# Heat storage in the underground

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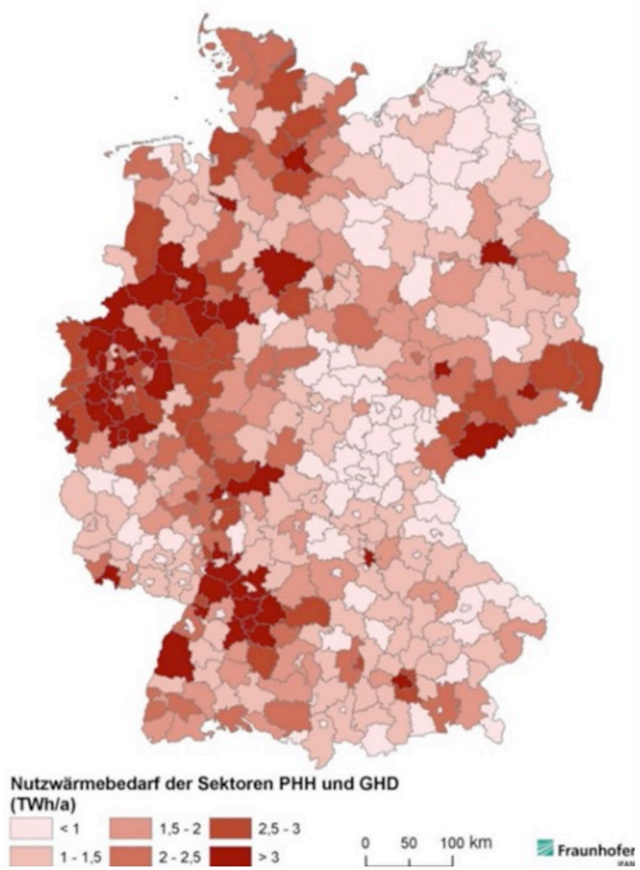
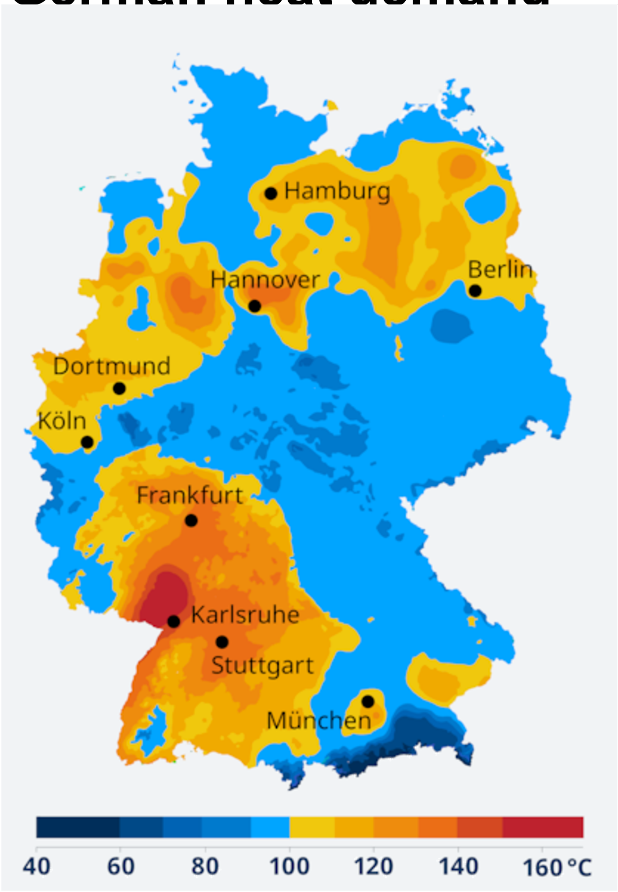
*H2020 DEEPEGS project: IDDP-2 well Reykjanes peninsular 4665 m*

# Hydrothermal potential in Germany

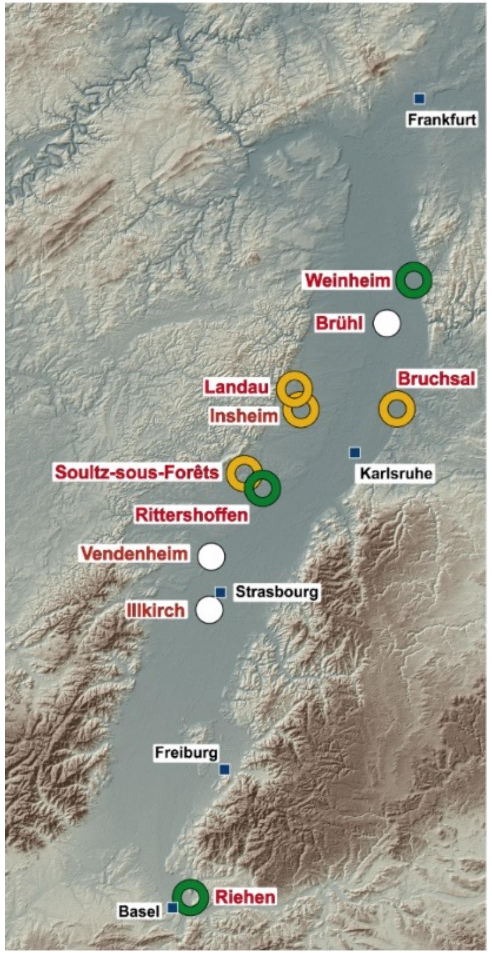
- >300 TWh/yr, i.e. 25% of the German heat demand

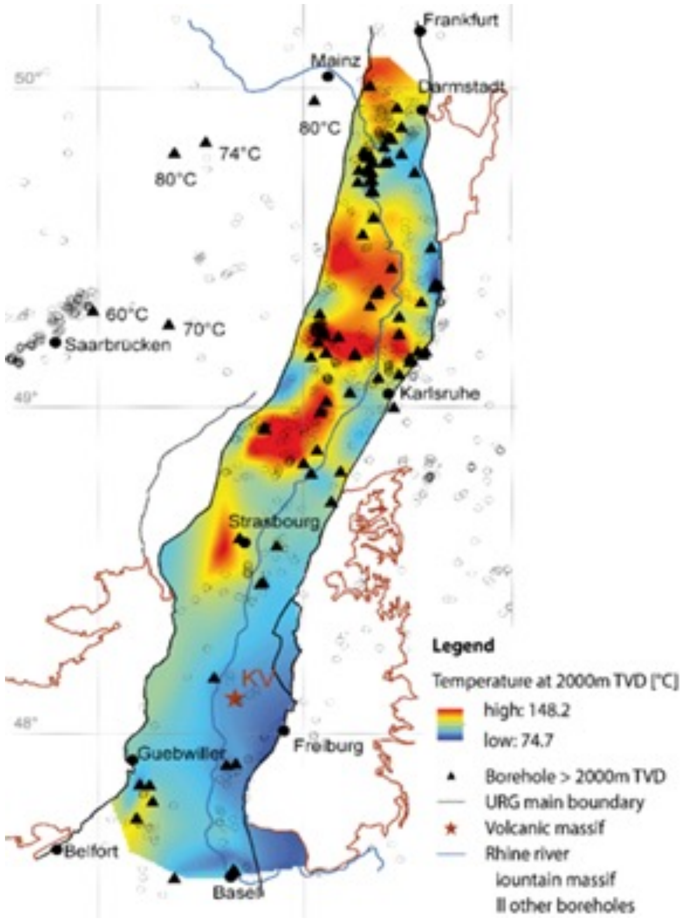




*Agemar et al. (LIAG)*

# Hydrothermal energy analogue at KIT-Campus North

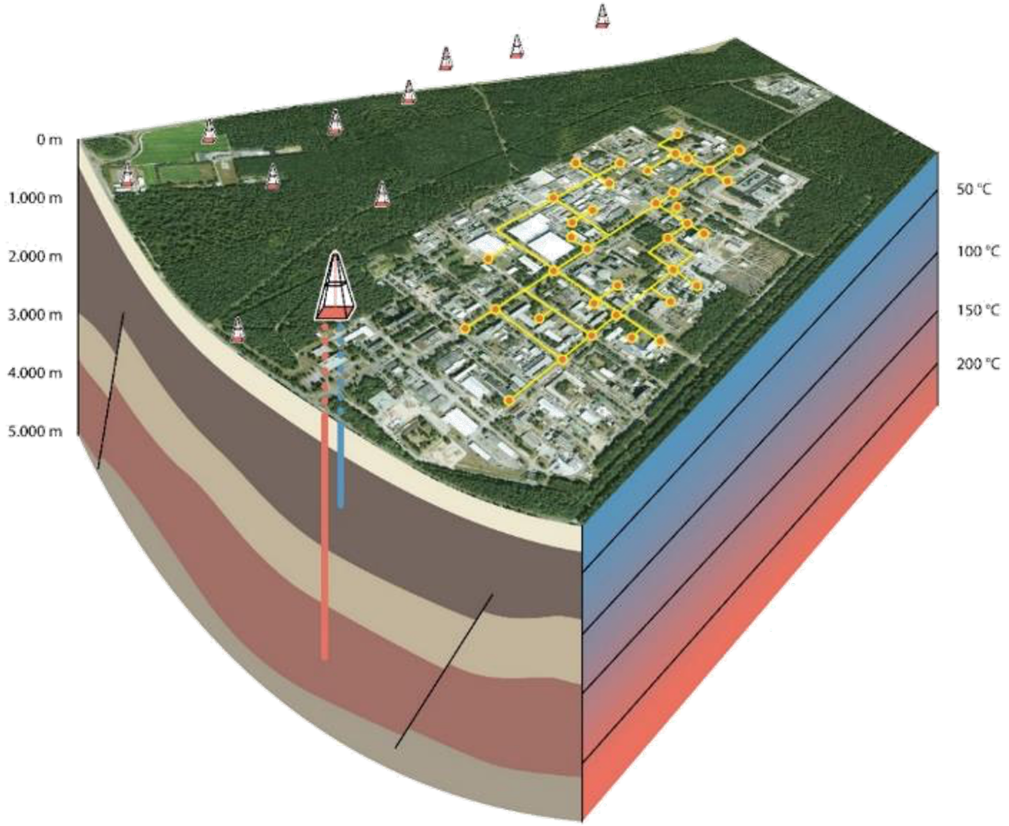



Meixner, pers.comm.




