Mechanism of delayed fragmentation of vesicular magma by decompression

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The fragmentation of vesicular magma is a key phenomenon to determine the style of volcanic eruption. To understand the magma fragmentation, we performed a rapid decompression experiment using bubbly syrup as an analogous material of vesicular magma. We classify the onset of fragmentation using a measure of brittleness ("critical brittleness") at the bubble surface at the time when the differential stress at the surface reaches the critical fracture stress. In our case, the brittleness is unity when the response of material is brittle. It is 0.5 when the material response is completely ductile. We find a delayed fragmentation which occurs when the differential stress sufficiently exceeds the critical stress, even if the critical brittleness indicates the ductile response of the material. The delayed fragmentation occurs within the characteristic time of bubble expansion in viscous liquid, while its onset is after the relaxation time of viscoelastic material. This means that the delayed fragmentation is "brittle-like" (solid-like) fragmentation. Magma fragmentation may be viewed as sequential brittle-like fragmentation.

To understand the cause of the delayed fragmentation, we tested the response of a large number of samples and experimental conditions, which vary in critical brittleness, volume, void fraction, and porosity distribution. The volume of samples is selected from 25 ml (small) or 100 ml (large). The void fraction is in the range of 3 to 28

From the experiments with small volume of samples, we observed some of the samples exhibit no fragmentation even if their critical brittleness was about 0.9. All the samples with large volumes fragment when the critical brittleness was 0.9. The pore distribution of the small samples is more uniform than that of large samples. Therefore, stress concentration in the small samples is weaker than that in the large samples.

We find that fragmentation does not occur in the sample with the void fraction less than 8

The critical brittleness was calculated using the differential stress on the bubble surface under the assumption of uniform pore distribution. Our experiments indicate that this calculated value may inadequate to evaluate the fragmentation. The "true" value of brittleness required to the onset of brittle fragmentation should be closer to unity. Our experiments also suggest that the delayed fragmentation observed with lower value of the critical brittleness is caused by non-uniform pore distribution, which leads to increase the local differential stress and brittleness in the sample.