First results of the Geothermal Resource Analysis in Rhineland-Palatine

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Introduction

In the past, the analysis of the surface heat flow and the measured temperatures in the subsurface has revealed clear geothermal anomalies in the Rhine graben of Rhineland-Palatine (e.g. Hurter and Schellschmidt, 2003). The aim of the new geothermal resource atlas of Rhineland-Palatine (Fig. 1) is to characterise the geothermal resources in terms of their potential geothermal energy production. The large-scale evaluation is conducted in the style of the Swiss Geothermal Atlas (Signorelli and Kohl, 2006). An enhanced 3D geological model is achieved using inversion of geophysical data. Temperature is evaluated by elaborating a 3D numerical thermal calibration model. The final results are reported for the possible aquifer types, but focus on the intense fault systems.

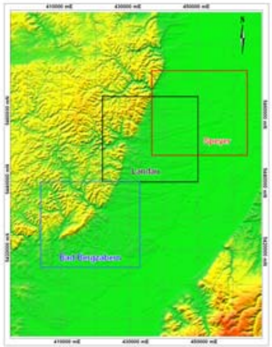


Fig. 1: Topographic map of the central Upper Rhine Graben with the three investigation areas for the geothermal resource analysis.

3D Geological Model

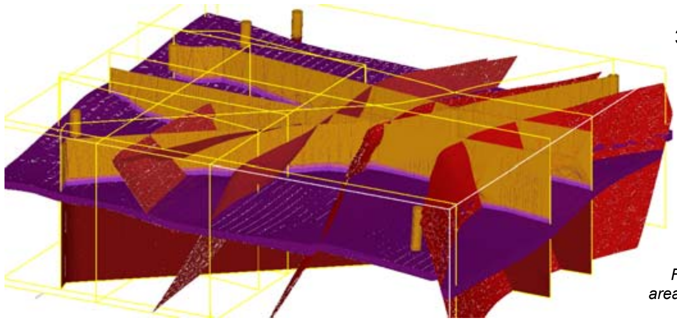


Fig. 2: Geological model of the area of Speyer (red: Major Faults, violet: Buntsandstein horizon)

Geological models have been calculated using a potential field approach (Lajaunie et al., 1997), which incorporates geological layers as equipotential surfaces and the geological dip as gradient of the geological potential. This approach is implemented in the software 3D Geomodeller (BRGM, Intrepid Geophysics). The input data were used: own field observation, geological maps, borehole information and interpreted seismic sections to calculated the 3D model (Fig. 2). A stochastic approach has been developed to validate the accuracy of the model regarding the uncertainties in the input data (Fig. 3, Wellmann et al., 2007)

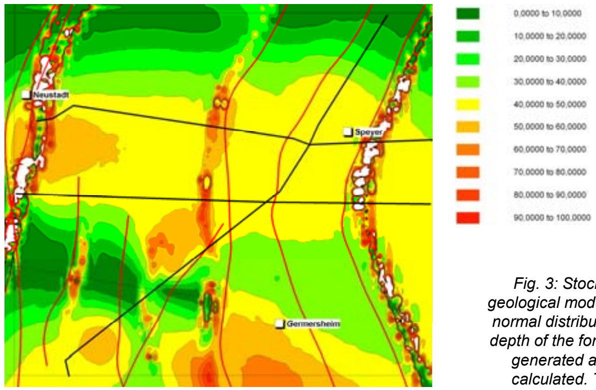


Fig. 3: Stochastic approach for the evaluation of the geological models (example Speyer). With an assumed normal distribution of the uncertainties (in this case the depth of the formations) 20 different input data sets are generated and the respective geological models are calculated. The result is given in standard deviation.

