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Healing experiments of fractures in a rhyolitic melt: Estimation of lifetime of degassing pathways

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Open-system degassing, the process in which exsolved gas phase escaped from the magma system to the outside, plays a central role in non-explosive eruptions. Permeable flow degassing is considered to be the main degassing mode in viscous silicic magmas in which Stokesian rise of individual bubbles is not at all efficient for significant gas loss. Interconnected networks of bubbles (Eichelberger et al., 1986) and/or shear-induced fractures (Tuffen et al., 2003; Gonnermann and Manga, 2003) would act as degassing pathways. Recent experimental studies have investigated mechanisms of bubble coalescence, effect of shear deformation on the coalescence and brittle failure (Larsen et al., 2004; Burgisser & Gardner, 2005; Takeuchi & Nakashima, 2005; Okumura et al., 2006; 2008; 2009).

Compaction of magma necessarily accompanies permeable flow degassing for decreasing the buoyancy of magmas and formation of dense and dry lavas. If the degassing pathways were closed off before sufficient outgassing, the magma would remain porous and water-rich. Thus, how long the degassing pathways are maintained (lifetime of the pathway) is essential in estimation of amount of lost volatiles. Previous studies on magmatic welding have investigated the compaction of glass ashes (Friedman, 1960; Quane & Russell, 2005). Since timescale of compaction in these experiments was reproduced through relaxation time of the melt (t=(viscosity)/(stress) :Sparks et al., 1999), the lifetime of degassing pathways has been estimated as the relaxation time. However, we suggest that the relaxation time cannot be applied to lifetime of the degassing pathways, because healing processes of the pathways involve welding and sintering as well as deformation and compaction. Even narrow interspace could work as degassing pathways, as reported in Yoshimura and Nakamura (2008). In order to evaluate the timescale of degassing, the lifetime of the pathways should be reexamined and established quantitatively.

In this study we have carried out healing experiments of degassing pathways in a rhyolitic melt under PT conditions of shallow volcanic conduit. Two cylindrical cores of natural obsidian were put in a stainless-steel or pyrophillite cylinder and fixed with a piston. This assembly was heated in an electric furnace at 850 to 1000 degC for 12 to 96 hours. The obsidian cores became vesiculated upon heating and generated pressure (1 to 3 MPa) in the constant-volume cylinder. The surface of the cores was kept in touch with each other, and the contact interface was welded and finally disappeared away. Water diffuses toward the interface until it is closed. When the interface is welded and becomes coherent, diffusive dehydration will cease and the profile of water content will be re-homogenised. Whether the interface is welded or not was determined using the water content profile and diffusion calculation. The experimental results show that the healing time is much longer than expected through relaxation time by two or three orders. For instance, if normal stress on the interface is 3~1MPa at T=850degC and H2O=0.6~0.35wt%, then the relaxation time is calculated as 10 to 140 seconds, while the actual healing time in the experiments is 24 to 96 hours. When temperature is 1000 degC, the interface was completely welded within 1 hour, whereas the relaxation time was computed as ~1 second.