EGS in the Permian of the North German Basin, Europe:

a borehole doublet utilizing a former exploration well

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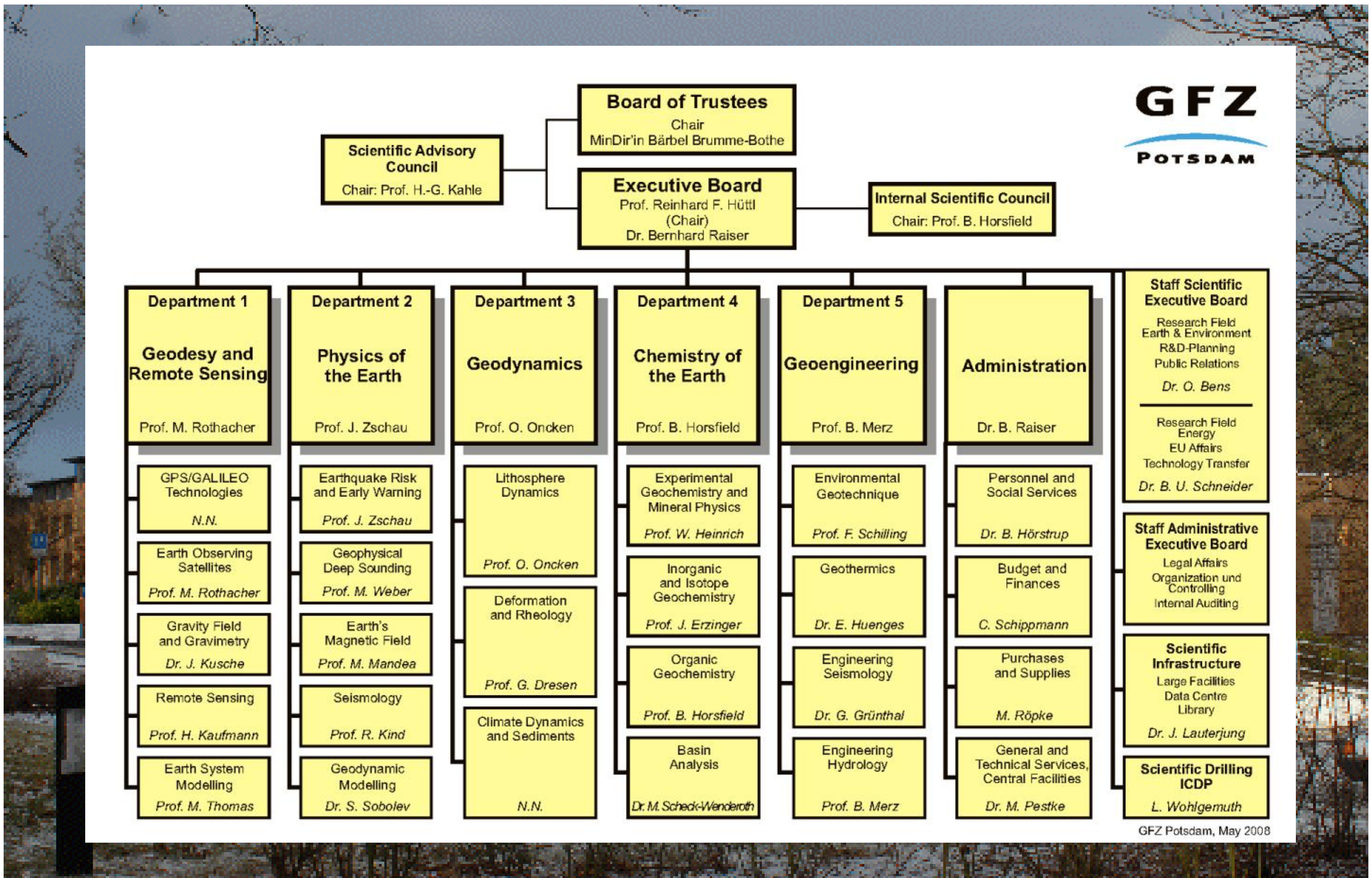
GeoForschungsZentrum Potsdam

a Helmholtz Centre

German Research Centre for Geosciences



Integrated Research: Technology Development for Geothermal Energy Utilization (electrical power, heating, cooling)

geology

geochemistry / mineralogy

geophysics / petrophysics

drilling technology

Exploration

petrophysics

geomechanic/
frac-technology

hydrogeology

Exploitation of the reservoir

Reservoir engineering

conversion cycle

cooling cycle

thermal water cycle

Design of geothermal (power) plants

Geothermal sites in Germany

Political promotion of renewables by *the renewable energy sources act:*
Electricity generation from geothermal energy is funded
Feed-in compensation
Bonus-programmes for environmentally friendly heat production

Geothermal power plants
Geothermal exploration sites

I-GET

EGS-Research

Groß Schönebeck

Enhanced Geothermal Systems

Commercial | **Potentially commercial**

Productive hydrothermal | *Enhanced geothermal* | *Hot dry rock*

Suitable for reservoir enhancement*

High —— *Natural permeability* —— **Zero**

*** Hydrofracture, targeted injection, acid leaching, directional drilling, etc.**

Enhanced Geothermal Innovative Network for Europe –

a milestone towards EGS demonstration projects

Programme " Integrating and strengthening the European Research Area", Period: 11/2005 – 10/2008

- **joint venture of 35 partners from 16 countries for coordination of current R&D-projects**
- **transfer of knowledge in and in between different branches of geothermal utilization**
- **platform for contacts between research institutes, industry, and politics**

I-GET Integrated Geophysical Exploration Technologies for Deep Fractured Geothermal Reservoirs

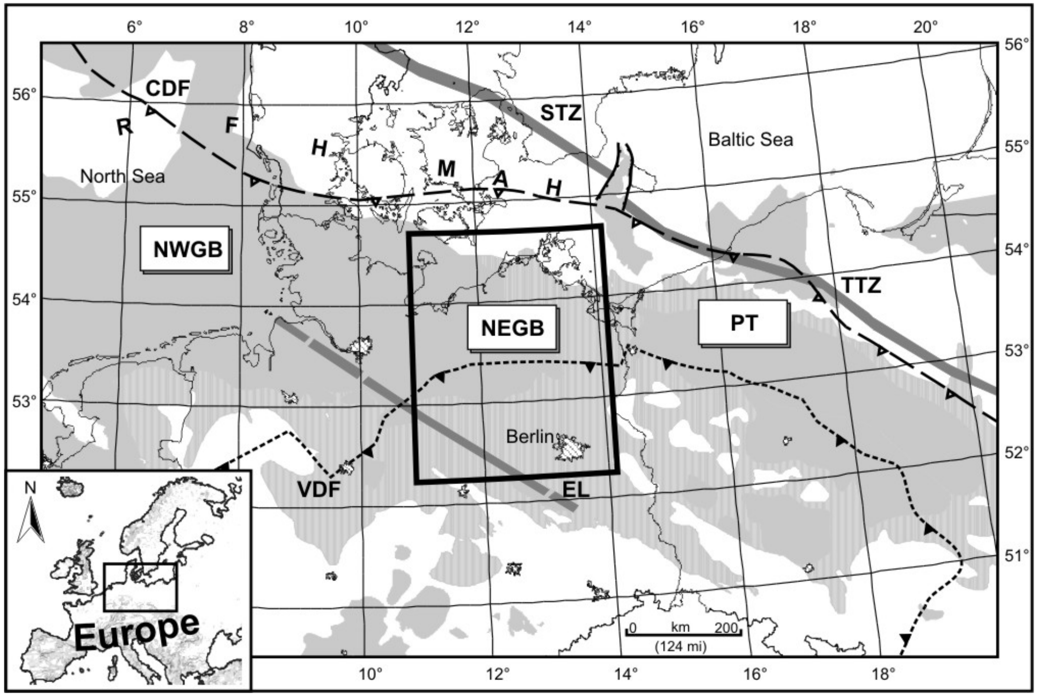
Programme "Integrating and strengthening the European Research Area ", Period: 11/2005 – 10/2008

Goal: **Development of innovative, sustainable, and cost-effective concepts for the geophysical exploration of geothermal reservoirs**

Methods: **Integration of available data**
- seismic und electro-magnetic (field-exploration)
- petrophysical (laboratory, logging, models)

Test Sites: **4 European sites**
- High-thermal conditions (metamorphous and volcanic rocks)
- "normal" thermal conditions (in sedimentary basins)

