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Experimental calibration and implications of olivine-melt vanadium oxybarometry for hydrous basaltic arc magmas

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Abstract

The strong dependence of vanadium partitioning between olivine and silicate melt ($D_V^{Ol\text{-}M}$) on redox conditions (f_{O_2}) can be used as sensitive oxybarometer in magmatic systems. Here we extend the experimental database on $D_V^{Ol\text{-}M}$, obtained so far at high temperatures (mainly above 1250 °C), to lower temperatures that are typical for island-arc basalts. Crystallization experiments were performed using a composition from Mutnovsky volcano (Kamchatka), and the investigated temperature, pressure, and oxygen fugacity ranges were 1025–1150 °C, 0.1 and 0.3 GPa, and ΔQFM of –0.5 to +3.2, respectively. The water content in melts ranged from 0.6 to ~6.5 wt% H_2O. The data demonstrate a strong negative correlation between $D_V^{Ol\text{-}M}$ and oxygen fugacity, similar to the behavior observed previously at higher temperatures and in MgO-rich compositions. The correlation between $D_V^{Ol\text{-}M}$ and ΔQFM in the range from –0.5 to +3.2 is described for melts with MgO < 12 wt% and Na_2O < 4 wt% at temperatures ≤1250 °C by the empirical equation: $\Delta QFM = -3.07^{+0.26}_{-0.29} \log D_V^{Ol\text{-}M} - 3.34^{+0.40}_{-0.49}$ with the standard error (SE) as a function of $\log D_V^{Ol\text{-}M}$: $2SE(\Delta QFM) = -0.275 \log D_V^{Ol\text{-}M} + 0.4$.

We suggest that this equation can be used as an oxybarometer, which is particularly well applicable to the hydrous island-arc magmas at relatively low temperature. Application of the equation to the composition of melt inclusions and their host olivine phenocrysts from basalts of Mutnovsky volcano, containing vanadium concentrations in the range of 250–370 and 4–6 ppm, respectively, reveals an oxygen fugacity in the range ΔQFM +1.9 to +2.3. The estimates are in a good agreement with olivine-spinel oxybarometry for Mutnovsky basalts and may be typical for moderately evolved island-arc magmas.

Keywords: Vanadium, oxybarometry, island arcs, melt inclusions, redox conditions; New Advances in Subduction Zone Magma Genesis