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Trace Element Partitioning Experiments in Orthopyroxene: Insights into Ultradepleted Mantle Signatures

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Our ability to model igneous processes depends on knowledge of the phases present. In the case of the mantle, the presence or absence of clinopyroxene in the protolith will control the productivity of the mantle as well as the trace element signature. Increasing evidence suggests that the mantle contains regions characterized by extremely depleted trace element signatures (Ti/Zr<140), consistent with a degree of melting (>20%) past the point at which clinopyroxene is exhausted. Until clinopyroxene is consumed, its relatively high partition coefficients control the trace element budget for the rare earth elements (REE) and high field strength elements (HFSE) at pressures below garnet stability. After clinopyroxene exhaustion, the geochemical evolution of subsequent melts is dependent on the trace element partitioning between orthopyroxene and melt. Therefore, understanding the degree of depletion of incompatible elements during melting of the mantle past clinopyroxene exhaustion requires accurate partition coefficients for the REE and HFSE between orthopyroxene and silicate melt for ($^{opx\text{-}melt}D_{REE,\ HFSE}$). However, the current experimental database for orthopyroxene/melt partitioning is compromised by inconsistencies in the number and distribution of data in temperature, pressure, and composition.

We report on a series of phase equilibria and trace element partitioning experiments that aim to further our understanding of the liquidus phase relations at upper mantle conditions and to constrain the $^{opx\text{-}melt}D_{REE,\ HFSE}$. The starting material is a powder composed of 65% of basaltic glass from Gorda Ridge, 25% En_{89} Kenya enstatite, and 10% Fo_{90} Kilbourne Hole olivine. Experiments were conducted in a piston-cylinder press at 5, 10, 15, and 20 kbar and various temperatures for 24 hours to obtain high degrees of partial melting. Major and trace element analyses were performed on the run products to characterize their texture, mineralogical assemblage, and calculate the $^{opx\text{-}melt}D_{REE,\ HFSE}$. Experiments at 10 and 15 kbars produced olivine and orthopyroxene ± clinopyroxene crystals larger than 50 mm which document the behavior of trace elements in low-Ca pyroxenes as a function of pressure, temperature, and degree of partial melting. Our investigation identifies the specific low-Ca pyroxene species in these experiments and discusses the improvement of analytical procedures to minimize analytical error.