Oil and Gas Exploration in NE Germany



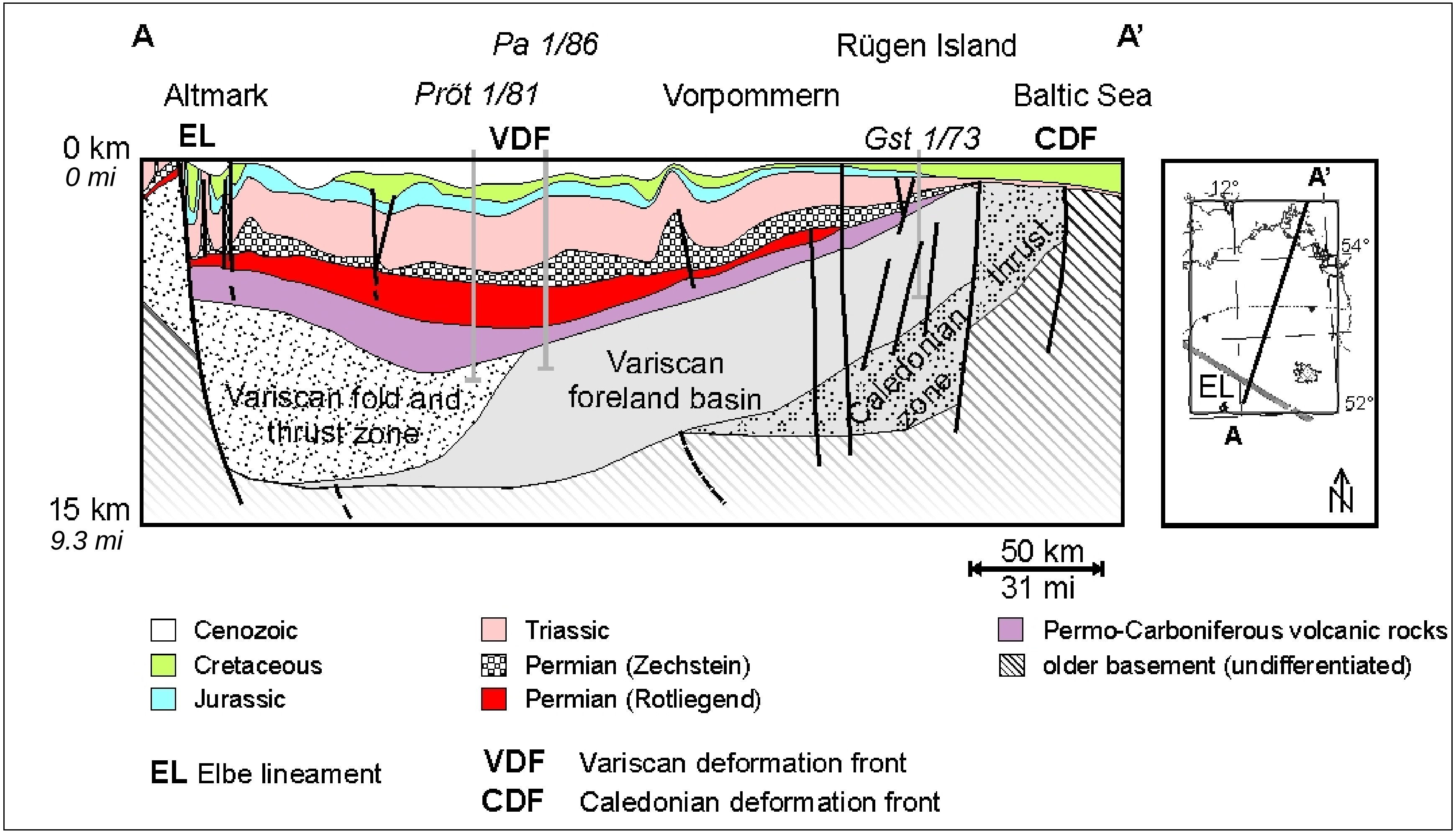
Distribution map of the sedimentary Rotliegend
(Lower Permian) in North Europe
(Norden and Förster, 2004)

Structure: North German Basin as part of the South Permian Basin

Target Horizon
Lower Permian Red Beds (Rotliegend)

Depth
3700-4400 m

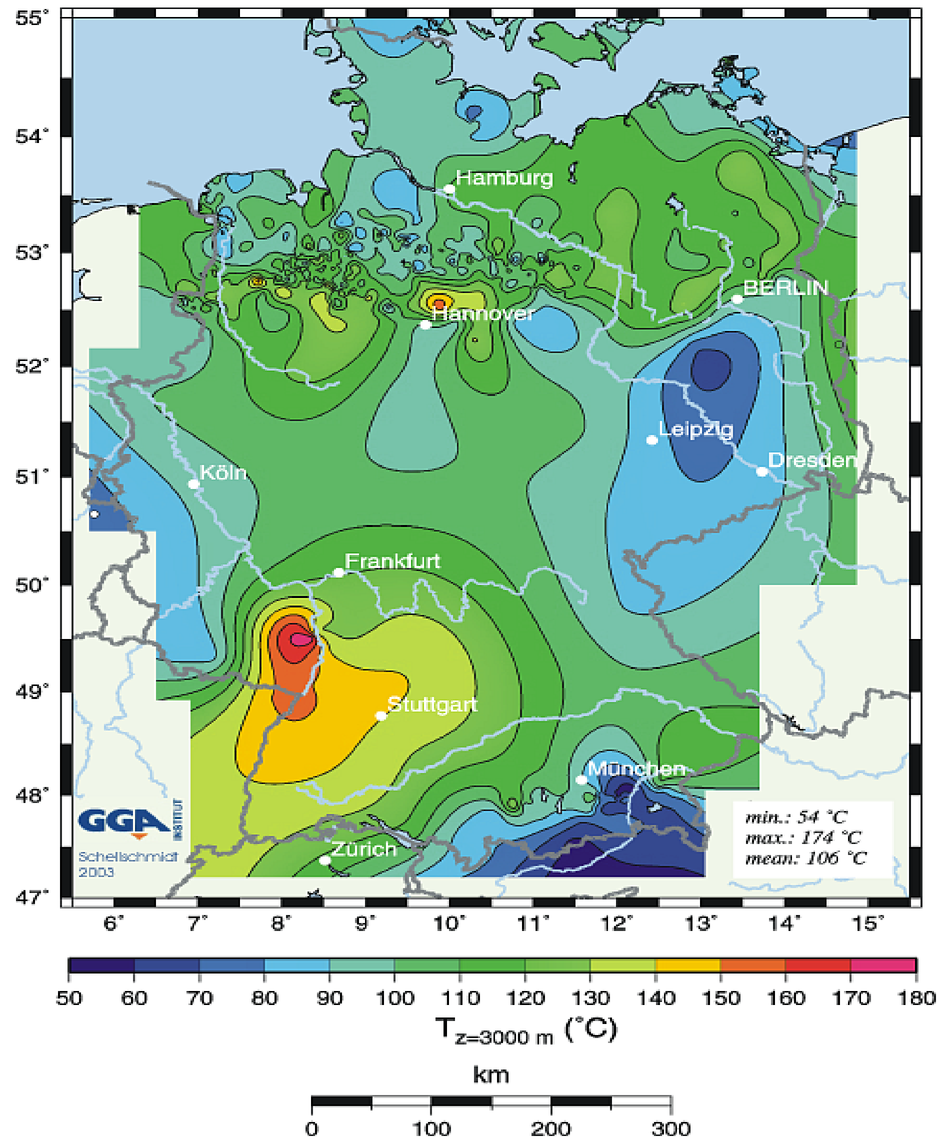
(Main) exploration period
1960-1990 (1970-1985)


A
Pa 1/86
Rügen Island
A'
Altmark
Pröt 1/81
Vorpommern
Baltic Sea
0 km
0 mi
EL
VDF
Gst 1/73
CDF
Variscan foreland basin
Variscan fold and thrust zone
Caledonian zone
thrust
15 km
9.3 mi
50 km
31 mi
12°
54°
52°
A'
EL
A
N
Cenozoic
Cretaceous
Jurassic
Triassic
Permian (Zechstein)
Permian (Rotliegend)
Permo-Carboniferous volcanic rocks
older basement (undifferentiated)
EL Elbe lineament
VDF Variscan deformation front
CDF Caledonian deformation front

