Geothermal power generation in the Upper Rhine Valley – The Project Offenbach/Pfalz

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Abstract

HotRock GmbH plans the construction of a geothermal power plant with an electrical performance of 4.8 MW in Offenbach/Pfalz in the Upper Rhine Valley of Germany. This part of the valley has particularly favourable geological conditions for geothermal heat development. The location was selected for the first project, because of the high geothermal temperatures (150°Celsius in a depth of 2500 m). The geothermal power plant will consist of a geothermal primary cycle and a secondary power cycle (Kalina Cycle). The geothermal primary cycle is a doublet with a vertical re-injection well and a deviated production well. Hot water production of 100l/s will come from a 110 m thick carbonate aquifer (Upper Muschelkalk). This project will demonstrate the quality of the aquifer for geothermal use. This layer is fractured and faulted due to the tectonic history of the Middle Upper Rhine Valley. High production rates will be realized using technologies from the oil industry. Horizontal drilling will be used for the first time in Germany for geothermal production and guarantees, in combination with the tectonic setting, an economically successful project. A geological model has been designed from existing geological information and the performance of the aquifer over time has been modelled using standard oil industry software. To identify faults and structures in the formation, to verify the model and to orient the horizontal wells, two east-west seismic lines will be shot north and south of the project location in June 2003. The results were presented at the conference.

Keywords: *geothermal power production, reflection seismic, modelling.*

1 The Project Offenbach/Pfalz

The German Renewable Energies Act guarantees a price of 8,9 Eurocents per kWh fixed for 20 years for electricity produced from geothermal resources in Germany. The most promising region for the production of electricity is the Upper Rhine valley. Here temperatures can be as high as 170°C at a depth of 2500 m compared to more than 4000 m for the same temperature in other regions of Germany (Figure 1).

For its first commercial geothermal project HotRock GmbH decided to select the most promising aquifer of the Upper Rhine Valley and will use standard exploitation techniques of the oil and gas industry to develop it.

1.1 Geology

The Upper Muschelkalk consists of 80 m of limestones (shelly, nodular and some oolitic) and dolomites with thin marls and mudstones, being at a depth of about 2500 m at the project location. Adding to the thickness of this reservoir are the overlying carbonates of the lower part of the Lower Keuper (Lettenkeuper) (15 m) and the upper part of the Middle Muschelkalk (15 m), leading to a usable aquifer thickness of about 110 m.

The target geothermal reservoir layers are dipping slightly to the east, thickness and lithology being constant over the area of the project.

