Stable isotope geomicrobiology – modern microbes and their ancient implications

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Microbial metabolisms leave behind geochemical fingerprints, such as stable isotope ratios, that can be preserved in the rock record for billions of years. Much of our understanding of the coevolution of Earth and life over geologic timescales relies on our ability to interpret these rock-bound geochemical signatures. Regardless, significant gaps still exist in our knowledge of many of the relevant biological isotope effects. I will present laboratory mesocosm and field analogue studies aimed at calibrating the magnitudes, mechanisms, and environmental dependence of stable isotope fractionations associated with specific biological reactions within the sulfur (and nitrogen) cycles, and discuss their implications for interpreting biogeochemical cycling from the sedimentary record.

A focus will be on recent work constraining the sulfur isotope signatures of biological sulfide oxidation. This metabolic feat reflects a critical evolutionary step in the global sulfur cycle, and has been tied both to the oxygenation of Earth's early environments and to the formation of the first extensive phosphorite deposits. Sulfide oxidation has been notoriously difficult to constrain from sedimentary records due to the small $\delta^{34}S$ fractionations involved in comparison to other S cycling processes. Multiple sulfur isotope analyses of products from laboratory experiments with photo- and chemotrophic S-oxidizing organisms has extended the magnitude of known fractionations and demonstrated unique signatures for oxidation of different reduced-S substrates, especially when the intermediate products (e.g., zero-valent sulfur, ZVS) are considered. These analyses highlight the utility of examining intermediates such as ZVS (and of devising strategies for extracting ZVS products from ancient samples) in modern and paleo-ecosystem reconstructions. In addition, a comparison of the isotope values of S compounds and sediments in a variety of relevant early Earth analogue environments (e.g., stratified lakes and sulfidic caves), suggests that the likelihood of transferring these oxidation signatures into the sedimentary record is variable. In some cases where the signal of oxidation is transferred to the sediments, the trends differ significantly from what has been previously expected, supporting recent paradigm shifts in interpretion of the temporal $\delta^{34}S$ records.