Episodic lid-overturn tectonics in the early Earth inferred from time-varying $^{142}$Nd 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. 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. 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) operated in the early Earth, best explaining the long life-time estimated for the Hadean proto-crust.