Physical sedimentology constrains the primary precipitates in banded iron formations

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Banded iron formations (BIFs) are iconic reminders of the biogeochemical peculiarity of the Precambrian surface environment. Interpretations of their record of, and influence on, the chemistry and biology of Earth's early oceans is strongly influenced by our understanding of the primary minerals that precipated to form BIFs. The identity of these primary mineral precipitates is an open question. Here we describe flame structures from a Mesoarchean BIF, and use stability theory to infer the identity of original mineral precipitates that made up the BIF's iron-rich layers.

We studied an exposure of chert-magnetite BIF in the Red Lake Greenstone belt, NW Ontario that was deposited ≈3.2 billion years ago on the flank of a submarine volcanic edifice. Alternating beds of chert-rich and magnetite-rich layers are ≈2-5 cm thick, and preserve delicate sedimentary structures including fine internal laminations and graded bedding. The beds are coherently deformed in slump folds and around mafic lava pillows, indicating that the sediments were coherent but only weakly lithified when deformed. Along with other indicators of syn-depositional deformation like localized chaotic bedding, these features imply that the chert-magnetite laminations formed during deposition rather than through grain-scale segretation associated with metamorphic recrystalization.

We identified flame structures on several bedding surfaces around the exposure. The flame structures each originate from a separate single bedding layer, and have a cuspate-lobate morphology with a regular spacing between the cusps. Flame structures form in layered sediments when a higher density layer overlies a lower density layer, creating a density gradient that drives material from the lower layer to intrude the upper layer at regular intervals. Stability theory indicates that the Rayleigh-Taylor instabilites represented by flame structures develop at a characteristic wavelength that is controlled by the densities and viscosities of the two sedimentary layers. Our stability analysis of the characteristic spacings of the flame structures, in combination with modal reconstructions of original bulk chemical compositions, implies that the magnetite-rich layers in the Red Lake BIF originated as green rust mineral precipitates.