Energy sources, behaviour, and durations of volcanic eruptions

Agust Gudmundsson[1], Nahid Mohajeri[2]

[1]Department of Earth Sciences, University of London Royal Holloway, UK, [2]Department of Geography, University College London, UK

E-mail: rock.fractures@googlemail.com

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 most volumetric flow rates (effusive rates in the case of lava production) decline rapidly after the peak, whereas some 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.

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 be issued during an eruption, there must be energy available to press the magma out of the chamber and to the surface. Here we provide energy models to explain (1) the duration of eruptions, as well as their (2) volumetric flow rates, (3) behaviour, and (4) the eruptive-volume size distributions. We show that the primary energy responsible for feeder-dyke formation is elastic energy, which consists of two parts: (1) the strain energy stored in the volcano before magma-chamber rupture and (2) the work done through displacement of the flanks of the volcano and the expansion/shrinkage of the magma chamber itself. Large volumetric flow rates are related to the size of the aperture of volcanic fissure, the magmatic overpressure, and the work done through the displacement of the flanks of the volcano.

In the absence of a collapse caldera formation, the duration of an eruption (from a chamber of a given size) is primarily related to the chamber excess pressure, which 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.

Normally, 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. We show 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.