Experimental Long-term Investigations on Geothermal Reservoir Rock Properties at Simulated In-situ Conditions

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Introduction:

Sustainable energy production from geothermal reservoirs requires an exact knowledge of the hydrological aquifer properties as well as the processes that could potentially alter its productivity. The latter comprise both mechanical and chemical effects.

To perform controlled long-term investigations on the evolution of sedimentary rock transport properties at conditions pertinent to deep geothermal reservoirs two new permeameters have been set up at the GFZ-Potsdam.

Experimental set-up:

The apparatuses **(Figures 1 - 4)** allow for a variety of continuous petrophysical measurements at a maximum temperature, lithostatic- and pore pressure of 200 °C, 140 and 50 MPa, respectively. The permeability, ultra-sonic p- and s-wave velocities and the specific electric conductivity of the rock can be determined. In particular, the use of corrosion-resistant parts allows for experiments with highly saline formation pore fluids that can be sampled under pressure for further chemical analysis. The typical duration of an individual test is four to twelve weeks.

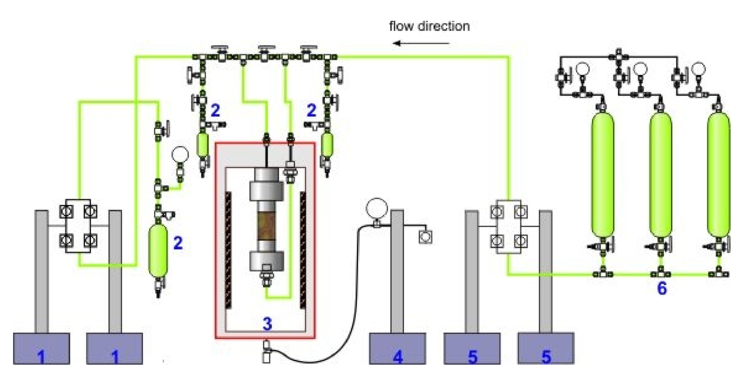

Fig. 1: Schematic set-up of the apparatuses:
1 and 5: pore fluid pumps
2: fluid reservoirs for chemical analysis
3: pressure vessel with specimen assembly
4: confining pressure pump
6: fluid reservoirs

Samples and Fluids:

Experiments are comparatively performed on two types of sandstones: a Lower Permian (Rotliegend) reservoir rock from Eberswalde, Germany and a pure Quartzite from Fontainebleau, France **(Figure 5)**.

In addition, two kinds of pore fluids are used: low salinity brine (0.1 mol/l NaCl) and a synthetic Ca-Na-Cl formation fluid with a TDS-content of 250 g/l.

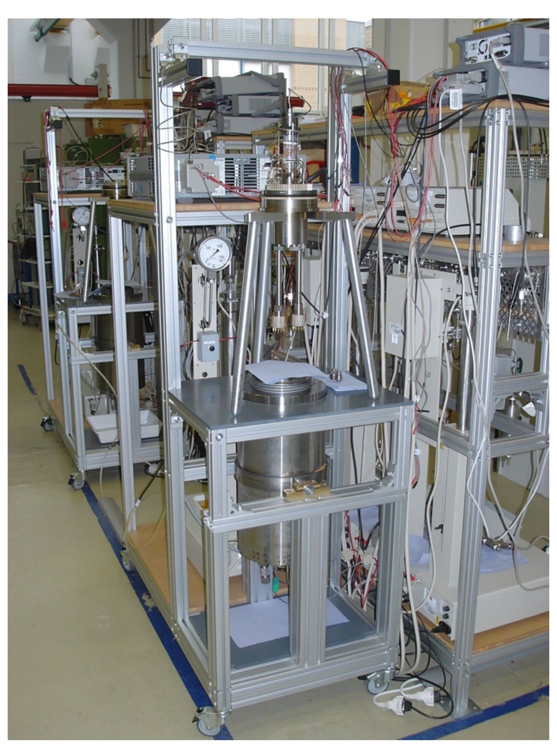

Fig. 2: General view (pressure vessels).

Fig. 3: General view (pore fluid pumps).

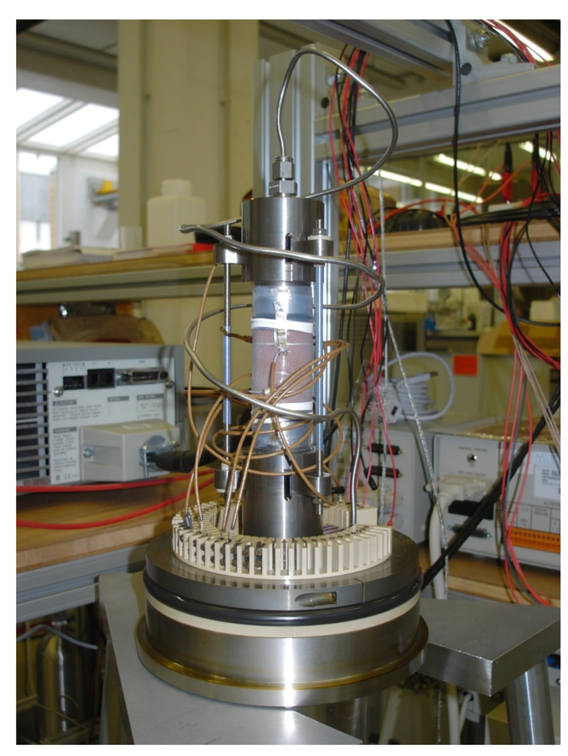

Fig. 4: Specimen assembly set-up.

