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Magma Permeability Revisited: Development with vesiculation and fragmentation in a single eruption

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Degassing of highly viscous magmas, in which bubble segregation is not effective, is considered to occur as permeable-flow. In this presentation, we present new permeability data of pumices from a single eruption process that represent a development of permeability in the course of magma vesiculation and fragmentation, and reexamine the relationship between vesicularity and permeability in the previous studies.

Permeable gas-flow occurs along interconnected paths through the ruptured melt films between bubbles. In a static microstructure (without temporal changes such as relaxation), permeability should be 0 at a vesicularity below the critical value, at which interconnected network is first established. The critical vesicularity is dependent on the melt viscosity, surface energy, and size and space distribution of the bubbles. The critical vesicularity for the run products of isotropic decompression experiments (Takeuchi et al., 2005; submitted) reaches ca. 80 vol.%. Compared to the experimental products, on the other hand, permeability of the natural erupted materials has higher value (larger than 10^{-14} m^2) gradually increasing from a low critical vesicularity below 30% (Klug and Cashman, 1996; Mueller et al., 2005). Since the natural data include the erupted materials with various eruption styles from various volcanoes, this gentle trend does not always represent the vesicularity development during magma ascent and decompression.

We have examined the juvenile pumices of Pleistocene Chijimiza-pyroclastic flow in the Onoda Formation, located in the south of Onikobe-volcano, Northwest Miyagi prefecture. We measured 2-dimensional (2-D) connectivity of the bubbles on the BSE images of the thin sections, and 3-D bubble connectivity with a porosimetry method. The white and gray pumices include relatively spherical bubbles, while pores of the dark-gray pumices have irregular shapes. The permeability of the white and gray pumices shows steep increase from 10^{-14} to 10^{-10} m^2 at a vesicularity of 70-80%. These data cover the range of the previous studies (Klug and Cashman, 1996; Mueller et al., 2005) and locate in the extension of that of Takeuchi et al. Permeability of the dark gray pumice is relatively high at low vesicularity ($10^{-12.5}$ - $10^{-13.4}$ m^2 at 43 - 52%). The 3-D bubble connectivity is higher than 90 % and shows no clear correlation with permeability, while 2-D connectivity steeply increases at a similar vesicularity range to that for permeability (i.e., 70-80%). This is probably because the pumices with high 2-D connectivity have small tortuosity paths. The increase of 2D connectivity and permeability is resulting from the rupture of melt films, namely, partial fragmentation. This suggests that the permeability-vesicularity trend composed of the data in Takeuchi et al. and in this study represent an isotropic vesiculation and fragmentation path. The relatively high permeability at low vesicularity of natural erupted materials may result from (1) formation of the bubble lineation or foliation, (2) high rupture probability of the bubble films due to low viscosity, and (3) non-spherical shape of vesicles as in the case of the dark-gray pumice.