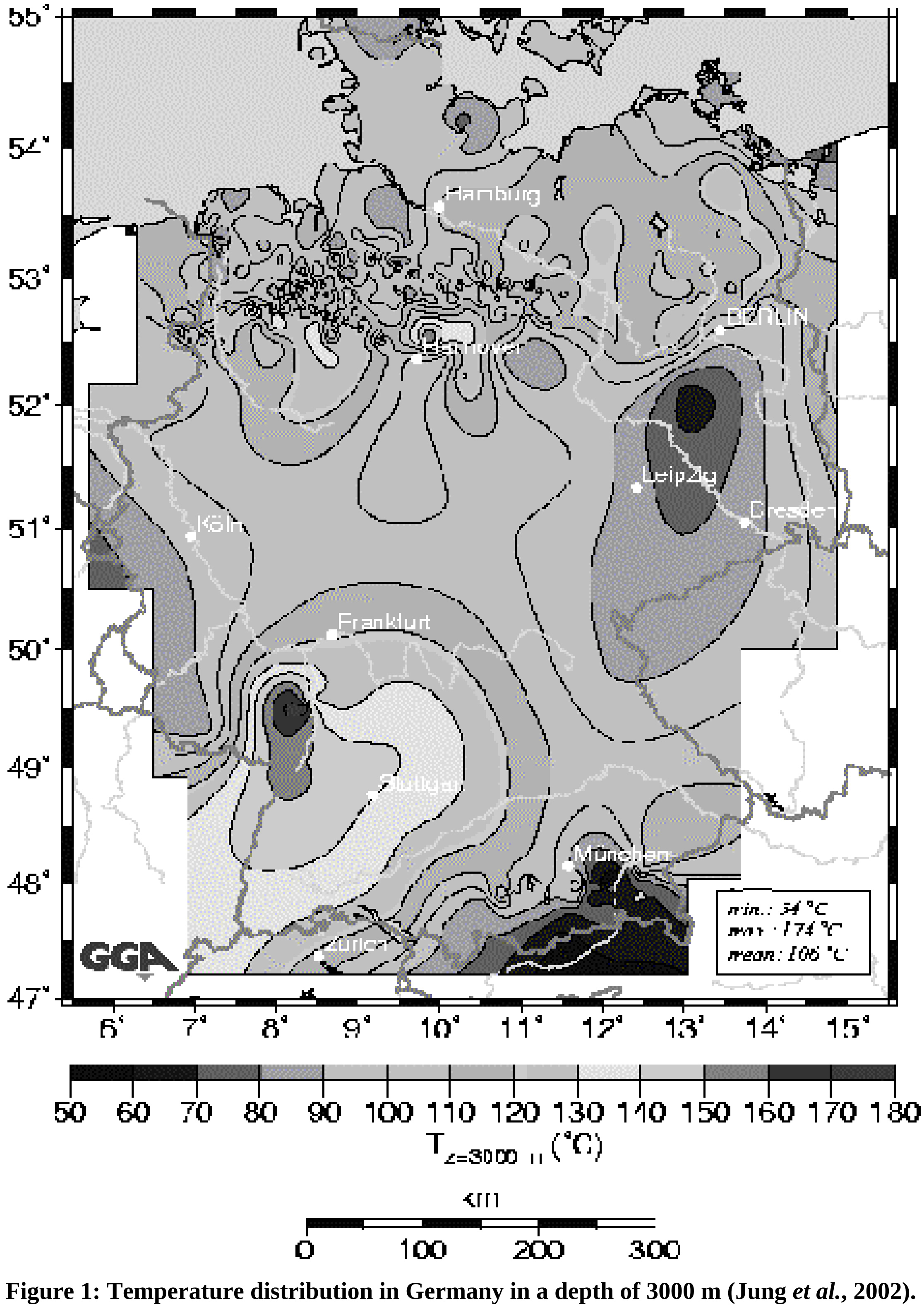

Figure 1: Temperature distribution in Germany in a depth of 3000 m (Jung *et al.,* 2002).

The brittle carbonate rocks are broken up and fractured by major fault zones in the Rhine Graben rift system. The system has a north-south trend and is one of the best-studied continental rifts in the world. During the opening of the rift, the middle part was structurally controlled by fault zones crossing the rift valley in a direction of about 50° (Figure 2). Harthill (2002) showed, that the high temperatures in the area of the middle Upper Rhine Valley and the major block faulting, with regularly-oriented fracture systems are associated with these fault zones. Dyke intrusions along these fault zones are the source of the high temperatures. Figure 2 also shows the break in the alignment of the rift in the middle part due to the northeast-southwest fault zones. The regularly orientated vertical open fractures are the basis of the exploitation concept adopted to allow high flow rates and therefore minimize the economic risk of the project.

1.2 Exploitation method

The specific new approach is the adoption of horizontal drilling techniques and well sidetracks for the exploitation of geothermal resources (Kreuter, 2002). These methods are state-of-the art technologies in the oil and gas industry. The horizontal wells will be orientated optimally to the fracture system and drilled as far as necessary to reach and penetrate as many fractures as needed. The major fracture systems to the East and West of the project location will be explored using geophysical methods before drilling (see section 3). Methods like acidising and thermal or hydraulic fracturing can be used additionally to stimulate the flow rates. Acidising especially has given good results in carbonate rocks while fracturing is limited.

