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THE STIMULATION OF A SEDIMENTARY GEOTHERMAL RESERVOIR IN THE NORTH GERMAN BASIN: CASE STUDY GROß SCHÖNEBECK

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ABSTRACT

In order to make the generation of geothermal electricity in a sedimentary reservoir rocks possible a deep former gas exploration well was reopened and deepened in 2000 to 4294 m depth. An in-situ downhole laboratory was established in this well with the purpose of developing appropriate stimulation methods to increase permeability of deep aquifers by enhancing or creating secondary porosity and flow paths.

The goal is to learn how to enhance the inflow performance of a well from a variety of rock types in low permeability geothermal reservoirs. Proppant-gel-frac techniques as well as waterfrac techniques were used in several different experiments. During the proppant-gel-frac two intervals of Rotliegend sandstones were hydraulically stimulated in January 2002. The experiment design comprised isolating the bottom boundary of the interval of interest by filling the bottom of the well with sand. The top of the interval was sealed with a mechanical packer. High-viscosity fluid with proppant was employed for stimulation. Flow rates were increased significantly, and a fracture with a length of 150 m was generated due to this operation. However, the productivity observed was insufficient for power production. Further stimulation of the reservoir rocks in this well was performed in two experiments in winter and fall 2003 using the waterfrac technique. More than 15000 m³ water was injected in different pressure steps with flow rates up to 80 ls^{-1}. Mechanical reacting reservoir properties were observed at injection flow rates above 9 ls^{-1}. Recent data of a production test show a productivity of 14 $m^3h^{-1}MPa^{-1}$.

INTRODUCTION

Sustainable and environmentally friendly energy can be generated from the conversion of Earth's heat (from formation fluids) into electricity. Production of deep thermal water with flow rates of about 50 m^3h^{-1} is a precondition for economic generation of electricity.

The required temperature for this purpose can be found in the North German Basin in 4000 m to 5000 m. However, in this depth permeability of the rocks is generally insufficient for the necessary flow rates.

The site Groß Schönebeck is promising. The well makes deep hydrothermal aquifers accessible with formation fluids of 150 °C and porosities of up to 10 % (Huenges & Hurter, 2002). Experiments in this in-situ geothermal laboratory should lead to a reliable technology for sufficient production of deep fluids in such reservoirs.

GEOLOGY

The drill site is located northeast of Berlin. The well encounters the typical sequence of various geological formations, known in the North German Basin. A series of 2370 m of Quaternary to Triassic sediments is under lied by 1492 m of the Zechstein salinar and the following section of this well, which was foreseen for testing, comprises 400 m of Rotliegend formation (siltstones, sandstones, conglomerates and 60 m of underlying volcanic rocks) up to the final depth of 4294 m (Huenges et al., 2002).

TECHNOLOGY DEVELOPMENT

Technologies have to be developed to enhance the existing flow. This can be summarized by the term *hydraulic fracturing*. During stimulation experiments fluids under high pressure penetrate into the rock and generate or extent fractures. These procedures are well known in hydrocarbon industry as well as in the Hot Dry Rock (HDR) technology. However, the objective for using hydrothermal reservoirs requires a special stimulation technique to be able to produce considerably higher amounts of fluids compared to hydrocarbon reservoirs. In contrast to the HDR technology our aim was not to install a heat exchanger but to get access to formation fluids in the reservoir. The most important parameters in these experiments include

- fracture fluids volume,
- its injection rate,
- its viscosity (water with added polymers)
- and its composition (chemical variants or adding proppants),
- and the selection of the depth interval to initiate new fractures.

Stimulation experiments

(i) Sandstone stimulation

Stimulation of the Rotliegend took place in January 2002. Several experiments were made using proppant-gel-frac techniques in two intervals of the Rotliegend sandstones. Experiment design comprised the isolation of the bottom boundary of the interval of interest by filling the bottom of the well with sand. The top of the interval was sealed with a mechanical packer. High viscosity fluid with proppant was employed for stimulation. Flow rates were increased significantly, and a fracture with a length of 150 m was generated due to this operation (see figure 2) (Zimmermann et al, 2003). The observed flow rates were not sufficient for economic power production. Legarth et al. (2003) conclude that the experimental results were strongly influenced by the proppant properties during the treatment. Another parameter to improve the results is the volume of injected frac fluid in a forthcoming experiment. Therefore, the experiments were continued with a procedure injecting at least two orders higher volume into the reservoir.

