

Hydrous partial melting of the upper mantle as judged from mineral/melt partition coefficients.

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It has been known for more than 10 years that nominally anhydrous minerals may incite small amounts of melting in Earth's mantle. In recent years, there has been a great increase in experimental data on the H₂O storage capacity of nominally anhydrous minerals. Yet, disagreement among models for the locus of dehydration melting in the upper mantle is growing rather than narrowing. Models span the gamut from requiring small amounts of hydrous melt throughout the upper mantle, to hydrous melting in a global low velocity zone layer at depths of ~80-200 km, to melting only beneath ridges and oceanic island in a restricted interval a few 10s of km beneath the locus of dry melting. These disagreements persist because direct experimental investigations of the influence of small amounts of H₂O on mantle melting are not feasible, and consequently understanding comes from parameterization of indirect experimental constraints.

One key constraint on the possible locus of hydrous melting in the upper mantle is the range of feasible concentrations of H₂O in near-solidus hydrous melts. For a mantle with a fixed amount of H₂O, $C_{\text{H}_2\text{O}}^{\text{mantle}}$, the maximum H₂O concentration of an incipient partial melt is given by $C_{\text{H}_2\text{O}}^{\text{mantle}} / D_{\text{H}_2\text{O}}^{\text{peridotite/melt}}$, where $D_{\text{H}_2\text{O}}^{\text{peridotite/melt}}$ is the equilibrium bulk partition coefficient between the peridotite mineral residue and the partial melt. Experimental determinations of $D_{\text{H}_2\text{O}}^{\text{mineral/melt}}$ for upper mantle minerals have been made feasible by new low-blank ion probe measurements. Although thermodynamic calculations of $D_{\text{H}_2\text{O}}^{\text{olivine/melt}}$ predict that it should depend on both pressure and H₂O concentration, such dependences are not apparent in the experimental data. Values for $D_{\text{H}_2\text{O}}^{\text{garnet/melt}}$ span a wide range, and are apparently controlled by the concentration of minor elements in garnet, notably TiO₂. Finally, values for $D_{\text{H}_2\text{O}}^{\text{pyroxene/melt}}$ depend strongly on the concentration of Al in pyroxene, and in particular on the abundance of tetrahedral Al in pyroxene.

Combining experimental constraints on $D_{\text{H}_2\text{O}}^{\text{peridotite/melt}}$ with the modal proportions and compositions of minerals near the peridotite solidus, it is possible to estimate the H₂O concentration of incipient partial melts. For mantle with 100 ppm H₂O, such partial melts have 1.2 wt. % H₂O at 3 GPa and 2.3 wt.% at 7 GPa. Such modest concentrations of H₂O provide only small stabilization of melt relative to a dry peridotite system, thereby supporting the inference that dehydration partial melting of normal mantle is feasible only near where the dry peridotite solidus is approached, meaning immediately below the locus of dry melting beneath ridges and mantle plumes.