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Outgassing in the lab: Permeability development in two-phase magmas during simple shear

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The mechanisms governing permeability development in rising magmas influence the nature of volcanic outgassing and, consequently, eruption style. Of particular interest for any given system are: 1) the conditions under which permeability develops; 2) when permeability develops; and 3) the structure of the permeable network. To explore this, we performed a series of in-situ permeability measurements made during non-coaxial deformation of two-phase magmas at various shear strain rates.

Samples were synthesized prior to each experiment by sintering a haplogranitic (HPG8) powder at a temperature of 1150˚C. During synthesis, both the confining (P_C) and pore fluid (P_f) pressures were equal to 300 MPa; the confining medium and pore fluid were argon. An effective pressure of 0 MPa (P_C=P_f) ensured that bubbles trapped between the sintering grains were pressurized while the sample retained its cylindrical geometry. The magmas were then isothermally decompressed to 60 MPa to allow bubble expansion. Synthesized samples were impermeable and had bubble fractions between 0.11 and 0.14. Prior to deformation, the temperature was lowered to 880˚C and a differential pore fluid pressure was applied across the sample. The magmas were deformed in torsion until the pore fluid pressures above and below the samples equilibrated, providing an in-situ measure of permeability.

At low strain rates ($<\sim 2\times10^{-4}$ s^{-1}) permeability was not established, even at very large strains ($\gamma>7$). In these samples, bubbles acted as passive strain markers and recorded the total strain on the sample. At shear strain rates between $\sim 2\times10^{-4}$ and 4.5×10^{-4} s^{-1}, samples experienced strain hardening until they became permeable at high strain ($\gamma>3$). The permeable network in these samples was constructed of en echelon, Mode I fractures distributed around the sample periphery. The bubble density adjacent to these features was reduced with respect to the rest of the sample, suggesting aspiration of surrounding bubbles into the fractures. Above shear strain rates of 4.5×10^{-4} s^{-1}, permeability developed shortly after the onset of inelastic deformation. Again, permeability was established through a series of en echelon fractures, but there was no reduction in bubble density surrounding these features, suggesting that there was insufficient time to drain the abutting bubbles.

These experiments highlight a transition in deformation mechanism that has a profound effect on sample outgassing. Critically, the Mode I fracture geometry may expedite volatile movement upwards from the interior of the magma column and outward to the conduit periphery.