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Stable isotope analyses of fluid inclusions in speleothems: opportunities and challenges for their application as paleo-temperature archives

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Speleothems (cave deposits) are robust continental paleo-environmental archives owing to their precise and accurate age-determinations, high-resolution (sub-decadal) and multi-proxy information. Fossil water may be sealed within micro-cavities in the crystal lattice as fluid inclusions. Recent analytical advances of $\delta^{18}O$ and δD measurements allow micro-volumes of fluid inclusion waters to be extracted and measured precisely. Quantitative paleo-temperature reconstructions can then be calculated based on the fractionation of oxygen isotopes between fluid inclusions water and the surrounding host calcite. Their efficacy as a paleo-temperature proxy comes into question, however, if post depositional alteration or non-equilibrium fractionation processes have occurred and caused deviations from the oxygen isotope equilibration between water and calcite.

Here, we present coupled fluid inclusion and carbonate stable isotope measurements from caves in diverse climatic environments (montane to semi-arid) spanning 0-500 ka. We couple this with detailed petrographic analyses to assess the relationships between speleothem morphology (e.g., crystal structure, diagenetic alteration) and processes (e.g., evaporative fractionation, non-equilibrium fractionation processes) in influencing the fidelity of calcite $\delta^{18}O$ reflecting the original isotopic composition of drip waters. Furthermore, we explore the relationship between the host calcite and fluid inclusion waters to assess whether they are depositionally ‘in phase’ or demonstrate isotopic offsets (e.g. seasonal) from ‘out of phase’ calcite deposition relative to fluid inclusion water incorporation. Finally, we determine their subsequent applicability as paleo-temperatures archives.