Experimental formation of brittle fracture in magma: Shear fracturing and fragmentation of magma induce open-system degassing ?

Satoshi Okumura[1]; Michihiko Nakamura[2]; Kentaro Uesugi[3]; Akira Tsuchiyama[4]; Tsukasa Nakano[5]

[1] Inst. Min. Petro. Eco. Geol., Tohoku Univ.; [2] Earth Planet. Materials Sci.; [3] JASRI; [4] Earth and Space Sci., Osaka Univ.; [5] GSJ/AIST

Open-system degassing of magma controls the explosivity and style of volcanic eruptions. Recent theoretical models for magma flow in a volcanic conduit have introduced a mode of open-system degassing that is induced by brittle failure of sheared magmas. However, its concrete processes such as textures after the brittle failure and effect to control the explosivity of volcanic eruptions are not well understood. In this study, we performed torsional deformation experiments of vesiculated rhyolitic melts at the temperatures of 780-975 deg. C, and show the textural characteristics of the fractured and fragmented rhyolites. The experiments were carried out with the rotational rate of 0.5 rpm and the rotational number up to 5. Under dry conditions and shear strain-rate of 0.02 to 0.03 s^{-1}, the brittle fractures were formed below 905 deg. C and the formation of the fractures became extremely pronounced around 855 deg. C, resulting in the formation of fine fragments ca. 100 um in size (fragmentation). At 780-830 deg. C, the torsion deformation was localized in a plane perpendicular to the cylindrical axis and the sample was twisted off. The condition in which the brittle failure was observed, i.e., the viscosity (temperature) at a given shear strain-rate, is consistent with that of previous experimental studies. The brittle failure of the vesiculated rhyolitic melts may form interconnected networks through ruptured melt films and hence induce the effective degassing, but this type of magma degassing can occur only at shallow depth (less than a few hundreds meters in depth), which is estimated based on the criterion for brittle failure of vesiculated rhyolitic melts, typical temperatures and water contents of rhyolite, and realistic strain-rates yielded in a natural system. On the other hand, our previous studies showed that the coalescence and elongation of bubbles in a flowing magma results in the formation of tube-like bubble network and the increase of magma permeability in a deeper volcanic conduit. Therefore, we infer that open-system degassing in the volcanic conduit occurs at first through the tube-like networks formed by bubble coalescence and elongation in the deep part, followed by the degassing along the shear fractures at the shallower.