Resolving temperature seasonality in near-entrance speleothems

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Temperature seasonality is an important characteristic of regional climate, but continuous reconstructions from terrestrial records are rare owing to the inherent instability of most depositional settings and challenges of obtaining subannual sampling for records with slow accumulation rates. We suggest that near-entrance speleothems that form in well-ventilated temperate settings may record seasonal temperature fluctuations via two independent proxies: $\delta^{18}O$ and Mg/Ca. Low $\delta^{18}O$ and high Mg/Ca values of calcite are both predicted for warmer temperatures, when the water-calcite $\delta^{18}O$ fractionation factor is smaller (e.g. Tremaine et al., 2011) and endothermic substitution of Mg in calcite is favored (Lea 2014). We test these predictions using micromill-IRMS for $\delta^{18}O$ and LA-ICP-MS for Mg/Ca in two near-entrance, actively-forming, stalagmite records, collected in 2009, from central Texas (WC-3) and southern New Mexico (SBF-C2), USA. Growth layers in WC-3 are predominantly 1-2 mm in thickness, whereas those in SBF-C2 are an order of magnitude thinner. Stalagmite WC-3 benefits from fast growth rates that enable ~monthly micromill sampling (125µm steps), and monitoring of the modern system (which confirms the predictions in monthly calcite formed on glass substrates). Resulting $\delta^{18}O$ and Mg/Ca stratigraphies for stalagmite WC-3 are both cyclic (consistently anti-correlated) and in sync with growth fabrics. Resolution of 52 cycles suggests that deposition began in Fall of 1957, consistent with ^{14}C evidence that the base of WC-3 could not be older than 1955. For stalagmite SBF-C2, a basal U-series age of 1863 ± 26 CE indicates an annual growth rate of ~130µm/yr. Although monthly sampling by micromill is impractical (11µm steps), preliminary results for sampling at 20µm steps support that seasonal $\delta^{18}O$ cycles are recorded. LA-ICP-MS scanning of SBF-C2, using a 25x150µm aperture at 5µm/s, demonstrates that Mg/Ca exhibits high-amplitude cycles (n = 138 ± 8) that also follow growth fabrics. By analogy with the WC-3 stalagmite and monitoring records, the Mg/Ca cycles are interpreted to be seasonal. On this basis, the Mg/Ca seasonal chronometer predicts an age of 1871 ± 8, consistent with the underlying U-series date. From comparision of $\delta^{18}O$, Mg/Ca and growth rates in these localities, LA-ICP-MS should offer an efficient tool for resolving temperature seasonality in speleothems with even slower growth rates.