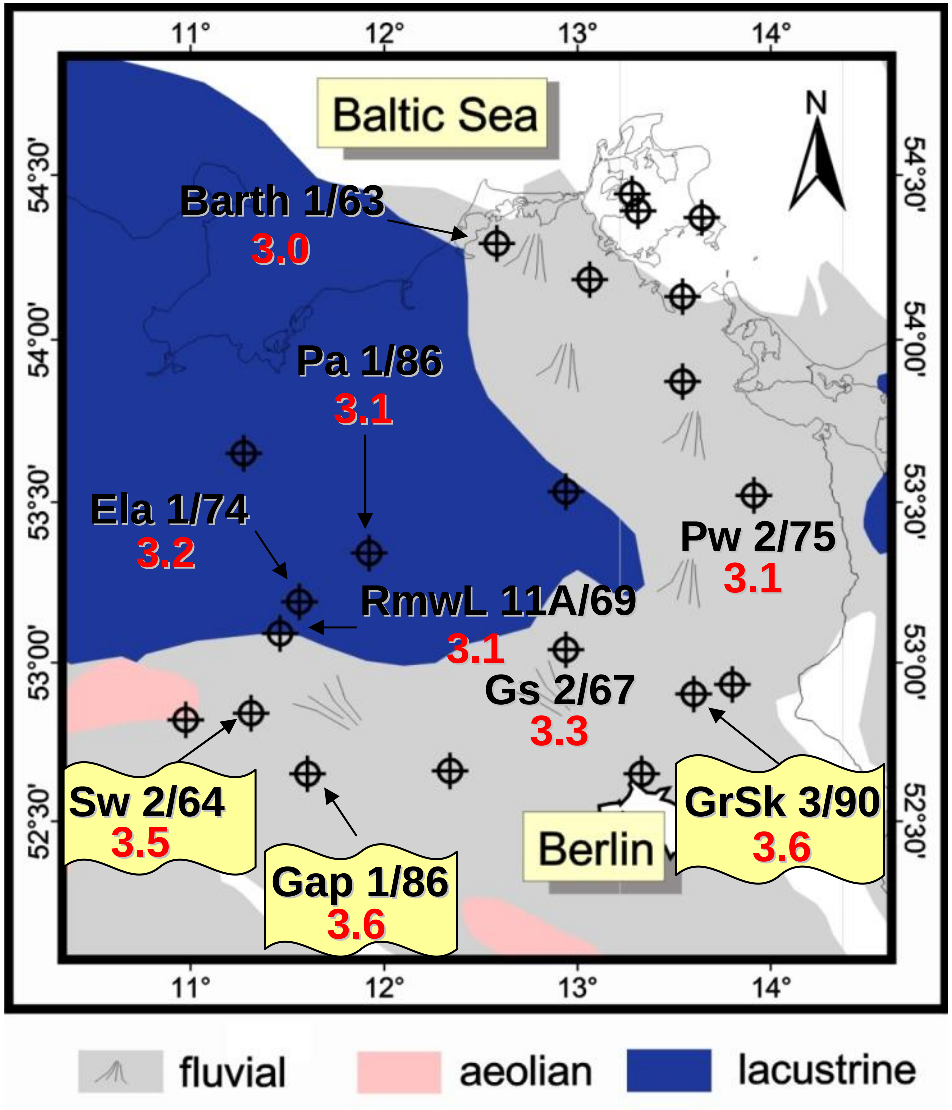
Temperature map of Germany

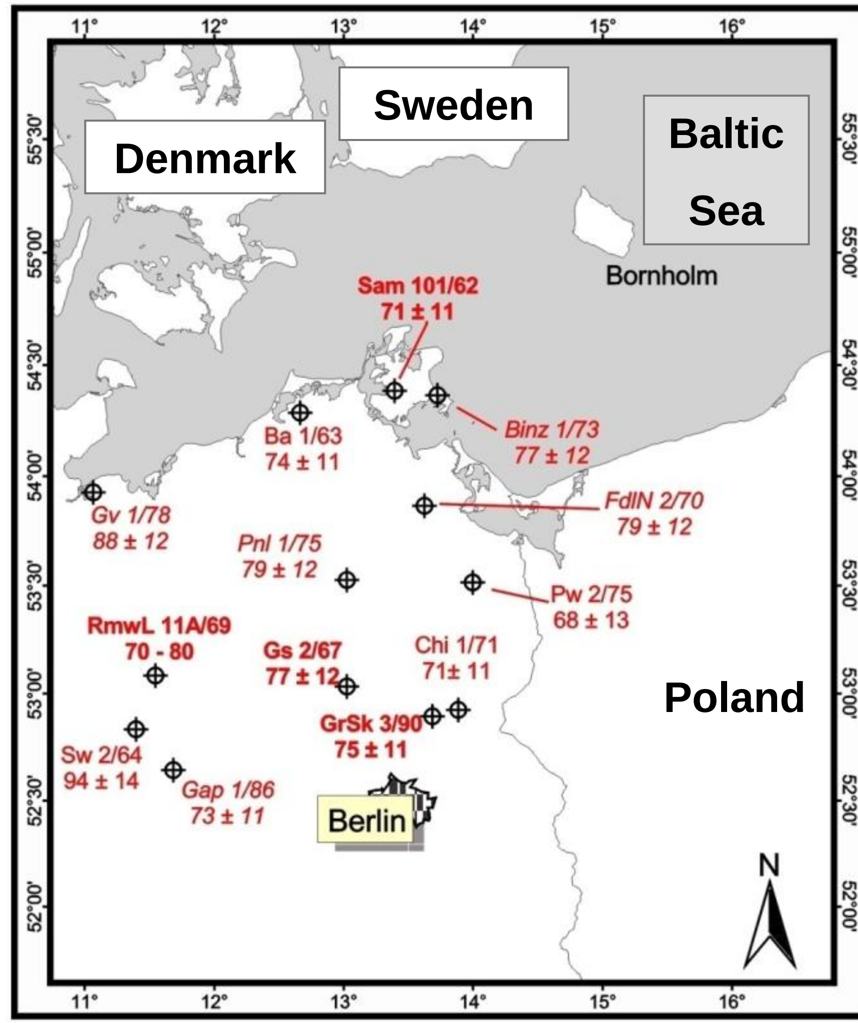
Temperature distribution in 3000 m depth

At most sites are low to moderate enthalpy reservoirs. These reservoirs can be efficiently used by enhancing the permeability.



Formation therm. cond. (W/m/K) and surface heat flow (mW/m²)

