

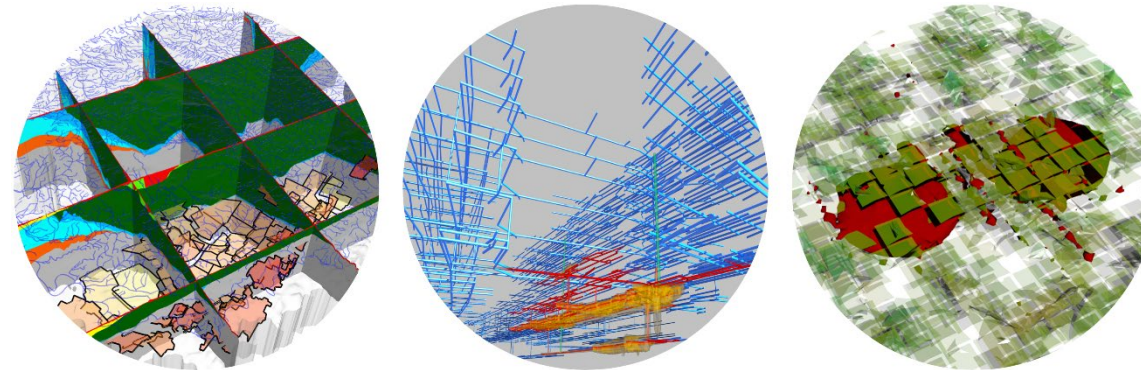


West Virginia Mine Drainage Task Force Symposium &  
15th International Mine Water Association Congress

April 21–26, 2024 | Morgantown, WV, USA

IWWA 2024–1110

WINZER: Multi-scale modelling concept for numerical modelling of seasonal thermal energy storage in groundwater-filled underground coal mines



April 25. 2024

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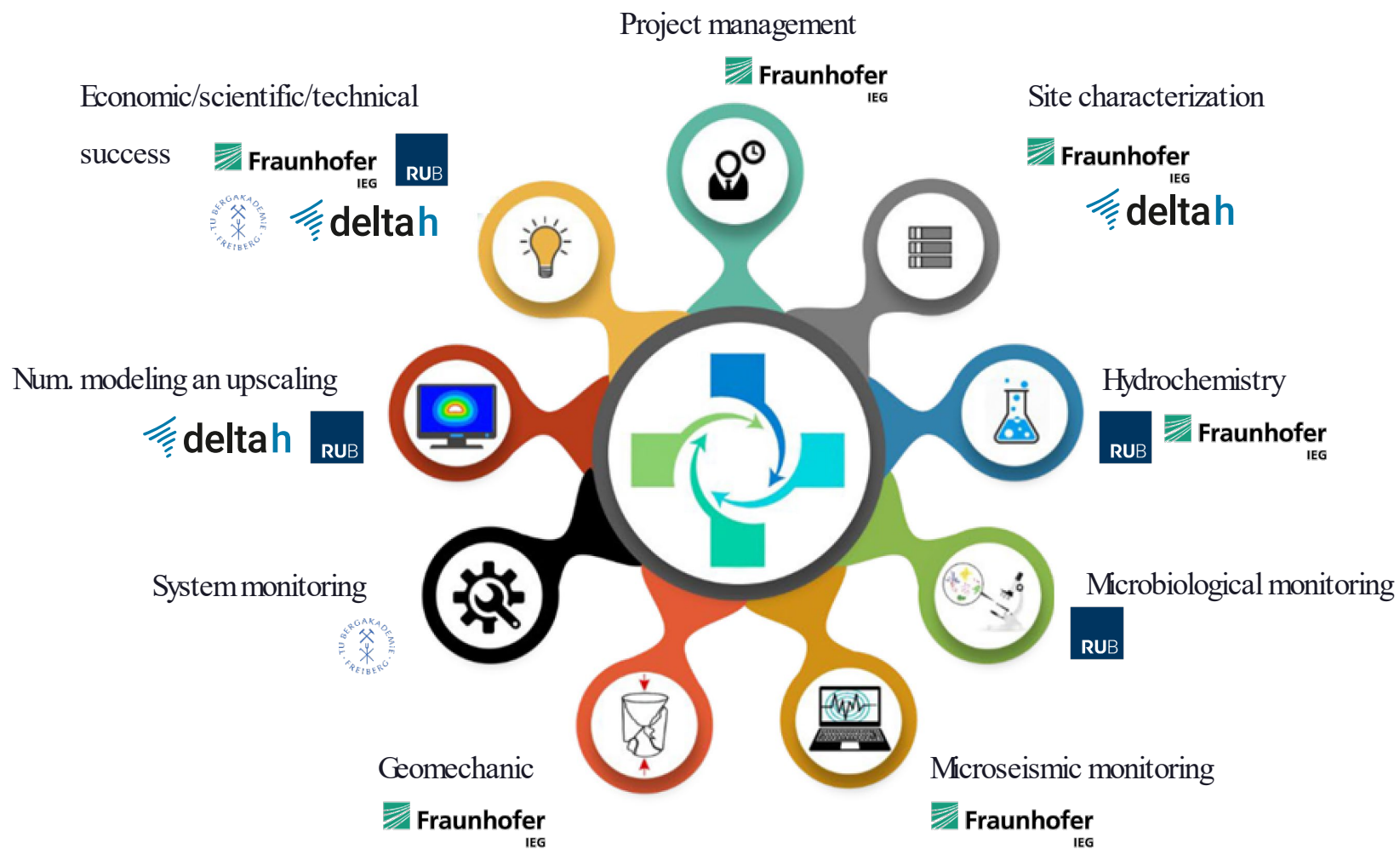
In cooperation with:



