Dissolution and precipitation in arkosic sandstones: Interrelations between authigenic mineral formation and fluid chemistry

Ansgar Schepers

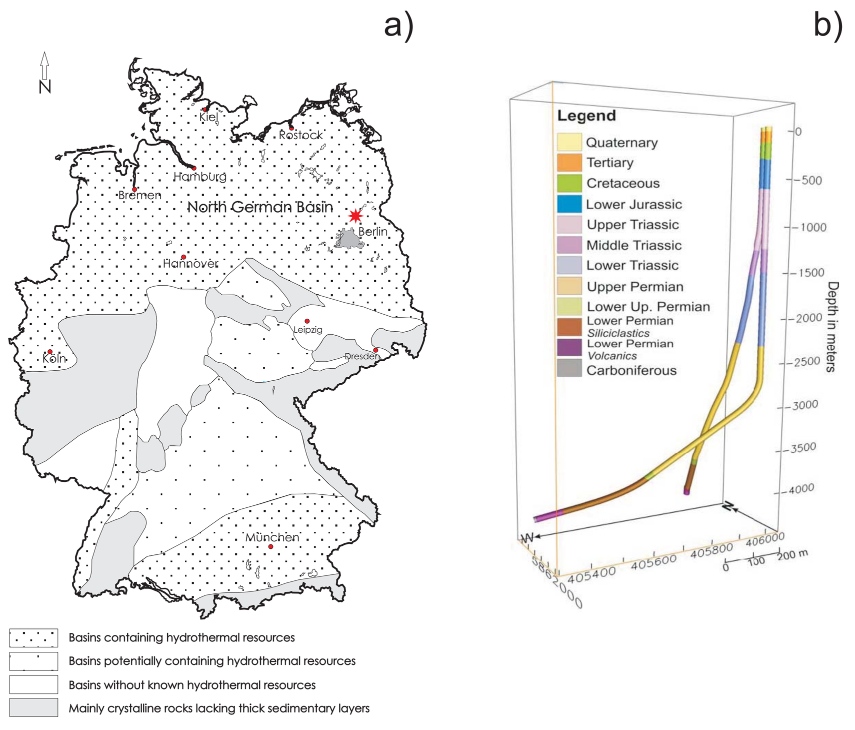
Helmholtz Zentrum Potsdam - Deutsches GeoForschungsZentrum GFZ, Telegraphenberg, D-14473 Potsdam (phone: +49 331 288 1576, eMail: schepers@gfz-potsdam.de)

Abstract

The extraction of heat from rocks during geothermal energy production leads to an alteration of thermodynamic fluid-rock equilibria within the geothermal reservoir. Potentially this induces dissolution and precipitation of different mineral phases. Several studies indicate that these processes affect the permeability of the reservoir rocks. To get insights into fluid-rock reaction mechanisms and kinetics encountered during geothermal energy production, flow-through and batch experiments in the system quartz-feldspar-water-salts are conducted. These experiments are aimed at simulating conditions within low-enthalpy sedimentary geothermal reservoirs as can be found in the North German Basin.

Introduction

Scientifically justified statements about the sustainability of geothermal energy production require a precise knowledge of the evolution of the reservoir productivity.
The GeoForschungsZentrum Potsdam (GFZ) maintains an in-situ geothermal laboratory at Groß Schönebeck approximately 50 km NE of Berlin (Fig. 1a).
The reservoir rocks at this site are Lower Permian Rotliegend sandstones (see Fig. 1b).



(modified after Huenges et al. 2002) (from Zimmermann et al. 2007)

