Laboratory simulation of shear deformation and outgassing of silicic magmas

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The bubble microstructures in magma control its rheology and the rate of outgassing from magma; hence, an understanding of the microstructural evolution of bubbles in magma ascending in a volcanic conduit is essential to understand and model the magma ascent processes and volcanic eruptions. For the last three decades, many experiments simulating magma decompression have been performed to understand the nucleation and growth processes of bubbles. In contrast, microstructural evolution of bubbles in deforming magma and the subsequent changes in gas permeability have been poorly understood. We performed a series of shear deformation experiments and clarified the evolution of gas permeability during magma deformation. The important findings of our experiments are: (1) shear deformation causes bubble elongation and coalescence, resulting in an increase in gas permeability when magma shows homogeneous deformation, (2) the increase in the gas permeability is inhibited if shear localization occurs, and (3) the shear localized- and fractured-zone has high gas permeability and exhibits frictional sliding. Based on these experimental results, we proposed the following scenario for the ascent of silicic magmas. During its ascent, magma experiences shear deformation and its gas permeability increases through vesiculation and deformation. When magma is sheared homogeneously, it outgases, resulting in lava effusion. In contrast, when shear localization occurs during the ascent, the degree of outgassing is inhibited and explosive volcanism may be caused. Shear localization at the shallow parts in a conduit induces the transition from a viscous flow of magma to the frictional sliding of the magma plug. This makes it possible to cause a rapid ascent of viscous magma because the friction stress decreases toward the surface and the shear stress of viscous flow increases due to magma dehydration and crystallization. As shown here, the coupled effect of magma rheology and outgassing may be a controlling factor of magma ascent rate and volcanic eruption, and we will need to test this model by coupling with field observations and physical models.