A Conductive Geothermal Model in the EU-project "Geopotentials of the deep Upper Rhine Graben (GeORG)"

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ABSTRACT

Within the framework of the EU-Project "GeORG" a regional numerical model was set up in order to investigate the steady-state conductive temperature regime. The target area is the Upper Rhine Graben.

Necessary data as well as the digital geological model was provided by the GeORG group. Geophysical data from 28 boreholes could be used to constrain the input parameters, amended by few laboratory measurements of thermal data.

Numerous bottom hole temperatures and a few temperature logs were made available, which allowed to calibrate the model to some degree.

1. CONCEPT OF NUMERICAL MODELLING

Numerical simulations are well known as important tools for exploration of geothermal reservoirs, since they can predict thermal and hydraulic reservoir conditions and are able to simulate the development of a reservoir while production (e.g. Mottaghy et al. 2011). However, reliable forecasts are only possible, if the subsurface geology of the area is known and the corresponding thermal and hydraulic properties are well defined. Therefore, as much as possible information should be compiled, in order to build up a geothermal model (Fig. 1).

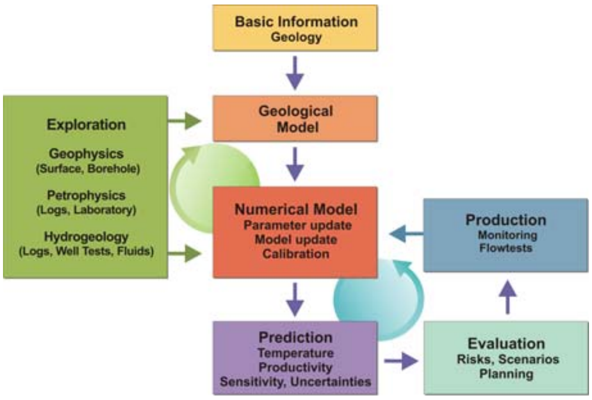

Figure 1: Flow diagram for the build up of a geothermal model.

2. DATA INPUT

The GeORG project group provided all necessary information and made the digital geological model available as a basis for the regional numerical model. From regional authorities logging data and borehole reports including information to lithology and stratigraphy were allocated for 28 boreholes. Additionally, a very few laboratory measurements of porosity and thermal conductivity were available.

Finally, we worked on 11 boreholes to derive specific thermal-hydraulic values for the model. These boreholes were selected with respect to the best geographic and stratigraphical coverage of the studied area (Fig. 2) and due to the amount and the quality of available log and core data. The names of the selected boreholes are: Landau-250a, Bruchsal-1, Stutensee-1, Maximiliansau-2, Niederlauterbach-101, Mothern-1, Niederrödern-Nord-1, Oberrödern-101, Rohrlach-1, GPK-1 and Rülzheim-2.

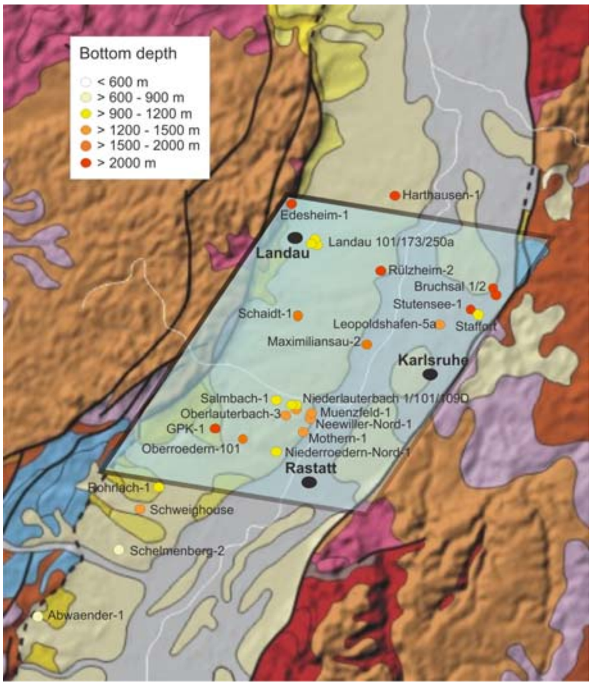

Figure 2: Map of the model area. 11 boreholes were made available for the study.

