Geological and Geothermal 3D Modelling of the Vienna Basin - Pilot Area of the project TRANSENERGY

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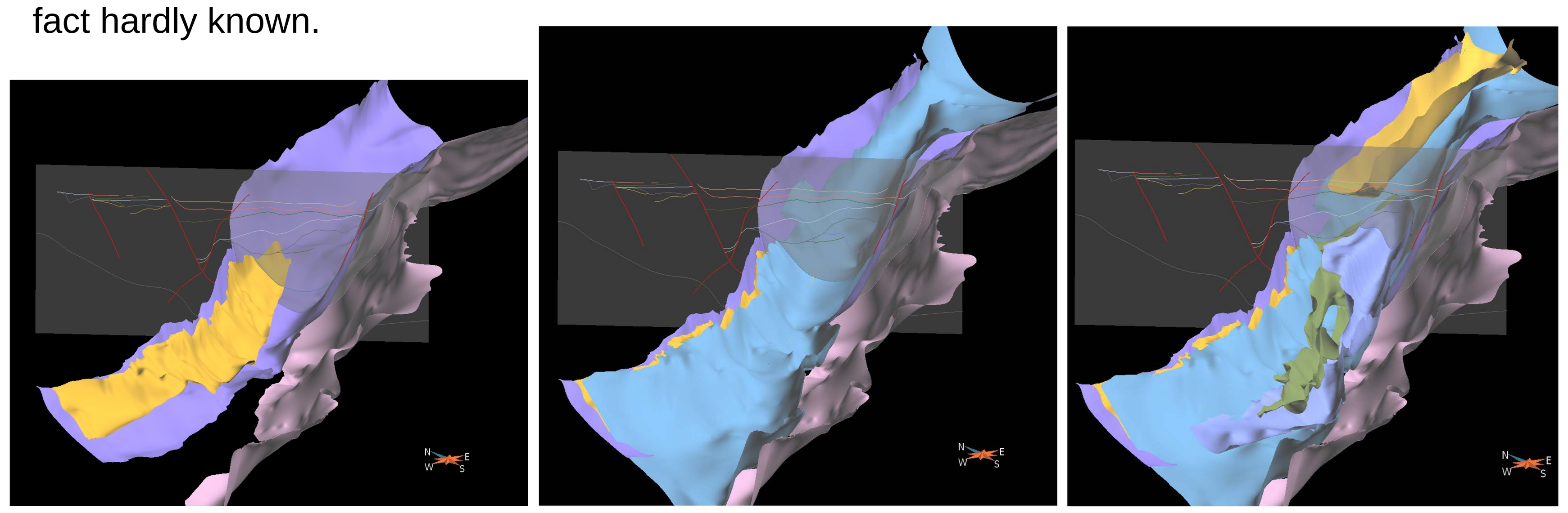
Project outlines and motivation

The city of Vienna is situated upon thick layers of Neogene sediments comprising the Vienna Basin fillings. Since large parts of the Vienna Basin are densely populated, geothermal power and heat could play a significant role in the future. The Vienna basin is a relatively cold system where the 100 °C isotherm is to be found at a minimum of about 2500 meters. This fact, meaning the need of deep thus expensive wells, adding the problem of space for drillings and geothermal power plants are challenging subjects in terms of exploitation.