Baillieux et al., 2013

**Largest heat anomaly in Germany with 170°C in 3 km depth**



# Geothermal potential in Germany including new developments

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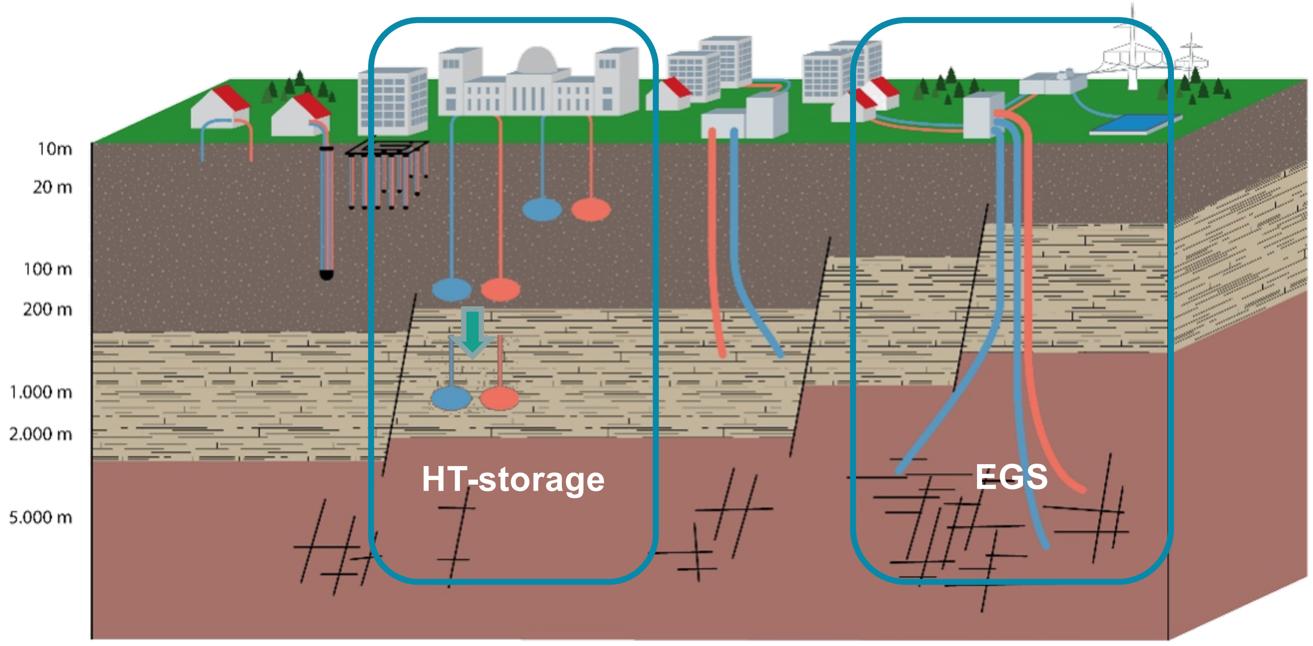
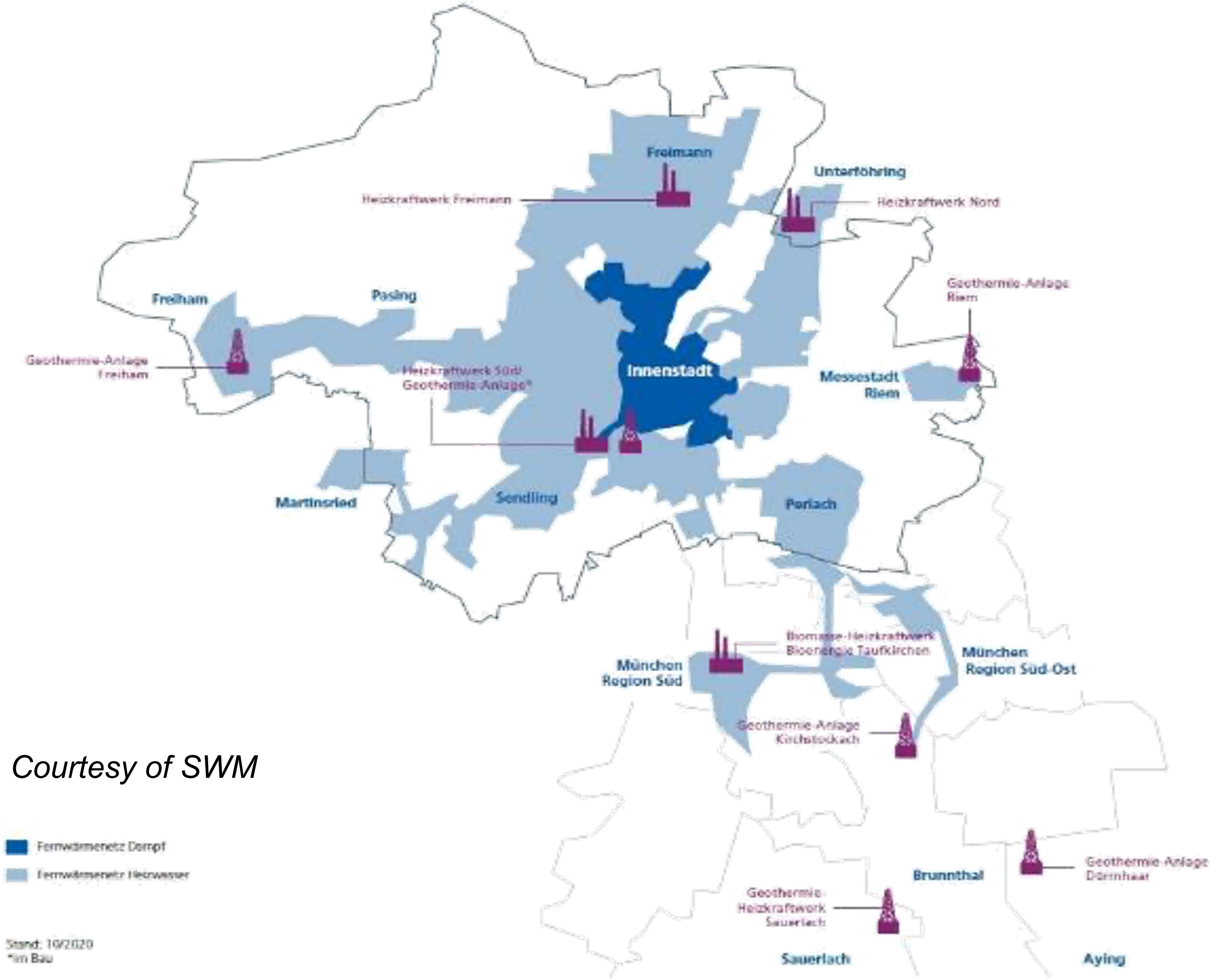
- **New developments**
  - EGS - Enhanced Geothermal Systems
  - Large-scale and high-temperature heat storage
- **>500 TWh/yr, i.e. 40% of the German heat demand**




# Hydrothermal energy
# Vision Heat Transition 2040 of SWM

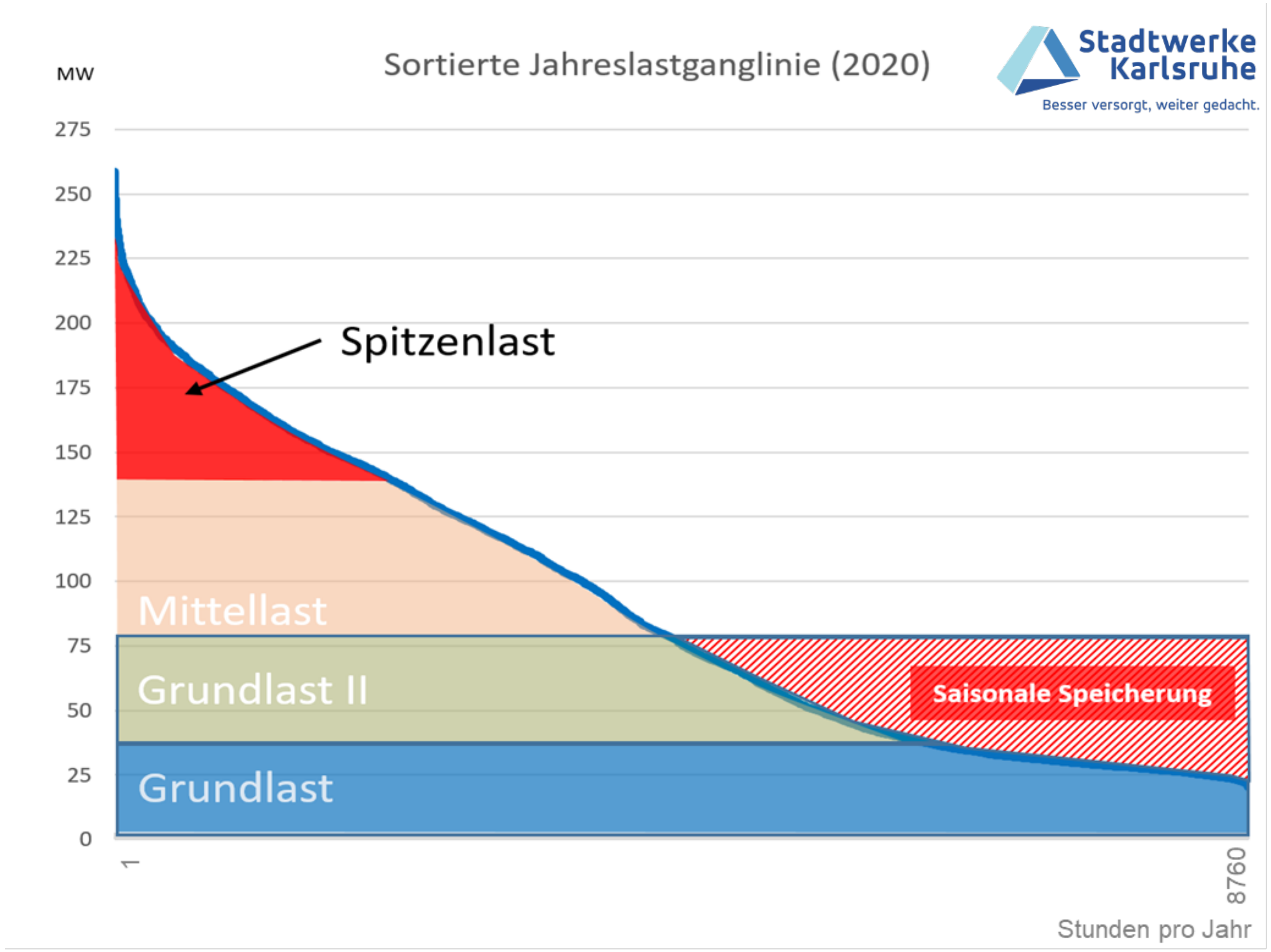
- District heating
  - 80% from geothermal energy (about 400 MWpeak)
  - **Heat load in summer: about 120 MW**



