Source mechanism regimes for the acoustic signals generated during the expansion of rising and bursting gas slugs in low-viscosity magmas.

Abstract

Experimental insights suggest that meniscus oscillation can only be a source mechanism for volcano-acoustic signals for non-explosive events. We suggest that the explosive source mechanism is a rapid pressure increase driven by slug expansion, and that any following oscillations represent a system-specific response.

Introduction

Atmospheric waves generated during gas escape from volcanoes (Figure 1) are linked to fluid dynamic processes within the conduit interacting with the atmosphere. These acoustic signals are often combined with seismic waves to interpret source mechanisms and conduit processes during explosive volcanic activity [e.g., Johnson et al., 2004].

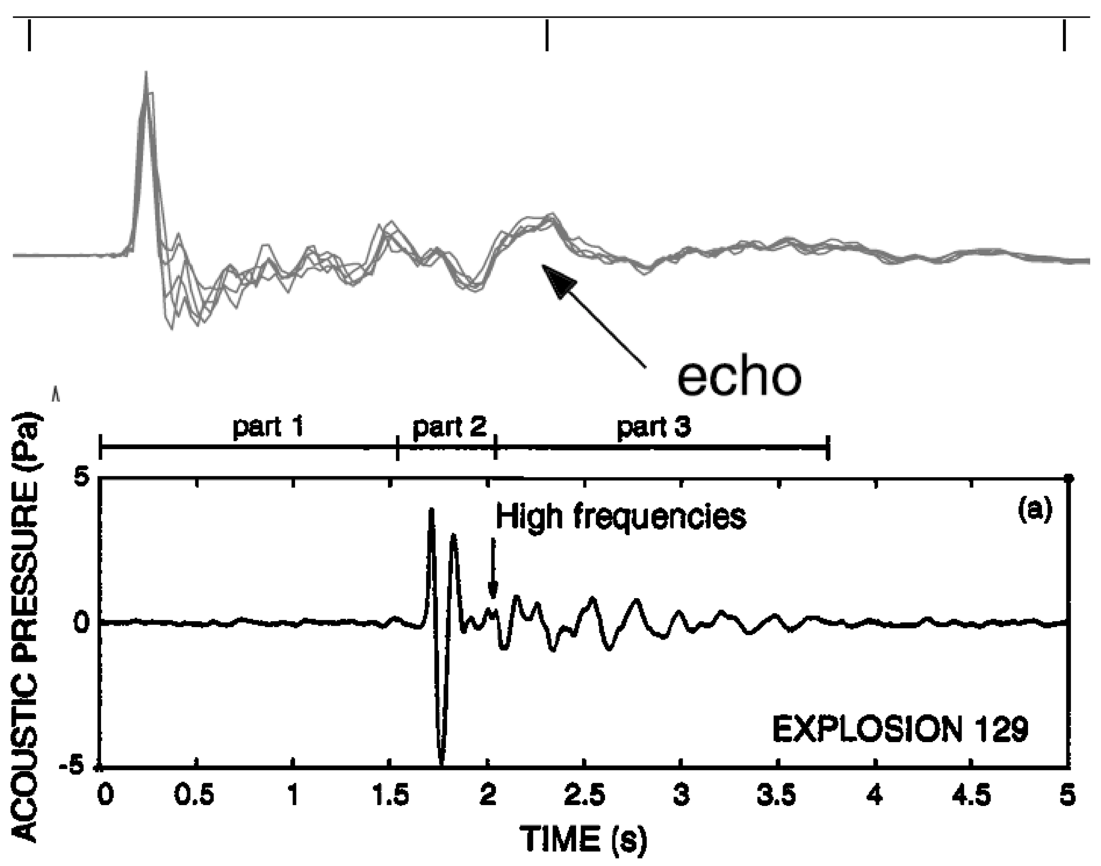

Figure 1. Acoustic signals from discrete strombolian bursts at Erebus [upper, Johnson et al., 2004] and Stromboli [lower, Vergniolle & Brandis 1994] both show an initial rise in pressure.

The signals are then subsequently different and this may reflect the responses of the individual system fluids and geometry to an initial stimulus.

