Hessisches Landesamt für Umwelt und Geologie

HESSEN

TECHNISCHE UNIVERSITÄT DARMSTADT

3-D Model of Deep Geothermal Potentials in Hesse

GeORG-Workshop, Freiburg, 18 Nov. 2010

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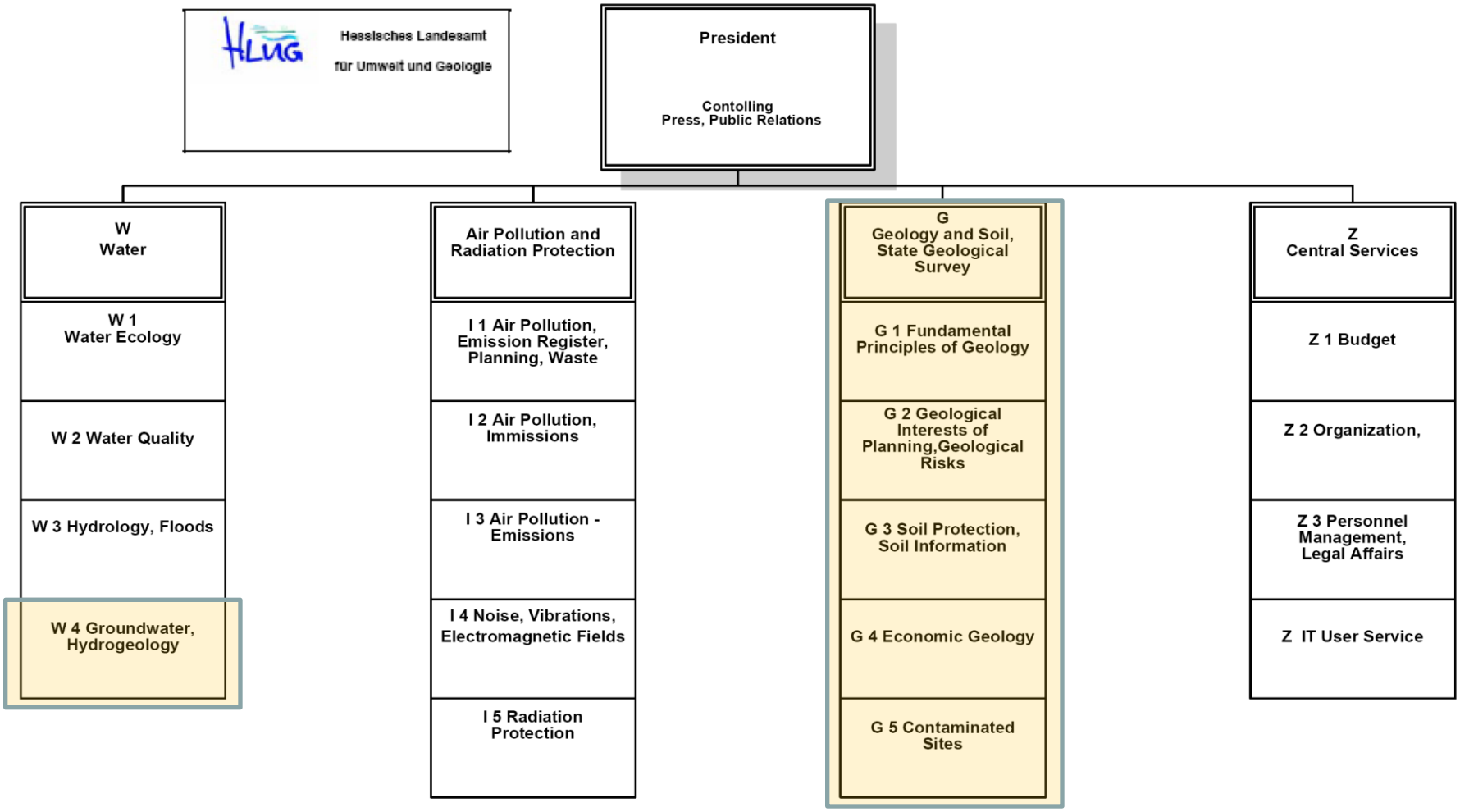
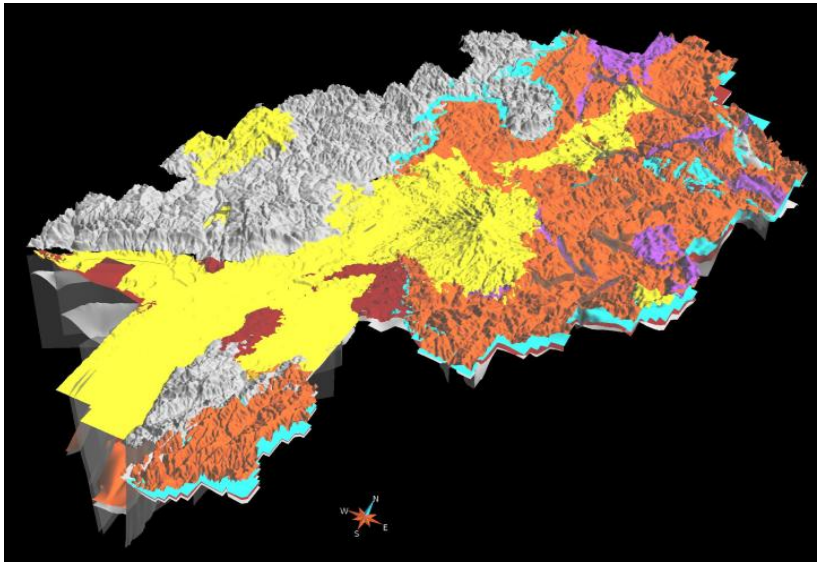
Organisation of the Geological Survey of Hesse



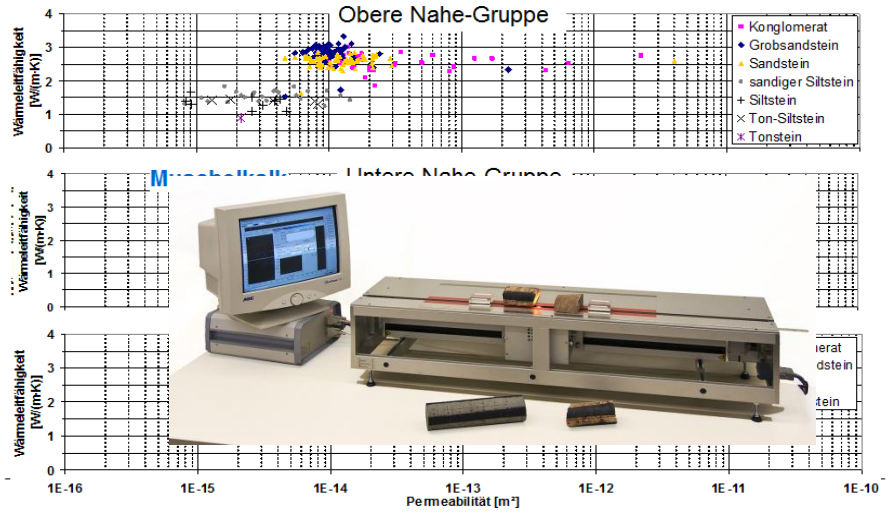
Development of a structural geological model (GOCAD)