delta h  
Parkweg 67  
58453 Witten / Germany  
Tel.: +49 2302 91 406 20  
<https://www.delta-h.de>



- Safe and efficient operation of ATEs in abandoned coal mines



# Bochum site - abandoned coal mine

## Colliery Dannenbaum

- Large scale mine
- 8 levels / 800 deep
- Direct connection to the main dewatering system

7.5 km

## Small colliery IEG „auf dem Kalwes“

- Small scale mine
- Close to surface
- Isolated

## Colliery Mansfeld

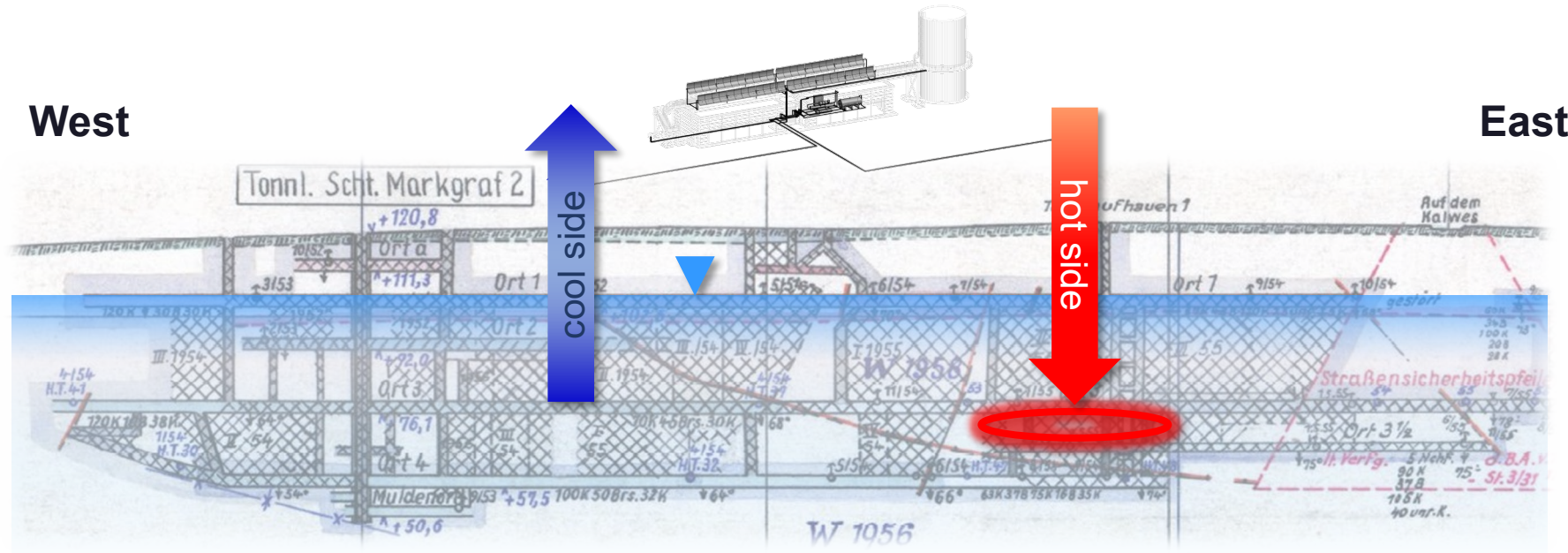
- Underground factory
- 10 m diameter
- Connection to the main dewatering system





