Effects of structural change and volatiles on physical properties of magma and magma separation in the upper mantle

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Structural changes in magmas influence physical properties of magmas such as density and viscosity. The volatiles also provide significant impact on physical properties of magmas. Density measurements of basaltic and peridotite magmas have been carried out using using X-ray absorption method that enables us to determine liquid density in-situ. Furthermore, we applied in-situ falling-sphere viscometry and in-situ X-ray diffraction to measure viscosity and structure of magmas, respectively. We can now present the complete dataset of the basaltic magma which allows us to examine the pressure-dependent changes of density, viscosity and structure. We also clarified the effect of volatiles on magma density.

X-ray absorption measurements were performed up to 4.5 GPa and 2000 K. The density of basaltic magmas increases rapidly at pressures of ~4 GPa. We also observed a viscosity minimum at pressure around 4-5 GPa. Our high-pressure experiments revealed that basaltic magma undergoes rapid densification and exhibits a minimum in viscosity near 4-5 GPa. Structural analysis of the basaltic magma confirmed an increase in Al-coordination number in the melt at this pressure range. We also measured density of peridotite magmas with and without volatiles, H_2O and CO_2 at high pressures using the X-ray absorption method. We did not observe any rapid densification of the peridotite magma density with pressure. Our measurements revealed that a rapid decrease of the partial molar volumes of H_2O and CO_2 in magma with increasing pressure. Based on these observations, we argue the effects of pressure, temperature, and volatiles on the magma density, and discuss the separation of magmas in the upper mantle.