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Hydrological conceptual model for reconstructing fire history from cave stalagmites

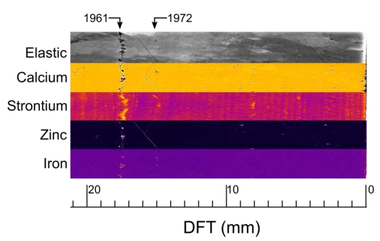
Overview

- Cave stalagmites (speleothems) are highly-valued archives of environmental information.
- Using stalagmites to reconstruct fire history is relatively new.
- Cave stalagmites may record fire history via dripwater.
- Advantages over traditional fire proxy archives include annual laminae providing seasonal to annual resolution and precise chronologies.
- We present a conceptual model of the flowpaths supplying dripwater to aid the selection of stalagmites that preserve fire events.

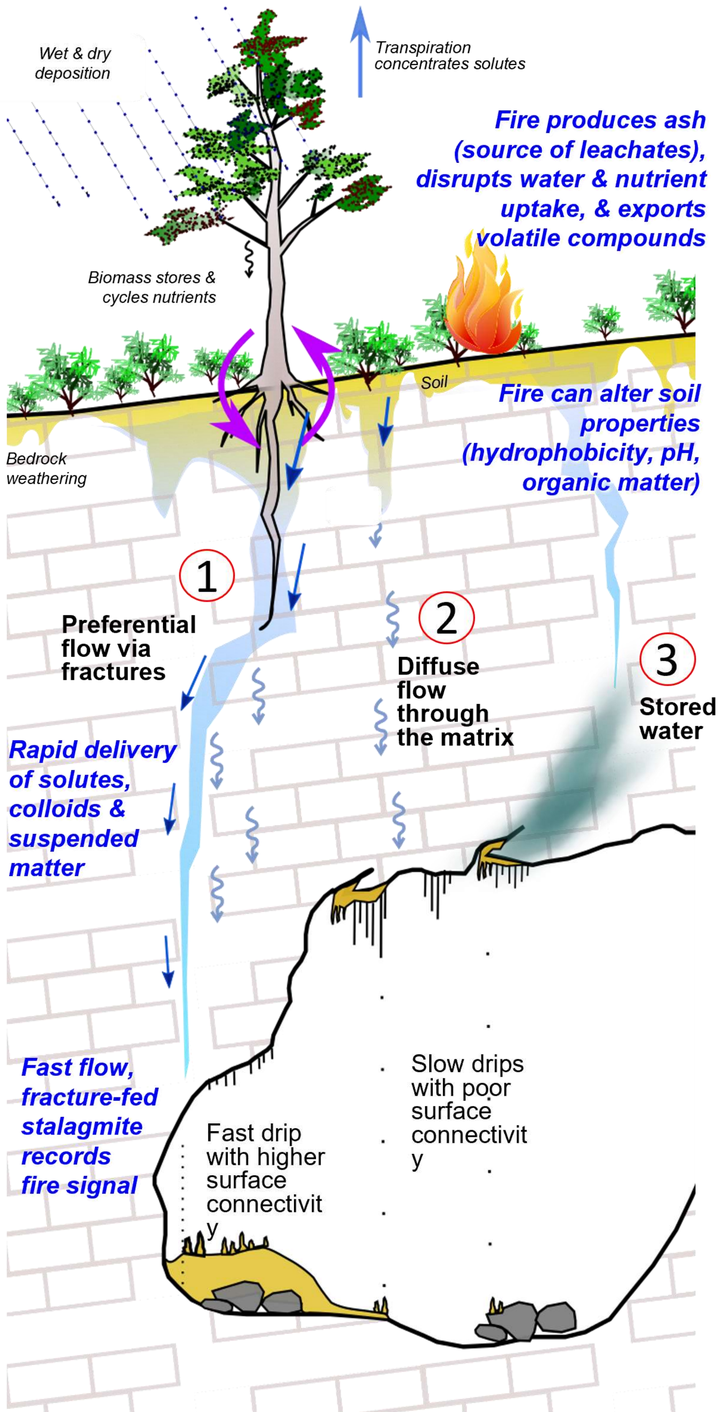
Karst flowpaths

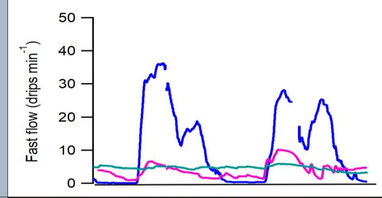
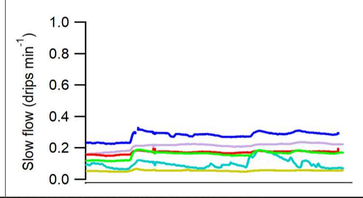
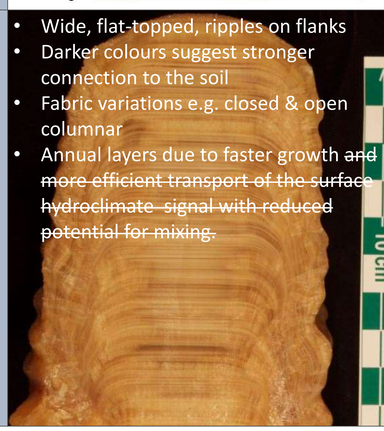
- Stalagmites grow from the deposition of $CaCO_3$ in caves following percolation of infiltrated rainwater along flowpaths.
- Karstification of carbonate rocks exhibit triple-porosity: primary=matrix, secondary=fracture, tertiary=pipes and conduit.
- Variability in dripwater characteristics can be directly related to whether flowpaths are dominated by preferential/quick flow along conduits or fractures or diffuse/slow flow via the matrix or poorly interconnected features.
- Several studies have shown that stalagmites fed by dripwater with a fracture-flow component contain higher concentrations of soil-derived trace metals and organics indicating a stronger hydrological connection with the surface.
- It logically follows that fracture-influenced flowpaths are more likely to transmit proxies for fire.

Fire events recorded in a cave stalagmite



- Zn and Fe peaks coincide with known fires over Crystal Cave, southwest Australia.