(ii) Massive waterfrac treatment I

January/February 2003 the borehole section was still without a casing between 3850 m and the final depth. A pressure step test using increasing injection rates up to 24 ls^{-1} were performed. At injection rates up to about 9 ls^{-1} a linear increase of pressure with increasing injection rate was observed. However, a lower slope of this correlation was typical for higher injection rates. This indicates more fluids could be injected with pressure. The analyzed shut in data after the lower pressure steps indicate a lateral fracture length above 150 m (Tischner et al., 2003).
After the massive injection with 24 ls^{-1}, 250 m^3 water was produced from depth within a 5 hours production test. This indicates in comparison with tests after the sandstone frac treatment a significant increase of productivity (see figure 3). This shows that the massive water injection had produced additional fractures, so that the experiment was noted successful. However, borehole breakouts took place resulting in an obstruction just at the upper part of the tested section at about 3900 m depth. Therefore, further technical borehole operations were necessary.

(iii) Reopening, deepening, and liner installation in the well

In October 2003 the well was re-opened and deepened to 4309 m, and for stabilisation of the well an additional liner from 3850 m down to the final depth was installed. Prior to the liner installation, an extensive logging program was performed to get information about the geological structure and the lithology of the borehole section of interest. FormationMicroImaging-Measurements show very clear the produced vertical fracture of 150 m length which was first observed by BoreHoleTeleviewer BHTV measurements after the sandstone frac treatment (see figure 2).
The liner was installed in the lower part beneath 4135 m installation depth with perforated tubes. A huge number of holes were drilled into the wall of the tube to ensure the hydraulic contact to the formation. In the stabilized well the massive water frac experiment was continued in fall 2003.

Figure 1.: Drilling rig for the opening and clearance of the borehole, Groß Schönebeck, October 2003

(iv) Massive waterfrac treatment II

After the liner installation the massive injection was continued with a pressure step test and a several day injection of 30 ls^{-1} and over a very short time up to 80 ls^{-1} into the open hole.
The pressure step test indicates multiple fracture generation and extension with opening and closure pressures between 60 and 88 bar above formation pressure. Within a 10 hours production test more than 1000 m^3 water was produced from depth indicating another increase of productivity in comparison with former tests (see figure 3).

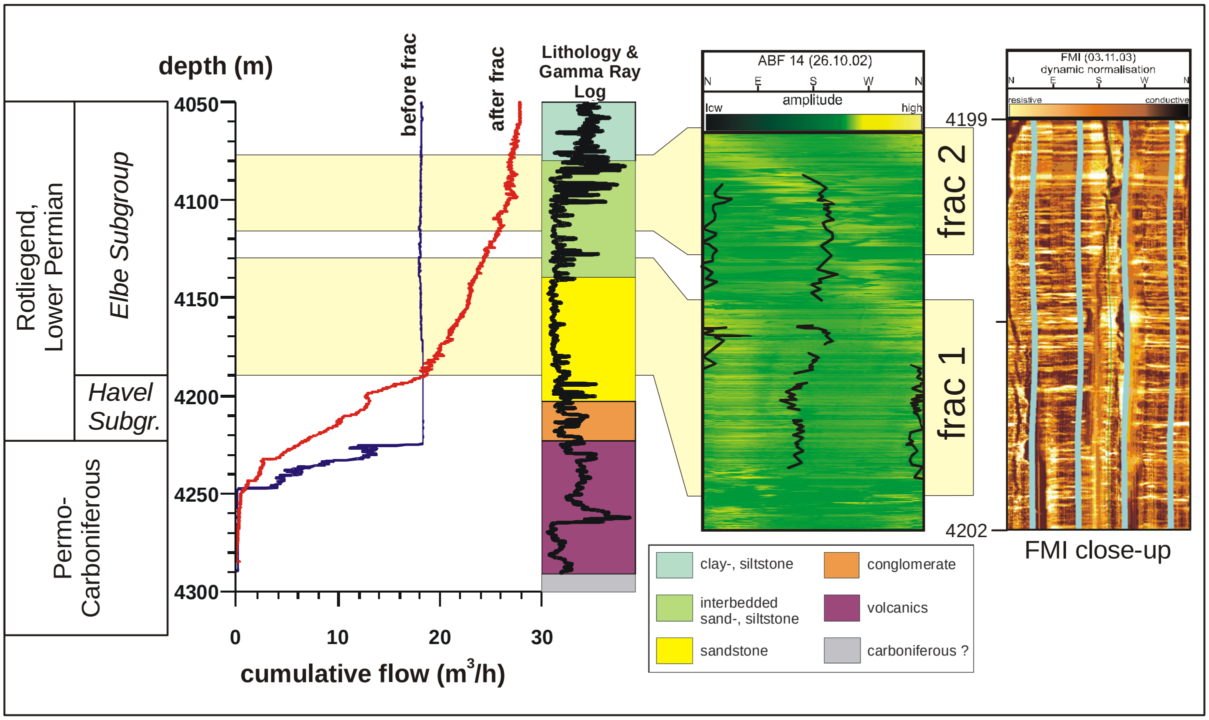

Figure 2: *Stratigraphy and lithology of the hydraulically fractured sections in the open-hole interval including a comparison of flowmeter logs (first PI=1.1 $m^3 * h^{-1} * MPa^{-1}$ and second production test PI: 2.2 $m^3 * h^{-1} * MPa^{-1}$). The BHTV(ABF14)- and FMI-images illustrate the open fractures parallel to the maximum horizontal compressive stress (S_H).*

