Greenalite nanoparticles in Archean BIFs: seawater precipitates or products of bacterial iron reduction?

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Banded iron formations (BIFs) are fine-grained chemical sediments comprising alternating iron-rich and silica-rich layers whose chemical constituents were derived from seawater. They have been widely used to decipher the chemistry of the Precambrian oceans and atmosphere, and the nature of the marine biosphere on early Earth. However, unlike other sedimentary rocks, it is still uncertain what phases were deposited from seawater and what phases formed during diagenesis.

Recent transmission electron microscopy of laminated chert in major BIFs from Western Australia and South Africa suggests that a major iron-phase was greenalite (a ferrous-silicate mineral) that precipitated as nanometer-sized particles and settled onto the seafloor as an iron-rich mud. However, it has also been argued that the original precipitates were ferric oxides/hydroxides, and that the iron silicate nanoparticles represent products of dissimilatory iron reduction (DIR) involving reactions between primary ferric oxide/hydroxide precipitates and organic matter.

Using microscopic and microanalytical techniques we investigate relicts of the purported depositional phases in well-preserved BIFs, including greenalite, siderite, magnetite and hematite. We find that siderite, magnetite and hematite do not display the characteristics of seawater precipitates, however, the texture of greenalite nanoparticles in chert closely resembles the fabric of freshly deposited muds, which typically comprise 70-90% water. The preservation of depositional fabrics implies that the nanoparticles were “frozen” by silica cement on or just below the seafloor, an interpretation supported by their presence in intraformational chert clasts containing greenalite nanoparticles and microganules. Our observations suggest that after deposition, amorphous silica rapidly entombed the greenalite precipitates in a chemically inert cement, which limited burial-related compaction and inhibited diagenetic reactions, thereby providing an unsullied look at the microfabric and mineralogy of the earliest formed phases in BIFs.