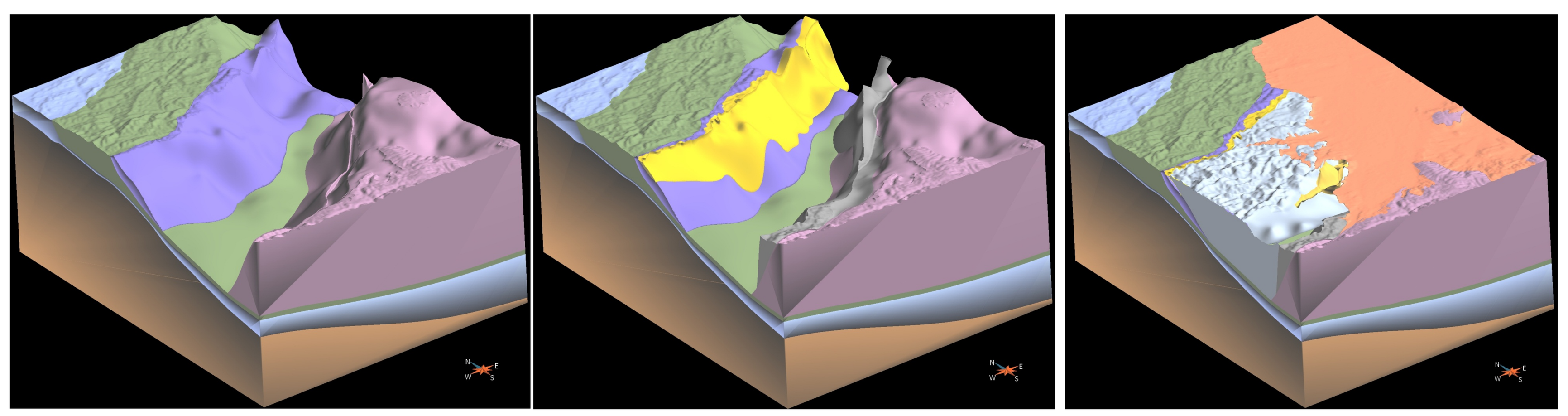
The aim of this project is to define potential reservoirs within the basin - with special respect to the border area between Austria and Slovakia in order to avoid possible international conflicts of energy/hot water demands.
Understanding the internal structure and the basin dynamics, especially the water – circulating systems and temperature distributions and providing this information to the public is essential in order to make geothermal energy use in this area more economic and more attractive to investors and consumers.

Modelling

As the Vienna Basins Neogene sediments are fairly well known from numerous drillings due to the extensive oil- and gas production, indications for the respective depth of formations and the stratigraphic correlation are present. Knowledge about the pre-Neogene basement derives from numerous drillings but also from seismic surveys, though the deeply buried parts are in fact hardly known.



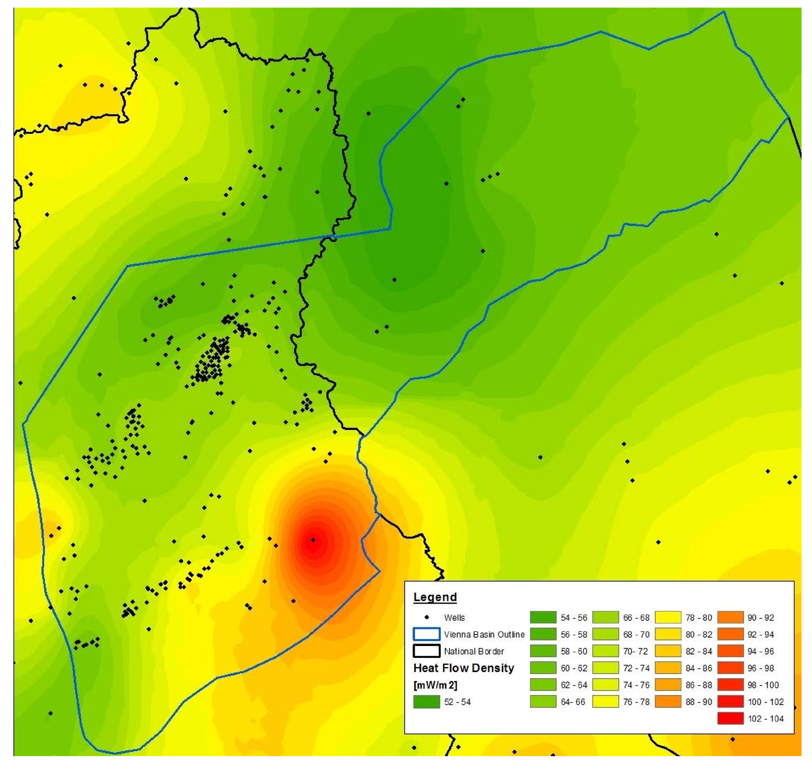
GOCAD surface model of the main units of the Vienna Basin – from left to right the base of: purble – Bajuvaric Nappes, yellow – Giesshuebel Gosau, pink – Mesozoic Carbonates, blue – Tirolic Nappes, yellow - Brezová-Myjava area Gosau, green – Giesshuebel Gosau, lavender – Juvavic Nappes.



