Vesiculation experiments of rhyolitic melt: constraints on the conditions for lava dome explosions

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Background
Lava domes often explode violently after emplacement, causing pyroclastic flows (e.g., 1902 Mt. Pelee, 1973 Santiaguito, 1991 Mt. Unzen; Ui et al., 1999). Such explosions are considered to be triggered by overpressures developed in bubbles (e.g., Sato et al., 1992). Therefore, to predict dome explosions, it is necessary to investigate the vesiculation kinetics of silicic magma. Previous experimental studies investigated the kinetics of vesiculation of rhyolitic melt, but their experimental conditions are not necessarily adequate for lava domes, because their starting obsidian was too H_2O-poor (0.1 wt%; Bagdassarov et al., 1996; Ryan et al., 2015) or too H_2O-rich (1.8 wt%; Stevenson et al., 1997). In this study, we carried out similar experiments under the condition close to the inside of lava domes (H_2O contents and temperature), and applied the results to lava explosions.

Experimental
Starting material was rhyolitic obsidian obtained from Wada Pass (H_2O contents=0.59 wt%). A slab was prepared from a chank of obsidian, and it was heated in a muffle furnace at 750, 800, 850, 900 deg C for 15 min ~ 95 hours. After quenching, vesicularity was measured with image analysis.

Results
Vesicularity increased with heating duration. At first, vesicularity increased slowly. And then, it increased rapidly and reached the equilibrium vesicularity (estimated by assuming all H2O exsolved). The vesiculation rate was strongly dependent on temperature, and was high when temperature was high.

Discussion
The Avrami equation was applied to the time-vesicularity relation, and the rate constant was estimated for each temperature. The activation energy was calculated from the rate constant and temperature, and it was 304 (+/-9) kJ/mol. This value was much closer to the activation energy of viscous flow of the rhyolitic melt (338 kJ/mol, Giordano et al., 2008) than that of water diffusion (88 kJ/mol, Zhang et al., 2007). Therefore, the vesiculation is considered to be rate-limited by viscous flow.

Application to lava domes
Experimental results were applied to prediction of lava dome explosions. After emplacement, dome surface immediately cools and vesiculation ceases, and thus the overpressure dose not increase any further. On the other hand, in the dome inside, vesiculation proceeds smoothly because temperature is maintained high, and thus the overpressure soon decreases. In the intermediate region, temperature decreases slowly, and thus the vesiculation rate decreases slowly. As a result, the overpressure and the explosion potential are maintained for a long period. We modelled these processes based on thermal conduction and the temperature-dependence of vesiculation rate, and calculated the duration during which the risk of explosions is reduced. Calculation results showed that when initial temperature of lava dome is 900 degC, the duration is 5 hours. When initial temperature is 750 deg C, the duration is 11 days.

Keywords: vesiculation, lava, explosion

