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What minerals control the REE+Y content and radiogenic isotopic compositions of the Earth's oldest banded iron formation?

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Banded iron formations (BIFs), consisting of Fe- and Si-rich layers, are chemical sedimentary rocks with a potential to record ancient seawater features. In the Isua Greenstone Belt of SW Greenland, 3.8–3.7 Ga BIFs record typical seawater REE+Y patterns and were used to constrain Nd isotopic composition of the early Archean seawater (Frei and Polat, 2007). However, BIFs were metamorphosed up to amphibolite facies, making it difficult to resolve primary from secondary geochemical signatures.

We performed a multi-isotopic and multi-elemental study on a BIF from the Isua Greenstone Belt (IF-G reference standard), recording typical seawater REE+Y patterns, to better understand radiogenic isotopic systematics of BIFs and the impact of post-depositional processes. The sample mineralogy is dominated by quartz and magnetite with metamorphic accessory phases. We separated magnetite and quartz from accessory minerals using hand magnet and measured trace element contents together with Sm-Nd, Lu-Hf and Pb isotopic compositions of the bulk sample and separated mineral fractions.

We found that the Sm-Nd isotopic composition of the bulk IF-G standard was homogenous with an average $e_{Nd\ (T=\ 3800\ Ma)}$ = 1.71 ± 0.85 (2SD, n=9), in good agreement with previous studies. Complete duplicate analyses of the bulk IF-G standard (n=9) however revealed significant heterogeneity in Hf and Pb isotopic composition with the present-day values being extremely radiogenic in Hf (+1403 < e_{Hf} < +1800 and 14.69 < $^{207}Pb/^{204}Pb$ < 14.74). Such isotopic variability allowed us to calculate a Pb-Pb isochron age of 3841 ± 68 Ma, which is consistent with the depositional age of the Isua BIFs. Surprisingly, the Lu-Hf isotopic systematics of the bulk IF-G standards are more scattered and provided a less precise isochron age of 3337 ± 500 Ma. Trace element contents of separated mineral fractions indicate that Lu-Hf isotopic systematics might be controlled by a mixing between accessory phases with high $^{176}Lu/^{177}Hf$ and magnetites with low $^{176}Lu/^{177}Hf$ ratios. The data suggests that magnetite is more likely to record primary geochemical signals for Lu-Hf than the bulk sample. We conclude that magnetite from BIF samples should be preferentially targeted to constrain initial Hf isotopic composition of Paleoarchean seawater.