Speleothems as archives for palaeofire proxies

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Introduction and motivation

- Wildfires affect ~40% of the earth's terrestrial surface (Giglio et al., 2010).
- Fire regimes are controlled by climate, vegetation, and human activity.
- Climate change is resulting in longer fire seasons and more dangerous fire weather (BOM and CSIRO, 2020; Jones et al., 2022).
- While satellite data underpin our understanding of fire regimes, they are too short to capture the full range of variability.
- Proxy archives (e.g. sediment and ice cores, tree scars, and speleothems - see Figure 1) record past fire activity.
- We can use these proxy data to better understand how fire regimes change with climate – important for mitigating future climate change.

Speleothems

- Speleothems (stalagmites, stalactites, and flowstones) form through the dissolution of a parent rock, followed by precipitation of calcium carbonate (Figure 3, centre image).
- Common in palaeoenvironmental research - they can be absolutely dated, can produce long and continuous records, and are comprised of multiple proxies.
- Inorganic proxies (trace and minor elements and stable oxygen and carbon isotopes) can be measured in speleothems at very high resolutions (annual-seasonal) using existing analytical methods (Synchrotron μ-XRF, LA-ICP-MS, SIMS, and IRMS).
- Here, we review the use of inorganic palaeofire proxies in speleothems.