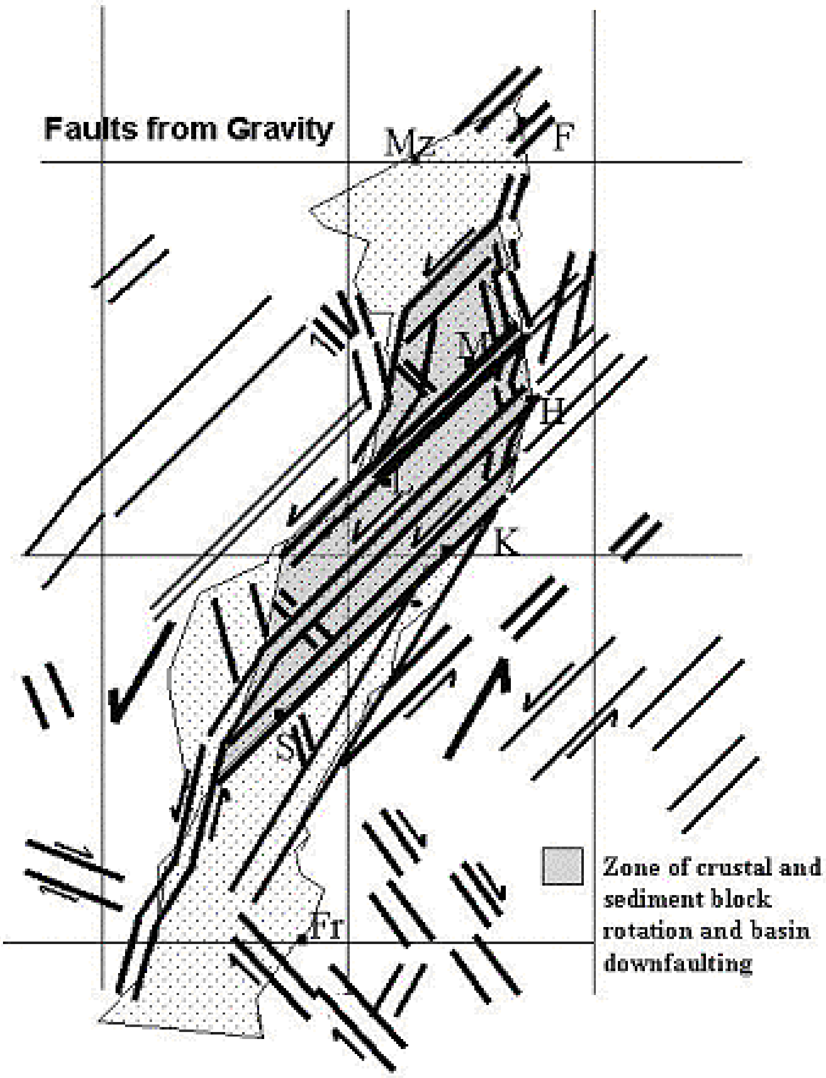

Figure 2: The Upper Rhine Graben rift valley (Harthill, 2002).

1.3 Project design

In the Offenbach Project hot water at 150°C will be taken from an aquifer at a depth of 2.5 km to the surface. The flow rate expected using the described exploitation concept is 100l/s. The hot water is passed through a heat exchanger to produce steam, which drives turbine that generates electricity.

The cooled water (70°C) is then reinjected down a second well back into the aquifer (Figure 3). The power station uses the Kalina Cycle and is build by Siemens who will be the general contractor for the surface installations. The power produced is expected to be about 4,8 $MW_{el.}$.

2 Modelling

2.1 The Geological Model

The effect of cold-water injection and hot water production on the temperature and pressure distribution within an aquifer can best be studied in a numerical reservoir simulation model. Such a model requires a geological model as an input. The geological model for the Lettenkeuper and the underlying Muschelkalk was constructed based on the available seismic and well data. The model was vertically separated in 4 layers, representing impermeable overburden and underlying layers, with the permeable Lettenkeuper and Muschelkalk layers forming the aquifer (Figure 4). The model was loaded into a reservoir simulator as a 22x30x4 grid with grid blocks of 250 m x 250 m size.

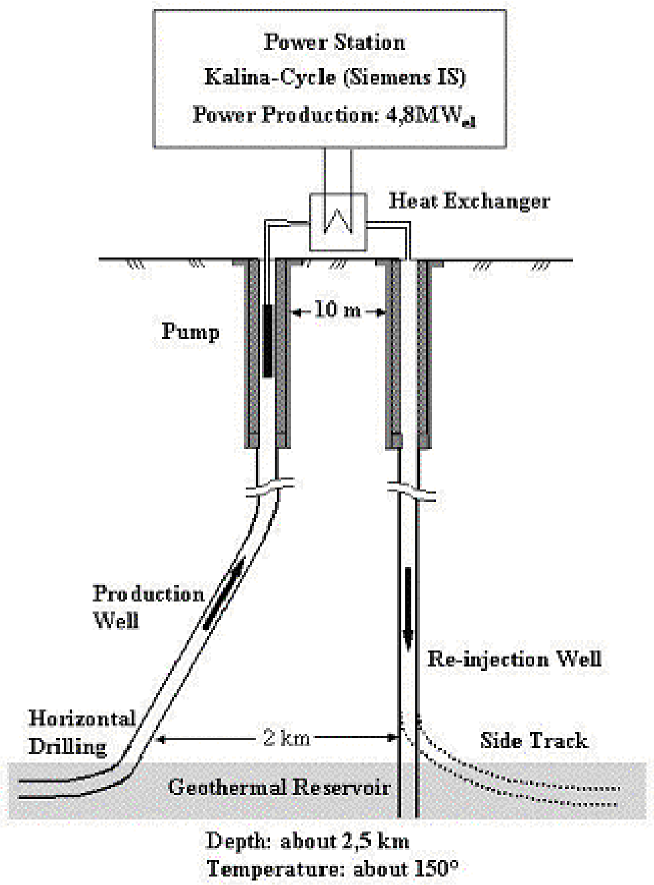

Figure 3: The concept of the geothermal power project in Offenbach/Pfalz.

