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SPECIAL COLLECTION: RATES AND DEPTHS OF MAGMA ASCENT ON EARTH

Experimental simulation of bubble nucleation and magma ascent in basaltic systems: Implications for Stromboli volcano

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Abstract

The ascent of H_2O- and H_2O-CO_2-bearing basaltic melts from the deeper to the shallower part of the Stromboli magmatic system and their vesiculation were simulated from decompression experiments. A well-studied "golden" pumice produced during an intermediate- to a large-scale paroxysm was used as starting material. Volatile-bearing glasses were synthesized at an oxygen fugacity (f_{O_2}) ranging from NNO–1.4 to +0.9, 1200 °C and 200 MPa. The resulting crystal- and bubble-free glasses were then isothermally (1200 °C) decompressed to final pressures P_f ranging between 200 and 25 MPa, at a linear ascent rate of 1.5 m/s (or 39 kPa/s) prior to be rapidly quenched. Textures of post-decompression glasses that were characterized by X-ray computed tomography result from different mechanisms of degassing that include bubble nucleation, growth, coalescence, and outgassing, as well as fragmentation. Homogeneous bubble nucleation occurs for supersaturation pressures (difference between saturation pressure and pressure at which bubbles start to form homogeneously, ΔP_{HoN}) ≤ 50 MPa. In the CO_2-free melts, homogeneous nucleation occurs as two distinct events, the first at high P_f (200–150 MPa) and the second at low P_f (50–25 MPa) near the fragmentation level. In contrast, in the CO_2-bearing melts, multiple events of homogeneous bubble nucleation occur over a substantial P_f interval along the decompression path. Bubble coalescence occurs in both H_2O- and H_2O-CO_2-bearing melts and is the more strongly marked between 100 and 50 MPa P_f. The CO_2-free melts follow equilibrium degassing until 100 MPa P_f and are slightly supersaturated at 60 and 50 MPa P_f, thus providing the driving force for the second bubble nucleation event. In comparison, disequilibrium degassing occurs systematically in the CO_2-bearing melts that retain high CO_2 concentrations. Fragmentation was observed in some CO_2-free charges decompressed to 25 MPa P_f and is intimately associated with the occurrence of the second bubble nucleation event. Textures of H_2O-CO_2-bearing glasses reproduce certain critical aspects of the Stromboli natural textures (bubble number densities, shapes, sizes, and distributions) and chemistries (residual volatile concentrations). Average bubble sizes, bubble size distribution (BSD), and bubble number density (BND) data are used together to estimate that the "golden" pumice magmas ascend from their source region in 43 to 128 min.

Keywords: Basalt, Stromboli, volatiles, magma degassing, magma ascent, bubble nucleation, fragmentation