



Do coarse garnet-peridotites represent equilibrium conditions in the lithospheric mantle? In-situ major and trace element analyses on mantle minerals

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The composition of unmetasomatised garnet-peridotite xenoliths is thought to represent equilibrium conditions of the deeper part of the subcontinental lithospheric mantle. These xenoliths show equilibrium textures and their mineral element compositions are commonly used to model mantle processes like melting, crystallisation and differentiation.

In our study we determine major and trace elements in-situ, with the high spatial resolution of secondary ion mass spectrometry (SIMS) and electron microprobe (EMP), directly within thin section. These analyses enable us to detect major and trace element variations within the mineral grains. Here we present data from different garnet-peridotite xenoliths where one group shows coupled major and trace element behaviour in garnet and clinopyroxene. In another group, some major and trace elements are decoupled, although this is not obvious from the textures.

The studied Vitim garnet-peridotite xenoliths are coarse grained and garnets are rimmed by thin kelyphite. Garnet, olivine, orthopyroxene and clinopyroxene in most samples are not zoned in major or trace elements, indicating equilibrium conditions. In other samples, some of the clinopyroxene grains have recrystallized, segmented rims composed of smaller secondary grains. In these samples, the clinopyroxene and also the orthopyroxene shows strong major element zonation. Calcium increases gradually from a plateau in the core to the recrystallized rims; the profile of Al is bowl-shaped with gradual enrichment from core to rim. The REE-profiles show an overall enrichment (factor 10) in the recrystallized rims, compared to the homogeneous cores. The

garnets have hardly detectable Cr-zoning, all other major elements are unzoned. However, the REE-patterns in garnet are slightly, but consistently zoned, with a gradual enrichment in LREE from core to rim and in HREE from rim to core, respectively (resulting in steeper REE patterns in the core). When plotted as profiles, the REE show a bell-shaped distribution from rim to rim with the highest concentrations in HREE. This means that the REE distribution between the garnet and other phases is not in equilibrium, but probably influenced by diffusion. P-T estimates on the mantle minerals yield higher temperatures and lower pressures for the rims than for the cores, if we assume that different mineral cores are in equilibrium and outermost rims likewise. This means that the xenoliths were reheated during entrainment into the ascending basaltic melts. Ascent of the xenoliths in the melts then caused decompression. During this process clinopyroxene rims recrystallized and garnet broke down to kelyphite. Within garnets, the REE were redistributed by diffusion.

The zonation of major and trace elements in garnet and the lack of it in high-Ca pyroxene is a common feature in mantle xenoliths (e.g. Griffin et al., 1989, Smith & Boyd, 1992). The interpretation for this behaviour can be quite complex.

Van Orman et al. (2002) carried out diffusion experiments with REE on natural pyrope and diopside (Van Orman et al., 2001), showing that diffusion of REE below 1500°C in pyrope is more rapid than in high-Ca pyroxene. However, the authors concede that there are two possible explanations: either the zoning profiles are too short to be detectable with the spatial resolution of the microbeam techniques they used; or the clinopyroxene in these rocks is not primary, but has recrystallized or precipitated from silicate fluids or melts. They describe that peridotites with zonation in garnet and the absence of any detectable zonation in clinopyroxene always show evidence of interaction with metasomatic fluids. The clinopyroxene rims might then have dissolved in melt and reprecipitated, whereas in the garnet elements were transported by diffusion. However, our samples from the Vitim volcanic field do not show clear evidence for interaction with metasomatic fluids, such as the water-bearing minerals amphibole or phlogopite. The REE-patterns of the clinopyroxene rims are completely parallel to the clinopyroxene core patterns, but are 10-times enriched. This shows that the distribution of REE was in equilibrium with a garnet, but probably this corresponding garnet is no longer present in the samples.

This study shows that major element analysis of minerals is not a sufficient tool to detect equilibrium conditions in the mantle and that only major and trace element analyses in combination can detect disequilibrium between mineral phases. Whole grain analyses can overestimate the trace element budget (e.g. REE), even if the patterns of the elements are the same. These overestimations of element concentrations can then lead to wrong modelling input data, because calculated distribution coefficients

can be up to 10-times higher than the correct distribution coefficients from minerals undisturbed by diffusion or melt interaction processes.

References:

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