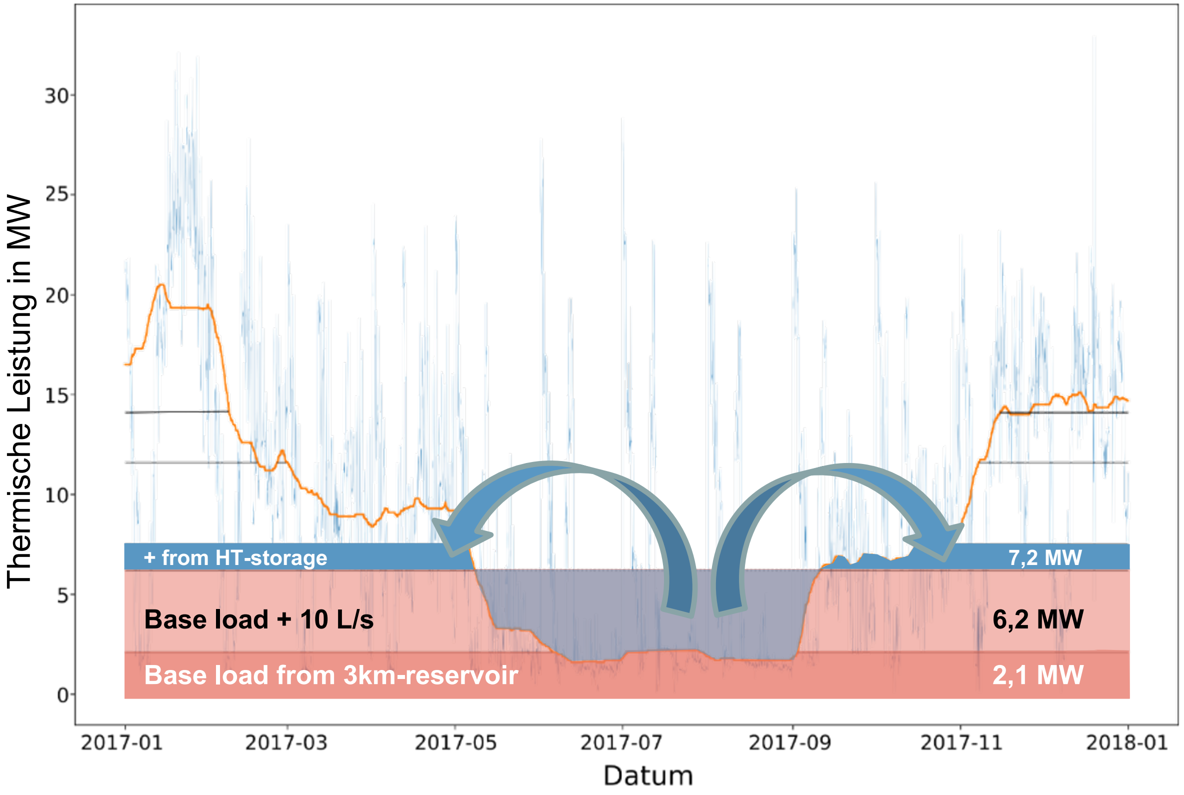

*Courtesy of SWM*

# Waste heat storage

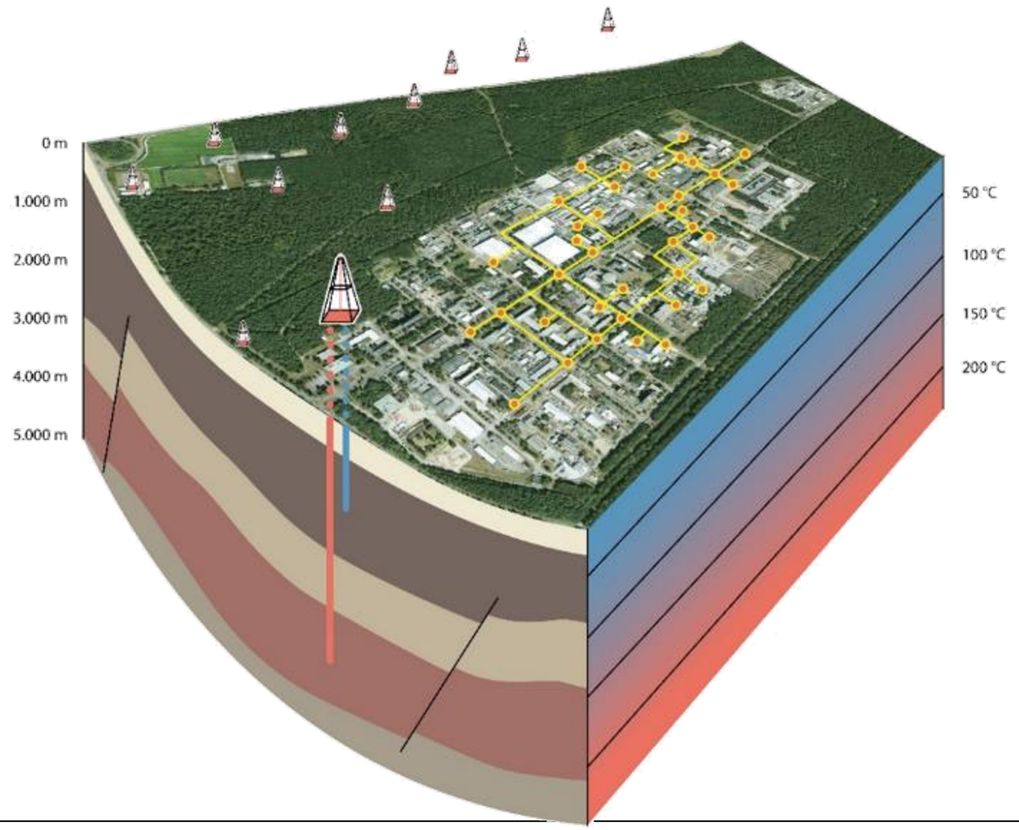
- Waste heat from the adjacent refinery

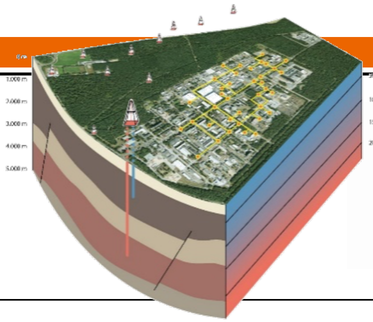


# HT heat storage analogue at KIT-Campus North




## Proven reservoir: Hydrocarbon field Leopoldshafen





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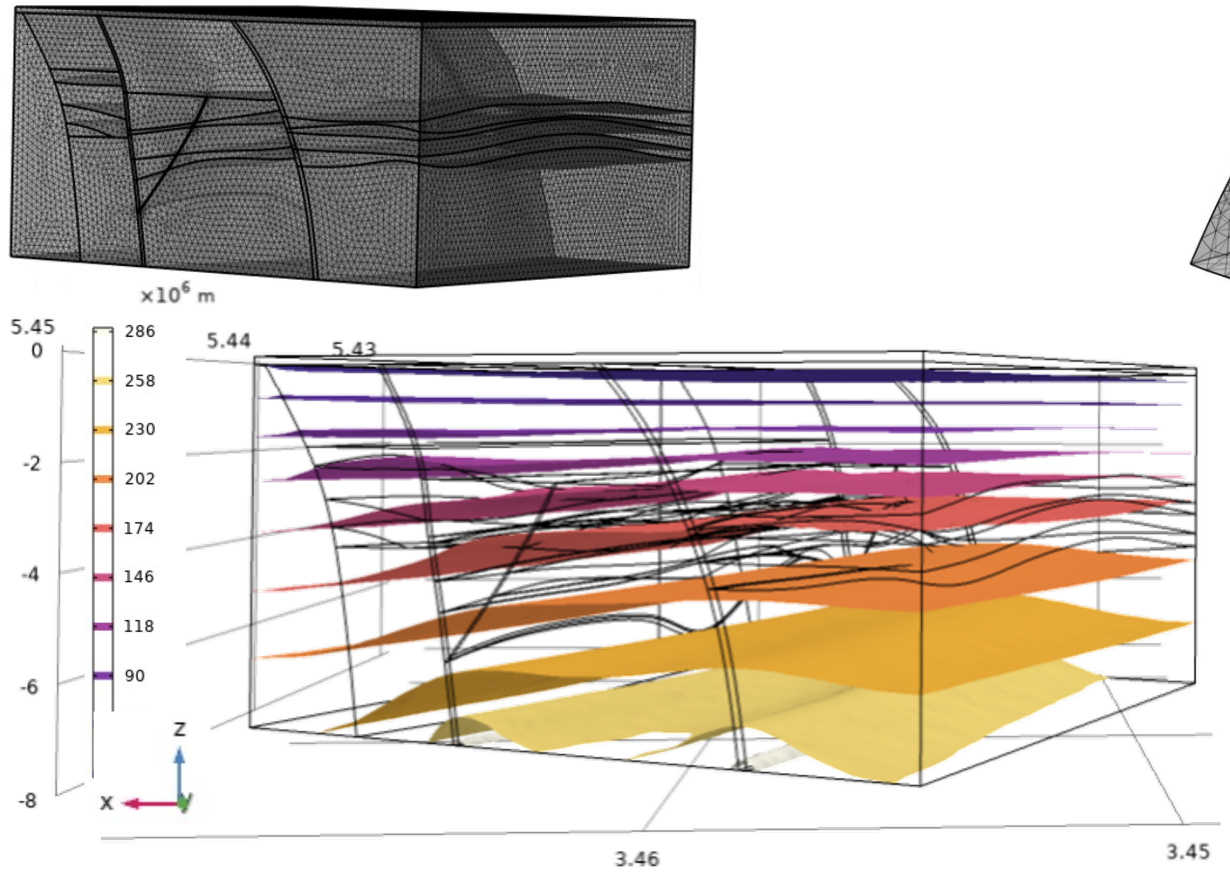
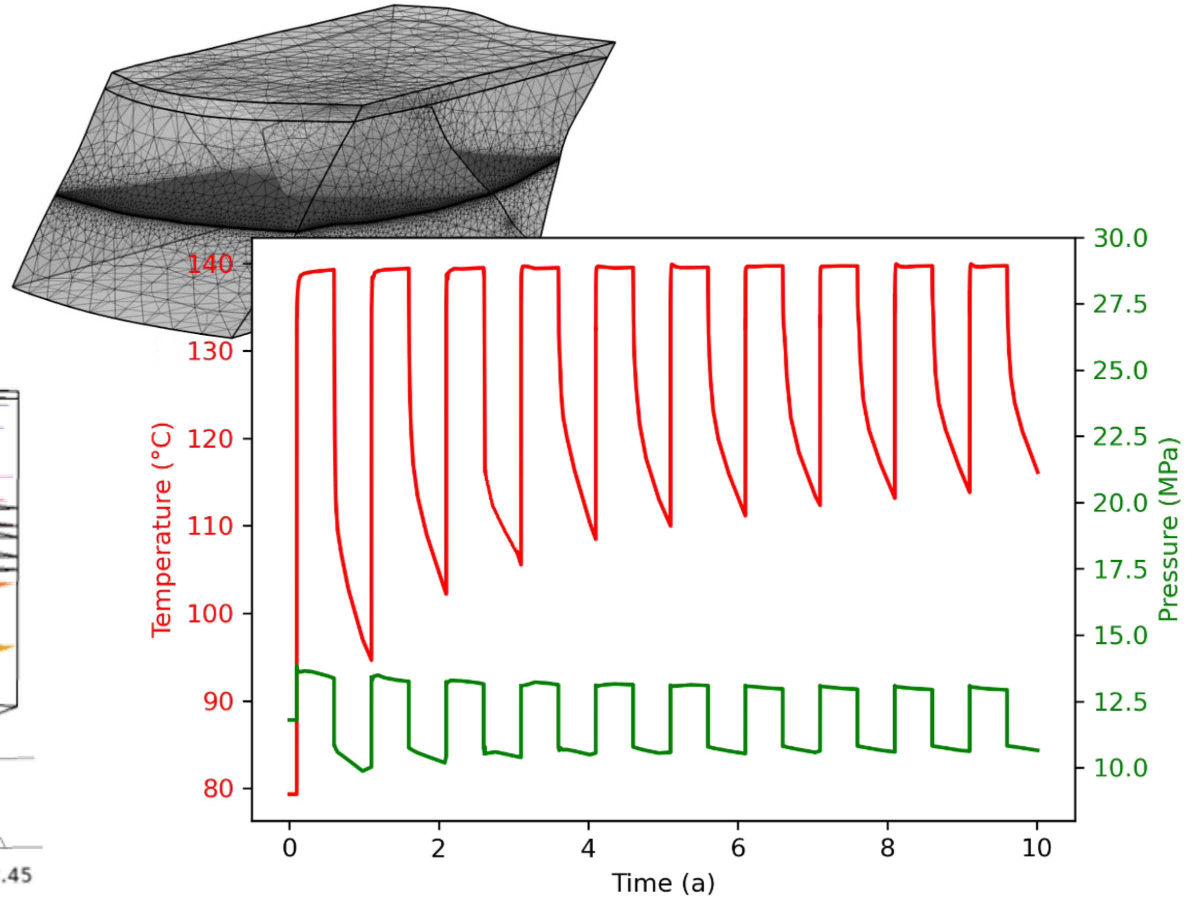
# Modelling of design scenarios

