Direct numerical simulation of two-phase flow: homogenization and collective behaviour in suspensions

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Melt transport mechanism has received much attention recently, since melting and melt migration play dominant roles in heat, composition and mass budget of the Earth. Whereas many aspects of melt migration processes are well known the physics of the processes remain a matter of discussion.

Melt migration and partial melting processes are generally solved by coupling solid and fluid flow. The theory of compaction-driven two-phase flow is based on macroscopic models considering the motion of a low-viscosity fluid moving through a high-viscosity, permeable and deformable matrix (e.g. McKenzie 1984). Previous work concerning modeling of two-phase flow has been performed by different authors. Nevertheless, models commonly are solved by neglecting and simplifying parts of the whole complex dynamical system such as the mechanical deformation of the solid, melting processes or the porosity treatment of the rock. Therefore many numerical codes use very simplified models. However, by reducing the number of unknowns and assumptions it is possible to study the dynamics of partially molten systems.

Here, we study the dynamics of two-phase flow by solving the equations directly on grain-size-scale using the Stokes equations for low-viscosity and high-viscosity regions in two dimensions. We performed systematic studies in order to characterize the mechanical behaviour of the system as a function of material parameters and melt fraction. Results indicate that for moderate to large melt fractions, particle interactions are significant, and result in macroscopic Rayleigh-Taylor like instabilities. This allows us to derive a formula for effective viscosity in a particle-suspension system. Additionally, we quantified the transition between Rayleigh-Taylor mode (strong interaction between particles) and Stokes-suspension (simple sinking of particles) mode systems.
To complete the scaling law in the full range of fluid fractions, we currently perform simulations at very low porosities.