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Dissolved H_2O distribution in vesicular magmatic glass records quench history and challenges emerging paradigm

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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 naturally vesicular pyroclasts and in experimentally-vesiculated samples, with unprecedented spatial resolution. We find that, contrary to expectation, the water concentration increases (by up to 3wt.%) in the $\sim$30 microns closest to the vesicle wall.

Our samples, both natural and experimental, 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 any pre-existing concentration profile resulting from bubble growth during eruption/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 (H_2O_t). Speciation data showing molecular (H_2O_m) and hydroxyl (OH) water concentrations around vesicles in these samples reveal that quench resorption is driven by rapid, disequilibrium diffusion of H_2O_m.

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 re-pressurization of magma in the shallow subsurface, prior to eruption. Our data also demonstrate that the diffusion of water in magmatic glass can, under the appropriate conditions, be orders-of-magnitude faster than is usually assumed, and that the failure of previous experimental studies of bubble growth to account for resorption may have led to incorrect conclusions.