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Characterization and application of mechanisms of microbially induced biomineralization

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Biomineralization has been well-catalogued, and new challenges lie in characterizing mechanisms, especially with regard to roles of cells and organic polymers, and the formation and evolution of nanoparticles. The results of characterization and experimental synthesis will also help refine existing criteria for detection of mineralogical biosignatures. Furthermore, applying biomineralization to remediation will require novel methods of monitoring progress. Combinations of molecular, microscopic, laboratory, and field-scale approaches will therefore be increasingly necessary.

Microbes that precipitate metal-sulfides or metal-oxides (i.e. UO_2) can strongly influence the fate of metals in sediments. These minerals represent a sink or source in remediation and biogeochemical cycling, or reactants in lithification. Size, structure, and relationship to organics constrain phase stability, aggregation and crystal growth, transportation, and deposition. We characterize with EXAFS and HRTEM UO_2 and ZnS formed by sulfate-reducing bacteria in vitro and in situ, and show how these phases can decrease metal mobility in contaminated sediments.

Organic polymers influence biomineralization, and potentially produce biosignatures. We use synchrotron X-ray microscopy to study extracellular polymers of iron-oxidizing microbes and associated iron oxides. We identify and show close association of polysaccharides with iron oxides, suggesting involvement in akaganeite growth. We experimentally synthesize natural processes, and simulate characteristics of oxide-polymer forms. Time-resolved spectral changes show interactions between polymer functional groups and growing iron-oxides.

We are also developing techniques to assess spatial-temporal variations in biomineralization in aquifers, including decreased hydraulic conductivity and substrate depletion. Changes in acoustic wave propagation and resistivity spectra in saturated porous media are correlated at column and field scales to provide information about subsurface biomineralization previously limited to direct well-bore sampling.