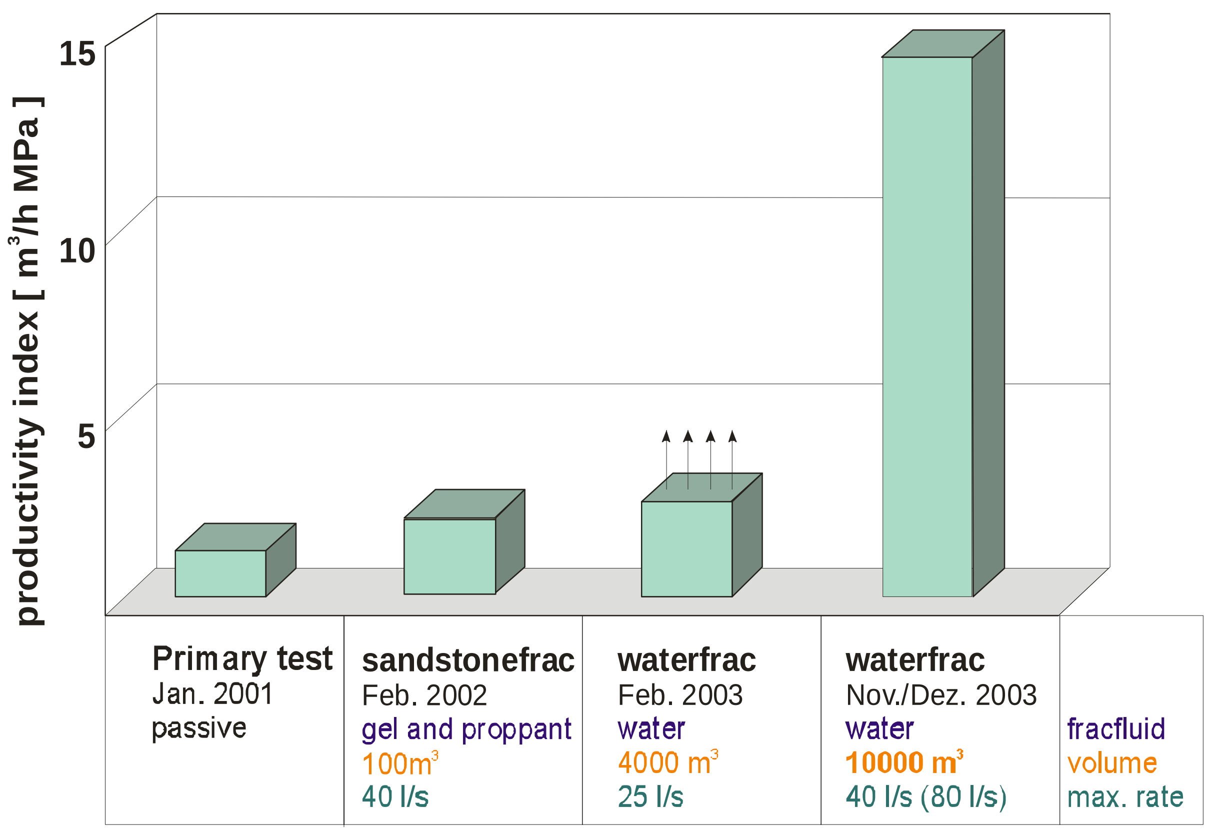

Figure 3: *Plot of enhancing productivity in Groß Schönebeck 3/90 during several reservoir treatments since 2000. The arrows at the Feb. bars indicate uncertainties due to an obstruction in the well. The values at the Nov. bars reflect productivity @ fracture closure pressure.*

The data shows that the stimulation treatments caused an increase of productivity up to 14 $m^3*h^{-1}*MPa^{-1}$- determined at fracture closure pressure. Self propping was not observed in the sandstones.

Conclusions

The results reflect the learning curve from several reservoir treatments (figure 3). These experiments are major steps towards developing a procedure to increase the thermal water productivity from a prior low permeable sedimentary reservoir. For "engineering" the reservoir we recommend a method of massive waterfrac with a proppant treatment at the end to ensure the opening of the fracture and long term stable width of the fracture.

The obtained values of productivity seem to show the feasibility of geothermal power production from a sedimentary geothermal reservoir.

The concept for power production from the Groß Schönebeck reservoir comprises a doublet of wells. The second well should be completed as a production well. The existing well can be used as an injection well.

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