EGU23-5441, updated on 06 Dec 2023
https://doi.org/10.5194/egusphere-egu23-5441
EGU General Assembly 2023

A 3D finite element magma reservoir simulator

Haiyang Hu, Pablo Salinas, and Matthew Jackson
Imperial College London, Earth Science and Engineering, United Kingdom of Great Britain – England, Scotland, Wales
(huhaiyang84@gmail.com)

IC-FEMRES (Imperial College Finite Element Magma REservoir Simulator), is a finite-element based numerical code for simulating the 3D dynamic behaviour of a two-phase, multi-component magma reservoir with chemical reaction. The code is built upon the open-source IC-FERST package (http://multifluids.github.io/) which includes advanced numerical features such as dynamic mesh optimization, to allow fine-scale solution features to be captured while simulating in a large domain.

The model solves for velocity using a finite-element approach, and for transport using a control-volume scheme to ensure the conservation of energy, mass, and components. Solid, melt and volatile phases are modelled as Stokes fluids with very different Newtonian viscosities. Individual crystals in the solid matrix are incompressible, but the solid phase is compressible to account for changes in melt fraction. The formulation captures viscous compaction and convection of the solid matrix, and flow of melt and volatiles via a Darcy-type formulation at low melt fraction, and a hindered-settling type approach at high melt fraction. It also captures heat transport by conduction and advection, and component transport by advection. A chemical model is used to calculate phase fraction and composition. The numerical package sequentially solves for: 1. Melt and solid velocity (mass and momentum conservation); 2. Enthalpy and component transport (energy and component conservation); 3. Phase fraction and composition (chemical model). Material properties such as density and viscosity can be coupled to solution fields such as melt fraction and composition to yield a highly non-linear system of coupled equations that are solved iteratively.

We demonstrate here the validation of the formulation against well-constrained test cases, and example results for a magma reservoir in the continental crust obtained using a simple two-component chemical model created by fitting a binary phase diagram to experimental melting data. Solutions show significant deviations from the predictions of 1- and 2D thermal models, or 1D models that include magma dynamics, and may explain some hitherto poorly understood aspects of magma reservoir formation, dynamics and chemical differentiation.