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RESULTS OF STIMULATION TREATMENTS AT THE GEOTHERMAL RESEARCH WELLS IN GROß SCHÖNEBECK/GERMANY

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ABSTRACT

The aim of this paper is to present the results of previously performed fracture treatments in the new geothermal research well GtGrSk4/05 at Groß Schönebeck. The fracture treatments included three hydraulic stimulations, two in the sandstone section of the Lower Permian (Upper Rotliegend) and one in the volcanic section (Lower Rotliegend). In the low permeable volcanic rocks we performed a cyclic waterfrac treatment over 6 days in conjunction with adding low sand concentrations. Flow rates of up to 150 l/s during the high stages were realized with a total amount of injected water of 13,170 m³. Monitoring the water level in the offsetting well EGrSk3/90, which is 475m apart at the final depth, showed a very rapidly water level increase due to the stimulation treatment. A possible explanation is a natural fracture system or a fault zone in the volcanic rocks, which connects the two boreholes via the new fractures. It was known from previous treatments in the offsetting well that the high permeable sandstones do not show a self propping effect, hence we carried out two gel proppant treatments in these sandstones to maintain long-term access to the reservoir. A total amount of 100 to of high strength proppant with 500 m³ of cross-linked gel were injected during each treatment. The subsequent production test in conjunction with flowmeter logging to obtain the inflow intervals showed the success of the fracture treatments.

INTRODUCTION

The aim of stimulation treatments in the geothermal research well GtGrSk4/05 is the enhancement of productivity of the reservoir targets as a prerequisite for geothermal power generation of the Rotliegend Formation as an Enhanced Geothermal System (EGS). The main targets are sandstones of the Upper Rotliegend (Dethlingen Formation/Lower Elbe subgroup) as well as the volcanic rocks (andesites) of the Lower Rotliegend, where permeability is mainly due to connected fractures. It is intended to use this system of fractures to optimize the total productivity of the well. The Dethlingen sandstones represent an effective reservoir horizon with a porosity of 8-10 % and a permeability of 10-100 mD (Trautwein, Huenges, 2005). The Elbe-Basis-sandstone as the lower part of the Dethlingen Formation exists in NE Brandenburg as a well sorted middle grained to fine grained sandstone, which has been deposited in a fluviatile setting. The effective reservoir thickness is approximately 80 m; due to the deviation of the well the apparent thickness is 150 m. In this horizon two gel-proppant fracs were carried out. The design of the doublet system including the scheduled fracs is displayed in Fig. 1. The well path of the deviated well GtGrSk4/05 consists of an inclination between 37 to 49° in the reservoir rock with an orientation from 288 to 296°N alongside the minimum horizontal stress direction (Holl et al., 2004; Moeck et al., 2007). The frac propagation is consequently parallel to the direction of the maximum horizontal stress (18°N) and hence perpendicular to the well path orientation.

STIMULATION AND TESTING IN THE WELL GTGRSK4/05

Three stimulation treatments were performed in the completed well GtGrSk4/05. In advance the stimulation treatments were simulated to obtain the characteristics of the treatments like pressures and expected geometry of the fracs (Zimmermann et al., 2007) for scheduling the treatments.

