

Transition between frictional sliding and viscous flow in magmatic fractured zone

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Silicic magma intruded into shallow parts of volcanic conduits experiences shear localization and shear-induced brittle fracturing, resulting in the formation of a magmatic fault along conduit wall. Once the fault is formed, the frictional behavior of the fault controls the magma ascent process. The weak magmatic fault lubricates magma plug in the conduit, which results in rapid magma ascent and hence explosive volcanism. In contrast, if the fault heals during magma ascent, the ascent is controlled by viscous flow. In the viscous flow, magma is sheared, which causes efficient outgassing through shear-induced bubble coalescence and elongation. Thus, the healing of the fault may result in non-explosive volcanism. Here, we observed torsional deformations of a rhyolitic melt and a magmatic fault gouge in-situ at temperatures of 800-900 °C using synchrotron radiation X-ray radiography. The torsional deformation rate was set to be 0.1 to 10 rpm, corresponding to equivalent slip velocities of 2×10^{-5} to 2×10^{-3} m s⁻¹ and shear strain rates < 1 s⁻¹. The experimental temperature is greater than the glass transition temperature; hence, the experiments were conducted for supercooled rhyolitic melts. In experiments for rhyolitic melts, we observed brittle fracturing and formation of magmatic fault along a rotational piston. The fault did not heal under the constant deformation rate. In experiments for the magmatic fault gouge, the magmatic fault showed a frictional sliding as well as viscous flow; the deformation is controlled by the viscous flow under higher temperature, low deformation rate, and high normal stress. Based on the experimental results, we propose the ratio of timescales of fault healing and deformation as a criterion for transition between frictional sliding and viscous flow. The experimentally calibrated transition criterion infers that frictional sliding is predominant from several hundred meters in the conduit during explosive eruption on silicic volcanism; this may explain the rapid magma ascent without efficient outgassing. In contrast, once the fault heals, magma ascent may decelerate, resulting in effusive eruptions. In addition, the repeated magma fracturing, sliding, and healing would be a possible explanation for the cyclic behavior of magma ascent.

Keywords: Silicic magma, Viscous flow, Frictional sliding, X-ray radiography