- Modelling of stratigrafic horizons and fault structures



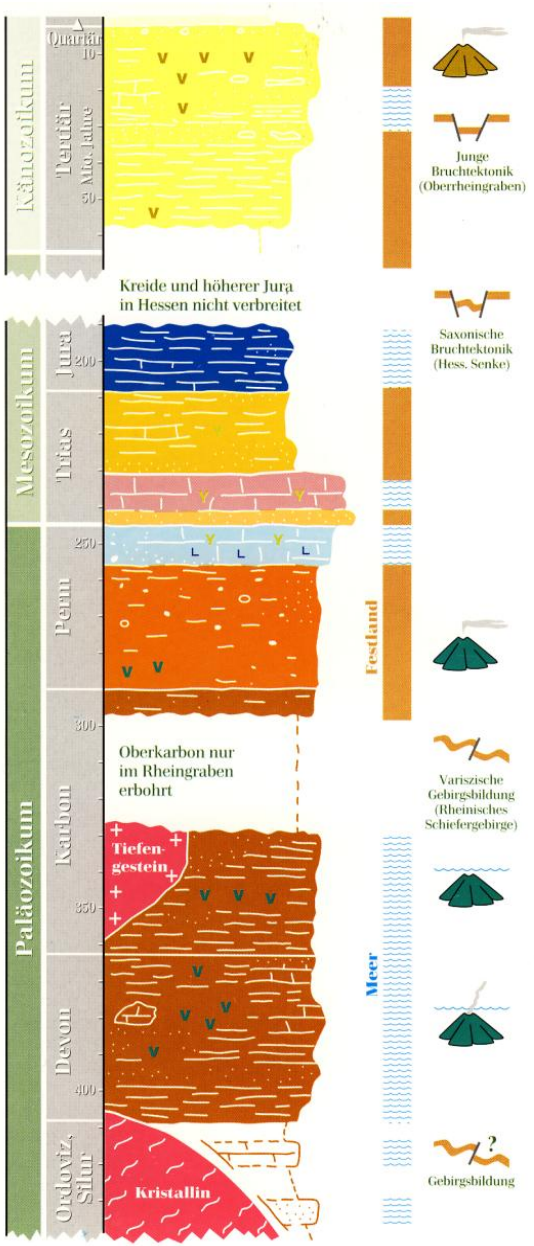
Development of a geothermal model

- Determination and attribution of physical parameters of rock units



Modelled Horizons

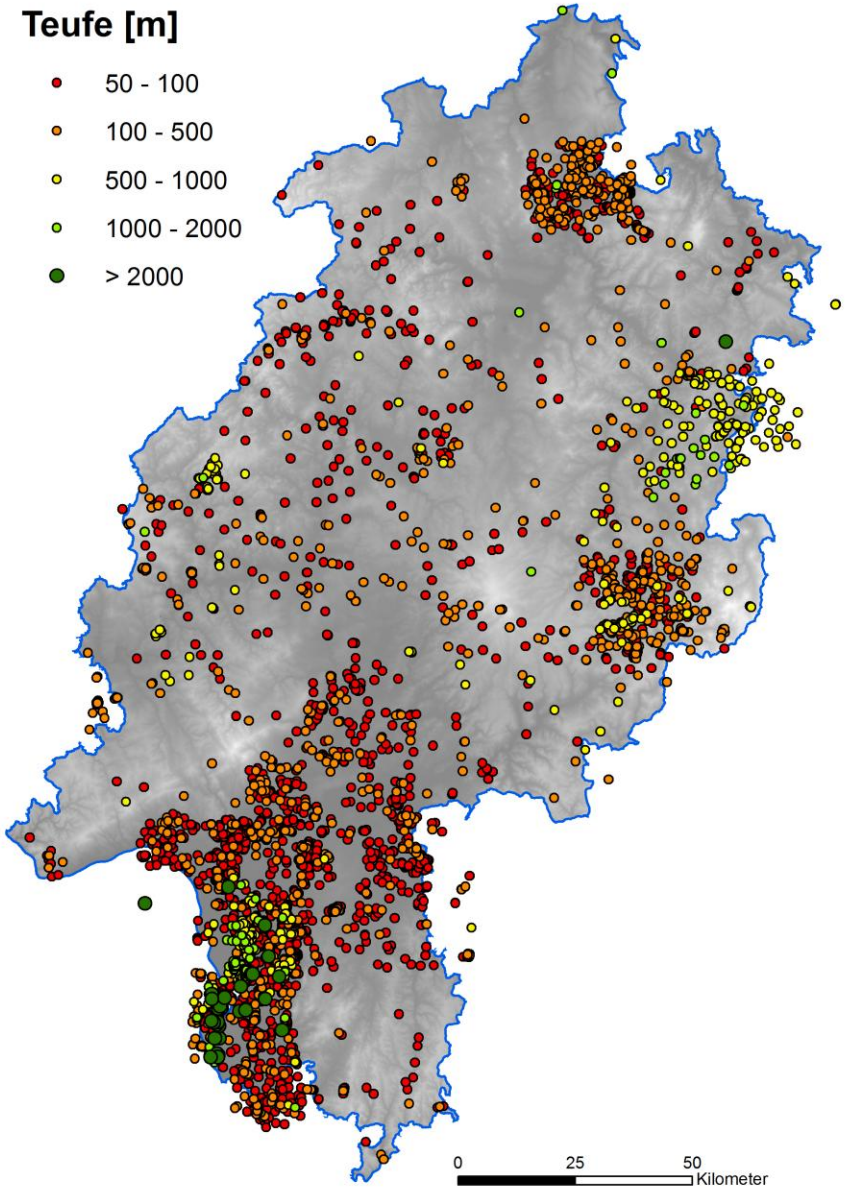
- Top Quarternary and Tertiary
- Top Muschelkalk
- Top Bunter (Buntsandstein)
- Top Zechstein
- Top Rotliegend
- Top Pre-Permian
  - Top of cristalline basement
  - Top of metamporphic rocks



Hoppe und Mittelbach (1999)

Used Data

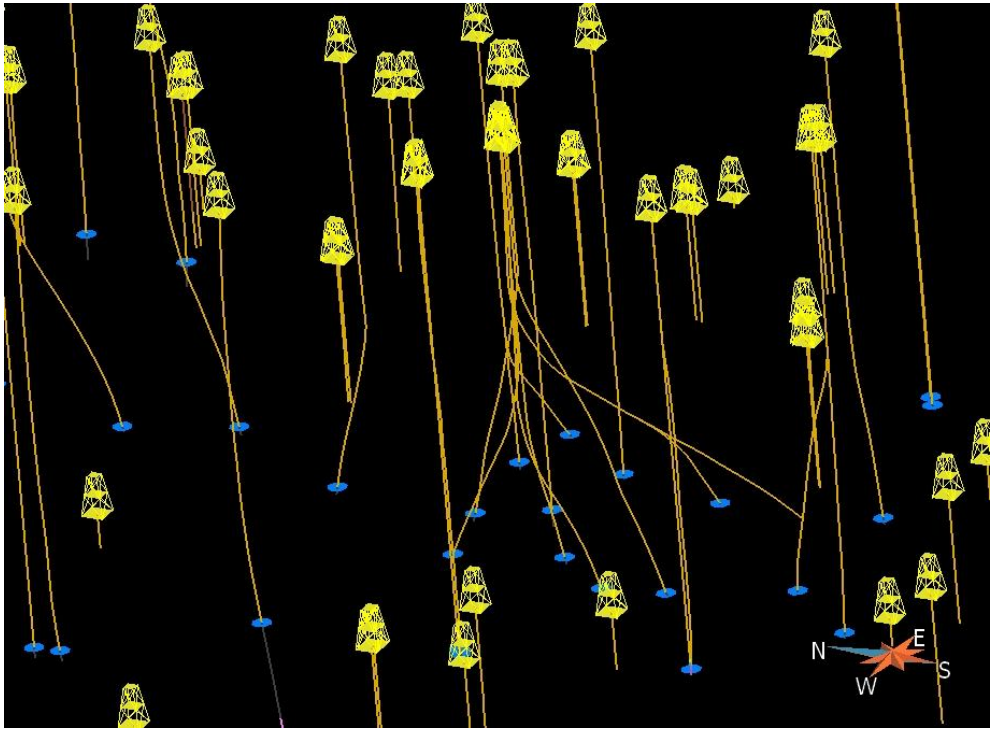
- Borehole data
  - -HLUG Archive
  - - German Geological Surveys (Kohlenwasserstoffdatenbank)
- Seismic data
- Literature
  - - Isolines and structural maps
  - - Geological maps (1 : 300,000, 1 : 200,000, 1 : 25,000)
  - - Geological cross sections
  - - Palaeogeographical maps
  - - Model estimations etc.



Compilation of borehole data

- Computer programme including borehole deviation

➔ Increase of density of data and accuracy



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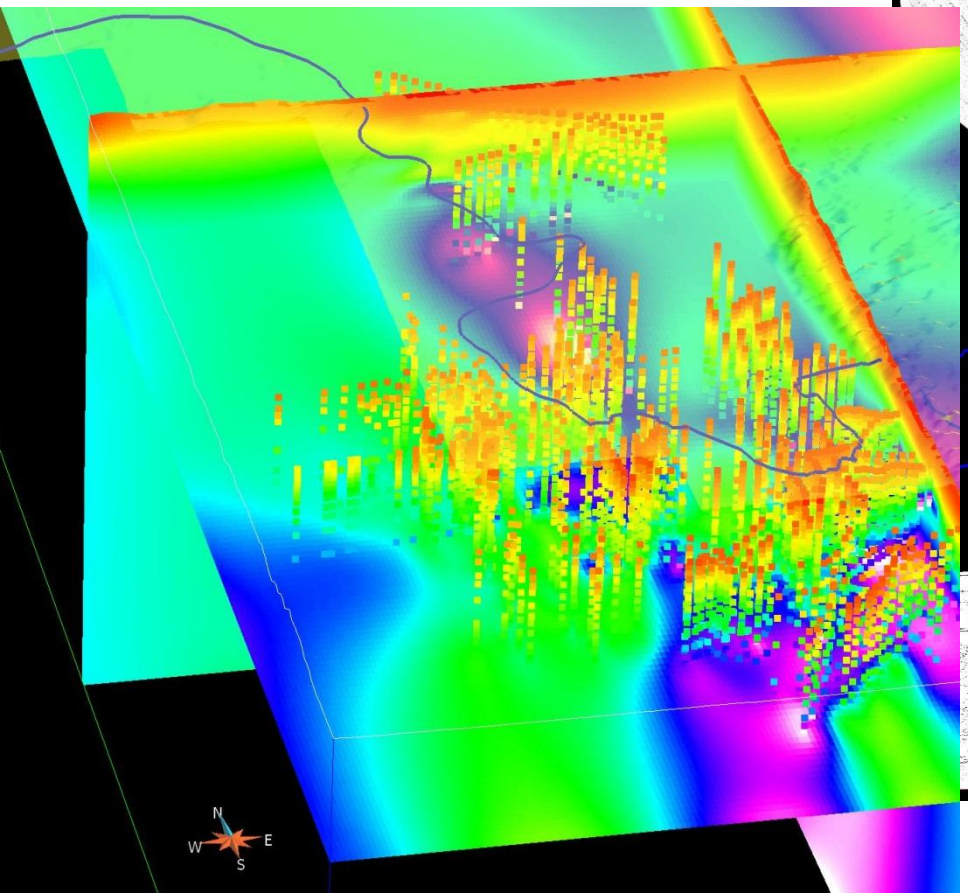

