Probing the water content of the Earth's mantle: Hydrogen mobility under extreme conditions

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Research over the past few decades has shown that nearly all of the nominally anhydrous minerals (NAMs) of Earth's mantle can incorporate substantial amounts of water as structurally bound hydrogen. This has important implications for understanding the geochemical and geophysical properties of Earth's interior as the presence of water influences numerous mantle properties and processes[1,2]. Water, as hydrogen, has been invoked to reconcile differences between conductivity models and geophysical observations of the mantle, but the amount present is yet to be satisfactorily quantified – with experimental estimates differing by several orders of magnitude[3,4]. Hydrogen-deuterium exchange experiments performed under mantle conditions are presented, that provide data on hydrogen mobility in olivine directly comparable with electrical conductivity data. These results will be used in conjunction with existing estimates of conductivity and magnetotelluric survey data in order to constrain the water content and conductivity of olivine, and thus the upper mantle.

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Evaluating proxies for oxygen fugacity at the Mariana arc

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Arc basalts are more oxidized than mid-ocean ridge basalts, but existing proxies for studying fO_2 present contrasting explanations for this offset. The $Fe^{3+}/\sum Fe$ ratio proxy indicates that the mantle wedge has higher fO_2 than mid-ocean ridge source mantle. In contrast, trace element proxies (V/Sc, Zn/Fe*, and [Cu]) suggest that the fO_2 of the upper mantle is uniform. Additionally, the $D_V^{ol/melt}$ proxy suggests that arc magmas are oxidized at the time of high-Mg olivine fractionation. We present major and trace element concentrations and $Fe^{3+}/\sum Fe$ ratios (μ-XANES) for melt inclusions and their olivine hosts from five Mariana arc volcanoes and Mariana Trough submarine glasses to compare the [Cu], Zn/Fe*, $D_V^{ol/melt}$, V/Sc, and $Fe^{3+}/\sum Fe$ ratio proxies for calculating fO_2.

The Zn/Fe* proxy returns $Fe^{3+}/\sum Fe$ ratios of primary mantle melts and is sensitive to variations in Zn/Fe^*_{source}. After accounting for source composition, the Zn/Fe* proxy yields agreement with calculated primary $Fe^{3+}/\sum Fe$ ratios for arc and back-arc glasses. Similarly, the [Cu] of arc melt inclusions are consistent with non-modal equilibrium melting of a source between QFM+1 and QFM+2, and fractional melting between QFM and QFM +0.5 for back-arc magmas. The V/Sc proxy returns more reduced primary fO_2s than the Fe-based proxy for all samples, however fO_2s for arc melt inclusions calculated using $D_V^{ol/melt}$ (QFM+2.7 ±0.3) are systematically more oxidized than their measured $Fe^{3+}/\sum Fe$ ratios indicate (QFM+1.3 ±0.3), suggesting that there may be a significant water, pressure, or source composition effect on the partitioning behaviour of V and Sc. These results show that the Fe-, Zn/Fe*-, and [Cu]-based proxies for fO_2 are in broad agreement and are consistent with an arc mantle source that is more oxidized than mid-ocean ridge source mantle.

DOI:10.1180/minmag.2013.077.5.2
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