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The importance of visco-elasto-plastic rheology in numerical modeling of two-phase flow

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We investigate the behaviour of a two-phase system that involves propagation of partial melt through a visco-elasto-plastic continental lithosphere and crust under ongoing tectonic deformation. Using two-dimensional numerical simulations we examine the coupled magmatic and tectonic processes leading to intrusive rock formation.

The numerical modeling approach is based on the assumption that the melt fraction is equal to the porosity of the rock and that porosity changes reflect the compaction or dilation of the matrix framework due to visco-elasto-plastic processes. All modes of compaction are connected to the effective pressure, which can be understood as effective compaction/decompaction stress acting on the host rock.

The rheology of the solid phase largely determines the mode and efficiency of melt transport. Therefore it is of considerable importance to formulate a realistic visco-elasto-plastic rheology. In the case of two-phase flow modeling, we additionally formulate a volumetric rheology to consitute compaction/decompaction deformation along with a standard deviatoric rheology for shear deformation.

First results indicate that melt propagation is strongly related to the regional stress field, and that plastic failure zones (decompaction tubes, dikes and sills) form important conduits for the propagation of partial melt, especially through the more competent parts of lithosphere and crust. We may distinguish three distinct regimes of style and efficiency of melt propagation that occur at increasing competence of the host rock.

A possible application of such models is to deepen the understanding of the processes involved in, and the geometry and field relations expected from, the emplacement of hydrated slab melts into the overriding continental plate in an ocean-continent subduction setting, covering rheological conditions in both the hot and weak asthenosphere as well as in the cooler and more rigid parts of lithosphere and crust.