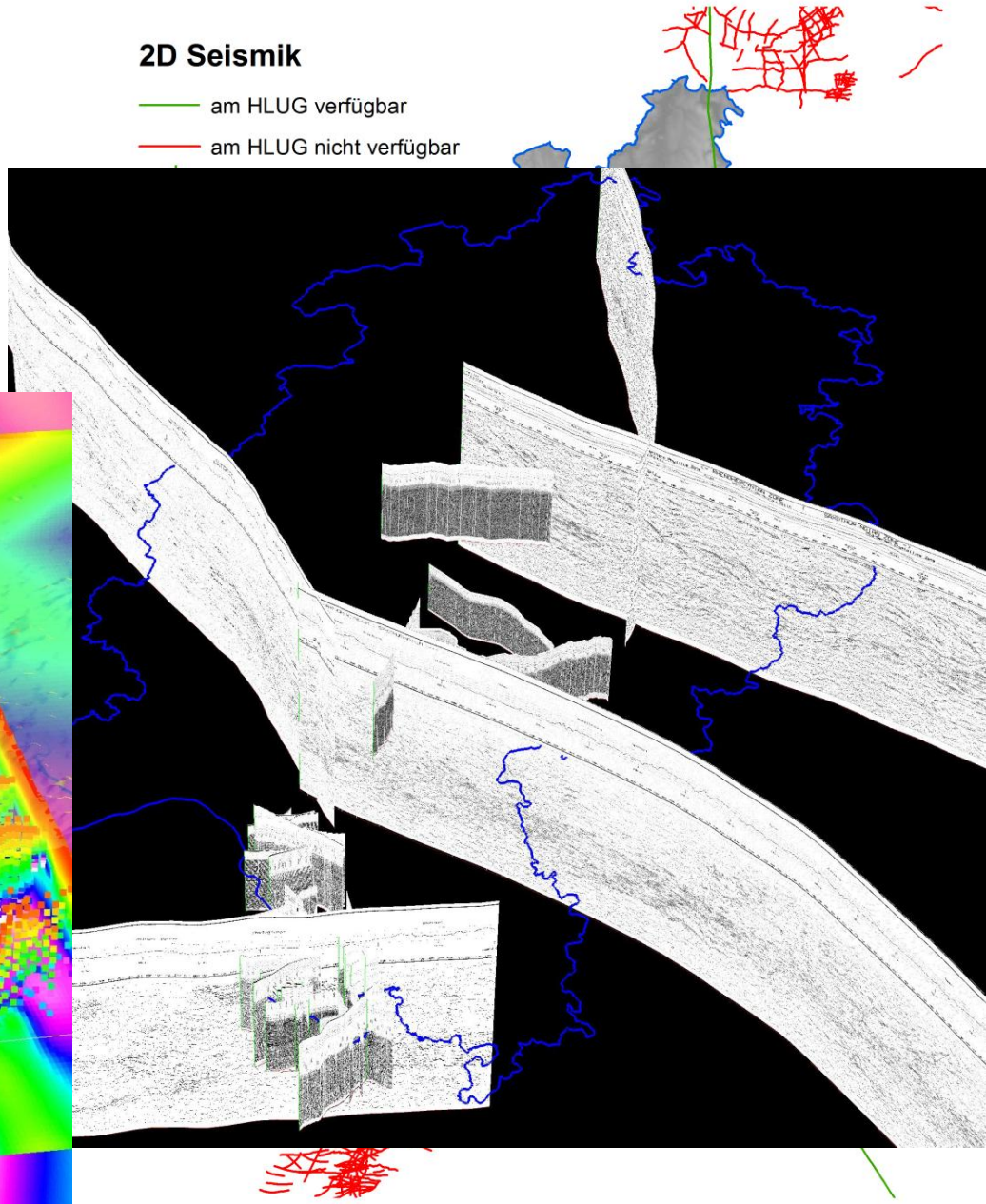

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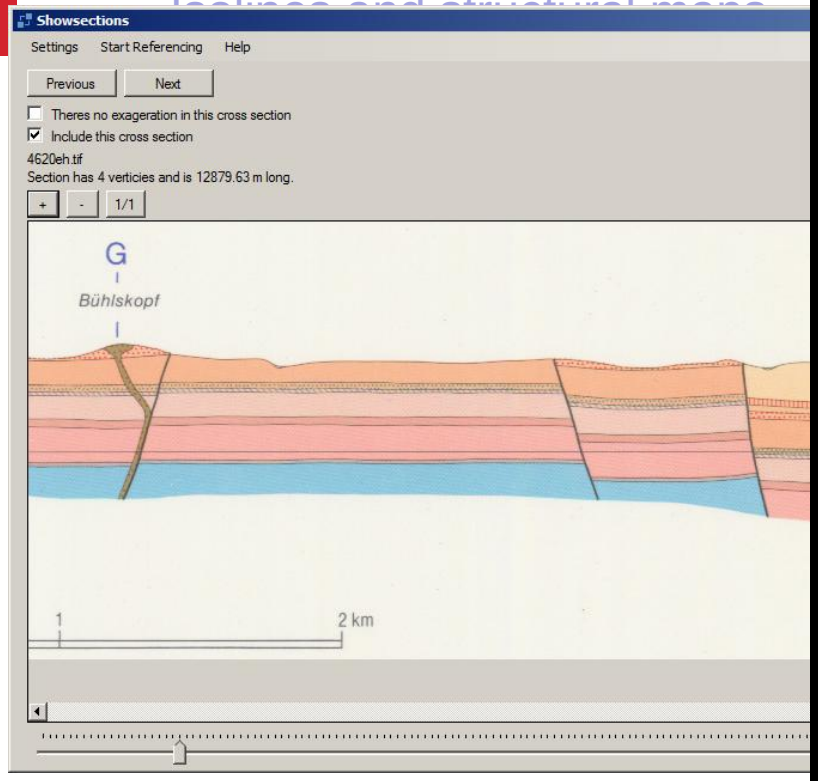
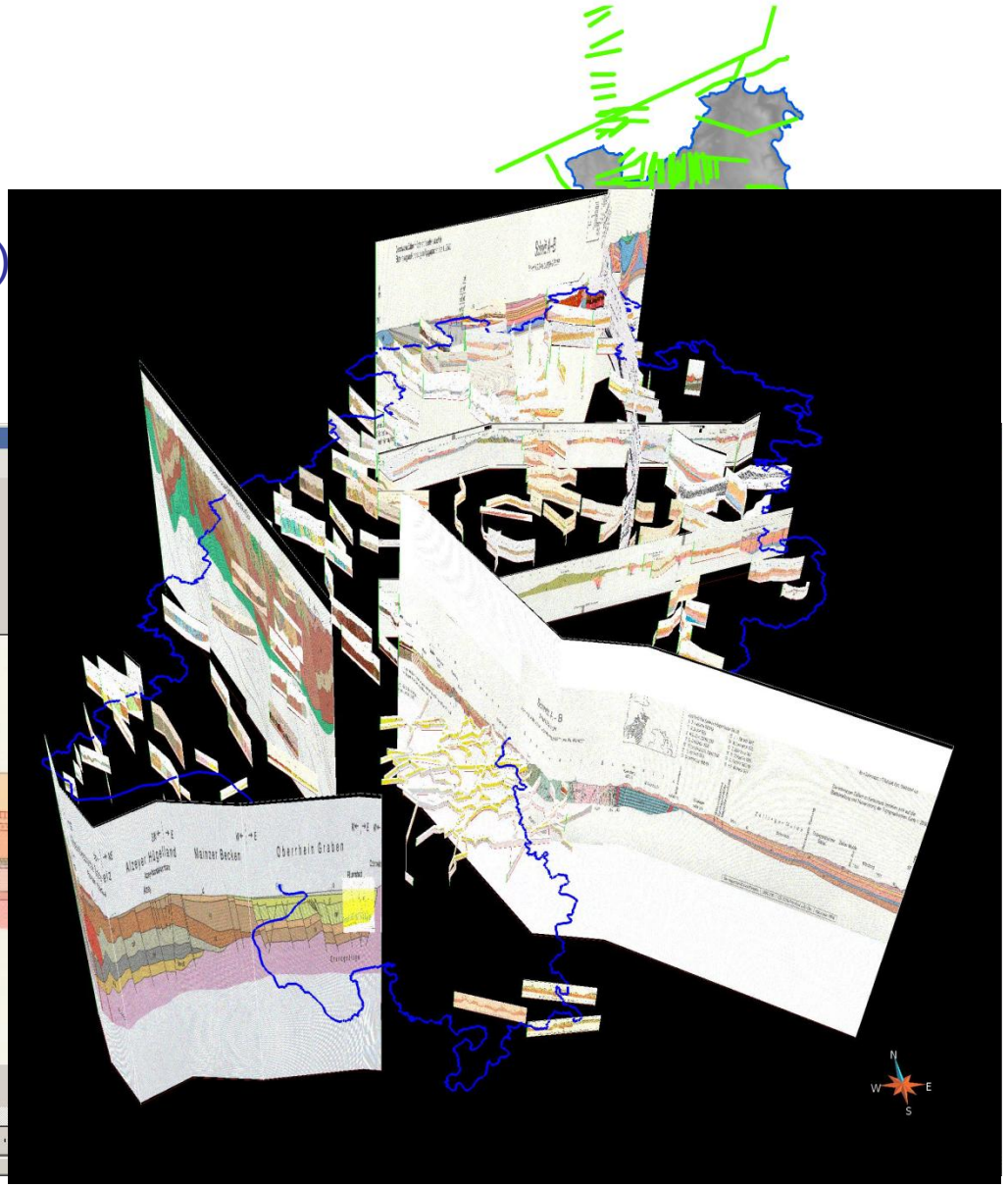
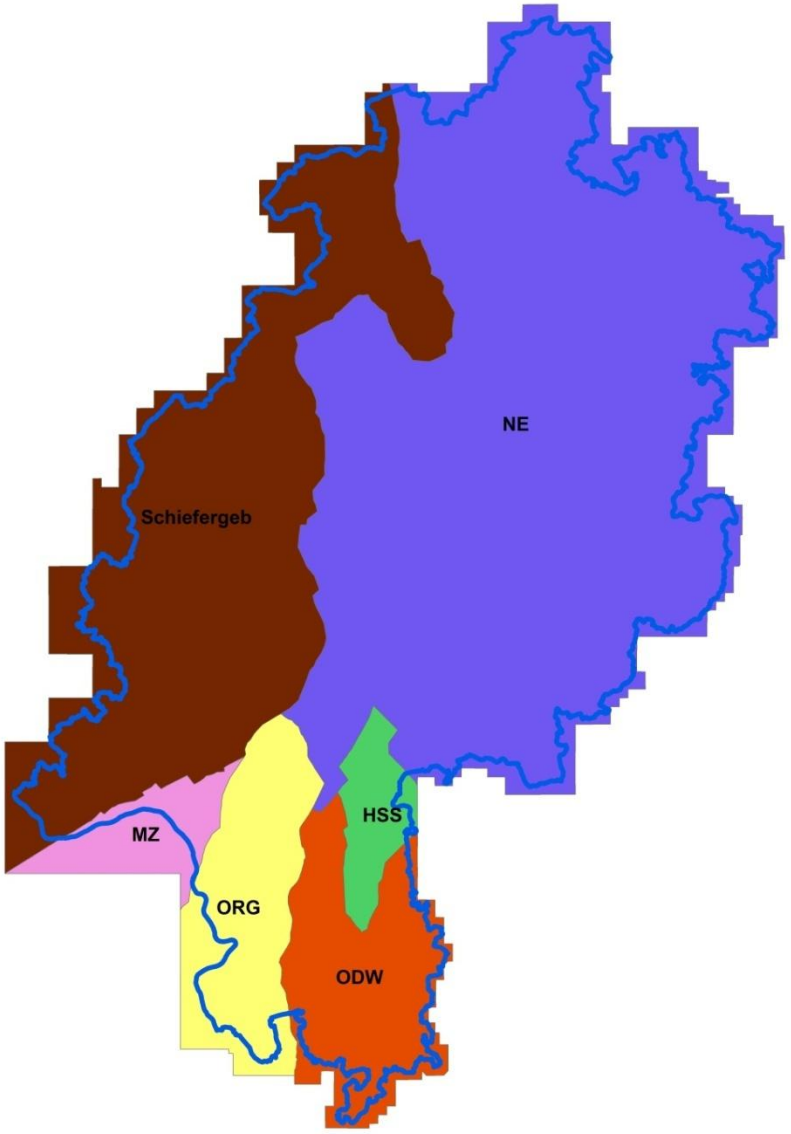




