Importance of Q as a measure of the fragmentation potential

*Atsuko Namiki[1], Yukie Tanaka[1], Satoshi Okumura[2], Osamu Sasaki[2], Kyohei Sano[3], Shingo Takeuchi[4]

1. Hiroshima University, 2. Tohoku University, 3. University of Hyogo, 4. Central Research Institute of Electric Power Industry

Fragmentation, which dramatically enhances the mobility of viscous magma, is one of the fundamental processes of an explosive eruption. Silicate melt with a viscosity of 10^{10} Pas can fragment in a brittle manner when the shear rate is faster than >0.01/(relaxation time). However, for a low viscous basaltic magma with a viscosity of $<10^3$ Pas, the required shear rate becomes $>10^5$ s^{-1}; this is an unrealistically rapid deformation rate. Instead, a low viscosity basaltic magma can fragment in a hydrodynamic manner, but observed pyroclastic deposits suggest they were brittly fragmented. The crystals in the magma increase the effective viscosity, and thus the relaxation time, lowering the required shear rate to cause a brittle fracture. Indeed, the elongation experiments show that the particle suspension fractures in a brittle manner (Moitra et al. 2018). The suspension sometimes has several relaxation time scales different from the Maxwell fluid with a unique relaxation time scale. Using Q may be appropriate to assess the possibility of fragmentation for such a complex fluid. Q is the ratio of the elastic to the viscous component of viscoelastic fluid and equivalent to the quality factor known as an inverse of the attenuation of the seismic waves. We can obtain Q by using oscillatory rheology measurements at various deformation rates (Namiki and Tanaka, 2017).

To know the relation between Q and the possibility of fragmentation of a complex fluid, we measured the rheology including Q and strength of high porosity rhyolitic magma at 500–950 degree C (Namiki et al., 2020). The occurrence of brittle fractures is observed in the low-temperature magma (<800 degree C). In this temperature range, the measured Q is high. That is, the elastic energy originated by deformations avoids attenuation and is stored in the bubbly magma until released by fracturing. Our measurements show that Q>1 is a required condition for the fragmentation of complex magma. Our measurements also show that the measured shear modulus and strength are several orders of magnitude lower than bubble-free rhyolite melt, implying that high porosity magma cannot avoid fracturing during magma ascent. Thus, Q can be a measure of the possibility of fragmentation of a complex magma. Knowing the attenuation of the seismic wave is useful to evaluate magma temperature and the possibility of a fragmentation event that may determine subsequent volcanic activities.

Reference

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Keywords: magma, bubble, rheology

