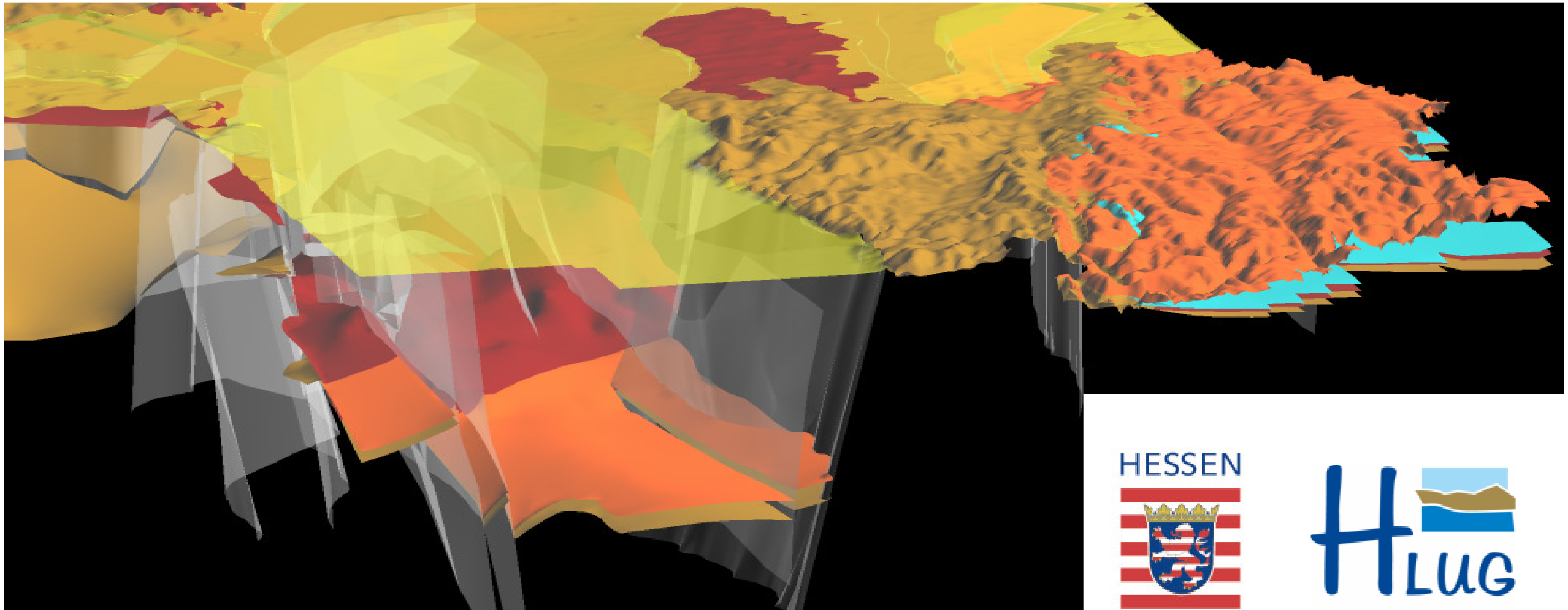
Geological structural model of the Federal state of Hesse (Germany) to evaluate geothermal potentials with consideration of parameter uncertainties

TECHNISCHE UNIVERSITÄT DARMSTADT

böhringer
a Gruner company



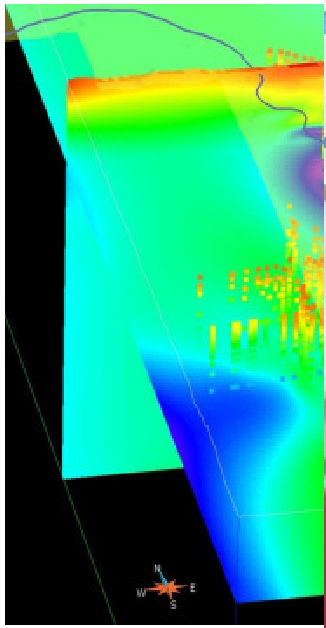
Dirk Arndt, Kristian Bär, Ingo Sass, Andreas Hoppe

HESSEN
Hessisches Ministerium für Umwelt, Energie, Landwirtschaft und Verbraucherschutz

HLUG
Hessisches Landesamt für Umwelt und Geologie

Input data for the 3D structural model

- Well data (> 4500)
  - Hessian Well-Database hosted by the HLUG
  - Well-Database of the Hydro-Carbon industry hosted by the LBEG
- Seismics
- Literature
  - Geologic cross-sections
  - Geologic maps (GÜK 300, GK200, GK25)
  - Contour maps
  - Paleogeographic maps

