Density of Hydrous magma and accumulation of the melt at the base of the upper mantle

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Seismological observations have showed the existence of low Q and low velocity zones at the base of the upper mantle above the 410 km discontinuity in some areas such as beneath China and north western United States. The small amount of melt may be responsible for such anomalies. The melt is estimated to be hydrous, because the temperature of the normal mantle is approximately 1,400 C at the depth of 410 km and the melting temperature is decreased by addition of water. No experimental investigations of the density of hydrous melt have yet been carried out to date. In the present study, the density of hydrous basaltic melt was measured in order to examine the stability of the melt above the 410 km discontinuity and determine the partial molar volume of water in silicate melt at high pressure.

The density of the hydrous silicate melt was determined using the sink/float test, which has been widely used for dry melts. The diamond density marker moves upward or downward depending on the density difference between the marker and the surrounding melt; thus, the density of melt is bounded by the density of the diamond marker. We measured the density of the hydrous MORB (Mid Oceanic Ridge Basalt) in the present experiments. The density of the hydrous MORB melts containing 2 and 8 wt.percent H2O was determined to be 3.55(5)x10E3 kg/m3 at 16.8 GPa and 2300C and 3.58(2)x10E3 kg/m3 at 20.0 GPa and 2200C, respectively, based on the equation of state of diamond. Assuming that the pressure derivative of the isothermal bulk modulus is the same as that of the dry MORB melt, i.e. dK/dP=5.0(0.7), the isothermal bulk modulus of the hydrous MORB melt containing 2 and 8 wt percent H2O were calculated by the Birch-Murnaghan equation of state to be K= 13.8(2.2)GPa and 6.5(1.6) GPa, respectively. The partial molar volume at 16.8 and 20.0GPa at 2200C was determined to be 8.5(0.7) and 7.5(0.2) cm3/mol, respectively.

We also estimated the density of the hydrous silicate melt formed by partial melting above the 410 km discontinuity, and found that a hydrous magma is stable in the lowermost upper mantle. The present results strongly indicate that the recent observation of a low velocity or low Q region just above the mantle transition zone can be accounted for by the accumulation of the dense and gravitationally stable hydrous magma.