An annually resolved stalagmite record of fire frequency for the last 250 years in south-west Australia

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Unprecedented catastrophic wildfires are becoming more frequent. It is therefore becoming increasingly important to understand links between past climate, land management, and fires. Multiproxy investigations of speleothems (cave mineral deposits) can help identify the timing of past fire events and the environmental conditions leading up to them.

Background

- Stalagmites record environmental change in their geochemistry, making them ideal for recording past fire events.
- Stalagmites from shallow caves are particularly suitable, as the proxy signal is less likely to be affected by long infiltration pathways, lag times and mixing of stored water with post-fire infiltration.
- Stalagmite YD-S2 from Yonderup Cave (4 m depth, Fig. 1) was analysed for changes in its chemical composition during known fire events, with results extrapolated back in time to determine past fire frequency.

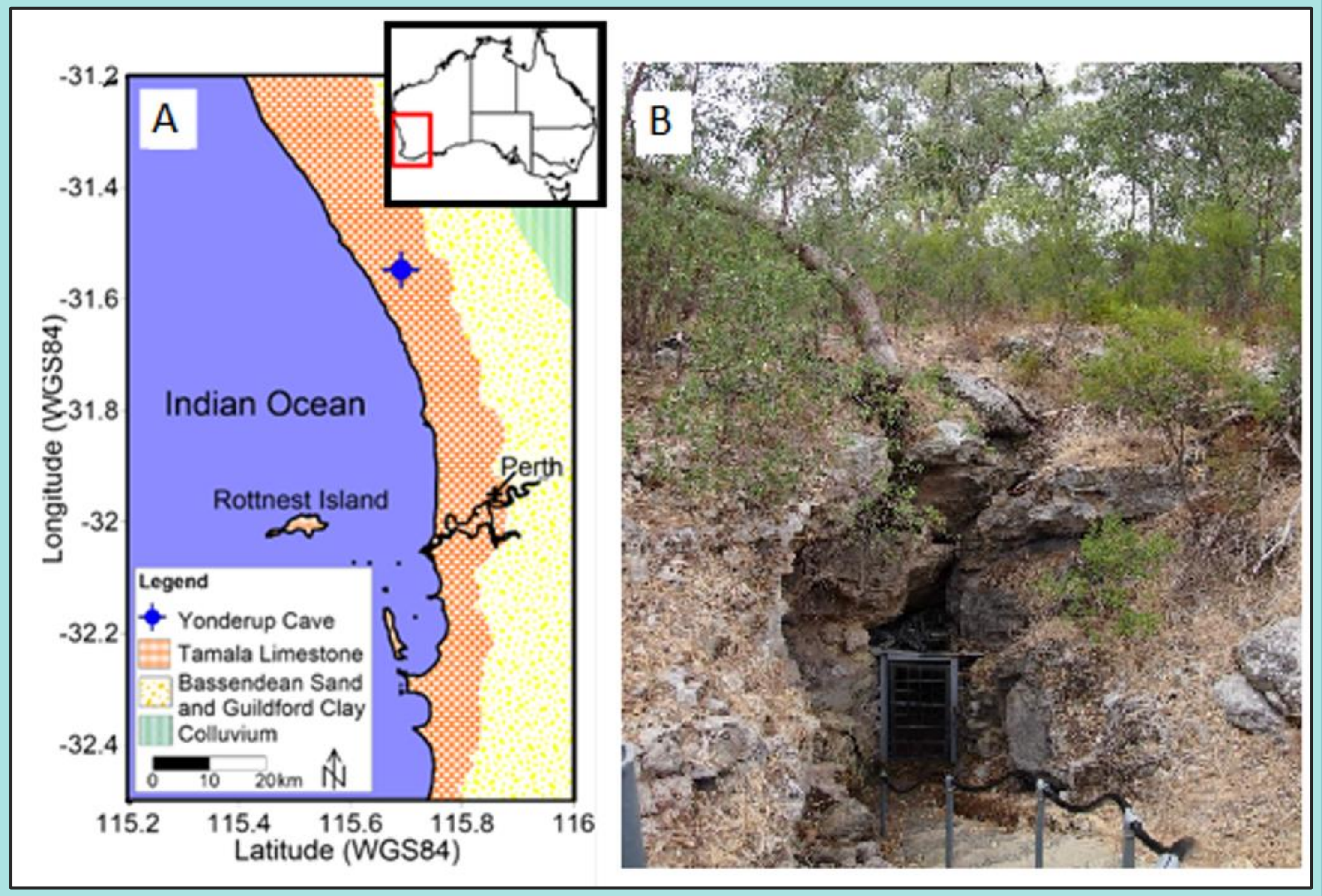

Figure 1: A) Location of study region and geology with Yonderup Cave indicated by blue marker. B) Photo of vegetation and surface environment above Yonderup Cave. Photo from Nagra et al. 2016.

