Viscoelastic effects on the fragmentation of vesicular magma by decompression

Masaharu Kameda[1]; Susumu Shimanuki[2]; Mie Ichihara[3]

[1] Mechanical Systems Engineering, TUAT; [2] Mech. Systems Eng., Tokyo Univ. of Agr. & Tech.; [3] ERI,Univ. of Tokyo

The fragmentation of vesicular magma is a key phenomenon to determine the style of volcanic eruption. In order to understand the magma fragmentation, we performed a rapid decompression experiment using an analogous material of magma.

Sicilate magma has viscoelasticity, whose characteristics are approximated using a linear Maxwell model. The Maxwellian viscoelastic material has a *relaxation time*, which indicates the duration to relax stress in the material. The Deborah number, which is defined as the ratio of the relaxation time to characteristic time of deformation, determines the material behavior as elastic solid or viscous liquid. The decompression time is the characteristic time in this experiment. In addition to the Deborah number, the porosity of the material, the initial pressure before decompression, and the amount of decompression are also important parameters because pressurized gas in bubbles is the source to induce the fragmentation.

An analogous material of vesicular magma is maltose syrup with oxygen bubbles. The viscosity of syrup depends on water content and temperature, while the rigidity is constant. Since the relaxation time is defined as the ratio of viscosity to rigidity, we can control the relaxation time of syrup. Oxygen bubbles are generated from hydrogen peroxide with manganese dioxide as catalyst. We can control the porosity of the syrup by the amount of hydrogen peroxide.

The experiment facility consists of a high-pressure vessel and a large vacuum chamber. After the specimen is set in the vessel, the vessel is compressed to an initial high-pressure revel. The vacuum chamber is decompressed to 10 kPa. There are double diaphragms between the vessel and the chamber. The vessel is decompressed by rupturing the diaphragms. Occasionally, an orifice is placed beneath the diaphragm to reduce the decompression rate. The response of the specimen is observed through window by high-speed photography. Pressure change of vessel is measured by pressure transducer. The initial high-pressure is set at 1.1, 2.1, and 3 MPa. The decompression rate is from 0.1 MPa/s to 280 MPa/s. We used the specimen having the porosity from 6% to 20% and the viscosity from 10^5 Pa s to 10^9 Pa s.

Different experimental conditions yield remarkable change in response of the specimen. We classified the response into three modes: (a) brittle fragmentation without expansion, (b) fracture after small ductile expansion, (c) ductile expansion without fracture. The mode (a) seems to be brittle fracture and the mode (b) seems to be ductile fracture.

We found that the Deborah number dominates the change of the response. The Deborah number should be larger than critical values when the fragmentation takes place. The mode (a) is observed when the Deborah number is larger than unity, irrespective of initial pressure and porosity. The critical Deborah number for mode (b) is smaller than unity, and depends on the initial pressure and the porosity. The critical stress on the bubble wall, which is frequently used as the criteria for fragmentation, is constant in mode (a). Its value for mode (b) rapidly increases as the Deborah number decreases. Thus, the brittle fragmentation is observed only when the stress is over a critical value within the relaxation time of the magma.

The onset of fragmentation occurs within the characteristic time of viscous expansion of the bubbles, though it is widely scattered from a few millisecond to several tens seconds. The fragmentation is ceased when the stress in the material is relaxed.