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Open-system degassing and compaction of flowing magma: constraints from torsional deformation experiments

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Open-system degassing from magma ascending in volcanic conduits controls the style and explosivity of volcanic eruptions. The rate of the degassing is limited by gas permeability of vesicular magma (e.g. Klug and Cashman, 1996 BV; Takeuchi et al., 2005 GRL). Recently, we experimentally demonstrated that the deformation of vesicular magma results in the increase in the gas permeability via the enhancement of bubble coalescence (Okumura et al., 2009 EPSL). Once gas loss from magma with high gas permeability occurs, vesicular magma is compacted and its density rapidly increases, which influences the dynamics of magma flow in volcanic conduits. It is, therefore, necessary to understand the processes of degassing and compaction of flowing magma, but these processes remain unclear. Hence, this study is aimed at clarifying the processes of the degassing and compaction of flowing magma.
In this study, we performed torsional deformation experiments for vesicular rhyolitic melt at a temperature of 933 degC. The microstructure of run products was observed using synchrotron radiation X-ray CT at SPring-8 (BL20B2). A starting material for the deformation experiments is core of 5 mm diameter of natural obsidian with 0.5 wt.% water. This sample was heated at 933 degC for 10 minutes to vesiculate sufficiently. The vesicularity was controlled by preparing the core sample with the different height for the constant cell volume. The vesicularity was controlled to be 46 - 70 vol.%. After the vesiculation, the sample was twisted for 10 minutes with the rotational rate of 0.8 rpm. In this experiment, we used pistons with V-shaped faces to induce the compaction of magma.
The shape of run products was strongly dependent on initial vesicularity before the deformation experiment. The hourglass-shaped run products were obtained at high vesicularities (>53 vol.%). These samples clearly showed that the compaction of vesicular magma occurred and the vesicularity was decreased. The compaction resulted in lower vesicularity at higher initial vesicularity. We also found that the compaction does not occur when we used flat pistons. The run product at an initial vesicularity of 46 vol.% has columnar shape but showed the radial heterogeneity of vesicularity. Namely, the inner part of the run product has low vesicularity but its outside is high vesicularity zone. This heterogeneity is caused by the compaction of vesicular sample at the inner part. On the other hand, at low initial vesicularities (about 10 vol.%), the run product has columnar shape and bubbles in the run product deformed toward the shear direction.
The experimental results showed that the degassing and compaction of flowing magma start to occur at vesicularity range of 10 - 46 vol.%, which is consistent with the critical vesicularity for the rapid increase in the gas permeability of flowing magmas (about 30 vol.%, Okumura et al., 2009 EPSL). The compaction of magmas with high vesicularities results in the formation of dense magmas whose vesicularities are approximately equal to zero. On the other hand, bubbles remain in magma when the compaction occurs at low vesicularities. This is because the connectivity of bubbles is high and the gas can outgas from most of bubbles at higher vesicularity. On the basis of these results, we infer that the degassing of flowing magma suppresses the increase in the vesicularity but the vesicularity does not decrease too much when the degassing and compaction start to occur at low vesicularity, and the dense magma may be formed if the compaction is

induced at high vesicularity.

Keywords: Open-system degassing, Compaction, Vesicularity