Experimentally validated bubble growth model for interpretation of magma ascent dynamics

J.P. COUMANS[1]*, E.W. LLEWELLIN[1], F.B. WADSWORTH[1], M.C.S. HUMPHREYS[1], S.A. MATHIAS[1], J.E. GARDNER[2]

[1] Dept.Earth Sciences, Durham University, Durham, DH1 3LE, UK (*email: jason.coumans@durham.ac.uk)
[2]Dept. Geological Sciences, Jackson School of Geosciences, Univ. Texas at Austin, Austin, TX, 78712-0254, U.S.A

Volcanic eruptions are driven by the growth of gas bubbles in silicate melts. The rate and timing of bubble growth is an important control on eruption style, determining whether or not magma fragments to produce an explosive eruption. As bubbles grow, volatile species (most importantly water) diffuse through the silicate melt and exsolve into the bubble. On quench, the spatial distribution and speciation of water 'frozen into' the glass records important information about the temperature and pressure history experienced through eruption. We present the first experimentally-validated numerical model for bubble growth in magma. It can be used as a forward model to predict dynamics of bubble growth in different eruptive scenarios, or as an inverse model to reconstruct eruptive history of vesicular volcanic products.

The model includes the kinetics of speciation, allows for arbitrary temperature and pressure pathways, and accounts for the impact of spatial variations in water content on diffusivity and viscosity. We validate the model against three sets of data. (1) Continuous vesicularity–time data collected using optical dilatometry of Krafla obsidian samples during thermally-induced vesiculation at magmatic temperatures and ambient pressure. This represents approximately isobaric, isothermal bubble growth under strongly disequilibrium conditions. (2) Final vesicularity data from decompression experiments at magmatic temperatures and pressures. This represents isothermal, decompression-driven bubble growth from equilibrium to strongly disequilibrium conditions. (3) Speciation data from diffusion-couple experiments on synthetic haplogranites at magmatic temperatures and pressures. The numerical model closely reproduces all experimental data, providing validation against equilibrium and disequilibrium bubble growth and speciation scenarios.

The validated model can be used to predict the growth and resorption of bubbles, and associated changes in magma properties, for arbitrary eruption pathways. It can also be used to reconstruct pressure–temperature–time pathways from textures and volatile contents of eruptive products. This will open up new ways of accessing the dynamics of magma ascent and eruption in unobserved volcanic eruptions.