Multi-proxy temperature records from a northern Borneo stalagmite reveal sample-specific challenges

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More information and vote

- Several new methods for **quantitative paleo-temperature** reconstructions with stalagmites have emerged over the last decades.
- Although uncertainties of each method are still being discussed, potential disagreements among paleo-thermometers applied to the same stalagmite have not been comprehensively addressed.
- Here we used GC08, a stalagmite from Northern Borneo, that covers MIS 14 – 11, to reconstruct paleo-temperatures.
- **Fluid inclusion microthermometry**, **fluid inclusion water isotopes**, and **TEX_{86}** are used for multi-proxy investigation, allowing direct comparison on the same stalagmite.

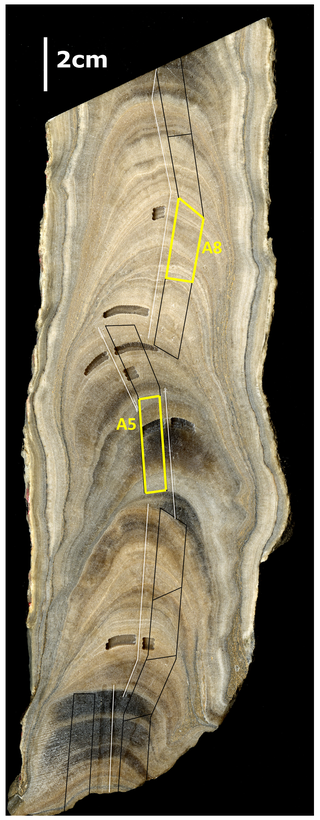

Fig. 1: High-resolution scan image of GC08. White lines indicate the previously studied isotope transect (**Fig. 2c, d**). Black lines indicate blocks that were cut during sample preparation. Yellow boxes indicate two blocks exemplified in **Fig. 4** for GDGT analyses.

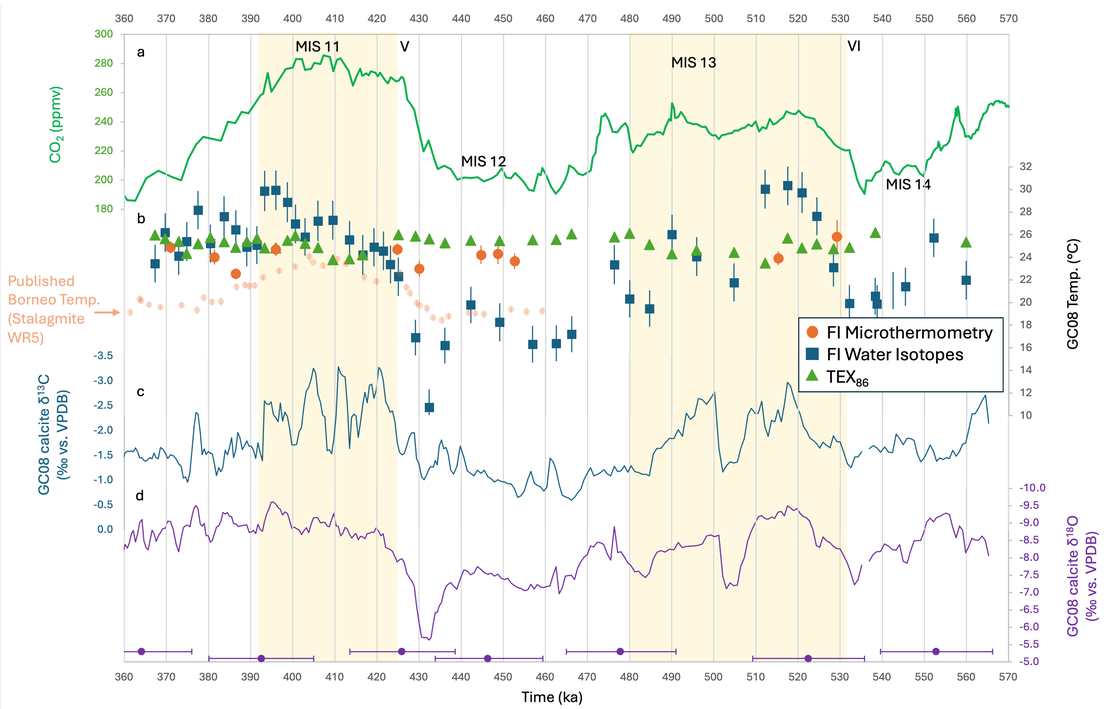

Fig. 2: a) Atmospheric CO_2 concentration from EDC (Bereiter et al., 2015). **b)** GC08 temperatures from this study. Translucent orange circles are FI microthermometric temperatures from WR5, a stalagmite nearby (Krüger et al., 2025), which has better temperature constraints. **c,d)** Calcite $\delta^{13}C$ and $\delta^{18}O$ of GC08 (Meckler et al., 2012). Age uncertainties of GC08 are shown at the bottom. Vertical color bars indicate two interglacial periods.

Take-Home Message

- Our study shows the limitations associated with individual paleo-thermometers applied to stalagmites.
- A range of in-cave processes can substantially influence the reliability of each proxy.
- The depositional context plays a critical role in proxy interpretation and therefore warrants greater consideration in any stalagmite-based paleo-temperature study.

Fluid Inclusion Microthermometry

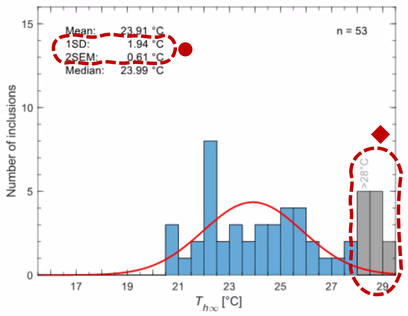

Fig. 3: An example of microthermometric temperature distribution of coeval fluid inclusions from a layer around 515 ka.

