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A Cretaceous Enhanced Hydrologic Cycle? Characterizing paleohydrology from Mexico using a multiproxy approach with shallow marine carbonates

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Reconstructing the paleoclimate conditions of key greenhouse periods like the Cretaceous (145-66 Ma) is critical for assessing the accuracy of climate model predictions of climate change. Using the isotopic composition of marine and terrestrial carbonates is a common geochemical method employed to gather quantitative results for such reconstructions. However, distinguishing between pristine carbonates that faithfully record surface climate signals versus diagenetically altered carbonates can be challenging. Here, we implement clumped isotope (Δ_{47}) and triple oxygen isotope ($\Delta'^{17}O$) analyses to unambiguously identify pristine carbonates from the Early Cretaceous Tlayúa Formation in south-central Mexico and reconstruct original formation temperatures and formation water $\delta^{18}O$ values. These reconstructed temperatures and formation water oxygen isotope values provide new constraints on the Enhanced Hydrologic Cycle (EHC) hypothesis, which proposes that elevated high latitude temperatures during greenhouse periods were driven by increased latent heat transport from the tropics to the poles. Three unique generations of calcite growth were identified in the Tlayúa Formation samples using cathodoluminescence analysis: dimly-luminescent micrite, luminescent spar, and non-luminescent spar. Subsequently, these carbonate types were subsampled and analyzed for Δ_{47} and $\Delta'^{17}O$ to constrain differences between primary and secondary geochemical signals. Calculated Δ_{47} temperatures of micrite samples (34 °C to 48 °C) were warmer than those of non-luminescent spar (29 °C to 34 °C) and luminescent spar (28 °C to 36 °C) samples. A comparison of the micrite Δ_{47} temperatures and $\Delta'^{17}O$ results to a fluid-rock interaction model suggests that most of the samples formed under evaporative conditions and afterwards experienced some degree of alteration at relatively low temperatures (<100 °C). Original formation temperatures were high (>30 °C) based on a single pristine sample that precipitated under conditions of isotopic equilibrium. This study demonstrates the power of using paired clumped and triple oxygen isotope analyses to disentangle equilibrium, disequilibrium and diagenetic isotope signals in carbonate samples and provides important new constraints on low latitude paleotemperatures and marine $\delta^{18}O$ values during the Early Cretaceous.