Stability of superhydrous phase B and phase G at high pressure and temperature, and water transportation into the lower mantle

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We made high pressure and temperature experiments to clarify the stability fields of superhydrous phase B and phase G under the conditions of the transition zone and the uppermost lower mantle. We used the 1000 ton and 3000 ton Kawai multianvil systems of Tohoku University. Superhydrous phase B is stable below 1200C at 18 GPa and below 1300C at 20 GPa. The sequences of the assemblages, Superhydrous phase B-->phase B+liq-->wadsleyite+MgO+liq--> anhydrous phase B+MgO+liq were observed with increasing temperature at 18~20 GPa. Phase G is stable below 1000C and wadsleyite+stishovite+liquid above 1000C at 18 GPa, phase G below 1100C and ringwoodite+stishovite+liquid above 1100C at 20~22 GPa, and phase G below 1200C and perovskite+stishovite+liquid above 1200C at 25 GPa.

It has been suggested that water is introduced into the deep upper mantle when the slab temperatures are lower than c.a. 600C at around 6 GPa, which corresponds to the depth of c.a. 200km. Water stored in serpentine in the descending cold slabs is transported into the depths greater than 200 km, where serpentine decomposes to a mixture of phase A, enstatite, and fluid. The amount of water transported into the mantle should have increased with cooling of the Earth. Water transported to the transition zone may be stored in wadsleyite and ringwoodite, and the amount of water stored in these minerals will be amount to about 0.5wt.percent in the normal temperature of the transition zone (1200-1600C). On the other hand, at lower temperatures corresponding to the cold slabs, superhydrous phase B and phase G may exist stably. In this work, we made high pressure and temperature experiments to clarify the stability fields of superhydrous phase B and phase G under the conditions of the transition zone and the uppermost lower mantle.

We used the 1000 ton and 3000 ton multianvil (Kawai anvil) systems of Tohoku University. We used the starting materials composed of the mixtures of MgO, Mg(OH)2, and SiO2 with the compositions corresponding to superhydrous phase B (Mg10Si3H4O18) and phase G (Mg1.2Si1.76H2.48O6). These starting materials were enclosed in a Pt capsule in order to avoid loss of water during the high pressure and temperature experiments. Experiments for the stability of superhydrous phase B were made in the pressure range from 18 to 20 GPa. Experiments for hydrous phase G were made at pressures from 18 to 25 GPa. In situ X-ray diffraction study at high pressure and temperature using MAX-80 apparatus and synchrotron radiation at PF was also made at 15 GPa. Analysis of the run products was made by using the micro-area X-ray diffractometer (MacScience M18XCE), micro-Raman spectrometer (JASCO NRS-2000), and electron probe microanalyser (EPMA: JEOL JXL8800M).

Superhydrous phase B is stable below 1200C at 18 GPa and below 1300C at 20 GPa. Following sequences of the mineral assemblages were observed with increasing temperature in the pressure range from 18 to 20 GPa: Superhydrous phase B-->phase B+liq-->wadsleyite+MgO+liq--> anhydrous phase B+MgO+liq. Phase G is stable below 1000C at 18 GPa, below 1100C at 20-22GPa, below 1200C at 25 GPa. Whereas wadsleyite+stishovite+liquid above 1000C at 18 GPa, ringwoodite +stishovite+liquid above 1100C at 20~22 GPa, and perovskite+stishovite+liquid above 1200C at 25 GPa.

Combining the present results with the previous works (e.g., Ohtani et al., 2000; Sieh et al., 1999), we estimated the change of the hydrous silicate phases in mantle peridotite with depths. In the low temperature slabs with peridotite composition with water less than 2 wt.percent, superhydrous phase B is the water reservoir up to the depth of about 1000km (about 30 GPa), and phase G up to the depth of about 1300 km (about 45 GPa). A dehydration zone may exist in the cold slabs at the depth around 1000-1300km. Water dehydrated from the deep dehydration zone may move upwards and may be stored in wadsleyite and ringwoodite in the transition zone.