Effects of gas exsolution on fragmentation types in explosive eruption

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We have studied mechanisms of magma fragmentation in explosive eruption introducing two types of fragmentation condition: 'expansion fragmentation' based on critical void fraction and 'stress fragmentation' based on critical tensile strength of magma. We coupled bubble growth with a one-dimensional steady conduit flow model using spherical cell model. The magma is treated as a Maxwell visco-elastic body ignoring the effect of gas exsolution. We have shown that the condition whether expansion or stress fragmentation occurs is determined by a non-dimensional number, that is, the ratio of wall friction force in conduit flow to the tensile strength of magma. This means that the fragmentation type depends on magma viscosity, conduit radius, and eruption rate. The stress fragmentation is more likely to occur as magma viscosity is larger, conduit radius is smaller, and eruption rate is greater. Furthermore, we demonstrated that there are multiple steady eruptions with different fragmentation types according to the eruption rates.

Among the above assumptions, the assumption of no gas-exsolution is expected to control the results most critically. As pressure decreases, volatile components dissolved in liquid magma exsolve into gas phase in bubbles. Thus mass fraction of the gas phase increases and volatile components dissolved in liquid magma decrease during magma ascent. In general, gas exsolution controls magma fragmentation and ascent dynamics in the following two ways. First, as the mass fraction of the exsolved gas varies as a function of pressure, the relationship between the stress around bubbles and the void fraction varies. Second, the magma viscosity increases because of the decrease of the volatile components in liquid magma. For example, it is expected that the stress fragmentation is more likely to occur because of the increase of the viscosity. The effect of gas exsolution is complex, because the pressure decrease, gas exsolution, and bubble growth are mutually related. The pressure decrease, which induces gas exsolution, depends on the loss of wall friction and gravity and the growth of volume fraction of gas, which are affected by the bubble growth after the bubble nucleation.

In this study, we examine the bubble growth from just after the nucleation and investigate how gas exsolution depends on the size and the number density of bubble nuclei. Moreover, we clarify the controlling parameter of fragmentation type considering the effects of gas exsolution.