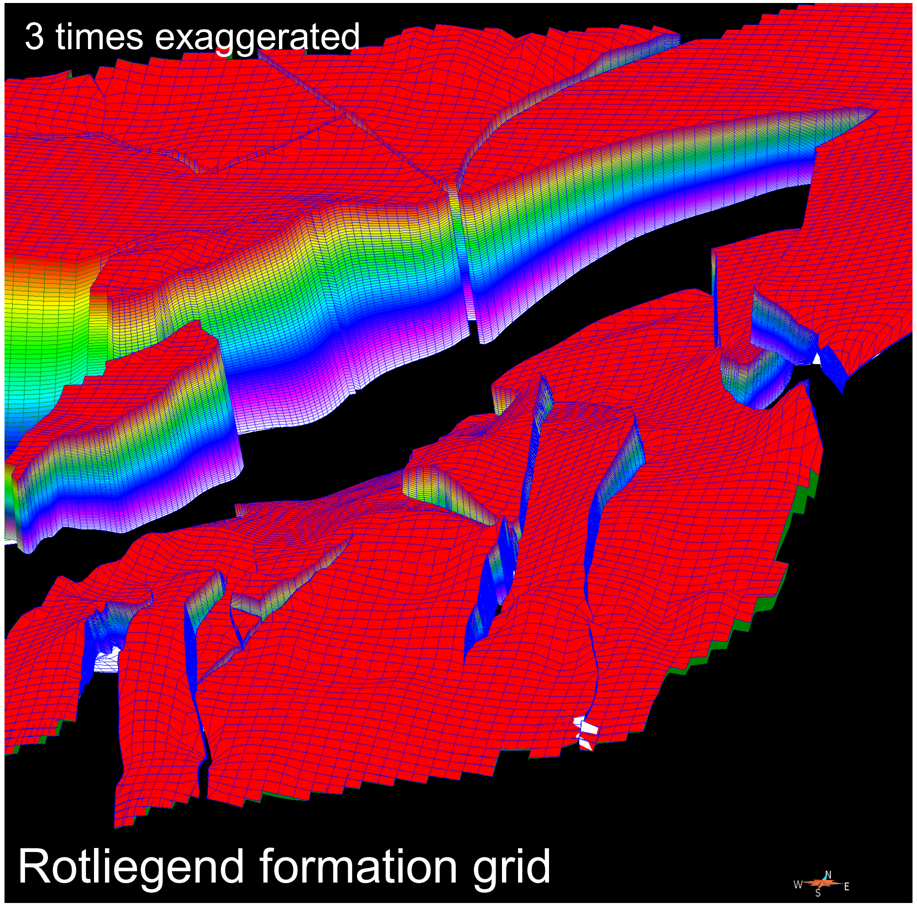



PraePerm
N
E
W
S

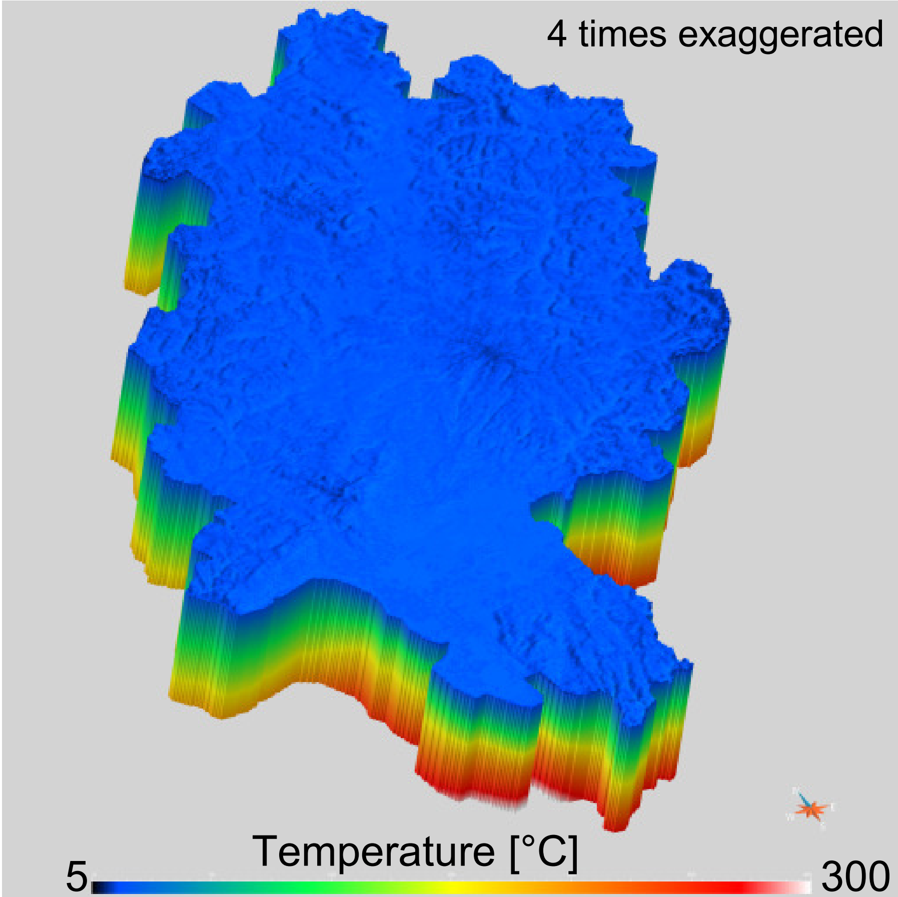
Gridded Objects from the 3D model

TECHNISCHE UNIVERSITÄT DARMSTADT

Reservoir-Grids

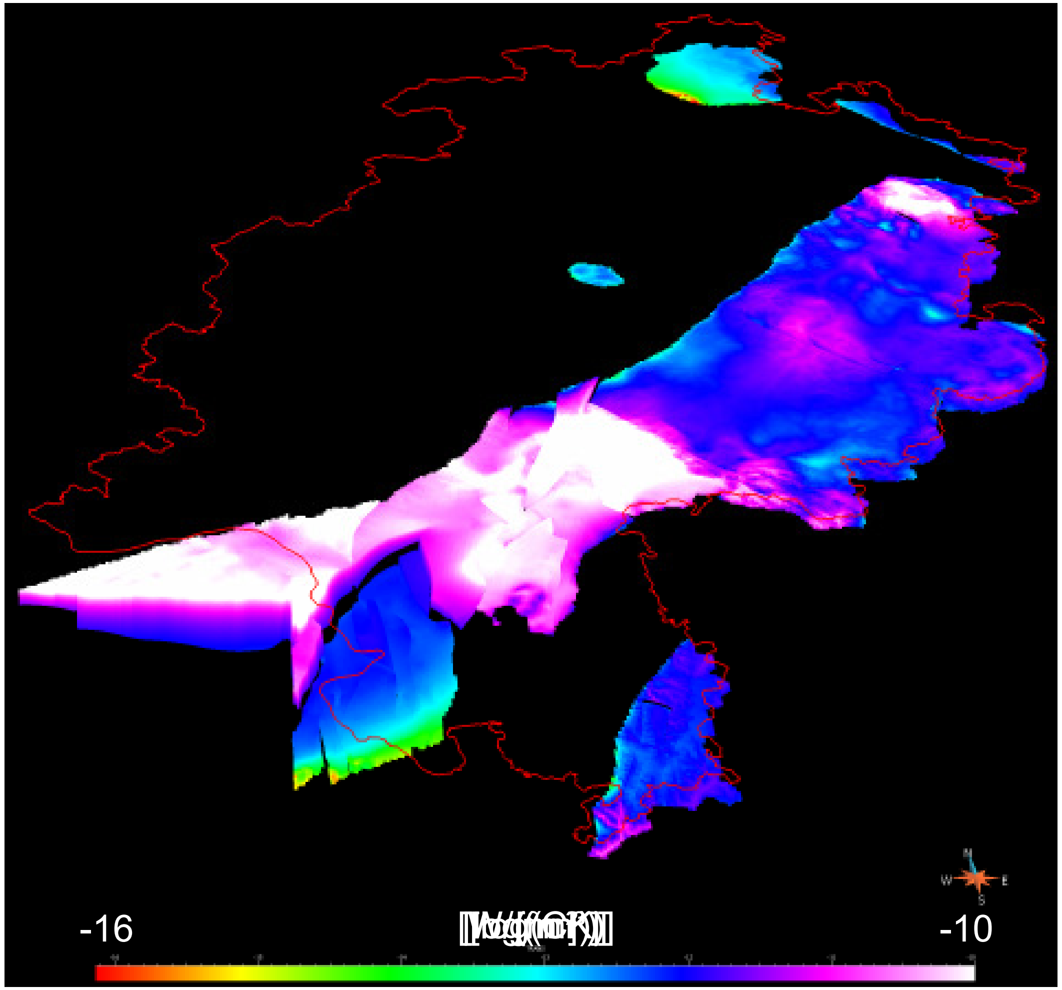


Overall Grid



Relevant Grid Properties

- Thermal conductivity
- Temperature
- Matrixpermeability
- Rock mass permeability
- Transmissibility
- Porosity
- Density
- Heat capacity
- Thermal diffusivity

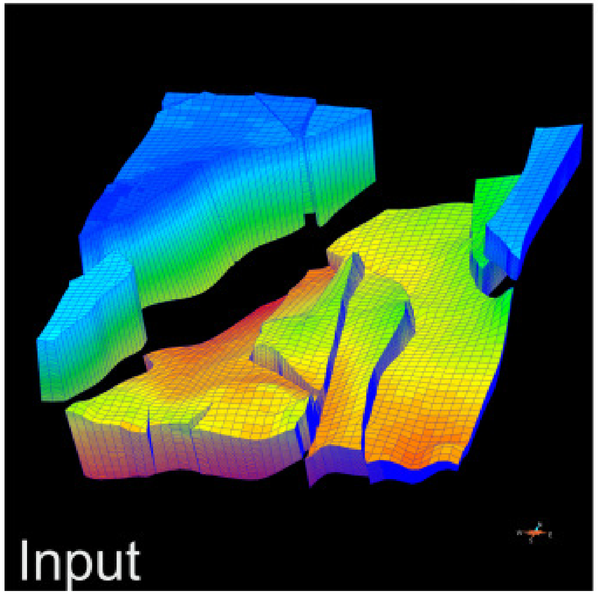


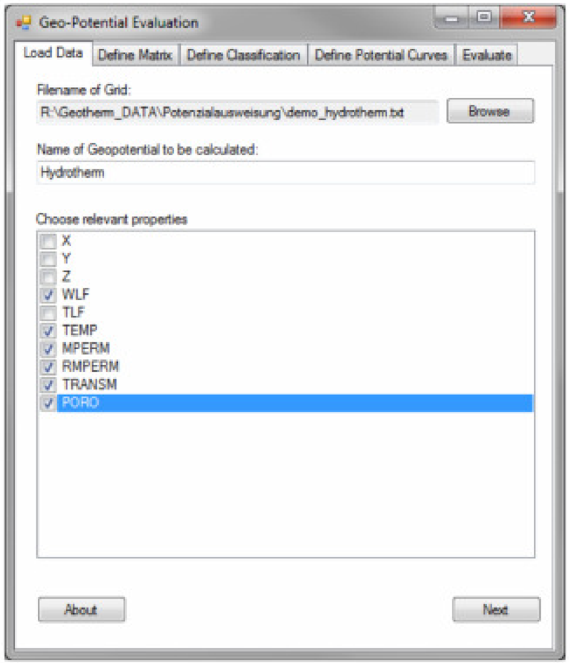
Multi-Criteria Method to evaluate geo-potentials

TECHNISCHE UNIVERSITÄT DARMSTADT

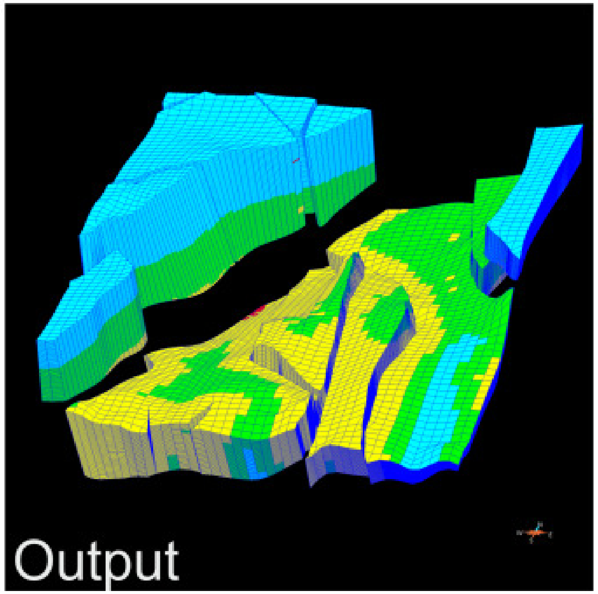
- The method uses the **A**nalytic **H**ierarchy **P**rocess (AHP) after Saaty (1977, 1980, 1990, 2005).