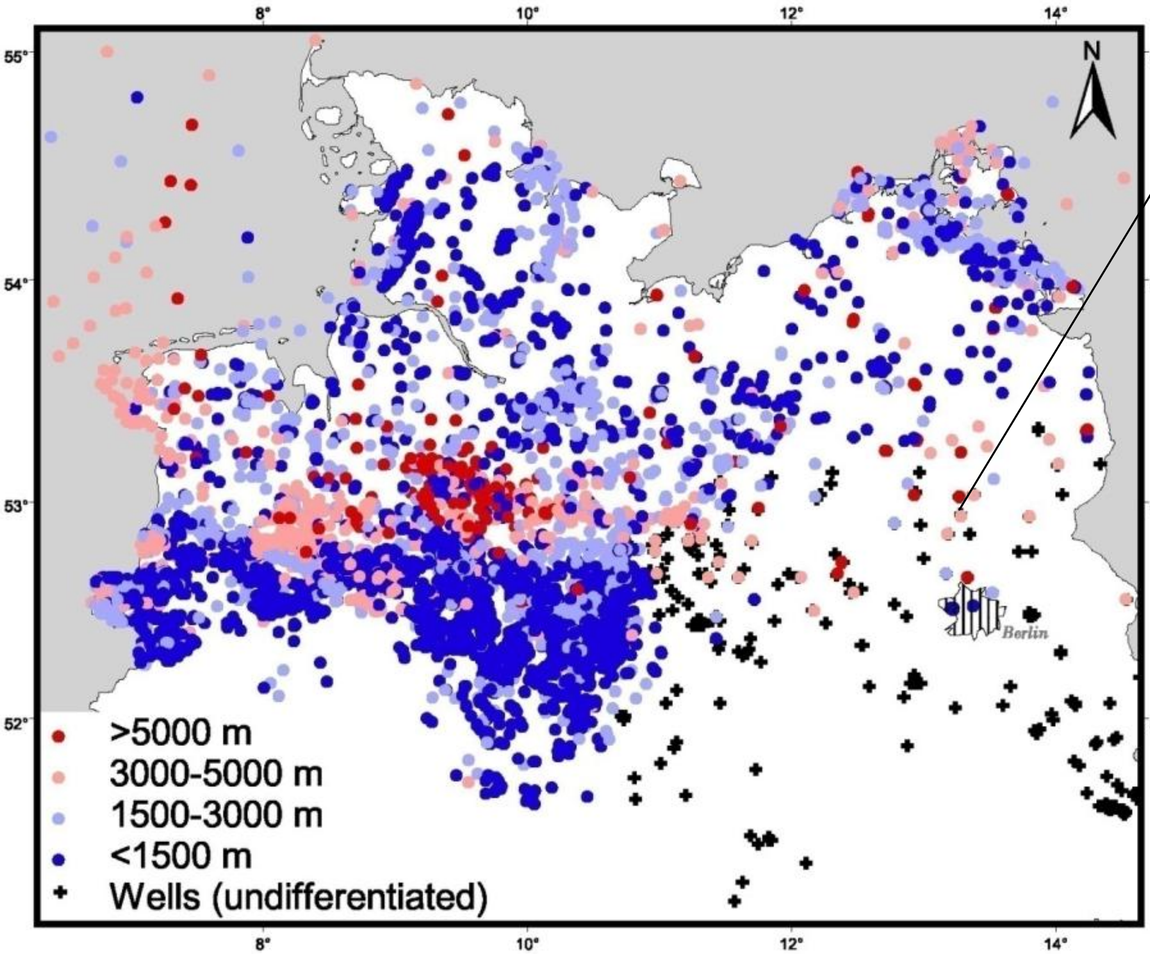




Range: 70-90 mW/m²   Mean: 77 mW/m²

The key site in the NE German Basin – Groß Schönebeck

Re-using an existing gas exploration well



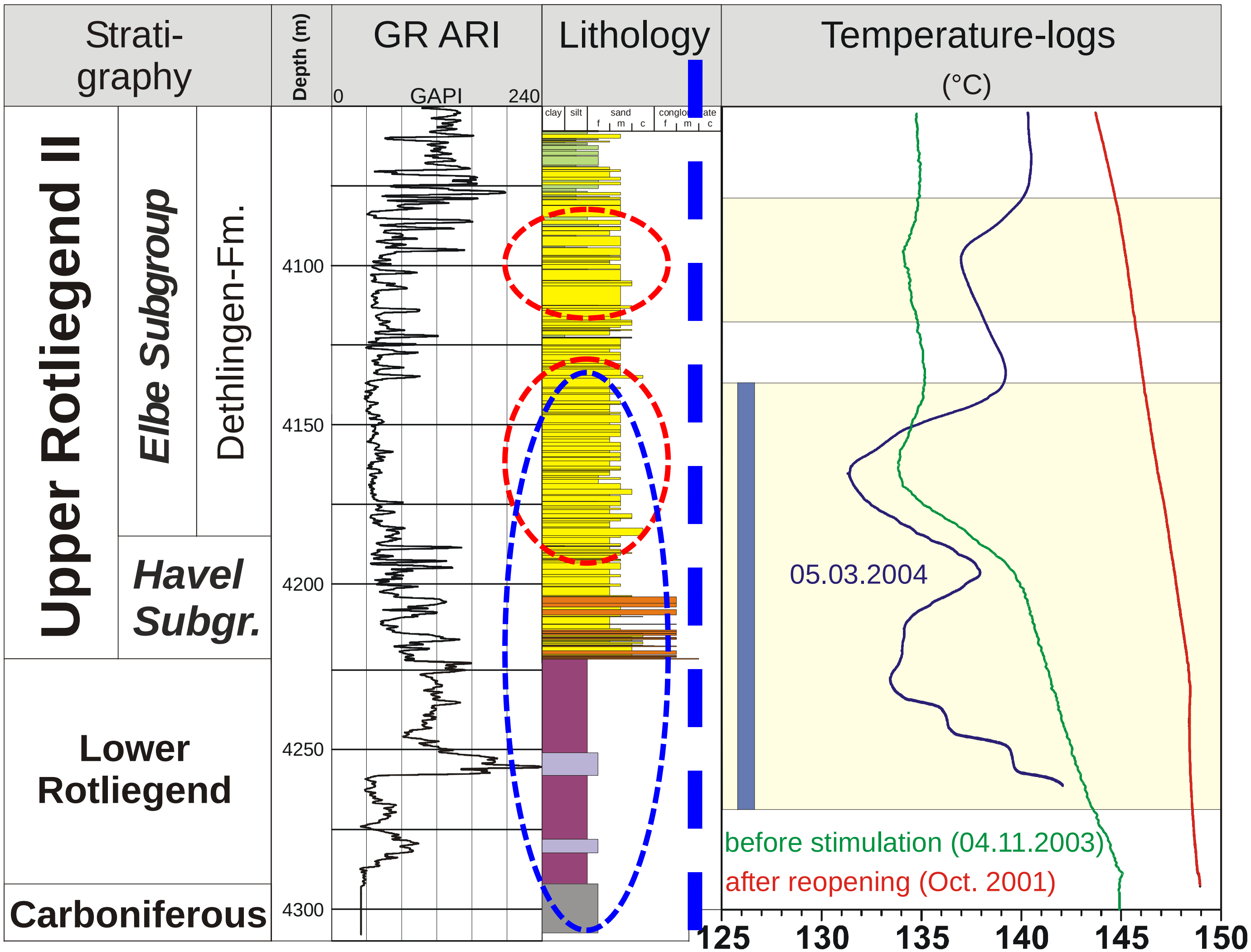
E GrSk 3/90

Existing HC wells in the North German Basin

Treatments and operations in the existing well in Groß Schönebeck

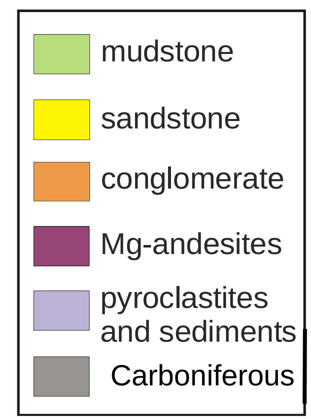
- **1990: drilled as gas exploration well, non-productive, abandoned**
- **2000: re-opening and deepend from 4230 to 4294 m depth**
- **2001: Hydraulic test, Logging**
- **2002: Gel/Proppant stimulation**
- **2003: Massive water treatments; deepening to 4309 m; Logging**
- **2004: Moderate injection test**
- **2005: Flow-back test**

