Numerically modeling routes of sequential magma pulses in the upper crust

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Understanding the evolution and generation of large scale igneous bodies is important to understand the evolution of the crust. The way igneous bodies are constructed and the timescale of construction control the location, volume and composition of melt (Annen, 2015). Despite many previous studies that address the construction of igneous bodies, it remains unclear why melt focusses within a specific area. Igneous bodies are usually the result of multiple magmatic pulses that solidify in the same location. In many cases the time between subsequent pulses is sufficiently long for the magma of one pulse to completely solidified before the next pulse arrives.

Magma will rise when the buoyancy of the magma is greater than the resisting forces in the host rock. The rising magma will however not always follow a vertical path to the surface. Variables like the direction of the least compressive stress, the presence of folding or faulting and weak contacts between layers are all factors that can cause melt to follow a different pathway. In the case of multiple pulses, the effects of earlier pulses can alter these factors. Thermal and chemical alteration is thought to lead to new preferred paths for the melt.

The granitic laccolith in Torres del Paine natural park in the south of Chile is a particularly well-studied example where magma seems to have followed the same path from the lower magma chamber to the present location of the laccolith over multiple pulses. This laccolith consists of three pulses of granitic magma that intruded into folded sedimentary materials over a timespan of approximately 90ka (Michel et al., 2008), all through the same same deeder channel. The time between pulses was sufficiently long for the magma to completely solidify. Therefore, thermal weakening can possibly be excluded as a reason why the magma followed the same path multiple times. Yet, why the feeder zone stayed in the same location for all pulses remains poorly understood.

Here, we therefore present numerical simulations in which we model multiple magma pulses and track whether multiple pulses follow the same path. The pulses start in a mid-crustal magma chamber and rise upwards through a folded host rock. We will employ a newly developed, thermomechanical parallel staggered finite difference code for that takes visco-elasto plastic rheologies into account. Systematic simulations are presented in which we test the effect of pulse-intervals, fold wavelengths of the host rocks, intrusion temperature and viscosities as well as the effect of preexisting weaknesses on the subsequent pathways of the magma.