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The temperature and pressure dependence of nickel partitioning between olivine and silicate melt.

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Ocean island basalts are thought to be produced by partial melting of the mantle at temperatures (T) and pressures (P) significantly higher than the conditions at which they erupt or are intruded in the crust/shallow upper mantle [1]. If T and P affect the olivine (ol)-liquid (liq) nickel partition coefficient, it is important that models used to describe ol-liq Ni partitioning during mantle melting include data from experiments at elevated T and P. Available data on Ni partitioning, however, is dominated by 1-atm experiments in which T and liquid composition are highly correlated, making it difficult to separate the effects of these variables on the observed variations in Ni partitioning between ol and liq [e.g., 2].

We conducted experiments on a mixture of MORB and olivine at 1 atm (1400°C) and 1-3 GPa (1450-1550°C). Ni loss from the silicate melt to the Pt-C double capsule was minimized by surrounding a chip of MORB glass with powdered olivine and sintering the assembly at a T below the solidus of the MORB chip. The data presented in this work is from a series of reversed experiments where T and P were increased in such a way that the liquid composition remained approximately constant (MgO ~ 17 wt. %), effectively isolating the effects of T and P from those of liquid composition on the ol-liq partition coefficient. The resulting partition coefficient decreases from ~5.0 to 3.8 (by wt.) as the temperature increases from 1400 to 1550°C. The rate of decrease of the Ni partition coefficient measured in these experiments (~0.8/100°C) is less than that of recent models, which predict a decrease of ~1.2/100°C [3].

Using the results of our experiments we fit a thermodynamic expression describing the ol-liq Ni-Mg exchange equilibrium, which is a function of both T and liquid composition. Using our expression we can then calculate the NiO contents of near-surface olivines as a function of the difference in temperature (ΔT) between low-pressure crystallization and the separation of the melt from the residuum, assuming the olivines in the residue always have 0.36 wt. % NiO [4]. Using estimated Hawaiian parental melt compositions, a ΔT of ~150°C is needed to reproduce the median NiO content of HSDP olivines [5]. Assuming that the slope of the liquidus represents the approximate change in P and T that a parental melt can undergo without changing composition, a ΔT of ~150°C corresponds to a depth of ~ 2.7 GPa. This primary melt separation depth compares favourably with the estimated depth of the lithosphere under Hawaii [3.0 GPa, 6]. Thus, partial melting and crystallization at different P and T can lead to the crystallization of high-NiO olivines from a melt that was in equilibrium with mantle with normal NiO concentrations.

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