GOCAD volumetric model of the southern part of the Vienna Basin – from the base to the top: Bohemian Massive and lower units (up to -15 km), blue - Molasse, green - Flysch Units, purple - Bajuvaric Nappes, yellow – Giesshuebel Gosau, grey – Greywacke Zone, lavender on the right – Central Alpine and Tatric Units, orange – Neogene Basin sediments.

The main inputs for the 3D model were interpreted cross sections (compiled drilling and seismic data) created by G. Wessely [1], J. Kysela [2] and B. Leško [3] and drilling data, as well as thickness maps [4] of the Neogene Sediments in the Slovakian part of the area.
The pre-Neogene Basement map [5] represents the best available information regarding the surface of the basins base and the extent of underlying formations. For a better structure of the basin fill, faults with a displacement of greater 500 meters were modeled and Neogene formations were cut and displaced along them. The software package GOCAD was used to create the geological 3D model, thus, it provides the necessary export-tools for the numerical simulations and visualization.

Input data



Total HFD Calculation

The estimation of the overall heat flow density in a well is based on the inverse optimization method [3], in which the heat flow density is varied iteratively until the difference between observed and estimated temperatures is minimal. 447 DST and 466 corrected BHT data were used for the 1D calculation. Inside the Vienna Basin, it was possible to calculate 202 values.
The figure (left) shows the HFD map which was used for geothermal modelling.

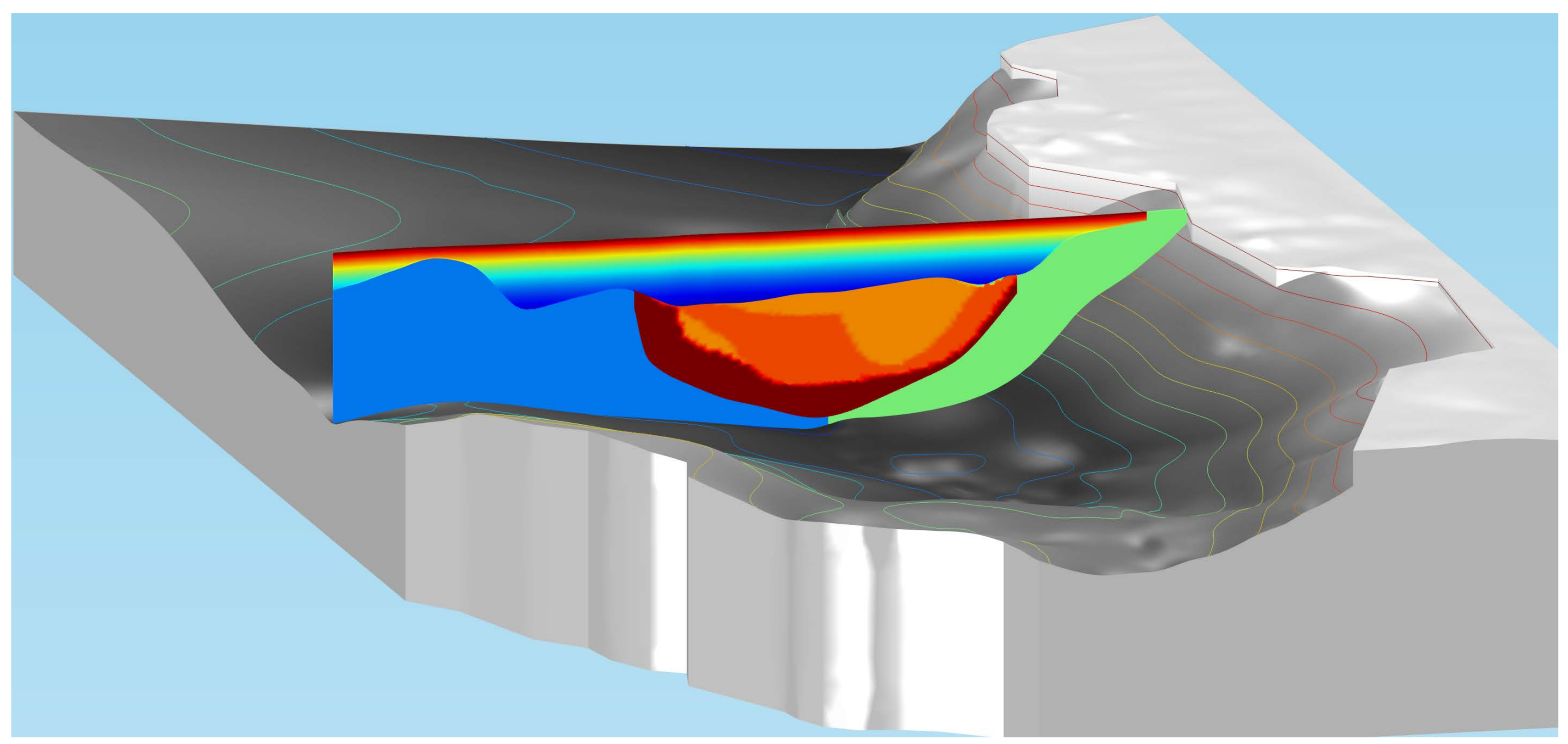
Petrophysical parameters:

Using core measurements and results from previous geothermal studies in the Vienna Basin, the required petrophysical parameters (porosity, thermal conductivity, heat capacity, density and radiogenic heat production) could be determined. The selection of the samples was randomly, but considering all tectonic units.

Numerical model

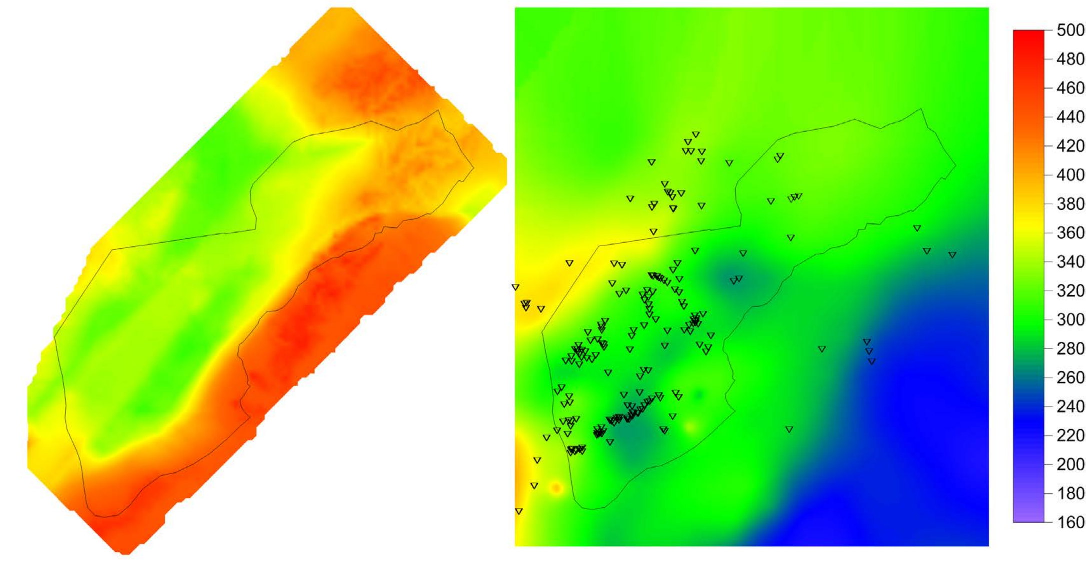
The numerical simulation is carried out using COMSOL (full 3D FEM solver) for the regional steady-state model and FEFLOW (layered 3D FEM solver) for the scenario modelling.

Major surfaces were imported into COMSOL as geometry objects, which is not practicable for very complex, fine structures. To represent smaller units inside the subdomains, the associated material parameters had to be imported as functions of the three space coordinates.



View „into" the basin from SW with a NW-SE section across the model area, the greyscale surface represents the top of the crystalline basement.
The Crystalline, Flysch Units() and the Mesozoic Carbonates() are consindered to have constant material properties. The variation of parameters within the Calcareous Alps (), consisting of Bajuvaric-, Tirolic-, Juvavic-, the Gosau Units and the Greywacke Zone (not visible in this section), are taken into account through 3D interpolation functions. The properties of the Neogene Sediments, particularly the porosity, are approximated using depth-dependent functions (exponential approach [1]).

