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Compositional evolution in crustal magmatic systems investigated by coupled petrological-geodynamical models

The chemical and mineralogical evolution of crustal magmatic systems are incompletely understood, as most studies are limited either by their temporal or spatial resolution. Exposed plutonic bodies lack information about the chemical, thermal and mechanical processes in the past, which strongly influence the evolution of each individual magmatic system. We focus in our study on the compositional evolution of plutonic systems affected by thermal and mechanical processes. For this, we coupled a 2D visco-elasto-plastic finite element code (MVEP2), with a thermodynamic modelling approach (Perple_X). Density, melt fraction, chemical liquid and solid as well as mineralogical compositions are computed for different starting rock compositions over a given *P-T* range. The evolving chemistry is tracked on markers via 10 main oxides (SiO_2-TiO_2-Al_2O_3-Cr_2O_3-MgO-FeO-CaO-Na_2O-K_2O-H_2O), of which there are initially ca. 1.3 million. As soon as the local chemistry changes due to melt extraction, new phase diagrams are computed based on the residual solid chemistries for the deflated magma chamber or on the liquid chemistry for newly generated magma filled fractures. More than 50,000 phase diagrams are computed to track the chemical evolution of each individual marker affected by melt extraction.

For studying crustal scale magmatic systems, we injected mafic sills periodically into the crust. How the composition in magmatic systems changes is controlled by mechanical processes as fractures transport magma through the crust and successively deplete the source region. The formation of magma filled fractures is tracked with a semi-analytical dike/sill initiation algorithm that forms new magma filled fractures as a function of the local stress field above the partially molten region. Dike generation is thus affected by the background strain rate, amount and depth of melt accumulations as well as parameters that control the plastic and viscous behaviour of the crust (e.g. cohesion, viscous creep flow law etc.).

Results show that the lifetime of magma chambers is influenced not only by the thermal structure but also by the formation of magma filled fractures that extract magma and thus deplete the source region. Deep sill injection zones and a lower rock cohesion value stabilize the melt in source and thus support the formation of SiO_2-rich rocks from basaltic injected magma. The local stress field affects the crack propagation direction and thus even controls how the surrounded crust is heated up. To which extend melting of crustal host rocks takes place, depends on the number, size and arrangement of magma filled fractures as well as the hydration state of the rocks. Magma mixing affects mechanical processes (fracturing) as well by changing the thermal and compositional structure and thus the amount of melt in the partially molten region.

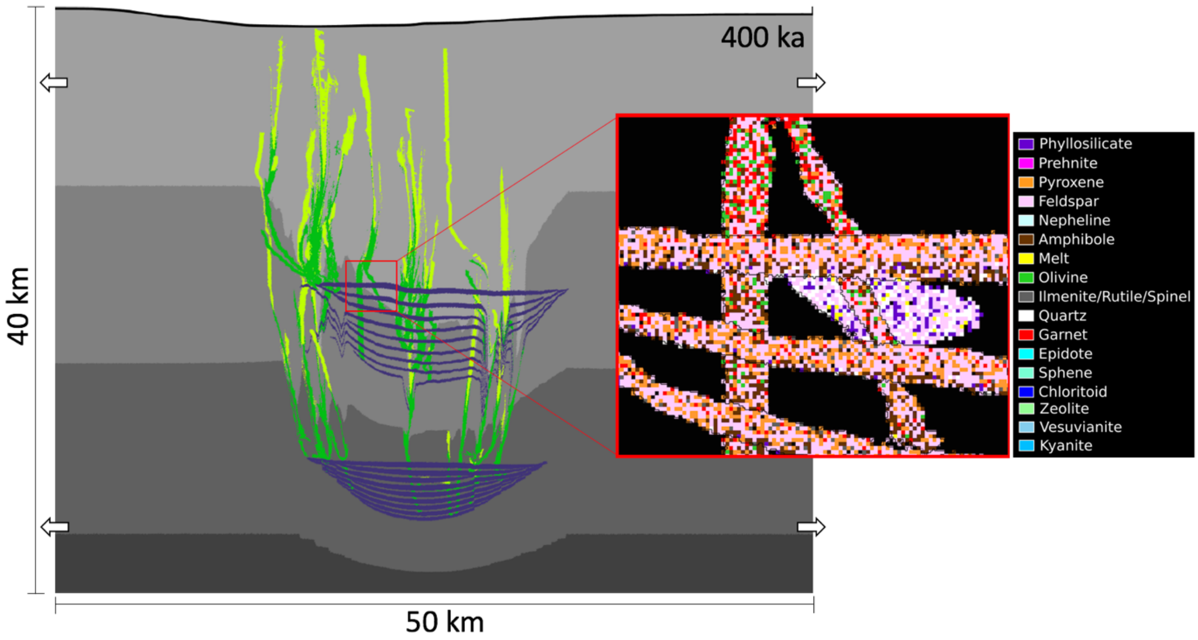

Figure 1: Snapshot of the magmatic system after 400 ka under extensional conditions ($\varepsilon_{BG} = 10^{-15}$ *1/s). Injected sills (blue) trigger dike formation (green/yellow). Compositional evolution of the system is tracked and thus also the mineral assemblages.*