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A fully coupled petrological geodynamical model to investigate the evolution of crustal magma chambers

Lisa Rummel (1,2), Boris J.P. Kaus (1,2), Richard W. White (1,2)

(1) Institute for Geosciences, Johannes-Gutenberg University, Mainz, Germany, (2) Center for Volcanoes, Atmospheres and Magmatic Open Systems (VAMOS), Mainz, Germany

The evolution of crustal magma chambers can be considered from a range of different physical and chemical perspectives. Most previous studies focus either on the petrological side (assuming only thermal effects and ignoring mechanics), or on the mechanical evolution (assuming a fixed melt chemistry). Here, we develop a method that fully couples petrological with geodynamic modelling, by combining a finite element code, MVEP2, with a thermodynamic modelling approach (Perple_X) that takes the evolving chemistry into account. The evolution of melt chemistry in a crustal magma chamber is analyzed by focusing on the effects of depth and temperature as well as size and shape of the magma chamber(s). The models show that each of these factors influences the melting behavior of rocks, the magma composition and their effects on the mechanics in the upper lithosphere. Interactions with country rocks (assimilation), ongoing rock depletion (fractional melting) and a possible open system behavior (fractional crystallization) and their effects on magma chemistry are taken into account.

The chemical and mineralogical evolution of the melt source, composition (10 oxide component system) of intrusive and extrusive rocks as well as melt fraction and density are tracked on particles using a marker-in-cell-method in the geodynamic code. After each melt extraction event, the employed phase diagram is updated or recalculated based on the residuum chemistry that shifts the solidus to higher temperatures with sequential melt extraction. The resulting wide range in chemical compositions and the volume of intrusive and extrusive rocks are tracked in time and space over the melting region. The newly generated crust employs phase diagrams which are directly computed from the chemistry of extracted melts. Plutons are able to melt again as long as the local temperature is higher in the model than the solidus temperature in the employed phase diagram.

As a result, our models make testable predictions on types of erupted lavas. We show an application to the plume-related intracontinental West Eifel volcanism (Germany), where our models explain a sudden change in K_2O/Na_2O-ratios in the volcanic rocks by a transition between melting a metasomatized and a pyrolitic mantle. We also show initial results from crustal melt extraction in an arc system.