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Remnants of early Earth differentiation in the deepest mantle-derived lavas

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The noble gas isotope systematics of ocean island basalts suggest the existence of primordial mantle signatures in the deep mantle. Yet, the isotopic compositions of lithophile elements (Sr, Nd, Hf) in these lavas require derivation from a mantle source that is geochemically depleted by melt extraction rather than primitive. Here, this apparent contradiction is resolved by employing a compilation of the Sr, Nd, and Hf isotope composition of kimberlites, volcanic rocks that originate at great depth beneath continents. This compilation includes kimberlites as old as 2.06 billion years and shows that kimberlites do not derive from a primitive mantle source but sample the same geochemically depleted component common to most oceanic island basalts, previously called PREMA (prevalent mantle) or FOZO (focal zone). Extrapolation of the Nd and Hf isotopic compositions of the kimberlite source to the age of Earth formation yields a $^{143}Nd/^{144}Nd$-$^{176}Hf/^{177}Hf$ composition within error of chondrite meteorites, which include the likely parent bodies of Earth. This supports a hypothesis where the source of kimberlites and ocean island basalts contains a long-lived component that formed by melt extraction from a domain with chondritic $^{143}Nd/^{144}Nd$ and $^{176}Hf/^{177}Hf$ shortly after Earth accretion. The geographic distribution of kimberlites containing the PREMA component suggests that these remnants of early Earth differentiation are located in large seismically anomalous regions corresponding to thermochemical piles above the core–mantle boundary. PREMA could have been stored in these structures for most of Earth's history, partially shielded from convective homogenization.

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