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Fragmentation wave velocities in porous viscoelastic medium: Influences of vesicularity and crystallinity

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It is widely recognized that the magma fragmentation is one of the most important processes determining the type and the energy of a volcanic explosion. Understandings of the necessary and sufficient conditions of the magma fragmentation and the physics governing progression speed of the fragmentation are particularly required in establishing the mathematical and numerical models for the explosive volcanic eruptions. It has been suggested that the mechanical properties of magma as a mixture of melt, bubbles, and crystals are the key factors in the phenomena by observation of the magma fragments in the fields and investigation of the mechanical properties of magma. Such a phenomenon as significantly depends on the complex properties of a mixture cannot be formulated only by theoretical consideration or by numerical calculation. It is thus useful to investigate the fragmentation process in the laboratory using analogous systems. In the present study, we conducted fragmentation experiment using silicone compound with various pressure, vesicularity, cristallinity and permeability.

The silicone compound (Dow Corning, 3179 Dilatant Compound) demonstrates obvious viscoelastic behaviors. We put a certain amount of the compound in the acrylic tube and kept the tube in a high-pressure nitrogen chamber for 8 hours, during which the compound absorb the gas. When the pressure of the chamber is slowly released, the dissolved nitrogen comes out as bubbles. The compound in the tube expands and protrudes from both ends of the tube. The compound is cut at the ends of the tube. The vesicularity is estimated from the weight of the material left in the tube and its volume. The vesicularity is controlled by changing the pressure in the nitrogen chamber and the rate of the pressure release. In order to make a specimen with crystals, we mix the crystals (salt crystals of about 0.5 mm-cubes) with the compound in advance. In some experiments, several longitudinal holes are made through the specimen in order to increase the permeability. Then the acrylic tube containing the specimen is attached to the bottom part of the shock tube.

The lower and the upper parts of the shock tube are separated by plastic membranes. The lower part containing the specimen at the base is pressurized with nitrogen very slowly. No significant deformation of the specimen is observed, which indicates that the pores are connected with each other and are filled with the high-pressure gas. Then the membranes separating the high-pressure part from the atmospheric pressure part are artificially ruptured, and the specimen is rapidly decompressed. The fragmentation behavior of the specimen is photographed by a high-speed video camera. The fragmentation wave velocity is measured from the video images. After each experiment, the fragments are taken out of the chamber on top of the shock tube carefully and the structures are observed. The dependence of the fragmentation wave velocity and the morphology of the fragments on the test parameters (pressure, vesicularity, crystallinity, and permeability) are evaluated. Although it is difficult to determine the permeability at each condition, it is estimated by comparing the pressure data taken above and beneath the specimen and the numerical calculation for the permeable flow model.

Fragmentation experiments using natural magmas are being conducted (Spieler et al., 2003; Scheu et al., 2002). They have measured the critical decompression magnitude and fragmentation wave velocity at the temperature as high as 900 degree C. as well as at the room temperature, and have revealed their dependences on the decompression magnitude, vesicularity, and permeability. The results of our analogous experiments are compared with their results, and the mechanisms governing the fragmentation phenomena are discussed.