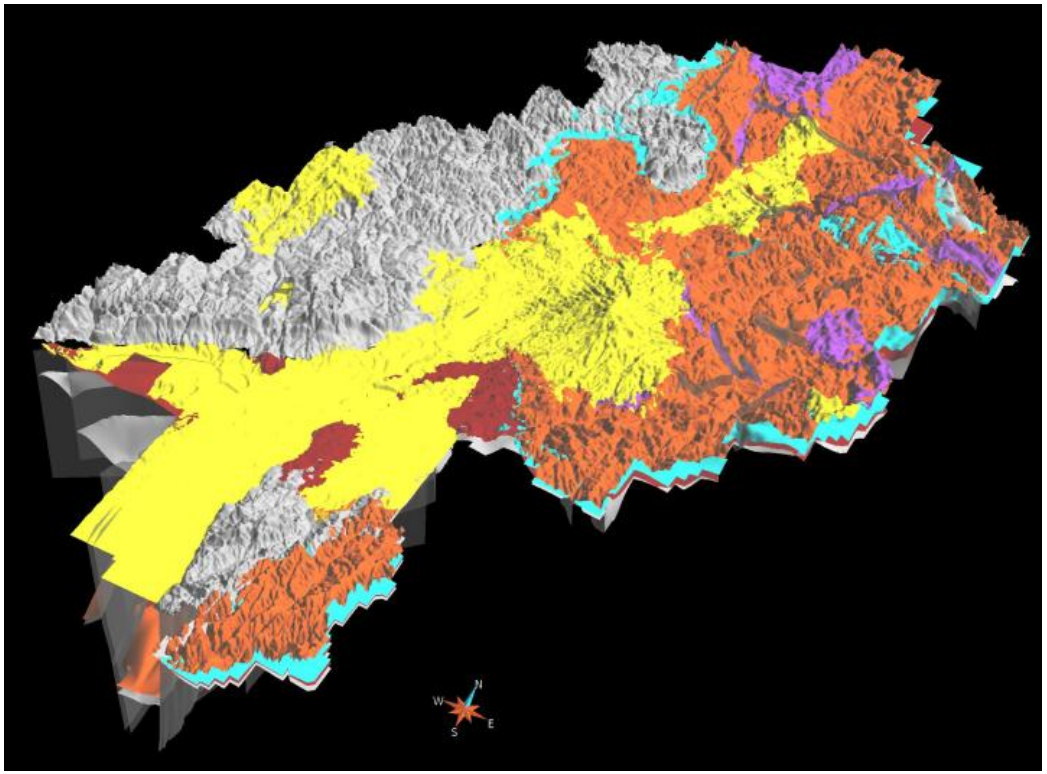
Submodels

- For easy handling: Structuring into 6 submodels

➔ The region borders are oriented to modelled fault zones reaching down to the Pre-Permian



Let‘s have a look at the model…



Geological 3D-Modell of Hesse. View from southeast with the model horizons Top Quarternary and Tertiary (yellow), Top Muschelkalk (violet), Top Bunter (Buntsandstein, orange), Top Zechstein (light blue), Top Rotliegend (red), Top Pre-Perm (grey) (ARNDT et al., 2010).

Properties for the quantification of geothermal potential

		Hydrothermal	Petrothermal	Deep BHE	Faults
Thermophysical Properties	**Thermal Conductivity**	3	2	1	-
	Rock density	3	2	1	-
	Heat Capacity	3	2	1	-
	Temperature	1	1	1	1
Hydraulic Properties	**Permeability/hydr. Conductivity**	1	2	3	1
	Transmissibilty/Transmissivity	1	3	3	-
	Porosity	1	3	3	-
	Productivity Index	1	3	-	-
	Hydraulic Test Data	1	1	-	-
Reservoir Properties	**Tectonics/Stress Field**	2	1	3	1
	Petrography/Rock Mechanics	1	1	2	1
	Reservoir Geometry/Heat Exchange Area	1	1	-	1

After SCHULZ et al. (2009), modified;
1 =very important; 2 =relevant; 3: low relevance; - no relevance in the moment