Multiparametergrid





Classified geo-potentials



Evaluation of hydrothermal potentials

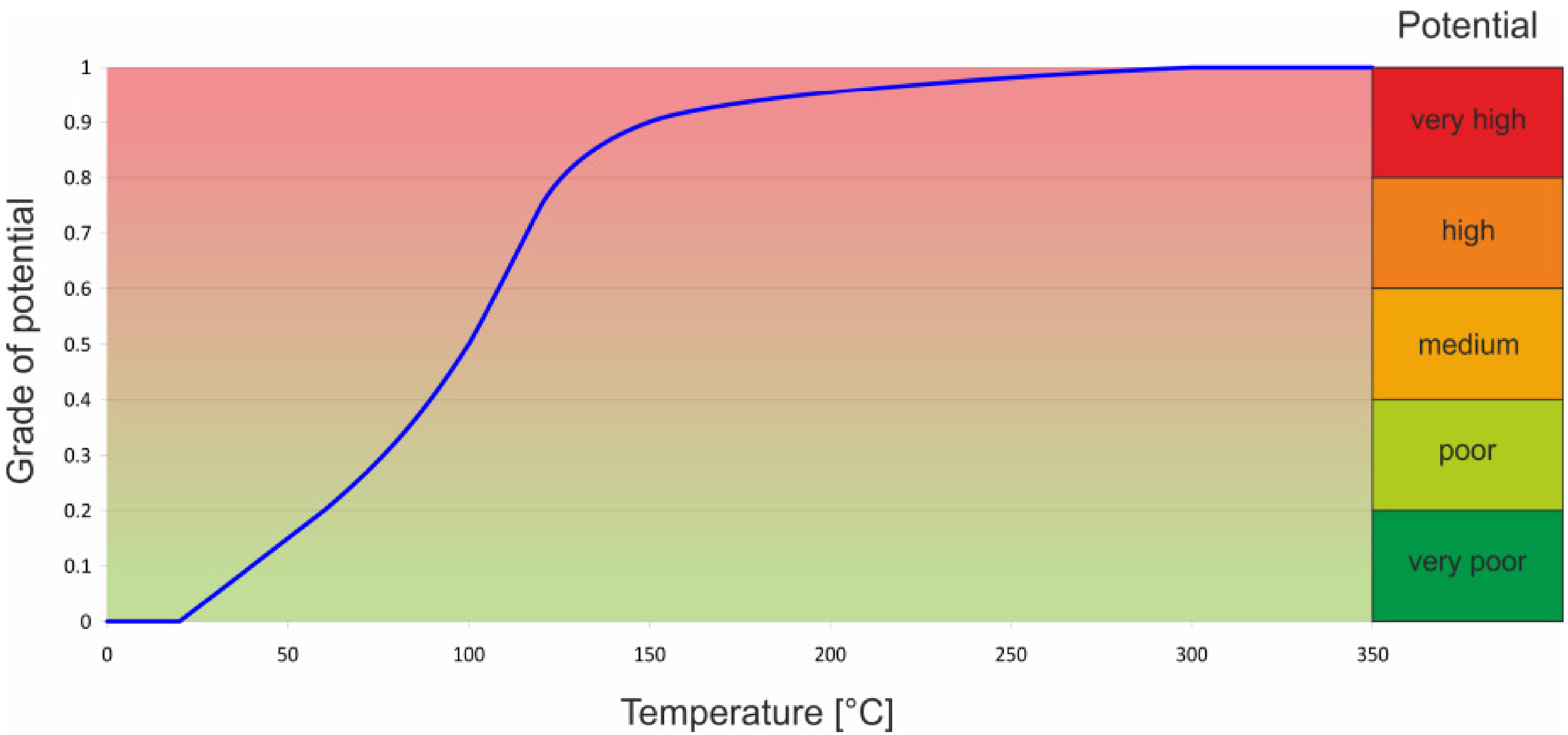
- A comparison matrix is created and a hierarchical weight vector is calculated using the AHP algorithm from Saaty (1990)

$$
\begin{array}{l}
\\
\text{Wärmeleitf.} \\
\text{Temperatur} \\
\text{Matrixperm.} \\
\text{Gebirgsperm.} \\
\text{Transmiss.}
\end{array}
\begin{array}{c}
\begin{array}{ccccc}
\text{Wärmeleitf.} & \text{Temperatur} & \text{Matrixperm.} & \text{Gebirgsperm.} & \text{Transmiss.}
\end{array} \\
\left[\begin{array}{ccccc}
1 & 1/9 & 1/3 & 1/5 & 1/7 \\
9 & 1 & 5 & 3 & 2 \\
3 & 1/5 & 1 & 1/2 & 1/4 \\
5 & 1/3 & 2 & 1 & 1 \\
7 & 1/2 & 4 & 2 & 1
\end{array}\right]
\end{array}
\xrightarrow{\text{AHP}}
\begin{array}{c}
\text{Gewichtung} \\
\left[\begin{array}{c}
0{,}039 \\
0{,}515 \\
0{,}069 \\
0{,}142 \\
0{,}236
\end{array}\right]
\end{array}
$$

Evaluation of hydrothermal potentials

TECHNISCHE UNIVERSITÄT DARMSTADT

- To translate each parameters cell values into potential-values, curves are used.



Evaluation of hydrothermal potentials

- The resulting potential is calculated cellwise by the scalar product of the hierarchical weight- and potential-vector.

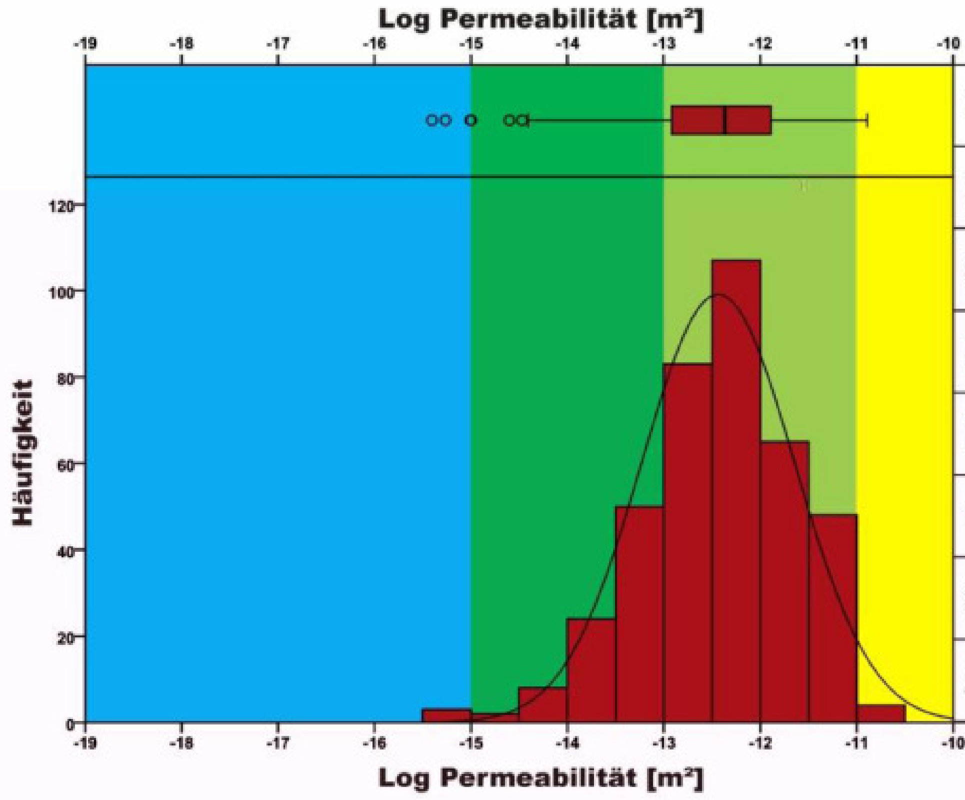
- The resulting potential can not be higher than the lowest K.O. parameter.

