The first multi-proxy speleothem paleoclimate record from Georgia and calculations of temperature variations during the last ~ 13500 years

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Background

Unfortunately, there are large areas where multimillennial paleoclimate timeseries are unavailable. Southern Caucasus, is such a region. Importantly, temperature-related proxies are virtually absent here.

This work provides the first paleoclimate reconstruction from Georgia (Southern Caucasus) spanning approximately the last 13500 years. Calcite $\delta^{18}O$-$\delta^{13}C$ ($\delta^{18}O_{sp}$-$\delta^{13}C_{sp}$) timeseries from four stalagmites show the main patterns of climate and environmental variations during the last glacial-interglacial shift as well as throughout the Holocene (figs. 1, 2, 3 and 4), which mostly agree in pace and tempo with global records.

Then, $\delta^{18}O$-$\delta^{2}H$ from speleothem fluid inclusions (FI) are applied to quantitatively calculate temperatures. Conveniently, FI resulted well aligned with the modern meteoric water line (MWL) in Georgia (fig. 3), indicating that isotopic fractionation was negligible. FI-derived temperatures document the effects of climate warming in Southern Caucasus related to the last deglaciation, with a ca. 4.5ºC increase of average temperatures from ~12 to ~10 ka. Paleotemperatures during the Holocene instead presents a gradual decrease of around 2ºC from ~10 ka to ~3 ka. This potentially supports the existence of a Holocene thermal maximum during the Early Holocene, which is still a matter of debate. However, calculation uncertainties make this finding debatable.

The interpretation of the record is refined by considering changes of rainfall (e.g., amount, provenance/source and seasonality) as well as soils (e.g., vegetation bioactivity), which impact $\delta^{18}O_{sp}$ and $\delta^{13}C_{sp}$ respectively. Interestingly, Zak- $\delta^{18}O_{sp}$ timeseries mimics the gradual increasing trend seen in Sofular Cave (Turkey) $\delta^{18}O$ curve (fig. 5), implying that they share similar paleoclimate triggers. Oppositely, Zak $\delta^{13}C_{sp}$ pattern better evidences the impact of Bolling-Allerod, Younger Dryas and Holocene inception reported by regional archives (fig. 4).

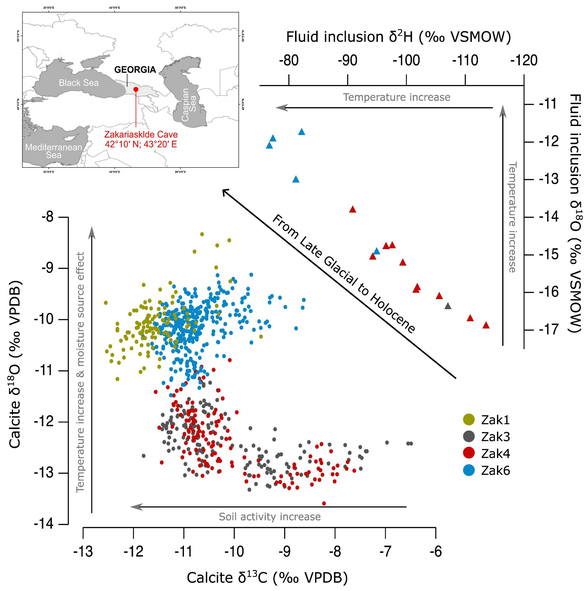

Fig. 1. Study area and main isotopic patterns from Zak-speleothems. Shifts toward lower Zak-$\delta^{13}C_{sp}$ and higher $\delta^{18}O_{sp}$ are interpreted as increase of soil activity and temperature during late glacial to Holocene transition, with concurrent effects of moisture source. Concurrently, higher $\delta^{18}O_{fi}$ and $\delta^{2}H_{fi}$ in speleothem fluid inclusions point to higher temperatures within the same period.

Materials and Methods

In Georgia, speleothem-based paleoclimate reconstruction is still in an early stage, although well decorated caves are abundant (Asanidze et al., 2019). Four stalagmites were collected from the Zakariasklde Cave (42°10′ N; 43°20′ E) (fig. 2). U-series and $\delta^{18}O_{sp}$-$\delta^{13}C_{sp}$ analyses were performed in the Massachusetts Institute of Technology and the University of Massachusetts, Amherst, U.S. Age models were constructed using "StalAge" (Scholz and Hoffmann, 2011). Fluid inclusions were performed in the University of Basel, Switzerland.

Paleotemperatures are calculated by applying Kim & O'Neill (1997) equation to the raw $\delta^{18}O$FI data as well as shifting these latter to the modern Georgian MWL, thus obtaining a range of reliable temperatures.

Calcite speleothems collected from Zakariasklde (ZAK) cave.

Fig. 2. Zak speleothems. Vertical lines identify the stable isotopes track. Horizontal bars point to the stratigraphic locations of U-Th subsampling. Circles indicate location for fluid inclusions subsampling.

