Experimental evaluation of a new $\text{H}_2\text{O}$-independent thermometer based on olivine-melt Ni partitioning at crustal pressure

XIAOFEI PU$^{1,*}$, GORDON M. MOORE$^2$, REBECCA A. LANGE$^1$, JACK P. TOURAN$^2$, and JOEL E. GAGNON$^3$

$^1$Department of Earth and Environmental Sciences, University of Michigan, 1100 North University Avenue, Ann Arbor, Michigan 48109, U.S.A.
$^2$NASA Johnson Space Center in Astromaterials Research and Exploration Science, 2101 NASA Parkway, Houston, Texas 77058, U.S.A.
$^3$Department of Earth and Environmental Sciences, University of Windsor, 401 Sunset Avenue, Windsor, Ontario N9B 3P4, Canada

**Abstract**

An olivine-melt thermometer based on the partitioning of Ni ($D_{\text{Ni}}^{\text{Ol/liq}}$) was hypothesized by Pu et al. (2017) to have a negligible dependence on dissolved water in the melt (and pressure variations from 0–1 GPa), in marked contrast to thermometers based on $D_{\text{Mg}}^{\text{Ol/liq}}$. In this study, 15 olivine-melt equilibrium experiments were conducted on a basaltic glass starting material (9.6 wt% MgO; 353 ppm Ni) to test this hypothesis by comparing the effect of dissolved H$_2$O in the melt on $D_{\text{Ni}}^{\text{Ol/liq}}$ and $D_{\text{Mg}}^{\text{Ol/liq}}$ on the same set of experiments. Results are presented for six anhydrous experiments at 1 bar, two anhydrous experiments at 0.5 GPa, and seven hydrous experiments at 0.5 GPa. Analyzed olivine and glass compositions in the quenched run products were used to calculate $D_{\text{Ni}}^{\text{Ol/liq}}$ and $D_{\text{Mg}}^{\text{Ol/liq}}$ values for each experiment, which in turn permit temperature to be calculated with the Mg- and Ni-thermometers calibrated in Pu et al. (2017) on anhydrous, 1-bar experiments from the literature. The Ni-thermometer recovers the temperatures of all 15 experiments from this study with an average deviation of $-3 ^\circ\text{C}$, including those with up to 4.3 wt% H$_2$O dissolved in the melt. In contrast, the Mg-thermometer recovers the anhydrous, 1-bar experimental temperatures within $+14 ^\circ\text{C}$ on average, but overestimates the hydrous experimental temperatures by +49 to +127 $^\circ\text{C}$, with an average deviation of +83 $^\circ\text{C}$. When the Mg-thermometer of Putirka et al. (2007) is applied, which includes a correction for analyzed H$_2$O contents (3.6–6.7 wt%) in olivine-hosted melt inclusions in the literature, leads to temperatures that match those obtained from the Putirka et al. (2007) Mg-thermometer that corrects for analyzed H$_2$O contents. This study demonstrates that a thermometer based on $D_{\text{Ni}}^{\text{Ol/liq}}$ can be applied to hydrous basalts at crustal depths without the need to correct for dissolved water content or pressure.

**Keywords:** Nickel, olivine-melt thermometry, subduction zone processes, phase equilibrium experiments

**Introduction**

Knowledge of the magmatic temperature of arc basalts is key to understanding subduction zone processes, including the interplay between hydrous flux melting and decompressional melting. Geodynamic models of these processes rely on high-quality data on both the temperature and water contents of erupted arc basalts. Most published olivine-melt thermometers are based on the partitioning of Mg (defined here as $D_{\text{Mg}}^{\text{Ol/liq}} = X_{\text{Ol}}^{\text{Mg}}/X_{\text{liq}}^{\text{Mg}}$) (e.g., Beattie 1993; Herzburg and O’Hara 2002), which has a strong dependence on dissolved water in the melt (e.g., Putirka et al. 2007). Therefore, olivine-melt Mg-thermometers require a correction term based on melt H$_2$O content (Putirka et al. 2007; Putirka 2008). A priori knowledge of the H$_2$O content in the melt at the time of olivine crystallization is therefore required for high-quality temperature estimates, yet it is not always available.

To address this issue, Pu et al. (2017) proposed an olivine-melt thermometer based on the partitioning of Ni, which is largely independent of dissolved H$_2$O in the melt. In that study, a new

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* Present address: Materials and Fuels Complex, Idaho National Laboratory, PO Box 1625, Idaho Falls, ID 83415, U.S.A. E-mail: xiaofei.pu@inl.gov. ORCID 0000-0003-2120-7054