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Dissolution and Precipitation in Sandstones: A Link Between Fluid-Rock Reactions, Electrical Rock Conductivity, and Permeability

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Geothermal energy production from deep sedimentary reservoirs interferes with thermodynamic fluid-mineral equilibria. Different dissolution and/or precipitation reactions might thus be induced, which affect the rock physical transport properties electrical rock conductivity σ_{rock} and permeability k. In general, this work addresses the risk assessment for geothermal energy production from deep sedimentary reservoirs in terms of formation damage. In this context it is important to constrain the processes leading to potential changes in k, evaluate whether they occur under in-situ $T-p-X$ conditions, and - if yes - provide tools to monitor changes in the physico-chemical properties of the fluid-rock system.

In the model system quartz-feldspar-water we conducted long-term hydrothermal flow-through and batch experiments under hydrostatic pressure conditions. The temperature range applied in the experiments covered 70 to 160°C to simulate conditions pertaining to a low enthalpy geothermal energy production scenario. The evolutions of σ_{rock} and k of feldspar-rich Rotliegend sandstone samples and analogue materials were monitored by means of a HPT-permeameter. Concentrations of the system's major cations c_i (i = Na^+, Al^{3+}, Si^{4+}, K^+, Ca^{2+}) in the (pore)fluids were measured using ICP-OES and were correlated to the electrical fluid conductivity σ_{fluid}. Microstructural and mineralogical investigations on the solid phases were performed by SEM and XRD, respectively.

In the first part of this study we investigated the relationship between σ_{rock} and the chemical saturation state of this specific fluid-rock system. It can be demonstrated that σ_{rock} is qualitatively dependent on changes in σ_{fluid}. Thus, monitoring of easily accessible σ_{rock} can be used to get insights into the chemical evolution of the present fluid-rock system. Hydrogeochemical modeling of the resulting porefluids showed that the system is supersaturated with respect to clay minerals and gibbsite. Consequently the kinetically controlled precipitation of these mineral phases in the pore space can lead to changes in pore geometries and thus to an alteration of k.

The second part of this study was focused on the evolution of k. We observed a partly reversible k-decrease due to heating and cooling of the samples and a comparatively low k-decrease at constant T. These may be due to physical (compaction, fines migration) or physico-chemical (dissolution-precipitation, secondary mineral formation) processes. We will also present results of X-ray CT scans that might image actual changes of pore geometries in the samples and may help to achieve a mechanistic understanding of the processes taking place in the pore space.