Solving Transport Problems for the Exploration of Mineral Deposits and Geothermal Reservoirs

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Abstract: Movement of water and other fluids in the Earth's crust is a key factor in the formation of ore deposits. The fluid transports chemical species and heat through the rock matrix at high pressure and temperature. Chemical species and water react with the rock leading to dissolution and precipitation of minerals. Numerical simulations can help us to understand these processes and predict the location of mineral deposits. Similarly, but on a different temporal and spatial scale, circulation of heat and fluids at shallow depths controls the location of geothermal resources, which may be exploited for geothermal energy. Through simulations the capacity and exploitation of a geothermal reservoir can be assessed.

Besides the relevant chemical reactions, numerical simulations have two key components: the solution of the Darcy flux equation to calculate the water flux and pressure in a porous medium, and the solution of the advection-dominated transport of heat and chemical species by the moving pore fluid. The equations are coupled as material parameters depend on pressure and temperature. Permeability is a key variable controlling fluid flow, and varies over more than ten orders of magnitude in the Earths crust. Solving the coupled fluid-heat-chemical transport problem in complex three-dimensional geological structures with varying permeability requires large finite element meshes and parallelized solution algorithms. When developing a simulation code it is highly desirable to use a single finite element scheme for all relevant sub-problems as this will simplify the transfer of data between sub-problems, and minimize software development and maintenance costs.

While non-conform approaches are typically used we will discuss in this paper how conform FEM methods can be used to solve the Darcy flux equation and advection-dominated transport. In the first case we will discuss the use of a least squares approach. In the latter we look into an algebraic up-winding scheme with flux correction. We also discuss the implementation of these methods using a parallelized FEM software package (in this case *escript*) and discuss their integration into a software environment used by geologists to run large simulations on HPC infrastructure.

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