Deformation experiments of foam during solidification -exploring the history of tube pumice-

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Tube pumice is a common product of explosive silicic eruptions forming calderas. It is characterized by bubbles which elongate in one direction. We expect that tube pumice records information about the process leading to a caldera eruption.

In the past, researchers focused on the capillary number ($Ca=R\eta_0 \varepsilon' / \Gamma$), which represents the competition between the timescale of shear deformation due to external velocity field and that of shape relaxation due to surface tension. R is the bubble radius, η_0 is the viscosity of the liquid surrounding the bubbles, ε' is the shear rate, and Γ is the surface tension. The more elongated bubbles are observed with the larger Ca in steady states.

However, bubbles deformed by flow may be relaxed if they have enough time in the stress-free condition before solidification of the pumice. We define the pumice number ($Pu=R\eta_0' / \Gamma$) which represents the competition between the timescale of solidification and that of shape relaxation. η_0' is the rate of viscosity increase of the liquid. The elongated bubbles may be preserved in the pumice if the pumice number is high.

In order to determine the effect of the pumice number, we conduct deformation-solidification experiments on polyurethane foam using a rheometer (Ohashi et al., 2016, VSJ fall meeting). Shear strain is applied by rotating the inner rod at a constant speed when the viscosity reaches a specified value. After solidification, we observe the bubble structures of the samples with X-ray computed tomography (CT) and analyze the size and the deformation ratio of bubbles in the 3-D images.

We find a tube-like bubble structure in the sample which experienced large strain. Because it is difficult to quantify the structure due to the limited image analysis technique, experiments are conducted with smaller applied strain. The results clearly show that the deformation ratio cannot be explained by Ca alone. Within a single sample, estimated Ca and Pu vary depending on the sizes and locations of the individual bubbles, and the deformation ratios also vary. For the same Ca, the deformation ratio is smaller for the larger Pu.

To explain the results quantitatively, we apply the time-evolution deformation model with an additional effect of the exponential viscosity increase. The results of numerical calculation show that the amount of the relaxation after the elongation decreases as Pu increases as supposed. However, in the unsteady states, bubbles do not elongate during the shear deformation of the surrounding fluid. The detailed explanation of these behavior will be conducted in the presentation.

In conclusion pumice records bubble elongation at the end of the last shear deformation when Pu is large enough. Tube pumice indicates that the last shear deformation has occurred with sufficiently large Ca and sufficiently large strains.

Keywords: tube pumice, bubble deformation, rheology