Estimating the parameter to determine bubble - crystal interaction styles

*Ikeda Kyoko[1], Atsushi Toramaru[1]

1. Kyushu University, Department of Earth and Planetary Science

In the magma, the interaction between suspended crystals and the rising bubble made by buoyancy is important because the interaction can be expected to control the chemical evolution of magma chamber and their stratification through the rheological properties and bulk densities. Beline et al (2010) showed that there are three interaction styles with changing bubble diameter and viscosity of the liquid by laboratory experiments using an analog material: a single plastic cube and a controlled single bubble in viscous liquid. However, the crystal - bubble interaction is still poorly understood since the factors to make a difference among the three interaction styles are not explained enough. In order to solve this problem, we give some constraint on the controlling parameters to determine three interaction styles by analogue experiments.

The experiments are performed in the tank filled with viscous liquid (analog material of silicate melt)and prepared three different viscosity(0.29 Pa・s, 6.46 Pa・s, 19.1 Pa・s). The plastic cube (analog material of crystal) with 10 mm is suspended in liquid by a rod. The bubble is injected into the liquid from 11cm below the plastic cube from a syringe connected to a motor controlled by the PC program by which we can change the initial bubble size. We examine the probability of occurrence of three styles of interaction: "stuck", "pass", and "split"; "stuck" in which a bubble stays under the solid cube, "pass" in which a bubble moves around the cube and "split" in which a bubble separated into two bubbles. To determine the probabilities, we did the repetition of 10 times for the same condition of initial bubble radii and viscosity.

In our experiments, we observed two styles of the interaction of "stuck" and "pass" and not "split". It is found that the smaller bubble tends to "stuck", on the other hand, the probability of "pass" became higher as the bubble radii are larger. To reveal the boundary of "stuck" and "pass", we use Bound number which is a dimensionless number representing the ratio of bubble relaxation time and the bubble rising time per their radius. From the results of the examination using the size ratio between solid cube and the final attached bubble, and Bond number, it is suggested that there are two regimes in the mechanism of interaction styles. These two different regimes are caused by Reynolds number which is the ratio of inertia force and viscous resistance. In low Reynolds number regime is controlled by the final maximum bubble diameter which resulted from mechanical interaction between bubble and cubes in the higher viscosity. For example, if the deformed bubble diameter is larger in the horizontal length than the cube width, the bubble path throws the cube. In high Reynolds number regime is controlled by inertia force. The probability of occurrence of "pass" is higher as the bubble radius becomes larger with inertia force.

Thus, we found that there are two regimes in the bubble-crystal interaction style; one is a static regime (low Re) controlled by the geometrical relation in the horizontal sizes including static deformation, another is a dynamic regime (high Re) controlled by the inertia of a rising bubble by buoyancy.

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