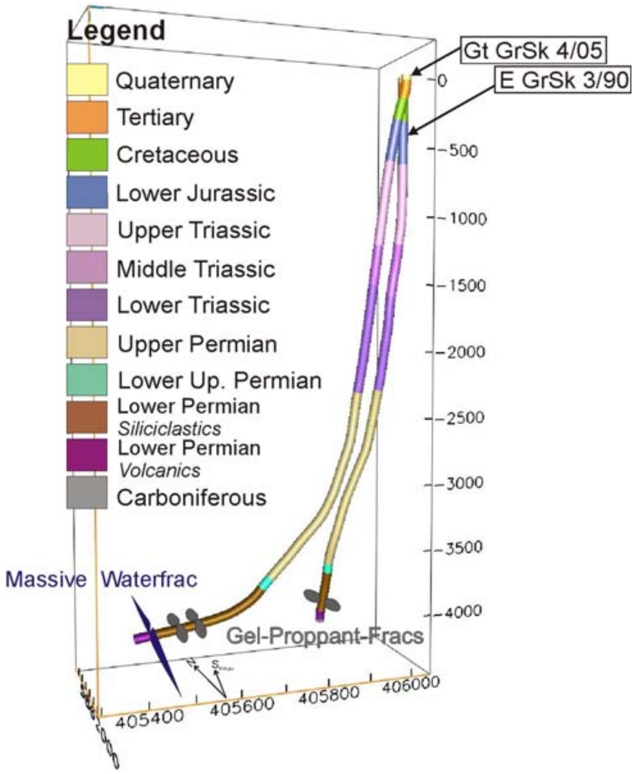

Figure 1 Alignment of the well path and the fracture treatments of the doublet system at the Groß Schönebeck drill site.

A first leakoff test in the volcanics (40 m of open hole in the bottom) was applied to obtain the frac gradient. Then a massive waterfrac treatment in the volcanics followed. After isolation of this part of the well with a bridge plug the lower sandstone horizon was perforated and tested (injection test). Subsequently, the gel-proppant stimulation followed. After isolating this interval as well the upper sandstone layer was perforated and stimulated with another gel-proppant treatment. Finally the bridge plugs were removed and a production test (casing lift test) was carried out to test all the stimulated intervals.

The treatments were accompanied by a passive microseismic monitoring in the adjacent well EGrSk3/90. For that purpose a seismic sensor was installed in 3,800 m depth to control and locate the produced fractures.
Communication experiments will follow including injection tests with pressure monitoring at operating conditions (flow rates up to 100 m³/h) as well as using the doublet for production and injection simultaneously.

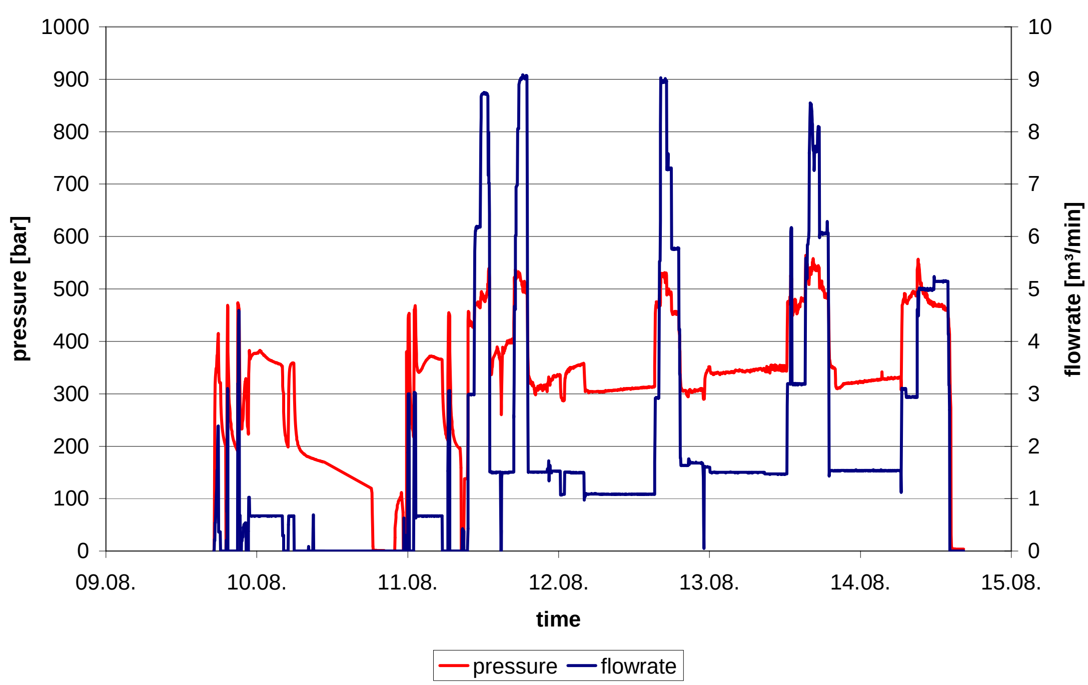

Figure 2 Schedule of the stimulation treatment in the volcanic rocks.

