Experimental determination of the damp peridotite solidus from 1.0 to 2.5 GPa

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The oceanic upper mantle contains ~50-200 ppm H_2O dissolved in nominally anhydrous minerals as point defects. The presence of small amounts of H_2O strongly influences the temperature at which upper mantle peridotite begins to melt at a given pressure – the solidus – and, thereby, the depth at which partial melting begins beneath oceanic spreading centers. Knowledge of the peridotite solidus constrains the relationship between the depth at which partial melting begins and mantle potential temperature. However, the effect of small concentrations of H_2O on the peridotite solidus is challenging to quantify experimentally because it requires identifying the presence of a small proportion of partial melt and characterizing the amount of H_2O dissolved in an experimental charge. The utility of existing experimental data on the peridotite solidus is, therefore, limited by the presence of an unknown amount of H_2O. This can be overcome through the use of spheres of San Carlos olivine, a few hundred microns in diameter, as hygrometers. Rapid volume diffusion of H equilibrates the spheres with the H_2O fugacity imposed by the peridotite within a few hours. Crossing the peridotite solidus is marked by a decrease in the H_2O concentration of the olivine spheres due to its incompatible behavior during partial melting. As isobaric partial melting proceeds, H_2O is progressively sequestered in the melt and the concentration of H_2O in the San Carlos olivine spheres systematically decreases. We used this approach to experimentally determine the peridotite solidus at 1.0 to 2.5 GPa. Results from mass balance calculations based on secondary ion mass spectrometry analyses of the olivine spheres indicates that the charges consistently contain ~145 ppm H_2O – within the range appropriate for the ambient oceanic upper mantle. On the basis of our experimental results, reverse cryoscopic calculations were used to estimate the temperature of the 0 ppm H_2O (anhydrous) peridotite solidus. Our results demonstrate that the 0 ppm H_2O peridotite solidus is hotter than previously thought, requiring an ~60 °C upward adjustment of existing mantle potential temperature estimates.