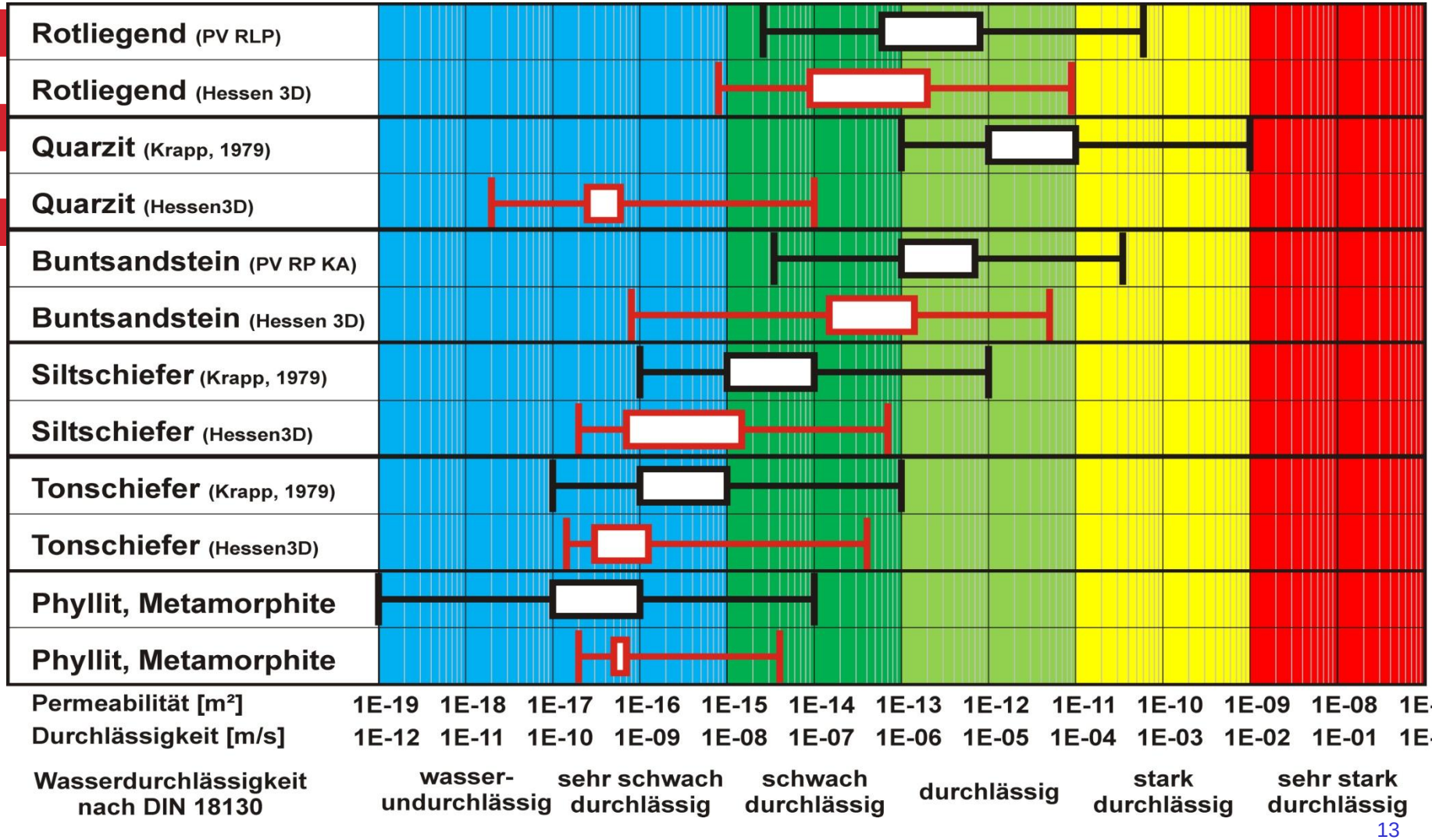
Used for estimation of potential

Limits for Hydraulic Parameters

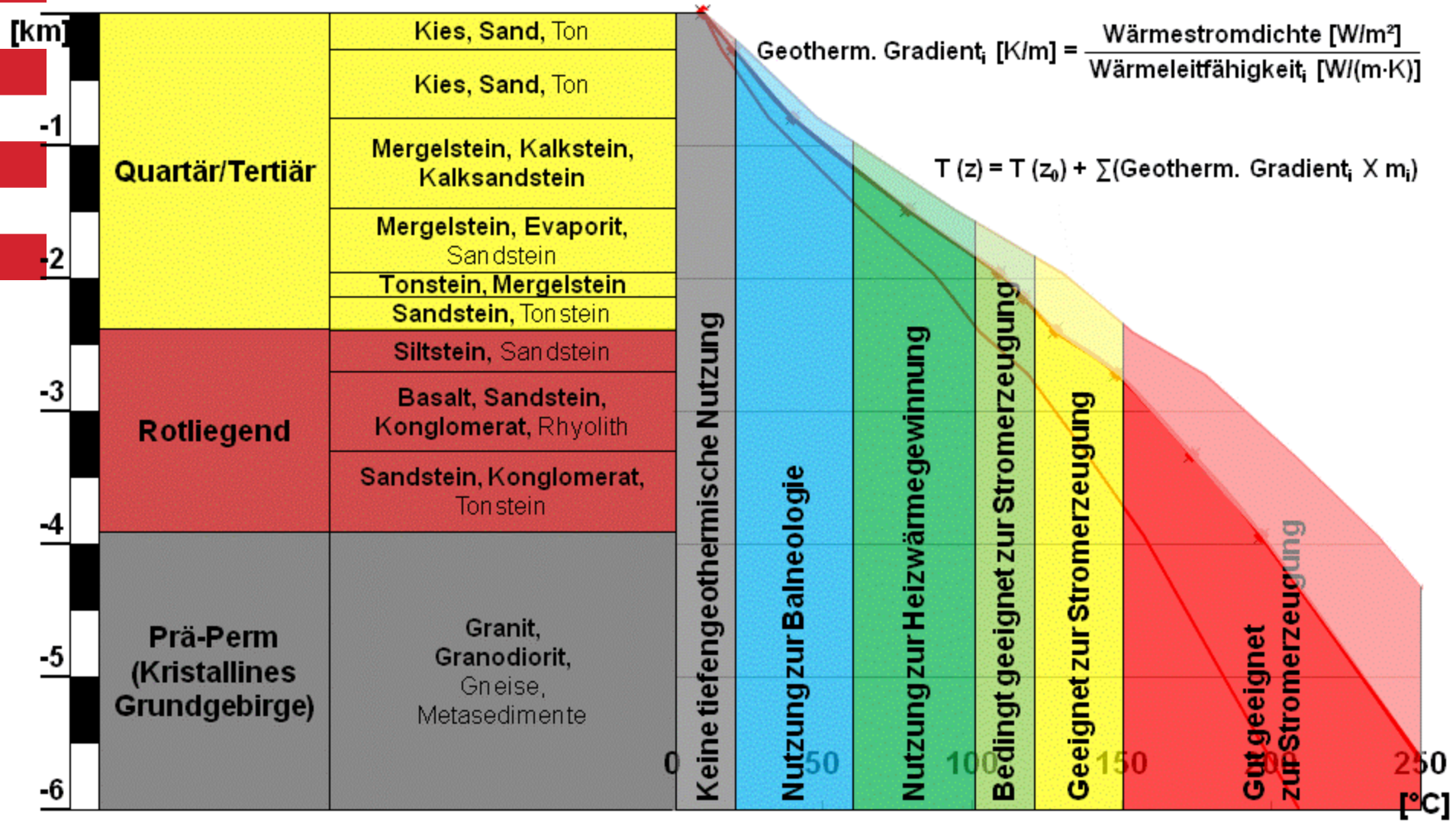
Grade of Permeability (DIN 18130)	Permeability [m²]/ Hydraulic Conductivity [m/s]	Transmissibility* [m³] Transmissivity* [m²/s]	Potential
Extremly high	> $1 \cdot 10^{-9}$ / $1 \cdot 10^{-2}$	> $5 \cdot 10^{-8}$ / $5 \cdot 10^{-1}$	Very high
Very high	> $1 \cdot 10^{-11}$ / $1 \cdot 10^{-4}$	> $5 \cdot 10^{-10}$ / $5 \cdot 10^{-3}$	high
medium	> $1 \cdot 10^{-13}$ / $1 \cdot 10^{-6}$	> $5 \cdot 10^{-12}$ / $5 \cdot 10^{-5}$	medium
low	> $1 \cdot 10^{-15}$ / $1 \cdot 10^{-8}$	> $5 \cdot 10^{-14}$ / $5 \cdot 10^{-7}$	low
Very low	< $1 \cdot 10^{-15}$ / $1 \cdot 10^{-8}$	< $5 \cdot 10^{-14}$ / $5 \cdot 10^{-7}$	Very low

* With presumed hydraulic effective thickness of 50 m

Bulk Permeability of reservoir (Pumping Tests) vs. Rock Permeability (Laboratory tests)



