Microbial-Scale Records of Early Life and Environment

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Life is hard to define, but we often 'know it when we see it'. Chemical signs of life are more significant when associated with morphological biosignatures, and vice versa. Looks can certainly be deceiving – and context is critical – but when asking whether something lives or once did, we search for spatial order. Life orders environments across widely ranging scales: from the structural and isotopic organization of molecules in a membrane to gas mixing ratios in atmospheres recognizable across interstellar space.

Earth's rock record implies that life was uniformly microbial for most of the planet's history and that the emergence of macroscopic, multicelluar eukaryotes was limited by the pace at which cyanobacterial oxygen escaped consumption by the young planet. Whereas a spectacular diversity of eukaryotic form was recorded in the wake of Neoproterozoic oxygenation, the earlier microbially-dominated fossil record is morphologically monotonous. Precambrian fossil diversity is expressed in the rare organo-mineralic preservation of microbial cells (microfossils) or their macroscopic, organosedimentary community structures (microbialites). Some clues to mode of life may be found in microfossil or microbialite morphology, but confident assignment of taxonomic affinity is elusive and likely requires chemical analysis at or below the cellular scale.

Molecular fossils are recognized in the systematic variety and complexity of intramolecular structure in labile sedimentary organic matter from the Paleoproterozoic to the present, but Archean biomarkers are either absent (destroyed by metamorphism) or suspect (as contamination). By contrast, more recalcitrant organic matter – kerogen – and common (bio)mineral classes including carbonates, phosphates, sulfates, sulfides, and iron oxides, can retain biologically influenced structural and isotopic organization from the earliest Archean. Many processes act to obliterate or homogenize biological order, and resolving the mechanistic contours of such alteration is crucial.

This presentation will explore current developments in and new results from microbial-scale, spatially resolved analysis seeking records of early life and environment on Earth and beyond.