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^{146}Sm - ^{142}Nd constraints on the evolution of the Hadean mantle

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Short-lived ^{146}Sm-^{142}Nd system ($T_{1/2}$ = 103 Ma) represents a selective tracer of very early (> 4.3 Ga) mantle differentiation processes. However, its application to early Earth is analytically challenging because the small initial abundance of ^{146}Sm in the solar system precludes development of ^{142}Nd anomalies larger than ca. 30 ppm in differentiated silicate reservoirs.

Here we present new ultrahigh-precision data obtained using TRITON, a new generation of thermal-ionisation mass spectrometer. The samples include komatiites from Barberton (3.5 Ga), metabasalts and metasediments from Isua (3.7 – 3.8 Ga), and gneisses from Amitsôq (3.6 – 3.8 Ga) and Acasta (4.0 Ga). Our improved external precision obtained via repeated analyses of the Ames Nd standard was 2 ppm (2σ) for $^{142}Nd/^{144}Nd$, which represents an improvement by a factor of 5 - 10 compared with previous studies. Our new results indicate that all lithologies from Isua and Amitsôq carry ^{142}Nd anomalies between 8 ± 2 ppm and 15 ± 2 ppm, in agreement with our previous report of a 15 ± 4 ppm excess in 7 Isua metasediments [1]. In contrast, no anomaly could be detected in Barberton and Acasta samples.

For long-lived isotope tracers such as ^{147}Sm-^{143}Nd, anomalies can be produced all along Earth history. In contrast, the production of ^{142}Nd anomaly can only occur prior to 4.3 Ga, and therefore ^{142}Nd isotope systematics can be used as a passive tracer to investigate mantle mixing. We have modeled $^{142,143}Nd$ isotopic evolution of the Earth's mantle using a two-box mantle-crust model. In this model, the crustal reservoir is formed at 4.46 Ga [1] and subsequent extraction of new crust is balanced by recycling. Isotopic heterogeneity in the mantle reservoir is parameterized as a function of the stirring time and the stirring time is related to the Rayleigh number. Results indicate that extraction of a crustal reservoir with $^{147}Sm/^{144}Nd$ = 0.12 and a mean lifetime of ca. 300 Ma generates a depleted mantle with $\varepsilon^{143}Nd$ = 1.5 ε units and $100 \times \varepsilon^{142}Nd$ = 10 ppm at 3.8 Ga, in close agreement with observations from Isua. By taking a stirring time a factor of 3 shorter than today, we find that mantle preserves ^{142}Nd heterogeneities of the order of 10 ppm up to 3.8 Ga. At 3 Ga, the initial ^{142}Nd anomaly is efficiently rehomogeneized and negligible heterogeneities survive.

References

[1] Caro et al., *Nature* **423**, 428-432 (2003).

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Early Earth differentiation using the coupled ^{146}Sm-^{142}Nd and ^{147}Sm-^{143}Nd

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A major ambiguity remains in ascertaining whether the silicate portion of the Earth underwent differentiation during the Hadean. This issue can be addressed by using possible fractionations of lithophile extinct nuclides and their daughters. The coupled ^{146}Sm-^{142}Nd ($t_{1/2}$ = 103 Ma) and ^{147}Sm-^{143}Nd ($t_{1/2}$ = 106 Ga) system is powerful in this context. The low initial $^{146}Sm/^{144}Sm$ ratio (= 0.008) and the low degree of fractionation of Sm over Nd observed on Earth, indicate that if differentiated reservoirs were produced between 4.5 and 4.3 Ga on Earth, they would show effects in ^{142}Nd of the order of a few tens of ppm. Early attempts to find ^{142}Nd anomalies in ancient rocks with high apparent ε_{Nd} (143) yielded conflicting results and suggested that better mass spectrometers/techniques were needed to measure the small anomalies (see e.g Sharma et al., 1996).

Recent attempts again give apparently conflicting results: Caro et al. (2003) use a new generation TIMS (Triton) and find that *all* rocks from 3.7-3.8 Ga Isua supracrustals, West Greenland give 15 ppm excess in $^{142}Nd/^{144}Nd$ ratio over the Ames Nd std. In contrast, Papanastassiou et al. (2003), using another Triton, find that an Isua felsic gneiss (IE 715-28; initial ε_{Nd} (143) = +4.0) contains no ^{142}Nd excess over the Caltech nNd-β standard. This is intriguing given that one of the Caro et al (2003) rocks apparently comes from the same outcrop as IE 715-28. Boyet et al. (2003) use multi-collector ICPMS, obtain an external precision of better than 20 ppm and find that of the 8 Isua metabasalt/metagabbro samples, 3 give a positive ^{142}Nd anomaly of ~+30 ppm, tantalizingly close to the technique's resolution. Different researchers have used somewhat different data collection and reduction methods so the question is, if the observed distribution is real. We investigated the problem using the Caltech nNd-β standard, three enriched standards and five samples from Isua; the latter were provided by D. A. Papanasatssiou and originally collected by R.F. Dymek. Data were obtained at Dartmouth using the Triton. High precision Nd isotope analyses of Caltech nNd-β standard (n = 41) gave $^{142}Nd/^{144}Nd$ = 1.1418271±78; $^{143}Nd/^{144}Nd$ = 0.5118924±39, $^{145}Nd/^{144}Nd$ = 0.3483995±30, $^{148}Nd/^{144}Nd$ = 0.2415778±26, $^{150}Nd/^{144}Nd$ = 0.2364447±60. By analyzing enriched standards we are certain we can resolve a ^{142}Nd anomaly of ≥ +10 ppm. We confirm that IE 715-28, along with three other Isua samples, does not have a positive anomaly. In contrast, two different aliquots of ID 27-2A yield ^{142}Nd excess of +17 ppm. This suggests that the silicate Earth underwent continuous differentiation during the Hadean and that highly depeleted but short-lived reservoirs were existed in the late Hadean.