Experimental study on melt segregation at intermediate melt fraction

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Partially molten material is composite of solid phase and its molten liquid phase. It is thought to exist in various sites of the present earth, for example bottom of volcano, beneath Mid-Ocean Ridge, at the core-mantle boundary, and in the most upper part of the inner core. Also, in early stage of the formation the earth is thought to have experienced large scale melting, that is, a magma ocean and have been partially molten at the mantle scale. The partially molten material is not stable to subtle fluctuation. Melt segregation, a process that a state of homogeneous distribution of low melt fraction evolves into a state of heterogeneous distribution of high melt fraction, should occur inevitably. The melt segregation controls material differentiation and thermal transport in the earth interior.

Several types of mechanism responsible for the melt segregation have been proposed (e.g., McKenzie, 1984; Stevenson, 1989; Spiegelman et al., 2001). These models are roughly characterized by a coupling process of compaction of the solid phase and permeable flow of the melt phase. However the permeable flow does not become expected and another type of the melt segregation would emerge at region of intermediate melt fraction with proceeding of the melt segregation due to loose of connection of the solid phase. Rheology of the partially molten material such as strength is expected to play important role on the melt segregation there. From a simple analogue experiment using composite of deformable granular material (acrylamide-gel) and viscous fluid (methylcellulose solution) Takashima et al. (2004) showed that the composite has yield strength at solid fraction of 55 to 75 % and when fluidization starts under stress beyond the yield strength, concentration of the solid phase into high shear region, that is, the segregation of the liquid and the solid phase, proceeds.

Detailed analysis of motion of the solid phase after that shows that the solid particle randomly flows interacting with the neighbor solid particles, some solid particles migrate to the low shear region, and others do to the high shear region. Since number of the solid particle that migrates to the high shear region is much larger than that of the solid particle that migrates to the low shear region, in the net the solid phase migrates to the high shear region. As a result the segregation of the solid and liquid phase proceeds. Many researches have reported such a style of the segregation process at high liquid fraction where the solid phase does not basically connect with each other and it behaves like suspension. We would like to discuss the segregation process at the intermediate liquid fraction from comparison with that at the high liquid fraction.