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Analogue modeling of slug-related geophysical signals in open vs. closed conduits: implications for Strombolian eruption dynamics.

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Strombolian activity is characterized by low-intensity, impulsive explosions, which may occur repeatedly over long periods of time. Strombolian explosions are thought to result from the bursting of discrete pockets (slugs) of magmatic gas that, deep in the plumbing system, decouple from the surrounding, low-viscosity magma and ascend through it. There are several different physical parameters that control the ascent and explosion of slugs and influence the nature of the resulting geophysical signals, including slug volume, conduit geometry and magma rheology. In this study, we investigate the role of vertical contrasts in magma rheology within the conduit, and the nature of the boundary conditions on magma flow at the top and bottom of the conduit; these parameters have so far received little attention in combination with slug flow. Variations in magma rheology in the conduit are perhaps more a rule than an exception at persistently active volcanoes, where gas-rich, crystal poor magmas share the conduit with their degassed and partially-crystallized counterpart, and where stiffened plugs develop quickly in vents in repose.

We have performed analogue experiments to investigate pressure and force changes resulting from the expansion and bursting of a slug in a liquid-filled pipe. The experimental set up is equipped with a high speed camera and pressure sensors, and the large vertical pressure gradient of the natural system is replicated by reducing the pressure at the top of the pipe with a vacuum pump. The lower end of the pipe may be either 'open' (constant pressure condition) or 'closed' (zero flux condition). The former is perhaps more geologically-sound, modelling a conduit that is connected with a constant pressure reservoir. The top of the pipe was either left fully open (to the constant-pressure partial vacuum) or 'plugged' with a layer of higher viscosity liquid, the thickness of which was systematically varied. Measured pressure variations inside and outside the pipe were correlated with high speed imagery of slug expansion and bursting. Data show that, during slug flow, open-base conditions develop an upward flux at the base of the pipe, which attenuates the magnitude of the pressure transients. We also find that rheological stiffening in the upper part of the pipe dramatically changes the magnitude of the observed pressure transients, favoring a more impulsive and more energetic pressure release into the overlying atmosphere. We discuss the implications of our results for the interpretation of the geophysical signals that underpin most of the monitoring systems at persistently active, mafic volcanoes.