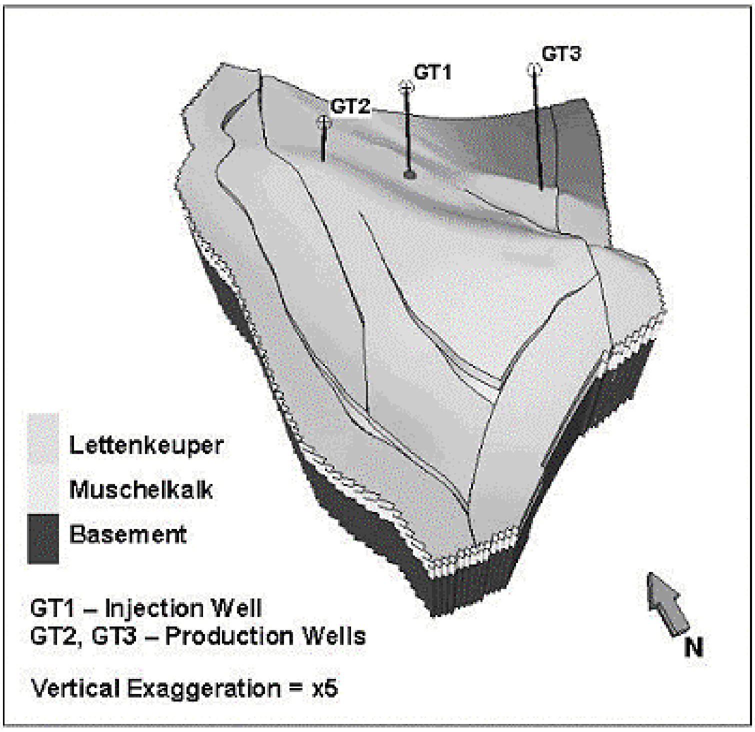

Figure 4: 3D Geological model of the aquifer showing the location of the faults and the wells. (The distance between GT1 and GT2 is 1.2 km and and between GT1 and GT3 is 2.2 km).

2.2 Modelling the thermal flow

The reservoir fluid properties were derived from correlations for typical brine with a salt content of 100,000 ppm. Constant rock properties were applied to the aquifer layers and a total horizontal transmissibility of 21.4 Dm was used for the aquifer. The thermal properties were kept constant for all layers and were in accordance with commonly used correlations for carbonate rocks. The modelling was undertaken with the 3D multiphase flow reservoir simulator REVEAL, which is commercially used in the petroleum industry.

The simulation runs were performed for a period of 25 years. Sensitivities included variations of the production and injection rates up to 200 l/s, one and two production well scenarios and the impact of reducing aquifer thickness to 35 m. A directional permeability of 140˚ was introduced to reflect the dominant open fracture trend. All the runs revealed only very minor temperature losses throughout the aquifer over the 25 year period and indicated that the cooling of the aquifer has a negligible effect on the temperature of the produced brine even after 25 years of production (Figure 5).

