Experimental study on mixing by compositional convection in a magma chamber

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In a crustal magma chamber, processes at the floor of the chamber are important to evolution of the magma. A mushy layer where solid and liquid phases coexist forms due to crystallization of the magma and melting of the crust there. The interstitial melt in the mushy layer is fractionated and compositionally lighter than the overlying magma so that it rises, driving compositional convection in the chamber. Melt flow in the mushy layer rises through chimneys that are channels like pipes and into the overlying magma as plumes. The plumes with fractionated composition mix with the ambient magma, composition of which changes with time. In this time, mixing is not always complete so that compositional gradient which is gravitational stable in the magma body. This compositional gradient affects composition of return flow from the overlying magma to the mushy layer where crystallization occurs.

We must solve two important problems in order to develop quantitative model of the spatial structure of the magmatic composition in the chamber and the liquid line of descent of the magma. One is to evaluate the diameter, spacing and flux of the rising plumes from the mushy layer. The other is to predict the compositional profile in the magma body by convective mixing with the plumes whose features are governed by external factors (i.e., processes in the mushy layer). In this study, I focus on the latter problem. I carried out a series of fluid dynamic experiments to clarify quantitative features of mixing. Features of plumes, which are the diameter, spacing, and flux, are controlled in the experiments. Here, I report preliminary results of the experiments.

I carried out the experiments that plumes of compositionally light liquid are generated at the bottom of a dense liquid in a tank and measured the vertical compositional profile in the liquid by convective mixing. I used a Perspex tank with inner dimension of 15 x 15 x 30 cm high. The floor of the tank has many holes with constant spacing, through which a light liquid were put into the tank. The diameter, spacing, and flux of the plumes were controlled.

At the present, I have carried out experiments to investigate effects of the flux of the light liquid on mixing using 5 wt% and 10 wt% salty water as dense liquid and pure water as light liquid. The initial thickness of salty water is 60 mm, and the diameter and spacing of the plumes are 2 mm and 20 mm, respectively. The range of the flux of the light liquid is between 6.5e-6 and 104e-6 m/s.

After start of each run, I observed upward laminar flow with the same diameter as the hole in the region between the floor and 1 to 2 cm high. Above this region, the flow became wider and turbulent like jet. The light liquid mixed with the ambient dense liquid. The mixing by the compositional convection was incomplete and the gravitational stable compositional gradient in the liquid formed in all the experiments. In both the series of experiments using 5 wt% and 10 wt% salty water, the compositional gradient in the liquid increases as the flux of the light liquid increases. This means that mixing is less efficient by more vigorous convection. On the other hand, the results of the previous experiments on mixing by compositional convection where features of the plumes are not affected by external factors indicate that mixing is more efficient by more vigorous convection. My results reveal that characteristics of mixing efficiency in the case where spacing of plumes is controlled by some external factors are completely different in a qualitative sense from the case where features of plumes are determined internally.

In order to clarify key parameters determining the mixing efficiency by compositional convection, I am proceeding with experiments where the diameter and spacing of the plumes and the density difference of the light and dense liquids are systematically changed.