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Magma drainage around rising gas slugs and burst overpressure in Strombolian eruptions

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Strombolian activity is characterized by the recurrence of mildly-explosive eruptions that are driven by the rise and burst of discrete gas slugs which ascend rapidly through a more-or-less stagnant column of low-viscosity magma. Explosion dynamics and vigour, as observed at the surface, are mainly controlled by the slug's overpressure with respect to the ambient pressure. Depth of gas slug formation and the amount of gas in the slug are, in turn, known to influence the slug overpressure at burst.

We present a physical model for the development of overpressure within a rising gas slug, which allows the overpressure at burst to be calculated. The model neglects inertial and viscous effects and demonstrates that significant overpressure may develop even in their absence. Results show that the thickness of the magma film draining around the rising slug exerts a primary control on the development of overpressure: a thicker liquid film (i.e. a more viscous magma) results in a greater burst overpressure. Film thickness is represented dimensionlessly through the geometrical parameter A', which is the fraction of the conduit section occupied by draining magma in the slug region. A number of models exist which relate A' to conduit diameter and liquid viscosity. We test these models by performing scaled laboratory experiments on air slugs ascending in cylindrical pipes filled with liquids with a range of viscosities. The best-fit model is used to calculate A' for the range of non-dimensional flow conditions expected in volcanic conduits.

We apply our model to calculate burst overpressure of Strombolian eruptions using appropriate volcano-scale parameters. Model outputs are compared with previously published estimates of bursting overpressure derived from a broad dataset of eruptions at Stromboli; our results show that magma-static load and geometrical factors alone can account for the observed overpressures during slug-driven explosions.