FRAC STIMULATION IN THE VOLCANIC ROCKS

The stimulation treatment was carried out between August 9 and August 14 in 2007. The lowest part of the well was stimulated by a slickwater treatment (Legarth et al., 2005). During the high flow rates a friction reducing agent was used to reduce the friction in the well and limit the maximum well head pressure to 580 bars. To avoid iron scaling of the injected water acetic acid was added to set the pH to 5. During the high flow rates of 150 l/s low concentrations of sand (20/40 mesh size) were added to support a sustainable fracture width. Transport of the sand in the fracture and the well was realized solely by the high flow velocity, because a gel to support the transport was no option due to the pH value.

In total, 13,170 m³ of fluids and 24.4 to of sand 20/40 mesh were injected into the volcanic rocks. Maximum well head pressure achieved 586 bars at the maximum flow rate of 9m³/min (150 l/s). The total duration of the treatment was 6389 minutes (Fig. 2).

MONITORING IN THE WELL EGRSK3/90

In the adjacent well EGrSk3/90 the water level was measured during the stimulation treatment (Fig. 3). After starting the first massive stimulation the pressure response showed a nearly instantaneous increase although the distance of the wells in the reservoir is ca. 475 m. The reason for this behavior is still an open question and potentially due to an assumed fault zone in the vicinity of the two wells.

The geophone in 3,800 m depth mainly recorded induced seismic events towards the end of the major stimulation phases with highest flow rates. The induced seismic events indicate an upward trend starting at the upper part of the open hole section in the volcanics suggesting a vertical fracture with an upward fracture growth into the sandstone layer. The orientation of the seismic events is approximately in the north-south direction and hence similar to the maximum horizontal stress direction (18°N) (Kwiatek et al., 2008, this issue).

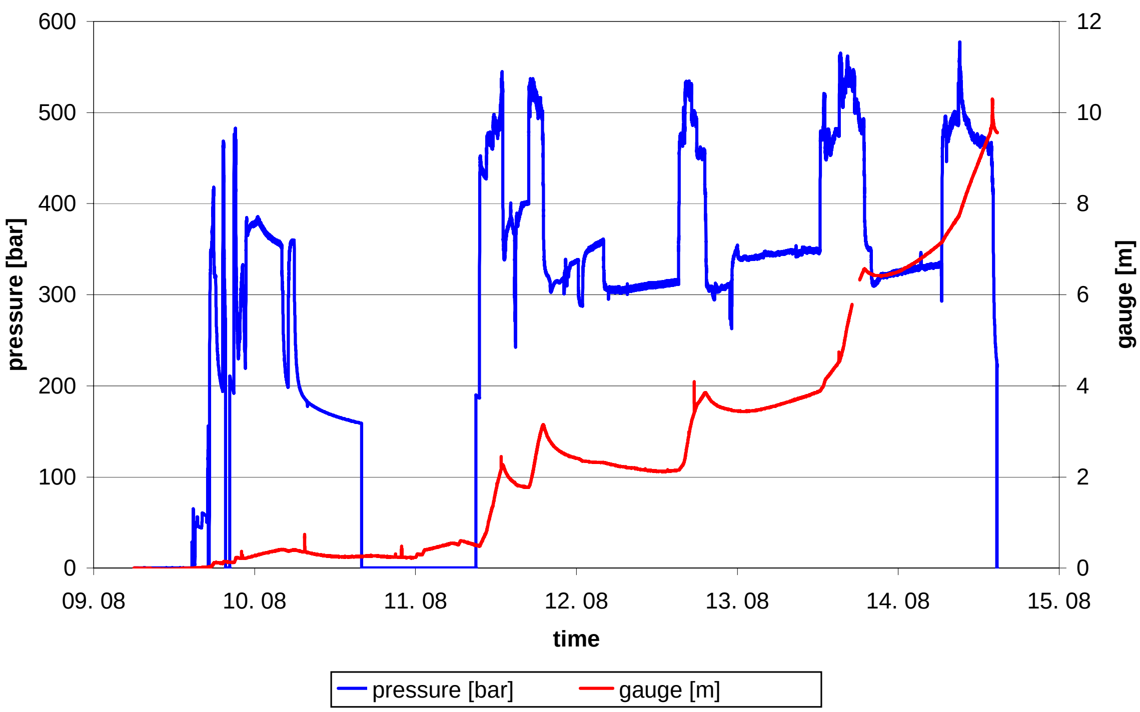

Figure 3 Change of water level in the well GrSk3/90 during the stimulation in the volcanic rocks.

