Convection in porous layer coupled with liquid layer: Effects of temperature dependent viscosity of fluid

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Structural evolution for magma ocean, inner core, magma chamber and inner ocean in icy satellites is controlled by efficiency of heat transportation between these layers and surrounding different phase layers. At the boundary between the two phases, solid and liquid coexist locally. For instance, partial melt zone and un-compacted solid zone will be formed. Therefore the system for the boundary layer coupled with the melt layer could dominate the evolution for the various global or local structures in planets and satellites. These boundary layers are composed of melt and solid mixture and can be modelled by porous media in which pores are filled by liquid. In this study, we explore the thermal system in porous layer and superposed or underlying liquid layer by laboratory experiments, and aim to clarify the convectional pattern occurred in such combined structure. The variation of viscosity of the fluid considerably affects the convective instability in both liquid and porous layers, therefore we take account for the temperature dependency of the viscosity.

We use transparent beads to compose the matrix of the porous layer, and select glutinous starch syrup for the fluid because of its temperature dependent viscosity. Two types of beads are used, one has greater density than syrup and another has smaller. Using these two types of beads, the system can be composed of saturated porous layer and superposed or underlying liquid layer. We keep the upper boundary at low temperature and the lower at high, and convections occurs in the system. Temperature-sensitive micro-encapsulated liquid crystal is used for visualizing the temperature field and flow field of the convection. We vary the ratio of the porous layer thickness to the liquid layer. We measure the mean temperature on the boundary between the porous layer and the liquid layer and calculate Rayleigh number of each layer.

When the liquid layer is superposed on relatively very thick porous layer, convection occurs only in the porous layer. With decreasing of the ratio, the convecion extends over both the porous and liquid layer. When the ratio is lower, convection in the liquid layer dominates the net thermal system. On the other hand, if the liquid layer underlies the porous layer, whenever the ratio is high, convection in the liquid layer always occurs. This is because, in any case Rayleigh number in the liquid layer exceeds critical value earlier than the value in the porous layer's. Therefore, when the viscosity of the liquid depends temperature sensitively, the thermal system in the porous layer coupled with the liquid layer is controlled by the configuration of the two layers and the ratio of their thickness. These results indicate that as the boundary layer between the different phases develops, the efficiency of the heat transportation varies, and this variation feeds back into the speed of the development of the layer.