THE LITHOSPHERIC MANTLE BENEATH CENTRAL EUROPE: EVIDENCE FROM XENOLITHS

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Abstract: The petrology and geochemistry of shallow continental lithospheric mantle (SCLM) can be studied via mantle xenoliths in alkaline magmas. The main process that controls mantle geochemistry is removal of basaltic melt. Interaction with melts and fluids gave rise to hornblendite veins and pyroxenite layers. Radiogenic isotope ratios show clustering around a component identical to Neogene alkaline magmatism. The effect of hydrous fluids from subducting slabs is also seen.

Key words: xenoliths, mantle

The lithosphere of western and central Europe was consolidated in Phanerozoic times, although evidence for crustal events as old as 2Ga can be found within the region. Major Phanerozoic events that have affected Europe include subduction and collision during both the Hercynian and Alpine orogenies. Upwelling of a plume beneath the European plate during Tertiary times gave rise to widespread mafic alkaline magmatism. Phanerozoic Europe contains numerous mantle xenolith localities and ultramafic massifs, the latter being emplaced into the crust during the Hercynian and Alpine orogenies.

Localities of ultramafic xenoliths are abundant in the Neogene mafic alkaline volcanics in Europe (Downes, 2001). Although documented mainly from France and Germany, mantle xenoliths have also been studied in Poland, Hungary, Austria and Romania, Italy, Spain, Bulgaria and Serbia. The European SCLM presents a very narrow range of common lithologies dominated by an anhydrous spinel lherzolite-to-harzburgite series which results from ancient depletion of the mantle due to extraction of basalts. The next most common rock-type is pyroxenite, considered by many authors to be the product of passage of asthenosphere-derived magmas. Hornblendite veins and amphibole peridotites/pyroxenites are generally considered to be formed by the passage of mafic alkaline magmas. Wehrlites which might represent mantle that has interacted with carbonatite melts are generally very subordinate and spatially restricted. Phlogopite-rich peridotites which could represent mantle that has experienced subduction flux are abundant in Europe only as xenoliths from Germany, central Spain and Italy.

Major element data from xenolith suites form very tight arrays from fertile lherzolite to refractory harzburgite, i.e. Al_2O_3, TiO_2 and CaO all correlate negatively with MgO. The arrays are usually considered to be due to removal of a basaltic component from the fertile upper mantle. These arrays are sufficiently robust to enable us to determine whether xenolith suites or massif samples show significant deviations from the normal SCLM. Mantle pyroxenites plot away from the peridotite major element trends, having lower MgO contents and variable but generally high concentrations of Al, Ca and Ti. Pyroxenites probably formed as cumulates from mafic melts, and their compositions are a reflection of (a) the nature of the magma from which they were formed, and (b) the abundances of their constituent cumulate minerals.

The ubiquitous LREE-depletion is also the result of extraction of basalt from the mantle. Even xenoliths which are apparently undepleted in major element terms still show LREE-depletion. Harzburgites additionally show HREE-depletion, probably due to extensive melting of clinopyroxene which is the major host of all REE in the anhydrous SCLM. Overprinting this depletion is a variable LREE-enrichment. Both LREE-enriched and LREE-depleted xenoliths can occur in the same volcanic vent.

Mantle that has interacted with a silicate melt would be expected to show increases in all incompatible elements, although the effect on elements such as Rb, Ba and Nb, which have been previously strongly depleted, may not be as obvious as in the LREE. Samples that may have been fluxed by subduction fluids would be expected to show strong enrichment in incompatible elements that are fluid-soluble, and may be phlogopite-bearing. Such samples tend to have negative anomalies at Nb, Zr and Hf relative to adjacent elements, and strong enrichment in Rb and Ba. Carbonatite melt-enrichment would also result in LREE-enrichment with extremely low concentrations of Nb, Zr and Hf. Metasomatism can affect the modal mineralogy of the SCLM, with the development of amphibole and phlogopite, e.g. as amphibole peridotites or hornblendites. Amphiboles in veins and in amphibole-rich peridiotites have high REE contents and are usually enriched in LREE. They are products of crystallisation of alkaline mafic magmas at mantle depths.

