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Fluid inclusion stable isotope analysis in speleothem calcite as a tool for paleoclimate reconstruction

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Over the past few years, techniques for the isotopic analysis of oxygen (δ18O) and hydrogen (δ2H) of fluid inclusions in speleothem calcite have advanced rapidly owing to the development of analytical techniques for continuous flow instruments. With growing experience, we have gained a better understanding of the boundary conditions for accurate determination of paleofluid composition based on fluid inclusion isotope analysis.
In speleothems, fluid inclusion stable isotope values potentially provide valuable paleoclimate parameters. The most straightforward information that can be retrieved is the isotopic composition of past rainfall. This is based on the assumption that fluid inclusion water is isotopically identical to drip water, which in turn represents yearly averaged rainfall over the cave. We here present several examples to show that, particularly in monsoonal setings, temporal fluid inclusion isotope variation can be substantial, and primarily reflects variation in rainfall amount.
Another important climate parameter that can be retrieved by fluid inclusion isotope analysis is cave temperature, which for most caves equals the annually averaged outside surface temperature. Coupled δ18O values of fluid inclusion water and the surrounding calcite allow speleothem growth temperatures to be calculated, provided the calcite grew in isotopic equilibrium. However, such reconstructions involve poorly constrained uncertainties, which can be grouped in roughly 3 categories: 1) uncertainties due to non equilibrium (kinetic) isotope fractionation during calcite formation, 2) uncertainties introduced by diagenetic alteration of speleothem calcite, and 3) analytical uncertainties related to fluid inclusion isotope analysis. Here we will show some case studies illustrating the uncertainties involved, and present strategies to improve the accuracy of climate reconstructions based on fluid inclusion isotope analysis.