

Proposed Studentship

Energy sources, behaviour, and durations of volcanic eruptions

Supervisor: Prof Agust Gudmundsson

Project description:

Why are some eruptions of long duration and others of very short duration? Why do some eruptions of short duration produce much more eruptive materials than other eruptions of much longer duration? Why do the volumetric flow rates (effusive rates in the case of lava production) decline rapidly after the peak, whereas others decline much more slowly? These are all fundamental questions in theoretical and applied volcanology that need to be answered in order to **forecast the likely behaviour and duration** of an eruption once it has started.

More specifically, to understand volcanoes and forecast what is going to happen during (1) an unrest period and (2) once an eruption has started, we need to explore and answer these questions. In this proposal **a new approach** is taken to answer the questions, namely the energy approach – via **thermodynamics**. The questions and the potential answers are recast within the framework of thermodynamics, focusing on the elastic energy that accumulates in the volcano before and during the unrest period – energy that is partly available to drive a dyke to the surface and magma out of the chamber once the eruption has started.

Background and working hypothesis

Thermodynamically, all volcanoes are open systems; they exchange heat and materials with their surroundings. For an eruption to occur, there must be sufficient energy within the volcano to propagate a feeder dyke to the surface. Furthermore, for a significant volume of magma to issue during the eruption, there must be energy available to press the magma out of the associated chamber and to the surface. **A principal aim** of the project is to provide energy models to explain so as to be able to forecast:

- (1) the duration of an eruption,
- (2) the volumetric flow rates during the eruption,
- (3) the eruption behaviour, and
- (4) the eruptive-volume size distribution of eruptions.

Using analytical methods, the aim is to explore the working hypothesis that the primary energy responsible for feeder-dyke formation is **elastic energy**. The elastic energy consists of two main parts:

- the **strain energy** stored in the volcano before magma-chamber rupture and dyke injection and
- the **work done** through displacement of the flanks of the volcano (or the margins of a rift zone) and the expansion and shrinkage of the magma chamber itself.

In the working hypothesis, it is proposed that large volumetric flow rates are primarily related to the size of the aperture of the feeder-dyke/volcanic fissure as well as to the magmatic overpressure and work done through the displacement of the flanks of the volcano during the initiation of the eruption.

It is suggested that, in the absence of a collapse caldera formation, the main factor that determines the **duration of an eruption**, from a chamber of a given size, is the excess pressure (the pressure in excess of the minimum principal compressive stress) in the chamber. This **excess pressure** can be maintained for a considerable time (giving rise to eruptions of long duration), depending on several factors. These factors include (1) flow of new magma (from a deeper reservoir) into the shallow chamber during the eruption; (2) gas exsolution and expansion in the chamber during the eruption; and (3) shrinkage (volume reduction) of the chamber during the eruption.

Experience from Iceland and elsewhere indicates that in most cases the rate of **inflow** of new magma into a shallow chamber is too low to have significant effects on the duration of the eruption. **Gas exsolution** and expansion is certainly one of the fundamental factors for determining the duration and volumetric flow rate of eruptions issuing evolved magmas, but is much less so for primitive magmas. Elastic, and inelastic, **shrinkage** of the magma chamber is a major factor contributing to the duration and volumetric flow rate of an eruption. The rate and size of shrinkage depends on the strain energy stored in the volcano before the eruption. The working hypothesis is that stratovolcanoes generally **store more elastic energy, per unit rock volume, than basaltic edifices**, a fact that partly explains their commonly widely different behaviour during eruptions.