Here we present experimental results of pressure changes in the gas above a liquid surface as a single large bubble (gas slug) rises in a tube, expands and bursts [James et al. 2008; 2009]. The ranges of observed behaviour are used to give insights into the fluid-dynamic source mechanisms of acoustic signals generated by strombolian eruptions, specifically those resulting from the bursting of large bubbles in low-viscosity magmas [e.g.,Vergniolle & Brandis 1994; Ripepe & Marchetti 2002; Johnson et al. 2003].

Experiments

Gas slugs rising from depth in magma will dynamically overpressure if sufficiently large [James et al. 2008; 2009]. The development of overpressure requires the slug to initiate at pressures some multiple that of atmospheric pressure. Experimentally, this pressure ratio was simulated by using an 'atmospheric' pressure of 1000 Pa to allow use of a relatively short flow tube (Figure 2). The initial slug volume was varied to explore the range of expansion and burst behaviours.

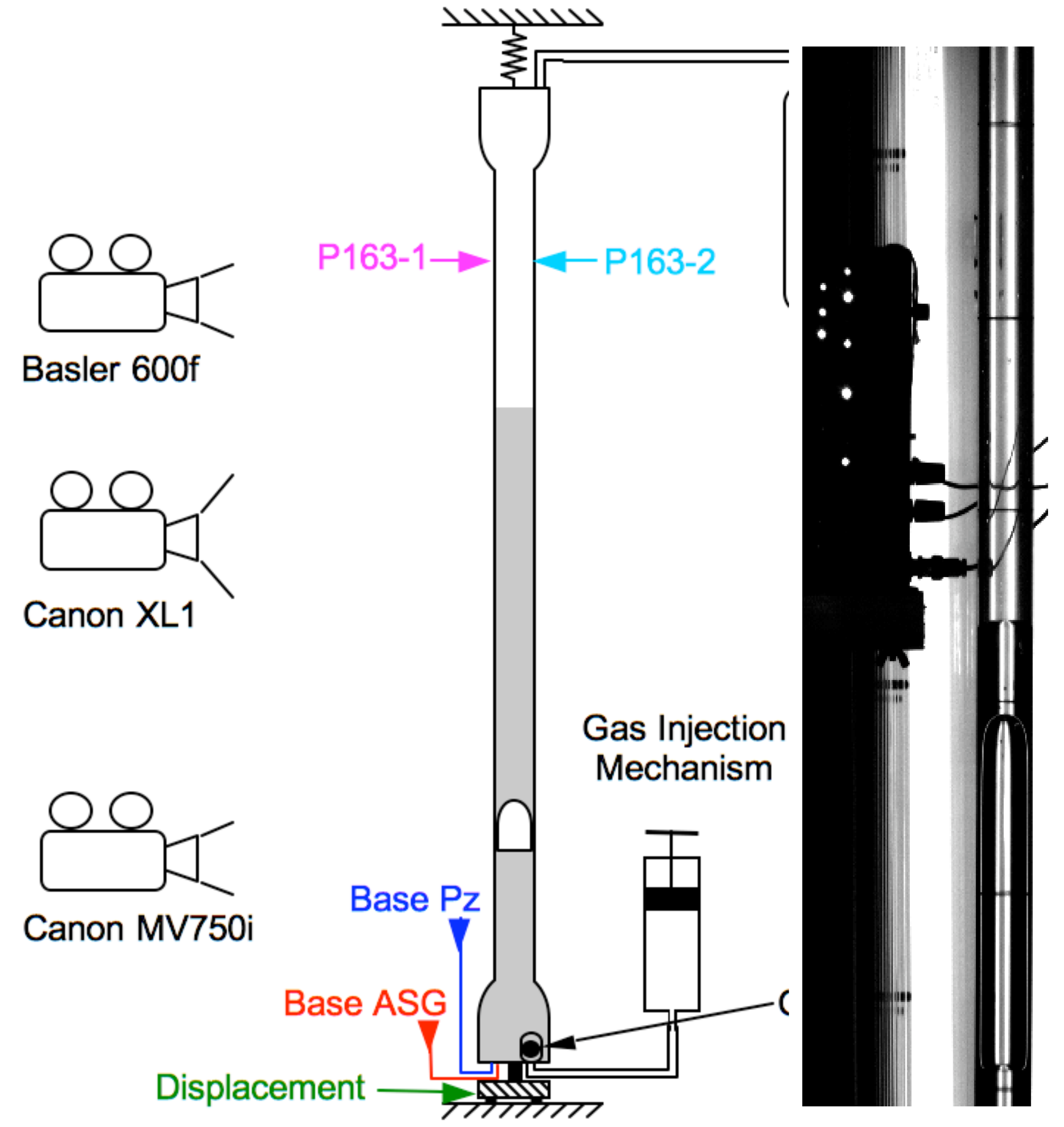

Figure 2. A single gas bubble is injected and rises to burst at the top of the liquid column.

'Atmospheric' pressure is established at 1000 Pa and measured using differential (P163) transducers. The flow was imaged with a range of video cameras.

Single video frames are correlated with logged data to enable matching of images and measurements.

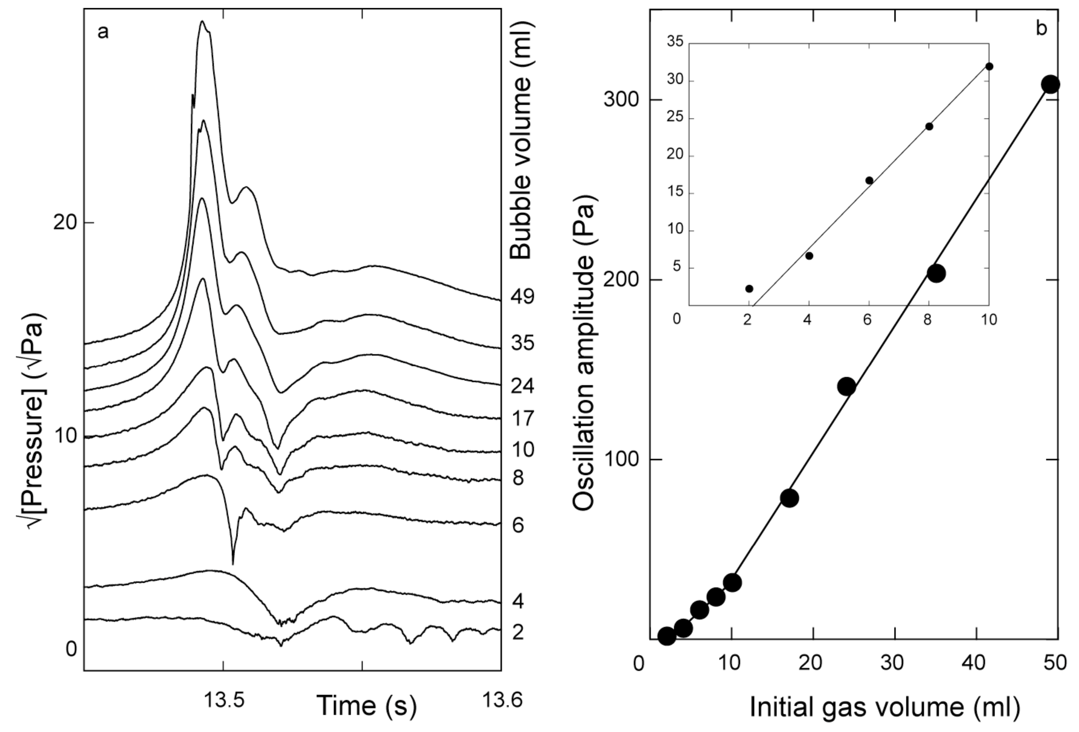

Figure 3.
(a) Amplitude of the pressure pulse on burst depends on initial slug volume.

(b) The relationship between amplitude and initial slug volume indicates two, and possibly three regimes of behaviour.

