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Exploring Banded Iron Formation Diagenesis Through Experimental Simulations

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Banded Iron Formations (BIFs) are iron- and silica-rich marine chemical sedimentary rocks that potentially hold a record of Archean biogeochemical cycles. However, using BIFs to interpret the ancient marine environment and possible metabolisms of early life requires unraveling the many reactions associated with early and burial diagenesis as well as post-lithification alteration. BIFs contain a diverse assemblage of iron minerals, with most better-preserved BIF cores dominated by magnetite, iron carbonates, iron phyllosilicate phases (e.g. greenalite and minnesotaite), and occasionally hematite. These reduced and oxidized iron minerals are in disequilibrium and are generally thought to have formed during post-depositional reactions, although greenalite and iron carbonate inclusions are preserved in early-mineralizing cherts. We sought to identify how diagenesis could contribute to the complex BIF mineral assemblage in order to differentiate early versus secondary minerals, and ultimately extract signals of the Archean ocean and sediment biogeochemistry from BIFs. Therefore, we used laboratory experiments to simulate potential microbial and temperature-induced diagenetic reactions. To explore the mineral products of microbial iron respiration, we incubated ferrihydrite, a proposed BIF precursor, with a model iron-reducing bacterium under conditions mimicking the predicted silica-rich Archean seawater chemistry. Siliceous experiments formed poorly layered iron-silica coprecipitates, likely incipient iron-rich silicates, suggesting that this microbial metabolism could produce early diagenetic iron phyllosilicate phases like those observed in the BIF record. We also investigated how higher temperatures associated with burial diagenesis can alter mineral phases. In this experiment, we subjected the products of partial iron oxidation in a solution replicating the Archean ocean (rudimentary iron silicates and siliceous ferrihydrite) to sequential steps of hydrothermal aging from 80 °C to 220 °C. During this simulated diagenesis, magnetite mineralized and the initial iron silicates crystallized into Mg-rich greenalite, with Mg content increasing with temperature. Ultimately, our experiments help reveal how the initial iron-silica coprecipitates from the Archean ocean can transform during diagenesis in high-silica environments, providing novel insights into how BIF minerals can be linked to ancient biogeochemistry.