Volcanic eruptions caused by seismic shaking (Ref IAP2-18-169)

Durham University, Department of Earth Sciences
In partnership with Glasgow University

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**Key Words**
1. Volcanology
2. Fluid dynamics & laboratory experiments
3. Modelling

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**Figure 1:** A panelled painting of the 1707 Hoei flank eruption from Mt. Fuji, which has been linked to the magnitude 8.6 fault movement on the Nankai megathrust on October 27th 1707.

**Overview**

Magas are subject to dynamic changes in pressure in the Earth's crust. These changes can be rapid, e.g. during earthquakes, or relatively slow, e.g. during magma convection, or ascent in conduits. Multiphase magmas – such as magma mushes, or magmatic foams – can be destabilised when pressures change or oscillate quickly. Foam collapse (in basalt systems) and mush remobilisation (in silicic systems) are both thought to be key triggers for volcanic eruptions.

Magma mush is a mixture of $\geq 60$ vol.% crystals with an interstitial melt. This is thought to be a jammed, immobile, and therefore uneruptible condition. However, recent work has shown that even a small perturbation can unlock a magma mush and remobilise it, such as when even a small fraction of bubbles grow in the melt, pushing the crystals apart from one another (Truby, 2016). Unlocking magma mush is thought to be a key triggering process for subsequent, large, silicic volcanic eruptions (see, for example, Cashman et al., 2017).

The student will test the extent to which crystal-bearing magmas can be remobilized when a pressure wave travels through the system. Transient oscillations of pressure are common in large seismic events, and may be of sufficient amplitude to (1) reorganise mush and trigger melt-crystal separation, and (2) rapidly nucleate and grow bubbles in the melt between crystals, unlocking the system. And yet, this process remains untested.

This project will take two approaches: numerical and experimental to answer these fundamental questions:

1. Can a transient pressure wave of seismic characteristic frequency, amplitude and duration, result in nucleation of bubbles in super-saturated melt?
2. Is the nucleation and subsequent growth of seismically induced bubbles sufficient to unlock a magma mush?

Well known seismically triggered eruptions will be used as case studies.

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**Methodology**
The student will use a combined numerical and scaled experimental approach. They will have access to recently developed numerical tools at Durham University for disequilibrium bubble growth in magmas, and to a host of models for the physical and chemical properties of magmas of all compositions. These models will provide a starting test bed for exploring the effects of pressure oscillation on a system in which gas exsolution and bubble growth are important. They will also have access to models for mush convection and mobilization (e.g. Roper et al., 2007).

They will build, test and use a new scaled experimental apparatus for applying a frequency and amplitude of pressure oscillation to a body of liquid containing solid particles – an experimental analogue of a real magma. The properties (such as viscosity, and density ratio) of this analogue system will be carefully scaled to natural scenarios, such that the same characteristic physical processes apply.

A gas phase can be dissolved in the liquid by pressurising the system prior to oscillation, such that during each oscillation the gas phase switches from exsolving to dissolving. This simulates the physical effect of a disequilibrium gas phase on mush reorganisation in natural magmatic systems.

The experimental materials will be designed such that they cover a range of liquid viscosities, crystal (particle) volume fractions, and potential gas contents. The variables will be chosen so that they cover a range of plausible scaled frequencies and amplitudes of pressure. Depending on the aptitude and preference of the student, more or less emphasis can be placed on either the numerical or the experimental campaigns. The below timeline is therefore advisory and an example possibility.

This project will be conducted in collaboration with Dr Ben Kennedy (UC, New Zealand), and Dr Jeremie Vasseur (LMU, Munich).

**Timeline**

One possible timeline for the project is as follows;

Year 1: Experimental campaign. Together with the supervisory team, the student will build, test and use a rig for imaging and measuring the dilation or contraction of 2-phase and 3-phase suspensions.

Year 2: The student will perform extended experimental campaigns using a wide range of 2- and 3-phase suspensions relevant to all magmas on Earth across scaled frequencies and amplitudes typical of large seismic events in the crust.

Years 2-3.5: The student will adapt and extend existing numerical tools developed at Durham University and University of Glasgow, for bubble growth and mush kinetics applicable to magma. These will be run using natural pressure-time histories for a range of pressure waveforms. Importantly, the student will apply their general and re-scaled results to specific cases of well-studied volcanic eruptions.

**Training & Skills**

The student will receive detailed training in all areas of physical volcanology, but in particular in:

- Experimental design, dimensional analysis, and scaling from experiments to natural conditions. These training points will be essential for performing well-posed experiments.
- Simple manipulation of seismic datasets to extract frequencies and amplitudes of ground motion at depth.
- Simple numerical methods for using and adapting existing codes for bubble growth in super-saturated magmas.

The student will join the Durham Volcanology Group; a dynamic collaborative research environment with 8 staff and approximately 20 postdocs and postgraduate students. Co-supervision will extend this group to LMU, Munich, and UC, New Zealand.

**References & Further Reading**


**Further Information**

Please contact fabian.b.wadsworth@durham.ac.uk for more information.