- These metals are typically insoluble, thus transport as organically-bound colloids is inferred, transported via fast/fracture flow.
- Sr map used for annual chronology.
- Elastic scattering and calcium maps show stalagmite fabric.



Drip type	Fast flow Path 1	Slow flow Paths 2 & 3
Karst properties	• Preferential flow routes along conduits or fractures • Higher permeability aids rapid and deep percolation from the surface to the cave	• Diffuse flow via the matrix or poorly interconnected features • Stored water in vadose zone
Ceiling pattern	Linear stalactite pattern = fracture control	• Random pattern
Hydrographs	• Fast response threshold rise 	• Slow consistent dripping 
Stalagmite appearance	• Wide, flat-topped, ripples on flanks • Darker colours suggest stronger connection to the soil • Fabric variations e.g. closed & open columnar • Annual layers due to faster growth ~~and more efficient transport of the surface hydroclimate signal with reduced potential for mixing.~~ 	• Narrow, candle-stick shape • Pale colours • Closed columnar fabric 

Sample selection for speleothem palaeofire research

- Cave stalagmites from fracture-fed flowpaths are more likely to preserve a record of fire events due to the stronger hydrological connection to surface.
- Cave depth is also an important factor in the preservation process with the detection of a fire signal more likely to be observed in dripwater from shallow caves (e.g. 5-10 m) owing to the potential for attenuation and mixing that may occur in deeper caves (Campbell et al., 2022).
- Cave stalagmite appearance (morphology, colour) can offer helpful clues when cave monitoring is not achievable.

Campbell. M. et al., Speleothems as Archives for Palaeofire Proxies. *ESS Open Archive*. July 24, 2022. DOI:10.1002/essoar.10511989.1.