Spatial stable isotope variability in modern lacustrine carbonate: How do local microbial processes translate to the sedimentary record?

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The abundance and distribution of carbon and oxygen stable isotopes within carbonate lake sediments are commonly used to reconstruct physicochemical conditions in ancient terrestrial environments (e.g., temperature, aridity, elevation, and vegetation). However, we hypothesize that microbe-sediment interactions in the subsurface alter the primary isotopic composition of carbonate either directly, e.g. by metabolic pathways such as sulphate reduction, or indirectly by altering the porewater dissolved inorganic carbon (DIC) pool from which authigenic carbonate precipitates. How does early, localized isotopic alteration manifest itself in the sedimentary record? In this study, we measure carbon, oxygen, and clumped (Δ_{47}) isotopic composition of carbonate sediments (carb), organic matter (OM), and porewater DIC from sediment cores in Great Salt Lake (GSL). When there is a strong microbial influence in the porewater-carbonate system, we expect an anti-correlated trend in $\delta^{13}C$ values of OM and carbonate due to mixing of DIC and DOC pools. In addition, carbonates associated with OM respiration typically have lower $\delta^{18}O$ values, and thus we test the fidelity of $\delta^{18}O$ as a secondary indicator of microbial influence on carbonate stable isotopes. We find significant $\delta^{18}O$ and $\delta^{13}C$ variability within and between sediment cores across ~1 km^2. The measured carbonate sediments and microbialites formed within geologically contemporaneous macro-environments, and thus isotopic variability likely reflects perturbations to local carbonate chemistry via biological processes in the sub-surface rather than changes in climate or environment.

A single sedimentary bed should record a snapshot in an environment's depositional history. Our data suggest that sampling across theoretically contemporaneous modern GSL sediments would yield ranges in $\delta^{13}C_{carb}$ and $\delta^{18}O_{carb}$ of at least 4‰ and 6‰, respectively. In the rock record, this variability would likely be interpreted as post-burial, late-stage diagenesis rather than biologically driven eogenesis in the sub-surface environment. Thus, we demonstrate the importance of lateral sampling of coeval geological sediments across intrinsically complex lake systems to fully characterize and use the geochemical and isotopic variability driven by localized biological processes to fingerprint true primary environmental signatures.