Magma ascent and bubble nucleation in the rhyolite-magnetite-H_2O system: Observation and characterization of a second nucleation event at low pressure by X-ray microtomography

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Volcanic eruptions are powered by decompression-induced exsolution of dissolved volatiles during magma ascent. The kinetics of bubble nucleation plays a major role on the exsolution process because it controls both the degree of volatile supersaturation required to nucleate bubbles and the number of bubbles formed par unit volume of liquid. Previous studies showed that bubble nucleation requires lower degrees of volatile supersaturation in the presence of crystals (heterogeneous nucleation; Hurwitz and Navon, 1994) and that the bubble number density (BND) is strongly dependent on the ascent rate of magma (Mourtada-Bonnefoi and Laporte, 2004; Toramaru, 2006). To better understand the kinetics of bubble nucleation in rhyolites and its effects on pumice textures (BND, bubble size distribution), we performed decompression experiments simulating the ascent of a magnetite-bearing rhyolitic magma in a volcanic conduit. The experiments were performed in an externally-heated pressure vessel at 825°C, with an initial pressure of 200 MPa, quench pressures of 170 to 40 MPa, and decompression rates ranging from 10 MPa/s to 10 kPa/s. The starting materials were magnetite-bearing glasses produced by saturating obsidian cores from Iceland under 200 MPa water pressure and controlled oxygen fugacity.

In all experiments, we observed a first event of heterogeneous bubble nucleation at high pressure: about 165 MPa, that is only 35 MPa below the saturation pressure. Below the nucleation pressure, the degree of water supersaturation in the liquid rapidly decreased to a few 0.1 wt %, the nucleation rate dropped, and the BND stabilized to a value strongly sensitive to decompression rate. A major new result is that a second bubble nucleation event was observed in all experiments quenched at 40 MPa, independently of decompression rate. The resulting bubble size distributions are distinctly bimodal as evidenced by X-ray microtomography. The finding of a second nucleation at shallow depth is in agreement with the numerical simulations of Massol and Koyaguchi (2005). The implications for magma fragmentation in volcanic conduits will be discussed.

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