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Controls on the formation of impermeable networks vs outgassing during vesiculation in rhyolitic magma

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Violent explosive eruptions pose some of the greatest threats to population and infrastructure in the earth system. Many of the largest explosive eruptions, with consequences that can reach the global scale, have been fed by rhyolitic magmas. The dynamics of magma degassing can exert a central influence on the explosivity of rhyolitic volcanoes via the role it plays in generating the bubble overpressure which is the source of the explosive energy of fragmentation. Bubbles grow in general via a combination of diffusion-controlled mass transfer from melt to bubbles, viscous relaxation of the melt, and decompressive volume expansion. The ultimate driving force of oversaturation-driven nucleation and growth of water-rich bubbles is the temperature- composition- and pressure-dependent water solubility in the melt phase. Another key process affecting the explosivity of volcanic eruptions is the formation of impermeable or connected bubble networks; the latter can result in varyingly efficient outgassing, reducing the explosive energy in an eruption or even may inhibit it.

Here, we experimentally investigate the role of heating on rhyolitic magma vesiculation in a shallow conduit. The experiments were conducted using cylindrical (5 mm-diameter and 3 mm-height) samples of both natural and rehydrated rhyolitic glasses with low initial water contents (0.15-0.32 wt% H_2O). Samples were heated at variable rates (1-60 ˚C/min) to final temperatures of 750-1000˚C in an optical dilatometer at 1 bar pressure, during which the evolution in time of sample volume, and therefore vesicularity, was monitored. During heating, sample volume increases nonlinearly due to bubble growth. Textural analyses performed using X-ray computed microtomography (μCT) and Scanning Electron Microscope (SEM) reveal low values of bubble number density (BND) for the natural obsidians and higher values for the rehydrated obsidians. The natural obsidians exhibit isolated bubble growth leading to the development of an impermeable bubble network. The rehydrated samples possess, in contrast, a high level of bubble connectivity that record significant bulk outgassing as evidenced by SEM and mass difference analyses. This starkly contrasting behavior is likely driven by the abruptness of water exsolution just above the glass transition temperature during heating. The presence of crystallinity in some samples also contributes to this thermal history of bubble nucleation and growth and the corresponding development of bubble connectivity yielding permeable pathways. Ongoing investigation is aimed at separating these effects.