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Ultra-depleted isotopic compositions in fertile asthenosphere-derived peridotites: constraints on the composition of the upper mantle

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Recent studies of abyssal peridotites (AP) and OIB xenoliths have reported refractory, isotopically ultra-depleted domains within the convecting upper mantle with Nd- and Hf-isotope compositions that extend far beyond the MORB field. These results have important implications regarding the average composition of the depleted upper mantle and the genetic relationship between MORB and AP. However, the abundance of ultra-depleted domains in the mantle is unclear. In addition, recent melt extraction processes at mid-ocean ridges make it difficult to evaluate the compositions of ultra-depleted domains prior to exhumation and thus evaluate their role in melt generation. To better constrain the abundance and composition of typical convecting upper mantle, we examined a suite of spinel peridotite xenoliths from the central Rio Grande Rift (RGR) where most of the preexisting lithosphere has been convectively removed and replaced with depleted upper mantle.

Seismic tomography indicates that the lithosphere beneath the RGR has been substantially removed (Gao, 2004), and geochemical evidence supports this. Two distinct populations of xenoliths are observed from Elephant Butte, central RGR. One population, interpreted to derive from residual Proterozoic lithospheric mantle, is refractory (bulk Al_2O_3 <2.3 wt.%), LREE- and LILE-enriched, has enriched Sr, Nd, and Pb isotopic compositions and along with xenoliths from the Eastern Colorado Plateau define a strong Lu/Hf-^{176}Hf/^{177}Hf “pseudo-isochron” with an apparent age of ~1.6 Ga. In contrast, the majority of the RGR xenoliths have fertile major element compositions (bulk Al_2O_3 ~ 4.0 wt %), low spinel Cr# (~10), and LREE-depleted trace element patterns, and overlap with composition estimates for the depleted mantle (Workman & Hart, 2005). We interpret these xenoliths to reflect recent replacement of the pre-existing lithosphere with material from the convecting upper mantle.

The fertile xenoliths have cpx Sr-, Nd-, and Hf-isotope compositions that extend from the range for MORB to more depleted values (^{87}Sr/^{86}Sr ranges from 0.7018-0.7025, ε_{Nd} ranges from 8-27, and ε_{Hf} ranges from 14-43). Hafnium- and Nd-isotopes are well correlated and extend the mantle array, in contrast to several ultradepleted AP suites which display decoupling between Nd- and Hf-isotopes. The observed Hf-isotope compositions overlap with the compositions of ultra-depleted samples from the Gakkel Ridge and Salt Lake Crater, Hawaii. However, whereas previously reported isotopically ultra-depleted samples have largely possessed refractory major element compositions, the RGR samples have fertile compositions and would, if advected beneath a mid-ocean ridge, contribute to melt generation.

Our results suggest 1) that mantle domains isotopically more depleted than MORB are in fact common, and that the average isotopic composition of the upper mantle may therefore be more depleted than suggested by studies of MORB; 2) these domains are not limited to refractory, non-melt productive lithologies. Therefore, the isotopic mismatch between average MORB and average peridotite samples from the convecting upper mantle require that a more enriched component, potentially eclogite or pyroxenite veins, is also involved in MORB genesis.

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