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Spinel-melt Fe^{3+} partition coefficient increases with spinel Cr#

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Oxygen fugacity (fO_2) in the oceanic upper mantle is a measure of the amount of oxygen available to react during the partial melting process that generates mid-ocean ridge basalts (MORB). Estimates for the fO_2 of the MORB-source mantle come from the products of melting (basalt glass $Fe^{3+}/\Sigma Fe$ ratios) and the residues of melting (ridge peridotite spinel-oxybarometry) [1]. But knowledge of mantle fO_2 prior to melting requires knowledge of the partition coefficients of Fe^{2+} and Fe^{3+} between melts and mantle minerals. Previous experiments demonstrated that the spinel/melt partition coefficient of Fe_2O_3 (DFe_2O_3) is sensitive to temperature and the Fe_2O_3 concentration of spinel [2]. It was not previously known whether spinel Cr#, which is sensitive to the degree of partial melting in the mantle, affects DFe_2O_3.

We performed experiments at 1 bar, 1225 ^oC, and from QFM-1 to QFM+2 at one log unit intervals on four compositions with spinel Cr#s ranging from 0.18 to 0.53 to test if spinel Cr# affects DFe_2O_3. We analyzed major elements in each experimental phase by EPMA. We calculated spinel $Fe^{3+}/\Sigma Fe$ ratios from EPMA analyses corrected using Mössbauer-characterized spinel standards and we measured $Fe^{3+}/\Sigma Fe$ ratios in the glasses by XANES.

At a given spinel Cr#, DFe_2O_3(spl/melt) increases as fO_2 increases, consistent with previous observations [2,3]. At any given fO_2, DFe_2O_3(spl/melt) increases by a factor of ~2 as spinel Cr# increased by a factor of ~3. Davis and Cottrell [2] previously determined that temperature and spinel Fe_2O_3 are important controls on DFe_2O_3(spl/melt), and we have now shown that spinel Cr# also has an important effect. As melting proceeds beneath ridges, residual peridotites become increasingly refractory, and spinel Cr#s increase such that Fe_2O_3 to will become more compatible in spinel during melt extraction. This may act to keep peridotite residues from becoming reduced even as Fe_2O_3 is depleted in the rock overall.

[1] Cottrell et al. (2021) Geophys Mono DOI: 10.1002/9781119473206.ch3 [2] Davis and Cottrell (2021) Contrib Mineral Petrol DOI: https:// doi. org/ 10. 1007/s00410-021- 01823-3. [3] Davis and Cottrell (2018) Am Mineral DOI: http://doi.org/10.2138/am-2018-6280