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Model experiments on melt ascent in the partially molten zone

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We report the results of model experiments using a mixture of viscous fluid and granular matter, a model of a partially molten zone, in order to understand the style in which the melt ascends within the mixture of fluid and particles. In the subduction zone, melt forms by lowering the melting temperature as the water is add. However, we cannot directly observe how the melt migrates. For the case in which the melt fraction is small, experiments have been conducted and a one dimensional model has been made (e.g.Daines,2000).In reality, melt ascent occurs in the three dimensional space and flow patterns should become more complex. This system can be modeled as a thin viscous fluid layer below a particle-fluid mixture. Here we study how the fluid layer rises by gravitational instability.
We filled a plastic case with glass beads(diameter:0.177-0.250mm) and silicone oil (viscosity:96.5, 485mPas), and after allowing the particle layer to compact for days, we rotated the case upside down. We filmed the whole temporal evolution and analyzed the distance, wavelength and amplitude of the interface between the viscous fluid and the layer of glass beads. We observed that the channels are formed if packing fraction(phi) of the glass beads layer is 0.52<phi<0.53, but when it is 0.60pm0.03, the silicone oil layer ascends forming a layer. Here we analyzed the latter case in detail. There are two stages during ascent. First, the 3 length scales, the distance, wavelength and amplitude, of the interface develop in an exponential manner, during which the glass beads falls by forming plumes and convection cells and a boundary layer form. The convection pattern is similar to thermal convection driven by internal heat sources (Namiki and Shibano in the session 'Geophysical Fluid Dynamics', 2010, JaGU). When the bottom most layer is filled with suspension, boundary layer disappears, and the second stage starts in which the growth rate decreases. When oil reach about 5~7 times(in 485mPas)or about 7~14times(in 96.5mPas) the thickness of the initial oil layer(h), the melt pockets form and eventually disappear. We found that the temporal change of the three length scales can be scaled by Stokes velocity and h.
Our results indicate that the ascent height of the oil layer depends on the initial fluid layer. In addition, if the melt fraction of the partially molten layer is 0.40pm0.03, because of interparticle actions are strong, the melt ascends as a layer with undulations whose wave length increase with time, after which melt pocket disappears to form a layer of suspension. This style of ascent differs from the Rayleigh-Taylor instability. In addition, the layer ascent velocity become 10~100times faster than the permeable flow velocity estimated using the bulk melt fraction and Kozeny-Carman formula for permeability. We suggest that if there a localized layer of melt, the melt migration can become much faster than that under a homogeneous melt distribution.

Keywords: partially molten zone, melt, granular matter, gravitational instability, channel