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Exploring the potential of banded iron formations (BIFs) as a biosignature

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Banded iron formations (BIFs), characterized by rhythmic alternations of Fe-rich and Si-rich laminae at millimeter to micrometer scales, are the Archean and Paleoproterozoic landmarks. Unlike stromatolites that persist through the Phanerozoic, the disappearance of BIFs after 1.8 Ga and the absence of modern analogues have fueled ongoing debates regarding the origin of their rhythmic laminae and potential links to microbial activities. Here, we show genetic relationships between Fe, Si, and P mineral phases, and suggest the coupled Fe-Si-P cycles in the BIFs formation. We propose that rhythmic depositions of Fe-rich and Si-rich laminae may reflect cyclic fluctuations of the intensity Fe redox cycles, consisting of Fe^{2+} oxidation in seawater and microbial Fe reduction in sediments with FeOOH shuttling seawater Si and P into sediments. Furthermore, we propose a novel microbial modulation hypothesis based on systematic variations in germanium (Ge) concentrations and iron isotope compositions ($\delta^{56}Fe$) between Fe-rich and Si-rich laminae. The self-organized periodic oscillations of seawater P-Fe-Si concentrations, driven by the processes of dissimilatory iron reduction and FeOOH-Si-P coprecipitation, could provide a potential formation mechanism for the micrometer-scale rhythmic laminae in BIFs. Our study strengthens the case for using BIFs as biosignature in Early Earth and other planets, such as Mars.