



Modelling kinetically controlled water-rock interactions during geothermal stimulation in typical poly-mineralic reservoir rocks from the Upper Rhine Graben, Germany

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A quantitative understanding of geochemically controlled reaction rates and their operating reaction mechanisms is crucial for the efficient exploration and exploitation of geothermal reservoirs. For example, the volume changes associated with dissolution and precipitation reactions potentially may affect the hydraulic properties of a reservoir during the production phase. The reactivity depends on a complex interaction of various parameters such as temperature, fluid flux and chemistry, mineral composition, reactive surface areas, etc. Most shallow geothermal reservoirs are constituted by highly permeable sedimentary rocks saturated by a fluid phase. The abundance of impermeable crystalline basement rocks (magmatic and metamorphic) increases with depth. Typically, hydraulic stimulation is necessary to create fluid pathways, i.e. the permeability of the rock is increased by the generation of new fractures and the reactivation of old fractures (Enhanced Geothermal Systems, EGS). Fresh, high energy surfaces are created by this treatment, constituting potential sites for intensive water-rock interactions. An increasing number of reactive transport models using equilibrium thermodynamic data shed considerable light on water-rock interactions. However, most models simplify the involved rocks to mono-mineralic phases and/or use rate data based on powder experiments with unnatural high reactive surface areas.

In this study we present a new numerical model approach to quantify the geochemical evolution and its mechanical feedback during geothermal stimulation of typical poly-mineralic reservoir rocks at elevated temperatures (150-200 °C). Rock samples representative for geothermal energy producing sites (limestone, sandstone, volcanic tuff and granite) were collected at the Upper Rhine Graben (URG) in southern Germany, i.e. one of the high potential locations for geothermal energy production in Germany. Samples have been characterized petrographically with regard to phase assemblage, grain size and textures to constrain input parameters for the model.

The model geometry approximates a fluid continuously circulating along the injection hole (3500 m), the reservoir rock (500 m) and production hole (3500 m) with a spatial discretization of 1 m per unit cell. Initial distribution of temperature and stratigraphy along the circuit reflect drill logs. Advective and diffusive transport of the fluid phase is solved using a finite volume scheme. The numerical code is written in FORTRAN and coupled to the IPhreeqc-application library that is used for the thermodynamic calculation of element speciation in the fluid phase and mineral solubility, respectively. Rates of occurring mineral reactions are linked to the mineralogy including the grain size. Time-dependent changes in fluid composition and mineral modes due to dissolution and precipitation processes are monitored for each cell.

Our modelling approach is able to spatially resolve the temporal geochemical evolution of the fluid chemistry as well as mineralogical changes by local mineral reactions including the formation of secondary alteration products.