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Episodic li-overturn tectonics in the early Earth inferred from time-varying 142Nd signature in Isua Archean rocks

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Application of short-lived ^{146}Sm-^{142}Nd chronometer to Archean rocks carrying ^{142}Nd/^{144}Nd anomalies relative to modern accessible mantle suggests differentiation of Hadean (>4.0 Ga) mantle to form crustal and depleted mantle reservoirs as early as ∼4.5 Ga.[1] Tracking the secular evolution of ^{142}Nd/^{144}Nd anomalies is important towards understanding the mode of crust-mantle dynamics in the early Earth. Excessive scatter in the published data, however, precludes identification of the fine structure of ^{142}Nd/^{144}Nd secular evolution.[2] New ultra-high-precision ^{142}Nd/^{144}Nd data for rocks from the Isua supracrustal belt (SW Greenland) using an improved MC-ICPMS analytical protocol, in which the analytical reproducibility on ^{142}Nd/^{144}Nd ratio is 2.4 ppm, show a well-resolved temporal variability in its ^{142}Nd/^{144}Nd signature. The decrease in the magnitude of ^{142}Nd/^{144}Nd anomaly from ∼10 ppm at 3.8 Ga to ∼5 ppm by 3.4 Ga suggests progressive homogenization of the Isua Hadean depleted mantle reservoir towards modern mantle composition with time. The temporally decreasing ^{142}Nd/^{144}Nd anomaly in Isua rocks provides a direct observational measure of mantle dynamics in the early Earth and define a mantle stirring timescale of <250 Myr. Using a crust-mantle box model that considers material transport across the reservoirs into account, the observed ^{142}Nd/^{144}Nd evolution is consistent with crustal residence times of ∼1000-2000 Myr. Such long crustal residence times, suggesting preservation of oceanic crustal lithosphere for periods much longer than today, are inconsistent with prevalence of modern-style plate tectonics until at least the mid-Archean. We infer that a stagnant-lid regime punctuated by episodes of strong mantle overturns (episodic lid-overturn tectonics[3]) operated in the early Earth, best explaining the long life-time estimated for the Hadean proto-crust.

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