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Behavior of fragmentation front in a porous viscoelastic material

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We are developing laboratory experiments to investigate dynamics of magma fragmentation during explosive volcanic eruptions. Experimental approach to this problem is important because of the following reasons.

(1) It is almost impossible to observe inside of a volcanic conduit during eruptions. Most of the existing models assume that magma fragmentation occurs in a narrow region called the fragmentation front and that the front moves against upward magma flow in the conduit. Existence of such a fragmentation front itself should be certified.

(2) Several researchers are trying to establish a theory to describe the fragmentation front regarding that it is a kind of discontinuity analogous to shock wave, evaporation wave and so on. It has been revealed that the theory needs to include a certain assumptions and models in order to determine the flow parameters across the front and the velocity of the front. Laboratory experiments performed on a simplified system would be useful to test the assumptions and to establish the theory.

(3) Numerical models for explosive eruptions require a criterion for magma fragmentation. The adequate criterion for fragmentation of such a mixture as magma, which consists of viscoelastic melt, bubbles and solid particles, is not known yet.

The authors have shown that viscoelastic silicone compound (Dow Corning 3179) is a useful analogous material to simulate magma fragmentation (Ichihara et al., 2002, accepted by JGR; Ichihara et al., 2001 Joint Meeting). A porous specimen made of the compound was rapidly decompressed and development of brittle fragmentation was observed. However, there were arguments against our previous results that the specimen was broken into only several pieces and the process was different from the actual processes which produce fragments as small as volcanic ash. The clear fragmentation front or its propagation was not recognized, either.

This time, results of the improved experiments are presented. Two major changes have been made. First, the range of decompression magnitude is increased from 5 bars, which was the maximum with the previous apparatus, to 24 bars. Larger decompression magnitude is also available. Second, the preparation process for the porous specimen is changed so that it has finer structure.

The experimental apparatus is a kind of a vertical shock tube, which mainly consists of high pressure test section and low pressure chambers. The test section is made of acrylate tube of which inner diameter is 25 mm. The high pressure section is designed to be operated with pressure higher than 50 bars. The internal phenomenon is recorded by a high-speed and a normal speed video cameras. Pressure is measured in the gas above the specimen and at the bottom of the tube by piezoelectric transducers.

The preparation process for the specimen is as follows. First, the compound is placed at the bottom of the test section and kept in nitrogen gas of about 45 bars. The compound absorbs the gas. It has been made sure that 8 hours are enough to attain equilibration between the compound and the gas. Next, the test section is decompressed back to the atmospheric pressure slowly at a rate of 0.05 bar per second. Bubbles are formed in the compound quite uniformly. Finally, the test section is pressurized again very slowly so that pores in the specimen are not crushed but the gas goes into the pores through connected paths.

The specimen is rapidly decompressed from 24 bars to almost vacuum. The high-speed video images demonstrate a sequence of the fragmentation process. We observe propagation of fracture front in the specimen. The major fracture surfaces tend to be horizontal, and small fragments are produced between them. Secondary fragmentation of pieces is also noted. Fragments from centimeter-scale to submilimeter-scale are produced.