	Cell values	Parameter-potential	Weight (AHP)
Thermal conductivity	2.4 W/(m K)	0.6	0.039
Temperature	155 °C	0.93	0.515
Matrixpermeability	-17 log(m²)	0	0.069
Rock mass permeability	-14 log(m²)	0.3	0.142
Transmissibility	-10.95 log(m³)	0.65	0.236

→ Resulting cell potential: 0.69

Permeability of the Rotliegend reservoir

- Parameter values are inhomogeneous and vary in XYZ directions
- Usually they can be described with a distribution in each cell

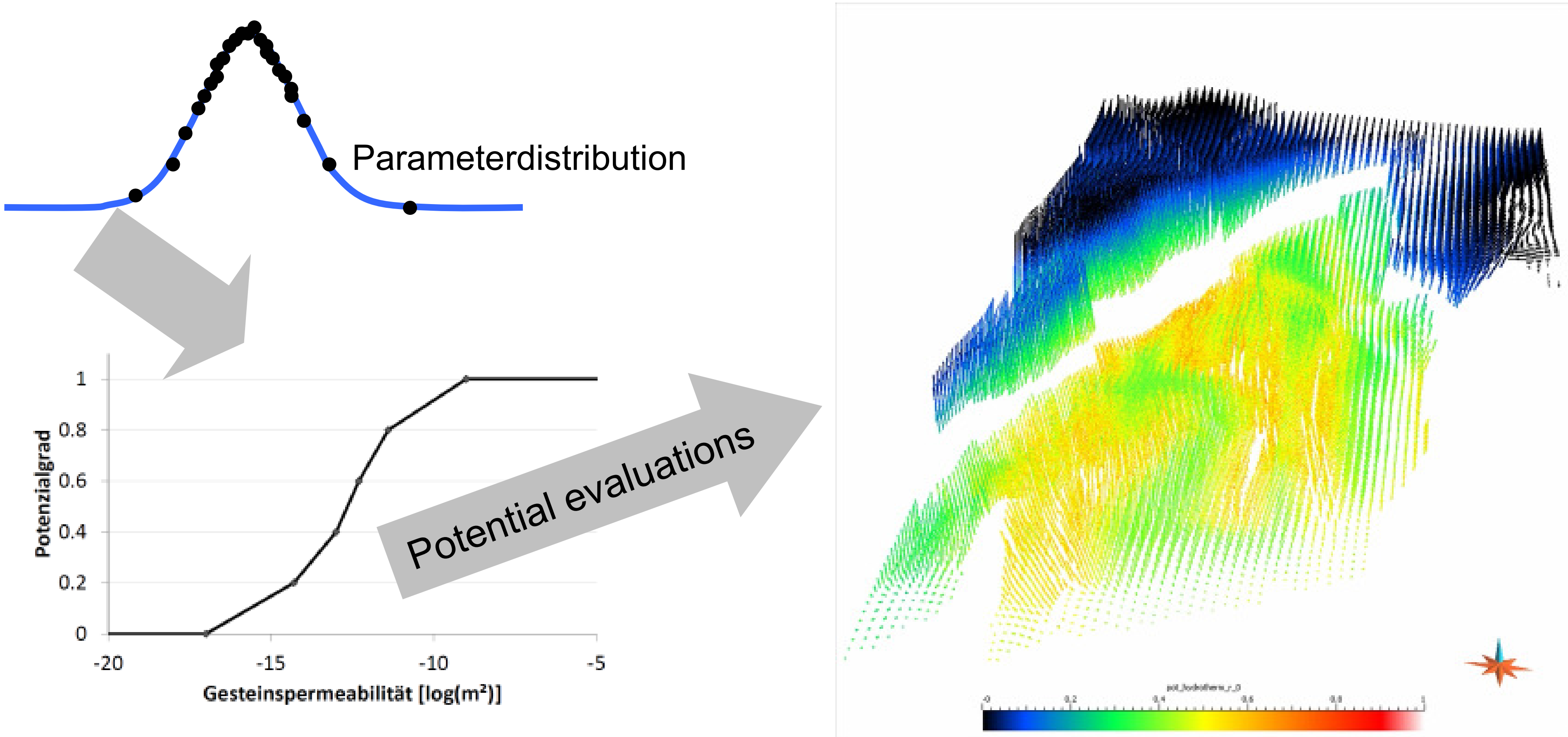


	[log m²]	[m²]
Mittelwert	-12,44	3,65E-13
Median	-12,37	4,28E-13
Standardabw.	0,79	
Minimum	-15,40	3,94E-16
Maximum	-10,89	1,29E-11
1. Quartil	-12,92	1,21E-13
3. Quartil	-11,89	1,30E-12
Anzahl	394	

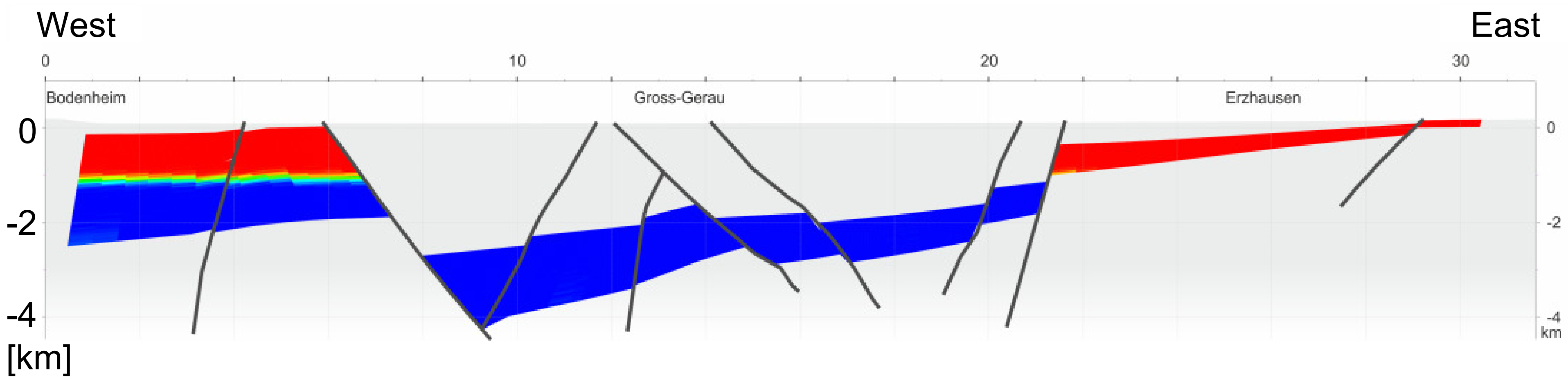
Monte-Carlo-Simulation of input parameters

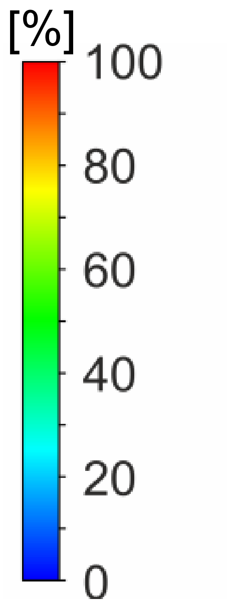
TECHNISCHE UNIVERSITÄT DARMSTADT

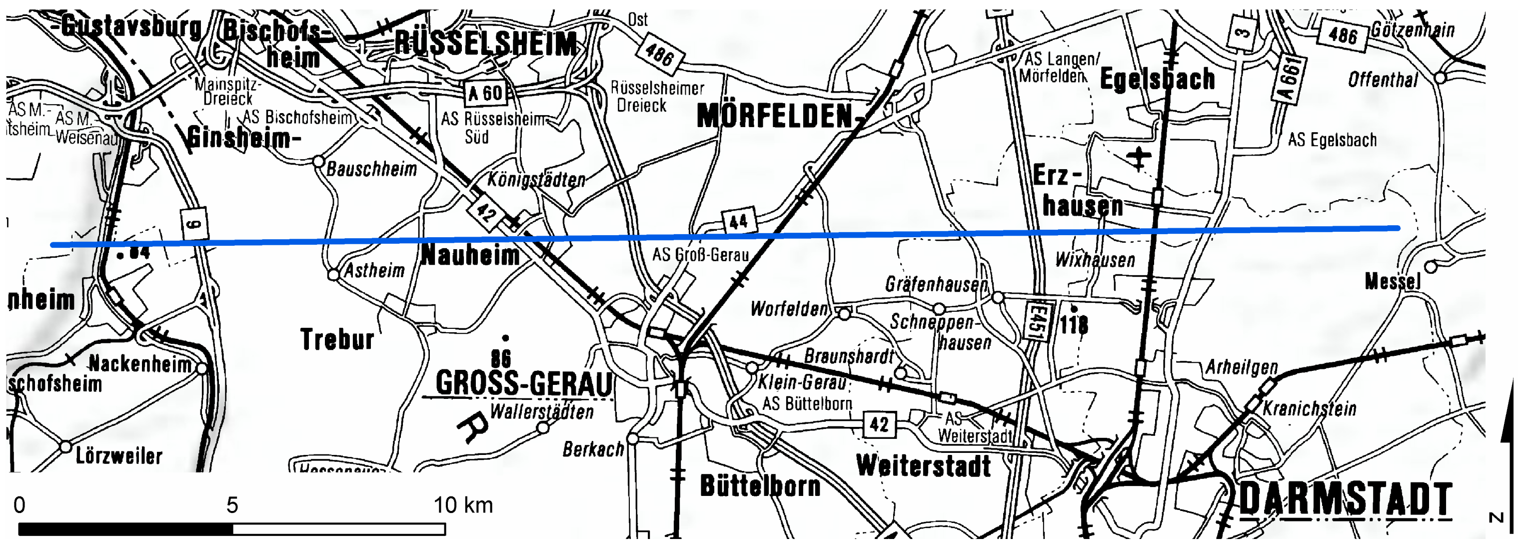
To quantify the impact of parameter uncertainties to the result, the geo-potential evaluation is calculated again using the Monte-Carlo method with 400 iterations