Figure 1 Conceptual model of how stalagmites record past fires

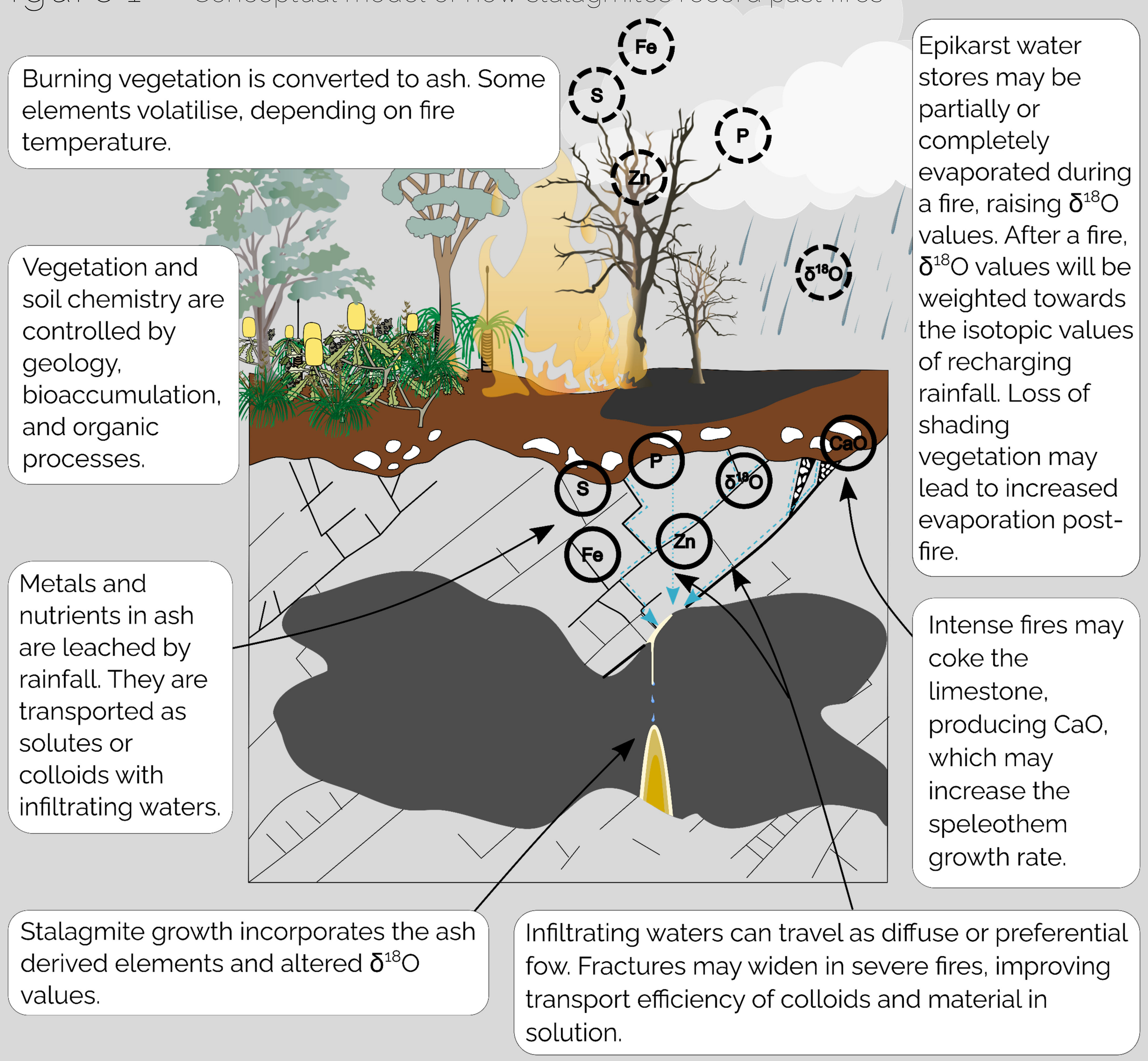


Figure 2 The geochemical response of dripwater to wildfires and prescribed burns from sites in SE and SW Australia.

