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THE IN-SITU GEOTHERMAL LABORATORY GROß SCHÖNEBECK - LEARNING TO USE LOW PERMEABILITY AQUIFERS FOR GEOTHERMAL POWER

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ABSTRACT

An in-situ downhole laboratory was established with the purpose of developing appropriate stimulation methods to increase permeability of deep aquifers by enhancing or creating secondary porosity and flow path. Effective stimulation is needed to use low permeability aquifers for generating electricity from geothermal energy. The laboratory was installed in the former gas exploration well Groß Schönebeck about 50 km northeast of Berlin. Before Christmas of 2000 this well was re-opened and deepened another 60 m to 4294 m. The openhole section of this well cuts through 400 m of the Rotliegend formation, comprising siltstones, sandstones, conglomerates and andesites. The maximum temperature measured was 149 °C. A first production test showed that most of the flow at present occurs in a section of volcanic rock and not in the overlying sandstones as was initially expected. Formation fluids were sampled and contain more than 250 g/l of total dissolved solids. Presently stimulation experiments are being carried out in the sandstone section. In these experiments the bottom part is isolated from the test interval by sanding up and a mechanical packer-system at the top.

INTRODUCTION

Enhanced productivity of thermal water is the indispensable condition for economic generation of geothermal electricity. Even if temperature is high enough in a reservoir of sufficient porosity and fluid content, exploitation may be precluded by low permeability, unless it can be enhanced with appropriate stimulation procedures. Geothermal electricity generation becomes attractive at temperatures above 100 ºC and flow rates of at least 50 m³/h. Such temperatures are found at depths of the order of 3000 - 4000 m in much of the North German Basin and large areas worldwide. Permeability to accommodate high flow rates, however, occurs less frequently in this depth range unless it can be created. A down-hole laboratory was established to perform stimulation experiments in various rock types, especially low permeability sediments.

The location for the in-situ geothermal laboratory was chosen according the following criteria:

(1) Temperature above 120 C, occurring in Germany at depths greater than 3000 m.
(2) The rocks should be representative of large areas so that results are applicable to other regions.
(3) A wide variety of rock types provides experience on many different scenarios.

The Rotliegend formation in the North German Basin fulfills these criteria. This basin is part of a larger structure which spreads from The Netherlands to Poland. The Rotliegend-Formation is a known gas reservoir and has been intensively drilled.

Figure 1: The in-situ geothermal laboratory Groß Schönebeck is situated in the North German Basin about 50 km northeast from Berlin.

RE-UTILIZATION OF PLUGGED WELLS

Most unused boreholes in the North German basin are closed with cement plugs. Re-opening these wells for other purposes, especially geothermal applications has the advantages of a known geology (small geological risk) and low drilling costs (drilling of a few hundreds of meters of cement compared to thousands of meters of rock).

For our project, a former gas exploration well at the location Groß Schönebeck, about 50 km northeast from Berlin, was selected (Fig. 1).

This well was drilled in 1990 and then shut down by placing three 100 m thick sections of cement separated by intervals filled with old heavy drilling mud. Renewed access was gained to the Rotliegend formation by drilling through the three cement sections. Fig. 2 shows the welding of a new flange to the old casing. The casing extends from the surface to 3875 m depth.

Figure 2: A new flange is welded on to the old casing.

The condition of the casing and cement were examined with a multi-finger (60 fingers) caliper and sonic log. The overall condition of the casing is good.

FIRST HYDRAULIC TEST

A production test was performed in the drill hole using nitrogen as a pressurizing agent. Fig. 3 shows the set up for the test. The production rates and down-hole pressure as a function of time are displayed in Fig. 4. The photograph in Fig 5 shows the drill rig and cylindrical containers used to take up the produced fluid.

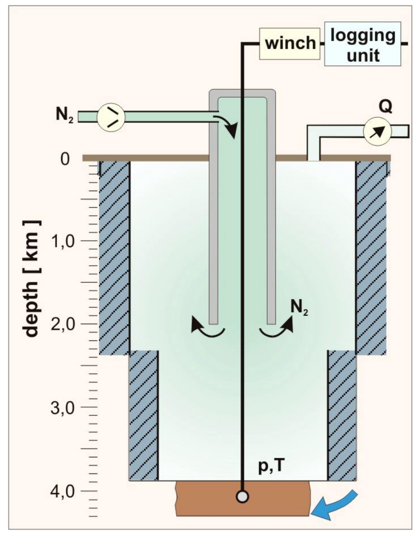

Figure 3: Production test in Groß Schönebeck. Set up of the drillstem test with pressure measuring devices at a depth of 4100 m.