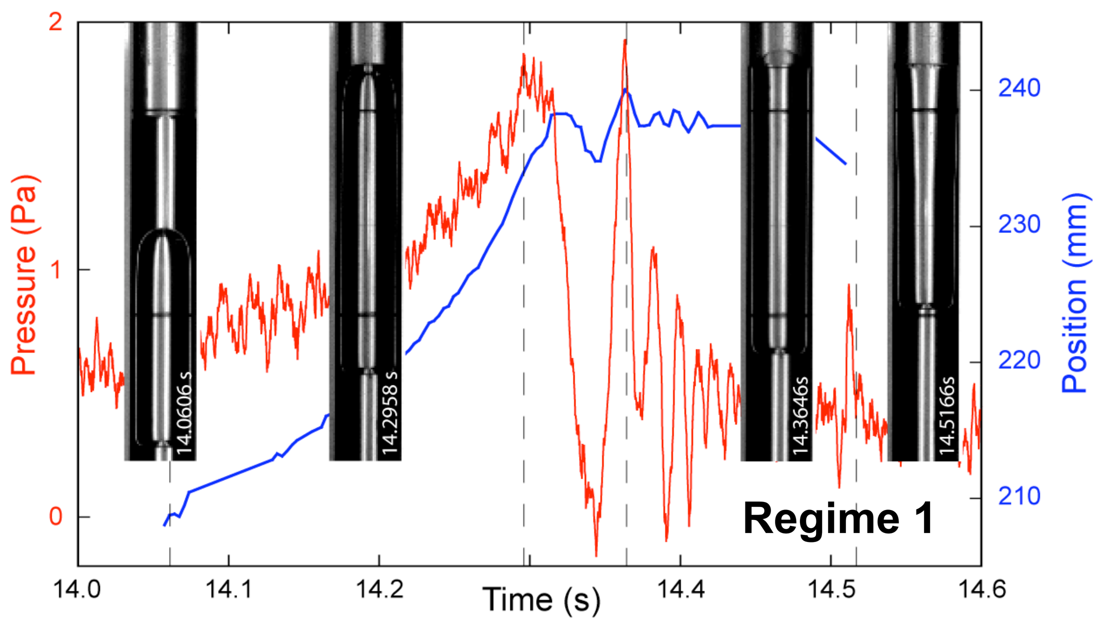

Figure 4. Regime 1 (2 ml slug): pressure rises as the slug expands to give a quiescent process with minimal dynamic overpressure.

Meniscus forms and oscillates [James et al., 2004] before bursting. This mechanism is similar to that proposed by Vergniolle & Brandeis [1994].

