Geophysical Research Abstracts, Vol. 8, 06339, 2006
SRef-ID: 1607-7962/gra/EGU06-A-06339

Pre-Mesozoic metasomatized lithospheric mantle beneath the Scottish Highland Terrane

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The petrology and geochemistry of spinel-peridotite xenoliths from Late Palaeozoic basic alkaline dyke at Rinibar in the Orkney Islands was investigated for major and trace element of their mineral phases and for Sr-Nd-Hf isotopic composition, in order to infer the lithospheric evolution and the nature of melts responsible for Precambrian to Lower Palaeozoic mantle processes. In contrast to the Rinibar xenolith, pre-Mesozoic mantle xenoliths are typically being hosted by lamproitic, kimberlitic or ultramafic lamprophyre magmas, mainly in cratonic regions. Therefore, the Permo-Carboniferous alkali basaltic province in the British Isles provides an unusual opportunity to sample pre-Mesozoic mantle material entrained by off-craton, mafic magmatism.

The xenoliths predominantly comprise spinel lherzolites $\pm$ phlogopite, although spinel wehrlites and harzburgites are also represented.

The lherzolites are typically fine-grained ($\leq$ 0.5 mm), with granoblastic or protogranular textures. Although the primary ferromagnesian silicates in most of the xenoliths have been extensively altered, primitive mantle textures survive in the great majority. The olivines have mg# values from 86.3 to 92.2, with Ni contents of 1,200-2,700 ppm), approaching those of Archaean on-craton mantle olivines. Within single samples, the mg# of orthopyroxenes and clinopyroxenes are similar but are slightly greater than those of coexisting olivines as is expected from the Fe-Mg partition coefficients indicating general chemical equilibration among the silicates.

The diopsidic pyroxenes have Al2O3 contents from 1.7 wt% to 6.7 wt% and TiO2

contents < 0.5 wt%. On chondrite-normalized diagrams they are LREE-enriched with strongly positive fractionated patterns ((La/Yb)n 6–32), with maxima at Ce (Pr) and are extremely enriched in Th and U (Th: 7.04 ppm ; U: 1.84 ppm). Based on their geochemical composition, the clinopyroxenes can be divided into two groups. Group 1 clinopyroxenes have the lowest concentrations of Ba, Rb, Sr and LREE, together with remarkably high contents of U-Th, Ti, Zr and Hf, and Zr-Hf-anomalies ranging from moderately negative to slightly positive. Group 2 clinopyroxenes, have somewhat lower Nb and Ta concentrations, continuously increasing in REE concentrations from Ho to Ce, and pronounced negative anomalies of Ti, Zr and Hf with conspicuous U-Th enrichments. Both groups have U/Th ratios which reflect partition coefficients (DU/DTh $\geq$1), higher than those calculated by several authors for cpx/low pressure basaltic melts (DU/DTh = 0.7–0.9). U and Th contents similar to those in the Rinibar pyroxenes have been recorded in clinopyroxenes, experimentally grown from K-rich low-degree partial melts (DU/DTh = 0.97-4.53) and from carbonatite melts (DU/DTh = 1.15-2.9) (Foley et al., 2001). The geochemical features of the Group 1 clinopyroxenes suggest that they may have been metasomatised by an alkaline-silicate melts whereas the high REE, U, Th, Ba and Sr contents together with the strong depletion in Ti and Zr-Hf of the Group 2 clinopyroxenes points, in contrast, towards extensive interaction with a carbonatitic metasomatizing agent.

In order to examine the nature of the metasomatic agent in relation to the peridotite prior the metasomatism, we performed high-precision Sr-Nd-Hf-isotope analysis by means of multi-dynamic thermal ionisation mass spectromentry (TIMS) and multi collector-inductively coupled plasma-mass spectromentry (MC-ICP-MS). Clinopyroxene separates have initial (252 Ma) 87Sr/86Sr ratios of 0.70322 to 0.70383, εNd of -0.19 to +4.39 and εHf of 22.92 to 28.9. These values coincide precisely with those from clinopyroxenes in diamond-bearing mantle xenoliths, diamond inclusions and Archaean to Proterozoic kimberlites of the western Canadian Shield, suggesting that the Rinibar mantle still records the isotopic characteristics of the pre-metasomatic lithospheric mantle.

The mantle xenoliths from Rinibar indicate temperatures of 870-970˚C These are, comparable to those of shallow cratonic mantle roots (Francis, 2003) or circum-cratonic regions (Pearson et al., 2003), and tend to be lower than those recorded worldwide for mantle xenoliths from Phanerozoic alkali basalts (1000-1100˚C). The very fine grain-size of these xenoliths reflects an efficient dynamic recrystallization and, together with the inferred geothermal regime, matches neither the cratonic mantle roots nor the Phanerozoic mantle hypothesis. Alternatively we suggest that they may represent portion of lithospheric mantle that has remained undepleted since Proterozoic times.

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