faraday cups system make possible the measurement of isotopic ratio. The detector for the rare isotopes is original made GIC (Gas Ionization Chamber). This GIC serves for the detection of Be-10, Al-26, Cl-36, Ca-41, I-129, and U-236. For Cl-36, GIC is set after a gas filled magnet. C-14 is measured by a semi-conductor detector.

Recently we have developed a new method for Ca-41 AMS. Just using presenting apparatuses, the background level of 2.0E-13 was achieved. We used CaF2 as the target material and 5.0 MV as the terminal voltage and 5+ charge state. Due to low current (< 300 nA) of CaF3- from CaF2 and not so high charge fraction (3%), the detection efficiency is not so high. At the final detector various unknown species are observed other than Ca-41. We are now trying to improve the background by an optimization of the configuration of GIC with the aid of simulation of ion and ionized electrons behavior.

At the first attempt, we detected U-236 (reported on AMS-14) using simply our GIC. The main factor limiting the background is U-235. By the calculation of the effect of our analyzing apparatus, i.e., the analyzing magnet, the switching magnet, and the electrostatic analyzer, the velocity of U-235 interfering at the final detector is found to be different from U-236. From this consideration, we are now introducing TOF system.

Stimulated by VERA's achievement we began to test the LPD (Laser Photo Detachment). We made a test-bench beam line involving the key device for LPD, an ion cooler with RFQ. Though our test-bench beam line is an assembly from junk parts, we successfully observe the negative ion reduction in the case of Sulfur beam by the 532 nm laser. However there are many challenges before the implementation to the real beam line.

MALT is a common use facility for academic scholars and various scientific studies are conducted using AMS, especially earth-environmental studies using both the natural occurred nuclides and anthropogenic nuclides.

Update on 129I, 26Al and 10Be AMS at KIST

Dr John A Eliades[1]
[1]*Korea Institute of Science and Technology, Seoul, South Korea*

Theme: T-7: Facility Reports
Type of presentation: Poster

This poster will update the state of measurements for 129I, 26Al and 10Be by accelerator mass spectrometry (AMS) on the Korea Institute of Science and Technology (KIST) 6 MV AMS system. The causes of a persistent 129I/127I ~ 10-^{10} background level were identified and eliminated. A 10B peak present in the 10Be spectrum that overlapped the 10Be peak and forced very careful selection of the region of interest was also eliminated. Since this improvement, measurements of 10Be/9Be on the order of 10-^{16} have been possible. The stability and current outputs for several cathode materials and target matrix combinations will also be compared for 129I and 26Al. Finally, a more convenient target press unit that consists of only four pieces that slide together and require no screwing was designed and has made sample pressing much faster and more convenient. Each unit can accept both of the standard High Voltage Engineering Europa (HVEE) target types, requiring no exchange of components for the different diameters.

Where the Wear is: Some Maintenance to Consider from the KIST 6 MV HVE Europa AMS System

Dr John A Eliades[1], Dr Gwanho Lee[1], Dr Byongyong Yu[1], Dr Joonkon Kim[1], Mr. Weon Cheol Lim[1], Mr. Jaeyol Kim[1], Dr. Jonghan Song[1]
[1]Korea Institute of Science and Technology, Seoul, Republic of (S.) Korea

Theme: T-7: Facility Reports
Type of presentation: Poster

This poster is primarily intended to aid others who run and maintain High Voltage Engineering Europa accelerator systems as these systems are now widely used. The KIST 6 MV system was installed in 2012 and commissioned in early 2013. While the system has run fairly well over the last ten years, there have been some problems that other users are likely to encounter after many hours of use. This will by no means be an exhaustive account. In each case, the system or component was inoperable until the problem was fixed. While the problems were not difficult to fix, identifying them took some time.

We have recently encountered problems with both of our SO110 ion sources. Firstly, the carousels have experienced sample loading failures due, at separate times, to the degradation of all of the potentiometers used to feedback carousel wheel position to the controller and also the brass rotation shaft assemblies used to actually rotate the carousel wheels. We replaced the potentiometers with equivalent but more robust units. The brass rotation shaft assemblies have been temporarily fixed by adjusting the rotation shaft locking position, but parts will likely need to be replaced in the near future. Secondly, we also experienced a vacuum leak at the Cs ionizer insulator cap. The leak was traced to a small crack at the thinnest section of this piece, where the bolts that hold the ionizer assembly to the insulator cap are screwed in place. This leak was sealed using a fairly cheap vacuum seal compound.

While most systems have probably been upgraded, we also experienced problems with Faraday cups that “fell off” of their insertion mounts. HVE has since changed the springs used to hold cups in position to a better, stainless steel material.

Our high voltage rf power supply has also suffered from false water cooling errors even though the cooling water quality and flow were fine. There is a “reed switch” unit inside the power supply, and after replacing this reed switch the system was able to be run normally. However, after four occurrences over the last five years, we are in the process of replacing this with a more robust flow meter.

We have also installed a monitor on the accelerator tank external motor used to turn the insulating shaft that is used to get power to the accelerator high voltage terminal. This is intended to detect wear on the rotation shaft as this is an expensive component to replace.