CO2-rich melts generated during basalt magma ascent and degassing

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To test mechanisms of basaltic magma degassing, experimental decompressions of volatile-bearing (2.7-3.8 wt% H2O, 600-1300 ppm CO2) Stromboli melts have been performed from 250-200 to 50-25 MPa at 1180-1140°C. Ascent rates were varied from 0.25 to ~ 1.5 m/s. Both the synthesis experiments that served to produce the volatile-bearing pre-decompression melts and the decompression experiments were performed in an internally heated vessel pressurized with Ar-H2 mixtures and fitted with a rapid-quench device. Charges were examined microscopically and by SEM. Vesicularities (% bubbles) were determined from image analysis on polished surfaces and in a few cases from X-ray microtomography. Electron microprobe analysis of post-decompression glasses shows that Fe loss to Au80Pd20 capsules is negligible. Concentrations of H2O and CO2 in both the pre- and post-decompression glasses, as well as their spatial distribution in the charge, were determined by FTIR. Both punctual analyses, 1D profiles and 2D maps were performed. H2O was measured on the 3530 cm-1 band and CO2 on the 1515 cm-1 band, using the background subtraction method.

Glasses after decompression show a large range of vesicularities, from totally bubble-free, bubble-poor to bubble-rich (~ 20 vol% bubbles), the latter with bubble number densities from 104 to 106/cm3, similar to Stromboli pumices. Bubble-poor or bubble-free samples (< 5 vol% bubbles) come from experiments decompressed either at constant rates to 50 MPa or at variable rates to 25 MPa. The bubble-rich charges are consistently found among those decompressed under constant and fast ascent rates to 25 MPa. These results suggest that, for our melt composition and dissolved volatile concentrations, homogeneous bubble nucleation requires a pressure drop of at least 150 MPa to be initiated. They also show that varying the ascent rate along the decompression path has a significant influence on bubble nucleation.

Final melt H2O concentrations are homogeneous and in all cases close to solubilities. In contrast, the rate of vesiculation controls final melt CO2 concentrations. The post-decompression melt CO2 concentrations are inversely correlated with vesicularities. Bubble-rich glasses have CO2 concentrations that follow theoretical closed-system equilibrium degassing paths and their volatile concentrations plot close to fluid-melt saturation isobars. In contrast, bubble-poor glasses show marked deviations from equilibrium degassing trajectories, with CO2 concentrations up to one order of magnitude higher than solubilities. Although both H2O and CO2 are progressively degassed at progressively lower pressures, most of the CO2 appears to be degassed at pressures < 50 MPa. In comparison, equilibrium degassing models would predict that CO2 is lost earlier (and therefore deeper) along the decompression path, mainly > 100 MPa. FTIR profiles and maps reveal a decrease of the glass CO2 concentration near (100-200 microns) the gas-melt interface, interpreted to reflect frozen diffusive motion of CO2 in the melt as a result of the establishment of local gas-melt equilibrium at the interface.

Our results stress the importance of bubble nucleation in basaltic melts as a factor of control of their final volatile concentration. For bubble-poor basaltic melts, degassing proceeds by volatile loss at the gas-melt interface and is kinetically limited by the diffusivities of the different volatiles in the melt. Our experiments show that CO2-oversaturated melts can be generated as a result of magma decompression, providing a new explanation for the occurrence of CO2-rich natural basaltic glasses and opening new perspectives for understanding explosive basaltic volcanism.