Magma flow style based on deformed bubble structure of pumice

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Bubble textures in pumice have been thought to reflect the history of magma ascent. Thus, it is valuable to create a new analysis method based on the morphological variables, such as bubble size, bubble number density, and bubble shape. The purpose of this study is to develop a new scheme to connect bubble shapes with the dynamics of explosive eruptions. Pumice containing highly deformed bubbles like tubes is called as tube pumice, and it is thought to record the flow history of magma up to fragmentation surface. In order to extract shear deformation and magma flow style from such a deformed bubble structure, it is necessary to solve the following three problems: (1) Calculate transient bubble deformation, (2) Evaluate the effect of bubble interaction on its shape, and (3) Calculate bubble deformation in an arbitrary velocity field.

First, using the droplet deformation model of Jackson and Tucker (2003), we developed a model that can calculate the transient deformation of a single bubble in an arbitrary velocity field. Next, to evaluate the interaction between bubbles, we performed tensile experiments with a solidifying foam. By comparing the experimental results of bubble shape with the numerical simulations, we confirmed that the average shape of bubbles coincided with the theoretical deformation model of a single bubble. This result suggests that the average of bubbles in pumice can be compared with the numerical simulation of a bubble in a conduit flow.

Next, the bubble deformation model and the quasi-two-dimensional steady conduit flow model were combined to solve the bubble deformation in the conduit. The bubble shape at the fragmentation surface significantly depends on the velocity profile across the conduit. Flow with a constant viscosity had a parabolic velocity profile and produced highly elongated bubbles, which were deformed mainly by simple shear. On the other hand, viscous-heating with the temperature-dependent viscosity led to a plug-like velocity profile and produced less elongated bubbles, which were deformed primarily by pure shear.

Finally, we conducted a bubble structure analysis of pumice erupted at Taupo Volcano. It was found that the plinian eruption had a single peak in the bubble shape distribution, while the ignimbrite eruption had a broad distribution and contained highly elongated bubbles. The comparison of the natural bubble textures with the results of the combined simulation of conduit flow and bubble deformation suggested that the velocity profile of the plinian eruption was close to a plug-like shape. We propose the reason why the ignimbrite eruption produced a large amount of tube pumice that the widening of the conduit reduced the viscous heating effect, delayed the transition from parabolic flow to plug-like flow, and increased bubble deformation during the parabolic flow regime.

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