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4D space-time FEM model for magma dynamics

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Underground magmatic processes play a crucial role in determining the current state as well as the evolution of a volcanic system. Magma transport inside the crust is a complex process and difficult to be studied by surface observations. We study the physics and dynamics of magma by constructing a mathematical model based on the fundamental physical laws and solve it for appropriate initial and boundary conditions. Our 4D (space-time) numerical model accounts the complex physics of multicomponent magmatic mixtures, as well as the complex geometries of multiple magma chamber-dike systems. The numerical model is based on the Galerkin Least-square stabilised space-time finite element method and solves the equations of conservation of mass, momentum and energy in compressible-incompressible regimes to determine the distribution and evolution of quantities such as composition, density, velocity, pressure, temperature, volatile partitioning, viscosity, etc. We present first the model and validation benchmarks, then the simulation of the 4D dynamics of magma chamber replenishment by volatile-rich magma, and the associated magma convection and mixing dynamics.