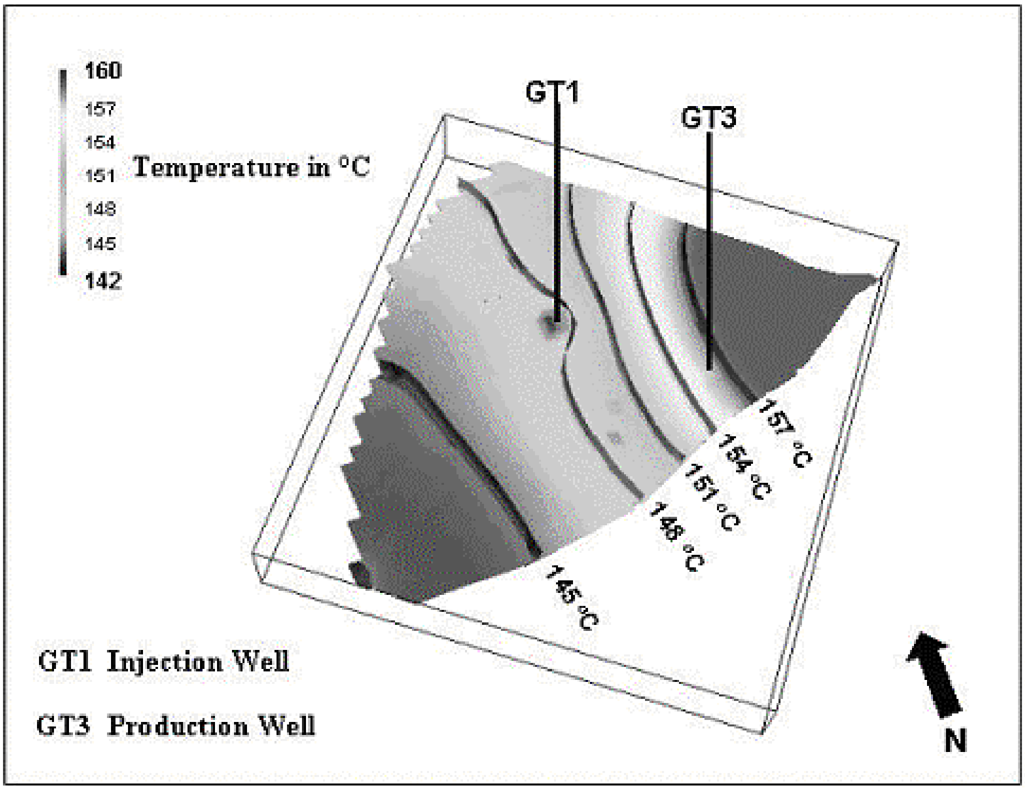

Figure 5: Temperature distribution at the top of the Muschelkalk after cold water injection at 70 ºC into well GT1 for 25 years with a balanced production/injection rate of 100 l/s. No cold water breakthrough has occurred at production well GT3. (The distance between GT1 and GT3 is 2.2 km).

3 Reflection Seismic

Geophysical exploration before drilling will show the depth of the geothermal reservoir and the location of the main fracture zones on the east and west side of the block. The seismic exploration done by the oil industry in the early seventies, and earlier, targeting the shallow oil bearing horizons and therefore only gave a vague impression of the Muschelkalk reservoir. The interpretation technology has developed to the point that seismic data can reveal less pronounced structures and almost vertical fracture zones, the target for directional horizontal drilling. Figure 6 shows the layout of the two seismic lines, each 12 km long, located about 1,5 km north and south of the drilling location and intersecting the almost vertical fault zones in the east and west. The seismic vibrators used by Deutsche Montan Technologie (DMT) for the survey are shown in Figure 7. The results of the survey will be presented at the conference.

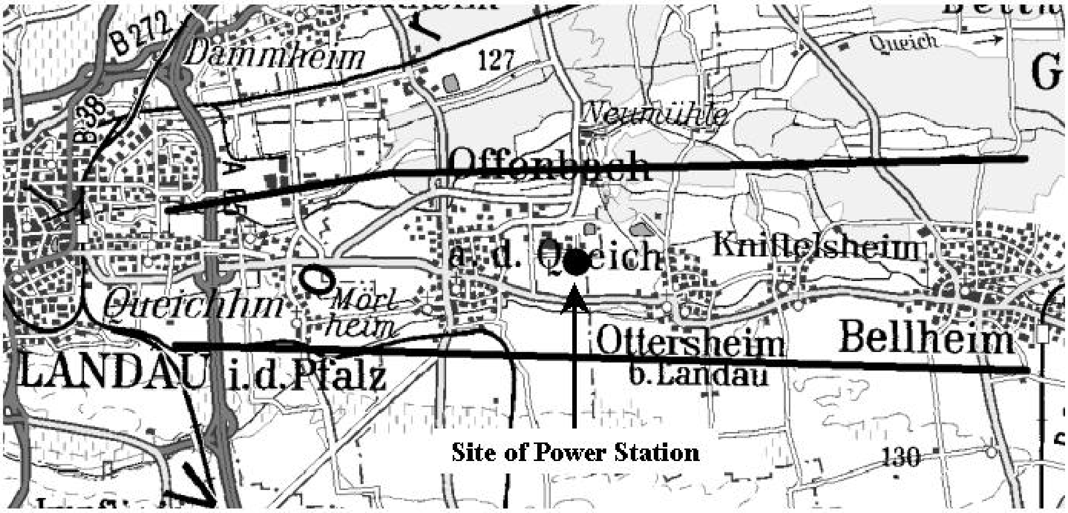

Figure 6: Layout of the seismic lines north and south of the Offenbach/Pfalz Project site.

Figure 7: Vibrators of Deutsche Montan Technologie (DMT) used for the seismic survey.

Acknowledgements

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4 References

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