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How depleted is the depleted mantle?

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Crust formation extracts incompatible elements from Earth's mantle, leaving behind an incompatible element depleted residual mantle that is thought to be the source for mid ocean ridge volcanism. Mass balance of the crust-mantle reservoirs provide poor constraints on the size of the reservoirs as the composition of the depleted mantle (DM) is open to different. Estimates of the composition of the DM based on the composition of mid ocean ridge basalts (MORB) [1] are biased towards the most fusible, incompatible element enriched components in the MORB source and potentially underrepresents more depleted mantle. Estimates based on abyssal peridotites [2] are biased by metasomatised peridotites that do not accurately reflect the incompatible element depletion of the DM.

Several lines of evidence indicate that the DM is more depleted than inferred from the composition of abyssal peridotites or MORB. Hafnium and Nd-isotope ratios that are more radiogenic than Pacific MORB are found in peridotite xenoliths from Hawaii [3]. Abyssal peridotites often have equal or higher Hf-and Nd isotope ratios compared to MORB, but some are much more extreme (ε_{Hf} >100) [4]. Both of these observations indicate that highly depleted residual mantle, termed ReLish (Residual Lithosphere)[6], exists in Earth's mantle. The effect of the highly depleted component is difficult to recognize in melts (MORB) as the concentrations are relatively low. The decoupling of Nd and Hf-isotopes in MORB on a global scale, despite well-defined correlations on a local scale, indicates that ReLish melts and contributes to the isotopic diversity of MORB [5]. Ultra-depleted melts are also observed in the oceanic lithosphere of the Lanzo massif where these depleted melts "enrich" residual peridotite [6].

A rough estimate of the amount of ReLish in Earth's mantle can be obtained by assuming ridge volcanism has occurred over Earth's history at a constant rate, resulting in a mass of the DM that approximates ten times the mass of time-integrated mass of the oceanic crust. Conservative estimates indicate that ReLish makes up half of the DM's mass. If so, present estimates of the Hf and Nd isotope composition of the DM would increase by 15 and 10 epsilon units, respectively, assuming an average depletion age of 2Ga.

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