3. THERMAL PROPERTY PREDICTION

Borehole data were checked for quality and verified with the responding descriptions of lithology and stratigraphy. Subsequently, the rock portions of shale and the matrix of sand or rather lime and the porosity were calculated (Fig. 3). Core data was used to calibrate the log results (Fig. 4). Defining matrix thermal conductivities for sediment and igneous rock components on the basis of literature data, continuous thermal conductivity (TC) profiles could be derived for each borehole. Partly, thermal conductivity values could be compared to core data recovered from the same borehole (Fig. 5). Otherwise core data from distant boreholes which are located in the Western Molasse Basin and penetrate the same formations were used for further calibration. Radiogenetic heat production (HPR) was derived from the GR-Log following an empirical relationship introduced by Bücker & Rybach (1996). The results of all boreholes were finally used to define the thermophysical input parameter for the conductive geothermal model.

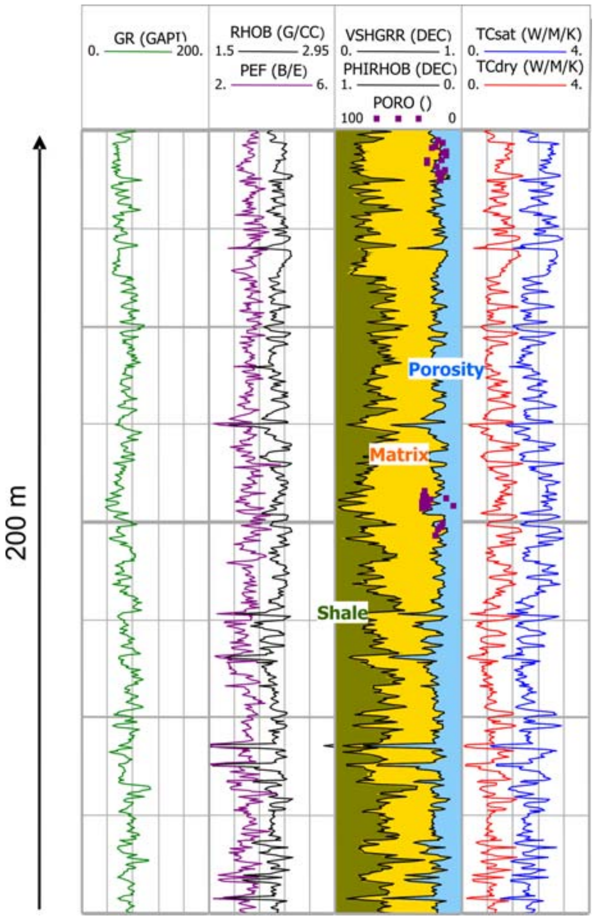

Figure 3: Shale volume and porosity prediction for tertiary rocks (silty marls). The Gamma ray log (GR) was used to define the shale content (VSHGRR), whereas the density log (RHOB) served for porosity calculations (PHIRHOB). Core data were used to calibrate the log results (small purple boxes).

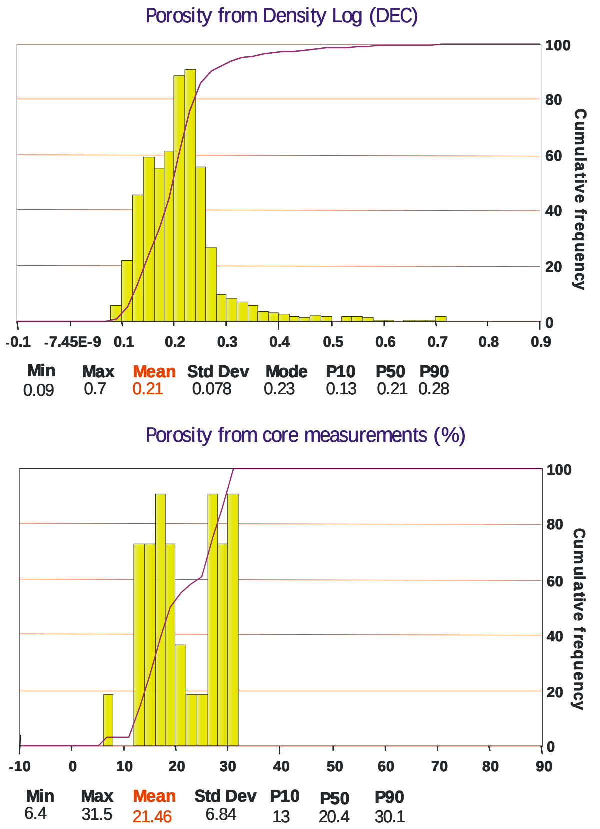

Figure 4: Comparison of core and log data with respect to porosity.