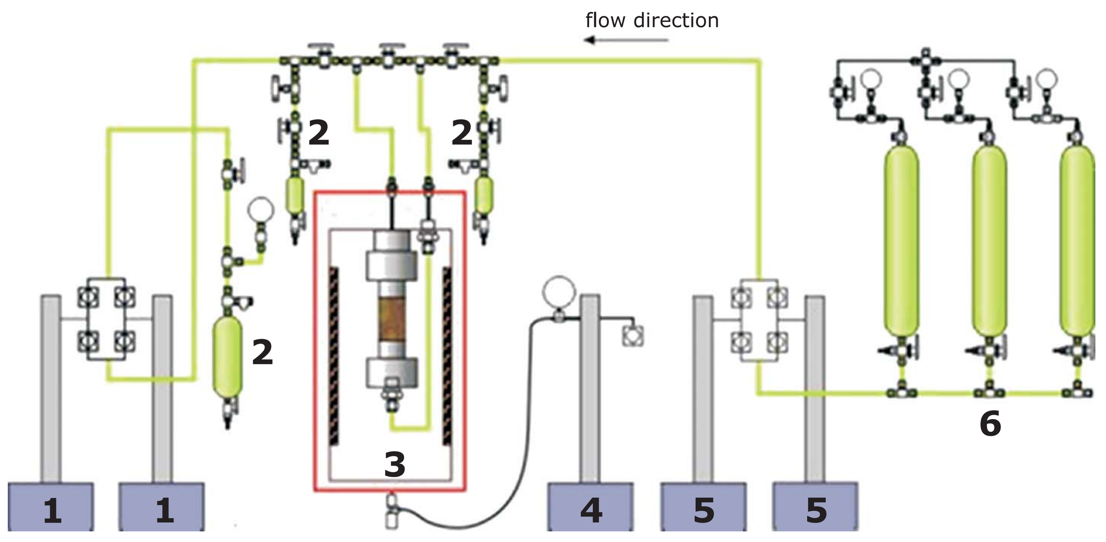
Fig. 1a: Schematic geological map showing a spatial interpretation of the hydrothermal potential in Germany. The red star marks the location where the in-situ geothermal laboratory Groß Schönebeck is situated.

Fig. 1b: Well-path of the two wells at the Groß Schönebeck site building up a geothermal doublet system. The targeted reservoir rocks are Lower Permian Rotliegend sandstones.

The reservoir rocks are rich in feldspar (arkosic litharenites) and typically consist of approximately 60-65% quartz, 15-20% feldspar and 20% rock fragments. The pore fluid is a highly saline Ca-Na-Cl water that is typical for the Permian of the North German Basin. The fluid temperature is approximately 150°C. The reservoir rock was artificially fractured (stimulated) to enhance its productivity.
Previous hydrothermal experiments under deviatoric stress conditions indicate a rapid decrease of rock permeability due to mineral precipitation (e.g. Tenthorey et al. 1998).

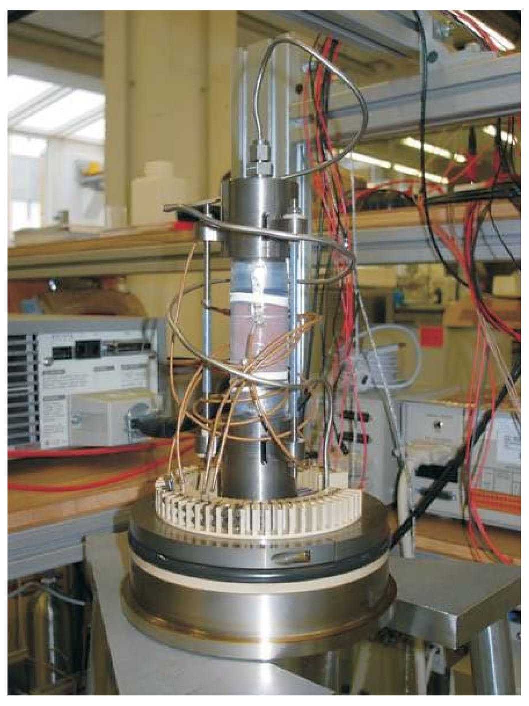
Experiments

Batch and hydrostatic flow-through experiments are conducted to constrain the potential occurrence of authigenic mineral formation induced by fluid-rock interactions and its effect on hydraulic permeability (Fig. 2 and 3).



(from Milsch et al. 2008)

Fig. 2: General set-up of the flow-through apparatus. 1 and 5 are the pore fluid pumps. 2 is a system for fluid sampling. 3 is the pressure vessel with heater and specimen assembly. 4 is the confining pressure pump. 6 is the fluid reservoir.



(from Milsch et al. 2008)

Fig. 3: Detail of the mounted specimen assembly. A Rotliegend rock-sample is located in the centre. Fluid is fed through the capillary system (silvery-gray spiral). Temperature and conductivity sensors are visible (brown cables).

Fig. 4: Photograph of a flown-through sample consisting of two Fontainebleau quartz-sandstone discs with a sand pack in the centre. The sand consists of quartz and labradorite (plagioclase feldspar).

Preliminary Results

First flow-through experiments conducted with a sandstone analogue (Fig. 4) showed an irreversible drop of permeability with time and increasing temperature (Fig. 5). The microstructure of the sample was analysed by an electron microprobe (Fig. 6). Evidence of authigenic mineral formation or pressure solution so far was not found.