Data and publications

The data for this research will be obtained from many resources, now widely available on the internet and through connections with colleagues worldwide. The data include:

1. **GPS deformation** data from active volcanoes (plenty of such data from volcanoes worldwide, including Italy, Iceland, USA, etc).
2. **InSAR deformation** data from active volcanoes (same as for point 1). In fact, there is a plan now to make all GPS and InSAR data, at least from the European Space Agency and some other institutes, available to all scientists who like to work on these data.
3. **Strain-meter data**. These are readily available for many volcanoes, but need to be partly collected from numerous publications. For example, strain meters have been monitoring strain in many volcanoes in Iceland over decades.
4. **Rock-physics data**. These are readily available for most volcanic rocks from the literature. Up-scaling of the laboratory data is needed, and the supervisor (Gudmundsson) has a long experience in upscaling for volcanoes and fault zones. There is already collaboration with several rock-physics laboratories in the UK.
5. **Field data** and experience for the PhD student will be obtained at several active volcanoes in Iceland, Italy, and elsewhere.
6. **Numerical** (Comsol, Beasy) programs are available at Royal Holloway.
7. The PhD student will become a member of the **Volcanotectonic Group** at Royal Holloway, participate in meetings in the UK and abroad, and write papers for publication in international journals in addition to writing the PhD thesis.

Selected recent relevant papers/abstracts

1. Gudmundsson, A., and Mohajeri, N., 2013. Energy sources and duration of volcanic eruptions. IAVCEI Meeting, Japan, July 2013.
2. Gudmundsson, A., and Mohajeri, N., 2013. The thermodynamics of fissure swarms and fault zones: application to the Husavik-Flatey Fault. International workshop on earthquakes in North Iceland, June 2013.
3. Gudmundsson, A., DeGuidi, Scudero, S., 2013. Length-displacement scaling and fault growth. Tectonophysics (online).
4. Gudmundsson, A., Mohajeri, N., 2013. Large and small eruptions. EGU, Vienna, 2013.
5. Gudmundsson, A., 2012a. Magma chambers: formation, local stresses, excess pressures, and compartments. J. Volcanol. Geotherm. Res., 237-238, 19-41.
6. Galindo, I., Gudmundsson, A., 2012. Feeder-dykes in rift zones: geometry, emplacement, and effusion rates. Nat. Hazards Earth Sys. Sci., 12, 3683–3700.
7. Gudmundsson, A., 2012. Strengths and strain energies of volcanic edifices: implications for eruptions, collapse calderas, and landslides. Nat. Hazards Earth Sys. Sci., 12, 2241-2258.

More details as to publications, research topics, and the activities of the **Volcanotectonic Group** (a part of the group **RF³ – Rock Fractures and Fluid Flow**) at Royal Holloway in general can be found at:

- Royal Holloway University of London homepages.
- The Volcanotectonic Group homepage at the Department of Earth Sciences
- ResearchGate pages (for the various Group members)
- Academia.edu pages (for the various Group members)
- Google Scholar pages (for the various Group members)

Potential funding:

We currently have a vacant NERC studentship available for the **2013 academic session** following a withdrawal of a previous student, which has a maximum funding of 3 years. The NERC studentship will be awarded to the best candidate over a range of PhD topics on offer.

Eligibility:

Eligibility for this studentship is restricted to UK citizens and applicants who have been ordinarily resident in the UK throughout the 3-year period preceding the date of application for an award, and has settled status in the UK within the meaning of the Immigration Act 1971 (i.e. is not subject to any restriction on the period for which he/she may stay). Further information can be found from the National Environmental Research council website <http://www.nerc.ac.uk/funding/eligibility.asp>.

How to Apply:

Please use the **online application system**

(<http://www.rhul.ac.uk/studyhere/postgraduate/applying/home.aspx>) to submit an application for this project. Applications should include 2 letters of reference, a cover letter and CV- applicants are also requested to email a copy of their CV directly to the lead supervisor of this project. Please ensure you complete your application **by Friday 23rd August 2013**.

Interviews will be in the week commencing 2nd September (most likely the 2nd or 3rd) and offers will be made soon after.

For administrative queries please email info@es.rhul.ac.uk and for project queries, contact the Lead Supervisor- staff contact details will be on the website:

<http://www.rhul.ac.uk/earthsciences/staffdirectory/home.aspx>