Wide variations in $^{87}Sr/^{86}Sr$ and $^{143}Nd/^{144}Nd$ isotopic compositions are present in clinopyroxenes from mantle xenoliths of Europe, ranging from ratios similar to those of depleted mantle to values more enriched than Bulk Earth (Fig. 1). Xenoliths from a single locality can cover this entire range. The depleted mantle signature is the time-integrated effect of extraction of basalt leaving a LREE- and LIL-depleted residue which has evolved to high $^{143}Nd/^{144}Nd$ and low $^{87}Sr/^{86}Sr$. The time-integrated effect of ancient enrichment in the SCLM will manifest itself in high $^{87}Sr/^{86}Sr$ and low $^{143}Nd/^{144}Nd$. Values around Bulk Earth could also be due to enrichment by passage of fluids and melts through the mantle. Among the xenoliths, a large number of samples fall within the field for European Neogene alkali basalts. This may indicate that some of the geochemical enrichment in the xenoliths may be due to infiltration of melts from the Neogene mantle plume beneath Europe.

Some SCLM samples (e.g. xenoliths from Hungary and Italy) deviate from the main field towards high $^{87}Sr/^{86}Sr$ values. This may be the influence of subduction-derived fluids as both these areas are situated above Neogene subduction zones. Subduction-fluids would contain relatively high concentrations of Sr, but very little Nd, and therefore their effect on the mantle would be greater in $^{87}Sr/^{86}Sr$.

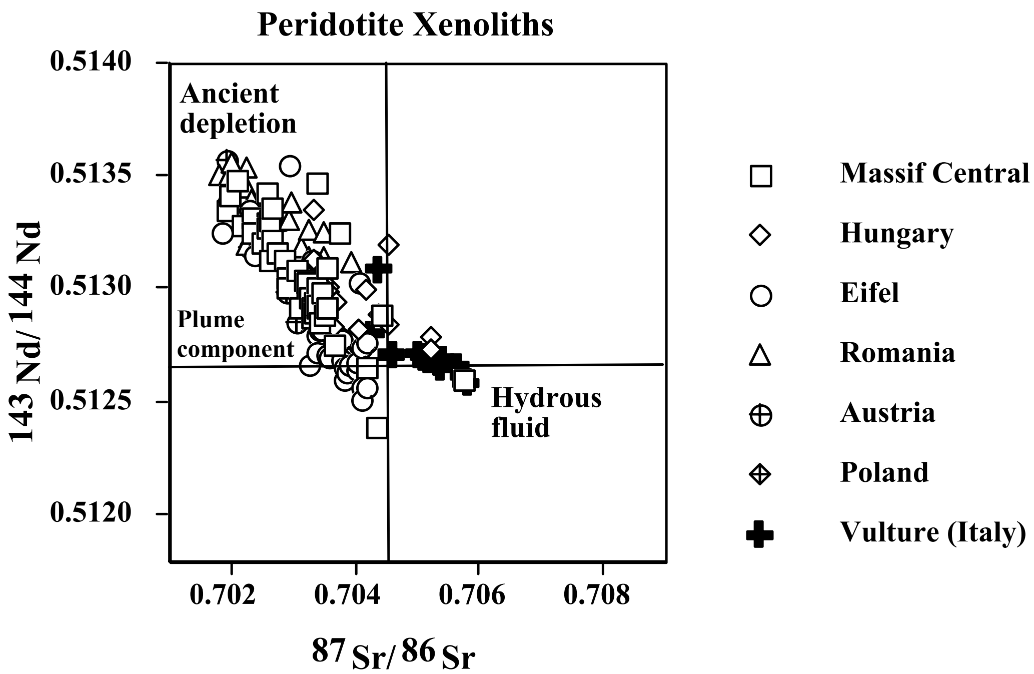

Fig.1. A compilation of isotope data for mantle peridotite xenoliths from Europe.

References

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