

Effect of melt structure on trace-element partitioning between clinopyroxene and silicic, alkaline, aluminous melts

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ABSTRACT

We have investigated trace-element partitioning between clinopyroxene and silicic melts ranging from 62 to 69 wt% SiO₂ in piston-cylinder experiments at 1.1 GPa and 1145–1155 °C. Run products consist of diopsidic clinopyroxene (with 3–5 wt% Al₂O₃ and ~1 wt% Na₂O) coexisting with silicic, aluminous, and alkaline melts. Clinopyroxene-melt partition coefficients for rare earth elements (REE) are significantly higher (e.g., $D_{Sm} = 0.76$ to 3.1) than previous studies of clinopyroxene-basaltic melt partitioning. The maximum D_{REE} is also shifted toward middle REE (e.g., Tb). Although the partition coefficients of Sr and Ti ($D_{Sr} = 0.23$ –0.39, $D_{Ti} = 0.28$ –1.0) are also elevated relative to clinopyroxene-basaltic melt, partition coefficients for Zr and Li (0.14–0.23 and 0.16–0.25, respectively) are within the range of literature values.

The high partition coefficients for REE, Sr, and Ti in this study do not reflect crystal-compositional effects. For instance, no relationship is observed between ^{IV}Al and these partition coefficients. REE and Ti partition coefficients correlate poorly with jadeite component of the clinopyroxene; however, the elevated Na₂O contents of both the melt and clinopyroxene make it difficult to discriminate fully the effect of jadeite component from the effect of changes in melt structure. The non-bridging oxygen to tetrahedral cation ratio (NBO/T; Mysen et al. 1985) varies from 0.08 to 0.17 and roughly correlates with ^{cpx/melt} D_{REE} , consistent with a recent study (Gaetani 2004) that concluded that melt structure significantly affects partitioning when NBO/T < 0.49. Notably, we find a strong correlation between the molar Ca²⁺/(M⁺ + M²⁺) of the melt and the optimum D (D_0) for the REE, indicating that melt structure, and not jadeite content, is the dominant control on clinopyroxene-melt partitioning in these experiments.

The partition coefficients for the REE, Ti, Zr, and Sr are in good agreement with observed clinopyroxene-silicic glass partitioning within mantle xenoliths (Chazot et al. 1996; Vannucci et al. 1998), indicating these results may apply to lithospheric melting. Furthermore, the origin of hump-shaped REE patterns observed in residual clinopyroxene from abyssal peridotites could be explained if shallow depleted melts of peridotite are silica-rich. A two-stage fractional melting model assuming clinopyroxene-silicic melt partitioning at shallow mantle depths from 10 to 30 km beneath a mid-ocean ridge can reproduce the observed hump-shaped REE patterns. If so, hump-shaped REE patterns may provide evidence for the existence and extraction of silica-rich melt created in the shallow mantle.

Keywords: Melt structure, partition coefficient, trace element, clinopyroxene