Thermodynamic Models: Advancing Understanding of High Degree of Melt Depletion in Mantle Peridotites

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The co-variation of spinel Cr# and olivine Mg# in mantle peridotites has been used as a sensitive indicator for the degree of partial melting, magma types, and metasomatism. Whereas the origin of spinel-olivine trends in relatively fertile peridotites can be well simulated by experiments, spinel-olivine trends in peridotites that have experienced high degrees of melt depletion are more controversial and experimental constraints are few. The original bulk composition, participation of water, oxygen fugacity, pressure, and temperature are some factors we need to consider for the formation of highly depleted residual peridotites.

Thermodynamic modelling has advanced to the point where it complements experimental studies, especially given the difficulties in experiments at low degrees of partial melting. Fractional melting processes in particular are difficult to simulate experimentally, but tractable in thermodynamic modelling. We use the most recent versions of THERMOCALC-based thermodynamic models (1, 2) to evaluate the feasibility of generating extremely depleted spinel peridotites, and to model the effects of water, bulk composition, Fe^{3+}/Fe^{2+}, temperature, and pressure on the residual mineralogy and phase chemistry in anhydrous and hydrous peridotites. The differences between batch and fractional melting models have also been explored. We produced spinel peridotites with >40% melt depletion during batch melting and <15% aggregated melt during fractional melting. These results have implications for understanding the origin of highly depleted melt residues that occur from the Archean through to the present-day.

(1) Holland et al. (2018), J. Petrol 59:881

(2) Tomlinson and Holland (2021), J. Petrol 62:egab012

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