Preliminary results

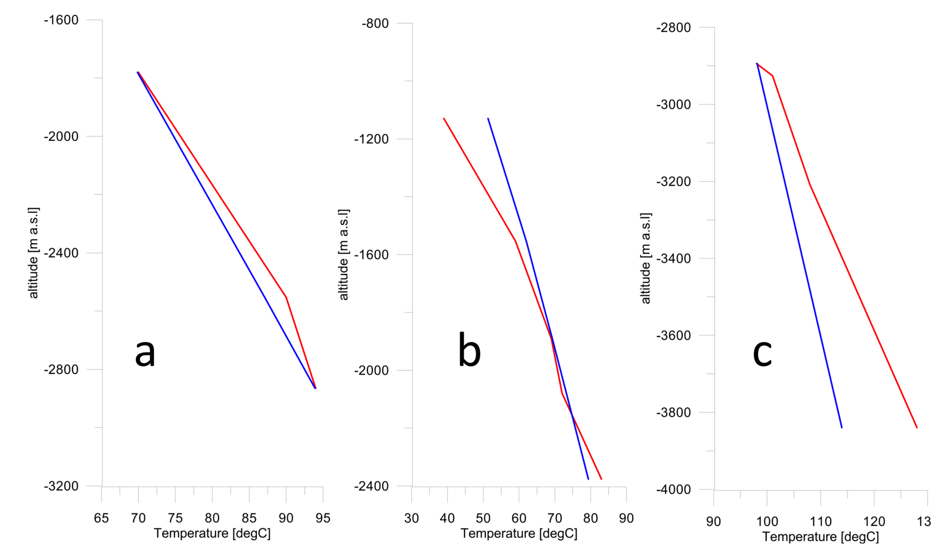


The figure shows the depth of 100°C isotherm.

Left: Result from numerical modelling.

Right: Results from interpolation of borehole data (DST and corrected BHT data). The black triangles mark the available wells.

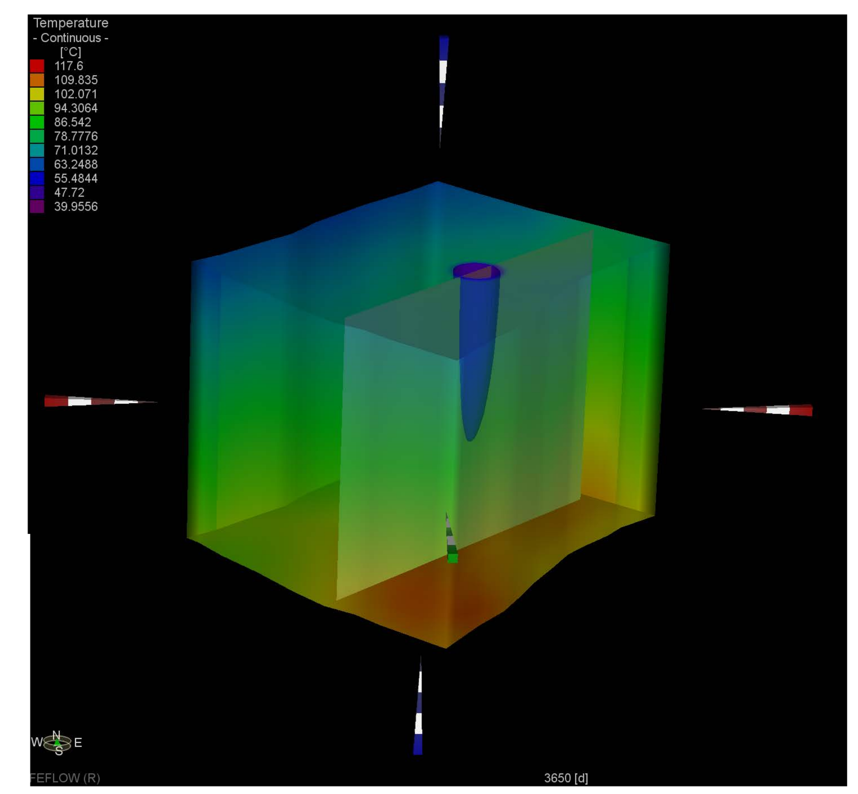
Inside the basin, the result from modelling fits the interpolation quite well, at the SE-margin (crystalline outcrop) we see opposite trends in the two datasets. The biggest deviations occur in areas with a low density of available wells, which indicates interpolation, not modelling errors. However, there is still necessity for further interpretation and processing.

