Evidence for biogenic origin of the Mn-enriched layer in Lake Superior sediments

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This study examines the bacterial communities of Lake Superior sediments to prove the biogenic origin of Mn-enriched layers. The potential for anaerobic Mn(II) oxidation occurring in the Mn layer is investigated using enrichment cultures, 16S rDNA pyrosequencing, and high resolution electron microscopy and spectroscopic mapping. Pyrosequencing analysis reveals that the Mn-enriched layer, compared with the Fe-enriched layer below, exhibits higher bacterial diversity and a higher proportion of classes with known Mn(II)-oxidizing members. These classes include the Alphaproteobacteria and Betaproteobacteria, containing members of the genera *Pedomicrobium* and *Hyphomicrobium*.

Microscopy and spectroscopy analyses of the Mn-enriched layer provide additional evidence of the formation of biogenic Mn oxides occurring *in situ*. Energy filtered transmission electron microscopy (EFTEM) images show bacterial cells encrusted with Mn oxides, suggesting that the accumulation of Mn-enriched layers is linked to bacterial cells. Pyrosequencing of enrichment cultures suggest that these bacteria may be *Bacillus* species, consequently proposing that anaerobic microbially-mediated Mn(II) oxidation contributes to the Mn-enriched layer formation. We also observe several virus-like particles that were encrusted with precipitates in close proximity to bacterial cells. The abundance of virus-like particles suggest an unrecognized role of viruses in biomineralization. Notably, biogenic Fe-phosphate formation has been observed, findings which support an emerging interest with little existing evidence (Figure 1).

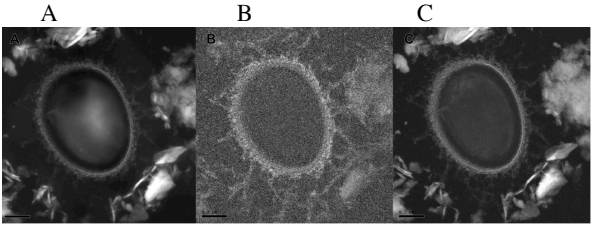

Figure 1. EFTEM images of an enrichment culture A) Image acquired using an electron backscatter detector. B) Fe map (Fe $L_{2,3}$-edge. C) P map (P $L_{2,3}$-edge), scale bar is 200 nm