- Hydrothermal production

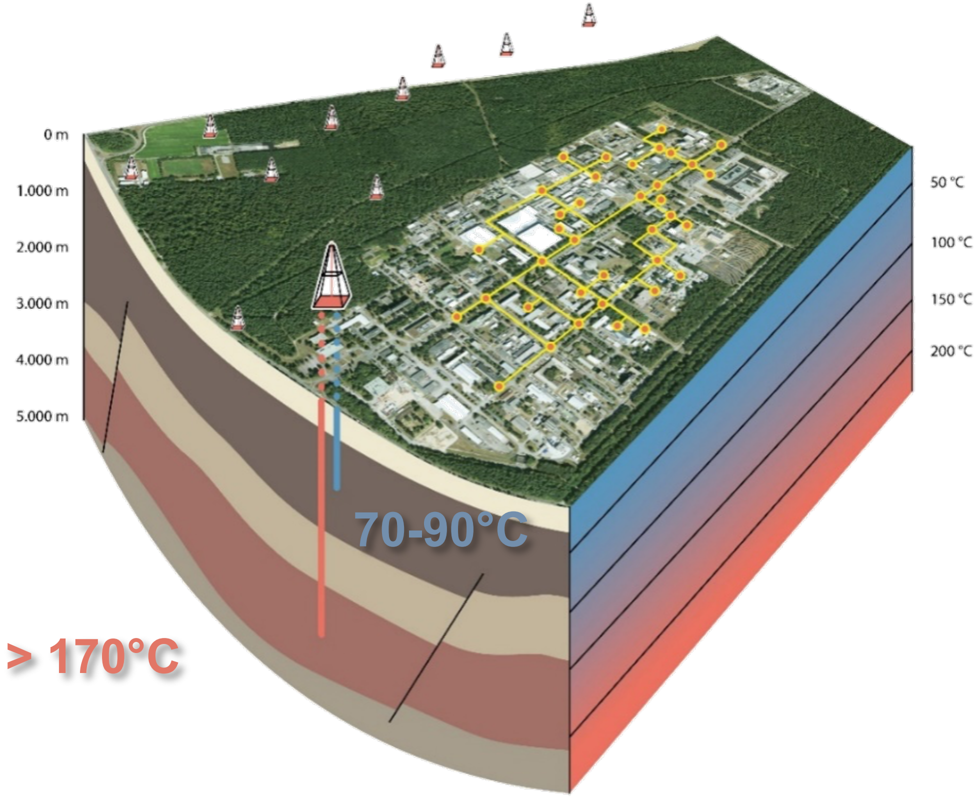



- HT heat storage



# Geoenergy Campus at KIT (https://www.geoenergiecampus.kit.edu/)

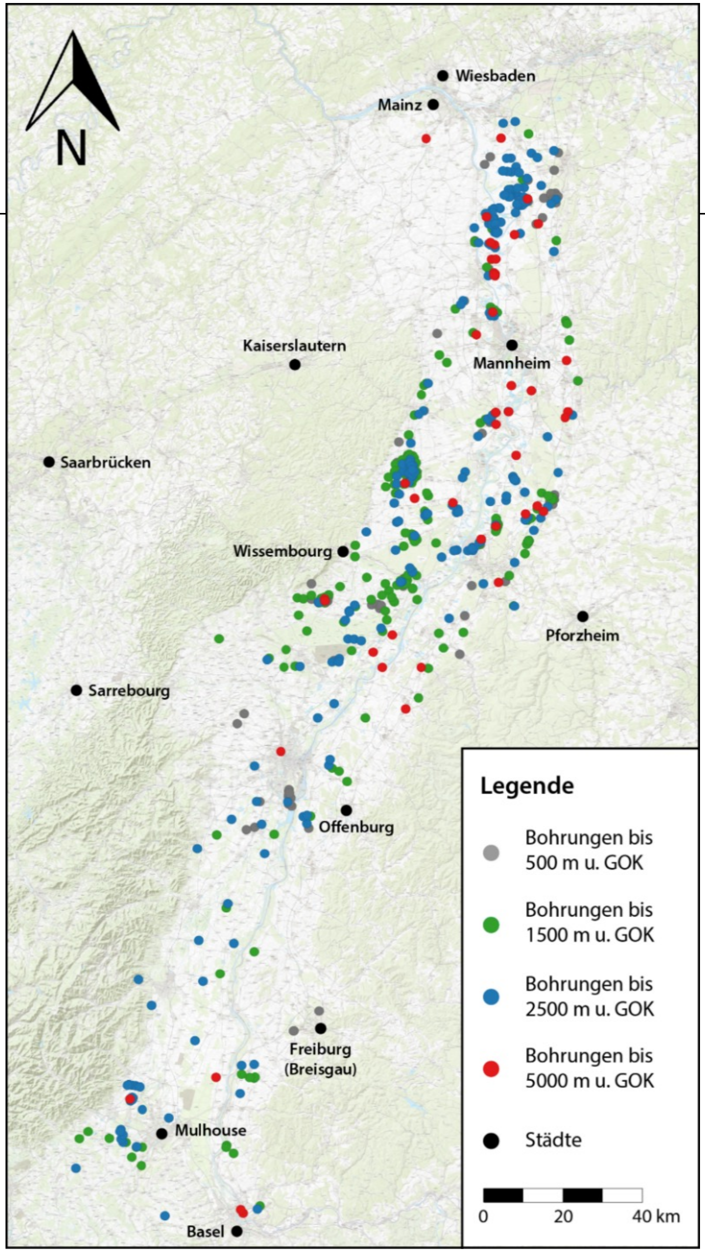
- Concept: Coupling of a deep geothermal power plant for heat supply with a high-temperature aquifer storage facility for the use of excess summer heat in winter.
- Storage Technology: HT-ATES (High Temperature Aquifer Thermal Energy Storage).
- **Key technical data:**
  - **Capacity increase through storage: 33.6 GWh**
  - **Power increase (4 storage, 2 deep geothermal wells): 10-11 MW**
  - **Storage period: 4-6 months**
- **Increasing the share of RE in heat supply through storage from 25 to > 65%.**



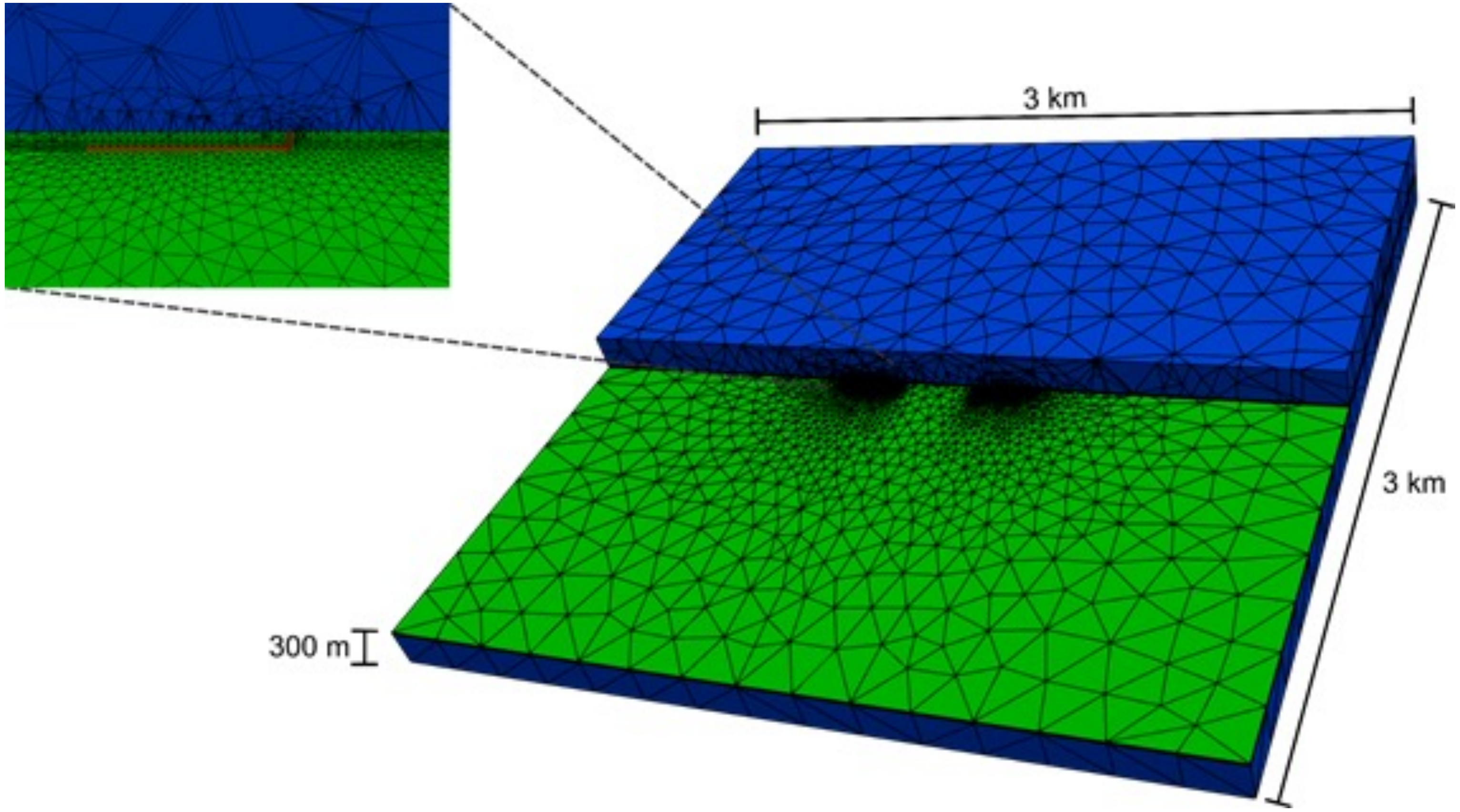
# Significance of the technology for the German energy transition

- Storage capacity in the about 1‘000 depleted hydrocarbon wells in the Upper Rhine Graben
- **10 TWh/a**

Stricker et al., 2020



# Model of storage potential in the URG

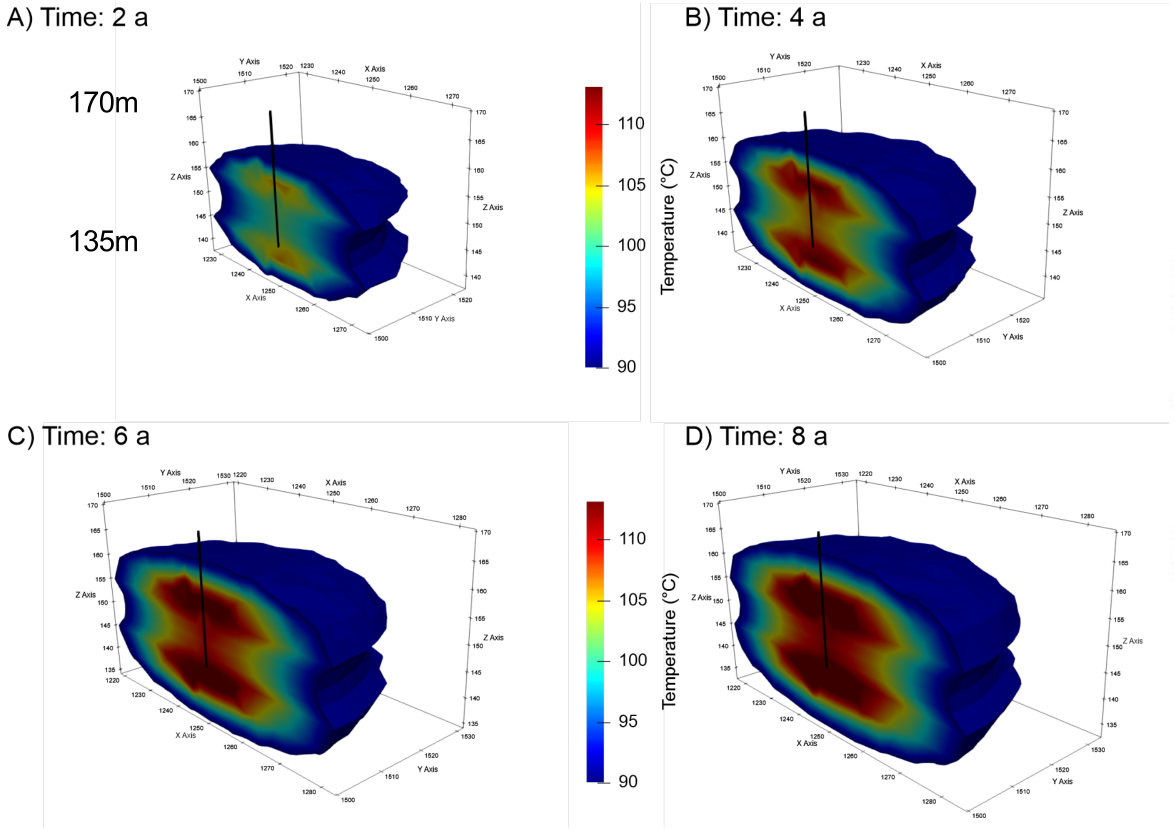


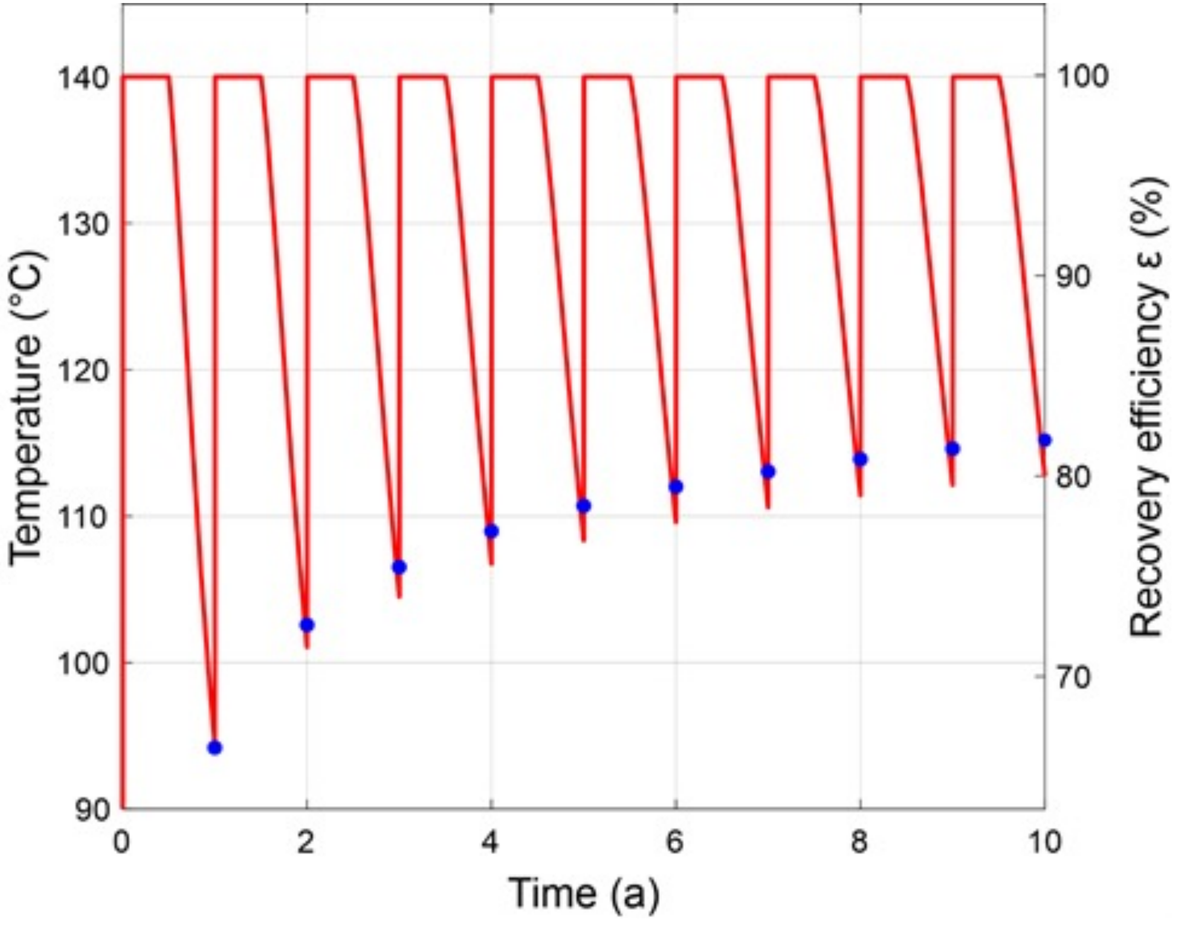

- Generic model with simplified geometry
  - only vertical well or
  - horizontal sections (100m long)
  - six-month cyclic operation



