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Coupled effect of magma degassing and rheology on silicic volcanism

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The eruption styles of silicic volcanoes range from explosive Plinian eruption to lava effusion. Classically, the eruption style and explosivity are thought to be controlled by the rate of degassing of magma during its ascent in volcanic conduits. When the degassing rate is high, the vesicularity of the lava remains low and the poorly vesiculated lava effuses to Earth's surface. On the other hand, if the degassing rate is low and magma vesiculation proceeds, magma fragmentation induces explosive eruption. Quantitative experiments have shown that the degassing rate of flowing magma is high and almost all the magma ascending in the conduit is degassed before it reaches the surface. This indicates that silicic magma inevitably undergoes degassing during ascent, resulting in the formation of poorly vesiculated magma, and an unknown mechanism contributes to the explosive eruption that releases highly vesiculated magma. We simulated rhyolite magma flowing at high temperature and pressure using an originally developed piston-cylinder-type deformation apparatus and observed the eruption process by synchrotron radiation X-ray radiography and computed tomography. We observed degassing and subsequent compaction in situ and found that shear localization induces efficient degassing through both bubble coalescence and elongation. Further, we observed magma fracturing in the shear-localized region and low rate of degassing in the other regions. In natural settings, shear can localize along the volcanic conduit at a high strain rate. This results in the formation of a highly permeable degassing layer along the conduit walls and non-degassed magma in the centre of the conduit, which has the potential for explosive eruption. In the absence of shear localization, only poorly vesiculated magma effuses to the surface. This new viewpoint that magma degassing and rheology have a coupled effect on the eruption style and explosivity explains geological and seismic observations.