Percentage „very low potential“

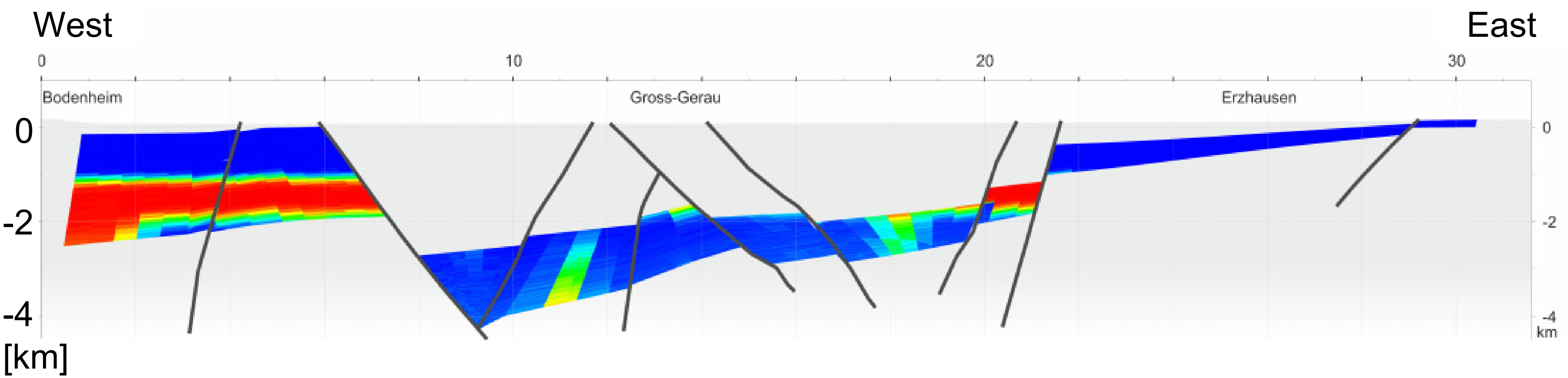


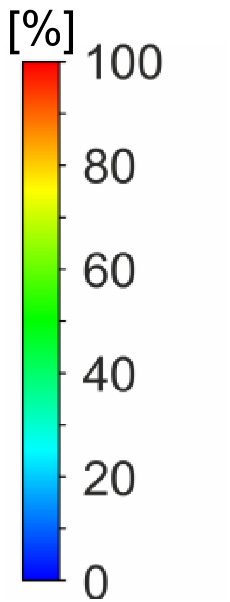


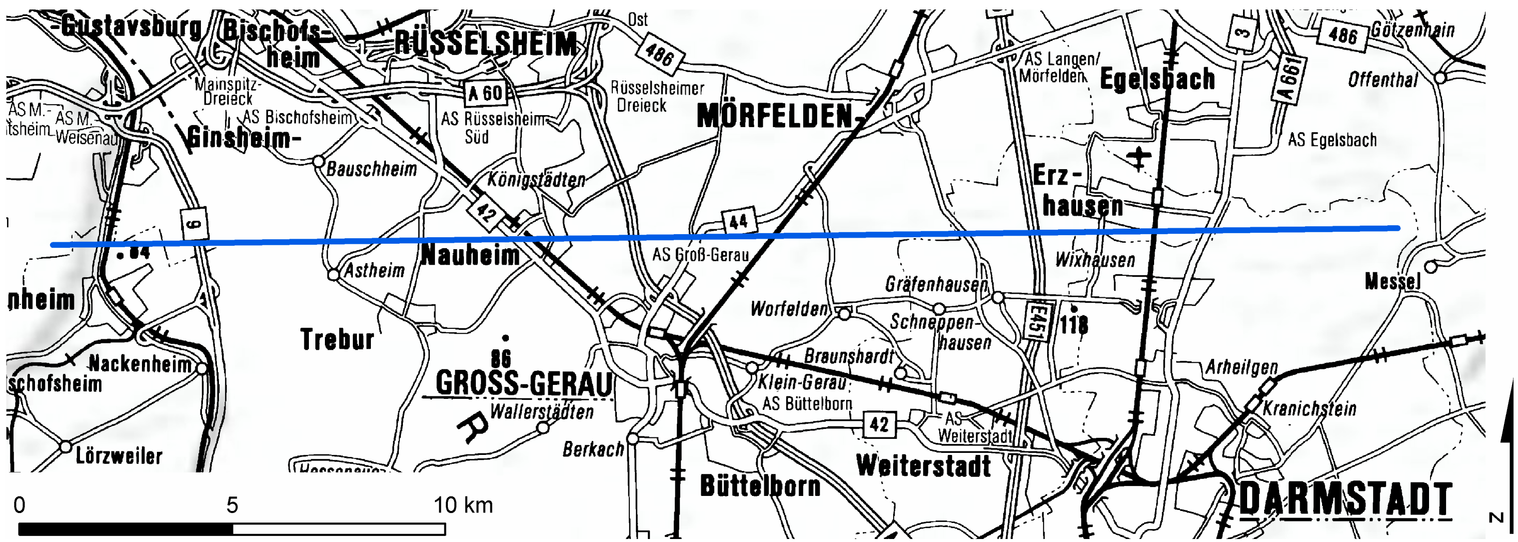


Percentage „low potential“

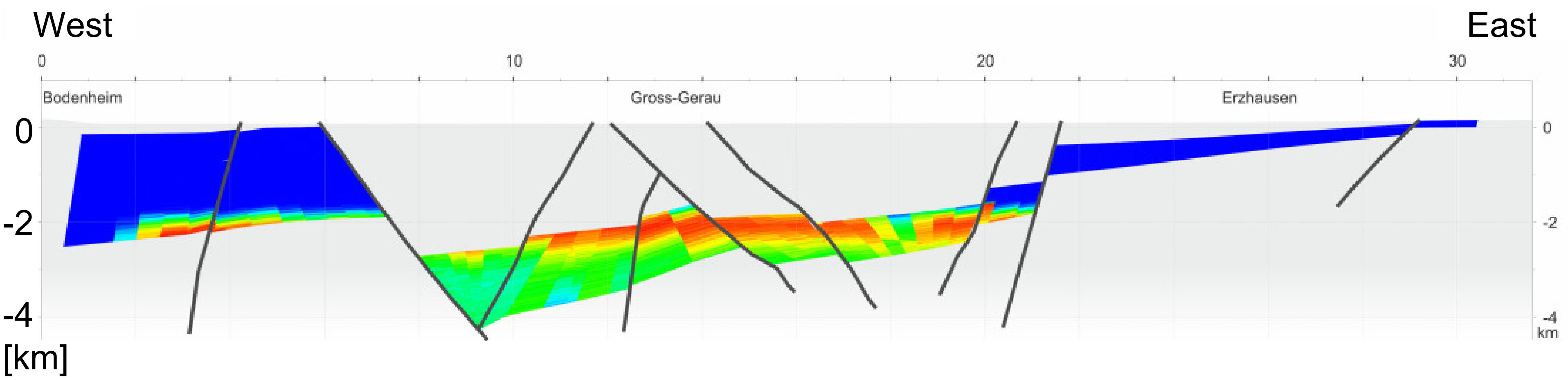
TECHNISCHE UNIVERSITÄT DARMSTADT

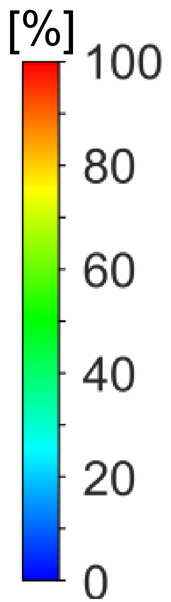


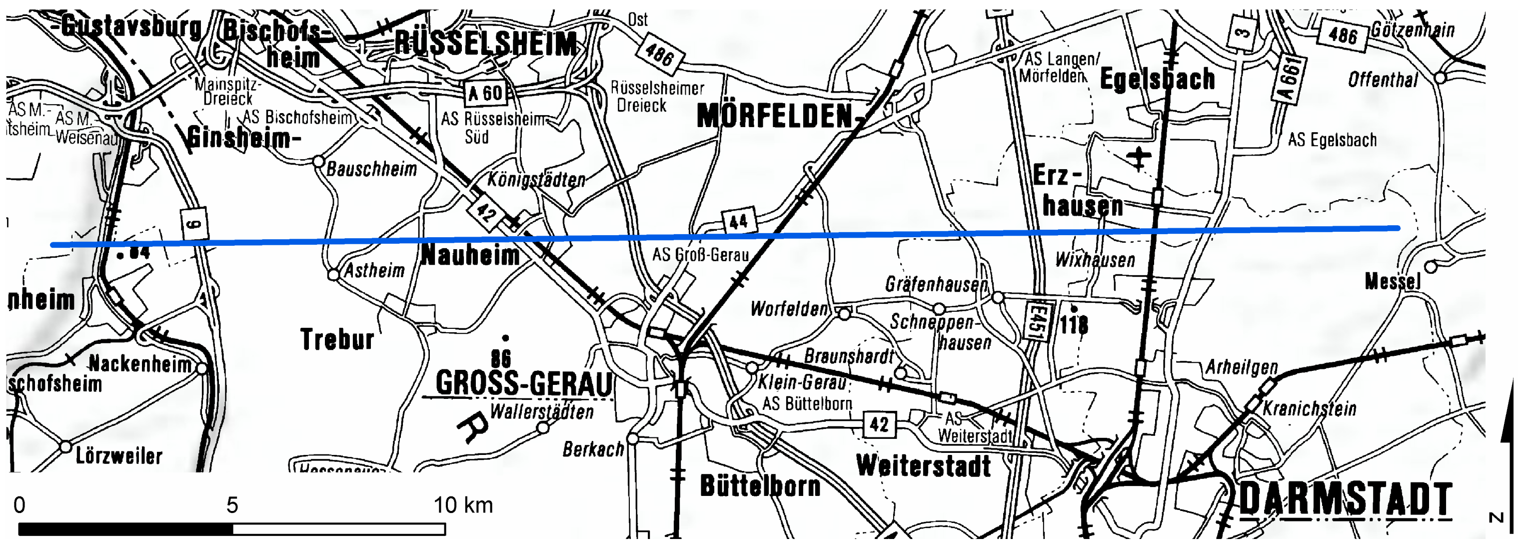




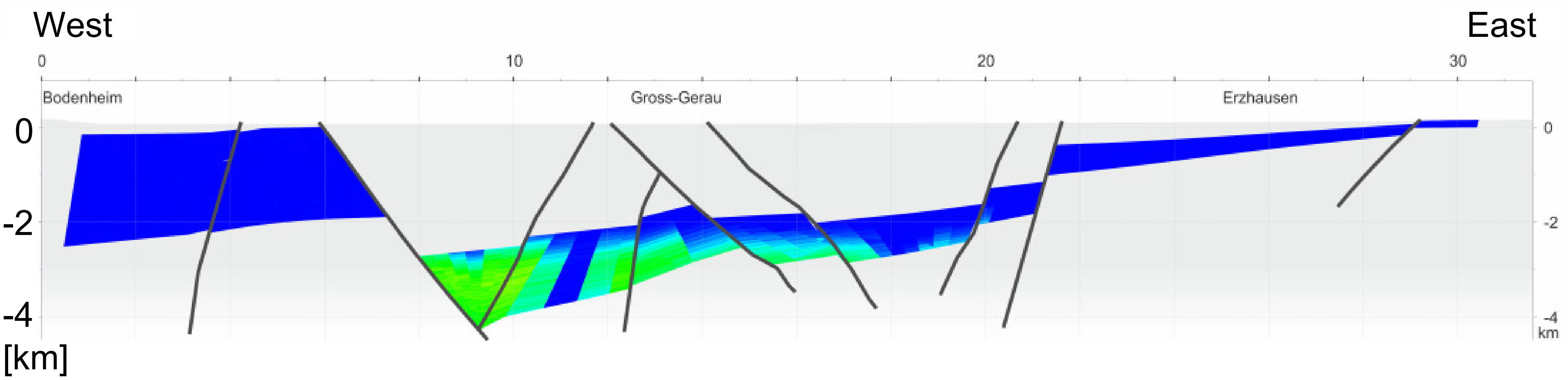
Percentage „medium potential“

