

## Neodymium in the Deep Earth

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The recent revelation that the present-day convecting mantle is approximately 20 ppm larger in its  $^{142}\text{Nd}/^{144}\text{Nd}$  ratio than average chondrites has inspired a lively debate on the Nd budget for the Earth. The isotope  $^{146}\text{Sm}$  decays to  $^{142}\text{Nd}$  with a half-life of 103 Myr. Because of the relatively small fractionation between Sm and Nd in cosmochemical and magmatic processes, these differences in  $^{142}\text{Nd}/^{144}\text{Nd}$  represent differences in Sm/Nd likely within the first 200 Myr of solar system history. Hence, the differences of  $^{142}\text{Nd}/^{144}\text{Nd}$  between these materials means that the convecting mantle in Earth evolved with a time-integrated Sm/Nd ratio from very early in its history that was approximately 6.3 to 8.5% larger than average chondritic. If the Earth is composed on average, of chondritic material, then to balance its Nd budget, materials must have been present in the early Earth that had a lower  $^{142}\text{Nd}/^{144}\text{Nd}$  ratio and respective Sm/Nd ratio. If so, it is possible that this material presently resides in the deep Earth, likely D'', and does not participate in convective mantle flow or magmatic production near the top of the mantle. Alternatively, Earth may have accreted with a higher Sm/Nd ratio than average chondrites, meaning its precursor materials did not have 'normal' relative solar system abundances in incompatible lithophile elements. Whichever of these two possibilities is correct provides key constraints on early nebular processes that lead to terrestrial planet formation as well as early differentiation and evolution of the interiors of these planets.

Evidence to present cannot yet distinguish between these two possible scenarios for the bulk Sm/Nd of the Earth. Recent studies of lunar basalts shows their coupled  $^{142}\text{Nd}$ - $^{143}\text{Nd}$  isotope systematics are consistent with a superchondritic bulk Sm/Nd ratio for the Moon similar to the present-day convecting mantle in Earth. The prevailing model for the origin of the Moon is that it formed from melt and vapor ejected from a giant cataclysmic collision between Proto-Earth and a Mars-sized impactor. The indistinguishable O, K, Cr, and W isotope compositions of the Earth and Moon are consistent with near- to complete-homogenization of the silicate portions of Proto-Earth and the impactor. If so, then the material that accreted to form the bulk Moon is likely to have a very similar Sm/Nd ratio as that for bulk silicate Earth. In this case, an additional reservoir with superchondritic Sm/Nd is unnecessary to balance to average chondrites unless complete homogenization of Earth and the impactor did not take place. Evidence from Hadean-early Archean southwest Greenland rocks indicates that the convecting mantle at 3.85 Ga had a  $^{142}\text{Nd}/^{144}\text{Nd}$  ratio that was even higher than the modern convecting mantle at 40 ppm greater than average chondrites, but by 3.6 Ga, the convecting mantle had progressively decreased to 30 ppm, and by 3.4 Ga or so, down to 20 ppm of the present-day convecting mantle and consistent with the lunar data. These data suggest that re-mixing of an early-formed reservoir with lower Sm/Nd occurred to drive the  $^{142}\text{Nd}/^{144}\text{Nd}$  ratio in the early Archean towards the present-day convecting mantle value. The question remains as to whether the bulk of this early reservoir was completely re-homogenized into the convecting mantle or if residual material remains deep in the Earth that can rebalance the Nd budget to average chondrites. Additional evidence will be discussed pertaining to this question and what future lines of evidence need to be explored to examine the Nd budget of deep Earth.