Fig. 5: Eberswalder Rotliegend (left) and Fontainebleau (right) samples with silver conductive paint rings for conductivity measurements. Sample size is 30 mm in diameter and 40 mm in length.

Experimental procedure and results:

In a first series the low salinity brine was used to petrophysically characterize both rocks as a function of temperature and effective pressure within the relevant range of up to 150 °C and 75 MPa, respectively. The results obtained for the reservoir sandstone are shown in **Figures 6 - 8**.

Consequently, in a continuous flow experiment, the permeability and the specific electric conductivity of the same sample were monitored as a function of time during six weeks at constant p-T-conditions **(Figures 9 and 10)**.

In an ongoing series similar continuous flow experiments are performed using the second, highly saline formation fluid **(Figures 11 and 12)**.

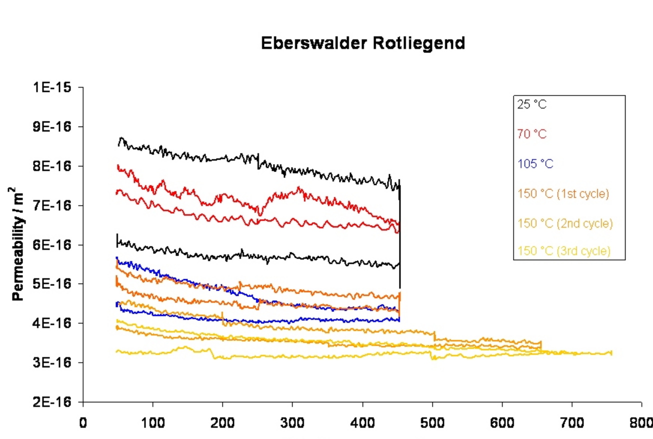

Fig. 6: Eberswalder Rotliegend sample. Permeability as a function of effective pressure for different temperatures.

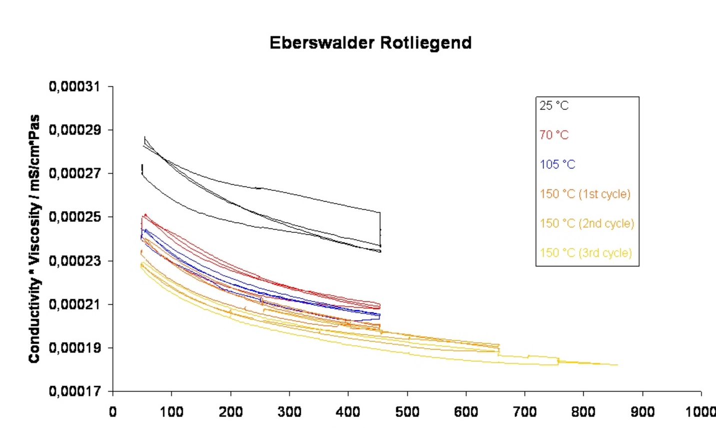

Fig. 7: Eberswalder Rotliegend sample. Electric conductivity times viscosity as a function of effective pressure for different temperatures.

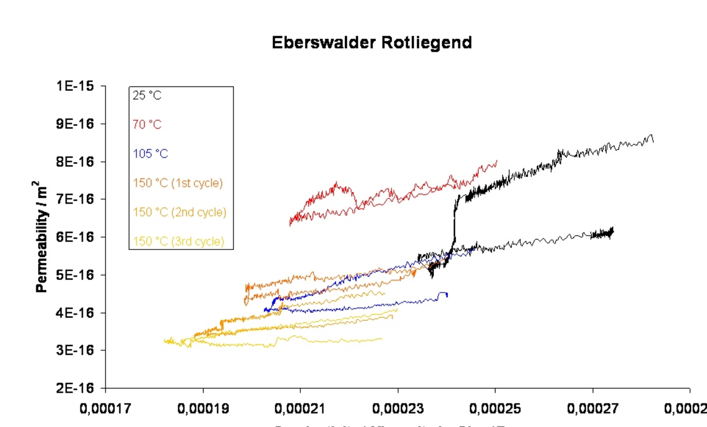

Fig. 8: Eberswalder Rotliegend sample. Permeability as a function of electric conductivity times viscosity for different temperatures.

