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# Evidence of permeable gas transport in magma from obsidian pyroclasts

Satoshi Okumura[1*]

[1]Department of Earth Science, Tohoku University

Permeable gas flow through connected gas bubbles in magma is thought to control the rate of outgassing from silicic magma and hence the style and explosivity of volcanic eruptions. Recent experimental studies (Okumura et al., 2009; Caricchi et al., 2011) demonstrated that gas permeability in magma starts to increase at a vesicularity of ca. 30 vol%; this vesicularity can be achieved at a depth of a few kilometers for typical rhyolite magma. This result supports the field observations of volcanic gases that indicate outgassing from magma at depths of a few to several kilometers (Edmonds et al., 2003; Ohba et al., 2008). In addition to these experiments and observations, this study exhibits that permeable gas transport occurs at a depth of a few kilometers on the basis of volatile content and bubble microstructure in obsidian pyroclasts.

In this study, obsidian pyroclasts were collected from the Kemanai pyroclastic flow deposit of the Heian eruption at Towada volcano. The obsidians were doubly polished and its water contents were measured using FT-IR microspectrometer. Obsidian pyroclasts were divided into two major groups, i.e., clear and dark brown obsidians. Clear glassy fragments include deformed and elongated bubbles and some fragments show banding structure. The bands with brown color seem to be formed along highly elongated bubbles but the bands continue even if the bubbles disappear. The composition of major elements is the same in clear and brown parts. In contrast, water content profiles perpendicular to the bands show the increase in water content from 2 wt% in the clear part to 3-4 wt% in the center of brown bands. The concentrations of hydroxyl group and molecular water show positive correlation and the equilibrium temperature (quenched temperature during cooling process) estimated from water speciation is approximately 500 degC. The width of hydration layer is 70-100 um, which can be explained by diffusion time of 100 ky, 7 hrs and 5 min at temperatures of 25, 500 and 1000 degC, respectively.

The analytical results of this study indicate that the hydration occurred at temperatures $>$500 degC. When we assume magma temperature of 1000 degC (Hunter and Blake, 1995), the depth at which hydration occurred is estimated to be 1600 m (40 MPa) on the basis of water content of 2 wt%. Because the hydration layer has high water content (3-4 wt%), permeable gas transport is expected to occur even at deeper part. If magma temperature decreases before the hydration, the estimated depth at which hydration occurred may be shallow (600 m at magma temperature of 500 degC). However, bubble collapse and space disappearance along brown bands imply that magma temperature is high enough to heal bubble networks even after the hydration. If magma temperature is 500 degC, healing timescale is $>$100 yrs (Yoshimura and Nakamura, 2010). This timescale is much longer than the timescale of volcanic eruption and water diffusion profile in the bands would be annealed during the healing. Therefore, magma hydration is inferred to be induced by permeable gas transport at a depth of a few kilometers.

Keywords: obsidian pyroclast, permeable flow, gas transport, magma, water