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Primary magnetite formation in ferruginous waters

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Banded iron formations (BIF) are Precambrian Fe-rich sedimentary deposits that contain important information on the ecology and geochemistry of ancient oceans. BIFs comprise large inventories of both Fe^{3+} and Fe^{2+} minerals, implying redox cycling of Fe in the Precambrian oceans. Magnetite, a multivalent Fe-mineral ($Fe^{2+}Fe^{3+}O_4$), dominates BIF mineralogy, yet its origins remain poorly known and contentious. Detrital, diagenetic, and metamorphic origins have been invoked, but primary water column formation is rarely considered, in part, because low temperature magnetite formation is rarely observed in modern environments. Lack of knowledge on the origins of magnetite in BIF confounds reconstructions of paleoecology and geochemistry that rely on BIF mineralogy and isotopic compositions.

We have used Fe-speciation measurements and mineralogical analyses to test for primary pelagic magnetite formation in the ferruginous (Fe-rich) Malili Lakes of Indonesia. Analyses of particles collected in sediment traps reveal the formation of oxalate extractable Fe phases directly in the water column. Oxalate extractions selectively dissolve magnetite suggesting primary pelagic magnetite formation in the Malili Lakes. By analogy to the Malili Lakes, our data imply that magnetite in BIF could have formed within Precambrian oceanic water columns. This would have facilitated the delivery of mixed valence Fe to BIF sediments influencing marine and sediment redox budgets. Primary magnetite may thus also capture water column isotopic signals and this should be considered in the interpretation of Fe isotopes in BIF.