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Ultra-refractory domains in the oceanic mantle lithosphere

E.-R. Neumann (1) and N.S.C. Simon (2)

(1) University of Oslo, PGP, Oslo, Norway (e.r.neumann@geo.uio.no), (2) University of Oslo, PGP, Oslo, Norway (n.s.c.simon@fys.uio.no)

Mantle xenoliths sampled in ocean island magmas are commonly significantly more refractory than average peridotites dredged and drilled from mid-ocean ridges. These rocks are referred to as ultra-refractory harzburgites. Ultra-refractory harzburgites are characterized by the absence of primary clinopyroxene, low whole rock Al2O3, CaO and HREE concentrations, low Al2O3 in orthopyroxene (<3 wt%), high Cr# in spinel (0.3-0.8) and high forsterite contents in olivine (>91.5). The occurrence of such rocks has potentially important implications for both mantle geochemistry and geodynamics; we therefore need to understand how these strongly refractory compositions form.

Some ultra-refractory ocean island harzburgites give high Os model ages (up to 3300 Ma), showing that their formation significantly pre-dates the oceanic crust in the area. Based on textural observations, equilibration temperatures and pressures, inferred physical properties, and the long-term depleted Os and Sr isotope ratios of some of the ultra-refractory harzburgites a genetic relationship with the host plume is considered unlikely. The formation of ultra-refractory harzburgite requires melting beyond the stability of clinopyroxene. Such high degrees of partial melting are probably achieved in two stages. The first stage may be decompression melting along mid-ocean ridges or in back-arc spreading centres. The second stage requires fluid-fluxed melting or potential temperatures significantly above those normally observed at modern mid-ocean ridges. Ultra-refractory harzburgites sampled in subduction settings are chemically very similar to the ultra-refractory peridotites found as xenoliths in ocean islands. The common occurrence of ultra-refractory harzburgites together with melts generated from a strongly depleted precursor in active arcs is an argument in support of a subduction related origin of ultra-refractory harzburgites both in arc settings and in ocean islands. However, if temperatures are sufficiently high, large degrees of melting may also be achieved in other types of settings. There is independent geochemical evidence that the Earth's mantle has suffered episodes of very high degrees of melting at certain stages in the past, possibly connected with major peaks in the formation of continental crust.

Independent of their mode of formation, their high ages imply that the presence of ultra-refractory peridotites in the oceanic mantle lithosphere mantle beneath ocean islands and mid-ocean ridges is accidental and genetically unrelated to ocean island magmatism or formation of the adjacent oceanic lithosphere. These ultra-refractory harzburgites must have a long history in the mantle. Due to their Mg-rich whole rock composition, ultra-refractory harzburgites have low densities and very high viscosities relative to "normal", more fertile asthenospheric material. Thus, they might be preserved as fragments in the convecting mantle over long periods of time and would tend to accumulate at the top of the convecting mantle, where they can accrete to younger oceanic plate. Because of their low density relative to "normal", more fertile asthenospheric material, these ultra-refractory residues may rise as diapirs and intrude shallower parts of the asthenosphere and be accreted to younger oceanic plate.