Did bacteria induce redox cycling of magnetite within Banded Iron Formations (BIFs)?

JAMES M BYRNE[1], MANEL SCHAD[1], CATHERINE MCCAMMON[2], ELIZABETH TOMASZEWSKI[1], ALBERTUS SMITH[3], VALERIO CERANTOLA[4], ANDREAS KAPPLER[1]

[1] University of Tuebingen, Center for Applied Geoscience, Geomicrobiology, Germany
[2] Universität Bayreuth, Bayerisches Geoinstitut, Germany
[3] University of Johannesburg, Department of Geology, South Africa
[4] ESRF, Grenoble, France

Banded iron formations (BIFs) provide one of the most comprehensive archives of the history of life on Earth. The exact mechanism behind BIF genesis remains under debate, however microbial activity is considered to be one of the most important factors. Oceans during the Archean were ferruginous (high Fe(II) concentrations). This Fe(II) was oxidized abiotically by O_2 produced by early cyanobacteria or biotically via microbial Fe(II)-oxidation leading to the precipitation of primary minerals such as ferrihydrite. The ferrihydrite underwent secondary transformation, via as yet unknown processes, to hematite, magnetite and siderite.

We recently showed that magnetite can undergo either microbial Fe(II) oxidation or Fe(III) reduction (Byrne et al., Science 2015). This study applied ^{57}Fe Mössbauer spectroscopy to evaluate changes to the oxidation state of magnetite depending upon the geochemical conditions it was present under. We speculate that such processes could have taken place following the initial formation of primary BIF minerals, and thus contributed to the overall oxidation state and mineral content of BIFs. Many Fe layers within BIFs have submillimeter thickness, which means conventional Mössbauer spectroscopy (typical beam diameter 1 cm) cannot distinguish between Fe minerals in different layers. However, synchrotron Mössbauer spectroscopy (SMS), has 15 x 10 μm^2 spot size, making it ideal for high-resolution spectroscopy.

We used SMS to investigate evidence of microbial Fe cycling of the mixed-valent mineral magnetite within several Paleoproterozoic BIF thin sections. We observed deviations in the magnetite Fe(II)/Fe(III) ratio from the stoichiometric value of 0.5 to either oxidized (0.2), or highly reduced (>0.7). Some of these differences appear to correlate to proximity to either siderite or hematite layers. This high-resolution data provides evidence of magnetite redox cycling, either during sedimentation or during diagenesis. These results have important implications for the interpretation of biosignatures within BIFs, especially with regard to understanding the (trans)formation processes involved in their genesis.