Framboidal magnetite formation in ferruginous waters

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Conspicuous raspberry-like (framboidal) forms of the mineral magnetite ($Fe^{2+}Fe^{3+}_2O_4$) have been sporadically observed in extraterrestrial bodies and ancient sedimentary rocks and may form biogenically in response to microbial Fe(III) respiration. Little is known about these rare mineral forms, however, and though they hold great promise as possible biosignatures and environmental fingerprints, more information is needed to connect framboid formation to the underlying biogeochemical processes. To explore pathways of magnetite formation we studied Fe cycling in two modern ferruginous lakes - Towuti and Matano in Indonesia - using geochemical and microscopic techniques. We find that framboidal magnetite forms as a likely product of water column Fe reduction and is deposited in the underlying sediments. Magnetite appears stable in these sediments over timescales of several thousands of years, implying strong preservation potential. We also find that identification of framboidal magnetite can be accomplished via Raman microspectroscopy, providing an attractive tool for future rover based in-situ analyses of planetary materials. Further investigation into the properties of framboidal magnetites from lakes Matano and Towuti, for example their Fe and O isotopic compositions, holds considerable promise for improving the diagnostic power of putative Fe-mineral biosignatures that may have deposited from ancient ferruginous oceans on Earth, or even remotely on other planetary bodies.