論文の内容の要旨

Comprehensive study of magma flow style based on deformed bubble structure of pumice

(軽石の変形気泡組織に基づくマグマ流動様式の総合的研究)

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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 thesis is to study the shape of deformed bubbles in various ways and develop a new scheme to connect bubble textures 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 on magma flow, especially the velocity profile, 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. We adapt three rheological models to reproduce various velocity profiles. In the Newtonian isothermal fluid, the velocity profile across the conduit became parabolic. On the other hand, in the fluid with viscous heating, the temperature near the conduit wall rose up sharply, leading to a strong reduction in viscosity. The velocity profile changes from a parabolic shape to a plug-like shape just above the conduit inlet. The bubble shape at the fragmentation surface depends significantly on the velocity profile. The parabolic velocity profile produced highly elongated bubbles deformed mainly by simple shear, but the plug-like velocity profile produced less elongated bubbles deformed primarily by pure shear.

Finally, we conducted a bubble structure analysis of pumice erupted at Taupo Volcano in order to discuss which velocity profile was reasonable. As a result of the analysis, 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 simulation results suggested that the velocity profile of the plinian eruption was close to a plug-like shape. The reason why the ignimbrite eruption produced a number of tube pumice was explained by shallowing the transition depth at which the velocity profile changed from parabolic to plug-like.

The velocity profile in a conduit flow is closely related to several essential eruption processes, such as degassing and brittle fragmentation. It is of great significance to give constraints to the velocity profile from the natural quantitative observation of pyroclasts.