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Roles of Transpiration, Forest Bioproductivity & Fire on a Long-Term Dripwater Hydrochemistry Dataset from Golgotha Cave, SW Australia

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PP23C-2320

1. Site description

Cave monitoring: Ongoing since 2005. Dripwater collected every 4-6 weeks.

Geology: Golgotha Cave is located in Quaternary calcarenite (dune limestone) of high primary porosity (7-43%). Surface is mantled with 0-3 m weathered Si-rich aeolian sand, aiding percolation & minimising runoff.

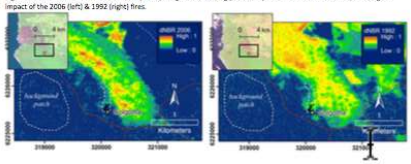
Climate: Annual precipitation is 1113 mm (May-Oct); actual ET is 730 mm dominated by transpiration (75%); MAT is 15°C. Marine aerosol flux is high.

Climate change: Annual precipitation has declined 15% overall since 1970.

Vegetation: Eucalypt forest with canopy height of 20-40 m & a dense understorey up to 10 m high.

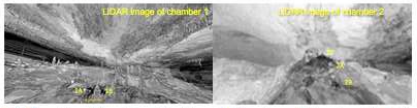
Fire history (Fig. 1A): Prescribed burn occurred 6 months after monitoring started. A hotter fire occurred in 1992.

Fig. 1A: Differential normalised burn ratio (dNBR) image created using pre-fire & post-fire Landsat 5 TM data, showing the impact of the 2006 (left) & 1992 (right) fires.



2. Flow Path Hydrology

Flow path hydrology has been investigated by a water isotope & forward model study (Treble et al., 2013); & by a coupled LIDAR & drip logger study to develop a geostatistical-based model of flow through this system (see oral PP21D-02 this session; Mahmud et al., 2015, in press).



Hydrology: Percolation is dominated by matrix-flow through the calcarenite aided by its high primary porosity.

Matrix-flow is evident in discharge profiles (see poster PP23C-2308) that are temporally uniform despite highly seasonal rainfall & in the stalactite distribution (Mahmud et al., 2015). Much of the ceiling appears dry suggesting that it acts as a capillary barrier, directing water towards the eastern wall & other low points in the ceiling.

Field observations suggest that matrix flow is focused into vertical pathways aided by deep tree roots & solution pipes. Calculations from coupled LIDAR & drip logger study support focusing of flow paths (see poster PP23C-2308).

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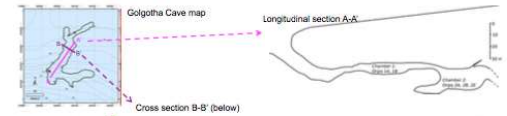
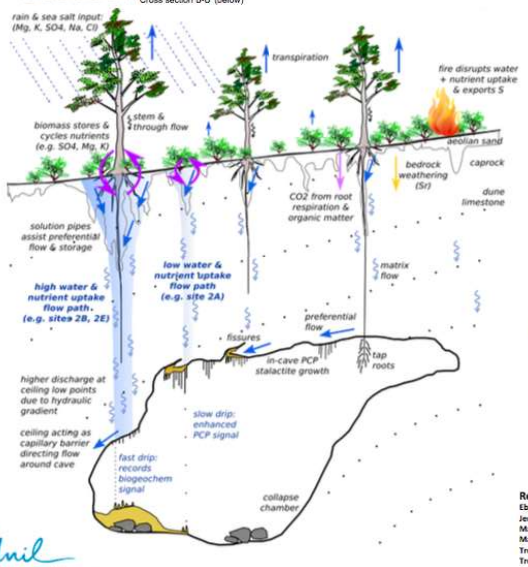
Summary & Conceptual Model