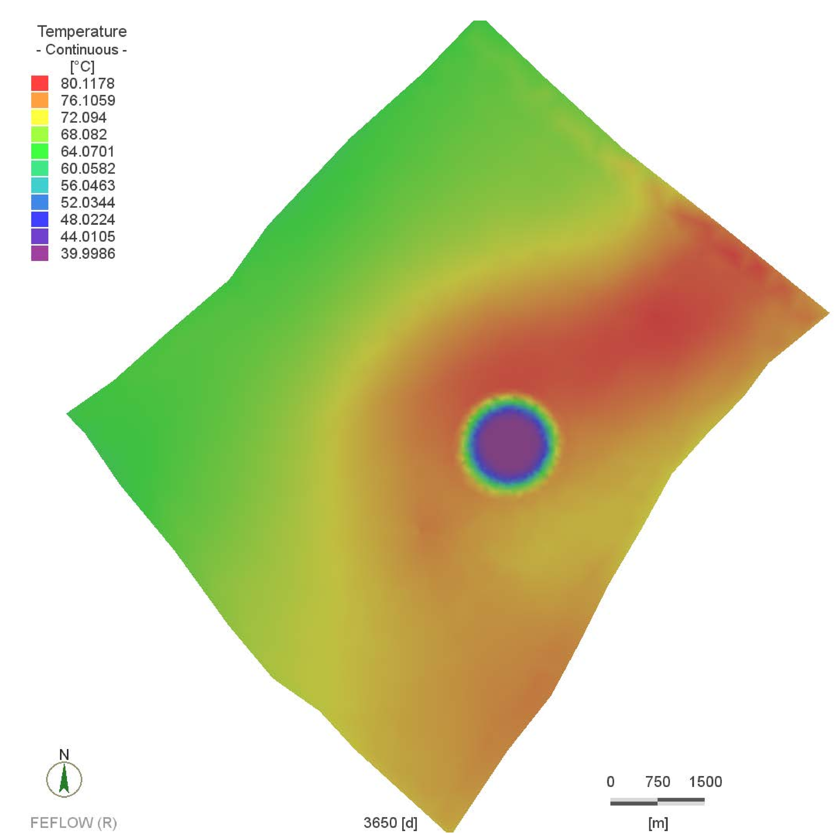


The linegraphs show a comparison between DST-measured (-) and modelled (-) temperatures of selected wells. Analysis of the deviations allows fine-tuning of the model parameters (λ, HFD), and forms the basis for further processing (Peclet-Analysis). Deviation of slope indicates a poor assumption of either HFD or conductivity (a,c), while a kink could be a sign for water circulation (a,b).

Outlook, scenario modelling

On the one hand, the scenario modelling will deliver critical success factors for exploitation of deep geothermal energy and help to determine the general geothermal potential of the Vienna basin area.
On the other hand the results shall also be „a helping hand" for the approval of possible geothermal energy exploitation projects in the future.





References:
[1] Wessely, G. (1983), Zur Geologie und Hydrodynamik im südlichen Wiener Becken, Mitt. d. Österr. Geol. Ges.
[2] Kysela J. (1983), Schematicky Geologicky Rez Viedenskou Panvou (geological cross section through the Vienna Basin), unknown source.
[3] Lesko B., Potfaj M. (1978), Geologicky Profil Okolia Vrtu – Lubina – 1 (geological cross section including the well Lubina 1), unknown source.
[4] Seifert, Jiricek (1989), Vienna basin and Molasse foredeep paleogeographic map with isopachs, Thirty years of geological cooperation between Austria and Czechoslovakia, Ustredni ustav geologicky, 1990, p .93-104
[5] Wessely G., Kroell A., Jiricek R., Nemec F. (1993), Geologische Einheiten des präneogenen Beckenuntergrundes, Geologische Themenkarten der Republik Österreich, Geologische Bundesanstalt, Wien
[6] Götzl et al., 2012: Coupled geothermal – hydraulic 3D modeling of the Southern Vienna Basin. Proceedings World Geothermal Congress 2012; Bali, Indonesia, 25-29 April 2010