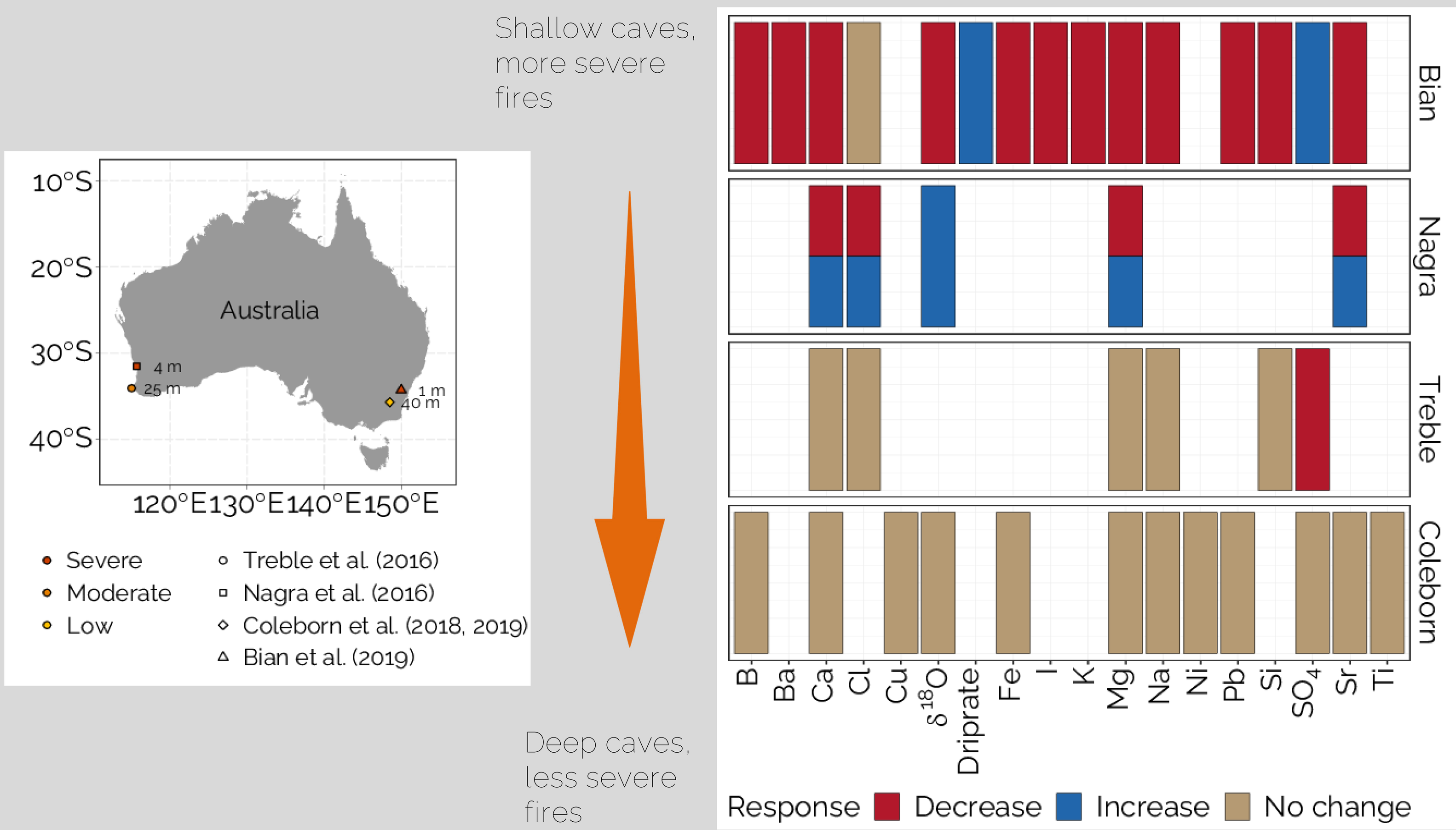


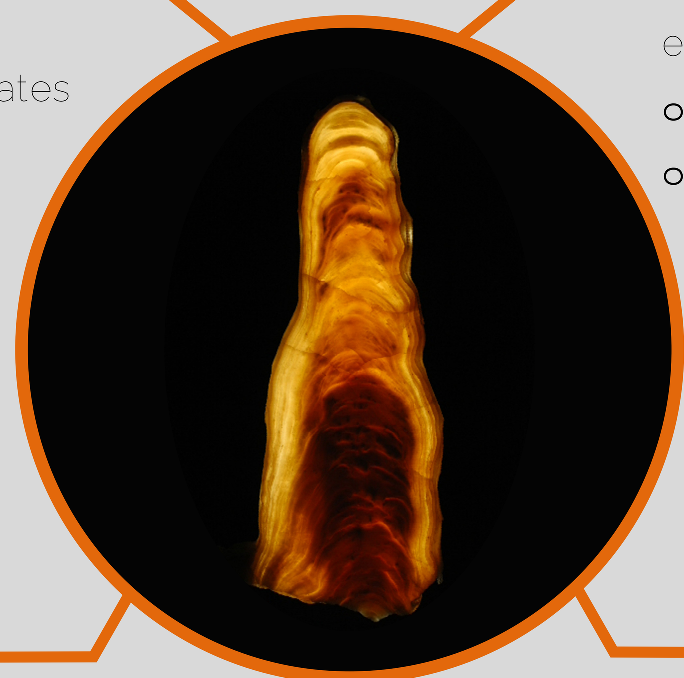
Figure 3 An overview of speleothems as archives for past fires

Site and sample selection

- Honey- and brown-coloured samples
- Mediterranean climates (high seasonality)
- Faster-growing

Proxies

- Trace and minor elements
- $\delta^{18}O$ and $\delta^{13}C$
- Extension rate



Chronology

- Annual laminae
- U-series dating
- Radiocarbon

Statistical methods

- Principal component analyses
- Changepoints

Laboratory methods

- Synchrotron μ-XRF
- IRMS
- LA-ICP-MS
- SIMS

Here we focus on high-resolution methods for inorganic proxies.

Poster EGU23-2932 | Poster EGU23-10651 | Read the paper! | References and contact

