Sulfur-Mediated Electron Shuttling during Bacterial Iron Reduction

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Understanding the flow of electrons through various types of microbial metabolisms is essential to predicting the fate and transport of contaminants as well as the speciation and distribution of carbon in the subsurface, rhizophere, and its release into the atmosphere. Fe(III) minerals are critical electron acceptors in many aquifers, but the extent to which they provide energy for the growth of microorganisms depends greatly on the thermodynamic energy that is available to them from their environment. In alkaline, oligotropic aquifers, for example, the amount of energy available to dissimilatory metal-reducing bacteria (DMRB) via the reduction of Fe(III) minerals decreases dramatically with increasing pH. Many DMRB, however, can also respire by reducing elemental sulfur [S(0)] to sulfide, a process which provides more energy under alkaline conditions than acidic ones. In a series of bioreactor experiments, we have shown that at pH 9, the DMRB Shewanella oneidensis MR-1 can respire S(0) but not goethite. The sulfide produced subsequently reduced goethite abiotically. In experiments conducted with a mutant strain of S. oneidensis (PSRA1), which is able to reduce Fe(III) but not S(0), no ferrous iron was produced. The reduction of S(0) to sulfide and the formation of mackinawite (FeS) was confirmed by sulfur K-edge x-ray absorption near-edge spectroscopy (XANES). Because the abiotic reaction of sulfide with Fe(III) produces S(0), in the absence of geologic deposits of S(0), DMRB in alkaline aquifers may require active respiration by sulfate-reducing bacteria (SRB) in order to respire. Under these conditions, Fe(III) reduction will proceed via S(0)-mediated electron shuttling pathways that requires a mutualistic partnership between DMRB and SRB rather than direct enzymatic reduction of Fe(III) minerals by DMRB alone.