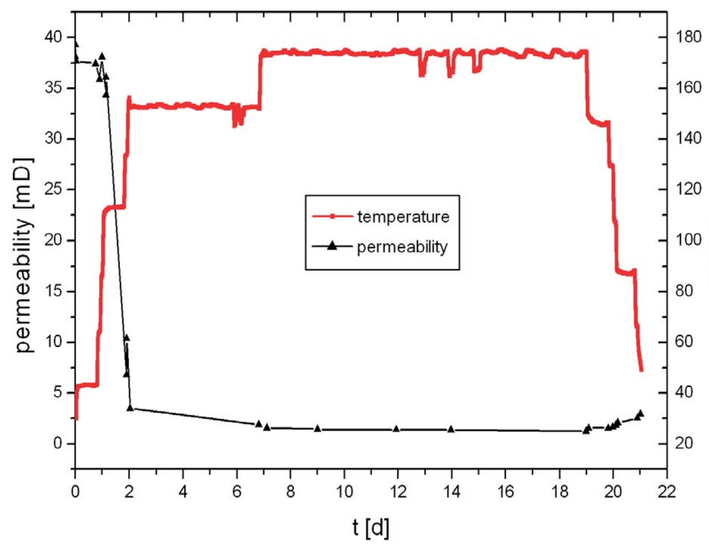


Fig. 5: Graph showing the evolution of permeability with temperature and time of a sandstone analogue consisting of quartz and labradorite.

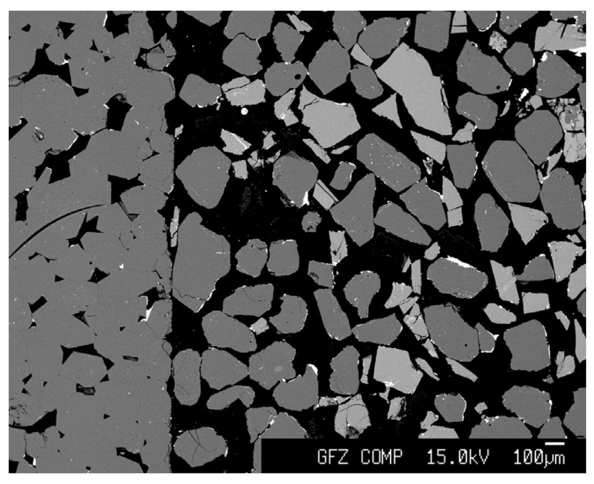


Fig. 6: BSE-micrograph of the boundary of the quartz-labradorite sand pack against a quartz-sandstone disc. Labradorite grains appear light grey, quartz grains are dark grey. The bright parts are remnants of the polishing process (a Pb-Sb alloy was used as the polishing disc coated with diamond powder).

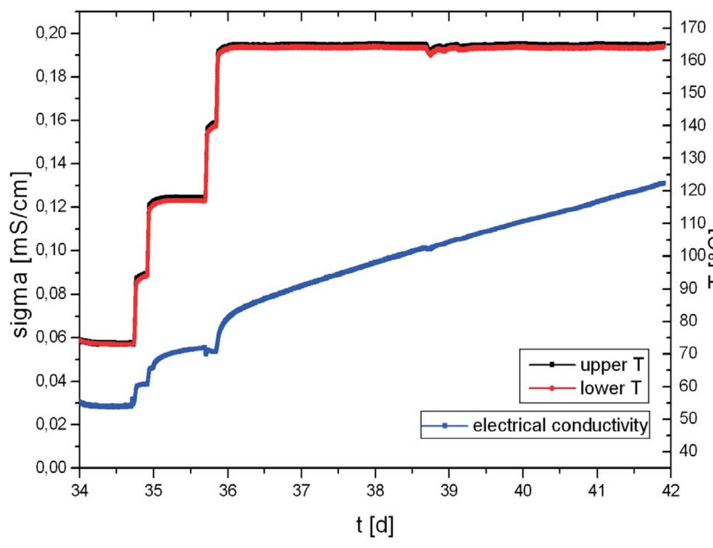


Fig. 7: Graph showing the relationship of temperature and bulk electrical rock conductivity under stagnant conditions as a function of time. The sample is an intact Rotliegend sandstone (Eberswalder sandstone).

Outlook

⇨ Further experiments to investigate the evolution of the fluid chemistry and its effect on bulk electrical rock conductivity (Fig. 7).

⇨ Simulations of occurring reactions with the hydrochemical modelling software PHREEQC.

References

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