Temporal variation of gas permeability in vesicular magmas

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Gas permeability in vesicular magmass is an important physical property to model volcanic degassing. The permeability in vesicular magmas has been estimated from permeability measurements of vesicular lavas and pyroclasts. However, the permeability of natural samples should be affected by various processes in the late stages of eruption. For a further quantitative understanding of permeability variation in vesiculating magmas during eruptive processes, Takeuchi et al. (2005) measured the permeabilities of the quenched products of decompression experiments, and showed lower permeability variation with vesicularity than those of natural samples. Their textural analysis for the products indicates the occurrence of bubble coalescence and relaxation of bubble shape after the coalescence in the timescale of the experiments. The result suggests that the permeable network was formed in bubble coalescence and shape relaxation processes. Because these processes are time-dependent, the permeability in vesicular magmas may depend on not only vesicularity, but also time. In order to examine the temporal variation of the texture and permeability in vesicular magmas, new experiments with various holding time after decompression and permeability measurement of the quenched products is presented in this study.

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). Gold tubes (5 mm in diameter and ca. 25 mm in length) were used as capsules. The sample powder was enclosed in the capsules with water of ca. 4.8 wt. %. The capsules were held for 1 day at 900 deg C and 180 MPa. Then, they were isothermally decompressed to a final pressure of 30 or 16 MPa in 20-40 seconds. After the decompression, they were held for various time at the final pressure, and then quenched. The permeability was measured by improved permeability measurement system of Takeuchi and Nakashima (2005).

The products held during 10 minutes at 30 MP after decompression has vesicularity of ca. 40 vol.%. The products held during 1 hour and 1.3 days have similar vesicularities of ca. 60 vol.%. The average bubble diameter is ca. 30, 60 and 300 micrometers for the samples with holding time of 10 minutes, 1 hour and 1.3 days, respectively. In contrast, the permeabilities decrease with holding time from 10ˆ-15 to -14 mˆ2 to below the detection limit of measurement system (below 10ˆ-16.3 mˆ2). The products held during 10 minutes, 1 hour and 10 hours at 16MP after decompression, have similar vesicularities of (ca. 70-80 vol.%). The average bubble diameter is ca. 50, ca. 100 and ca. 300 micrometers for the samples with holding time of 10 minutes, 1 hour and 10 hour, respectively. In contrast, the permeabilities decrease with holding time from 10ˆ-13 to -12.5 mˆ2 to 10ˆ-14 to -13 mˆ2.

The result shows that the bubbles enlarge with holding time at constant pressure due to bubble coalescence and shape relaxation after coalescence, and the permeability is likely to decrease with the temporal variation of vesicular texture. Our interpretation for this is that bubbles expand, coalesce each other and form permeable bubble network during rapid decompression. Then, during holding time at constant pressure, bubble-melt surface tension causes local conglobation of coalescing bubbles and segmentation of permeable network, resulting in decrease of gas permeability. When decompression rate is slower and shape relaxation processes are faster than bubble expansion and coalescence processes during decompression, formation of isolated bubbles may be more predominant than formation of permeable bubble network. This effect may produce decompression rate-dependent permeability variation of vesicular magmas.