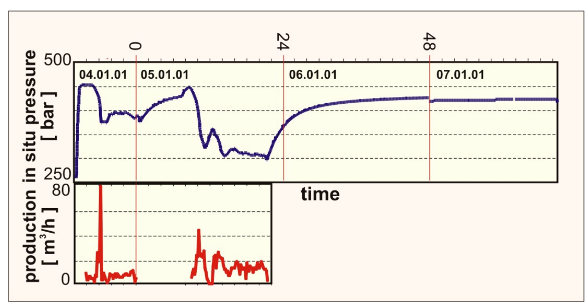

Figure 4:Production rate and down-hole pressure as a function of time. About 335 m³ of fluid (more than two borehole-volumes) were removed from the well.

During the test 335 m³ of thermal water was extracted from the well at an average rate of 11 m³/h and a maximum pressure drawdown of 14 MPa. Gas- and fluids were sampled three times from 4200 m depth. The fluid from the Rotliegend-formation is classified as Ca-Na-Cl type. The TDS (Total Dissolved Solids) amount to 256 g/l. The headspace-gas-content is 0,73 m^3/m^3 (normalized gas volume with respect to normalized water volume). The dominant component of gas is nitrogen accompanied by some methane. The CO_2-content is subordinate.

Figure 5: Drillstem test using nitrogen as a pressurizing agent at Groß Schönebeck.

FLOWMETER LOG

At the end of the production test, a flowmeter log was run. This log is displayed in Fig. 6 together with porosity and permeability data. These data represent measurements made on cores. Core porosity and permeability in the sandstones reach values above 10 % and above 10 mD, respectively. The flow log shows a significant inflow only between 4224 m and 4248 m, i.e. from the volcanic rocks. The Rotliegend sandstones are completely blocked.

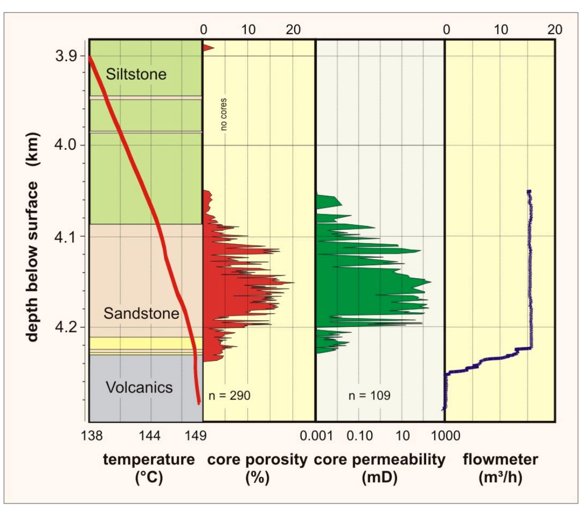

Figure 6: Temperature log (left), lithology, porosity and permeability as well as flowmeter log (right) of Groß Schönebeck.

TEMPERATURE

Repeated temperature logs were run. The maximum temperature reached was 149 °C (Fig. 7). Over a period of 10 months since the production test (the last thermal pertubation in the well), the temperature in the upper part of the well has increased up to 2 °C, while in the bottom the warming amounts to 0,5 °C. The temperature gradient correlates well with the geology. The lowest temperature gradient was registered in the Zechstein formation, which is composed of (high thermal conductivity) cyclic evaporites.

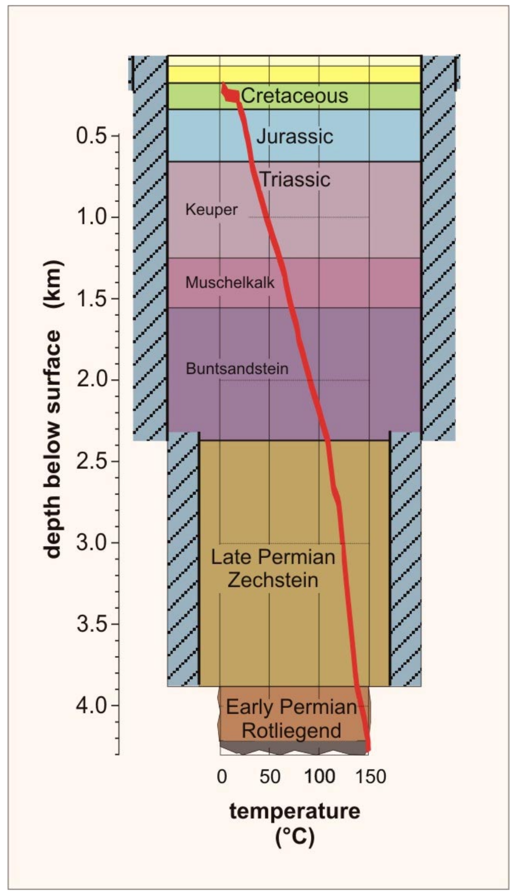

Figure 7: Stratigraphy of Groß Schönebeck. The red line is a temperature log.

