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Exchange flow experiments and implications for degassing processes at basaltic volcanoes

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Persistent degassing at basaltic volcanoes can be sustained by an exchange flow of magma within the conduit, driven by the density difference between degassed crystallised magma at shallow levels and ascending buoyant gas rich magma. Experiments have been conducted to investigate buoyancy-driven, low Reynolds number, long time period, exchange flow of viscous fluids in a vertical pipe (length 1 m diameter 38.4 mm) between two reservoirs. The viscosity ratio between the two fluids, defined as the viscosity of the more dense fluid divided by the viscosity of the less dense fluid, was varied from 2 to 1900. Two distinct flow regimes were observed; axisymmetric core annular flow in which the less viscous fluid occupies a cylindrical core and the denser fluid flows downwards in an annulus, and side by side flow where both fluids are in contact with the pipe walls, and a single interface exists between them. The flow regime formed is dependent on the viscosity ratio between the two fluids. Core annular flows form at high viscosity ratios, $\gtrsim 100$. Side by side flows form at lower viscosity ratios, $\lesssim 100$.

Using data from the literature we define the properties of the ascending and descending magma as a function of pressure at Stromboli (Aeolian Archipelago). We use MELTS (Ghiorso and Sack, 1995; Asimow and Ghiorso, 1998) to constrain the composition of the melt and crystallinity and a gas solubility model to characterise the vesicularity, from which we calculate the viscosity of the respective magmas and hence viscosity ratio. We find that at pressures > 200 MPa the flow regime is core annular, but undergoes a transition to side by side flow at lower pressures as the viscosity of the ascending and descending magma become more similar. Using knowledge of the persistent, non explosive, gas flux and non-dimensional scaling relationships determined from the experiments the radius of the conduit and the volumetric flux of magma at Stromboli are calculated.