Stricker et al. (2020)

# Development of the temperature over 10 years




Stricker et al. (2020)

# Challenges in HT heat storage I

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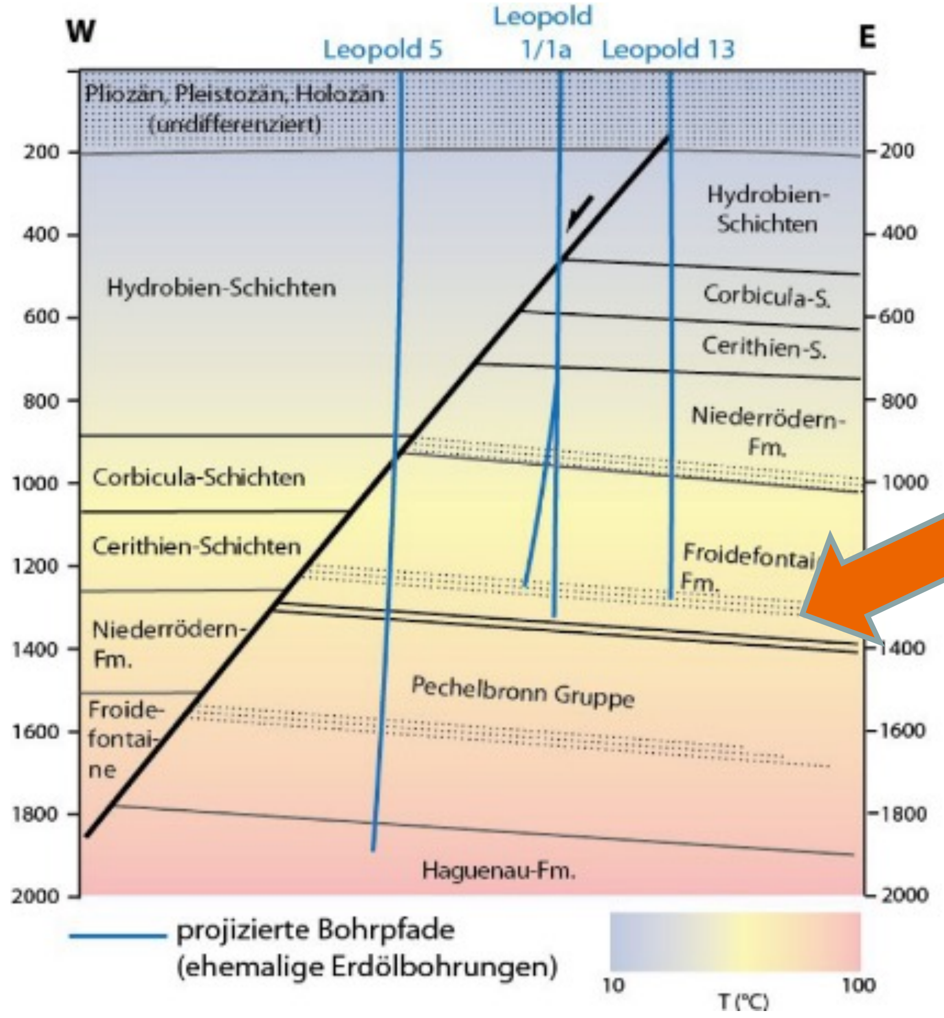
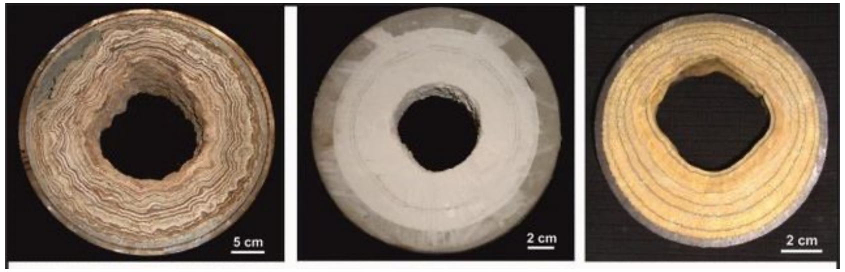



| T (°C) | pH | | $Al^{3+}$ | $Ca^{2+}$ | $Cl^{-}$ | $Fe^{2+}$ |
|---|---|---|---|---|---|---|
| 80 | 6.0 | (mg/kg) | n/a | 3910 | 67,600 | 78.10 |

| $HCO_3^-$ | $K^+$ | $Mg^{2+}$ | Na+ | $SO_4^{2-}$ | $SiO_{2(ag)}$ |
|---|---|---|---|---|---|
| 216 | 274 | 814 | 37,900 | 493 | 6.51 |

Banks et al., 2021

- Example carbonate scaling in geothermal plants of the Pannonian basin

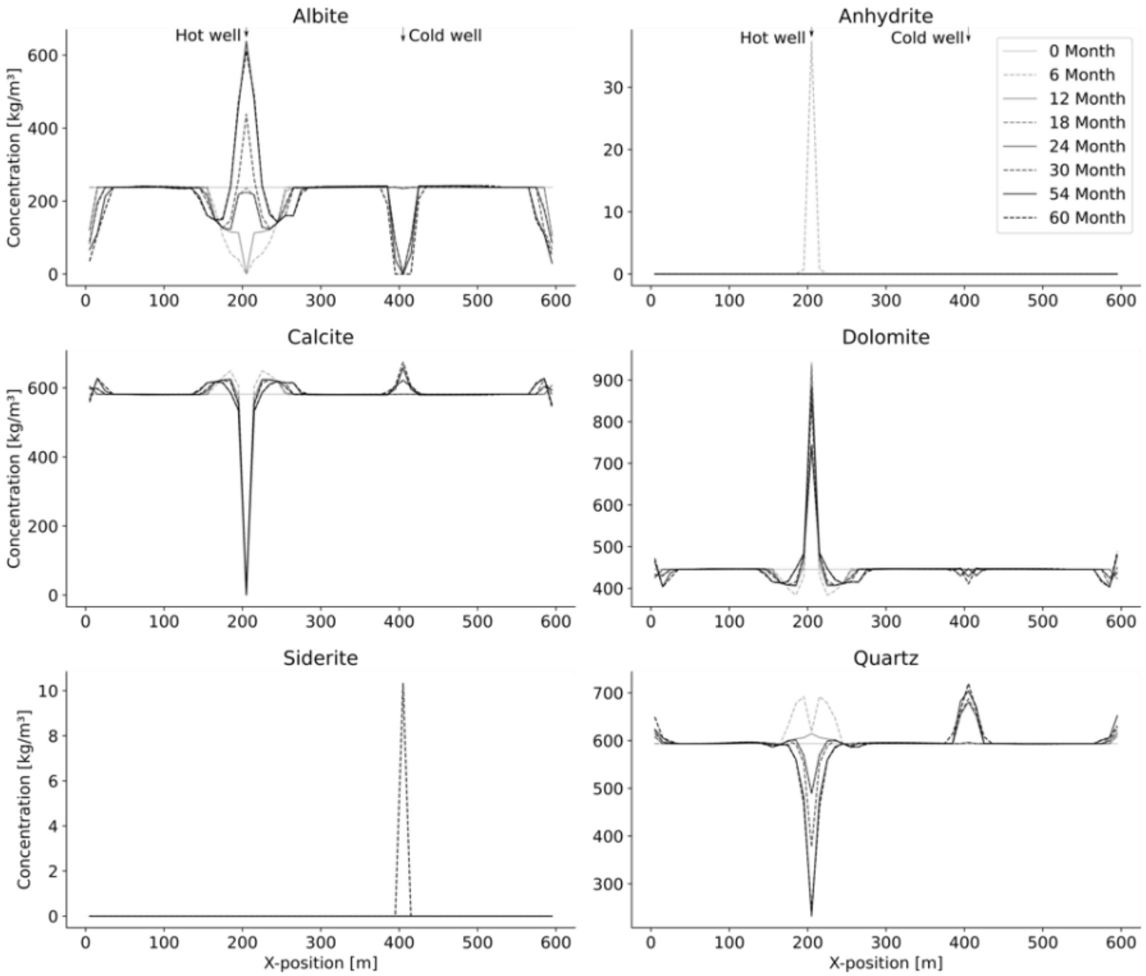



Bloch et al., 2016

# Challenges in HT heat storage I

- TDS of foramation water = 120 g/L

- Potential chances from reactive transport modelling
  - Change in reservoir mineral (non-phyllosilicates) concentrations ($kg/m^3$)

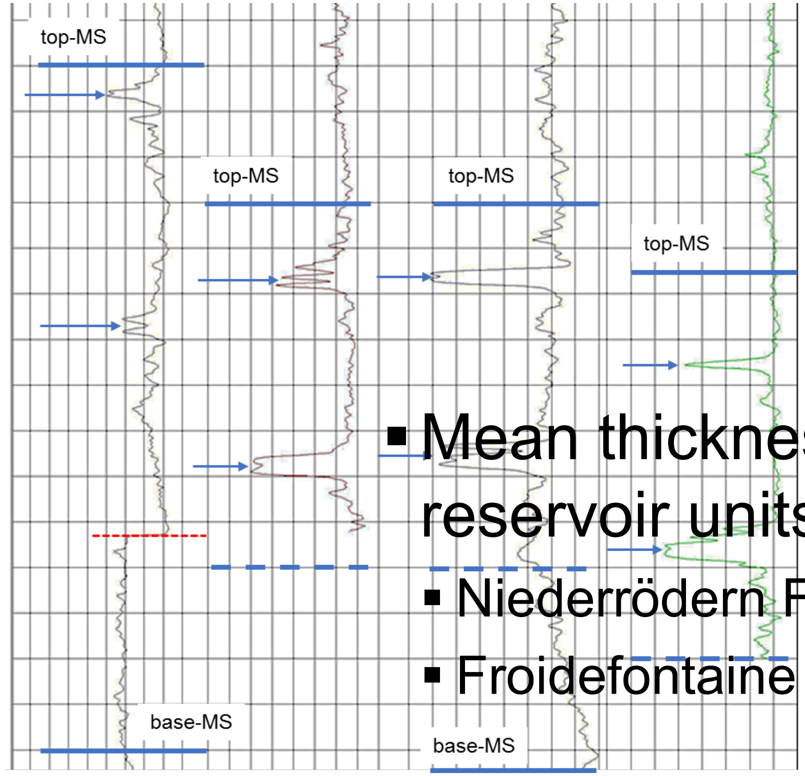



Banks et al., 2021

# Challenges in HT heat storage II

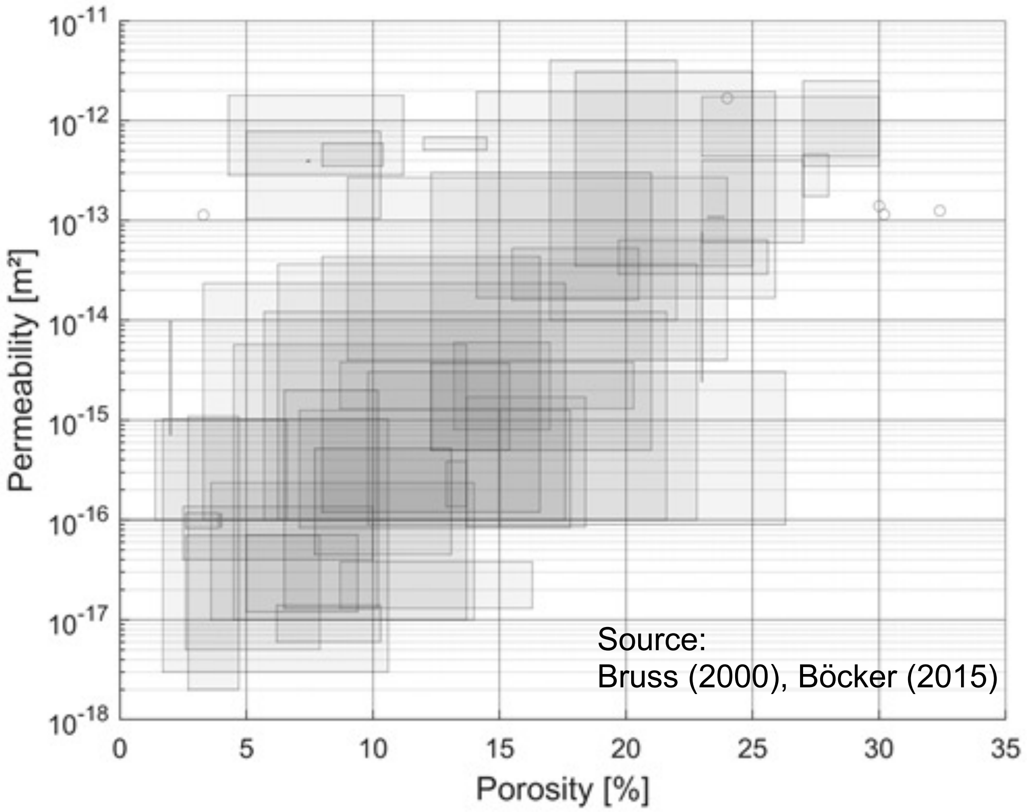
- Self-potential logs from Leopoldshafen field

