

Dissolved H₂O distribution in vesicular magmatic glass records bubble resorption

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Volcanic eruptions are driven by the nucleation and growth of bubbles in magma. Bubbles grow as volatile species in the melt, of which water is volumetrically the most important, diffuse down a concentration gradient towards and across the bubble wall. On cooling, the melt quenches to glass, preserving the spatial distribution of water concentration around the bubbles (now vesicles). We use Backscatter Scanning Electron Microscopy (BSEM), Secondary Ion Mass Spectrometry (SIMS) and Fourier Transform Infra-Red spectroscopy (FTIR) to measure the spatial distribution of water around vesicles in both experimentally-vesiculated and naturally erupted samples, with unprecedented spatial resolution. We find that, contrary to expectation, the water concentration increases (by up to 3wt.%) in the ~30 microns closest to the vesicle wall.

Our samples record significant resorption of water back into the melt around bubbles during the quench process. We propose that the observed resorption profiles result from the increase in the equilibrium solubility of water as temperature decreases during the quench to glass, and that the resorption locally overprints the pre-existing concentration profile resulting from bubble growth during decompression. Our experimental samples demonstrate that the bulk of the resorption occurs above the glass transition, while the melt is still plastic; consequently, resorption may reduce bubble volumes and sample porosities by as much as a factor of two. Experimental samples are quenched too rapidly (1-5 seconds) for observed resorption profiles to be generated by diffusion of 'total' water (H₂O_t). Speciation data showing molecular (H₂O_m) and hydroxyl (OH) water concentrations around vesicles in these samples reveal that quench resorption is driven by rapid, disequilibrium diffusion of (H₂O_m).

Failure of previous experimental studies of bubble growth to account for quench resorption may have led to incorrect conclusions. We present here a methodology, using BSEM and SIMS, for a first order correction of such datasets. Our work lays the foundations for a new tool for the interpretation of the pressure-temperature history of natural pyroclasts, and challenges the conclusions of two recent studies which interpret similar features as evidence of repressurization of magma in the shallow subsurface, prior to eruption. Bubble resorption can cause significant rehydration of surrounding melt and may therefore be an important mechanism controlling melt viscosity and the glass transition. Our data also demonstrate that the diffusion of water in magmatic glass can, under disequilibrium speciation conditions, be substantially faster than is usually assumed. In dynamic volcanic systems such conditions may occur in a variety of situations; hence our findings are relevant to a broad range of studies.