Japan Geoscience Union Meeting 2011
(May 22-27 2011 at Makuhari, Chiba, Japan)

SVC047-14 Room:301B Time:May 24 12:00-12:15

Brittleness on the fragmentation of vesicular magma

Wataru Okabe[1*], Masaharu Kameda[1], Mie Ichihara[2]

[1]Mechanical Systems Engineering, TUAT, [2]ERI, Univ. of Tokyo

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 an analogous material of magma.

Silicate 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 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. According to our latest research, the onset of fragmentation is independent from the initial pressure. Therefore, this experiment can be well explained by using the Deborah number and the differential stress between inner and outer bubble. There is the critical differential stress for causing the fragmentation.

We classify the onset of fragmentation using a new parameter brittleness (Ichihara and Rubin 2010) in the case where Deborah number is in the range from 0.1 to 10. In this case, the viscosity is no longer negligible. Brittleness explains how amount of the total deformation energy is used for the elastic deformation, and is a function of the stress, the rate of change of the stress and the distortional strain. Our purpose is to correlate the onset of fragmentation with the brittleness under various initial conditions. Ichihara and Rubin (2010) have showed that our early experiment (Kameda et al. (2008), the porosity of the material is 0.06 and the initial pressure after decompression is 3MPa) is well explained by the brittleness.

An analogous material of vesicular magma is maltose syrup with oxygen bubbles. The viscosity of syrup depends on the water content and the temperature, while the rigidity is constant. The experiment facility consists of a high-pressure vessel, a large vacuum chamber and double diaphragms. The vessel is decompressed by rupturing the diaphragms. The response of the specimen is observed through window by high-speed photography. Pressure change of vessel is measured by a pressure transducer. The initial high-pressure is set at 1.1 to 3 MPa. Various decompression rates were tested. The specimen had the porosity from 6% to 20% and the viscosity from 105 Pa s to 109 Pa s.

Difference in experimental conditions leads to 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, and (c) ductile expansion without fracture. The mode (a) corresponds to brittle fracture and the mode (b) corresponds to ductile fracture.

The experiment is classified using the brittleness at a bubble surface when the differential stress reaches the critical fracture stress: Mode (a) (the brittleness is from 0.9 to 1.0) occurs regardless of the value of the differential stress; on the other hand, mode (b) (brittleness is from 0.6 to 0.9) occurs only when the excess of differential stress is observed. This means that mode (b) does not occur when the maximum differential stress is close to the critical stress. Finally, mode (c) (brittleness is smaller than 0.6) occurs regardless of the value of the differential stress. This is because that most of the total deformation energy is dissipated due to the viscosity of magma.

We concluded that (1) the fragmentation occurs only when the brittleness is close to unity (magma response is dominated as elastic) if the maximum differential stress is slightly larger than the critical stress; (2) the fragmentation occurs when the brittleness is in the intermediate range if the maximum differential stress is much larger than the critical stress.

Keywords: fragmentation, viscoelasticity, analogous experiment, brittleness