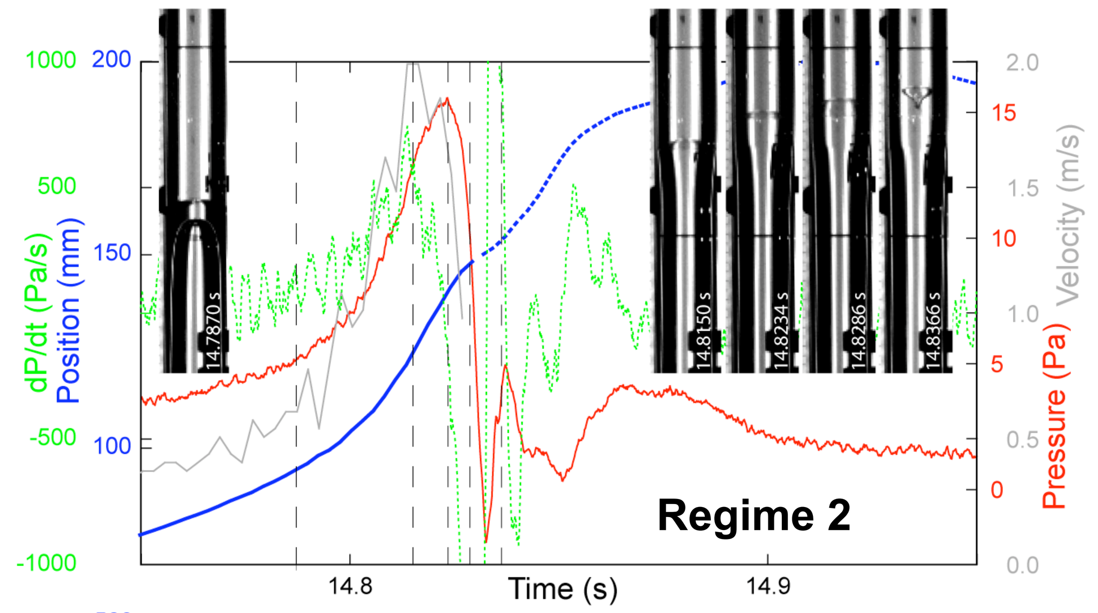

Figure 5. Regime 2 (6 ml slug): meniscus forms and then detaches from wall (bursts) *after* pressure peak.

Slight dynamic over-pressure folds meniscus into bubble and liquid drops.

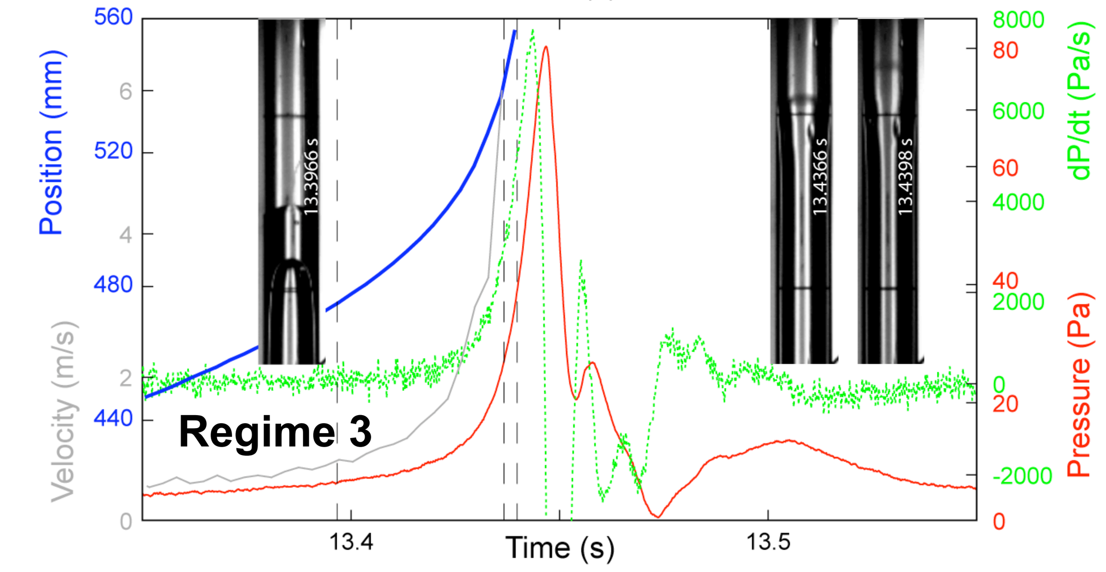

Figure 6. Regime 3 (17 ml slug): meniscus is disrupted into droplets by high level of dynamic overpressure in slug.

Slug bursts *before* pressure peak is recorded in this explosive event.

Discussion and Conclusions

The experimental results (Figures 3 - 6) show an initial increase in pressure that is consistent with field observations (Figure 1).

Quiescent events (Figure 4) generate small pressure increases as a result of slug expansion causing the liquid level to rise. The absence of overpressure allows the meniscus to be long-lived and oscillate as slug expansion stops. The waveform generated is similar to that measured by Vergniolle & Brandeis [1994], but for an *explosive* event at Stromboli (Figure 1).

Increasing slug volume creates dynamic slug overpressure and increasingly explosive events (Figures 5 & 6). The overpressure increase (remember that absolute pressure in slug is *decreasing*) becomes substantial and on burst the meniscus becomes a passive marker of the rapidly expanding gas. Pressure increase results from (a) rapid slug expansion pushing the liquid level upward, followed by a seamless transition to (b) slug burst releasing the overpressured gas. The waveform generated (Figure 6) is similar to that measured by Johnson et al. [2003] for an explosive burst at Erebus (Figure 1).

References

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