SRV report: Ascent of large bubbles through a foam – application to basaltic volcanic eruptions

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Volcanic eruptions are driven by the growth of gas bubbles that exsolve from the magma. In the uppermost parts of the sub-volcanic plumbing system the gas fraction is often $> 70\%$; i.e. the magma is a foam. In the case of basaltic magma, collapse of this foam may produce larger bubbles that rise through the foam and burst explosively at the surface. Understanding the behaviour of bubbles in basaltic magmatic foam is important because the explosions constitute a local hazard, and because similar foam collapse events within the crustal magma reservoir have been invoked as triggers for the onset of eruptions.

The purpose of this SRV was to create and characterize surfactant-free high-viscosity foams as laboratory analogues of magmatic foams and to investigate the dynamics of large bubbles in these foams. We dissolved a raising agent into golden syrup, which released gas over a period of 6-10 hours creating foams with gas fraction in the range 80-90% (see figure 1).

We probed the internal structure of these highly-opaque foams using Durham's x-ray tomography facility. The scanner accommodated columns of foam (diameter 10 cm, height 1 m) and was used both for radiography (single projections acquired in ~ 0.2 s) and tomography (full 3D reconstruction acquired in ~ 5 min) Repeated tomographs were collected during foam maturation over several hours. As desired, the maturation of the foam was slow as a result of the high liquid viscosity. At early times, less than about 3 hours, the foams were remarkably uniform, with low variation in bubble size. Following this, we observed an increasing amount of internal film rupture, which we plan to characterise using the tomographic data.

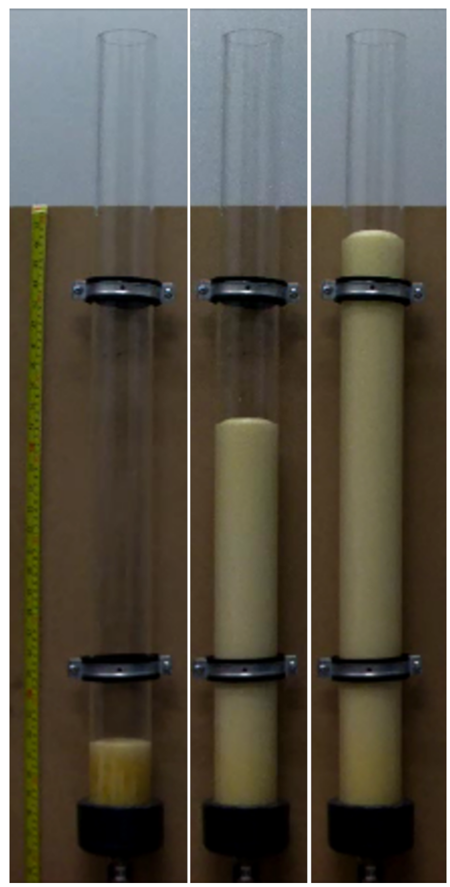

Figure 1: *Foam growth after one hour, five hours and eight hours respectively, at which point the foam is about 60cm high.*

We introduced a steady stream of gas at the base of the foams and observed a rapid collapse of the foam structure, leaving a small amount of foam at the base of the column and a layer of foam a few bubbles thick adhering to the walls. Adding smaller amounts of gas resulted in bubbles that rose more gently through the internal structure, but which were visually undetectable from the outside. We anticipate that the tomographic reconstruction will give more information about their passage.

These preliminary experiments have allowed us to confirm that working with syrup at room temperature can reproduce many of the characteristics of foamy basaltic magmas. In particular, the rapid collapse that we observed is consistent with observations of large, decoupled bubbles that burst in lava lakes, and more work is required to determine the conditions under which this occurs. The preliminary results of the x-ray imaging are encouraging, and demonstrate that the technique can be used to reconstruct internal structures in our analogue material. We anticipate needing to use synchotron-source x-ray – which allows ultra-fast imaging – to characterize the dynamics of bubble ascent through the foam.

The visit has also clarified the requirements for modelling: there are distinct differences between surfactant-stabilised foams and viscosity-stabilized foams, and incorporation of film rupture is important in predicting bubble motion in these foams.