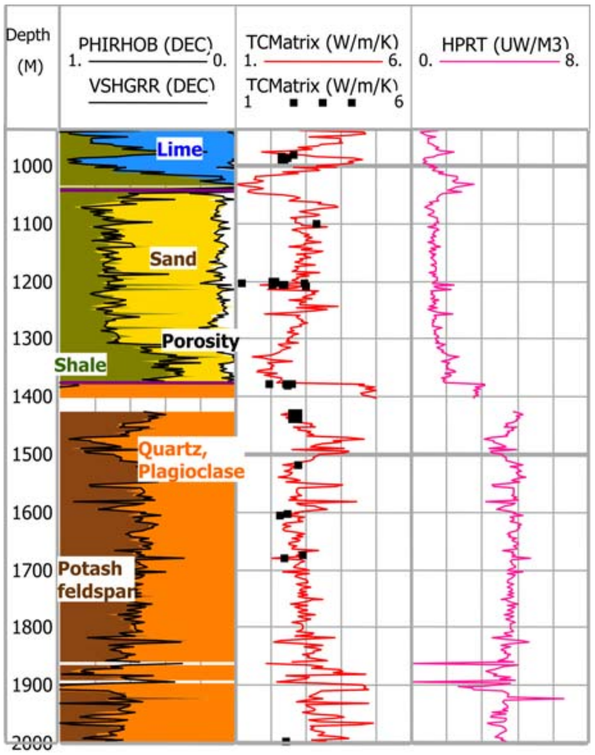

Figure 5: Thermal conductivity and heat production logs calculated for the GPK1 well. Thermal conductivities from core data (small black boxes) and logs are in good agreement.

4. NUMERICAL MODEL SIMULATION

The geometry of the model units / stratigraphic layers was taken from the structure geological model, built up by the GeORG project team. Well log analysis results in a thermophysical characterization of each of the model units and provides representative model input parameter. First simulations runs were performed for temperature predictions, assuming a fully conductive regime (Fig. 6). Comparison of model results and measured data in borehole highlights zones of thermal anomalies produced by advective heat transport (Fig. 7).

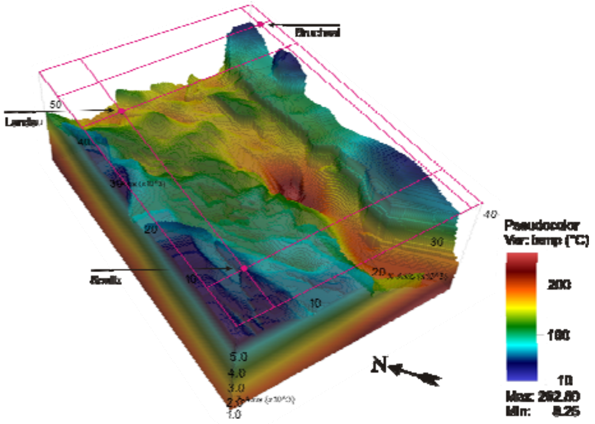

Figure 6: Regional conductive thermal model of the study area. The figure shows the temperature distribution at the top of the Muschelkalk formation.

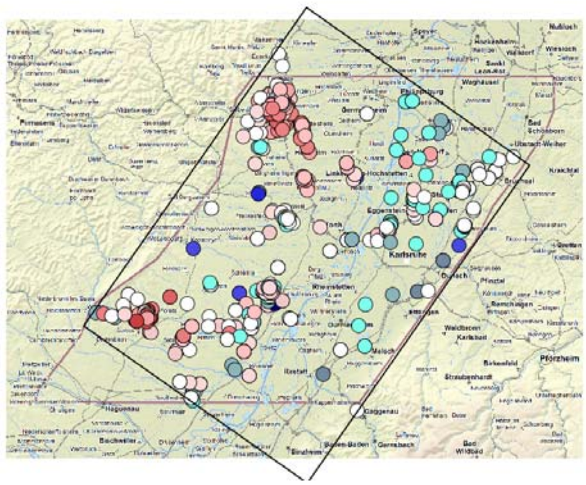

Figure 7: Comparison between modelled temperatures and BHT data. The red colors indicate that the BHT data are higher than the modelled ones, thus implying a conductive influence in these areas.

4. CONCLUSIONS

By comparison of model results with measured data we could highlight zones of thermal anomalies, likely produced by advective heat transport but also by the heterogeneous geological situation in the Upper Rhine Graben, which is characterized by varying thicknesses of the sediment layers. The strong contrast between thermal properties of tertiary sediments and the crystalline bedrock yield large lateral temperature variations within one depth layer. Thus, our model gives valuable information on the steady-state, conductive temperature field, which can be used as background information for geothermal exploration.

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