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The Nature of the Sub-Continental Lithospheric Mantle: Hf Isotope Evidence from Garnet Peridotite Xenoliths from Siberia

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Lithospheric continental mantle is generally considered as a refractory residue produced by partial melting of asthenospheric mantle. Alternatively, the lithospheric mantle may grow downwards by accretion of asthenospheric material to the base of the lithosphere upon cooling. Xenoliths of deep-seated rocks brought up accidentally by mantle-derived magmas are samples of the otherwise inaccessible deep lithosphere and can be used to constrain its age and mode of origin. Here we report the first results of a Lu-Hf isotope study of garnet peridotite xenoliths from Cenozoic alkali basalts of the Vitim volcanic field (eastern Baikal region, southern Siberia), which equilibrated at 20-22kbar and 1000-1050ºC (Ionov et al., 1993).

The interest of Hf isotopes in the study of garnet-bearing mantle-derived rocks lies with the high partition coefficient of Lu compared to Hf for garnet with respect to other minerals. Because garnet does not fractionate Sm from Nd to the same extent, garnet/melt fractionation can lead to Hf-Nd isotope decoupling with samples evolving out of the terrestrial Hf-Nd array (Salters and Zindler, 1995; Vervoort et al., 1999). The Lu-Hf isotope system further has the advantage over the Rb-Sr, Sm-Nd, and U-Pb systems that Lu and Hf are more compatible in peridotites during partial melting than Rb, Sr, Sm, Nd, U, and Pb and therefore tend to be less affected by metasomatism. Finally, Lu and Hf are held by the same phases as used for P-T estimates implying that Lu-Hf ages should correspond closely to those of P-T equilibration.

It is preferable to know for how long a rock evolved before it reached its present isotopic composition. Garnet-clinopyroxene pairs give the age in addition to the isotopic composition when the rock formed. Garnet-clinopyroxene pairs from four Vitim garnet peridotite xenoliths define 30-75Ma two-point Lu-Hf isochrons. These ages are comparable to Sm-Nd ages of 28-48Ma (Ionov and Jagoutz, 1989) obtained on garnet-clinopyroxene pairs from the same samples, with the younger ages approaching the eruption age of 18Ma (K-Ar; I. Ashchepkov, pers. comm.) of the host volcanic rocks. The spread in the ages may reflect incomplete re-setting of the Lu-Hf and Sm-Nd systems due to the thermal effect of the ascending host magmas in the sub-continental lithospheric mantle. Whole-rock ^{176}Lu/^{177}Hf ratios of the xenoliths calculated using clinopyroxene and garnet modal estimates range from 0.033 to 0.060 indicating moderate depletion in Hf relative to Lu compared with BSE (0.0332). This is similar to, though less than the total range shown by garnet pyroxenites from Beni Bousera, Morocco (Blichert-Toft et al., 1999). Calculated whole-rock ^{176}Hf/^{177}Hf ratios of the Vitim xenoliths range from 0.28331 to 0.28400, which is higher than average OIB (0.2831) and MORB (0.2833) (as are ^{143}Nd/^{144}Nd ratios which vary from 0.51335 to 0.51403) and consistent with the higher-than-chondritic Lu/Hf ratios. Isotopically, the Vitim xenoliths resemble garnet pyroxenites from Beni Bousera (Blichert-Toft et al., 1999) and spinel lherzolites from Salt Lake Crater, Hawaii (Salters and Zindler, 1995). The results so far for all types of lithospheric mantle, whether sub-oceanic (Hawaii) or sub-continental (Vitim), are therefore consistent in that they show highly radiogenic signatures. Consequently, the lithospheric mantle sampled by xenoliths does not seem to be able to produce melts and is a poor analog for basalt sources.

The strongly depleted isotopic compositions of the Vitim xenoliths contrast with their very fertile chemical and modal compositions, which is inconsistent with an origin as residues after generation of MORB or CFB. This study and other evidence (PGE contents, S-isotope compositions) further rule out direct derivation of lithospheric mantle beneath Vitim from the modern source regions of oceanic basalts. Rather, the fertile lithospheric mantle domains that gave rise to the Vitim xenoliths may have been derived by slow vertical accretion to the base of the lithosphere of convecting asthenospheric mantle accompanied by expulsion of low-degree partial melts from the accreting material. This removal of low-degree partial melts increased whole-rock Lu/Hf and Sm/Nd ratios that over time resulted in the radiogenic Nd and Hf isotopic compositions now characterizing these samples and being distinct from MORB. For the radiogenic ingrowth to take place, melt extraction must have predated the modern volcanic episode. A Palaeozoic or even a Proterozoic age is not inconsistent with the Hf and Nd isotope data.

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