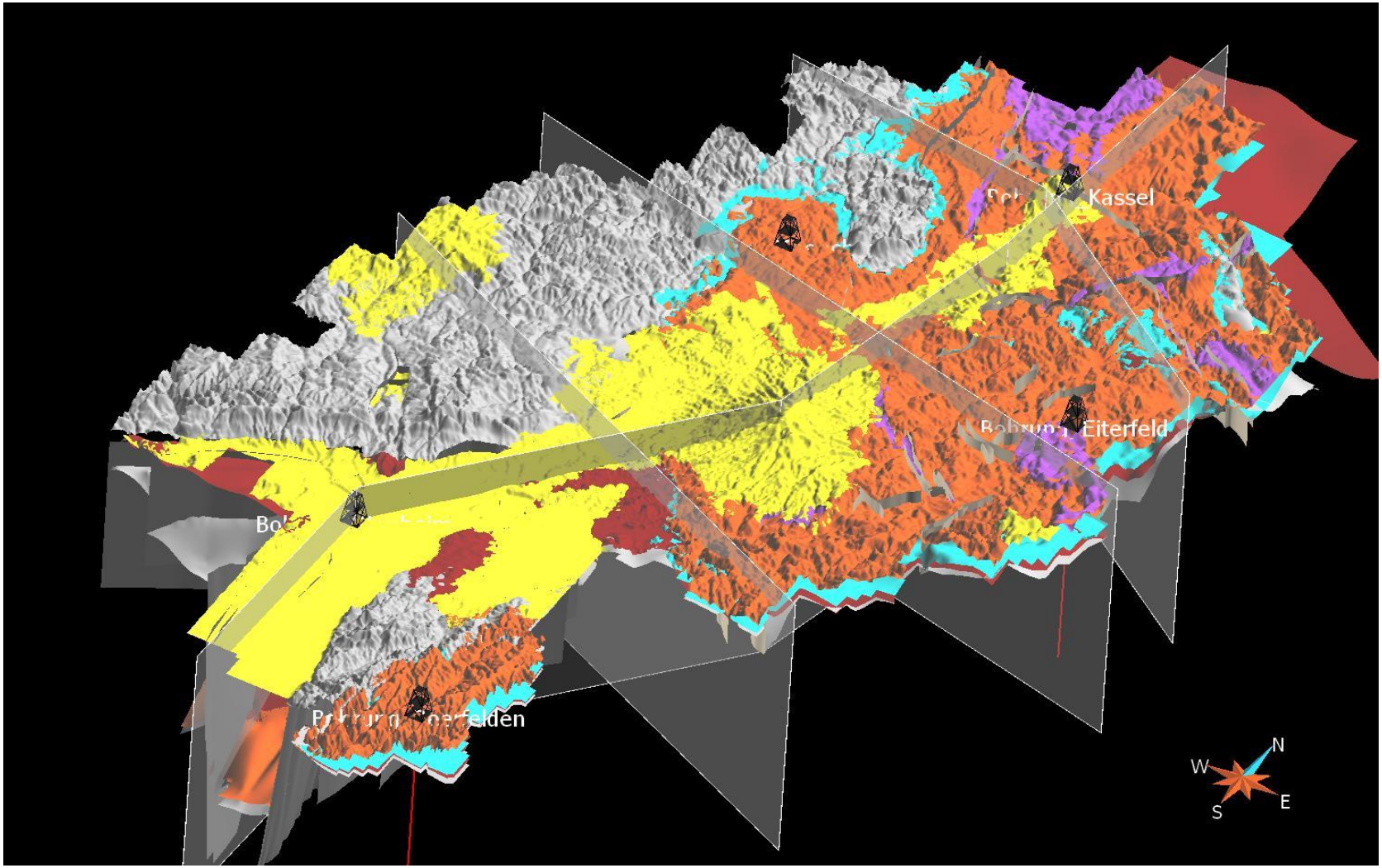
Example: Suitability of a prognostic borehole for several geothermal uses based on the factors geothermal gradient and temperature



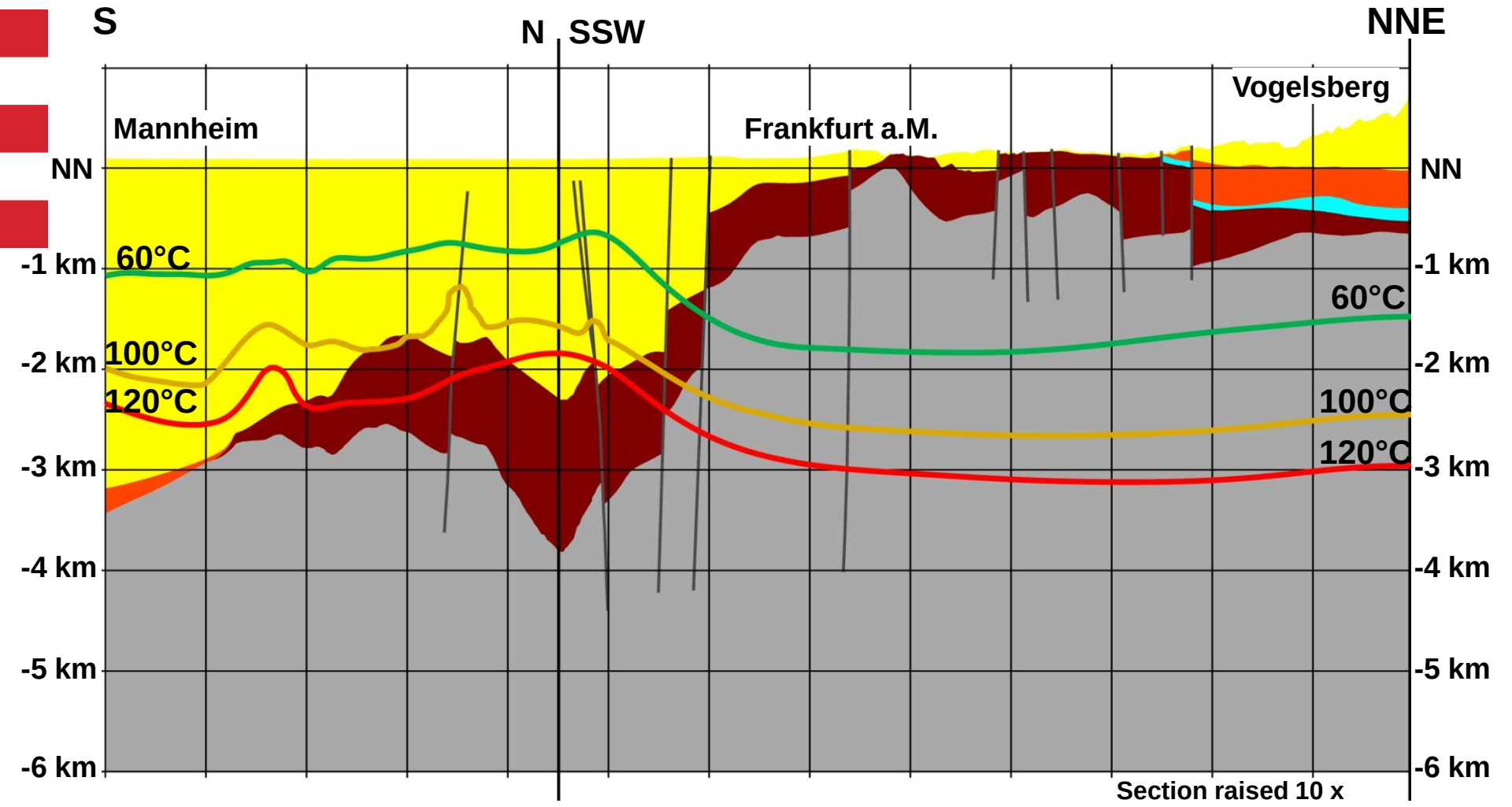
Example: Suitability of a prognostic borehole for several geothermal uses based on the hydraulic properties (blue: very low to red: very high)

[km]			Mittlere Permeabilität [m²]	Maximale Permeabilität [m²]	Mittlere Transmissibilität [m³]	Maximale Transmissibilität [m³]	WLF [W/(m·K)]
	Quartär/Tertiär	Kies, Sand, Ton					
-1		Kies, Sand, Ton	1,0E-12	1,0E-10	3.65E-10	3.65E-08	2.5
		Mergelstein, Kalkstein, Kalksandstein	1,5E-16	2,0E-15	1,0E-13	1,4E-12	1.7
-2		Mergelstein, Evaporit, Sandstein	3,5E-16	3,0E-15	1,7E-13	1,4E-12	1.5
		Tonstein, Mergelst.	1,0E-17	1,0E-16	1,8E-15	1,8E-14	2.1
		Sandstein, Tonstein	8,5E-13	8,0E-12	1,4E-10	1,2E-09	2.2
-3	Rotliegend	Siltstein, Sandstein	4,3E-15	1,5E-14	6,8E-13	2,4E-12	1.5
		Basalt, Sandstein, Konglomerat,	8,5E-14	3,0E-12	3,6E-11	1,3E-09	2.3
-4		Sandstein, Konglomerat,	8,3E-15	2,5E-14	3,0E-12	9,1E-12	2.5
-5	Prä-Perm (Kristallines Grundgebirge)	Granit, Granodiorit, Gneise, Metasedimente	1,0E-18	1,0E-17	2,0E-15	2,0E-14	3.0
-6							

