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Modelling Melt Ascent in the Continental Crust: Testing Extraction Mechanisms

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The physics of melting and melt ascent within the continental crust is important for understanding the magmatic processes contributing to the crust's structural and compositional evolution. We developed a thermo-mechanical-compositional two-phase flow formulation based on the conservation equations of mass, momentum, and energy for melt and solid, including compaction of the solid matrix, melting, melt segregation, melt ascent and freezing. We use a simplified melting law to track the enrichment or depletion in SiO_2 of the advected silicic melt and solid. The non-linear visco-plastic rheology includes the effect of melt porosity.

In a study on fundamentals of magmatism in thick continental crust a 2D-model was designed to explore sensitive parameters, dynamics, physical behaviour and limits of geologically interpretable results. Cases without and with differential melt-matrix flow, i.e. batch and fractional melting, were carried out. Controlling parameters, actually the bottom heat flow, the retention number Rt, e.g. melt mobility, and the matrix strength, have been varied. The models show that diapirism is not the dominating process of melt migration in the crust. Melt additionally segregates by two-phase flow and accumulates beneath the solidus of the stiff upper crust. A new process called CATMA which also may be interpreted as "micro-stoping" allows further ascent. Finally, when cooled down, strongly enriched zones may be interpreted as granitic layers.

From observation it is known that faster melt transport mechanisms exist. They act on a short time scale, and a widely used approach is melt extraction and intrusion in a given emplacement level or at the surface. Typically a melt fraction threshold is defined, above which all excessive melt is extracted. More advanced approaches use a parameterization of three critical parameters where vertically connected partially melted zones serve as source region. The extraction areas undergo compaction, inducing under-pressure attracting ambient melt. In a higher, colder crustal level the emplaced melt dilatates the matrix, and usually freezes immediately; heating and an increase of enrichment takes place.

Such approaches locally violate mass and momentum equations due to extraction and redistribution more or less, and, more importantly, magma is redistributed at ad-hoc positions. Results and interpretations of model variations will be presented. On the other end, short time scale magma transport through the subsolidus region is modelled by the dyke propagation community, but the source regions of these dykes are usually chosen in an arbitrary way.

Final aim of our research project is modelling the combination of two-phase flow, and consistently draining the melt from the top of the partially molten regions into dykes, run a dyke propagation model moving the magma dynamically through the subsolidus elastic region, and treat stagnant freezing dykes as intrusion. In a first step we started to extend our three parameter extraction approach by moving the extracted melt along trajectories of the compressive principle stress directories.