

Experimental cpx/ and garnet/melt partitioning of *REE* and other trace elements at high pressures: Petrogenetic implications

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Introduction

Refinement of petrogenetic models requires knowledge of the crystal/melt partitioning behaviour of trace elements. Application of high pressure experimental methods and advancements in analytical techniques provide researchers with the means to gather increasingly precise partitioning data. This paper reviews recent experimental partitioning studies and presents new results from 32 piston-cylinder experiments pertaining to the effects of pressure and temperature on clinopyroxene/melt and garnet/melt partitioning of 14 rare earth and other trace elements in basaltic systems in the 20–30 kb pressure range, and discusses the implications of these data on petrogenetic questions.

Methods

Data are presented from recent experiments done at the University of Tokyo using piston-cylinder apparatus. Starting material for the experiments was 1921 Kilauea basalt glass. The glass was powdered, dried at 120°C, fused in a standard 1 atm. furnace in a Pt crucible at 1300°C at $f_{O_2} = 10^{-8}$, quenched and then repowdered. Variable amounts of 99.9% pure trace element oxides of Sr, Y, Zr, Nb, Hf, La, Nd, Sm, and Lu were added as spikes in different combinations to this starting powder, but total doping was generally <1 wt% and did not exceed 2 wt% in any of the mixtures.

Samples were loaded in graphite capsules and then weld-sealed inside platinum capsules. This assembly was then packed inside a graphite furnace with Pyrex and talc sleeves wrapped in Pb foil and loaded into the solid media piston-cylinder apparatus. Experiments on doped and undoped charges were run from 5–120 hours at 20–20 kb and 1300–1470°C using the piston-out technique.

Samples were polished and analyzed by 5-channel wavelength dispersive JEOL 733 electron microprobe at University of Tokyo and Cameca IMS-3f ion microprobe at Woods Hole Oceanographic Institution.

Results

In all runs, the melt quenched to a clear, brown glass with no quench phases. Liquidus phases were generally clinopyroxene, but in one run at 30 kb, large garnet and small clinopyroxene co-precipitated. The glass was homogeneous in composition, and the mineral phases were generally unzoned except in a few runs; these were not included in the calculation of partition coefficients. Partition coefficients were calculated simply by using averaged glass compositions and individual mineral spot analyses.

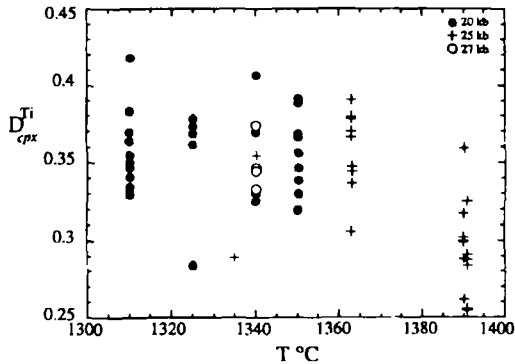
Experiments showed that a run time of about 36 hours was needed to achieve a leveling-off of partition coefficients. Partition coefficients are listed in Table 1.

D^{Ti} in cpx shows slight temperature dependence (Figure 1), but the temperature effects on D 's of *REE* and other trace elements appear to be less striking; within analytical uncertainty, there does not appear to be a strong pressure dependence.

Partition coefficients plotted on extended trace element diagrams show a negative Zr anomaly

TABLE 1. Calculated partition coefficients

	D_{cpx}	D_{garnet}
Nb	0.004	0.0042
La	0.050	0.0016
Ce	0.072	0.0051
Sr	0.096	0.003
Nd	0.177	0.052
Zr	0.128	0.27
Hf	0.230	0.24
Sm	0.281	0.25
Ti	0.347	0.28
Dy	0.420	2.2
Er	0.360	3.6
Y	0.421	2.8
Yb	0.432	6.6
Lu	0.439	7.1

FIG. 1. Temperature dependence of $D_{\text{cpx}}^{\text{Ti}}$.

relative to REE in clinopyroxenes and a positive Zr and negative Y, Ti, and Sr anomalies in garnet (Figure 2, Table 1).

Discussion

For the most part, the results of this study are in accord with previously published partitioning data on cpx and garnet. D^{Nb} in cpx is lower than some published results (e.g., McCallum and Charrette, 1978; Dunn and McCallum, 1982; Johnson and Kinzler, 1989), but is in the range of others (Green *et al.*, 1989; Hart and Dunn, 1993). D^{REE} in cpx fall within published ranges (e.g., Irving, 1978; McKay *et al.*, 1986), but show slightly greater fractionation than results at lower pressures (e.g., Fujimaki *et al.*, 1984; Grutzeck *et al.*, 1974). D^{REE} in garnet are slightly more fractionated than previous results (Shimizu and Kushiro, 1975).

Coupling of the Nd and Hf isotope systems has been used to constrain melting depths in MORB and OIB (Salters and Hart, 1991). The difference between $D_{\text{Sm}/\text{Nd}}$ and $D_{\text{Lu}/\text{Hf}}$ in cpx and garnet provide the leverage in these models, and modeling results are a critical function of these values. The Critical Partitioning Parameter ($\text{CPP} = \frac{D_{\text{Lu}/\text{Hf}}}{D_{\text{Sm}/\text{Nd}}}$; Hart and Dunn, 1993) is a measure of the fractionation of the parent/daughter elements for Nd and Hf isotope systems. Salters and Hart (1991) used a CPP of 1.17 in clinopyroxene and of ~ 0.2 in garnet as the basis for modeling significant degrees of melting in the garnet stability field. Hart and Dunn (1993) found $\text{CPP}_{\text{cpx}} = 0.92$. This study finds that CPP_{cpx} falls in the range 0.52–0.92, and

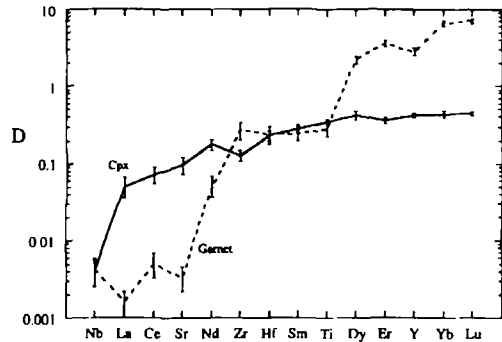


FIG. 2. Partition coefficients for cpx and garnet.

$\text{CPP}_{\text{garnet}} = 0.16$. This means that CPP for cpx and garnet are closer than in previous estimates, and that it will be harder, but still possible, to distinguish the effects of melting in the garnet stability field based on this parameter. Moreover, melting models may not require as much melting in the garnet field as proposed by Salters and Hart (1991).

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