SLUGS AND PLUGS – BIG EXPERIMENTS IN VOLCANO PHYSICS

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Key words Strombolian eruption; analogue experiments; volcanic conduits; gas slugs.

Strombolian activity is characterized by quasi-periodic, short-lived explosions, which vary greatly in magnitude. The explosions are understood to be driven by the bursting of large, overpressured ‘slugs’ of magmatic gas, which have ascended the conduit. We report analogue experiments[1,2], which model the fluid dynamics of slug-driven basaltic eruptions. Experiments were conducted in liquid-filled vertical pipes at a range of scales, from 0.02 to 0.25 m in diameter, and 2 to 13 m in height, allowing us to investigate Reynolds numbers $10^{-3} < Re < 10^{5}$, encompassing the natural range for volcanoes. The dynamics of both discrete gas slugs (Taylor bubbles) and continuous sluggy flow were quantified. A significant novelty of this study is that we explore the role played by the boundary conditions at the top and bottom of the conduit, which may be either blocked, plugged with a viscous liquid, or held at constant pressure, allowing us to mimic a range of natural conditions.

The presence of a viscous plug at the top of the conduit has been inferred from recent studies of strombolian pyroclasts, which indicate that degassed, crystal-rich magma, and gas-rich, crystal-poor magma co-exist and mingle in the shallow part of the volcanic conduit. We investigate the impact of the plug on eruptive behaviour experimentally, and find that the presence of a viscous plug enhances explosivity by increasing the overpressure within the ascending gas slug. We also find that the plug is prone to fluid-dynamic instability as the gas slug passes through it, causing the low and high viscosity magma analogues to intermingle, explaining the origin of the mingled pyroclasts observed in nature. The instabilities can also cause the slug to break into smaller pockets of gas, providing an explanation for pulsations in strombolian explosions, recently revealed by high-speed videography.

Separate analogue experiments, and numerical modelling, are used to investigate slug ascent under contrasting lower boundary conditions: zero-flux; and constant-pressure. Analogue conduit experiments typically use a zero-flux lower boundary (i.e. the base of the pipe is sealed). We show that a more-realistic constant-pressure boundary condition dramatically changes slug ascent velocity and the development of overpressure. Together these two studies constitute a new framework for understanding the role of the boundary conditions in shaping strombolian explosive activity.

Figure 1. Left) The Large Analogue Volcano Apparatus (LAVA); middle) analogue eruption of LAVA; right) eruption of Stromboli, Italy (from Stromboli online).

References

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