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An experimental study of heterogeneous bubble nucleation in oxide-bearing rhyolitic magmas

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Volcanic eruptions are powered by the exsolution of volatiles dissolved in magma due to decompression. The eruption intensity depends not only on the amount of gas exsolved but also on the rate of exsolution. Most recent experiments were focussed on the early stages of exsolution, namely the kinetics of bubble nucleation because it controls two important parameters: the degree of volatile supersaturation ΔP at which the bubbles begin to form, and the number of bubbles nucleated per unit volume of liquid, N. Previous studies showed that high values of ΔP are required to trigger homogeneous bubble nucleation, and that the bubble number density N is strongly dependent on the ascent rate of magma. The high ΔPs required for homogeneous nucleation are due to the large value of rhyolite-water surface tension (of the order of 0.1 N/m). The degree of volatile supersaturation required for bubble nucleation, and therefore the departure from equilibrium degassing, can be strongly decreased in the presence of crystals. The effect of crystals will depend primarily on their wetting relationships with the coexisting liquid and bubbles, and may become very significant if the bubbles wet the crystal faces.

To better understand the kinetics of heterogeneous bubble nucleation in rhyolites, we carried out an experimental study aimed at: (i) defining the critical nucleation pressure at which water bubbles nucleate in an oxide-bearing rhyolite melt; and (ii) quantifying the evolution of the main textural parameters (vesicularity, bubble number density, bubble size distribution, etc.) with decreasing pressure as a function of decompression rate. The decompression experiments were performed in an externally-heated pressure vessel at 800˚C, with an initial pressure of 200 MPa, quench pressures of 100 to 20 MPa, and decompression rates ranging from 1000 kPa/s to 27.8 kPa/s. The starting materials were hematite- or magnetite-bearing rhyolitic glasses produced by saturating obsidian cores from Turkey and Iceland under 200 MPa water pressure and controlled oxygen fugacity.

In the hematite-bearing rhyolites, heterogeneous bubble nucleation occurred at a high degree of volatile supersaturation (ΔP = 135 MPa), just slightly lower than in the case of homogeneous nucleation. By comparison, the supersaturation required for heterogeneous bubble nucleation in the magnetite-bearing rhyolites was much lower (ΔP = 40 MPa). In both series, bubble number densities were relatively low, and appeared to be controlled mainly by the decompression rate, not by the number densities of oxide crystals. The implications of our experiments for the wetting relationships between rhyolite liquid, oxide minerals and bubbles, and for the dynamics of volcanic eruptions will be discussed.