Geological Cross Section „Hesse South-North“

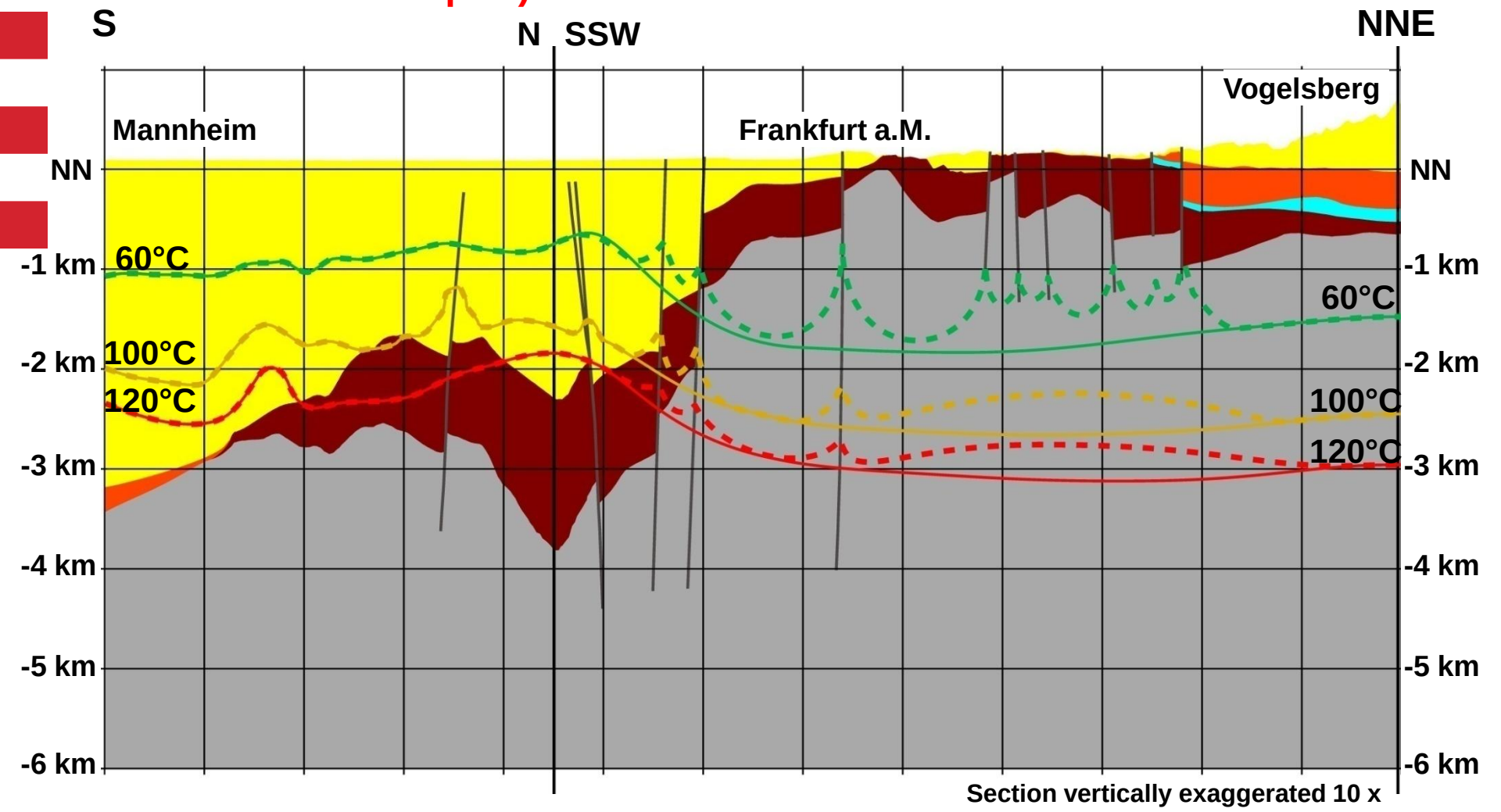


Geological –geothermal Cross Section „Hesse South-North“, Part South With temperature Isolines from the Model (temperature peaks are caused by data of bottom hole temperature measurements)

