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Ghost Garnet Signature in Residual Abyssal Peridotites?

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Abyssal peridotites are generally accepted as residues of mid-ocean ridge partial melting. Melt extraction is nearly fractional i.e. small melt increments are immediately separated from the residue (Johnson et al., 1990). This is shown by strong LREE depletions in many residual cpx. The pressure range over which the melting occurs is currently intensely debated. U-series disequilibrium data on MORB suggest that initial melting took place in the presence of garnet (Bourdon et al., 1996). However, recent mineral/melt partitioning experiments suggest that HREE are compatible in high-pressure clinopyroxene (Blundy et al., 1998). Thus, residual garnet may not be required in the melting region and melting may therefore take place in a narrower pressure interval. In order to test the role of garnet in MORB melting from the perspective of residual abyssal peridotites, we obtained new mineral major and trace element data on 25 residual peridotite samples from seven locations along the Central Indian Ridge (CIR).

The CIR samples are petrographically residual, meaning that plagioclase and cross-cutting magmatic veins are absent. The samples are harzburgites, lherzolites and one opx-dunite. Spinel Cr-numbers (Cr/(Cr+Al)) range from 0.17 to 0.57 and all spinel TiO_2 contents are below 0.15 percent, confirming their residual nature. Trace elements were measured on fresh cpx grains on the Cameca IMS-3f ion microprobe in Mainz. Cpx in CIR peridotites have LREE depleted convex-upward REE patterns and span the most depleted part of the global abyssal peridotite REE spectrum. Chondrite-normalized Ce and Yb concentrations vary from 0.003 to 0.08, and 2.1 to 5.4, respectively. Ce/Yb ratios, however, do not correlate with major element melting indicators, such as spinel Cr-number.

Spinel Cr-number correlates well with HREE concentration in cpx (r-squared = 0.9) for these and literature abyssal peridotites data (N=63). The most incompatible trace elements, such as the LREE, Sr and Zr show no correlation with this or other major element melting monitors. Thus, LREE in mantle residues cannot be used to quantify the extent of melting. On the other hand, the coupling between major elements and moderately incompatible trace elements (M- to HREE) confirm that both are useful tracers of partial melting beneath mid-ocean ridges.

Because of the LREE decoupling, we focused our attention on the M- to HREE concentrations. A remarkable aspect of the CIR peridotites is that many cpx have highly fractionated ratios of MREE to HREE at relatively high absolute HREE concentrations. Their chondrite-normalized Sm/Yb ratio ranges from 0.02 to 0.56 at Yb concentrations between 2 and 5 times chondritic (Figure 1). Using pure fractional melting models to obtain the maximum fractionation (starting conditions of Johnson (1998)), such values still cannot be reached in a spinel peridotite assemblage. This is shown by melting curve denoted J98 in Figure 1, which would have to be steeper in order to match the CIR data. Application of the new cpx/melt partition coefficients of Blundy et al. (1998) shows that HREE are kept constant in the residue, as predicted by Blundy et al. However, the ratio of MREE to HREE is hardly fractionated and high degrees of melting are needed to match the observed fractionations. Further clarification of the pressure-dependent variation of the Blundy et al partition coefficients is required to fully understand this issue.

This fractional melting model was applied to a garnet peridotite starting composition. As shown by the thick stippled line, the Sm/Yb ratio in cpx decreases rapidly by fractional melting of a garnet-bearing source at a virtually constant Yb abundance. This garnet peridotite melting trajectory is a projection from a garnet-bearing to a garnet-free spinel peridotite assemblage, using an instantaneous garnet- to spinel-facies breakdown reaction from Johnson et al., (1990). The actual cpx composition in equilibrium with garnet is shown by the thin stippled trajectory. Initial melting of a garnet-bearing source, followed by subsequent melting in the spinel stability field, can account for a very efficient fractionation of the M- to HREE as observed in the low Sm/Yb ratios of many clinopyroxenes of the CIR peridotites. Either garnet or a Blundy et al type scenario is required to satisfy the range of observations.

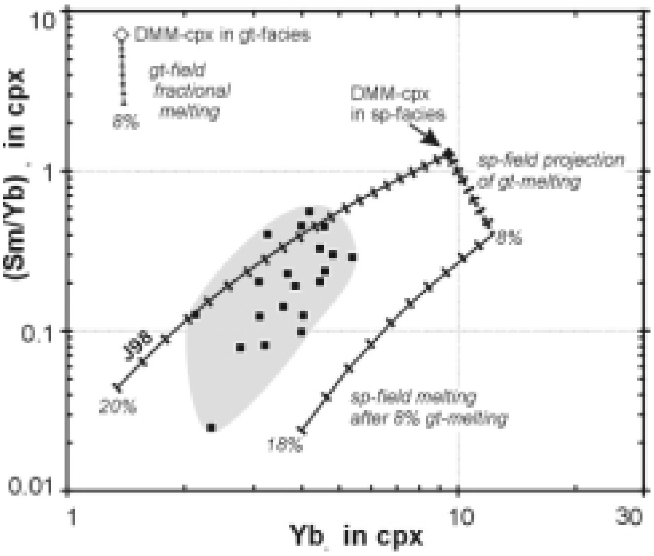

Figure 1: Chondrite-normalized Sm/Yb ratio in cpx vs Yb in cpx of Central Indian Ridge abyssal peridotites (black squares). Melting curves are marked in 1 percent increments.

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