Log interpretation from the existing well

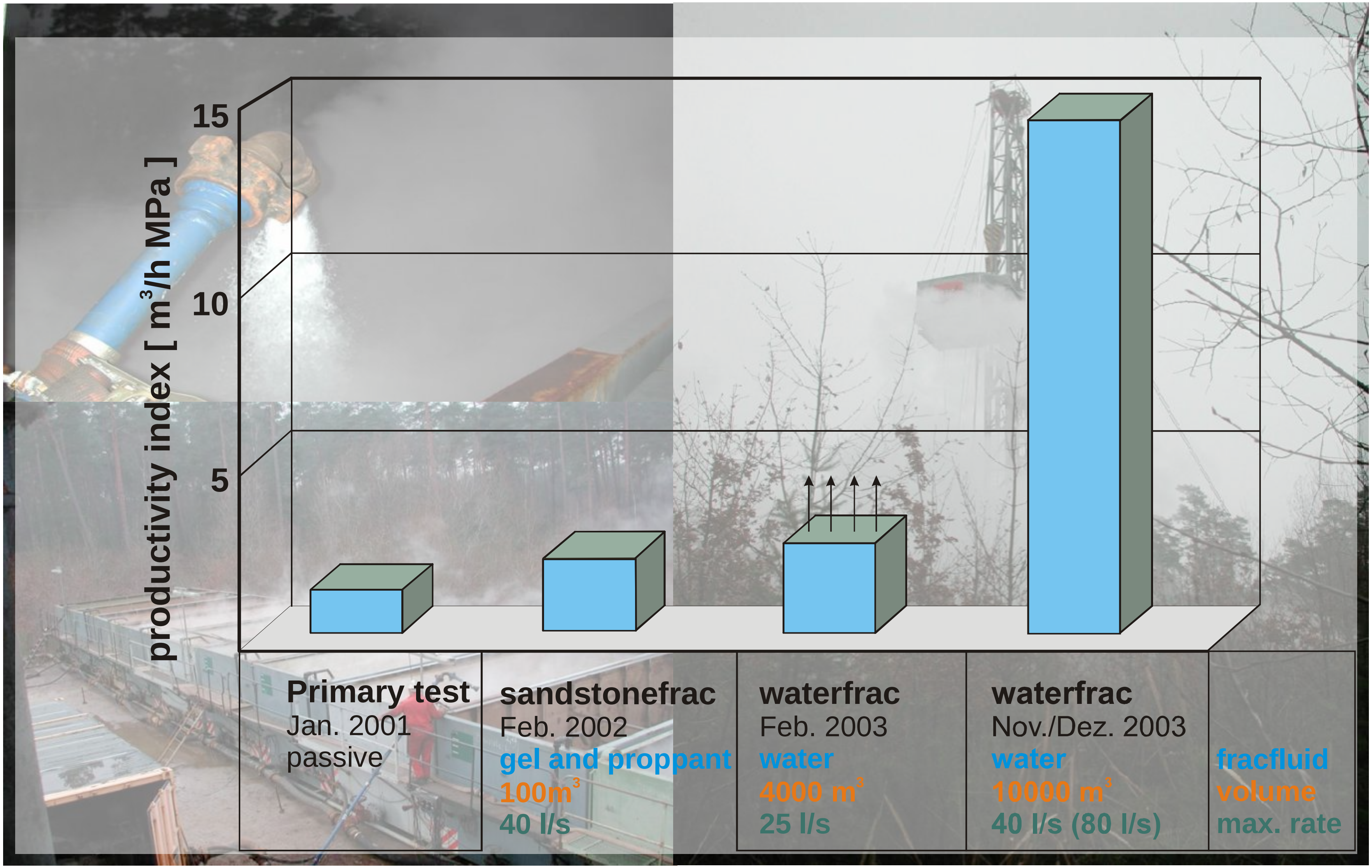


Reservoir Characteristics

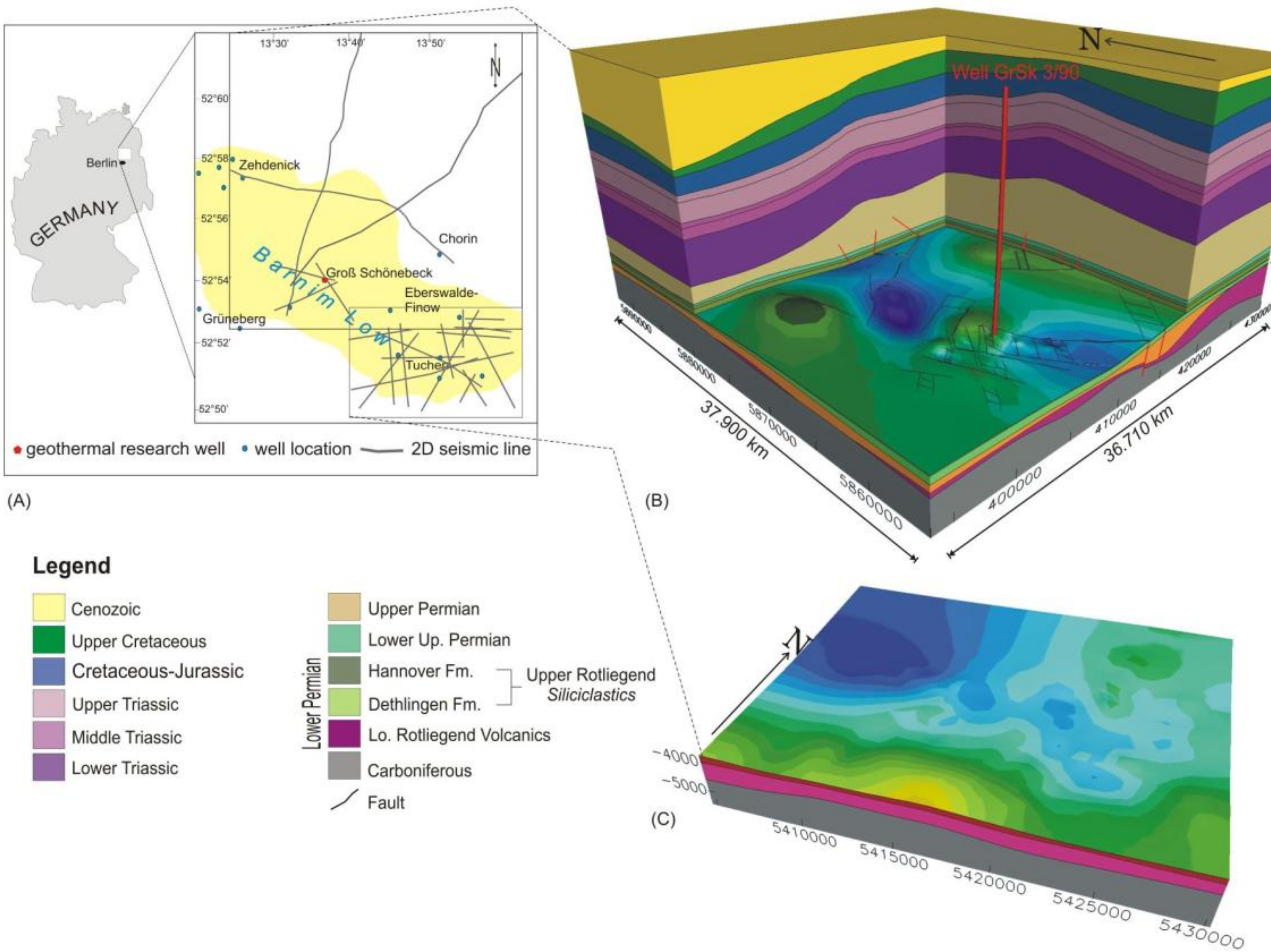
- well sorted middle grained sandstone
- fractured-porous
- 10-100 mD
- 150°C fluid
- thickness 80 m



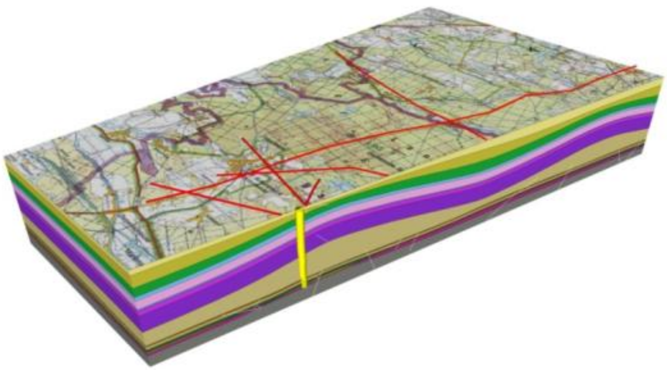
Learning curve „Enhancing productivity“ GrSk 3/90



Re-using seismic and well data for new 3D Modelling

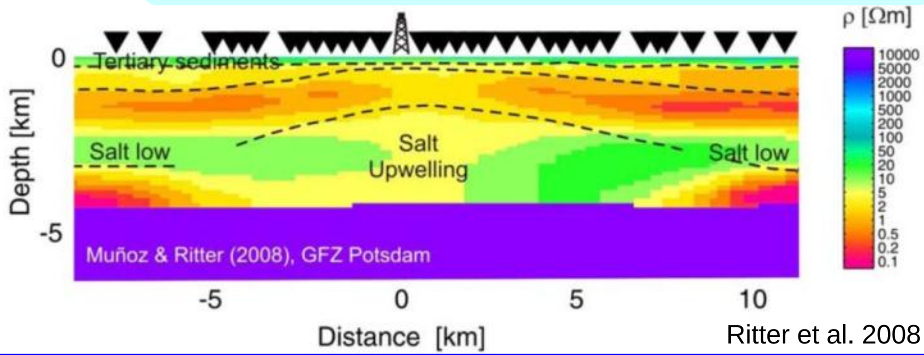


Development of innovative geophysical exploration methods

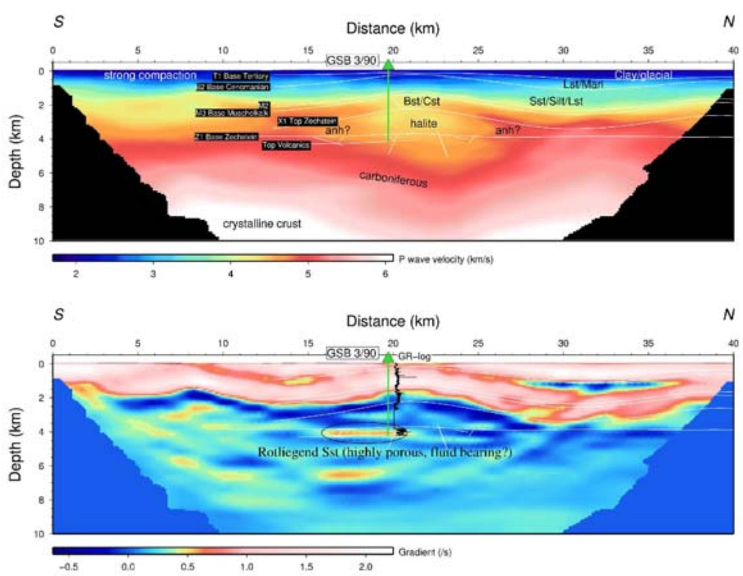


Bauer et al. 2007

Magneto Telluric profiles



Ritter et al. 2008



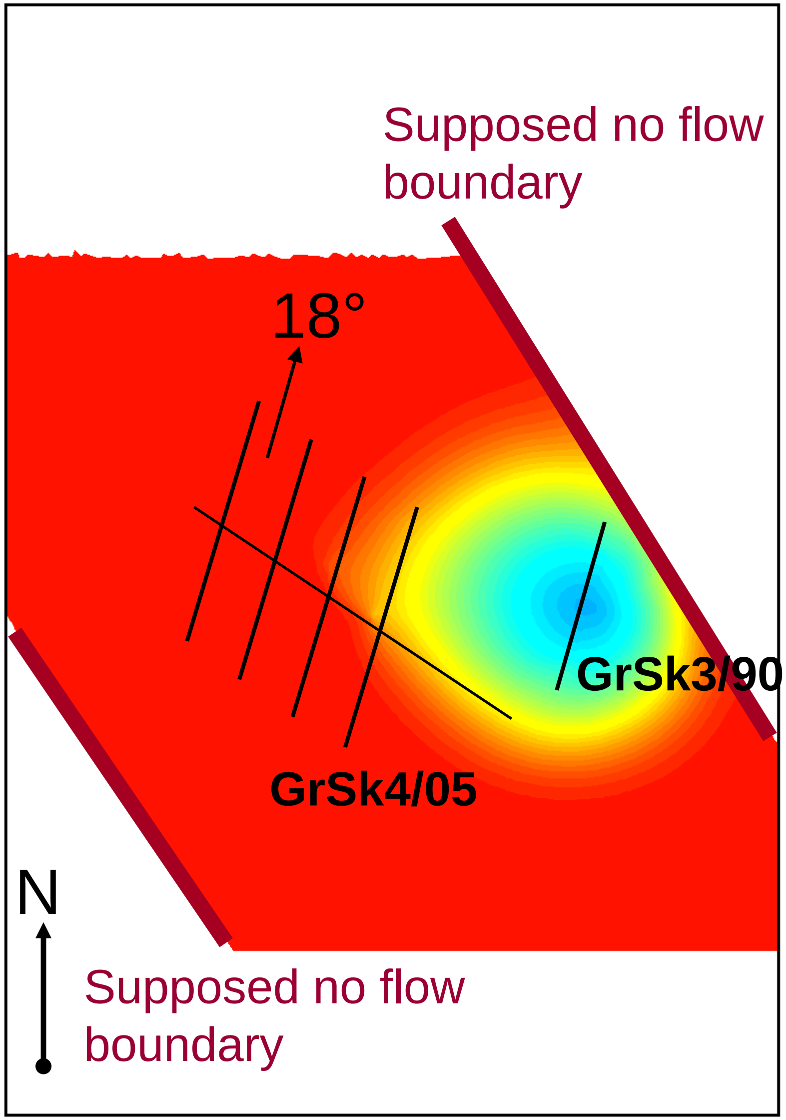
Seismic tomography

Sources:

- 20 m deep wells
- 30 kg (profile)
- 15-20 kg (star)

Bauer et al. 2007

Thermal-Hydraulic simulation



Injection-temperature T = 70°C

Reservoir-temperature T = 150 °C

Q = 75 m³/h

Simulation-period = 30 Jahre

Fracture conductivity = 1Dm

Reservoir permeability: 10-100 mD

Heat conductivity = 3.0 W/(m*K)

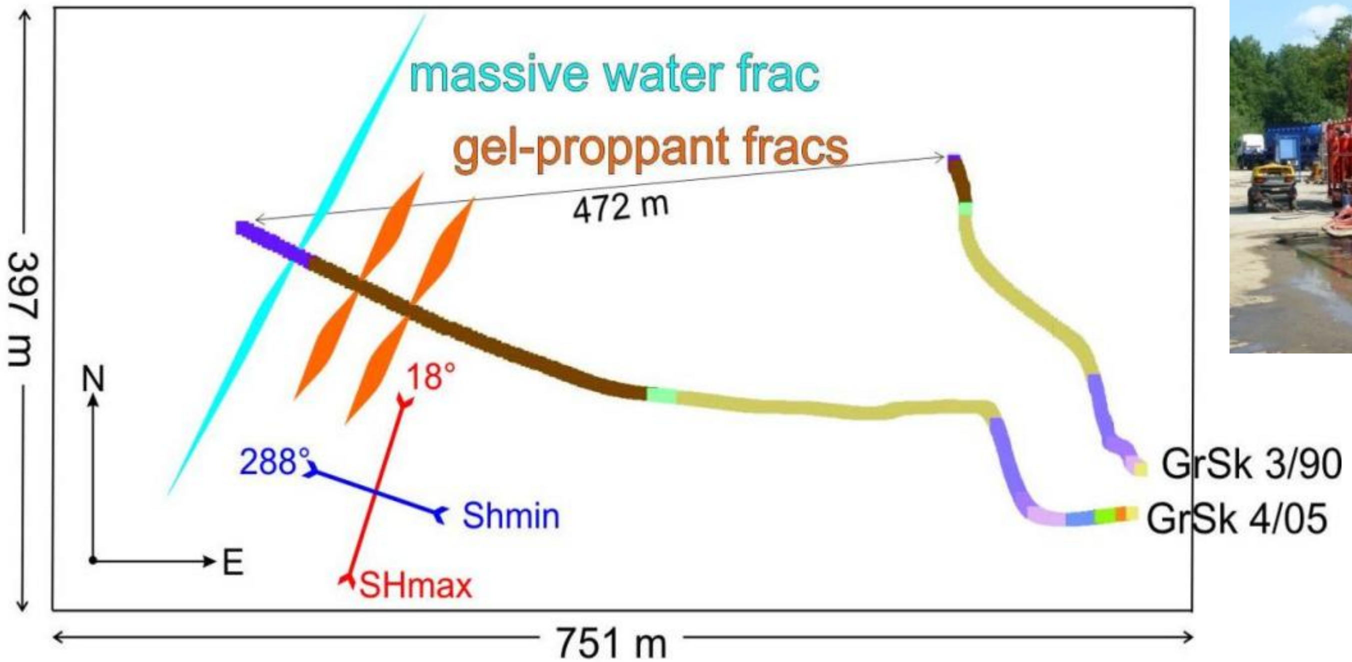
Fracture half length GrSk3/90 = 150 m

Fracture half length GrSk4/05 = 250 m

Reservoir thickness = 120 m

Installation of a well doublet I

Drill paths of the two geothermal wells



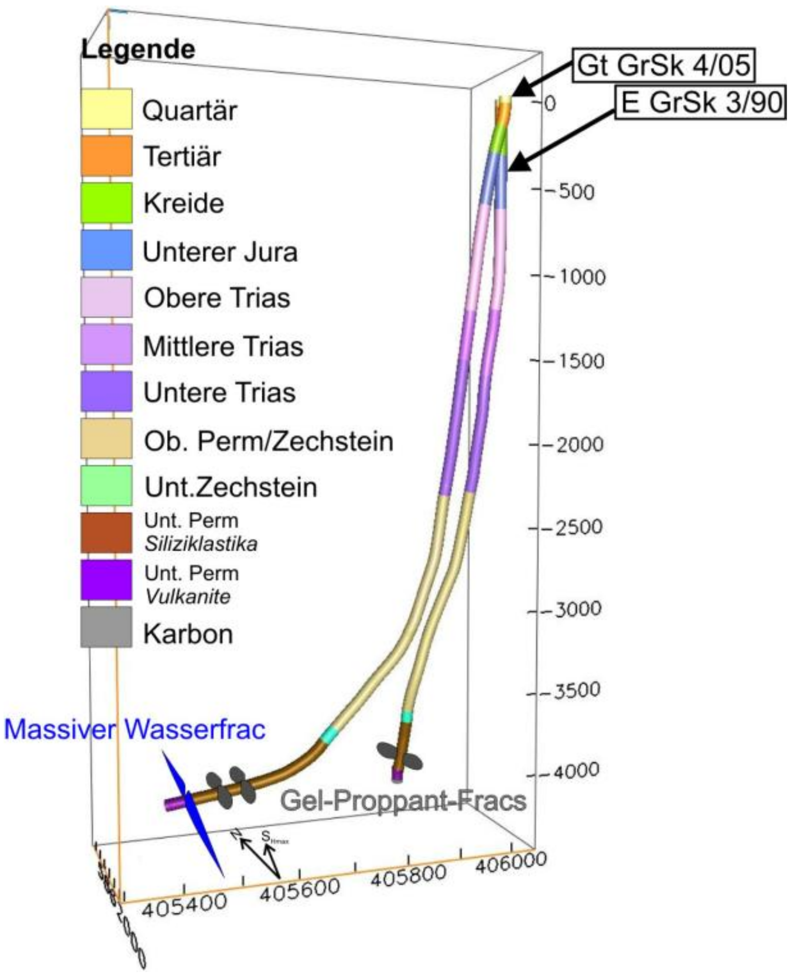
(*Moeck et al. 2007, Backers & Moeck, submitted*)

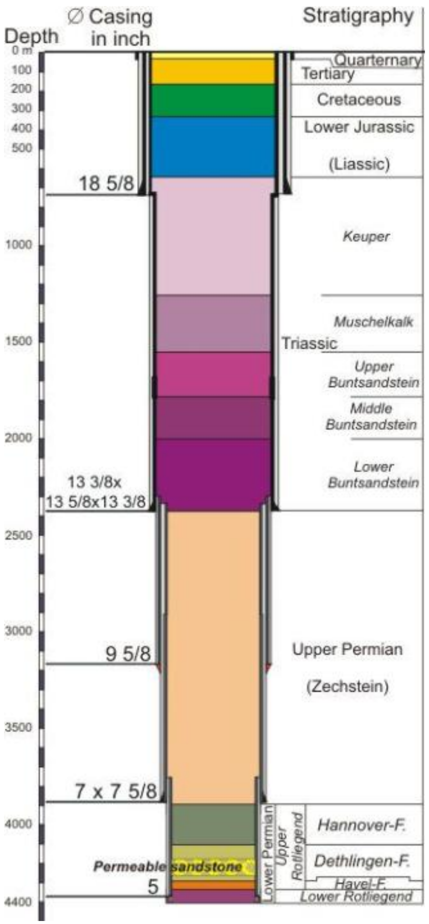
Installation of a well doublet II

Planning and drilling a new geothermal well

Requirements on geothermal wells

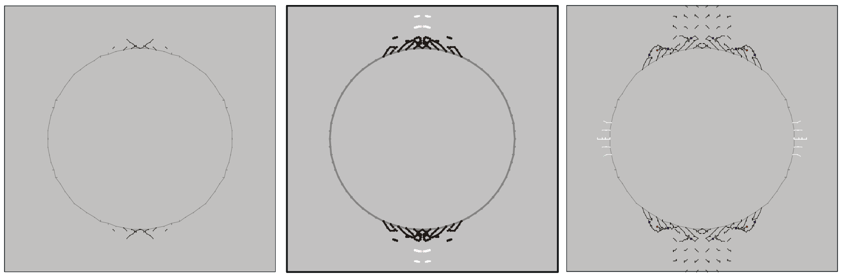
- large diameters
- directional drilling
- near-balanced drilling in the reservoir