Garipi et al. (in prep)



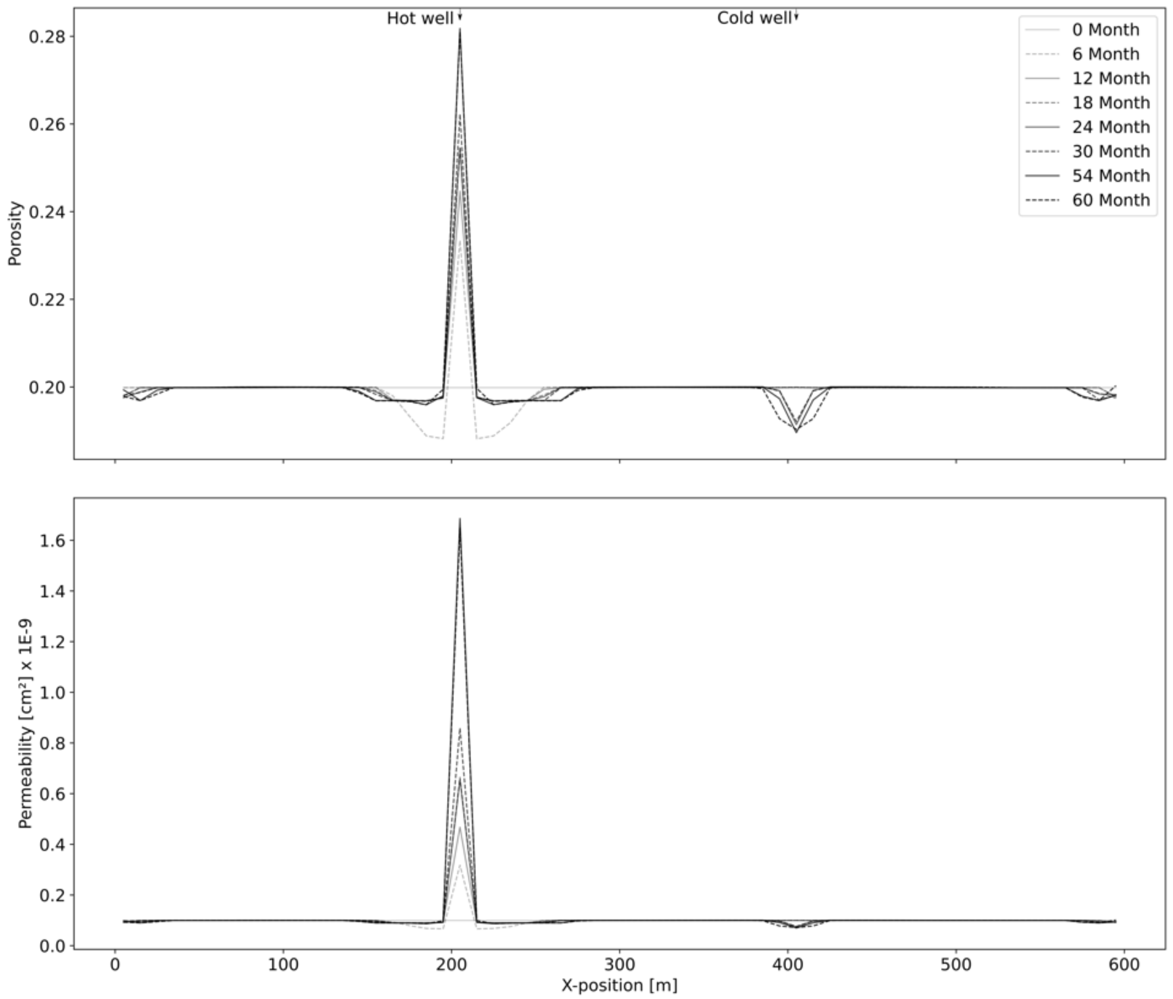

- Mean thickness of reservoir units:
  - Niederrödern Fm: 5-7 m
  - Froidefontaine Fm: 6-7 m

- Variation in porosity and permeability in the URG



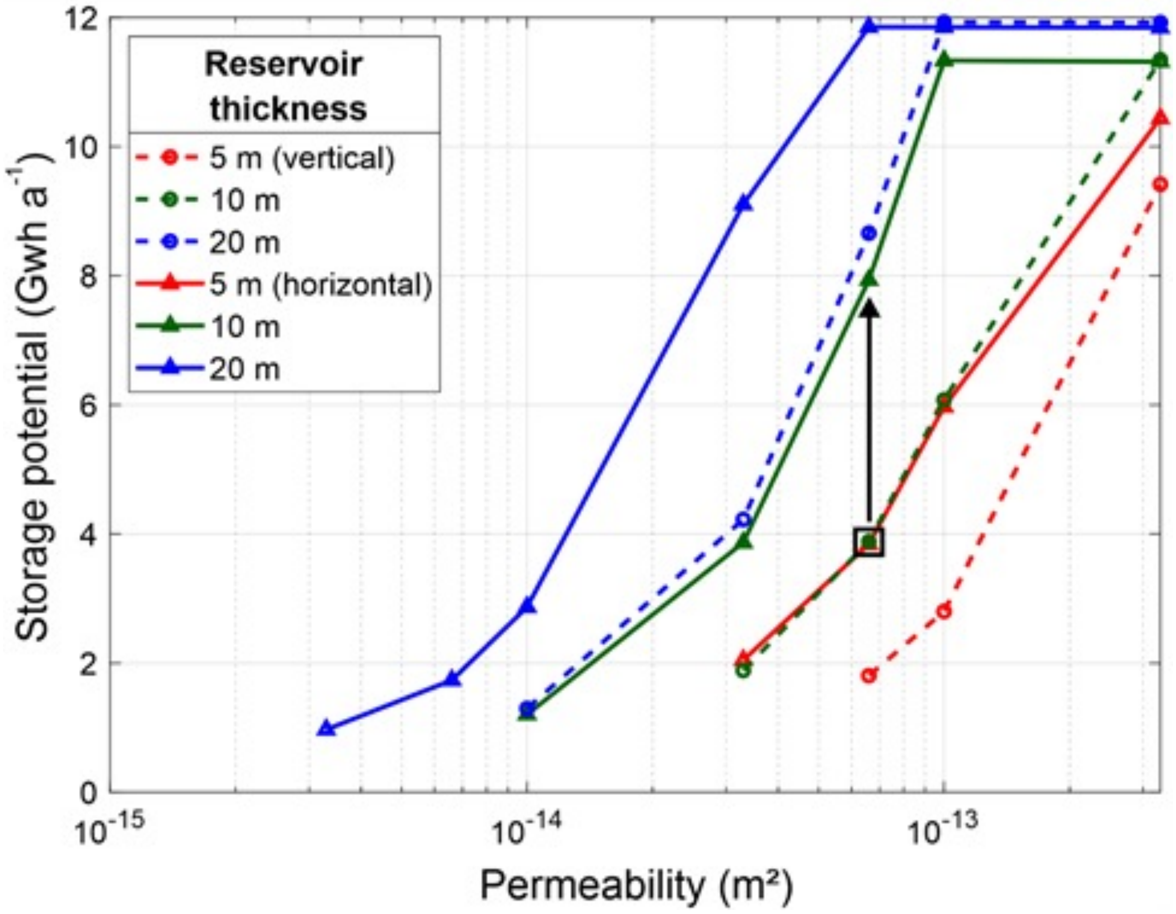

Source:
Bruss (2000), Böcker (2015)

# Expected porositiy and permeability changes



# Storage potential in thin reservoirs

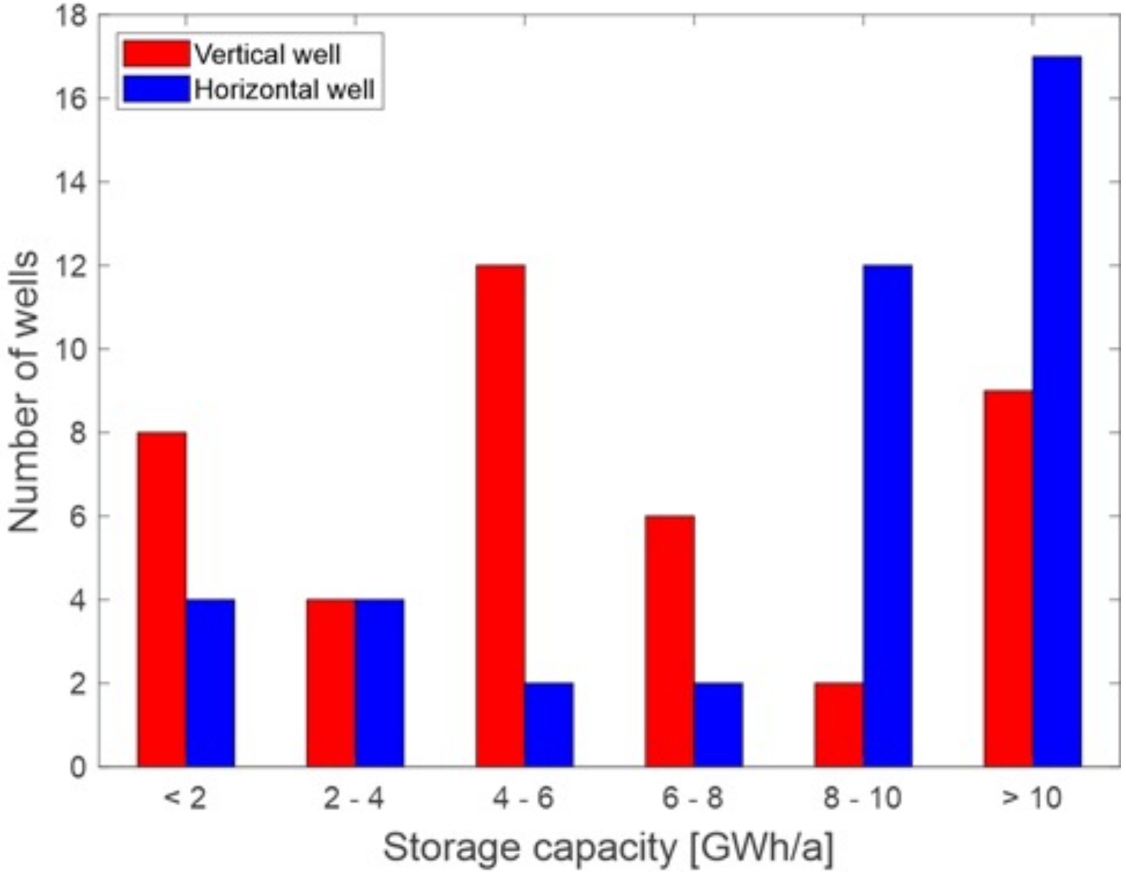
- Increase by horizontal sections




- Storage potential of individual wells reaches **10 GWh per year** at
  - $4 \cdot 10^{-14}$ m² for 20 m thickness in **horizontal** wells
  - $8 \cdot 10^{-14}$ m² for 20 m / 10 m thickness in **vertical / horizontal** wells
  - 2-$3 \cdot 10^{-13}$ m² for 10 m / 5 m thickness in **vertical / horizontal** wells