STIMULATION OF THE SANDSTONES

The stimulation treatment in the sandstones of the lower Dethlingen was carried out from Aug. 18 to Aug. 19 2007. The intended interval from 4,204 to 4208 m was isolated with a bridge plug in 4,300m and then perforated with big hole perforations (20 per meter, circumferential). Transport of the proppants was provided with a cross-linked gel with high viscosity. To kind of proppants were applied: high strength proppants coated and uncoated. Both consist of a diameter of 0.4 to 0.8 mm (20/40 mesh size); the coated proppants were used at the end of the treatment to support the sustainable fracture opening in the near well bore vicinity.
The treatment started with an injection test with flow rates between 0.3 m³/min and 0.57 m³/min. In total 250 m³ were injected into the reservoir at a maximum well head pressure of 416 bars.

Subsequently a leakoff test was carried out to obtain the frac gradient (0.16 bar/m). Then followed a step-rate test to calculate the friction and tortuosity at the perforation. Finally followed the gel-proppant treatment where 95 to of proppants and 280 m³ of cross-linked gel were injected into the Lower Dethlingen formation with a flow rate of 4 m³/min (Fig.4).
The second gel-proppant treatment was carried out from Aug. 23 to Aug. 24 2007 in the sandstones of the Upper Dethlingen. The treatment was similar to the previous. The bridge plug was set in 4,123 m depth and the interval above from 4,118 to 4,122 m was perforated. The treatment started with an injection test with rates between 0.3 m³/min and 0.62 m³/min and a total volume opf 170 m³. The leak off test analysis yielded a frac gradient of 0.15 bar/m. In the following stimulation treatment 113 to of proppants and 310m³ of cross-linked gel were injected at flow rates between 3 -3.5 m³/min.

