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Thermodynamic Models Illustrate How to Generate Extremely Cr-rich Spinel During Melting of Mantle Peridotites

MR. DAOHENG WANG, ROBERT W LUTH AND D. GRAHAM PEARSON

University of Alberta

Presenting Author: daoheng@ualberta.ca

The mantle array of co-varying spinel Cr# and olivine Mg# has been used as a sensitive indicator for the degree of partial melting, magma types, and metasomatism of mantle peridotites. The formation of extremely Cr-rich spinel in peridotites remains controversial, however, because of the difficulty in producing high Cr-spinel in melting experiments. We use the most recent versions of THERMOCALC-based thermodynamic models [1, 2] to evaluate the feasibility of generating extremely Cr-rich spinel during *fractional* melting of peridotite, and to model the effects of water, bulk composition, Fe^{3+}/Fe^{2+}, temperature, and pressure on the mineralogy and phase chemistry in anhydrous and hydrous peridotites. The TH21 model is restricted to anhydrous conditions, so we also used the HGP18 silicate melt model, which includes H_2O, to explore the effects of hydrous melting.

The calculated results for anhydrous batch melting of KLB-1, KR4003, and MM3 using TH21 agreed well with experiments, except for the higher olivine Mg#. Varying bulk Fe^{3+} had minimal effect on spinel stability. Using HGP18, the anhydrous calculations did not agree as well with experimental results. Further, modelling hydrous melting with HGP18 produced mineral assemblages and compositions of minerals and melts that did not agree well with the experimental observations.

For TH21, the results for the different fertile peridotite starting compositions are similar. In contrast, a depleted bulk composition has a wider range for the stability of spinel and develops higher spinel Cr#. At 2 GPa, the spinel Cr# in the depleted bulk composition reaches 78 compared to 65 in the fertile KLB-1. For isobaric fractional melting at 2 GPa, spinel Cr# for the depleted bulk composition is near 70 for ~14% aggregate melting, much higher than the maximum value of 28 for KLB-1 reached just before spinel disappears from the residue. Interestingly, adding alkalis to the depleted composition increases the maximum spinel Cr# to >85 in both batch and fractional melting.

[1] TH21: Tomlinson and Holland (2021), J. Petrol 62:egab012

[2] HGP18: Holland et al. (2018), J. Petrol 59:881