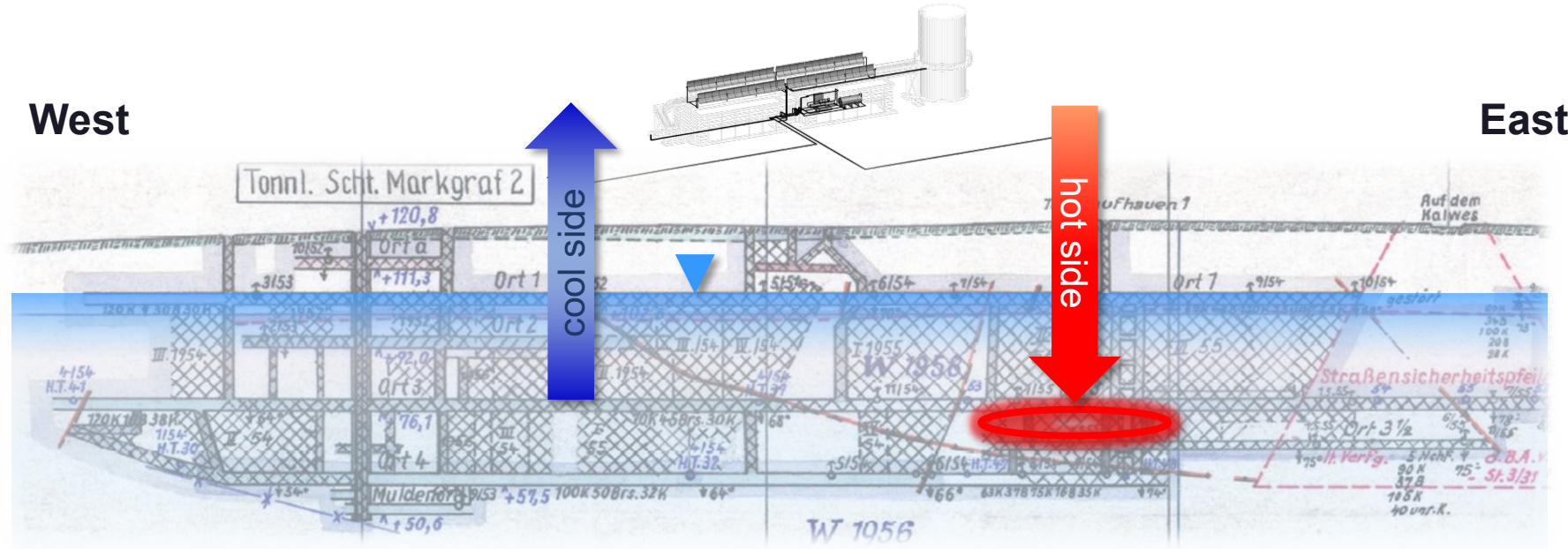






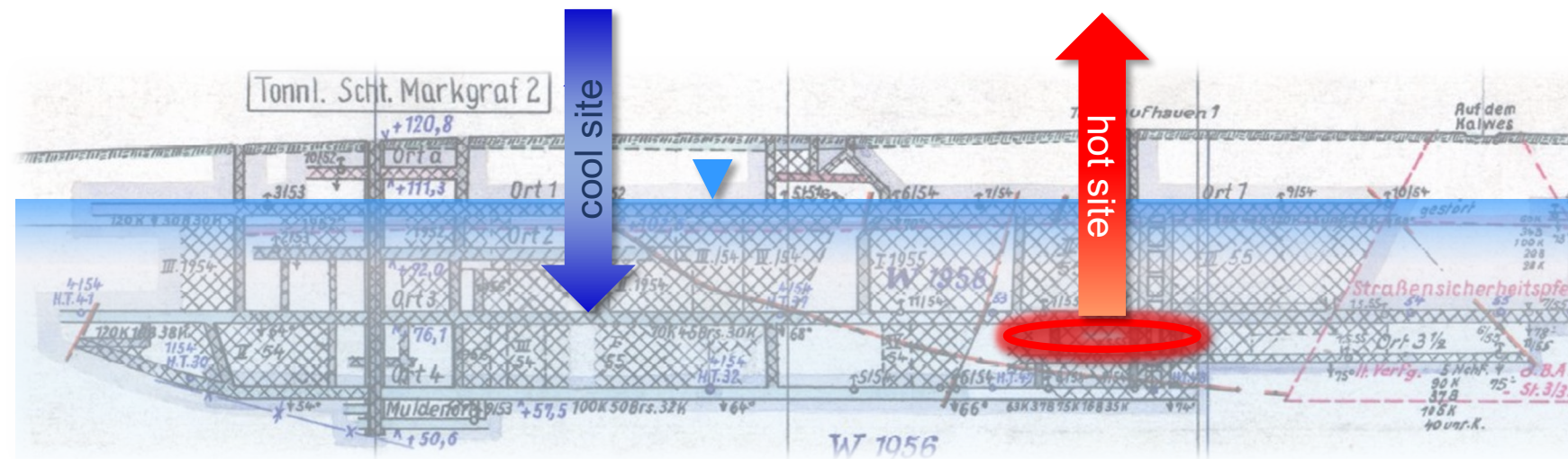
Summer:

