

Trace element partitioning between silicate minerals and carbonatite and silicate melts at 18kb to 46kb pressure

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Introduction

The equilibration of mantle mineralogies with silicate or carbonatite melts may fractionate trace elements in the mantle in distinctively different ways. To address this question in this study, we present new experimental data to quantify the manner in which selected trace elements (Rb, Ba, Na, K, Nb, Ta, Sr, Zr, Ti, Y, Lu, Cr) may distribute between garnet, clinopyroxene and phlogopite and silicate- and carbonatite-melts. New data are also presented for describing the partitioning of these elements between olivine and orthopyroxene and a carbonatite melt.

In terms of major elements, three bulk systems are considered (1) carbonate dominated, (2) silicate (carbonate-absent) and alkali-rich and (3) silicate (carbonate-absent) and alkali-poor. The composition and phase relations of the carbonate bulk system are given in Sweeney (1994). The alkali-rich silicate bulk system has a MARID (principally comprising mica-amphibole-diopside) bulk composition (AJE137, Sweeney *et al.*, 1993) and the alkali-poor silicate bulk composition is the quartz tholeiite of Ringwood and Green (1966). In terms of their major element composition, the liquids produced in these three bulk systems are (1) alkali-rich dolomitic melts, (2) K-rich silica-undersaturated basaltic melts, and (3) K-poor silica-saturated basaltic melts. It is suggested that these melt compositions cover the likely spectrum of low degree melt compositions in the Earth's upper mantle. Melts (1) and (2) may be produced in a mantle peridotite at low melting degrees and (3) by the partial fusion of a subducting slab. It is these low degree melts which may carry substantial budgets of incompatible elements and thus we consider the bulk systems studied to be relevant to the quantification of mantle metasomatism.

Experimental technique

Carbonatite compositions were doped to *c.* 1000 ppm with Nb, Zr, Ta, Y, Ce, Lu, Ba and Sr. Experiments were carried out in a Boyd and England-type piston cylinder (where $P < 32$ kb) and a Walker-type multi-anvil device where $P > 32$ kb. Run products were analysed using a Cameca SX50 wavelength dispersive electron microprobe (Na, K) and proton-induced X-ray emission (PIXE) at the National Accelerator Centre (NAC) in South Africa (Rb, Ba, Nb, Ta, Sr, Zr, Ti, Y, Lu, Cr). The PIXE probe is based on a 6 MeV single-ended Van der Graaff accelerator and uses Oxford Microprobe triplet lenses for beam focussing (Tapper *et al.*, 1993). In this application 3 MeV proton beam was used, focussed to between 5–10 micron for silicates and rastered over areas 40–200 microns in diameter for the quenched carbonate/silicate matrix. With an effective depth of analysis of < 30 microns, care was taken to select grains large enough to avoid inclusion of the underlying matrix. The energy dispersive spectra were analysed using GeoPIXE software (Ryan *et al.* 1990). The PIXE setup was calibrated earlier (Van Achterbergh *et al.*, 1993) and accuracy was confirmed against trace element standard BCR-1 and a secondary standard (Sweeney *et al.*, 1994a) containing the trace elements of interest to this study and reproducibility was found to be better than $\pm 5\%$ relative (Sweeney *et al.*, 1994b). Preliminary partition coefficient (concentration in mineral/concentration in melt) results are presented in Fig. 1.

Discussion

There are some significant differences in the trace element budget of garnets and phlogopites depending on whether these minerals have equilibrated with a carbonatite (cbtmelt) or silicate (silmelt) melt (Fig. 1a, b). These differences cannot be ascribed to variations in the major element component of these minerals, as the

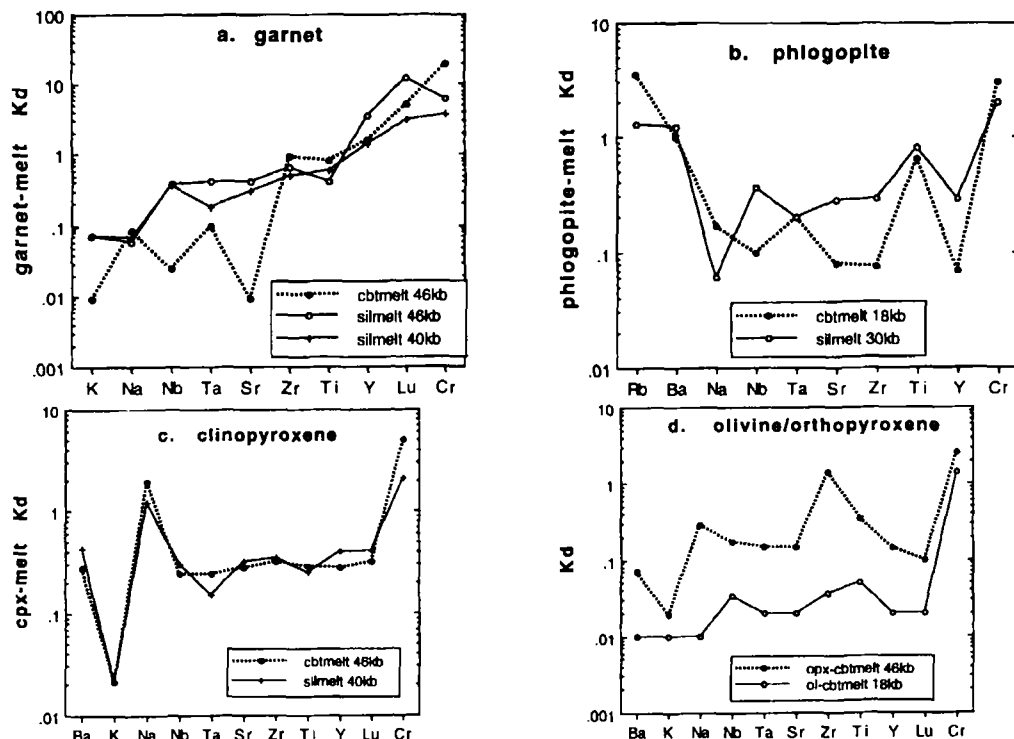


FIG. 1.

partition coefficients are similar for garnets in equilibrium with very different bulk compositions (with a MARID at 46kb and the quartz tholeiite at 40kb) (Fig. 1a). The differences therefore reflect the ability of carbonatite and silicate melts to coordinate elements differently. The lower K_d's for Nb and Sr in garnet-cbtmelt and Nb, Sr and Zr in phlogopite-cbtmelt are therefore a function of the preference (ease of co-ordination) that these elements have for a carbonate over a silicate melt. Clinopyroxene K_d's are similar for both carbonatite and silicate melts (Fig. 1c).

Two factors govern the effectiveness of mantle minerals to fractionate interelement ratios when residual to any melt: mineral abundance and relative differences in the K_d's. In terms of distinguishing the effects of small volume silicate- and carbonatite-melts garnet satisfies both these criteria: comprising typically 5–6 vol% of a peridotite and has changes in K_d's of 10³ (Fig. 1a). Garnet, thus offers the best option for determining whether a peridotite has equilibrated with a carbonatite or silicate melt and fractionating some interelement ratios in such a melt. For example, Ti/Nb, Zr/Nb, Zr/Sr, Lu/Nb and Lu/Sr will be progressively lowered in any carbonatite melt (and therefore in any mantle it equilibrates

with) with continued percolation through a garnet-bearing mantle. Significantly, Zr is also compatible in orthopyroxene (comprising typically 10–30 vol% of a peridotite) when in equilibrium with a carbonatite melt (Fig. 1d), which would further reduce the Zr/Nb ratio.

References

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