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Permeability Development in Volcanic Conduits during Persistent Degassing

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During persistent volcanic degassing, magma rises relatively slowly, and volatile exsolution and bubble growth can occur. Previous studies suggest that basaltic magmas, typical of persistently-active volcanism, contain sufficiently high initial volatile contents that high gas volume fractions, and the formation of permeable foams, can be achieved at depths well below the surface (e.g. Burton et al., 2007). The dynamics of the process of permeability development under conditions of magma rise rates typical of persistently-active systems, and its control on the degassing dynamics, are currently only poorly understood.

In this study, the processes of permeability development due to decompressional bubble growth in a viscous liquid were investigated using laboratory analogue experiments. Aerated Golden Syrup and water-syrup mixtures, containing bubbles of about 100 micron diameter, were decompressed at a range of rates in shock tube apparatus, to simulate bubble growth during magma rise. Calibrated light intensity measurements were used to determine the evolution of porosity within the liquid as pressure decreased. It was observed that porosity remained approximately uniform throughout the liquid depth until a critical threshold value was reached, when permeability developed in a narrow region near the liquid top, leading to rapid formation of a gas pocket, and subsequent foam collapse after the gas escaped.

We investigated the process of gas segregation from a narrow foam layer using experimental observations and a one-dimensional numerical model in which gas segregates by percolation through the magma, driven by buoyancy and the compaction of the foam layer (Michaut et al., 2009). The model was applied to Stromboli Volcano, Italy, where volatile contents suggest that a porosity of 0.5 (typical for permeability development) are attained at depths of about 80 MPa (or about 3 km; Burton et al., 2007). We find that the high magma rise speed and low viscosity only permit the formation of thin foam layers (of up to about 0.1 m depth) which can collapse on timescales of about 3 seconds to a final porosity which is only slightly lower than the threshold porosity for the onset of permeable flow. Magma rise speeds enable decompressional bubble growth to increase the final porosity to the threshold porosity in about 10 s. Gas segregation thus provides a mechanism for generating a cyclic source of segregated gas on a timescale of 1 to 10 s at moderate depths in the conduit. The volume of gas segregated is about 0.1 cubic metres at 80 MPa, which corresponds to the typical volume of gas puffs at the surface (Harris and Ripepe, 2007). We find that the model results are relatively insensitive to the precise values of threshold porosity (over the range considered typical for magmas) and magma rise speed, primarily as a consequence of the low magma viscosity providing limited viscous resistance to foam collapse.

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