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Source heterogeneity for the 2.3-2.2 Ga Yuanjiacun banded iron formation in China: Implications for the Nd cycle in Earth's early oceans

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The recognized worldwide gap in BIF deposition between 2.4-2.0 billion years ago has long been considered as an obstacle to fully determining the geochemical composition of seawater at that time (Bekker et al., 2010). However, the recently dated 2.3-2.2 Ga Yuanjiacun banded iron formation (BIF) in the North China Craton (NCC) offers a possibility to redress these uncertainties.

This BIF is within a metasedimentary rock succession of the Yuanjiacun Formation in the lower Lüliang Group. The Yuanjiacun Formation had been originally deposited in a passive margin setting, most probably on a stable continental shelf (Wang et al., 2015). Iron oxide (magnetite and hematite), carbonate, and silicate facies are all present within the iron-rich layers. Shale-normalized rare earth element-yttrium (REE+Y) patterns of the BIF and interlayered meta-chert samples show features characteristic of other Archean and Paleoproterozoic BIFs (Planavsky et al., 2010), with HREE enrichment relative to LREE, positive La and Eu anomalies, and superchondritic Y/Ho ratios comparable to modern seawater. Very low Al_2O_3 (<0.5 wt%) and high field strength elements (HFSE) concentrations (<10 ppm) indicate an essentially detritus-free depositional setting, while positive Eu anomalies are attributed to an imprint of high-temperature hydrothermal fluids.

Sm-Nd isotopic data and corresponding correlations between Nd isotopes and major components of the BIF and meta-chert samples allow for a further characterization of the two interacting water masses (ambient surface seawater and seafloor-vented hydrothermal fluids). The former is characterized by negative $\varepsilon_{Nd}(t)$ values (inferred end-member $\varepsilon_{Nd}(t)$= -2.4), similar to the one defined by spatially associated clastic meta-sediments, and is associated with high Si fluxes. The REE contents were controlled by solutes derived from weathering of nearby continental landmasses. The latter is characterized by positive $\varepsilon_{Nd}(t)$ values (inferred end-member $\varepsilon_{Nd}(t)$=+3.5) and is associated with high-Fe fluxes. The Sm-Nd isotopic feature was sourced from hydrothermal alteration of depleted oceanic crustal rocks. The Nd isotopic mass balance calculations of the Yuanjiacun BIF indicate that most (>50%) of the Nd and iron were derived from hydrothermal sources related to mid-ocean ridge volcanism.

Taking other reported Nd isotopic data of the Archean and Paleoproterozoic BIFs together (e.g., Jacobsen and Pimentel-Klose, 1988; Alexander et al., 2009), the Nd isotopic evolution of the coeval Precambrian seawater is obtained. It is concluded that the great majority of Nd in bulk seawater prior to 2.3 Ga originated from the hydrothermal circulation through depleted mantle-derived mafic source rocks rather than sedimentary continental source material transported by river water. However, negative and continent-like $\varepsilon_{Nd}(t)$ values recorded in some BIFs argue against a mid-ocean ridge hydrothermal system as the dominant REY source, thus reflecting spatial and temporal heterogeneity with respect to the Nd isotopic composition in Earth's early oceans, as is the case today in the modern oceans.

References:

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