Hydrous Silica in the Lower Mantle

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While mineral phases stable in the mantle transition zone (such as wadsleyite and ringwoodite) can store up to 3 wt% H_2O, those in the lower mantle such as bridgmanite and ferropericlase can contain a very small amount (<50 ppm). While such dramatic differences can lead to dehydration/hydration and hydrous melting at 660-km depth in the mantle [1,2] it is uncertain how much water can be transported and stored at these depths.

In order to answer this question, we have conducted a series of high pressure experiments in laser-heated diamond-anvil cell and multi-anvil press combined with X-ray diffraction, infrared spectroscopy, laser Raman spectroscopy, and secondary ion mass spectrometry. Initially we examined the water storage capacity of dense (Al free) silica polymorphs at high pressure and temperature. We found that water can dramatically reduce the rutile-type to $CaCl_2$-type phase transition from 55 GPa to 25 GPa and stabilize a new "disordered inverse" inverse NiAs-type phase at pressures above 50 GPa, which is not stable in dry SiO_2 system. The $CaCl_2$-type and NiAs-type silica polymorphs contain up to 8 wt% of H_2O at 1400-2100 K up to at least 110 GPa. We next explored the effects of water on the mineralogy of the lower mantle and found that hydrous Mg_2SiO_4 ringwoodite (1 wt% H_2O) breaks down to silica + bridgmanite + ferropericlase at pressures up to 60 GPa and 2100 K. The recovered silica samples contain 0.3-1.1 wt% H_2O, suggesting that water stabilizes silica even under Si-undersaturated systems because of their large water storage capacity. Therefore, our observations support the stability of silica in hydrous regions in the pyrolitic lower mantle. In the subducting oceanic crust (basalt and sediment), silica represents 20-80% of the mineralogy. Because its stability range spans the mantle transition zone to the deep mantle, hydrous silica is expected to play a major role in the transport and storage of water in the deep mantle.

[1] Schmandt et al. (2014) *Science* **344**, 1265-1268. [2] Tschauner et al. (2018) *Science* **359**, 1136-1139.