In situ observation of brittle fracturing of rhyolite magma by X-ray radiography

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Brittle fracturing of silicic magma during its ascent in a volcanic conduit is thought to trigger seismicity (e.g. Tuffen et al., 2008). The brittle fracturing of dense highly crystalline lava has been studied well on the basis of laboratory experiments (e.g. the crystallinity >50 vol % in Lavallee et al., 2008). In the lava, the crystals can form network; hence, the fracturing is probably controlled by the interaction between crystals. On the other hand, the relationship between fracturing and seismicity in crystal-free melt and the effect of gas bubbles are unclear. Tuffen et al. (2008) demonstrated that glassy obsidian shows seismogenic fracturing at high temperature (645 ℃); however, the temperature is very close to its glass transition and low to simulate magma fracturing. In this study, we observed the fracturing of rhyolitic melts (0.4-0.5 wt % water) under torsional deformation at temperatures of 700-820 ℃ by using X-ray radiography at SPring-8 (BL20B2) in Japan. Sample size is 3-4 mm long and 5 mm in diameter and the rotational rates were set to be 0.05 and 0.5 rpm, which correspond to shear strain rates of $3\text{-}4\times10^{-3}$ to $3\text{-}4\times10^{-2}$ s^{-1}. The confining pressure was controlled to be 4-5 MPa. The acoustic emission (AE) and the pressure change during the fracturing were also monitored. The brittle fracturing of rhyolitic melts was observed in runs at temperatures of 800-820 ℃ under the rotational rate of 0.5 rpm and at temperatures of 700 ℃. The deformation and fracturing processes are summarized below: (1) shear stress increased with deformation (elastic manner), (2) shear stress started to decrease and large AE was monitored, and this AE corresponds to the formation of cracks, (3) the crack formation localized to a horizontal plane around a piston, (4) AE increased again, which probably corresponds to the pulverization of fragments, and (5) finally stable sliding along the fractured zone occurred. In some experiments, the effect of annealing of the fractured zone was investigated by holding melt at the same temperature. After 15 minutes, deformation started again. In this stage, the deformation showed the sliding along the fractured zone and large AE such as that found in (2) was not monitored. The experimental results indicate that brittle fracturing of crystal-free magma releases the AE before the weakening of magma and then the large AE is not released from the fractured zone as long as it is perfectly welded. This may indicate that the acceleration of magma ascent involving brittle fracturing is accompanied with seismicity, if the AE is directly linked to the seismic observation although it has still been under debate (e.g. Chouet and Matoza, 2013).