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Long-term cave monitoring on the Edwards Plateau of Texas (USA) to advance speleothem paleoclimate proxies

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Our cave monitoring efforts in the semi-arid karst landscapes of the Edwards Plateau of Texas (USA) have expanded in scale and complexity over 13 years with the goal of clarifying transfer functions relating environmental conditions to speleothem proxies. Understanding how hourly to decadal variations in climatic and hydrologic inputs influence the composition and growth rates of speleothems improves the accuracy of these proxies at decadal to millennial time scales. We present results in the context of variations in 1) cave ventilation, 2) trace elements and 3) stable isotopes.

Cave air monitoring across the plateau demonstrates parallel pCO_2 variations at seasonal, synoptic and diurnal scales. Based on these results, we have developed models suggesting that seasonal ventilation regimes, and thus seasonally biased proxies, are most prevalent where winter and summer temperature extremes contrast with cave air temperatures for extended periods. High cave pCO_2 related to reduced summer ventilation is a common cause of speleothem growth hiatuses. In contrast to the seasonal ventilation typical of most Plateau caves, the shallow cave, WC, has multiple entrances and ventilates year-round, yielding continuous speleothem growth.

In the seasonally-ventilated caves, drip rates correlate with effective moisture or Palmer Drought Severity Index (PDSI) at some sites, while dripwater Mg/Ca correlates negatively with PDSI. This correlation allows speleothem trace elements to be linked to tree ring proxies, which are strongly correlated with PDSI. The co-variation of Mg/Ca, Sr/Ca and $^{87}Sr/^{86}Sr$ distinguishes between calcite or dolomite recrystallization and prior calcite precipitation (PCP). A forward model, driven by two dominant controls on dripwater Mg/Ca and Sr/Ca variation - conduit vs. diffuse flow paths and continuous vs. seasonal speleothem growth, demonstrates how speleothem Mg/Ca and Sr/Ca can reflect paleo-dripwater compositions and that cyclic growth hiatuses yield distinct patterns in geochemical time-series.

Monitoring $\delta^{18}O$ in modern calcite and associated dripwater indicate: 1) a 1.5 ‰ larger calcite-water isotopic fractionation factor than is commonly applied, 2) a growth-rate dependent shift in calcite $\delta^{18}O$, and 3) that invariant $\delta^{18}O$ along a speleothem growth layer does not necessarily indicate isotopic equilibrium. Time-series of the $\delta^{13}C$ of soil CO_2, cave air and cave water DIC suggest that: 1) CO_2 enters the caves primarily by gas diffusion or advection, except in the winter when dripwater degassing is important, 2) trees influence $\delta^{13}C$ of cave-air CO_2 and dripwater DIC disproportionately compared with the abundance of grasses, and 3) the open epikarst system allows carbon exchange between gas and water and therefore dripwater DIC does not contain a $\delta^{13}C$ signal from the host limestone.

In the continuously ventilated cave WC, dripwater Sr/Ca and Ba/Ca are apparently controlled by PCP, calcite growth rate, and their effects on Sr and Ba partitioning coefficients. Dripwater $\delta^{18}O$ values do not vary seasonally; indicating that mixing in the vadose zone smooths rainfall $\delta^{18}O$ variability. Modern calcite $\delta^{18}O$ variability in WC is correlated with temperature. These results indicate the value of monitoring studies in advancing proxy interpretations and that monitoring at non-traditional sites may yield new proxy applications for speleothem studies.