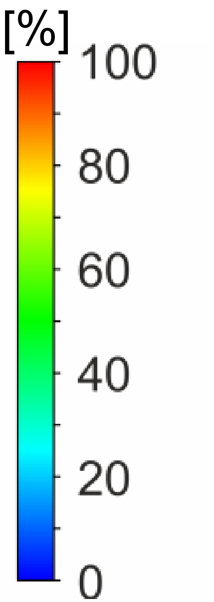


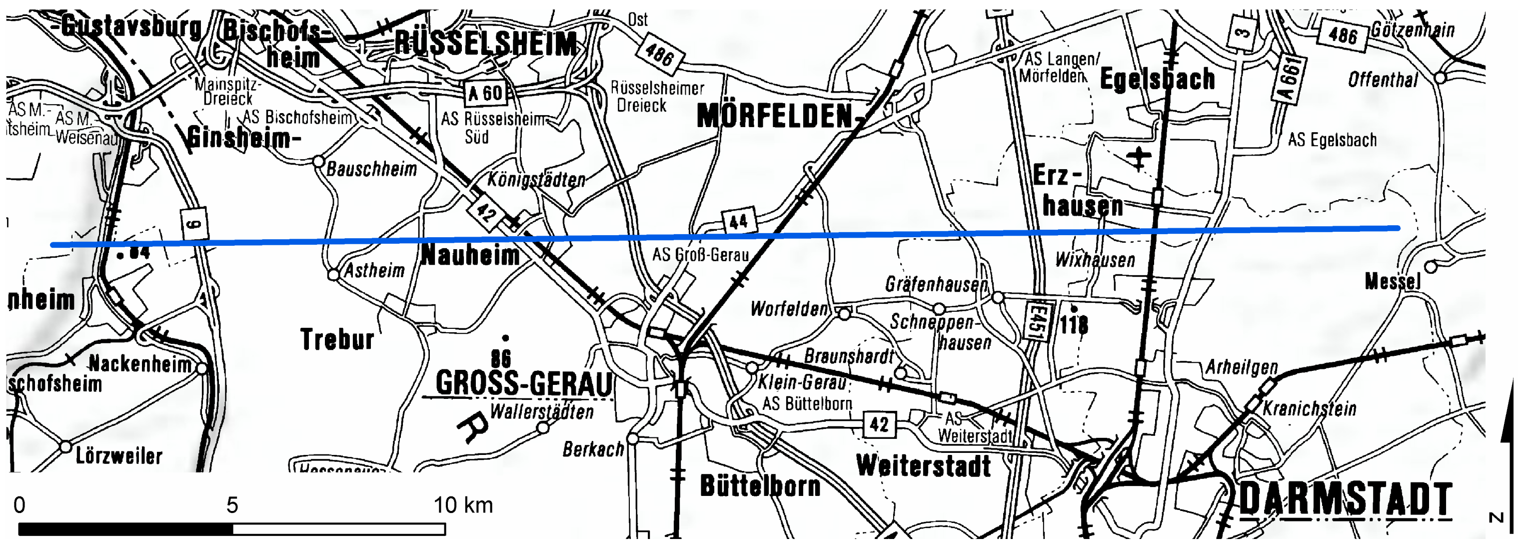




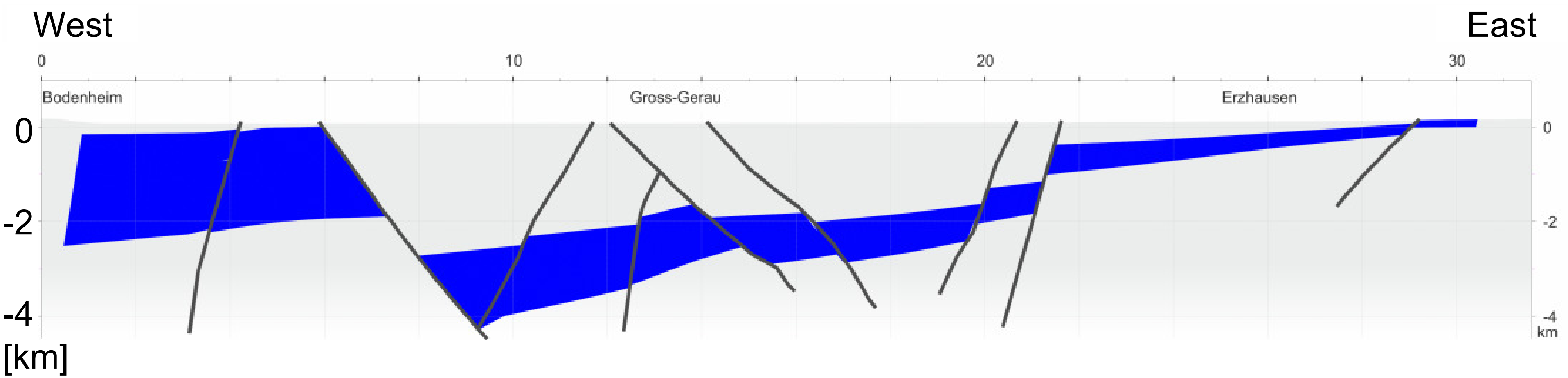
Percentage „high potential“

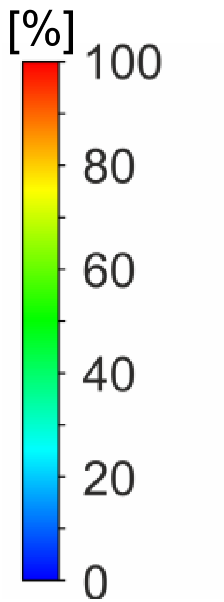


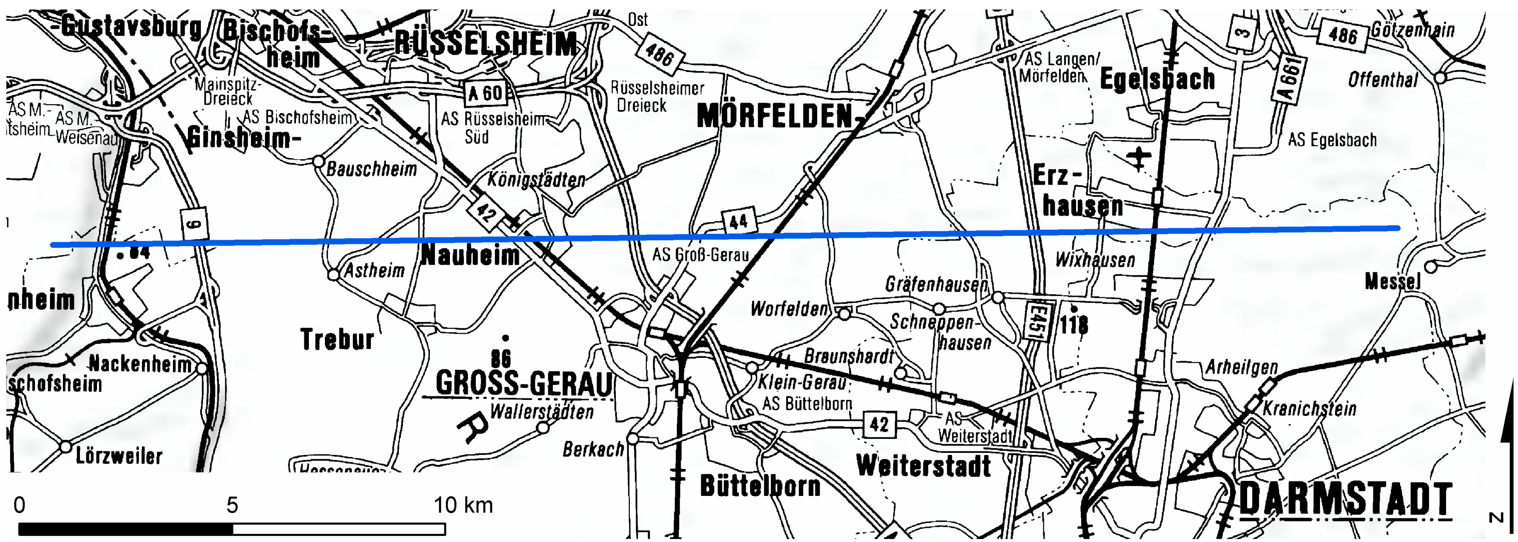




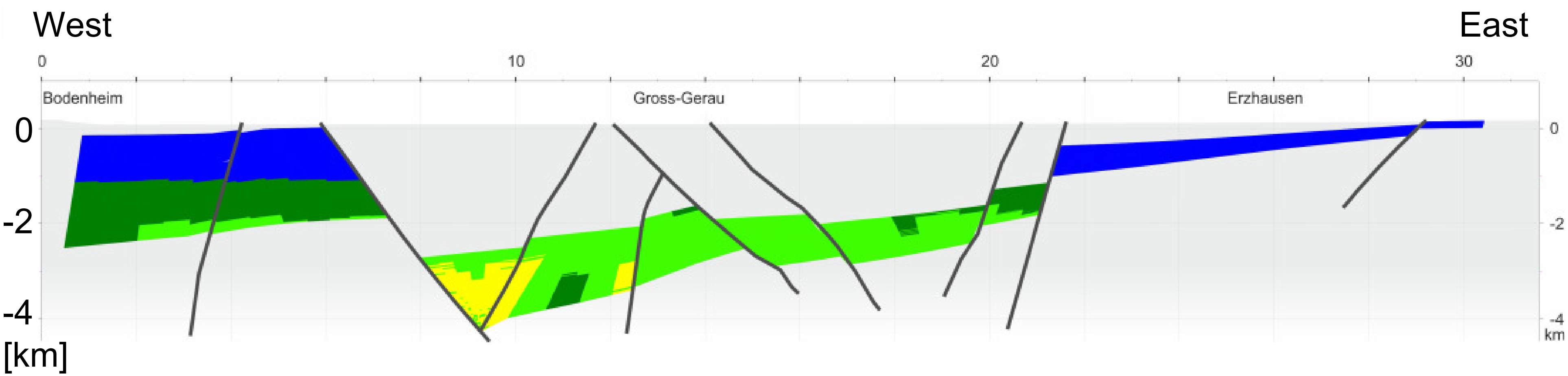
Percentage „very high potential“

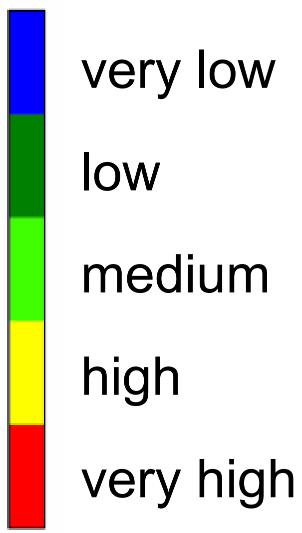


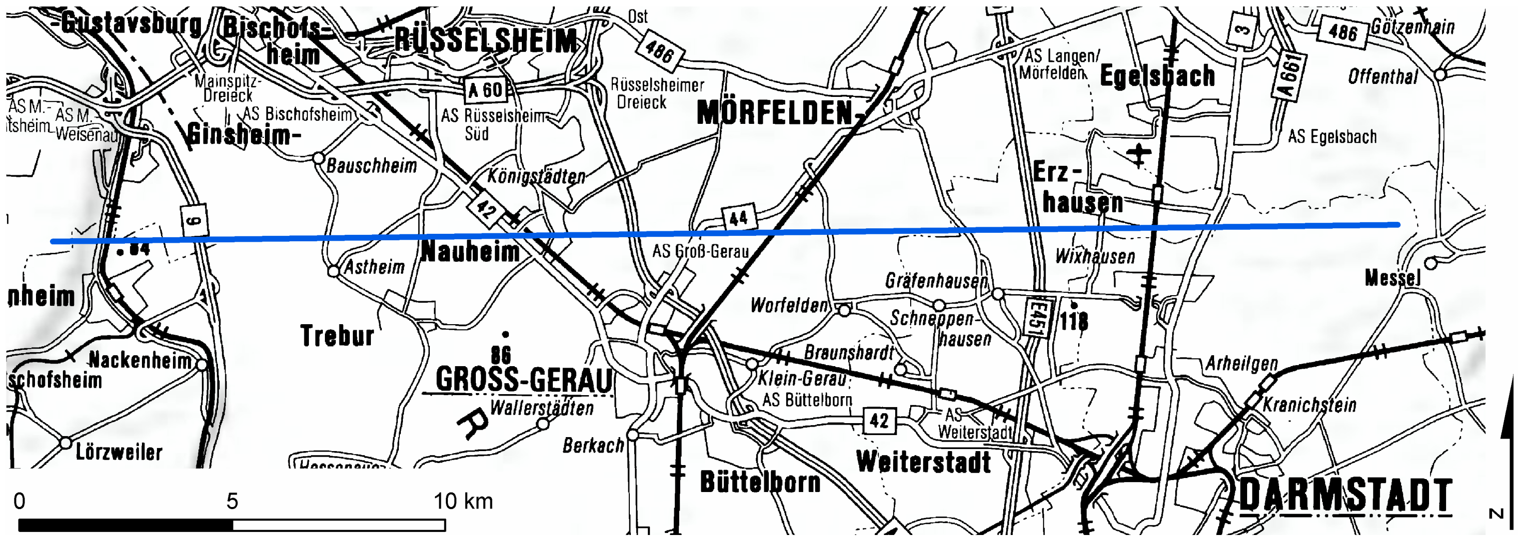