13500 years of temperature variations in Georgia

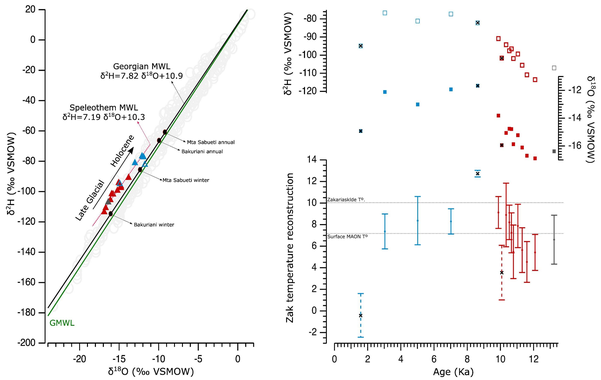

Fig. 3. Zak fluid inclusions and temperature reconstructions. On the left, Zak $\delta^{18}O_{fi}$-$\delta^{2}H_{fi}$ (triangles) compared to the Georgian (black line) and global (green line) MWL. On the right, the calculated paleotemperatures.

Multi-proxy timeseries

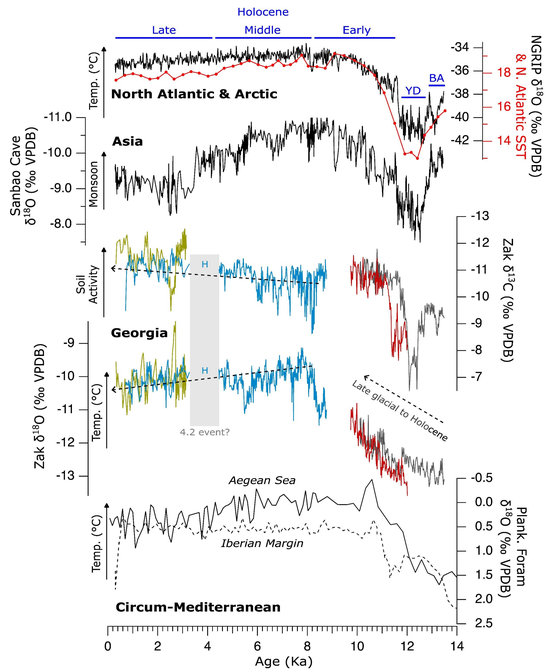

Fig. 4. Zak-$\delta^{13}C_{sp}$-$\delta^{18}O_{sp}$ timeseries vs regional records over the last ca. 13500 years. The main chronozones are reported, at the top of the graph, by using blue bars.

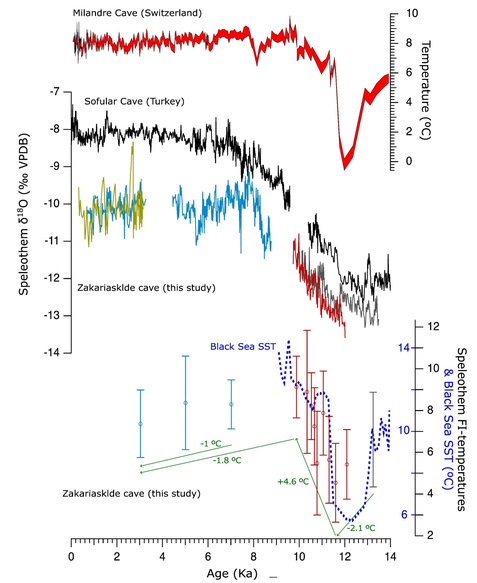

Fig. 5. Zak $\delta^{18}O_{sp}$ timeseries and FI-derived temperatures vs local records.

Conclusion

- Zak FI-derived temperature highlights -2.1ºC decrease during the Younger-Dryas, and +4.6ºC increase at the Holocene inception. It also preliminarly demonstrates the occurrence of the «Holocene Thermal Maximum» in Georgia.
- Zak $\delta^{18}O_{sp}$ is driven by temperatures, but likely modulated by the change in moisture source $\delta^{18}O$ during the glacial-interglacial transition as occurring in Sofular Cave.
- Zak $\delta^{13}C_{sp}$ reports a clear Bolling/Allerod-Younger-Dryas and Holocene inception shape given by changes in soil bioproductivity during these times of global to local climate oscillations.
- Ongoing new FI analyses will reinforce and improve the presented dataset.

Authors & References

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Asanidze, L. et al. 2019. Karst map of Georgia (Caucasus region) scale: 1:1,500,000. Carbonates and Evaporites, 34. 1205-1212.

Kim, S.T. and O'Neil, J.R. 1997. Equilibrium and non-equilibrium oxygen isotope effects in synthetic carbonates. Geochimica et Cosmochimica Acta, 61. 3461-3475.

Scholz, D and Hoffmann, D.L. 2011. StalAge - an algorithm designed for construction of speleothem age models. Quaternary Geochronology, 6. 369-382.

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