Shear deformation experiments on vesiculated rhyolitic melts: Evolution of bubble connectivity

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Vesiculation and degassing of magma ascending in a volcanic conduit control flow dynamics and eruption behavior. A controlling process on eruption behavior is the formation of bubble network followed by magma degassing, because the magma degassing suppresses the eruption explosivity. Recently, Okumura et al. (2006) have experimentally shown that the degree of bubble coalescence was increased by shear. Based on their experimental results, they proposed a possibility that the formation of bubble network was promoted by shear. However, their experiments covered only the ranges of low vesicularity and small strain. This study aims to explore the evolution of bubble network whose formation is enhanced by shear during magma ascent. For that purpose, we have performed deformation experiments at higher vesicularity and larger strain than those of previous study and taken the 3-D images of experimental samples by using X-ray computed tomography.

The deformation experiments were performed by using a piston-cylinder type apparatus with a rotational lower piston. Rhyolitic obsidian with 0.5 wt% initial water (Wadatouge, Nagano) was used as a starting material for deformation experiments. Before deformation experiments, the cylindrical obsidian (dia. 4.7mm x 5mm) was heated at 975degC to vesiculate the sample. Then the vesiculated sample was twisted by rotating the lower piston in the experimental apparatus. In this study, the deformation experiments were carried out with the rotational rate of 0.3 to 0.5 rpm and the rotation number of 0.5 to 10. After the deformation experiments, the samples were cooled by switching off the heater. The bubble number, size and shape in the experimental samples were obtained from the 3-D images taken by X-ray CT technique. This study performed the X-ray CT analyses at BL20B2 of SPring-8. The images obtained were converted to binary images which were used for the analyses of bubble structure.

The vesicularity of samples roughly ranges from 20 to 40 vol%. The bubble size distributions in the samples with similar vesicularity but different rotational degree show that the medium size bubbles decreased and a big bubble was formed with increasing the rotational degree. Bubble connectivity (B/V) defined by the ratio of the volume of maximum bubble (B) to total volume of bubbles (V) starts to increase at the vesicularity of 20 to 30 vol% on the experimental condition of this study, i.e. the size of maximum bubble rapidly increases at the vesicularity range. The vesicularities at which the connectivity starts to increase appear to be lower at the 0.5 rpm experimental samples than 0.3 rpm experimental samples. The connectivity increases with vesicularity and rotational degree, and becomes 0.84 at the vesicularity of 43 vol% and the rotation number of 10 when the rotational rate is 0.5 rpm.

The shear rate in deformation experiments (maximum shear rate of 0.03 s^{-1}) is possibly yielded in magmas ascending in a volcanic conduit (Gonnermann&Manga, 2003; Rust et al., 2003). The shear rate at near conduit wall is expected to be larger than that at conduit center. Hence, we infer that the coalescence of bubbles in the ascending magma is enhanced at near conduit wall and the connectivity at near the conduit wall first increases rather than that at conduit center. And the connectivity approaches up to 0.8 at the vesicularity of 40 vol% and the strain of 40 which appear to be achieved during magma ascent. This means that the highly-connected bubble network is formed at near conduit wall followed by magma degassing which might control the transition of flow dynamics. Namely, the degassing results in the formation of bubble-less and viscous layer at near conduit wall, which might makes magma ascent rate slow. To verify this relationship among the formation of the channel-like bubble network, degassing and rheological behavior, we will investigate experimentally the change of stress during shear deformation.