Zinc and Nickel signature for abiogenic and biogenic magnetite: implications for the origin of magnetite in banded iron formations

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There are longstanding and ongoing controversies about the abiogenic or biogenic origin of magnetite in banded iron formations (BIFs). The trace element composition of magnetite was proposed as a promising tracer for distinguishing biogenic from abiogenic magnetite, which, however, remains to be explored quantitatively. Here, we compared the partitioning of trace elements Zinc (Zn) and Nickel (Ni) in both abiogenic and biogenic magnetite produced either by an abiotic reaction of ferrihydrite with $\text{Fe}^{2+}_{\text{aq}}$ or by Fe(III)-reducing bacteria Shewanella oneidensis MR-1. We compared the transformation of three different ferrihydrite (Fh) starting materials: 1) Control Fh without added trace elements, 2) ferrihydrite with co-precipitated Zn (ZnFh) and 3) ferrihydrite with co-precipitated Ni (NiFh) – both in either NaHCO₃ or HEPES buffer. We monitored Fe concentration and speciation in both aqueous and solid phases over time using the spectrophotometric ferrozine assay, analyzed Fh transformation products by Mössbauer spectroscopy as well as X-ray diffraction and quantified Zn and Ni in solution and in the minerals by iCAP-Qc quadrupole mass spectrometer after acidic dissolution of the minerals. In summary our results revealed that both Zn and Ni are much more depleted in abiogenic magnetite than those in biogenic magnetite, independent of whether magnetite was precipitated in NaHCO₃ or HEPES buffer. Although further analyses are needed, this suggests that the trace element distribution could be a chemical signature to distinguish biogenic from abiogenic magnetite in BIFs.