# Storage potential in thin reservoirs in the URG

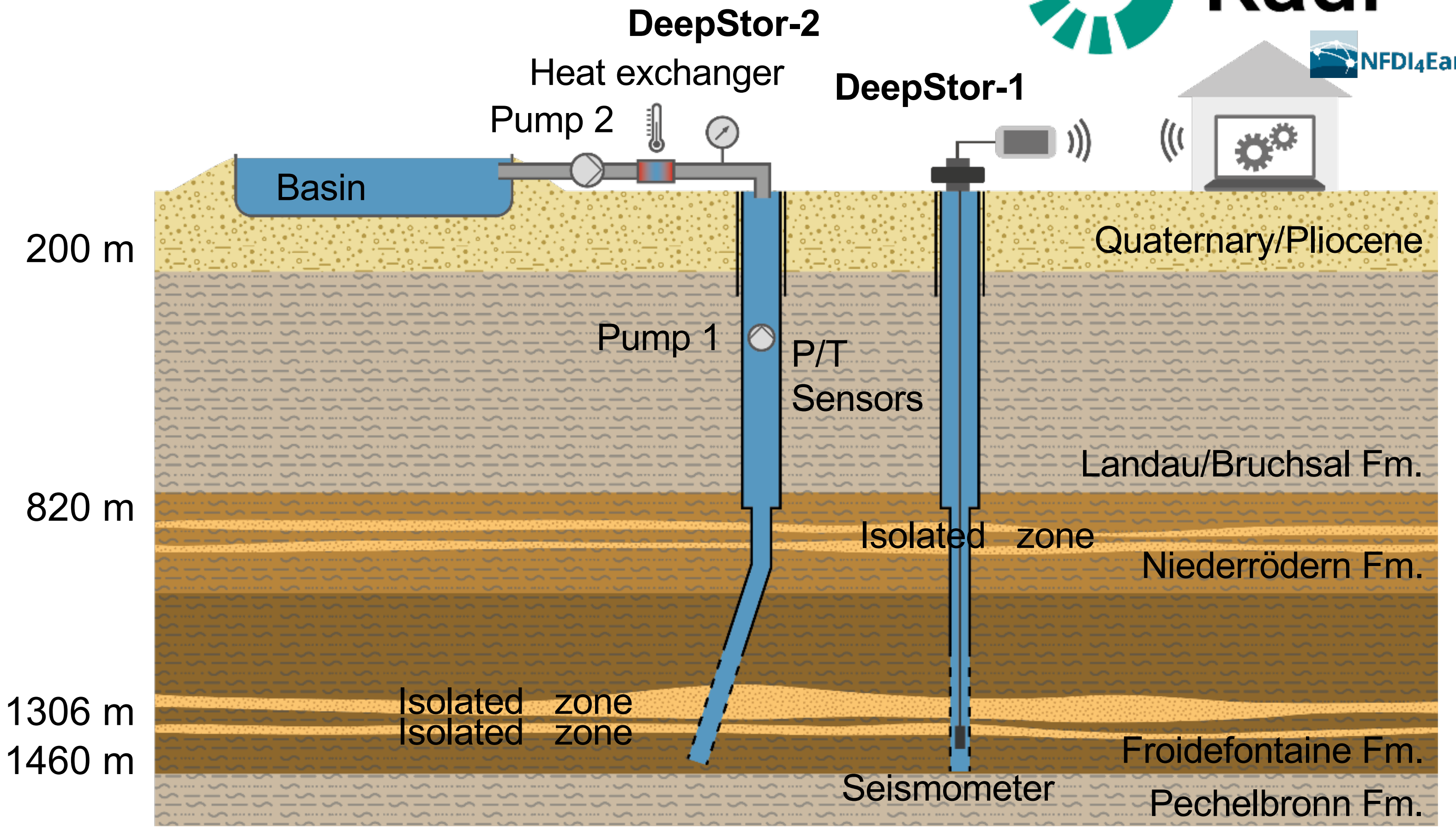
- Increase by horizontal sections



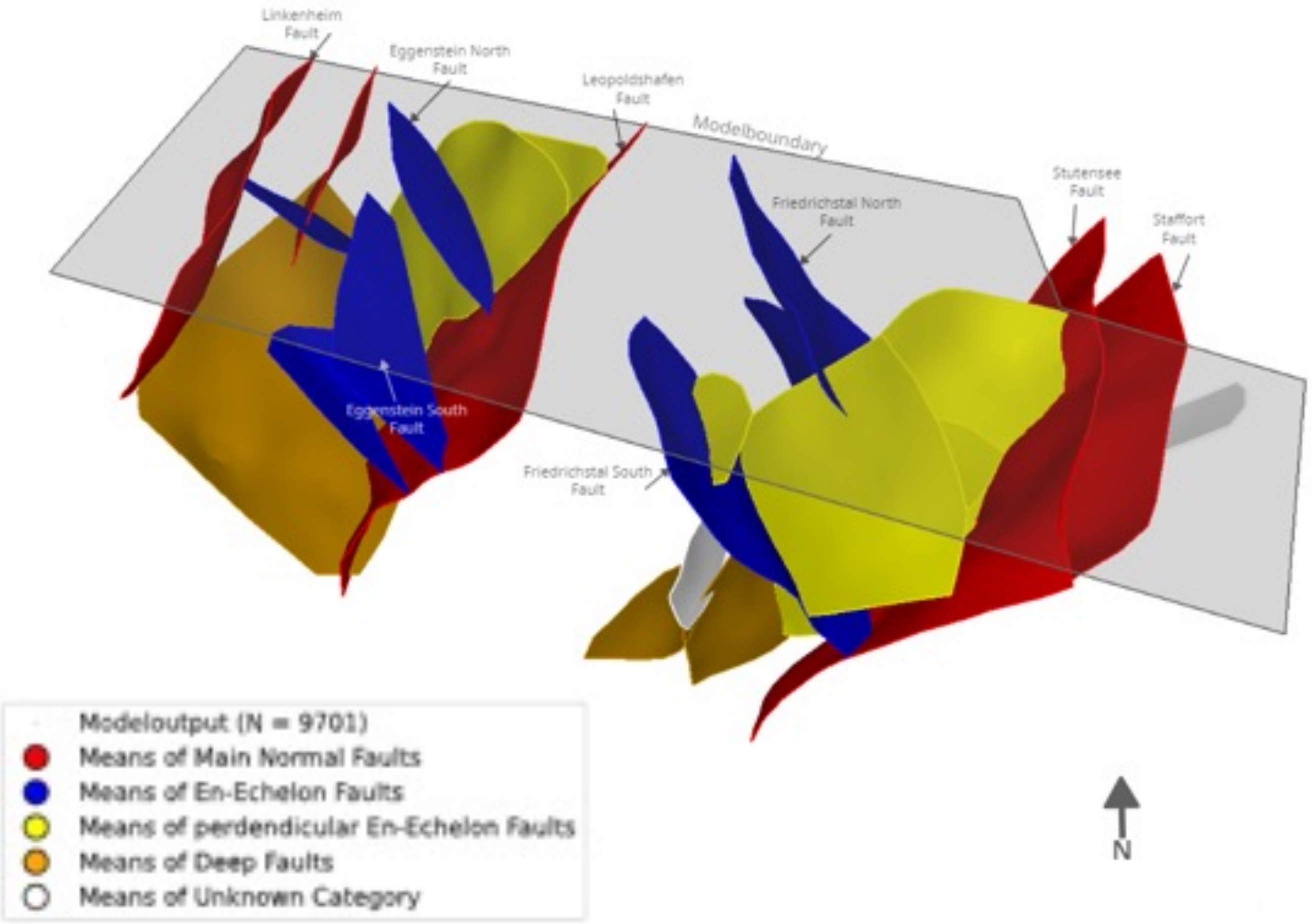

- Storage potential of individual wells reaches
  - **> 8 GWh in horizontal wells in 2/3 of the wells**
- Overall storage potential reaches
  - **10 TWh/a**

# Helmholtz research infrastructure DeepStor at KIT – Campus Nord

- DeepStor-1:
  - Exploration (logs, cores, hydraulic. tests).
  - Monitoring (3 isolated zones, P/T/seismic sensors, fluid sampling).
- DeepStor-2:
  - Production tests (Pump 1)
  - Injection tests (Pump 2)
- Separation and reinjection of hydrocarbons
- Basin
  - Volume of 4'000 $m^3$
    (i.e., >20 days testing at flow rates of 2 L/s)
- Heat exchanger incl. mobile heating station



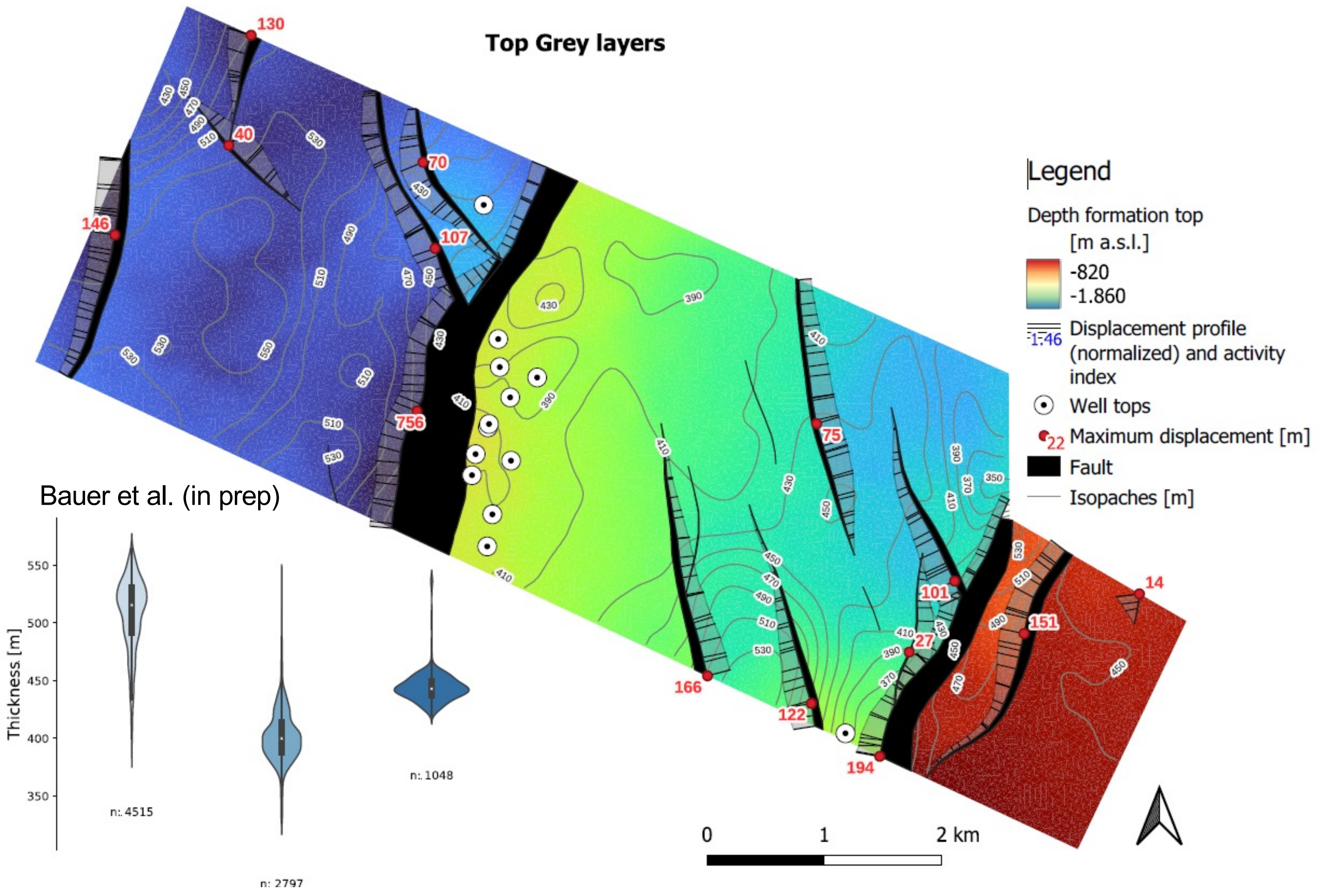
# 3-D geological model




Bauer et al. (in prep)