STIMULATION IN THE SANDSTONES

In December 2001/January 2002 the first stimulation experiments (hydraulic fracturing) in the down-hole laboratory were performed. Two intervals in the sandstones were selected: 4130 – 4190 m (SFrac1) and 4080 - 4121 m (SFrac2), respectively.

The stimulation concept follows traditional oil/gas procedures: isolation of the test interval with packers (Fig. 8), the use of thickened fluids (polymers) and proppants (Carbolite). The great depth and high temperature for an open-hole stimulation experiment impose a technical challenge for the set up, instrumentation and fracturing fluid. For instance, the thickening agent in the fluid must withstand high temperatures for the duration of the experiment and it should degrade again after the test is completed.

Figure 8: Mechanical packer used successfully in the sandstone stimulation experiments.

In Groß Schönebeck, the section below the lower boundary of the experiment interval was isolated by filling the bottom of the well with sand. At the top of the interval a mechanical packer was set.

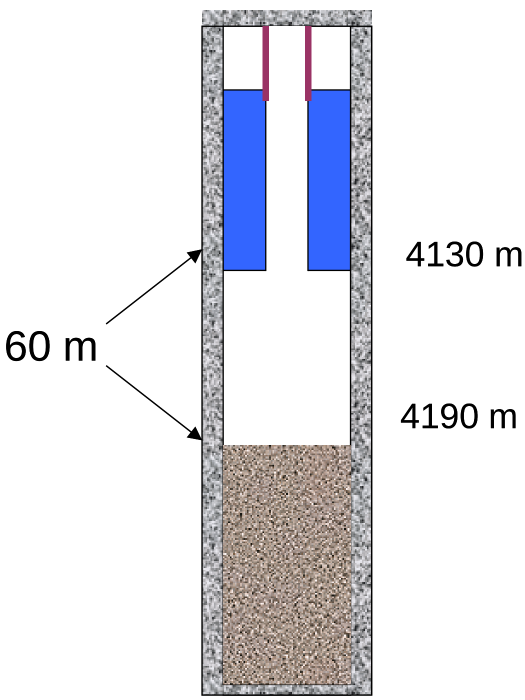

Figure 9: Stimulation concept for the sandstones. Bottom of the well is isolated with sand, the packer is set at the top of the interval.

Preceding the stimulation of the first interval (SFrac1), open-hole perforation (14 shots over 1 m interval) was performed at a depth of 4179 m. This procedure had the purpose of setting the initiation point of the fracture in the bottom of the interval of interest. This did not work out. Temperature logs after the first stimulation showed that the fracture nucleated straight underneath the packer.

After the stimulation of the first interval, the packer was removed and more sand filled into the bottom of the well, elevating the sand surface to 4121 m. A new packer was placed at 4080 m. Basically the same procedure was followed as for SFrac1, except that no perforation was used this time.

Following the second stimulation, the sand was flushed out of the borehole and operations put on hold while the polymer used in the fracturing fluid degrades. This is the present status at the time of preparing this manuscript. In a few weeks a casing lift production test will take place and reveal the effectiveness of the two stimulation experiments.

CONCLUSION AND OUTLOOK

Technology to stimulate deep geothermal reservoirs in sedimentary basins is the purpose of installing the down-hole geothermal laboratory in a former gas exploration well in Groß Schönebeck.

Surprisingly, the first test indicates water inflow not directly from the permeable sandstone but, from volcanic rocks below. Sealing of the bore hole wall within sandstone horizons due to long time infiltration has to be taken into account after reopening a well 10 year after drilling.

First stimulation experiments in the sandstones were performed in January 2002. Operations were a technical success, but the evaluation of these experiments to increase flow rates in the sandstones is to be tested with a production test in March. The aim is to enhance the productivity of the drill hole so that electrical power generation from geothermal reservoirs will be feasible in deep sediments of the North German Basin.

ACKNOWLEDGEMENT

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