Methods

- Synchrotron X-ray Fluorescence Microscopy, Laser Ablation Inductively Coupled Plasma Mass Spectrometry, $\delta^{13}C$ and $\delta^{18}O$
- Age-depth model generation and principal Component Analysis (PCA)

See QR code for more details on methods in McDonough et al (2022).

Results / Discussion

- Known fire events were associated with PC3 peaks, which represented short-term spikes in P and metals (Cu, Zn, Al, Pb, Fig. 2).
- No single proxy was impacted during all fire events, and ratios of metal concentrations varied between events (possibly the result of variations in fire severity).
- P concentrations at the timing of peaks in PC3 are lower (p = 0.02) and less variable (var. = 1.9, n = 10) prior to the suppression of cultural burning by Indigenous Australians compared to after (var. = 11.5, n = 12, Fig. 2).

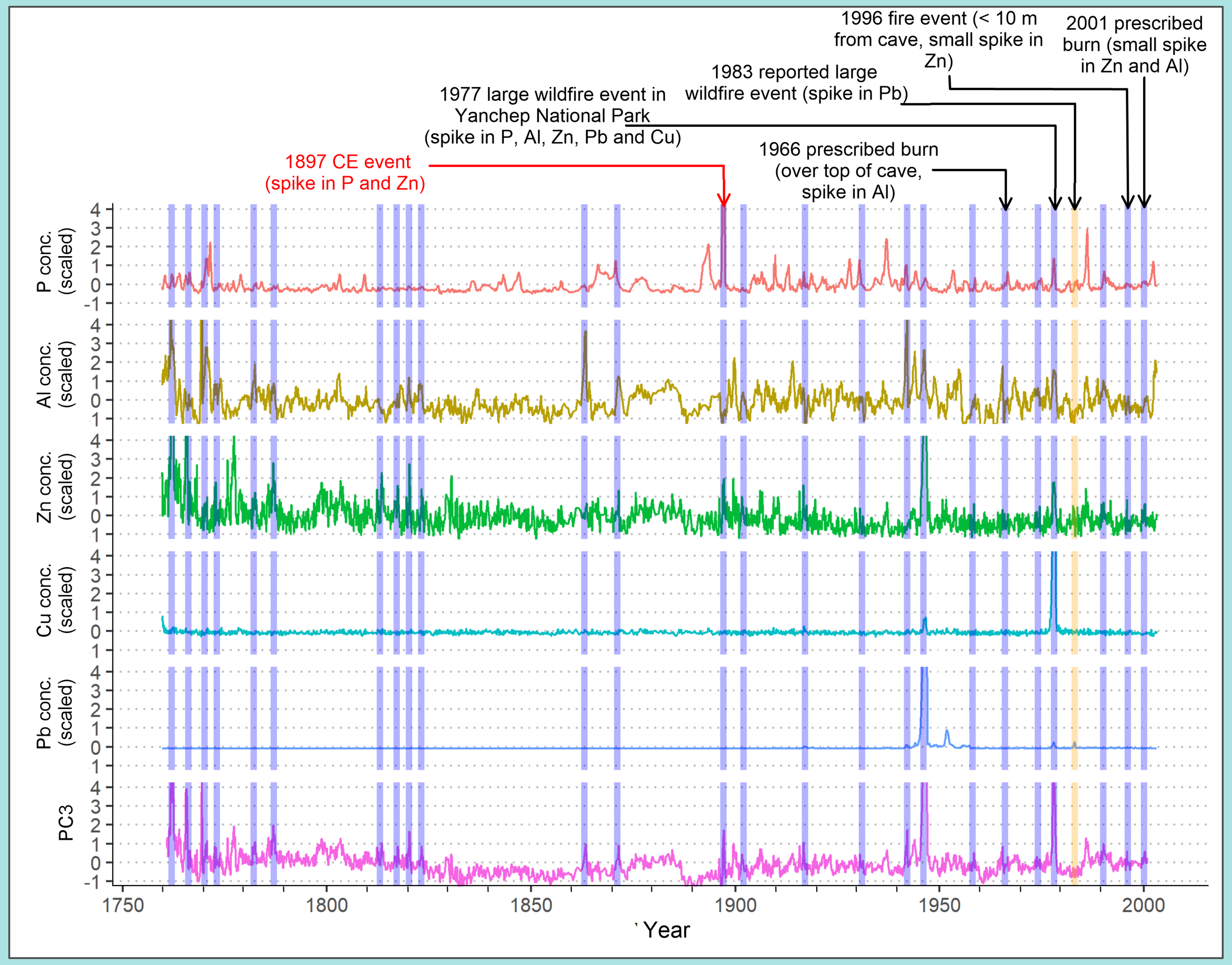

Figure 2: Timeseries of metals and P, with PC3 showing peaks at the timing of known fire events. Blue bands represent points where the rolling median PC3 value exceeds 2.5 times the rolling standard deviation

- A large palaeo-fire event (Fig .3) was identified in 1897 through a spike in P, $\delta^{13}C$ and $\delta^{18}O$. This fire was preceded by a multi-decadal drought and likely exacerbated by reduced cultural burning and fuel build up.

