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Beyond paleoclimate: constraining biomineralization processes and predicting diagenetic patterns with boron, dual-clumped and triple-oxygen isotopes

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Reconstruction of past climates has historically been hindered by so-called “vital effects” and diagenetic processes; identifying these processes in geological samples is thus a priority for improving climate records. Vital effects, often considered a bane to good paleoclimate reconstruction, provide tremendous value to biologists and paleontologists aiming to study the mechanisms that drive skeleton formation. Similarly, understanding the fingerprints of diagenetic processes allows for more detailed studies of the post-depositional history of strata. Evaluation of how all three of these processes (primary climate, vital effects, diagenesis) affect the resulting isotopic composition is challenging, however can begin to be approached with numerical modeling. To this end, we have developed a numerical model that can simultaneously model the results of rate-limiting isotope kinetics during biomineralization and subsequent dissolution/reprecipitation processes. Cross-membrane diffusive mobility of non-charged molecules, such as CO_2 and $B(OH)_3$, and active transport of alkalinity and calcium affect the chemical and isotopic composition of a mineralization space in ways that ultimately contribute to non-equilibrium isotopic compositions. Because $\delta^{13}C$, $\Delta^{17}O$, $\delta^{18}O$, Δ_{47}, Δ_{48}, B/Ca and $\delta^{11}B$ all respond to these same processes in different ways; they can collectively be used to understand the extent of these processes, potentially allowing for simultaneous reconstruction of calcification pH and primary temperature and water composition. Such models can further be used to simulate water-rock interaction, allowing the exploration of different diagenetic scenarios.