Stability field of Phase D in hydrous basaltic system at the mantle transition zone

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The distribution of water in the mantle and its effects on mantle dynamics are significant to understand the evolution of the Earth. It’s believed that the water is transported from the surface into deep mantle via a variety of hydrous minerals in the subducting oceanic slabs (Ohtani, 2015). However, stability of hydrous mineral(s) in basaltic system at the pressure temperature conditions equivalent to cold slabs in the transition zone, remains unclear.

High-pressure and high-temperature experiments were conducted in a hydrous basalt similar to primitive MORB composition (JB-2 basalt plus brucite, water content=3.5wt.%) at 17-25 GPa, and 800-1200°C using multi-anvil apparatus (SAKURA in Magma Factory) at Tokyo Institute of Technology. We used Au/Pt double capsules as sample containers. In runs below 20 GPa, the sample was loaded into an Au inner capsule and the oxygen fugacity was buffered at ~NNO by NiO + Ni + $Ni(OH)_2$ powder, which stuffed in the space between Pt outer capsule and Au inner capsule. Simple Au capsule was used in higher pressure runs. The run products were analyzed by FE-EPMA (JEOL-JXA8530F, ELSI Tokyo Institute of Technology). The water contents in hydrous phases were estimated from total deficits in FE-EPMA analyses.

The phase assemblages of the run products include majorite, stishovite, Ca-Ti perovskite, hollandite, silicate melts and hydrous phase(s). The hydrous phase is Fe-Ti hydroxide at pressures lower than 18GPa or Al-bearing phase D at pressures higher than 18GPa. These two hydrous phases coexisted in one experiment (18GPa, 900°C). Our results show that the phase D (containing 46-51 wt.% SiO_2, 19.1-20.6 wt.% MgO, 7.3-16.0 wt.% Al_2O_3, 3.8-5.1 wt.% FeO, 11-14 wt.% H_2O) is stable in wide pressure ranges of the mantle transition zone at pressures of 18-20 GPa and temperatures of 800-1000°C. In our experiments, the Al_2O_3 content and (Fe+Mg)/Si ratio of phase D increase with increasing pressure while MgO and FeO content remains constant, relatively. It is important to note that wadsleyite coexisting with Al-bearing phase D seemed to be nearly anhydrous in our experiment suggesting the importance of the subducting basaltic crust as a water carrier in mantle transition zone.

Consequently, we propose that the phase D is one of major water reservoir in cold subducting oceanic crust at the mantle transition zone. Moreover, if the subducting slabs stagnate at the bottom of the transition zone and warmed up, the water would be released from phase D in the subducting crusts, which may be the dominant way to hydrate the transition zone or to cause magmatism in back arc hot spots. Experiments at 25 GPa and 1000°C show coexisting bridgemanite, stishovite, Ca-perovskite, ferropericlase and very Al-rich phase D indicating that subducting clod MORB crust could be the major carrier of water from transition layer to the lower mantle by the Al-bearing phase D.

Keywords: water transportation to deep Earth, subducting oceanic crust, phase D