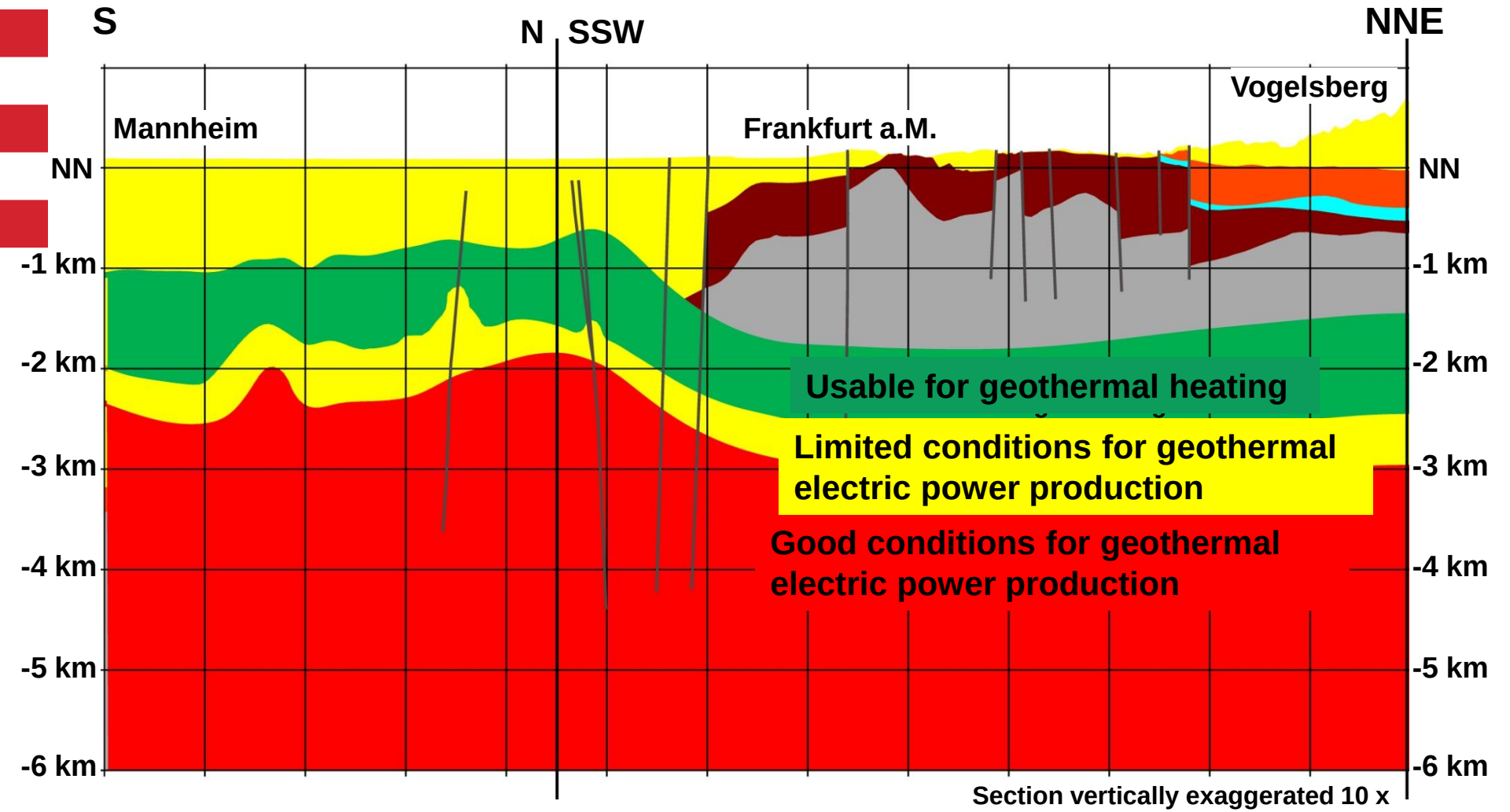


Geological –geothermal Cross Section „Hesse South-North“, Part South

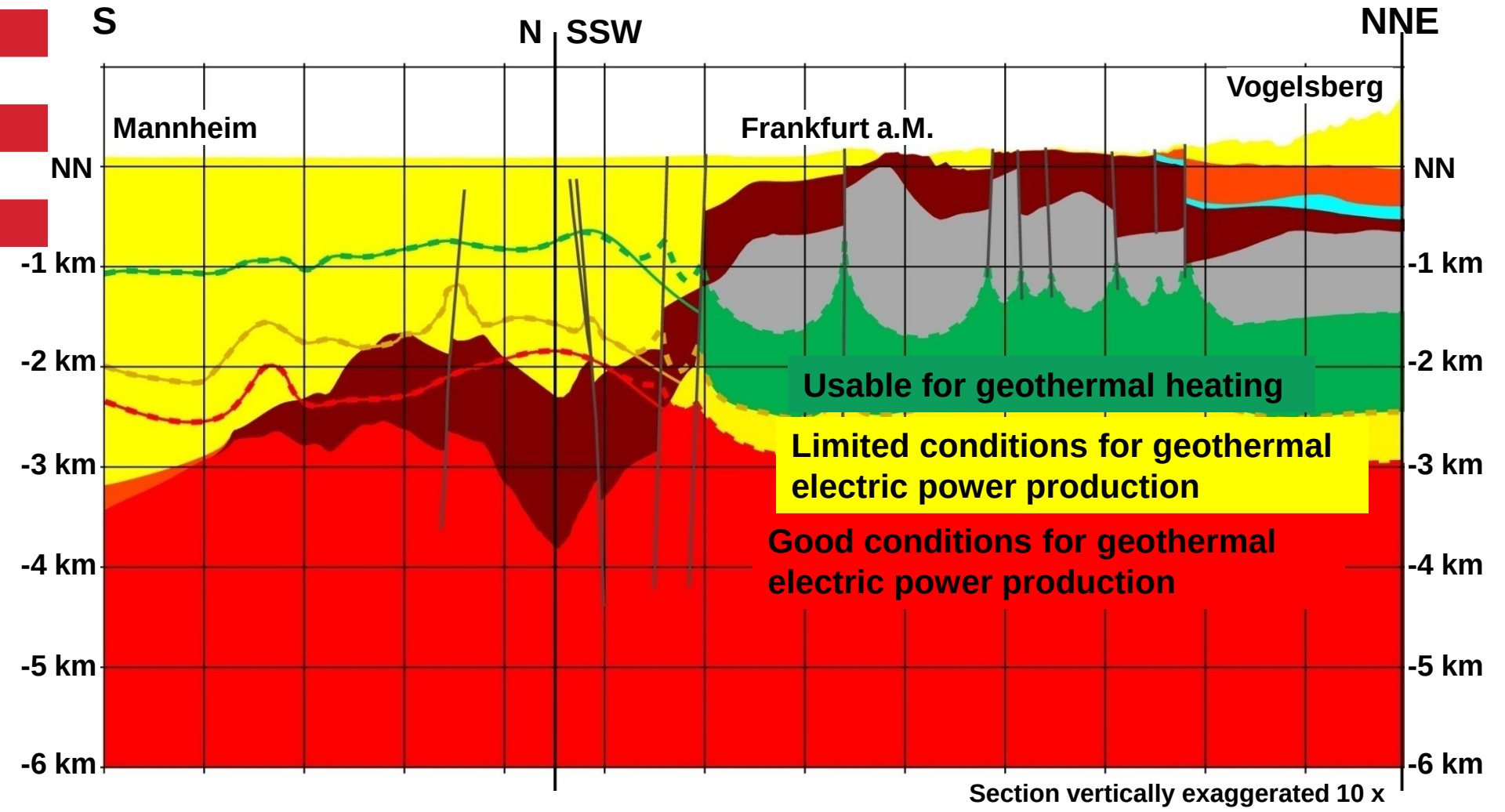
Modified Temperature Isolines considering fault zone convection (dotted lines are schematic, following the assumption that faults zones could favour convective heat transport)



Geothermal Cross Section „Hesse South-North“, Part South
Classification for several types of use depending on Temperature

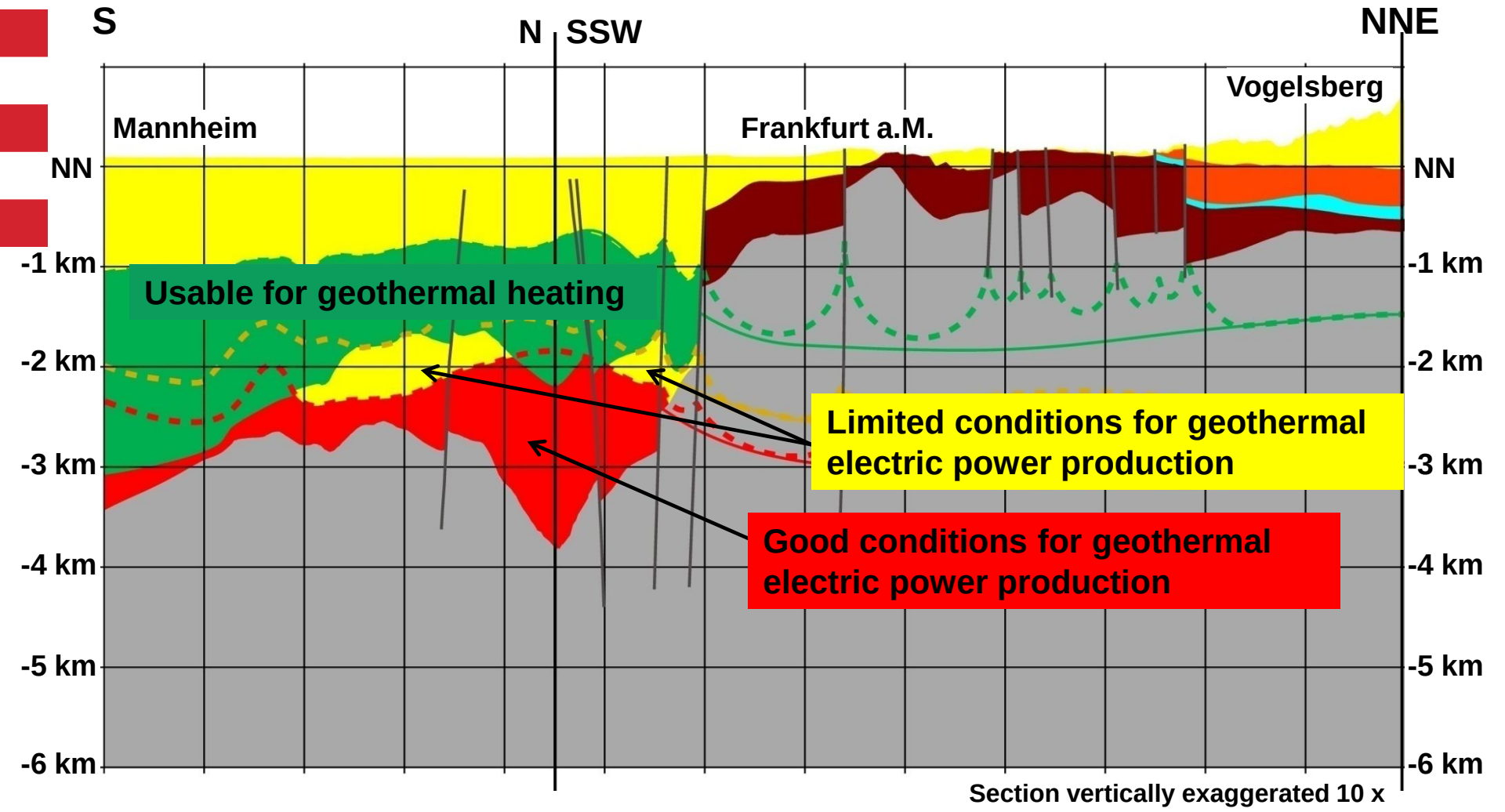


Petrothermal Cross Section „Hesse South-North“, Part South, Only basal cristalline complex usable, (classification schematic, based on the assumption that fault zones favour convection)



Hydrothermal Cross Section „Hesse South-North“, Part South

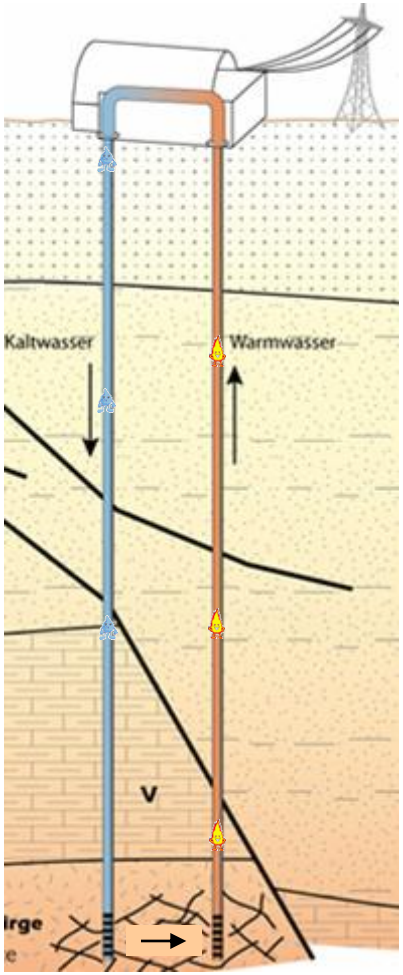
Only sediments with adequate permeability usable (classification schematic, based on the assumption that fault zones favour convection)



Conclusions:

- **With the present state of scientific and technical knowledge (hydrothermal systems) it is possible to establish geothermal electric power production in Hesse in the Upper Rhine Graben**
- **In entire Hesse petrothermal systems can be used for electric power production**
- **Near the rim of the URG a high potential for electric power production is already found in medium depths**
- **The 3-D-Model will be finished in the end of June 2011**
- **A three-dimensional qualitative and quantitative characterization of the deep geothermal potential for entire Hesse up to a depth of 6 km will exist**
- **The publication of this work is intended to be accessible to the public as a map viewer, with a 3-D viewing programme (e.g. Adobe Reader, Geocando) and as a web-map service**

Thank you very much for your attention!



Thanks to the entire working group „Hessen 3-D“:
BÄR, K.; ARNDT, D., FRITSCHE, J.-G.; GÖTZ, A. E.; HEGGEMANN, H.; HOPPE, A.; HOSELMANN, C.; KRACHT, M., KÖTT, A.; LIEDMANN, W.; SASS, I. & STÄRK, A.