Geophysical Research Abstracts
Vol. 12, EGU2010-675, 2010
EGU General Assembly 2010

Osmium isotopes suggest fast and efficient mixing in the oceanic upper mantle.

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The depleted upper mantle (DUM; the source of MORB) is thought to represent the complementary reservoir of continental crust extraction. Previous studies have calculated the "average" DUM composition based on the geochemistry of MORB. However the Nd isotope compositions of abyssal peridotites have been shown to extend to more depleted compositions than associated MORB. While this argues for the presence of both relatively depleted and enriched material within the upper mantle, the extent of compositional variability, length scales of heterogeneity and timescales of mixing in the upper mantle are not well constrained. Model calculations show that 2Ga is a reasonable mean age of depletion for DUM while Hf - Nd isotopes show the persistence of a depleted terrestrial reservoir by the early Archean (3.5-3.8Ga). U/Pb zircon ages of crustal rocks show three distinct peaks at 1.2, 1.9, and 2.7Ga and these are thought to represent the ages of three major crustal growth events. A fundamental question therefore is whether the present day upper mantle retains a memory of multiple ancient depletion events, or has been effectively homogenized. This has important implications for the nature of convection and time scales of survival of heterogeneities in the upper mantle.

Here we compare published Os isotope data from abyssal peridotites and ophiolitic Os-Ir alloys with new data from Hawaiian spinel peridotite xenoliths. The Re-Os isotope system has been shown to yield useful depletion age information in peridotites, so we use it here to investigate the distribution of Re-depletion ages (TRD) in these mantle samples as a proxy for the variability of DUM. The probability density functions (PDF) of TRD from osmiridiums, abyssal and Hawaiian peridotites are all remarkably similar and show a distinct peak at 1.2-1.3 Ga (errors for TRD are set at 0.2Ga to suppress statistically spurious age peaks). The Hawaiian peridotites further show a distinct peak at 1.9-2Ga, but no oceanic mantle samples with TRD older than 2Ga have been reported. The TRD age peaks overlap with two major crustal building events recorded in the U/Pb crustal zircon ages. Therefore, peridotites from the convecting upper mantle can retain some memory of ancient depletion events, and these depletions are perhaps linked to major crustal building or large-scale mantle melting events. In the case of the Hawaiian peridotites, an ancient depletion event is further supported by some extremely radiogenic Hf isotope compositions. However, the vast majority of oceanic mantle samples show a narrow rage of Os isotope compositions (187Os/188Os = 0.123-0.126) with TRDs at 300-600 Ma. If the upper mantle has been produced continuously (or episodically) since at least the early Archean, it is then surprising that almost all oceanic mantle samples record such young depletion ages. We suggest that convective mixing in the mantle is rigorous enough that effectively re-homogenizes and resets the Os isotope composition of previously depleted peridotites within short time scales (<500Ma). Similarly recent ages have been derived from modeling the Sr, Nd, Hf, Pb isotopic composition of MORBs. This resetting and homogenization can be due to re-equilibration of depleted mantle with enriched components, e.g. recycled basaltic crust or more fertile mantle. Ancient depletion events are only effectively preserved in the sublithospheric mantle samples (e.g. Kaapval, Slave, Wyoming cratons) because they remain isolated from the convective mantle.