Physical controls on the frequency and magnitude of volcanic eruptions

Luca Caricchi[1], Catherine Annen[2], Jon Blundy[2]

[1]Section of Earth and Environmental Sciences University of Geneva, Switzerland, [2]School of Earth Sciences, University of Bristol, United Kingdom

E-mail: luca.caricchi@unige.ch

The frequency at which volcanic eruptions occur is inversely proportional to the volume of magma released in a single event. The volumes of erupted magma range from a fraction of a cubic kilometer up to thousands of cubic kilometers during rare super−eruptions. The rate at which magma is supplied from depth, the mechanical properties of the Earth′s crust and the regional tectonic regime are known to play a role in controlling volcanic eruptions, but their relative contribution has not been quantified. We combined results from thermo−mechanical modeling and Monte Carlo simulations to quantify the relative contribution of magma fluxes and the physical properties of the crust on likelihood and volume of volcanic eruptions. The calculations were performed considering the pulsative injection of magma and varying randomly and within geologically reasonable values, size, shape and frequency of magma injections together with the long−term average rate of magma input, and the visco−elastic properties of the crust.

The average rate of magma supplied to the upper crust over hundreds of thousands of years appears to control the volume of magma that can potentially be released during a single eruption, whereas the time interval between short−lived pulses of magmatism, affects the total duration of magma injection preceding an eruption.

Our calculations reconcile the relationship between erupted volume and upper crustal magma residence times, and replicate the correlation between erupted volumes and caldera dimensions. Our modeling shows that pressurization associated with magma injections is responsible for relatively small and frequent eruptions, whereas magma buoyancy is key to triggering super−eruptions. These calculations also permit to define the largest physically possible eruption that could occur on Earth, which is important to improve the statistical significance of the relationship between frequency and magnitude of volcanic eruptions.