Finding the proxy signal

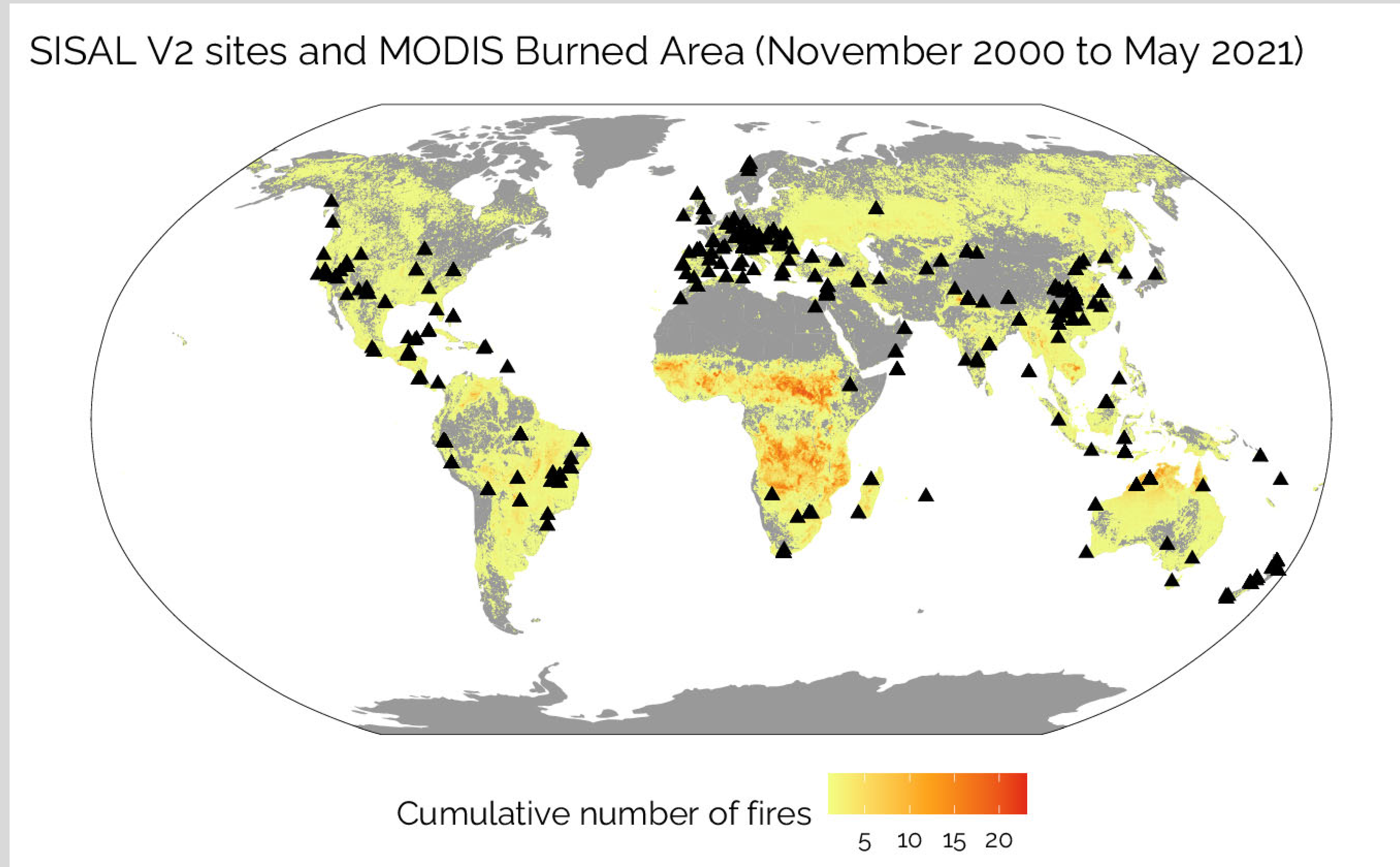
- Dripwater monitoring showed that geochemistry changed after some fires (Treble et al., 2016; Nagra et al., 2016; Bian et al., 2019), but not all (Coleborn et al., 2018, 2019).
- The signal was clearest in shallower caves with more severe fires (Figure 2).
- These results, together with speleothem geochemistry (McDonough et al., 2022; Campbell et al., 2023) suggests that the best speleothem samples will be sourced from caves with high soil-water contact and with a high proportion of preferential flow.

See Poster EGU23-2932 in this session to learn more about the hydrological processes driving proxy transport.

Testing the proxy signal

- Our new review paper (follow QR code below) presents four case studies:
  - Wildfire ash is a likely contributor to the speleothem proxy signal.
  - Stalagmite S and Cl may reflect postfire vegetation recovery, although speleothem sulphate requires supporting dual sulphate isotope data for interpretation.
  - Stalagmite trace elements and stable isotopes recorded a severe bushfire in the late 1800s (see Poster EGU23-10651).
  - Deep caves may record past fire events if there is a sufficient quickflow component to transport the surface fire signal (see Poster EGU23-2932).

Figure 4 The locations of samples in the SISAL V2 speleothem database overlayed on MODIS burned area data



~50% of sample sites in the SISAL V2 database (Comas-Bru et al., 2020) were burned between November 2000 and May 2021 (Figure 4). The database contains relevant metadata (e.g. depth overhead, whether the samples are annually laminated) to inform the selection of samples for future palaeofire research.

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