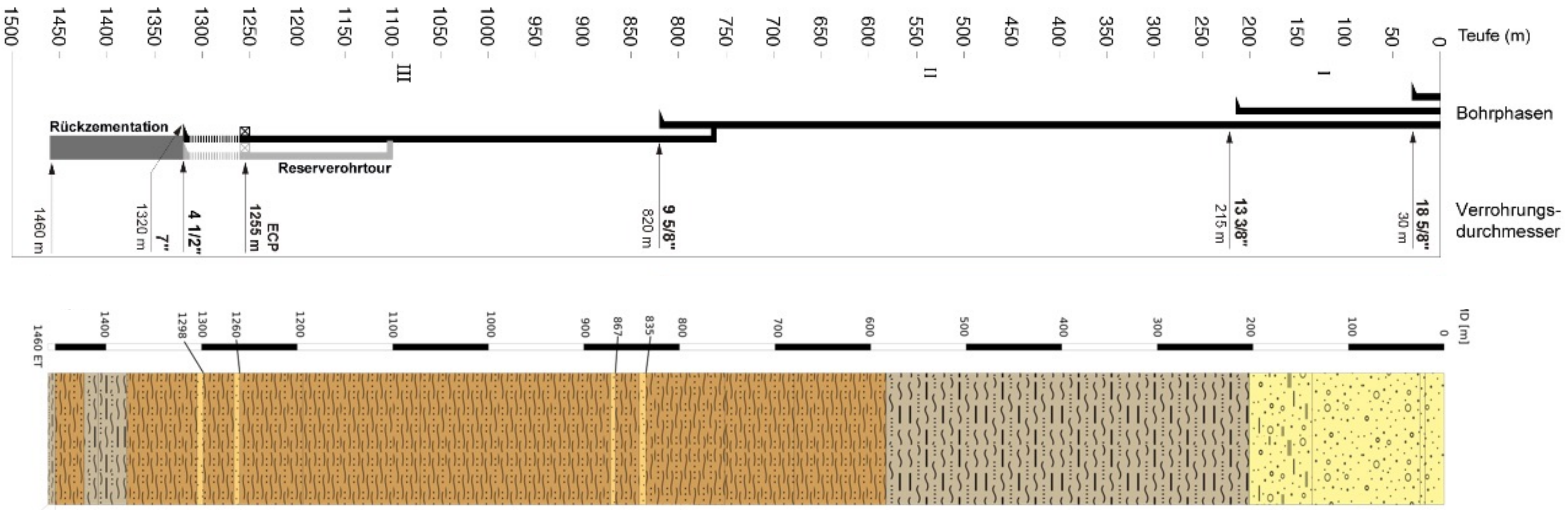
- Based on 3-D seismic and well data (vertical resolution about 40 m)
- Major normal faults Leopoldshafen and Stutensee
- En-echelon branch faults indicating strike-slip component
- DeepStor-1 and -2 target an undisturbed part of the Tertiary sediments.

# Complexity of the target layers



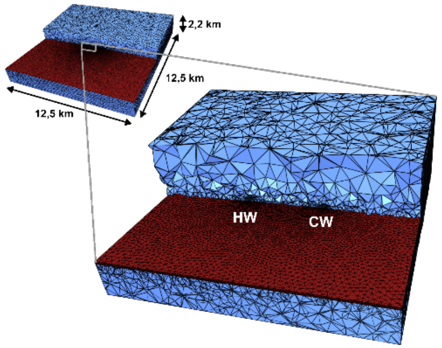

- Three compartments separated by two major faults
- Active en-echelon branch faults with diplacements up to >150m
- Considerable difference in thickness across the three compartments
- High and different variability within the compartments
- Extrapolation of data to a wider area is difficult

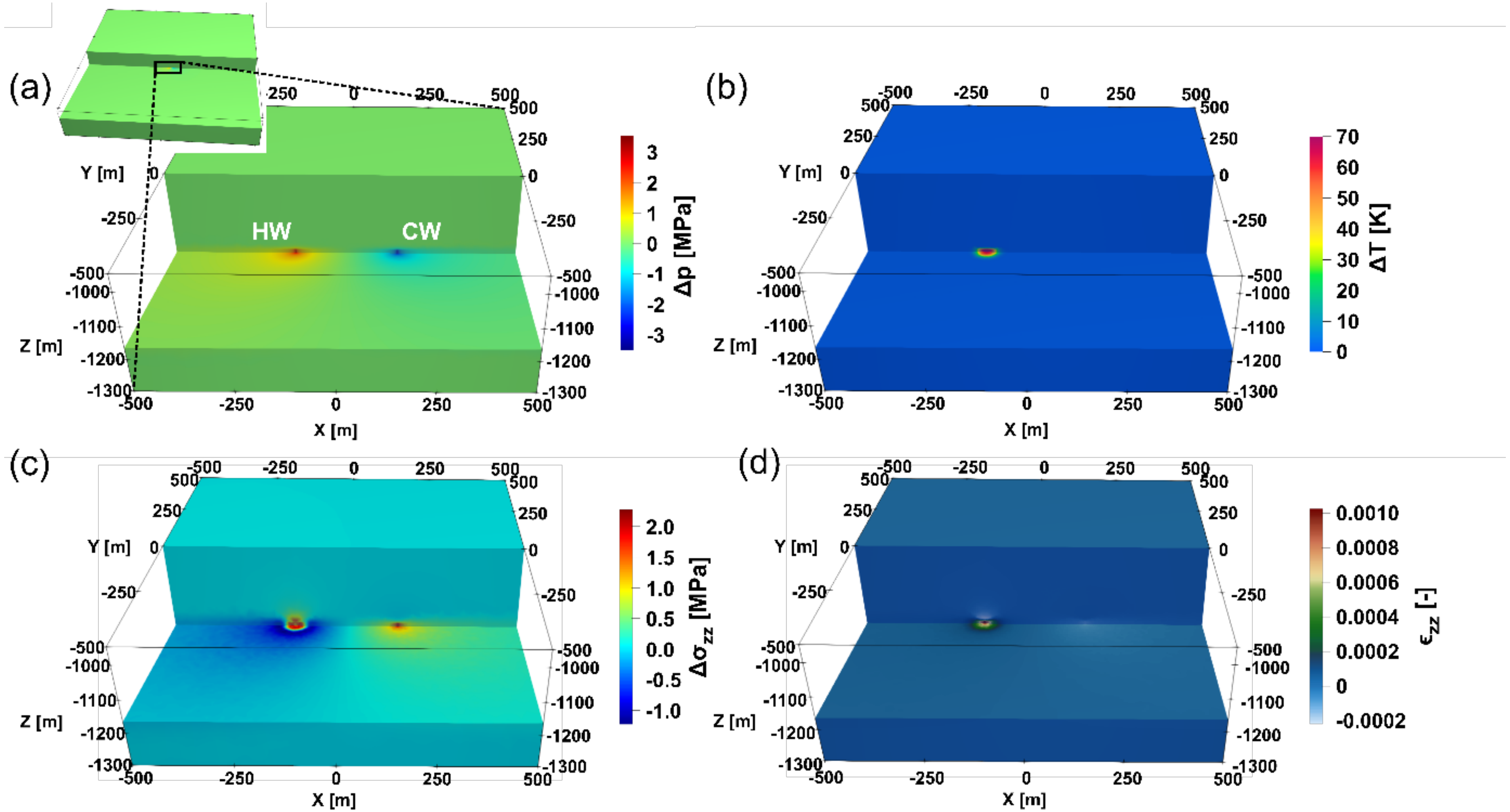
# DeepStor-1 prognosis profil



# Field perturbations near the wells after one injection period (6 months)

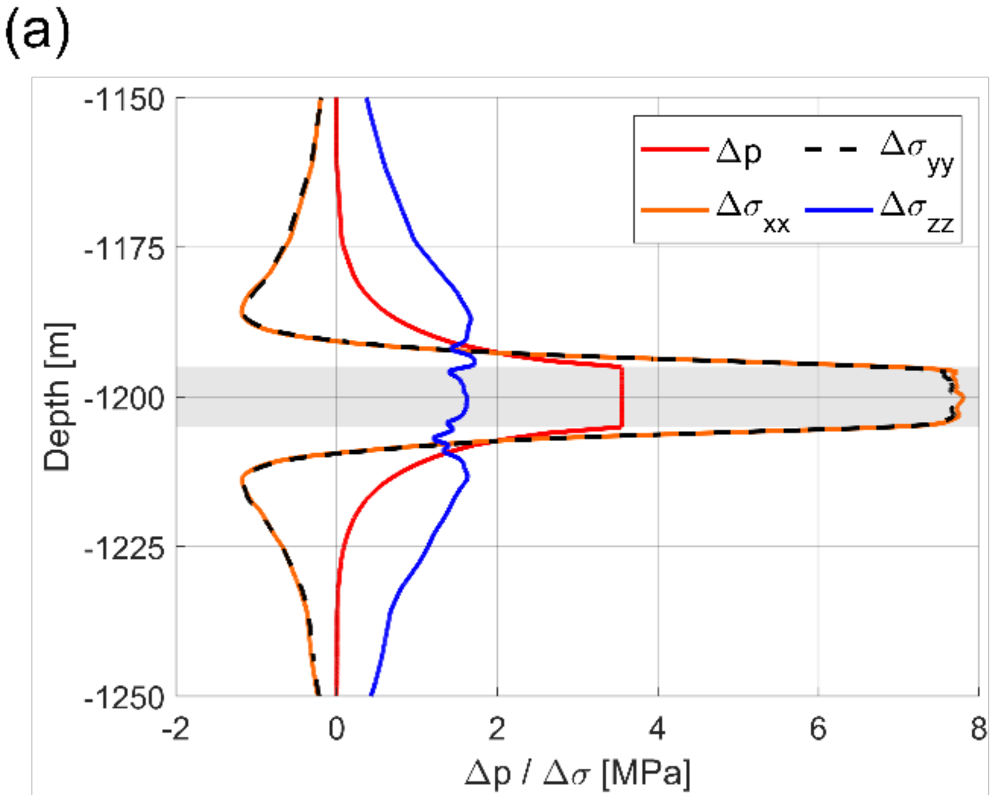
- Differential pressure
- Temperature
- Vertical stress
- Vertical strain

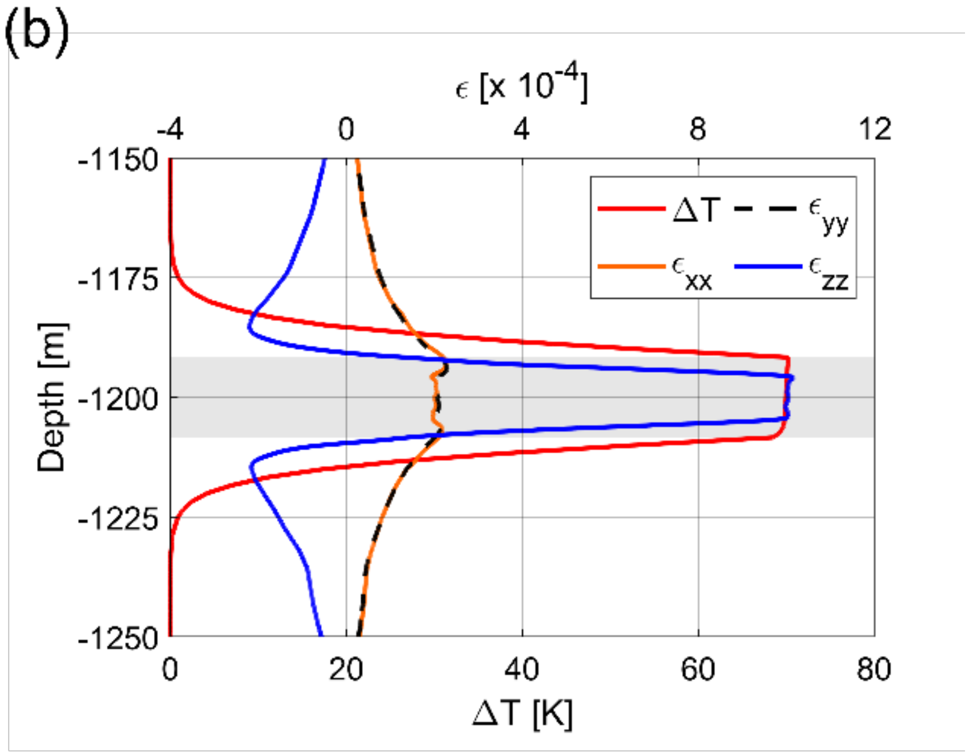


# Field perturbations near the wells after one injection period (6 months)

- Differential pressure and the three principal stress components
- Temperature and the three principal strain components



# Vertical displacement through seasonal operation

- Top reservoir
- Surface