- solar thermal charging



Summer:

- solar thermal charging

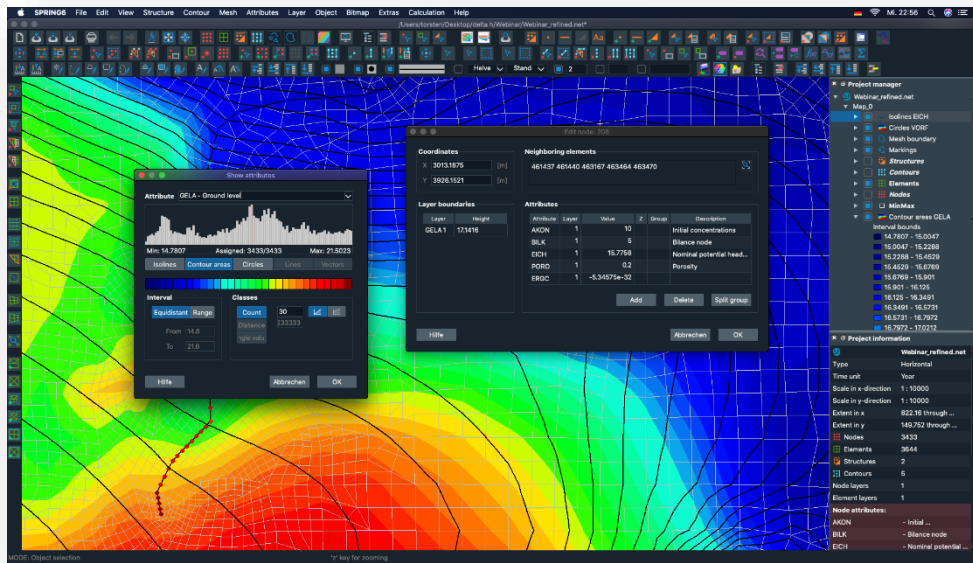


Winter:

