Experiments on fragmentation of porous viscoelastic liquid: Implications to magmatic fragmentation

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The present experiments is intended to simulate the fragmentation process of vesicular magma. The main focus is on the relation between the characteristic time of time-dependent physical property of the matrix and the time scale of the applied decompression. For this purpose, viscoelastic compound is used and decompression rate is controlled in the experiment. The property tests on the material is conducted. The experimental results demonstrate that brittle fragmentation occurs when the magnitude of decompression exceeds a critical value within the time range of elastic response of the material.

There are two types of volcanic eruptions, explosive and effusive eruptions. Magma fragmentation is regarded as the defining point of the explosive eruption. In addition, the intensity and the style of an explosive eruption may depend on the detailed process of fragmentation. However, the actual feature of the fragmentation is not known yet. In order to develop a quantitative model for an explosive eruption, we need a microscopic criterion and more knowledge on the macroscopic feature of the fragmentation.

Previous experiments intended to simulate magma fragmentation have developed ideas on the fragmentation process. However, few experiments have investigated the effect of decompression rate in relation to the brittle-ductile transition time of the material, which is considered to be essential in the problem of magma fragmentation. The present experiment focuses on this effect, using viscoelastic material and controlling the decompression rate. In this paper, we propose a microscopic criterion for fragmentation.

The experiments are conducted in a vertical shock-tube type apparatus. The test section is made of pylex glass and the internal phenomena is recorded by high-speed motion picture camera and CCD video camera. The decompression rate is controlled by an orifice inserted in the middle of the glass tube. Pressure is measured in the gas below the orifice and at the bottom of the glass tube by piezoelectric transducers.

The experimental material is viscoelastic silicone compound (Dow Corning 3179). The frequency-dependent viscoelastic properties are measured by shear-torsion tests and ultrasonic tests. The relaxation time is 0.3 sec, the high-frequency rigidity is 3 MPa, and the viscosity at low frequencies is about 5000 Pas. Porous columnar specimen with void fraction of 50 % are made of the compound. They are filled with crashed dry ice and inserted into the glass tube from the bottom. The tube is closed soon and the internal pressure gradually increases as the dry ice sublimates. The experiment is done after the specimen warms up to the room temperature.

On rapid decompression, the specimen is disintegrated with several rupture surfaces perpendicular to the decompression axis, and the fragments flies upward. The fragments still contain high-pressure pores and slowly expand with ductility. The time scales of the fragmentation and expansion are 10 msec and 1 sec, respectively. The fragmentation time scale increases and the number of rupture surfaces tends to decrease with decreasing decompression rate. When the decompression rate is further reduced, the specimen just expands without fragmentation.

The experimental results demonstrate that whether fragmentation occurs or not is determined by the decompression rate and not dependent on the total magnitude of decompression. In more precisely, fragmentation occurred when the amount of decompression exceeds 200 kPa within 0.1 sec after decompression, regardless of the final magnitude of decompression. The critical amount of decompression, 200 kPa, may reflect the strength of the specimen. The time 0.1 sec is in the same order as the viscoelastic relaxation time of the material, and also as the initiation of viscous expansion of the voids. Which of these time scales is responsible for the fragmentation threshold is not distinguished yet.

The following ciriterion for fragmentation is proposed. Brittle fragmentation occurs, when the pressure difference between inside and outside the porous body exceeds the strength of the body within a time shorter than the relaxation process.

We observed brittle fragmentation and following ductile expansion of porous viscoelastic material. The fragments of the compound in our experiments look similar to the natural pumice. Our pressure data also has common features to what obtained by other group using the real magma. We believe that the present data include further information on fragmentation process of magma.