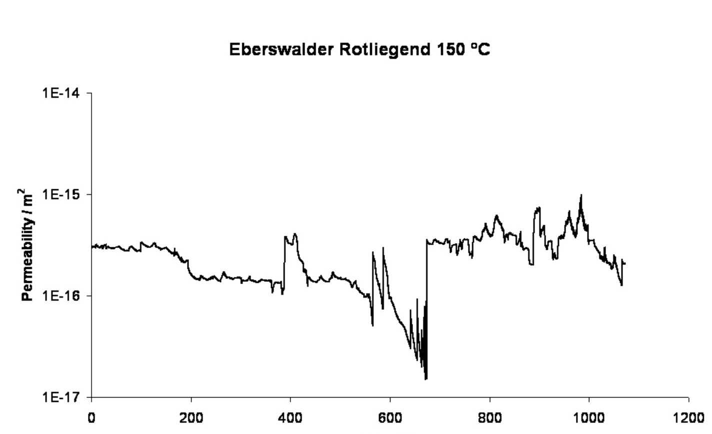

Fig. 9: Eberswalder Rotliegend sample. Permeability as a function of time at T = 150 °C and p_{eff} = 450 bar. Pore fluid: low salinity brine.

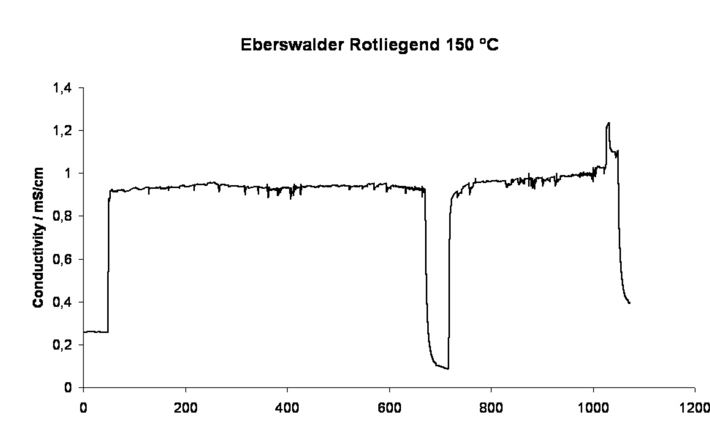

Fig. 10: Eberswalder Rotliegend sample. Electric conductivity as a function of time at T = 150 °C and p_{eff} = 450 bar. Pore fluid: low salinity brine.

Discussion and Summary:

The experiments demonstrate a negative, non-linear dependence of both permeability and electric conductivity on effective pressure as well as a first order linear coupling of both parameters.

The long-term investigations indicate no changes in the hydraulic and electric transport properties of the rock for the run durations investigated regardless of the type of fluid used.

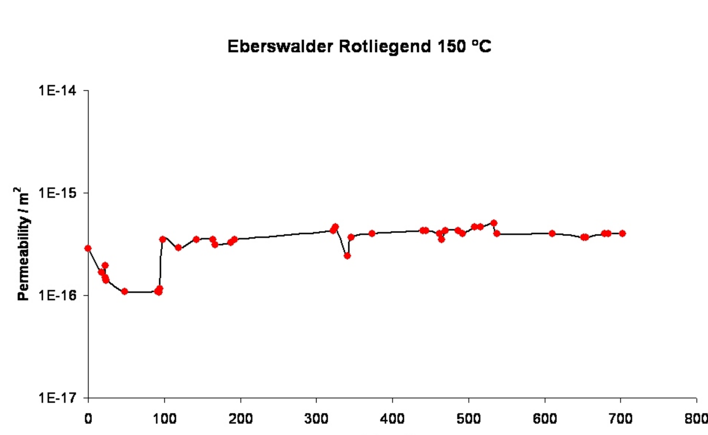

Fig. 11: Eberswalder Rotliegend sample. Permeability as a function of time at T = 150 °C and p_{eff} = 450 bar. Pore fluid: synthetic formation fluid.

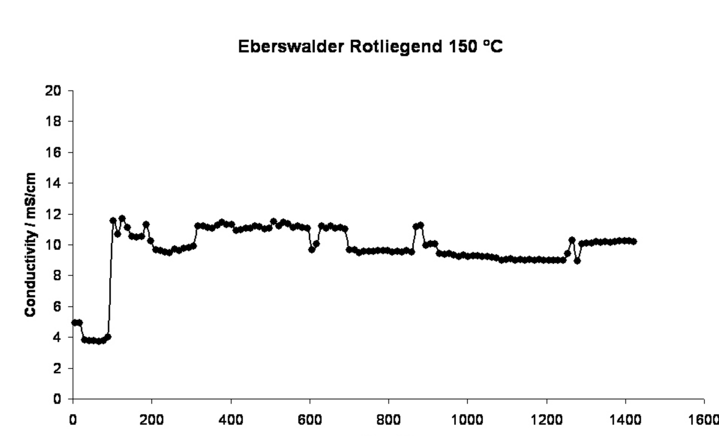

Fig. 12: Eberswalder Rotliegend sample. Electric conductivity as a function of time at T = 150 °C and p_{eff} = 450 bar.
Pore fluid: synthetic formation fluid.

Acknowledgements:

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