Geophysical Research Abstracts
Vol. 21, EGU2019-13469, 2019
EGU General Assembly 2019

Relating the evolution of upper crustal silicic magma reservoirs to the timing of eruptions and passive gas escape

Wim Degruyter (1), Meredith Townsend (2,3), Christian Huber (2), Olivier Bachmann (4), Francesca Forni (5), and Andrea Parmigiani (6)

(1) School of Earth and Ocean Sciences, Cardiff University, Cardiff, United Kingdom (degruyterw@cardiff.ac.uk), (2) Department of Earth, Environmental and Planetary Sciences, Brown University, Providence, RI, USA, (3) Department of Earth Sciences, University of Oregon, Eugene, OR, USA, (4) Institute of Geochemistry and Petrology, ETH Zürich, Zürich, Switzerland, (5) Asian School of the Environment, Nanyang Technological University, Singapore, (6) FlowKit, Lausanne, Switzerland

Upper crustal magma reservoirs produce a wide range of activity that can be expressed at the earth's surface through complex variations in eruption frequency, passive gas loss, or periods of quiescence. This complexity depends strongly on the interplay between various processes occurring in the sub-volcanic magma reservoir. We attempt to disentangle these processes with a thermo-mechanical magma chamber model that includes (i) recharge of new magma from deeper levels in the crust, (ii) crystallization, (iii) volatile exsolution, (iv) heat loss to the crust, (v) visco-elastic response of the crust, (vi) gas loss from the chamber, and (vii) mass withdrawal due to eruptions.

The model results can be analyzed in a framework that consists of three fundamental timescales: the magma injection timescale, the cooling timescale, and the timescale for viscous relaxation of the crust. They indicate that magma chamber growth is promoted by rapid injection and rapid crustal relaxation, and that there exists a zone within the parameter space in which chambers are expected to simultaneously grow and erupt. This zone is particularly sensitive to the storage depth, which appears ideal around 2 ± 0.5 kbar. We apply our results to four examples of long-lived magmatic systems (Laguna del Maule, Campi Flegrei, Santorini, and Aso) and find good agreement with patterns of eruption frequencies and volumes at these volcanoes. We further provide a scaling relationship that can be used to determine the amount of chamber growth and volatile exsolution from changes in the frequency and volume of eruptions. The scaling matches the model results well and suggests that recent post-caldera eruptive phases at Laguna del Maule, Campi Flegrei, Santorini, and Aso all were triggered by magma recharge and accompanied by significant reservoir growth.

We then combine the model with a pore-scale model to study the efficiency of gas escape from the chamber. We find that loss of gas from the reservoir will be most significant at intermediate to high crystal fraction, when the system has reached a mature mush state. Shallow volatile-rich systems that tend to exsolve volatiles through second boiling and gas channels form efficiently as soon as the crystal volume fraction reaches $\sim$0.4 to 0.5. We, therefore, suggest that estimates of volatile budgets based on volcanic activity alone may be misleading because they tend to significantly underestimate the transport of magmatic volatiles to the surface and lead to inaccurate ratios of elements with different solubilities.