Basalt glass Fe-XANES and spinel peridotite oxybarometers agree

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Oxygen fugacities (f_{O2}) recorded by spinel-olivine-orthopyroxene equilibria in ridge peridotites range from 2.5 log units below to 0.5 log units above the quartz-fayalite-magnetite (QFM) buffer with a mean of QFM-1 [1]. $Fe^{3+}/\Sigma Fe$ ratios in primitive mid-ocean ridge basalt (MORB) glasses, analyzed using X-ray absorption near-edge structure (XANES) analysis, suggest a mantle f_{O2} of QFM-0.25 to QFM+0.25 with an average near QFM [2]. If ridge peridotites are melting residues of MORB, then the peridotites and glasses should record the same mantle f_{O2} at the time of melt generation. These two oxybarometers rely on Fe oxidation states recorded in different phases and analyzed by different techniques; therefore, bias in one or both of these methods may be a source of the incongruence. We performed a series of experiments that generated basaltic melts in equilibrium with olivine, orthopyroxene, and spinel that allows us to directly compare results of the two oxybarometers.

Experiments were performed in a 1-atm. vertical gas-mixing furnace at 1225 °C with f_{O2} set by a $CO\text{-}CO_2$ gas mixture between QFM-1.9 and QFM+2.3 at roughly 0.5 log unit intervals. Experiments generated basaltic glasses in equilibrium with Fo_{90} olivines, orthopyroxenes, and Cr-rich spinel (Cr# > 0.6). Spinel $Fe^{3+}/\Sigma Fe$ ratios were measured by electron microprobe [3]. Glass $Fe^{3+}/\Sigma Fe$ ratios were measured by XANES at the National Synchrotron Light Source [4].

Oxygen fugacities calculated from glasses and the mineral assemblage agree with one another, and the gas mix, to within 2σ across the f_{O2} range investigated, and to within 1σ in the range QFM-1 to QFM+1. The agreement demonstrates that the incongruence between f_{O2} of MORB and ridge peridotites does not result from method bias. Moreover, both the Mössbauer-based XANES calibration for basalt [4, 5] and the spl-oxybarometer are accurate. The offset in average f_{O2} from the two proxies at ridges, and the wider range of f_{O2} recorded by the peridotites, result from incomplete and non-overlapping sample coverage of the two global datasets, from petrological processes occurring after melt segregation at the ridge, or indicate that the ridge peridotites are not melting residues of MORB.

[1] Bryndzia and Wood, Am. J. Sci. 1990. [2] Cottrell and Kelley, EPSL, 2011. [3] Davis et al., Am. Min. 2017. [4] Cottrell et al., Chem Geol., 2009. [5] Zhang et al. in prep.