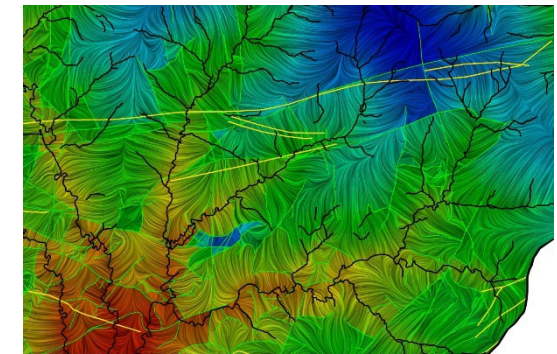
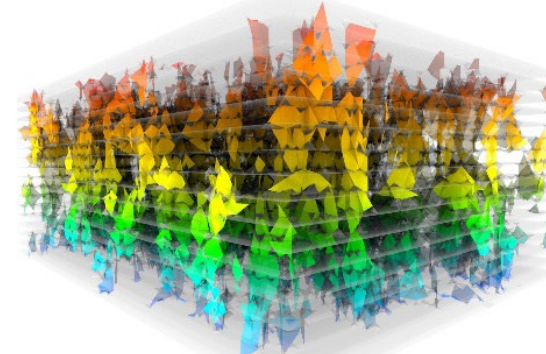
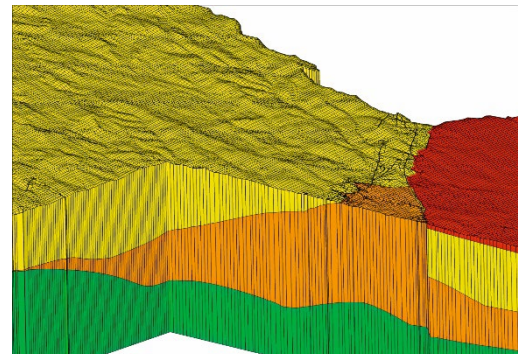
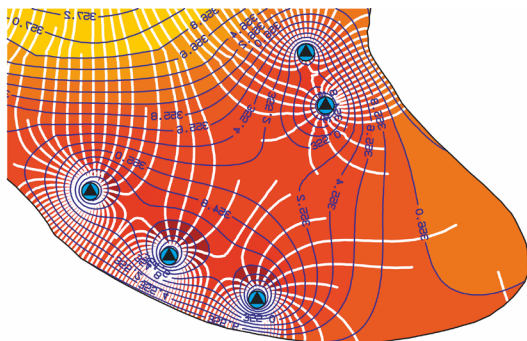
- geothermal discharge