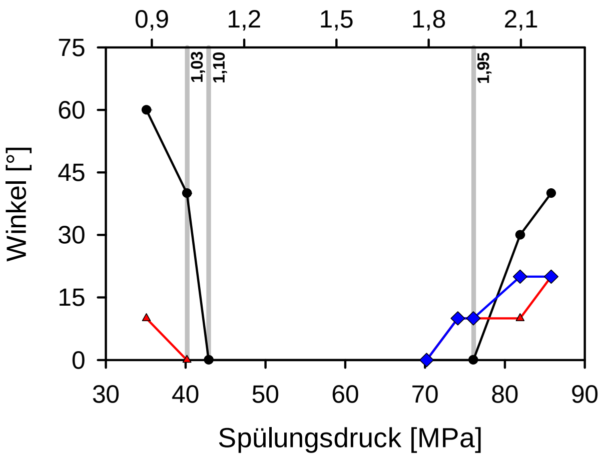


Well controll and mitigation of formation damage

Fracture mechanical failure modell to understand borehole stability



SH = 90 MPa SH = 97 MPa SH = 130 MPa



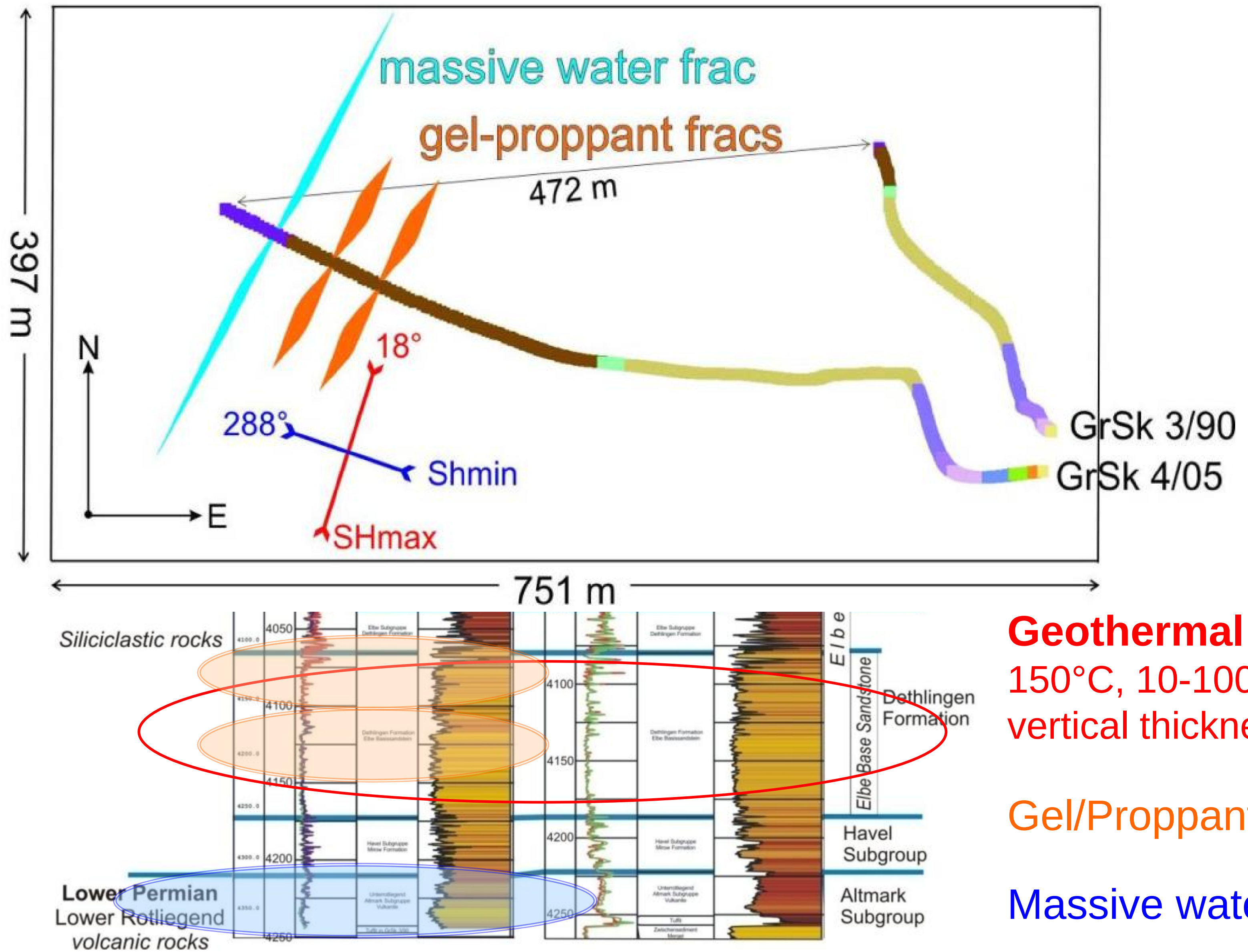
(*Moeck et al. 2007, Backers & Moeck, submitted*)

Near-balanced drilling in the reservoir

Analysis of borehole breakouts in 4100 m depth

Fracture mechanical analysis of initiation and growth of breakouts, using data from LOTs, FMI and core testing

Simulation of borehole breakouts under changing mud pressures



Geothermal aquifer
150°C, 10-100 mD
vertical thickness: 80 m

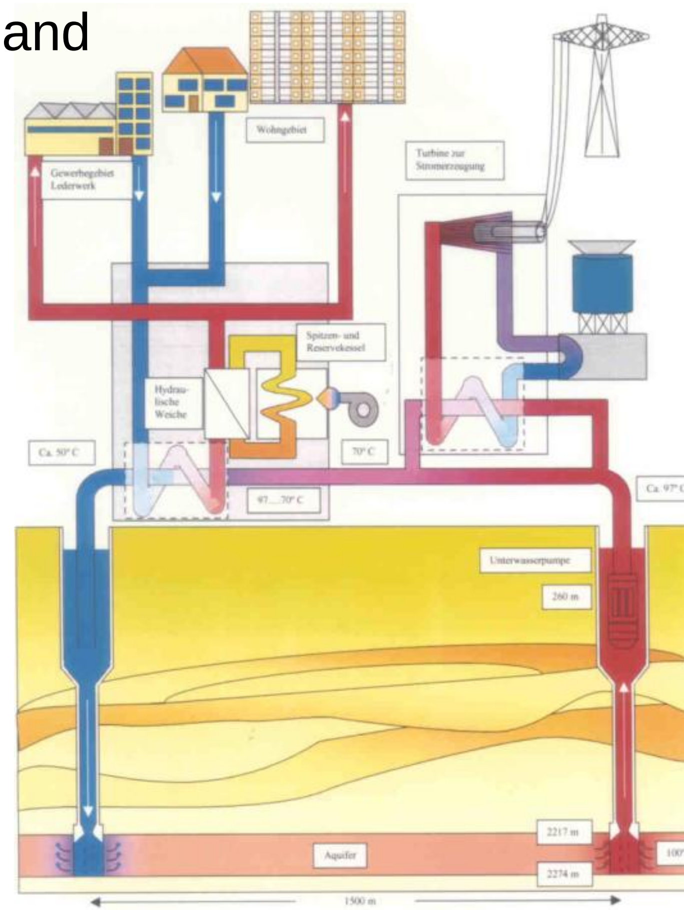
Gel/Proppant fracs

Massive water frac

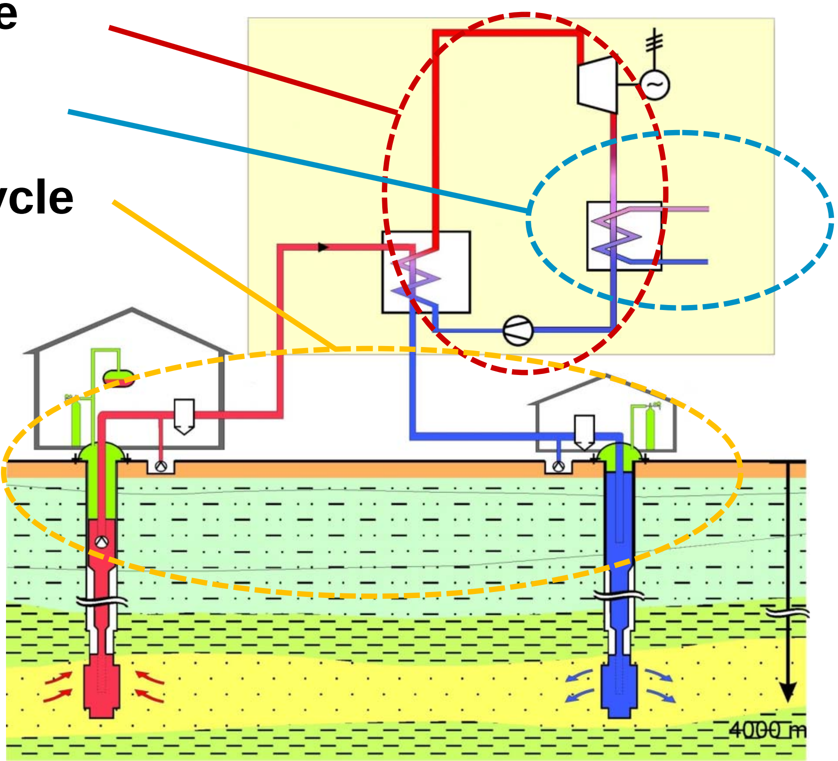
Outlook
Process engineering
Generation of energy