- **Resulting temperatures exhibit constant warm condition.**

● Temperature distributions are wider than normal, with average 1SD of ~ 2 °C and 2SEM of ~ 0.7 °C, two times the common precision.
◆ Many fluid inclusions do not homogenize below the set threshold of 28 °C.
- Measurements are done in columnar fabrics. However, generally complex calcite fabric, irregular shape of fluid inclusions, and/or organic tissue in the stalagmite might affect the precision.

▲ TEX_{86}

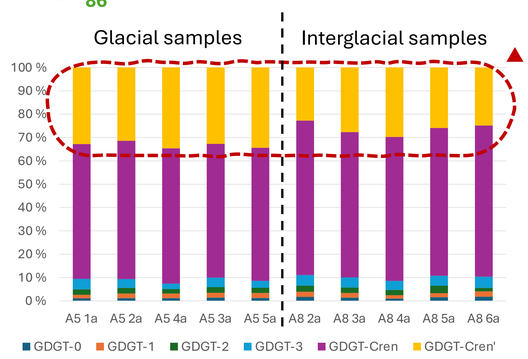

Fig. 4: Examples of isoprenoid GDGT distributions in GC08.

- **Resulting temperatures exhibit constant warm condition throughout two glacial-interglacial cycles.**

▲ While typical percentage of Cren' for stalagmites is 0-10%, an average of 25% in GC08 indicates soil-sourced contamination.
- High Cren' mathematically keeps TEX_{86} values high, damping the variation:

$TEX_{86} = (GDGT\ 2 + 3 + Cren')/(GDGT\ 1 + 2 + 3 + Cren')$

- Employed adjusted index excluding Cren':

$TEX_{86\ adj} = (GDGT\ 2 + 3)/(GDGT\ 1 + 2 + 3)$

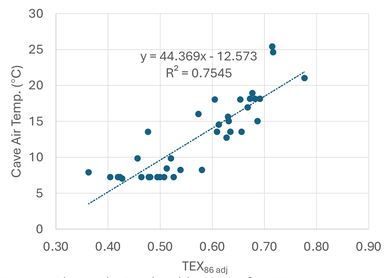

Fig. 5: New hypothetical calibration for $TEX_{86\ adj}$ using dataset from Baker et al. (2019).

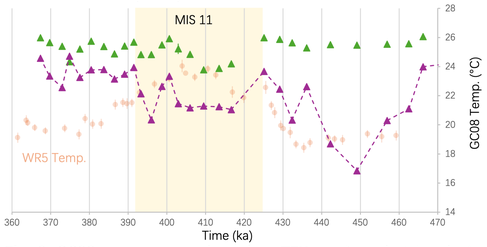

Fig. 6: GC08 temperatures based on $TEX_{86\ adj}$ (purple triangles), compared to TEX_{86} (green). Only the younger interval is shown.

■ Fluid Inclusion Water Isotopes

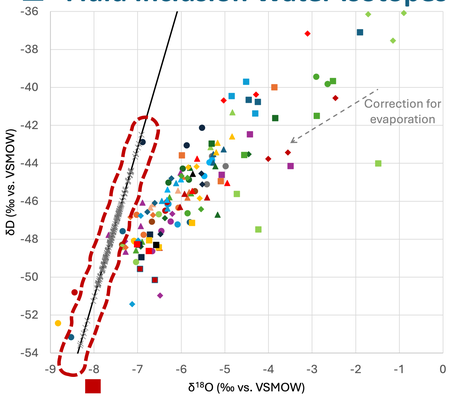

Fig. 7: Crossplot of fluid inclusion δD versus $\delta^{18}O$ showing all measured replicates, with each color and symbol combination representing one sample. Black solid line shows the local dripwater line. Grey dashed arrow indicates the slope (1.41) of the correction for in-crusher evaporation towards the local dripwater line (Fernandez et al., 2023). Grey crosses are the corrected replicates.

- Water isotope compositions deviate from local drip water line suggesting in-crusher evaporation.
- **When corrected for in-crusher evaporation, temperatures exhibit extreme glacial-interglacial variation.**

■ Correction for evaporation "flattens" the water $\delta^{18}O$ values, might lead to the very low temperatures reconstructed for dry intervals.

- Borneo stalagmite WR5 provides good temperature constraints, allowing calculations for theoretical water $\delta^{18}O$ for GC08.
- Both in-cave and in-crusher evaporation could shift water isotope compositions away from the dripwater line during dry periods.

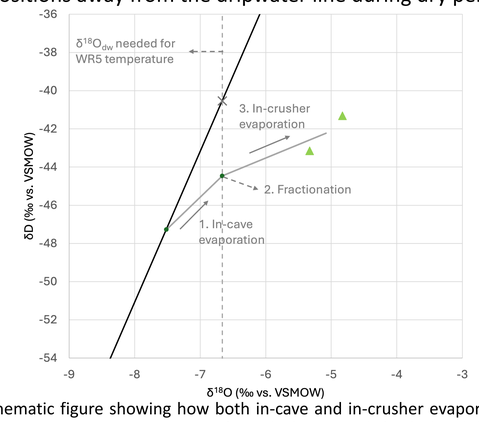

Fig. 8: Schematic figure showing how both in-cave and in-crusher evaporation affect measured water isotope compositions (sample from 429 ka). Black solid line shows the local dripwater line. Grey dashed line indicates calculated theoretical water $\delta^{18}O$.

References

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