A mechanism of magma fracturing revealed by in-situ X-ray imaging and diffraction

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Explosive volcanism is one of the most spectacular phenomena on Earth. Explosive volcanism is characterized by the vigorous release of magma fragments and volcanic gases to the surface. In such cases, the magma is the continuum in the crust but becomes fragmented during its ascent. In particular, brittle fragmentation of silicic (relatively SiO2-rich) magma results in explosive eruptions. Therefore, the cause of brittle fragmentation of magma determines whether the eruption will be explosive or effusive.

The viscoelasticity of magma and the relaxation timescale of its structure are currently thought to control fragmentation (Dingwell, 1996 Science). Under rapid deformation rates, magma exhibits elastic behaviour, while viscous magma behaviour is dominant when the deformation rate is slow. Fiber elongation experiments for magmas clearly demonstrate the transition from viscous elongation to brittle fracturing with increased elongation rates. This transition is empirically formulated and can be applied to the modelling of volcanic eruptions (Gonnermann and Manga, 2003 Nature). In contrast, the atomic- to nano-scale structure of melt across this transition is poorly understood. For example, magma exhibits shear thinning (viscosity decreases as shear rate increases) behaviour when the shear rate is close to the conditions at which magma fracturing occurs. No explanation for the relationship between shear thinning and brittle fracturing has yet been proposed. Understanding the atomic- to nano-scale structures across viscous to brittle transition will provide important information for clarifying the mechanism of magma fragmentation. We have investigated magma fracturing by using in-situ X-ray imaging and diffraction techniques. Some preliminary results of our work will be introduced in this presentation.

Keywords: Volcanic eruption, Magma, Fracturing, X-ray imaging, X-ray diffraction

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