Mineralogy of the Hydrous Lower Mantle

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The hydrous ringwoodite inclusions found in diamonds suggest water storage in the mantle transition zone. However, water storage in the lower mantle remains unclear. Bridgmanite and magnesiowustite appear to have very little storage capacity for water. Here, we report experimental results indicating significant changes in the lower-mantle mineralogy under the presence of water. We have synthesized Mg_2SiO_4 ringwoodite with ~2 wt% water in multi-anvil press at 20 GPa and 1573 K at ASU. The hydrous ringwoodite sample was then loaded to diamond anvil cells with Ar or Ne as a pressure medium. We heated the pure hydrous ringwoodite samples at lower-mantle pressure using a CO_2 laser heating system at ASU. We measured X-ray diffraction patterns at the GSECARS sector of the Advanced Photon Source (APS) and 12.2.2 sector of the Advanced Light Source (ALS). For the separate Pt-mixed samples, we have conducted in situ heating at the beamlines using near IR laser heating systems. We measured the infrared spectra of the heated samples at high pressure and after pressure quench at 1.4.4 sector of ALS.

In the in situ experiments with hydrous ringwoodite + Pt mixture as a starting material, we found formation of stishovite together with bridgmanite and periclase during heating with a near IR laser beams at 1300-2500 K and 35-66 GPa. However, some hydrous ringwoodite still remains even after a total of 45 min of heating. In contrast, the hydrous ringwoodite samples heated without Pt by CO_2 laser beams are transformed completely to bridgmanite, periclase and stishovite at 31-55 GPa and 1600-1900 K. We have detected IR active OH mode of stishovite from the samples heated at lower-mantle pressures. The unit-cell volume of stishovite measured after pressure quench is greater than that of dry stishovite by 0.3-0.6%, supporting 0.5-1 wt% of H_2O in stishovite in these samples. Stishovite is a thermodynamically forbidden phase in the dry lower mantle because of the existence of periclase and bridgmanite. However, our results indicate that stishovite can exist together with periclase and bridgmanite when water is present, because water is stored in stishovite. Therefore, water-rich parts of the lower mantle, such as regions with subducting slabs, would have distinct mineralogy from their dry counterparts, containing stishovite as a water storage mineral.