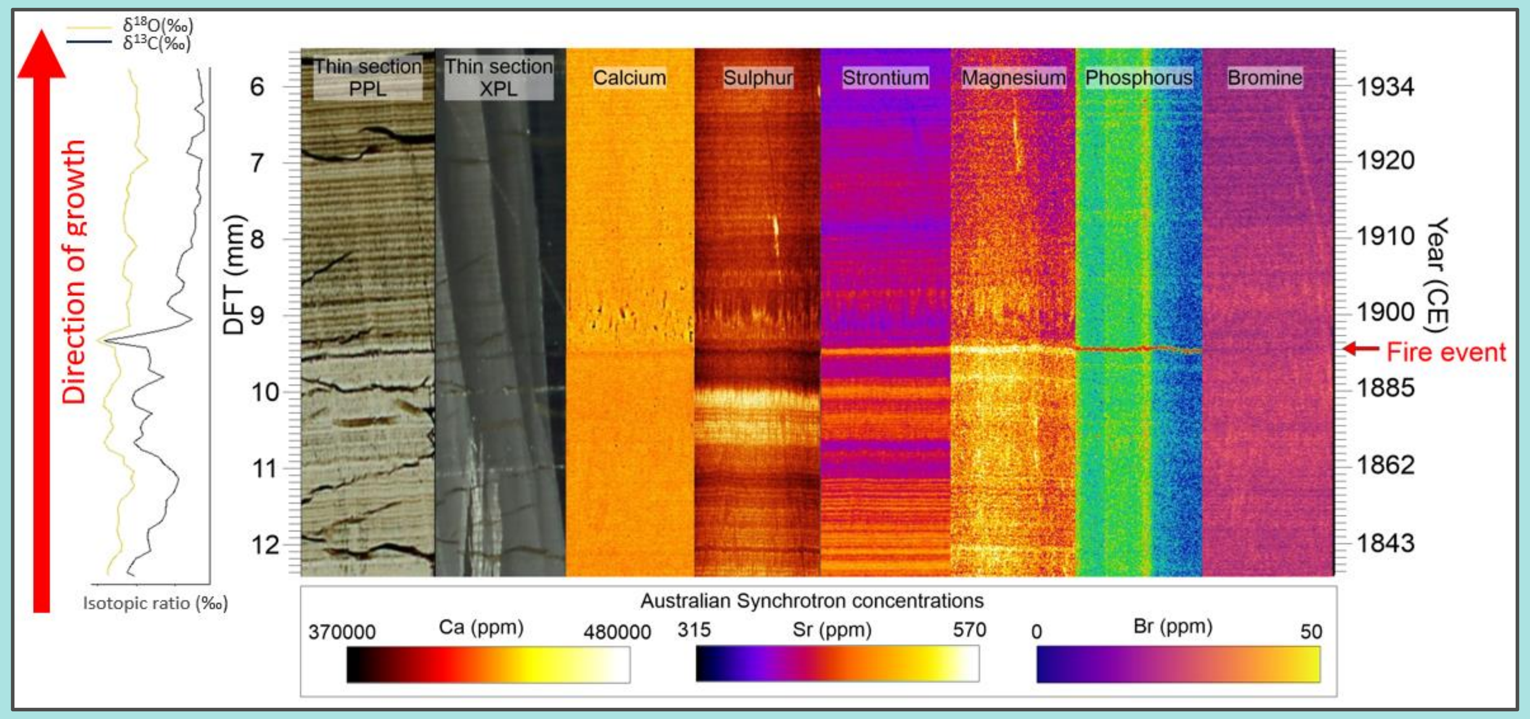

Figure 3: Stable isotope timeseries, thin section and XFM scans of YD-S2 over the 1897 fire. NB: matrix-matched standards were not available to obtain absolute concentrations for Mg, P and S.

Conclusions

- Speleothems record fire events through spikes in ash-derived elements (P, Zn, Cu, Al, Pb). The ratios of these elements are likely impacted by fire intensity.
- Suites of bedrock-derived elements (Mg, Sr, Ca) do not appear to be reliable indicators of fire alone. Rather, they record climate leading up to a fire event, as well as changes in hydrology post-fire.
- This world-first demonstration of fire events recorded in stalagmites reveals their potential to provide accurate records of both fire frequency and changes in climate, suggesting they may be useful in guiding land management.
- See posters EGU23-2932 and EGU23-11016 for more information on the use of speleothems as palaeo-fire proxies.

Scan the QR code to read more about this research

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References: Nagra, G., Treble, P.C., Andersen, M.S., Fairchild, I.J., Coleborn, K. and Baker, A. (2016) A post-wildfire response in cave dripwater chemistry. *Hydrology and Earth System Sciences* 20, 2745-2758.