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Permeability variation of vesicular silicic magmas with constant decompression rates

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Gas permeability through connected bubble network in silicic magmas is an important physical property controlling magma degassing during volcanic eruptions. Recent experimental progress enables us to measure permeability of quenched products of hydrothermal decompression experiments, in which various condition can be controlled (Takeuchi et al., 2005). Takeuchi et al. (2005) performed decompression experiments and show permeability variation with increasing vesicularity. But their experiments did not simulate decompression path of actual eruptions. In addition, we found that their permeability data are overestimated, especially for low permeability samples. Their samples for permeability measurement were manufactured by mounting the quenched products in resin and slicing them, without separating the vesicular products from noble metal capsules used in decompression experiments. However, our recent measurements detect slight amount of gas flow through boundary between vesicular product and capsule inner wall.

In this study, we perform decompression experiments with constant decompression rates, in which actual eruptive conditions are roughly simulated. In order to prevent the influence of boundary gas flow, we separate noble metal capsules from vesicular products in manufacturing the samples for permeability measurement.

Decompression experiments were performed by internally heated pressure vessels with rapid-quenching device and decompression-control units installed at the Geological Survey of Japan, AIST. The starting material is powder of rhyolitic glass (JR-1) with ca. 4.8 wt. % water. Gold or silver tubes (5 or 12 mm in diameter and ca. 25 to 30 mm in length) were used as capsules. The samples were held for 1 day at 900 degree C and 180 MPa. Then, they were isothermally decompressed to a final pressure of 30, 16, 10 and 5 MPa with constant decompression rates of 0.05, 0.005 and 0.0016 MPa/s, and quenched. The permeability of the quenched products was measured by improved permeability measurement system of Takeuchi and Nakashima (2005). Compressed air was used as working gas. The permeability was calculated by using Forchheimer equation, in which inertial effect of pore gas flow is considered (Rust and Cashman, 2004). Vesicularity (total porosity) was estimated from analysis for reflected-light images of the cross section of products.

The experimental products have vesicularities of 40-90 vol.%. The vesicularities of products with same final pressure are roughly similar, even if the decompression rates are different. Typical bubble diameters range from 50 to more than 1000 micron meter. The typical bubble diameters increase with decreasing final pressure with same decompression rate or decreasing decompression rate at same final pressure. The permeabilities of products with less than 80 vol.% vesicularity were not detected (less than 10ˆ-16 mˆ2). For the products with more than 80 vol.% vesicularity, the permeabilities are detectable. The products with lower decompression rate tend to have higher permeabilities, even if they have similar vesicularity. For example, the permeabilities of products quenched at 5 MPa (ca. 90 vol.% vesicularity) with decompression rate of 0.05, 0.005 and 0.0016 MPa/s are 10ˆ-12.5, -12.0 and -11.7 mˆ2, respectively. This suggests that the permeable bubble network of products with lower decompression rate are composed of larger bubbles and aperture, which facilitate gas flow through the network.

Eichelberger et al.(1986) show that silicic magmas with permeability of 10ˆ-12 to -13 mˆ2 can degas in timescale of lava dome eruption. In our experiments, such a high permeability is observed in the products at quenching pressure of less than 10 MPa (more than 80 vol.% vesicularity). This pressure corresponds to lithostatic pressure of less than ca. 500 m depth. This suggests that degassing of silicic magmas occur in very shallow conduit of less than ca. 500 m depth.