Measured and calculated effect of water on P-wave velocities of peridotites

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Water in subduction zones plays an important role in geochemical and geophysical processes such as partial melting and plastic flow, and therefore it is important to evaluate water abundance in subduction zones. Recent high-resolution seismic studies demonstrate the presence of low P-wave velocity (Vp) anomalies in the mantle wedge and within subducting slabs. Combining the experimental and theoretical evaluation of the effect of water on P-wave velocities of peridotite with high-resolution seismic images of subduction zones could yield an important constraint for estimating H2O abundances in subduction zones. Here we show the measured and calculated effect of hydrous minerals (serpentine and chlorite) and the released H2O on P-wave velocities of peridotite, and discuss the nature of seismic low velocity anomalies in subduction zone. According to the experimental results of Kono et al. (2007), serpentine in peridotite cause significant decrease in Vp (-10 % at 4.1 wt.% H2O), while the influence of chlorite on Vp is around half of that of serpentine. The strong decrease in Vp attributed to the existence of serpentine is comparable to the seismologically observed low Vp anomalies in subducting slabs (up to 14 %) (Abers, 2005). In contrast, the effect of H2O fluid on Vp is small (less than 3%) at the water content of less than 0.05 (vol. ratio), whereas we observed significant decrease in Vp of more than 10 % at high water content. Comparison of the experimental results with the theoretical calculation by the Oblate Spheroid model shows that the experimentally determined Vp decrements at 1 GPa and 900 C is comparable to the calculated result of the aspect ratio of 0.2-0.4. The data well correspond to the fact that the dihedral angle of olivine grains at the measured P-T condition is 70-80, which is comparable to the aspect ratio of more than 0.2. It is known that the dihedral angle decrease with increasing pressure and temperature, and significant decrease in Vp should occur at the P-T condition of upper mantle. It should be noted that the effect of H2O fluid on Vp is more significant than that of hydrous minerals, and therefore the dehydration of hydrous minerals cause marked Vp discontinuity at the dehydration front. As results, subduction of hydrous minerals and the dehydration at the deep part of upper mantle should produce more than two seismic velocity discontinuities above the subducting slabs among anhydrous peridotite (or eclogite), serpentinized peridotite (or with other hydrous minerals) and the peridotite with co-existing H2O fluid. Recent seismological observation by Kawakatsu et al. (2007) shows only a seismic discontinuity above the subducting slab, and it is difficult to explain by the water transportation model. We need another mechanism to explain such seismological observation.