Triple oxygen isotopes in speleothems: A case study from Cave of the Bells, AZ, USA

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Speleothems are commonly used as paleoclimate archives because they record climate-related variations in $\delta^{18}O$ of precipitation. Although variability in speleothem $\delta^{18}O$ is generally understood to relate to climate change, paleoclimate interpretations can be ambiguous because $\delta^{18}O$ of precipitation relates to many factors, including precipitation seasonality, intensity, and source region. Evaporation can further modify water $\delta^{18}O$ and, within a cave, kinetic effects during mineralization may cause imperfect recording of the $\delta^{18}O$ of dripwater.

We address some of these problems by adding more information in the form of the triple isotope parameter $\Delta^{17}O$ (where $\Delta^{17}O = \delta'^{17}O - 0.528 \times \delta'^{18}O$). We use a model framework to identify which of three primary processes dominated speleothem $\Delta^{17}O$ vs. $\delta^{18}O$ data. In this framework, data defining a horizontal trend (slope ≈ 0 per meg/‰) results from equilibrium fractionation processes in the atmosphere (i.e., Rayleigh distillation; [1]); data defining a negative trend (slope ≤ -2) results from changing aridity (i.e.., evaporation; [2]), and data defining a positive trend (slope ≈ 7; [3]) theoretically results from disequilibrium isotope effects in caves (e.g., drip rate).

Here, we tested interpretations of the previously investigated Cave of the Bells (COB), AZ, USA speleothem $\delta^{18}O$ record. This record, which covers 50–10 ka, has been interpreted largely in terms of precipitation variability, and we therefore hypothesized that $\Delta^{17}O$ vs. $\delta^{18}O$ data would define a horizontal trend. The null hypotheses were that the slope would match either of the "kinetic" trends caused by evaporation or disequilibrium isotope effects (i.e., slope = -2 or +7, respectively). Our samples define a trend of slope = -0.1 in $\Delta^{17}O$ vs. $\delta^{18}O$ space that is distinct from the disequilibrium trend, but that is not resolvable from the evaporation trend. These results support previous precipitation-based interpretations of the COB record, but underscore the need for higher precision in $\Delta^{17}O$ analyses to better resolve the effects of minor evaporation.

[1] Luz and Barkan, 2010, *GCA* vol. 74, p. 6276–6286
[2] Surma et al., 2018, *Sci Rep* vol. 8, 4972
[3] Guo and Zhou, 2019, *GCA* vol. 267, p. 196–226