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Effect of crystals on the bubble microstructure and gas permeability in a rhyolitic melt: experimental constraint

Satoshi Okumura[1*], Michihiko Nakamura[1], Kentaro Uesugi[2]

[1]Dept. Earth Science., Tohoku Univ., [2]SPring-8/JASRI

Permeable gas transport in magma is a key process to understand the dynamics of volcanic eruptions and the evolution of magmas in the upper crust. The permeable degassing from the magma ascending in a volcanic conduit controls the bifurcation of explosive and non-explosive volcanism (e.g., Jaupart and Allegre, 1991 EPSL). The gas movement from mafic to silicic magmas may change their volatile chemistry, and the migration of hot gas originated in the hot magma may be an important process that transports heat in the upper crust (Bachmann and Bergantz, 2006 JVGR). Hence, it is essential to evaluate the rate of permeable gas transport in magmas. Although the gas permeability of vesicular silicic melts has been investigated by recent experimental studies (e.g., Okumura et al., 2009 EPSL), these studies did not evaluate the effect of crystals. In this study, we have investigated the evolution of bubble microstructure and gas permeability in crystalline magmas.

We prepared powdered rhyolitic glasses and 100 mesh Al_2O_3crystals as an analogue for phenocrystic minerals. These were mixed in 7:3 and 1:1 volume ratio; then, the mixed samples were sealed in Au tubes (3 mm O.D.) together with known amounts of water (ca. 3 wt% in melt water content). The samples were initially heated at a temperature of 800 degC under a pressure of 80 MPa for 24 hours by using a cold seal pressure vessel. At this condition, the rhyolitic melt was not saturated with water. The pressure was then decreased to 10 to 50 MPa in order to form bubbles and kept for 1 or 10 hours. The bubble microstructure in some of the run products was observed by using a synchrotron radiation X-ray computed tomography (BL20B2 at SPring-8); the gas permeability of the run products was measured with a gas permeameter.

Main characteristics of bubble microstructure in run products are summarized as follows: (1) the bubbles were heterogeneously nucleated on the Al_2O_3crystals and (2) the shape of some large bubbles is constrained by crystals, especially at high crystallinity (50 vol%). The results of permeability measurements showed that the permeabilities of all the run products which have melt vesicularities of 7-65 vol% (4-53 vol% in bulk vesicularity) were less than the detection limit of the permeameter (log K <-15, where K is the Darcian permeability in m^2), except for one run product of which crystallinity and melt vesicularity are 50 and 65 vol%, respectively.

Previous studies showed that the permeability of vesicular melt without crystals is less than $10^{-15} m^2$ at vesicularities <80vol% when the melt is isotropically vesiculated or the extent of deformation is small (e.g., Okumura et al., 2009 EPSL). In the present experiment, we demonstrated that the permeability of crystal-rich magma is small at least at the melt vesicularities <65 vol%. These results indicate that the presence of crystals does not assist permeable gas transport in isotropically-vesiculated magmas. Hence, we infer that the permeable gas transport may become significant only at a shallow depth unless shear deformation or other processes enhance bubble connection. Further investigation of the effect of crystal wettability is necessary.

Keywords: magma, degassing, fluid flow, vesiculation experiment