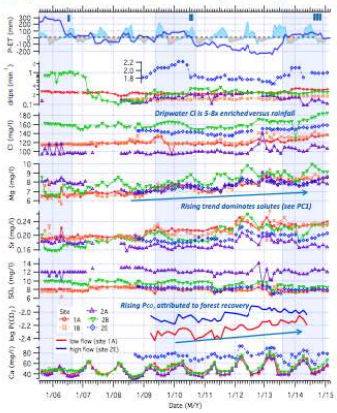
- We present a **conceptual model** that represents a synthesis of key findings from our ongoing monitoring study of Golgotha Cave published in **Treble et al. (2013; 2015; submitted) & Mahmud et al. (2015, in press)**.
- Golgotha Cave is developed in dune limestone & is located in a Mediterranean-type climate with high transpiration (~50% of precipitation) owing to the extensive overlying forest.
- **Water & nutrient uptake** by deeply-rooted trees contributes to spatial & temporal variability in dripwater solute concentrations (see *"Dripwater chemistry"*).
- These findings support the existence of a **close relationship between deep tree roots & vertical flow paths** in the karst; aiding preferential movement of water deep into the karst system feeding dripwater (see *"Flow Path Hydrology"*).
- The impacts of **post-fire forest recovery** are evident in a 20% rise in dripwater Cl concentrations (& similar rise in other solutes); depletion of dripwater SO_4 & a rise in epikarst Pco_2 (see *"Dripwater Chemistry"* & *"Mass Balance"*).
- Treble et al. (2015) showed that **Prior Calcite Precipitation (PCP) dominates at our slow dripping sites** (>30 s drip interval) during cooler months when Golgotha Cave is ventilated. Modelling experiments showed that PCP is primarily an in-cave process resulting in enhanced stalactite growth at the slower dripping sites.
- This study is necessary for the future interpretation of trace element data from SW Australian stalagmite records (see "Implications for Speleothem Records").
- The implications are relevant to any karst area that is forested or where transpiration is significant.

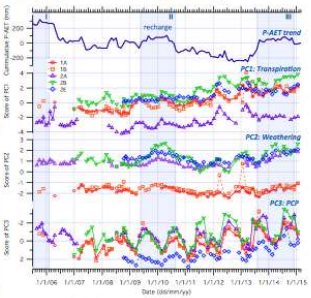


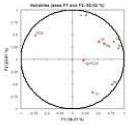


3. Dripwater Chemistry & Principal Components Analysis

Treble et al. (submitted)







PC1: Interpreted to be transpiration. Dry-season maxima & higher loadings from 2010. Inverse trend to water balance but no relationship to recharge events I-III. Negative loadings for SO_4 imply greater removal when transpiration is high.

PC2: Interpreted to be weathering influenced by spatial variability in bedrock composition (chamber 1 vs. 2) as well as temporal variability during recharge events II & III impacting dripwater Sr & Si. Opposite loadings on SO_4 & K imply reduced plant nutrient uptake.

4. Mass Balance

(see oral PP21D-04)

A mass balance was constructed to describe & **quantify water & elemental fluxes between potential sources & sinks.**

The main finding was a **significant sink for SO_4 (up to 60%) in the soil/biomass that has increased** through the duration of the study.

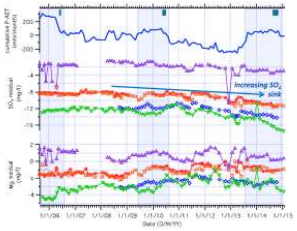
Preliminary data obtained for S isotopes supports biomass cycling over SO_4-reduction.

$[ion]_{marine\ aerosol} + [ion]_{residual} + [ion]_{bedrock} = [ion]_{dripwater}$

	1A	1B	2A	2B	2E
	mg/l	mg/l	mg/l	mg/l	mg/l
Sr					
Aerosol	0.02	0.02	0.04	0.07	0.06
Bedrock	0.18	0.16	0.17	0.18	0.21
Residual	0.01	0	-0.03	-0.04	-0.08
Mg					
Aerosol	8.3	8.3	6.8	12.7	9.71
Bedrock	0.37	0.37	0.33	0.35	0.47
Residual	-1.1	-1.2	-0.98	-2.3	-2.3
SO_4					
Aerosol	16.8	17.3	14.2	22.4	20.4
Bedrock	0.33	0.33	0.31	0.31	0.31
Residual	-9.2	-9.9	-7.1	-19.1	-12.2

Sr is dominated by **bedrock weathering**.

Mg & SO_4 are dominated by **aerosols** but have negative residuals indicating **sinks** along the flow path. These ions are macro-nutrients for vegetation & confirms the role of vegetation in modifying dripwater concentrations.



5. Implications For Speleothem Records

Short-term signals of biomass recovery from fire may be present in speleothem records. **Speleothem S is a potential proxy for past fire history** while ions such as **Mg could be a proxy for transpiration** (water balance plus fire history) provided it is known how the ion/Ca ratio is affected.

Speleothem **Sr may be a proxy for weathering.**

Speleothem records of these biogeochemical fluxes may be preserved at our high-flow sites. By contrast, Treble et al. (2015) showed that speleothem records from our low-flow sites will be dominated by an in-cave PCP signal.

We will further investigate the impact of fire on our speleothem records in a future study by examining high-resolution trace elements from modern speleothems against the known catchment fire history.

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