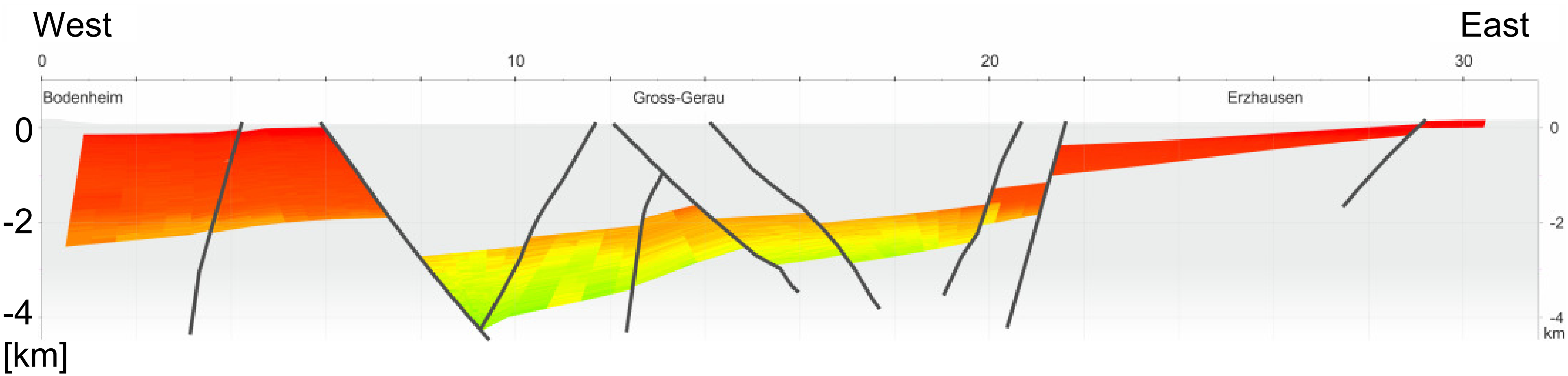
Median of all realisations

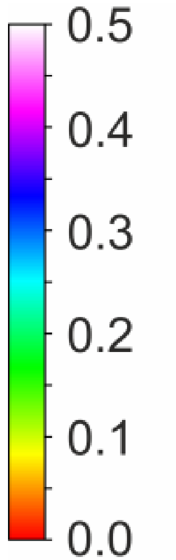


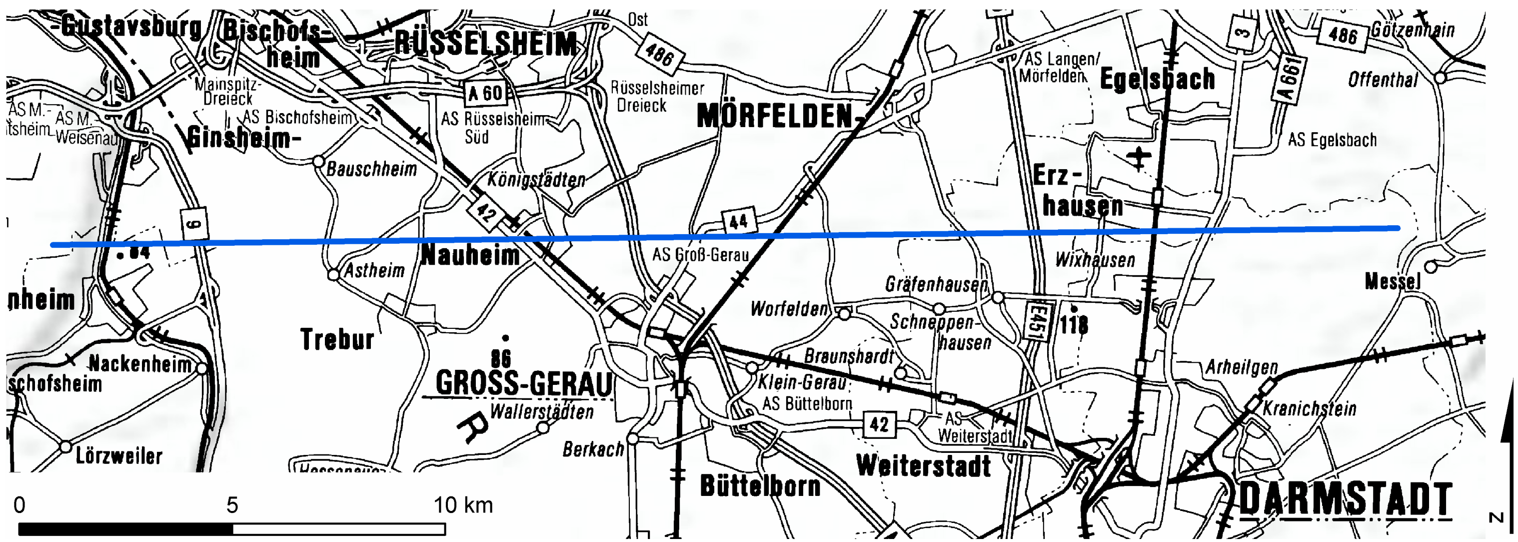




Standard deviation





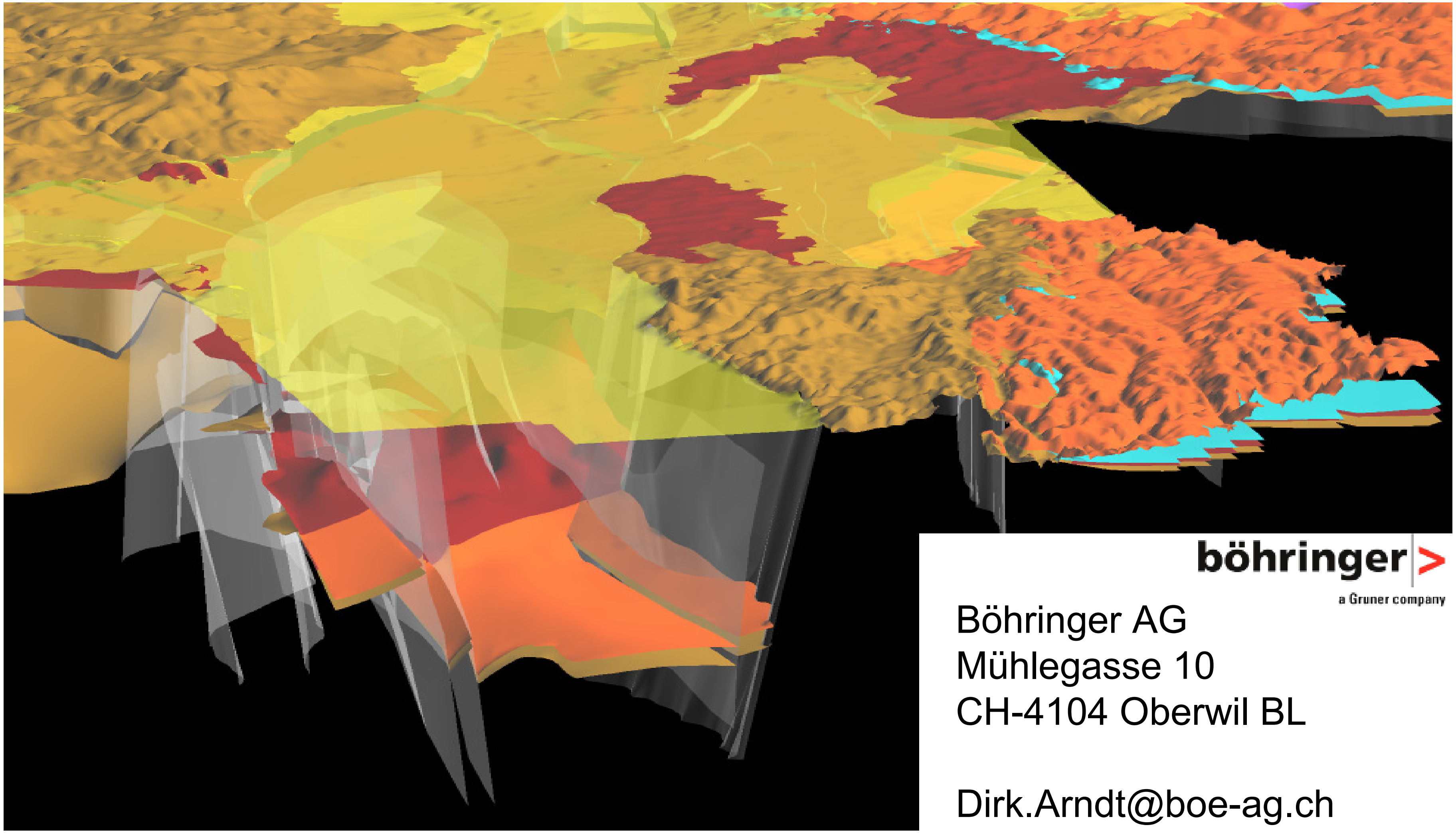


Conclusions

- The presented model and method are capable to evaluate geo-potentials.
- The impact of parameter uncertainties can be quantified using a Monte-Carlo approach (unfortunately structural uncertainties are not that easy to simulate).
- 3D models are a powerful tool to visualize and interpret geoscientific data, and make it easier to understand geologic structures for both: geoscientists and descision makers.

Thank you for your attention!

TECHNISCHE UNIVERSITÄT DARMSTADT



böhringer >
a Gruner company

Böhringer AG
Mühlegasse 10
CH-4104 Oberwil BL

Dirk.Arndt@boe-ag.ch