Coupled power and heat generation

Definition of corrosion-robust materials



- Power plants serve for net power production
- Net power = gross power - auxiliary power
- Auxiliary power
  - **conversion cycle**
  - **cooling cycle**
  - **thermal water cycle**

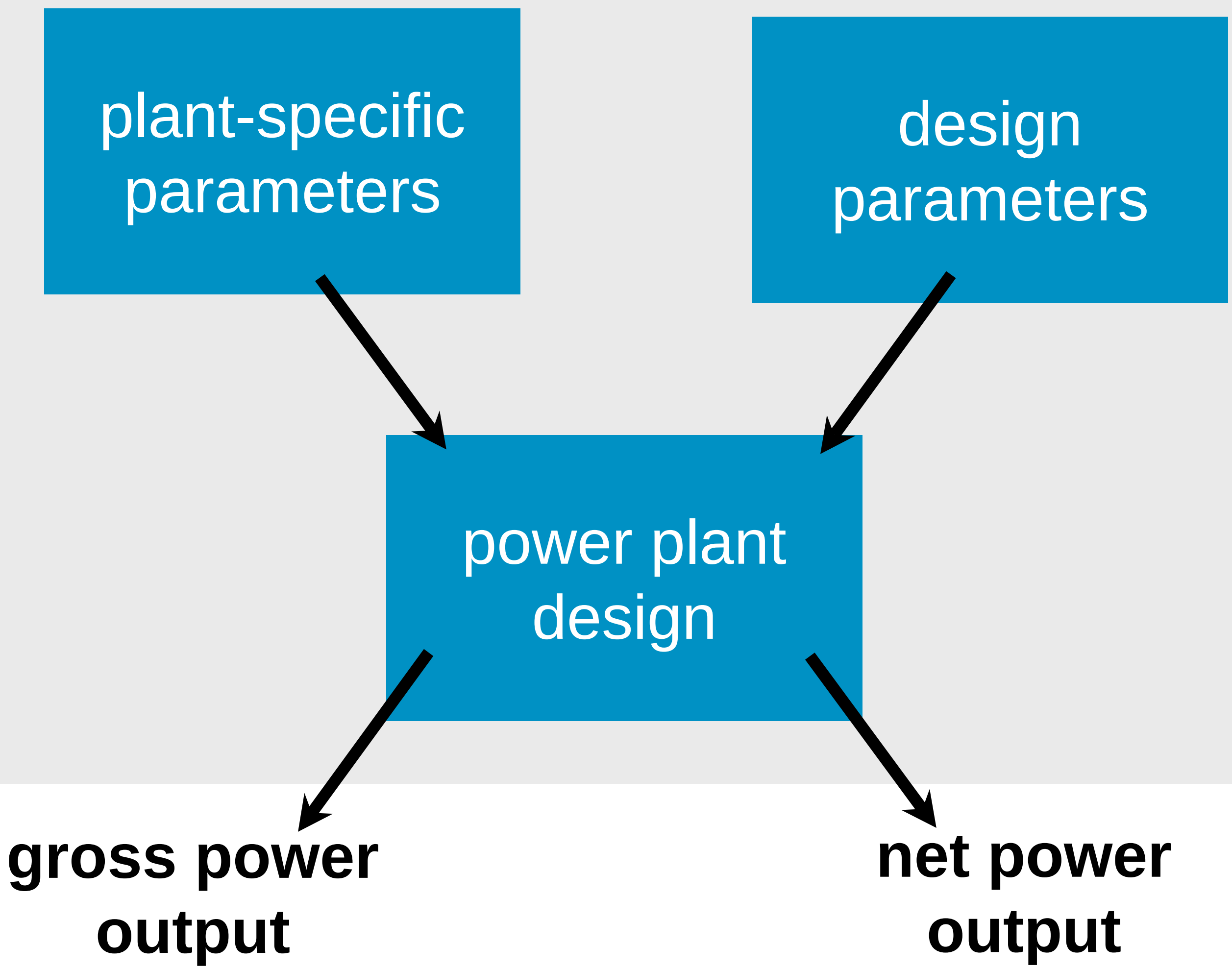


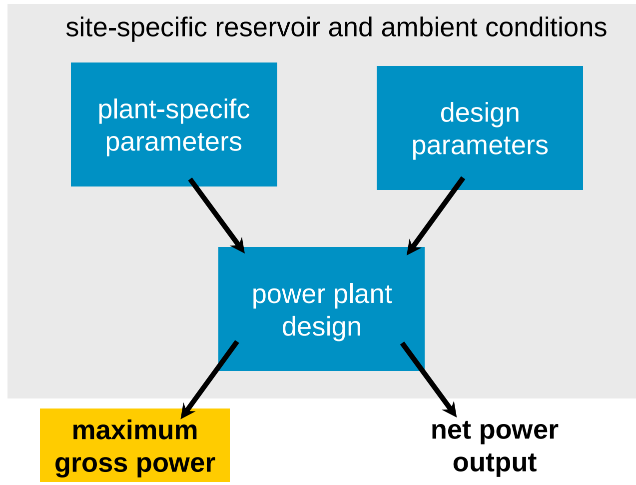
➡ A maximum net power output can't be reached by maximizing the gross power

➡ Geothermal power plant design needs a holistic approach

Approach to power plant design

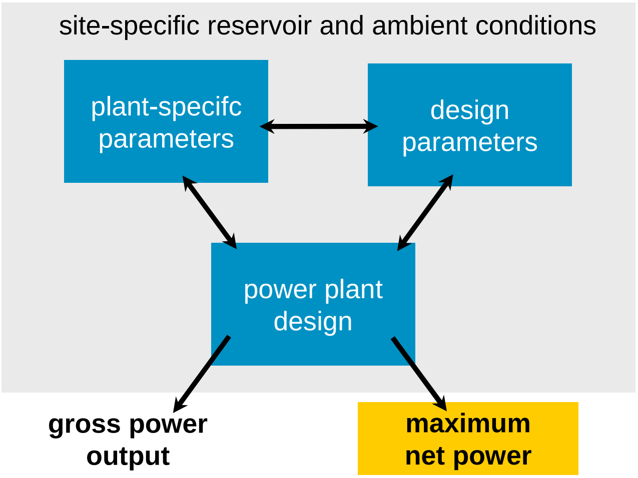
site-specific reservoir and ambient conditions





	maximum gross power (wet cooling)	maximum net power (wet cooling)
reservoir conditions	T_{TW} = 150 °C, PI = 30 m³/(h MPa), $depth_{reservoir}$ = 4,500 m	
thermal water mass flow	56 kg/s (14.8 gps)	
th. water injection temp.	66 °C (151 °F)	
condensation temp.	30 °C (86 °F)	
gross power	1,8 MW	
net power	460 kW	

Plant-specific parameters, ambient conditions = const.



	maximum gross power (wet cooling)	maximum net power (wet cooling)
reservoir conditions	T_{TW} = 150 °C, PI = 30 m³/(h MPa), $depth_{reservoir}$ = 4,500 m	
thermal water mass flow	56 kg/s (14.8 gps)	41 kg/s (10.8 gps)
th. water injection temp.	66 °C (151 °F)	71 °C (160 °F)
condensation temp.	30 °C (86 °F)	33 °C (91 °F)
gross power	1,8 MW	1,3 MW
net power	460 kW	600 kW

Plant-specific parameters, ambient conditions = const.

Conclusions

- Geothermal technology combines engineering and geosciences is therefore multidisciplinary
- Groß Schönebeck demonstrates the feasibility of power generation from low-enthalpy EGS systems under economic conditions
- Fitting the power plant type and processes to the geological reservoir characteristics requires a holistic approach
- Our learning curve allows the adaptation of profitable workflows to equivalent sites

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Bundesministerium
für Umwelt, Naturschutz
und Reaktorsicherheit