A validated numerical model for the growth and resorption of bubbles in magma

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Abstract

The rate and timing of bubble growth in magma is an important control on eruption style, determining whether or not magma fragments to produce an explosive eruption. Bubbles nucleate, grow, shrink, and de-nucleate in magma in response to changes in pressure and temperature, and these changes may be recorded in the spatial distribution and speciation of water 'frozen into' the glass in eruptive products. Accurate modelling of growth and resorption is therefore essential both for forward modelling of eruptive processes, and for inverse modelling to reconstruct pre-eruptive history. We present the first experimentally-validated numerical model for bubble growth and resorption in magma.

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 and in-situ synchrotron-source x-ray tomography of natural and synthetic magma during thermally-induced vesiculation and resorption at magmatic temperatures and ambient pressure. This represents approximately isobaric bubble growth and resorption under 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/resorption 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.

Abstract presented at: Llewellin, E. W., Coumans, J. P., Humphreys, M., Wadsworth, F. B., Dobson, K. J., Allabar, A., ... Coggins, J. (2019). A validated numerical model for the growth and resorption of bubbles in magma. V23F-0265. Paper presented at American Geophysical Union, Fall Meeting 2019, San Francisco, United States.