Feeding a basaltic volcanic eruption (Ref IAP2-18-92)

Durham University, Department of Earth Sciences
In partnership with British Geological Survey

Overview
Basaltic volcanic eruptions span a wide spectrum of styles, from the relatively gentle effusion of lava, to violent explosions that produce lofting ash plumes. The eruption style, and its evolution in time and space, depends to a large extent on multiphase fluid dynamic processes that occur within the magma as it travels through the sub-volcanic plumbing system. Most basaltic eruptions are fed by dykes, which are a ubiquitous feature of eroded basaltic volcanoes. When a dyke intersects the surface, it first forms a fissure eruption (figure 1). Usually, the eruption localizes to a single vent within a few days, and often builds a scoria cone or shield, depending on its vigour.

Beneath the vent, the conduit retains a dyke geometry, and various lines of evidence indicate that complex magma flow patterns develop within the dyke, shown schematically in figure 2. Understanding the magma flow pattern within a dyke, and how it changes with time, is crucial because it controls the nature of the eruption at the surface. In particular, localization of gas-rich magma into rapidly upwelling jets is expected to promote more explosive eruption styles.

The main goals of this project are:
1) to collect field evidence and use laboratory experiments and/or numerical models to reconstruct magma flow processes in volcanic conduits from textural evidence in dykes;
2) to interpret magma flow patterns in exposed volcanic conduits in the UK and Western US.

Bubbles and crystals are very common in dykes, and often show preferential alignment that is imposed by the magma flow. These textures provide a record of the flow history through an eruption, however, their interpretation has been hindered by a lack of understanding of the processes that create them. In this project we will investigate and quantify the process of marginal accretion of crystal- and bubble-bearing magma as it flows along a conduit, using laboratory experiments and/or numerical modelling, depending on the skills of the applicant. Results will be used to analyse and interpret field samples from dykes exposed at different depths within the subvolcanic plumbing system, allowing us, for the first time, to reconstruct dyke flow processes through time and space.

Figure 1: 2014 fissure eruption of Holuhraun, Iceland (copyright www.gudmund.is)
Methodology

Experiments:
Suspensions of bubbles and particles in molten wax will be pumped through a model dyke (a high-aspect-ratio duct) with one cooled wall. The wax will solidify against the wall, producing a marginally-accreted facies that will be texturally analysed using x-ray computed tomography. Experimental parameters will be systematically varied, including: size, shape and concentration of particles; size and concentration of bubbles; wax flow rate; cooling rate; duct geometry. Parameters will be scaled to the natural system.

Fieldwork:
Textures exposed in dykes of the British Tertiary Igneous Province will be mapped at the crystal/vesicle scale in the field, and samples will be collected for XRCT and SEM analysis. The samples will inform laboratory experimental parameters. Later fieldwork in the Western US will focus on mapping spatial and temporal changes in textural indicators of magma flow, in order to reconstruct 4D flow patterns.

Modelling:
For a student with strong quantitative skills, there is significant scope for numerical modelling of physical processes at a range of scales. For example, at the micro-scale, the shapes of bubbles/vesicles that are deforming during accretion can be modelled; and at the macro-scale, convective flow processes within the dyke can be modelled (figure 2), along with the thermal structure that develops around the dyke.

Interpretation and application:
The proposed project links in with the NERC-funded DisEqm consortium (Universities of Manchester, Durham, Bristol, Cambridge, and Arizona State), which aims to develop a whole-system numerical model of magmatic flow in the sub-volcanic plumbing system. Collaboration with the broader consortium team will provide the ideal environment for applying the findings of the studentship project. The interpreted field data will provide a robust validation of the DisEqm numerical modelling; conversely, the DisEqm model will provide a ready framework for applying studentship findings and realising impact.

Timeline

Y1: BTIP fieldwork; textural analysis of field samples; development of laboratory experimental approaches
Y2: Laboratory experiments; textural and data analysis; numerical modelling
Y3: Fieldwork in Western US; 4D reconstruction of flow in dykes exposed to different depths
Y3.5: Application and implications; thesis write-up

Training & Skills

The student will be trained in:

- Laboratory techniques, including experimental design, scaling and dimensional analysis, and safe working practices
- Field analysis of dykes and their marginal facies
- X-ray tomography and textural analysis
- Numerical modelling, as appropriate.

The student will be embedded in the Durham Volcanology Group, a vibrant and collaborative group of 8 staff and around 20 postdocs and graduate students. Co-supervision will link the student to the BGS Volcanology Team who research volcanic processes, hazards and risks, and work on applied science through engagement with policy and decision makers. Links to the DisEqm project are an opportunity to be part of a major international research project.

References & Further Reading


Further Information

Please direct queries to ed.llewelin@durham.ac.uk