Hot and Heavy or Cool and Fresh: Resolving Meteoric from Burial Diagenesis Using Clumped Isotopes

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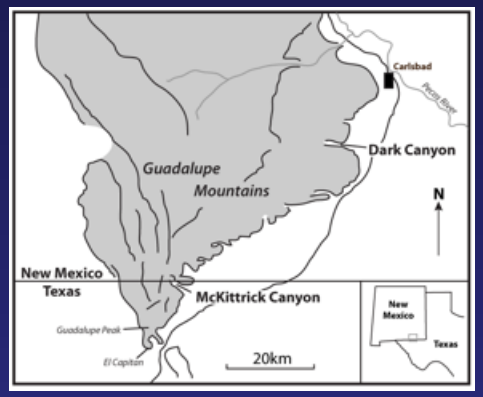
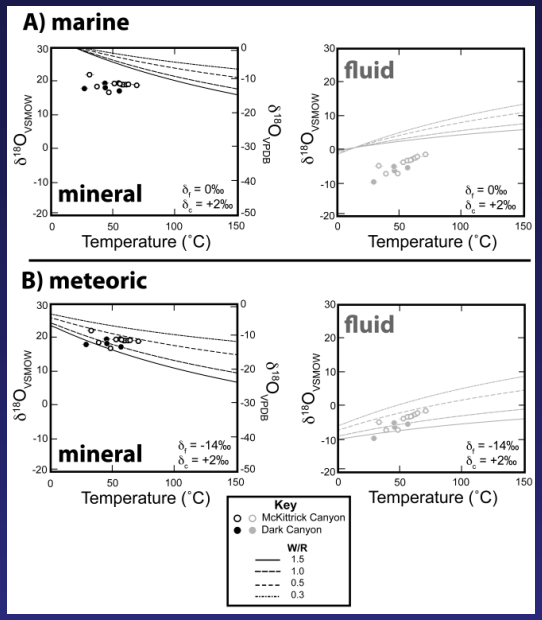
- Key finding: Evidence for diagenetic mineralization at shallow depths – i.e. 'on the way up'



Evidence that late-stage cements were emplaced at relatively cool temperatures and meteoric fluids, implying precipitation occurred at shallow depths. Diagrams show the correlation between clumped isotope temperature and pore water oxygen isotope compositions and overlain with modeled water-rock ratios (W/R) generated using an initial fluid with (A) a marine $\delta^{18}O_{fluid}$ (0‰) value or (B) a meteoric (–14‰) value. δ_f = $\delta^{18}O_{fluid}$, δ_c = $\delta^{18}O_{carb}$.



Despite its widespread occurrence, the timing of cement emplacement in carbonate sequences is poorly constrained due to ambiguities associated with the interpretation of traditional oxygen isotope values in carbonate rocks, with cements assumed to form progressively as sediments are buried. Clumped isotope thermometry allows us to clearly document the average temperature and pore fluid composition associated with cementation. We examined the Permian El Capitan Formation, one of the most widely studied carbonate sequences within which blocky calcite spar is an extensive lithologic component. We use clumped isotope data from calcite spar of the fore-reef facies in order to constrain formation temperatures and provide insight into precipitation timing, and directly study the yet untested hypothesis that late stage cements formed as the sequence was buried.

We find precipitation temperatures range from ~30 to 75˚ C and show strong positive correlation with reconstructed pore water $^{18}O/^{16}O$ values, indicating rock-buffered behavior. Evaluation of the data using a simple water-rock model indicates that the fluid(s) involved in diagenesis must have had a significant meteoric component. These values are similar to modern rain waters falling on outcrops of the El Capitan Formation and such depleted fluids were likely only achieved in the very recent past (< 5 million years ago) based on paleogeographic reconstructions. Both the temperatures and fluid compositions, when taken in conjunction with previously reported outcrop and core relationships, indicate spar precipitation did not occur during burial but instead occurred during uplift/exhumation of the El Capitan Formation. The occurrence of this style of diagenesis ('on the way up') may be more common in other rock units than previously thought and must be considered when interpreting paragenetic evolution.