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Geochemical modeling of bacterially induced mineralization of schwertmannite and jarosite in sulfuric acid spring water

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ABSTRACT

Mineralogy and geochemistry of a sulfuric acid spring water with a pH of 3.37 to 2.89 were investigated to verify the formation processes of iron minerals and the effects of bacteria on their formation. To estimate the solubility of schwertmannite, experimental dissolution in 10.0 mM H_2SO_4 was conducted and this solubility data was used for geochemical modeling. Experimental incubation of the spring water containing bacteria was also performed and compared with a simulated abiotic system to evaluate the role of bacteria in the mineral formation. The spring water seeps through cracks of hydrothermally altered andesitic rocks containing pyrite, and precipitates schwertmannite and jarosite. Schwertmannite appears as a film-like thin layer floating on the water surface and composed of aggregates of spherical particles with diameters of 1 to 5 μm. Jarosite is produced as a precipitate on submerged rock surfaces. The precipitate contains well crystallized jarosite spheres 5 to 10 μm in diameter. Some ellipsoidal to rod shaped bacteria covered or decorated by poorly ordered iron minerals are also present in close association with the schwertmannite spheres. Results of the experimental incubation demonstrate that the oxidation rates of Fe^{2+} are 5.3×10^3 to 7.2×10^3 times greater than those of the simulated abiotic system, suggesting that the formation of the iron minerals is promoted by bacterial oxidation of Fe^{2+}. The dissolution experiment indicates that the solubility product of the schwertmannite having an average chemical composition of $Fe_8O_8(OH)_{5.9}(SO_4)_{1.05}$ is approximately $\log K_s = 7.06 \pm 0.09$. Using this data, geochemical modeling reveals that the spring water is supersaturated with respect to schwertmannite and also goethite and jarosite, but undersaturated with respect to ferrihydrite. Additionally, it is confirmed that the bulk solution chemistry deviates slightly into the stability field of goethite rather than jarosite. This suggests that the aquatic environments in contact with the rock surfaces may be more acidic and/or enriched in SO_4^{2-} relative to the bulk solution, which may eventually lead to the formation of jarosite instead of goethite.