Long-term consequences of early Earth differentiation

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Evidence for early Earth differentiation, for example the excess 129Xe in MORB attributable to the decay of 129I, has been available for some time. Additional evidence for the importance of these early events now includes non-chondritic terrestrial abundances of 182W, 107Ag, and 142Nd caused by the decay of short-lived 182Hf, 107Pd and 146Sm, respectively. While the Hf-W and Pd-Ag systems are most sensitive to core-mantle separation, the 146Sm-142Nd system more likely tracks the differentiation of the silicate Earth. The ~20 ppm or larger excess 142Nd/144Nd found in all terrestrial rocks compared to chondrites reflects the formation of a terrestrial reservoir with superchondritic Sm/Nd while 146Sm was still extant, likely within the first 30-50 Myr after solar system formation. A likely consequence of this result is that the major volume of Earth's mantle was depleted in incompatible elements even before continent formation began. For the moderately incompatible elements (e.g. Sm, Nd, Lu, Hf) this early-formed depleted reservoir is closer in composition to the MORB source mantle than to bulk-silicate-earth (BSE) mantle estimates derived from comparison with chondrites. Consequently, the primitive undegassed (e.g. high 3He/4He) mantle should be associated with superchondritic 143Nd/144Nd and 176Hf/177Hf as has been suggested in a number of recent studies. Using crust-mantle mass balance modeling, a relatively smooth, but incompatible-element depleted, chondrite-normalized refractory lithophile element pattern is obtained for the model when the mass of the early depleted mantle exceeds 80% of the current mantle mass. This early depleted mantle will have U and Th abundances only 50-70% of those estimated for the BSE with consequences for heat production and the balance of heat and 4He production. If the BSE has chondritic relative abundances of the refractory lithophile elements, then a complementary early-formed mantle reservoir enriched in incompatible elements must exist. This reservoir would constitute but a small volume of the mantle and has never obviously participated in producing crustal rocks. The fact that the early depleted reservoir can be modeled with a smooth BSE-normalized incompatible element pattern suggests that this early differentiation event was most likely accomplished by relatively shallow (< 200 km) melting in the mantle. The enriched compliment to the early depleted reservoir could then be a primary mafic/ultramafic crust that was removed from Earth's surface prior to the formation of the oldest preserved crust (> 4 Ga), possibly by subduction to the deep mantle.