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Distribution of first-row transition elements between clinopyroxene, orthopyroxene, olivine, spinel and garnet in mantle peridotites

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The concentrations and ratios of first-row transition elements (FRTEs) are broadly used as tracers (e.g., Zn/Fe, Mn/Fe and V/Sc) of the origin of peridotites and mafic igneous rocks. However, inter-mineral FRTE partitioning in peridotites remains insufficiently constrained, particularly for spinel and garnet. The uncertainties in partition coefficients (D, for individual elements) and exchange coefficients (K_D, for element pairs) hinder the interpretation of FRTE data.

Here, we report high-precision concentrations for Sc, Ti, V, Cr, Mn, Fe, Cr, Co, Ni, Cu and Zn obtained by LA-ICP-MS in coexisting olivine, orthopyroxene, clinopyroxene and spinel or garnet for a suite of seventy-two texturally equilibrated peridotite xenoliths with a P-T range of 855–1210°C and ≤1.5–6.0 GPa. The suite includes 56 basalt-hosted spinel peridotites from eight sites and 16 coarse garnet peridotites from the Siberian craton; melt-metasomatized and vein peridotites (e.g. dunites) are not included to focus on FRTE variations produced by melt extraction and equilibrium inter-mineral distribution. We calculate inter-mineral FRTE partition and exchange coefficients, and we also develop quantitative models for FRTE partition coefficients by logarithmic fitting with temperature as well as concentrations of Na in clinopyroxene and Cr in spinel. The FRTE distribution is found to be mainly controlled by equilibration temperature and mineral compositions whereas the exchange coefficients for Mn/Fe, Co/Fe, Ni/Co, Zn/Fe and V/Sc among clinopyroxene, orthopyroxene and olivine display no temperature dependence. By contrast, we find, for the first time, that spinel-clinopyroxene exchange coefficients for Co/Fe, Ni/Co, Zn/Fe and V/Sc are considerably affected by temperature. Although spinel and garnet are minor phases in mantle peridotites, typically constituting less than 10% of the modal abundance, they are known to host a significant proportion of the trace elements in the whole-rock composition. Finally, a melting model is established to infer the values of $Zn/Fe \times 10^4$, $Mn/Fe \times 100$ and V/Sc in the primitive melt of spinel or garnet peridotite.

Overall, the new partition and exchange FRTE coefficients obtained in this study further advance the application of FRTEs and their ratios to examine generation of primary magmas, mantle depletion and P-T-dependent inter mineral fractionation.