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Improving interpretation of stalagmite $\delta^{18}O$ and growth-rate with cave-analogue calcite growth experiments

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An increasing number of studies report stable-isotope and trace-element records in speleothems. This variation is controlled by diverse environmental variables including the climatically important variables, temperature and rainfall. There is, however, a paucity of laboratory studies attempting to understand the influence of these environmental controls on stalagmite geochemistry. Quantitative data from such studies would dramatically improve our ability to reconstruct palaeoclimate from stalagmites.

We have completed a new series of carbonate growth experiments in karst-analogue conditions in the laboratory. The setup closely mimics natural processes (e.g. precipitation driven by CO_2 degassing, low ionic strenth solution, thin solution film) but with a tight control on growth conditions (temperature, pCO_2, drip rate, calcite saturation index and the composition of the initial solution).

Calcite is dissolved in deionized water in a 20,000 ppmV pCO_2 environment and an aliquot of trace metals solution added. This solution is then dripped onto glass plates (coated with seed-calcite) in a lower pCO_2 environment (<2500 ppmV pCO_2). Experiments were performed at 7, 15, 25 and 35^oC. At each temperature, calcite was grown at three drip rates (2, 6 and 10 drips per minute), on separate plates within the same environment.

These controlled experiments provide quantitative evidence of the conditions that favour calcite growth for which $\delta^{18}O_{calcite}$ is in equilibrium with $\delta^{18}O_{H_2O}$. Low temperature, fast dripping conditions are the most favourable for equilibrium growth. Yet equilibrium is also possible at higher temperature, providing suitably fast drip rates and non-evaporative conditions. The results also demonstrate that caution is required in the application of the Hendy test.

We derive a relationship between growth mass, temperature and drip rate. It demonstrates the substantial increase of growth mass with temperature, the small influence of drip rate on growth mass at low temperature and a non-linear relationship between drip rate and growth mass at the higher end of the temperature scale.

Collectively, these experiments therefore provide a more robust understanding of the way that stalagmite carbonate responds to climatically important environmental variables.