Biogenic mineral transformations of Fe(III) (oxyhydr)oxides at high temperatures

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Distinct organic and/or mineral signatures of specific biological processes need to be defined using tools currently available or plausible on spacecraft, in order to detect life in our Solar System. Here we study dissimilatory iron reduction by two hyperthermophilic archaea: *Pyrodictium delaneyi* (marine) and *Pyrobaculum islandicum* (freshwater) [1,2] using six nanophase Fe(III) (oxhydr)oxides. We seek to understand an early microbial process [3] on a fundamental basis, and to describe the range of mineral transformation products with spacecraft-relevant spectroscopies.

Results from growth and Fe(II) production kinetics experiments demonstrate that both organisms grow at the highest rates and produce the most Fe(II) using ferrihydrite, although *P. delaneyi* produced four times as much Fe(II) compared to *P. islandicum*. Lepidocrocite and akaganéite are the next two most accessible mineral species for reduction by both organisms. Highly (or more) crystalline phases such as hematite, goethite, and maghemite are poorly reduced in comparison. Transmission electron microscopy reveals an increase in crystal size for transformation products of ferrihydrite, lepidocrocite and akaganeite with *P. delaneyi* but not *P. islandicum*.

Spectral analyses using visible-near-infrared, fourier-transform infrared, attenuated total reflectance, Raman and Mossbauer spectroscopies indicate the formation of magnetite and/or maghemite phases with ferrihydrite, a ferrous carbonate phase reminiscent of siderite with lepidocrocite, and a ferrous phosphate similar to vivianite and magnetite with akaganeite. These findings expand the current view of bioavailable Fe(III) (oxyhydr)oxides for reduction by hyperthermophilic archaea when presented as nanophase minerals. They demonstrate that many possible types of mineral transformation products may result from bioreduction at high temperatures.

[1] Lin *et al.* (2016) *IJSEM* **66**, 3372-3376. [2] Huber *et al.* (1987) *Arch. Microbiol.* **149**, 95-101. [3] Vargas *et al.* (1998) *Nature* **395**, 65-67.