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Experimental and numerical insights into seismo-acoustic signals generated during the expansion of rising and bursting large gas bubbles in low-viscosity magmas

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Strombolian activity produces gas-rich, magma-poor eruptions suggesting the separation and concentration of volcanic gases within the plumbing system. These gases are assumed to rise as relatively large bubble rafts or individual 'slug' bubbles that can cause detectable seismic activity on interaction with conduit geometry. Rising within the magma column, a gas bubble must expand appreciably in order to maintain magma-static pressure, for instance volume would increase by a factor of c. 200 for a 1 km rise to the magma-atmosphere interface. For a near-conduit-filling gas slug this expansion is one-dimensional (i.e. length-wise) and increases in rate non-linearly on approach to the surface. As they ascend, small gas slugs can expand sufficiently rapidly to maintain approximate magma-static pressure, but large gas slugs become dynamically overpressured.

In laboratory experiments, these unsteady flows of gas and liquid generate pressure changes measurable below the gas phase. They also cause apparatus motion that does not apparently relate directly to these changes. Computational fluid dynamic (CFD) simulation of experiments reproduces the pressure changes within the liquid and allows visualisation of the viscous shear force exerted on the conduit wall around and above the slug as it rises and expands. CFD simulations at volcanic scale then give estimates of the various force contributions that could occur in the natural system.

During the experiments, pressure change driven by slug expansion and burst was also measured in the ambient atmosphere above the upper liquid surface. We present experimental evidence of a range of burst processes that depend on the degree of gas overpressure in the slug. These processes range from the quiescent formation of a relatively long-lived liquid film that bursts some time after the gas slug has reached the liquid surface, through complex transitional behaviour where the meniscus detaches from the tube walls to form a bubble, to wholesale meniscus disruption when overpressure becomes appreciable. The nature of the atmospheric pressure response changes with the burst process, but is predominantly driven by two slug-depressurisation processes, namely the rise of the liquid-atmosphere interface and burst of an overpressured slug.

We compare simulated results to existing seismic and acoustic measurements from a number of volcanic centres and discuss the insights this gives in understanding flow dynamics during strombolian eruptions as well as identifying where laboratory, numerical and field approaches could be more closely related to provide more accurate descriptions of the eruption process.