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Effects of fluid-rock interactions in arkosic sandstones: Long-term direct monitoring of changes in permeability, electrical conductivity, and pore fluid chemistry

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In the context of low enthalpy geothermal energy production from deep sedimentary reservoirs laboratory experiments and simulations in the system quartz-feldspar-water were conducted. To constrain the effect of fluid-rock interactions on permeability under hydrothermal in situ conditions an interdisciplinary approach covering petrophysical, petrological and hydrogeochemical methods was applied.
Long-term flow-through experiments were conducted under hydrostatic pressure conditions in a HPT-permeameter. Two arkosic sandstones, one pure quartz arenite (Fontainebleau) as well as one sandwich sample containing a quartz-feldspar powder of defined grain size and composition were investigated. The pore fluid was distilled water. At a maximum temperature of 160°C both permeability and electrical rock conductivity were simultaneously monitored. The maximum run duration was three months. Complementary batch experiments were performed with quartz-feldspar powders to constrain the mechanisms and kinetics of potentially occurring hydrothermal reactions. The resulting fluids were analysed with ICP-OES and the reacted powders were characterised with XRD and SEM. Additionally, the hydrothermal reactions were modelled with PHREEQC.
It will be demonstrated that permeability decreases in the course of the experiments. However, compared to similar experiments conducted under deviatoric stress conditions (Tenthorey et al., 1998) the decrease in permeability is low. For both arkosic sandstones and at stagnant flow conditions the electrical rock conductivity showed an asymptotical increase indicating that the respective pore fluid approaches a saturation state. Furthermore, fluid samples taken at the end of the Fontainebleau experiment exhibit supersaturation with respect to quartz. In addition, PHREEQC simulations of the feldspar-quartz-water equilibrium indicate that different clay minerals and gibbsite are supersaturated in the resulting fluid.
Consequently and despite the sluggish dissolution kinetics of quartz and feldspar as revealed by both the batch experiments and simulations there is a potential for authigenic mineral formation in the pore fluid of the investigated rock samples. This finally implies a risk of permeability damage even at comparably low temperatures and specifically when the fluid-rock equilibrium is disturbed, e.g. by a temperature decrease.

References:
Tenthorey, E., Scholz, C.H., Aharonov, E. (1998): Precipitation sealing and diagenesis: 1. experimental results. J. Geophys. Res. 103 (B10), 23951-23967.