Hydration State of the Transition Zone and Lowermost Mantle (EAR-1452344)

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The global water cycle is connected to the Earth's deep interior through plate tectonics. Hydrous minerals within oceanic crust carry the components of water (H_2O) into the mantle at convergent plate boundaries, having influence on melt generation and volcanism as part of a cycle that returns H_2O to the surface repeatedly over geologic time. How deeply the water cycle extends into the Earth's mantle is not known. However, evidence is mounting that certain mantle minerals such as ringwoodite, found in a layer called the transition zone (410-660 km depth), may contain a significant – if not the largest – geochemical reservoir of H_2O in the planet. The presence of just a few weight percent H_2O bound in minerals of the transition zone would constitute more water than is present in the oceans. Determining the scale and distribution of H_2O in the mantle has implications for understanding the geochemical water cycle, deep melt generation, and determining the Earth's composition and origin of Earth's water.

This study combines mineral physics experiments on laboratory-grown, hydrated mantle materials at high pressures and high temperatures with new and forthcoming regional seismic studies emanating from NSF's Earthscope (USArray) to constrain the scale and distribution of water in the Earth's mantle transition zone. At deep mantle conditions, water is no longer found in the familiar liquid form, but rather bound as hydroxyl (OH) through charge-coupled chemical substitutions in the crystal structure of high-pressure silicates. Hydrous melts may also be present at depths where the H_2O storage capacity of minerals such as bridgmanite is relatively low. Experimental techniques including GHz-ultrasonic interferometry at Northwestern University and Brillouin scattering at the Advanced Photon Source, Argonne National Laboratory, will be employed to measure the influence of hydration on the elastic properties of mantle minerals such as wadsleyite, ringwoodite, and majoritic garnet, as well as on silicate glasses. Those results will be used to build a publically-available thermoelastic database, which provides input such as elastic moduli and their pressure-temperature derivatives needed to forward model expected seismic velocities in the mantle as a function of depth, temperature, and water content. Combined with observations from regional-scale seismic studies of the mantle, the results will be used to infer the mantle hydration state beneath North America and more globally as high-resolution seismic data become available.