Input Parameter for the Temperature Model

The temperature model is calibrated using temperature measurements from boreholes. For the calibration model a conductive heat transport and heat production are considered a first step. The transport of heat is calculated assuming thermal energy conservation:

$$\rho c_p \frac{\partial T}{\partial t} = \nabla (\Lambda \nabla T) - Q$$

with pcp = thermal capacity, T = temperature, t = time, Λ = thermal conductivity, Q = heat sources. The following input parameter have been used (Tab. 1). The basal heat flow was calculated according to the distribution of neat production rate in granitic basement of Soultz-sous-Forêts (Pribnow et al., 1999), which was extrapolated to a depth of 8000m. A static thermal conductivity was determined for the basement using the temperature of 200˚C at 5000m and the geothermal gradient of about 30˚C km^{-1} in a depth of 4000-5000m at Soultz-sous-Forêts as reference. For the sediments values have been estimated from the literature.

	Λ [W m^{-1} K^{-1}]	ρc_p [J kg-1 K-1]	Q [W m^{-3}]
Tertiary	2.1	2.2 E+6	0.5 E-6
Muschelkalk	2.2	2.2 E+6	0.5 E-6
Buntsandstein	2.6	2.2 E+6	0.5 E-6
Basement	2.7	2.4 E+6	3.3 E-6
Initial basal heat flow	0.095 Wm^{-2}		

Tab. 1: Input parameter of the initial calibration model (Fig. 4).

Temperature Calibration

For the temperature calibration three wells have been used:

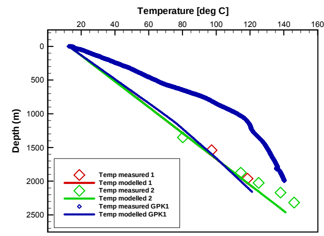


Fig. 4: Temperature calibration of three wells in Bad Bergzabern.

Temperature Calibration with a Convective-Diffusive Approach

For the temperature calibration of the convective-diffusive thermal field, the wells GPK1 and GPK2 at Soultz-sous-Forêts have been used. The simulation of the convection has been carried out using local differences in heat distribution (Fig. 5).

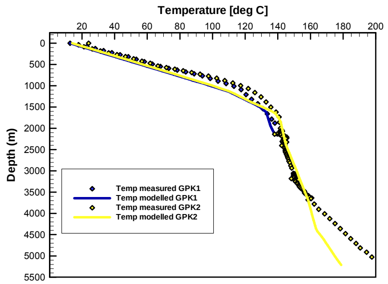


Fig. 5: Temperature calibration of GPK1 and GPK2.

Convective-Diffusive Temperature Field of the Bad Bergzabern

The temperature field of the area Bad Bergzabern could calibrated using a convective-diffusive approach. The temperature distribution is given in Fig. 6 and 7.

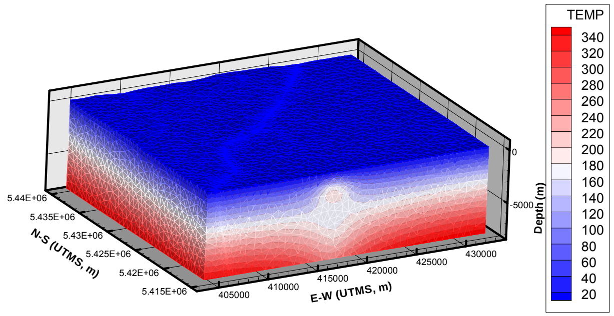
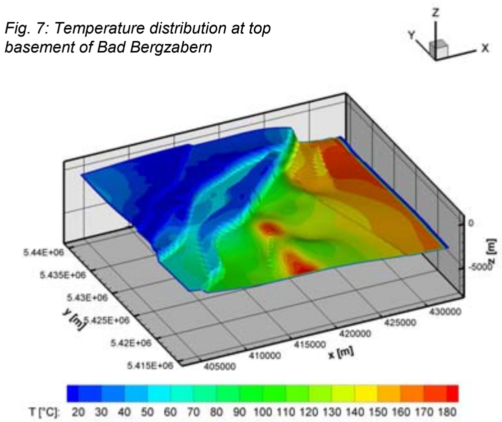


Fig. 6: Convective-diffusive temperature field of Bad Bergzabern

Fig. 7: Temperature distribution at top basement of Bad Bergzabern



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