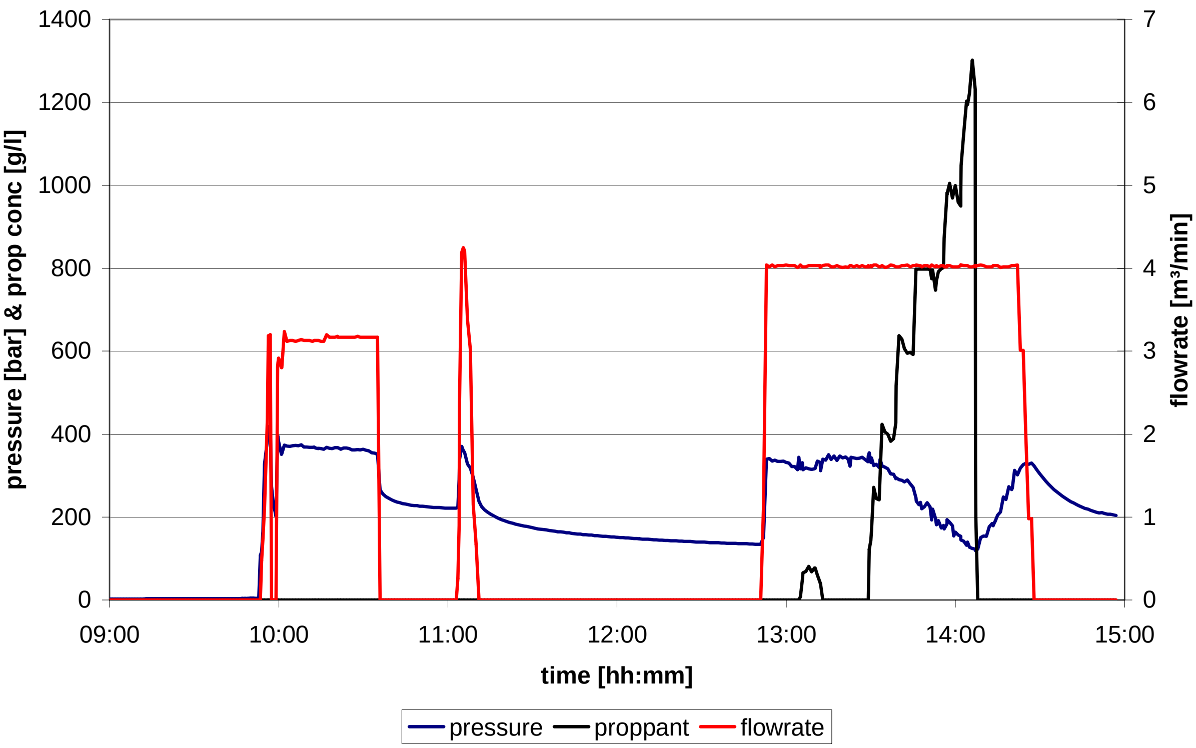

Figure 4 Schedule of the gel-proppant treatment in the Lower Dethlingen sandstones starting with a leakoff test and a step-rate test.

PRODUCTION TEST

After stimulation of the reservoir sections a casing lift test (CLT) with a nitrogen lift in conjunction with a flowmeter profiling was performed to test the stimulated intervals. In advance additional perforations (deep penetration charges) were carried out in the sandstone sections. Over a period of 12 hours approximately 300 m³ were produced. Fig. 5 shows the pressure and temperature response in the reservoir measured by the flow meter tool, which was installed in 4,110 m depth. During production two runs (up and down respectively) were performed by the flowmeter to obtain the inflow profile (Fig. 6). The results of the flow profile show that 30 % of flow is originated from the volcanic rocks. Nearly 50 % of flow can be attributed to the first gel-proppant treatment and 15 % is due to the second gel-proppant treatment. Only 5% can be assigned to the post perforations. A possible reason might be the drilling fluid, which was used to build a filter cake at the borehole wall to protect the reservoir. To enhance the performance of the post perforations it is intended to acidize these intervals.

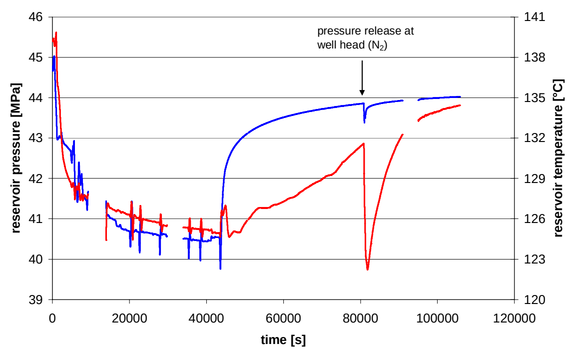

Figure 5 Schedule of the production test including the shut-in with pressure and temperature response.

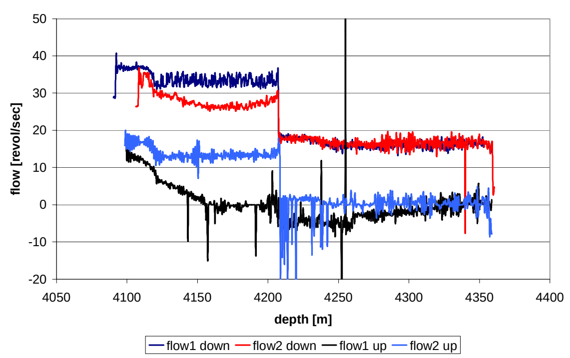

Figure 6 Flowmeter logs during the production test.

CONCLUSION

During the stimulation of the volcanic rocks a total volume of 13,000 m³ were injected in 4 cycles with flow rates up to 9 m³/min and a final phase with a flow rate of 5 m³/min. The aim of this stimulation was to establish a connection of the well from the volcanic rocks through the low permeable conglomerates into the sandstones. During these 4 cycles 24 to of sand were placed in the volcanic rocks to support the opening of the generated fractures beyond their own self propping potential. The result of the production test in conjunction with a flowmeter profile showed a 30 % contribution of the volcanic rocks to the total flow rate. Furthermore two gel-proppant treatments were realized to connect the well to the high permeable layers.

These treatments completed the doublet of the Groß Schönebeck wells and a geothermal power production can be achieved in the near future.

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