## SPRING – Simulation of Processes in Groundwater



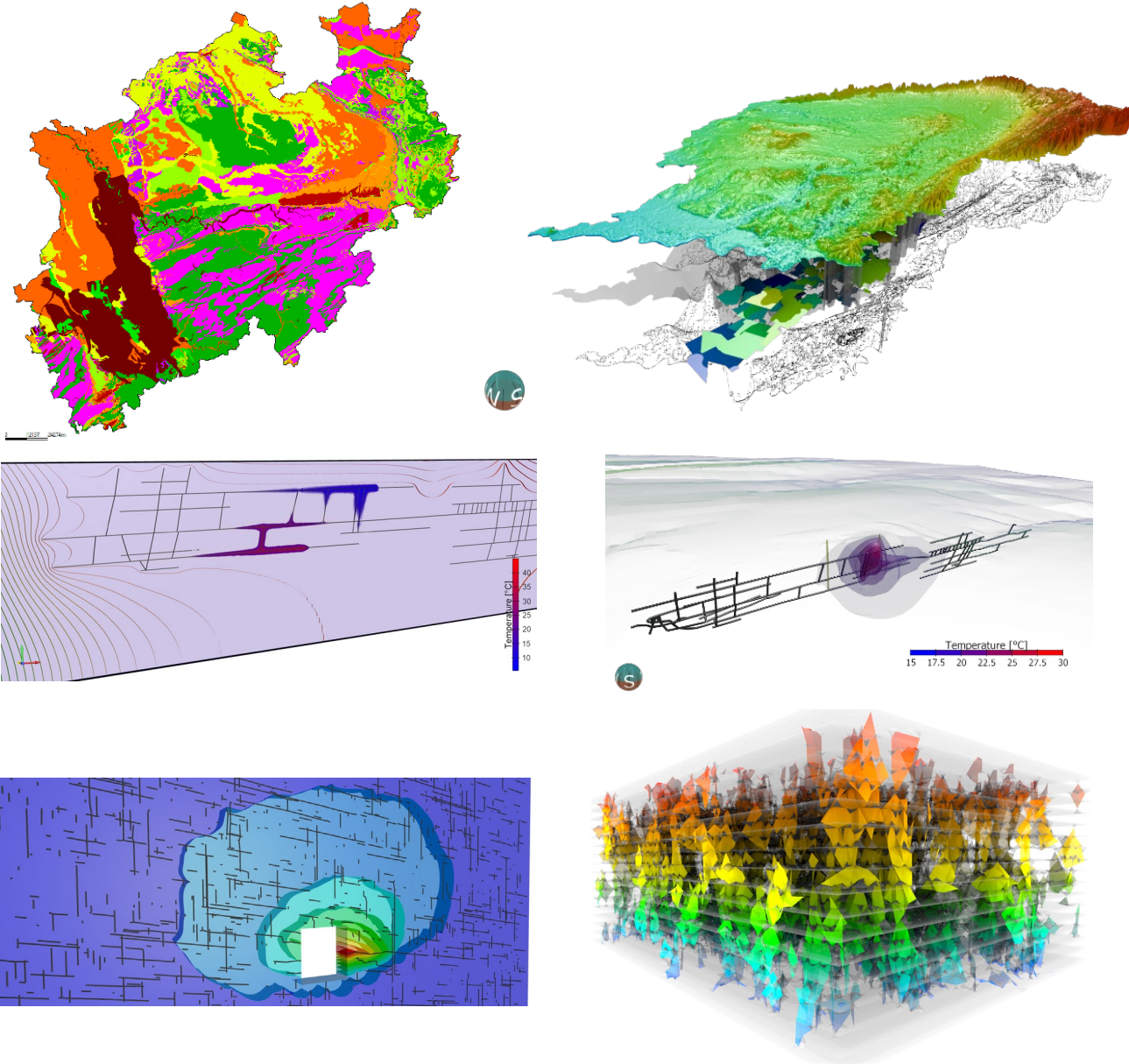
- Flow, mass and heat transport
- Steady state/transient calculation
- Fully saturated/partially saturated
- Density dependent
- Degradation/Sorption
- Processes in fractures
- Basis: Finite Element Method









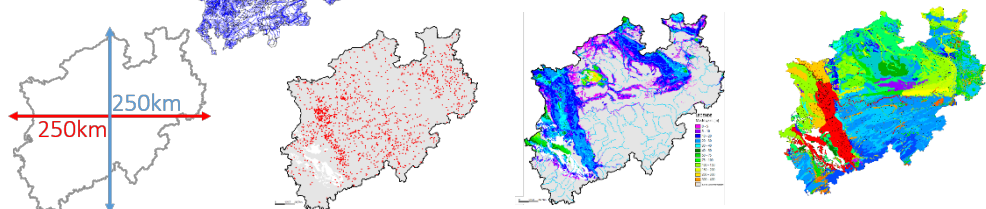
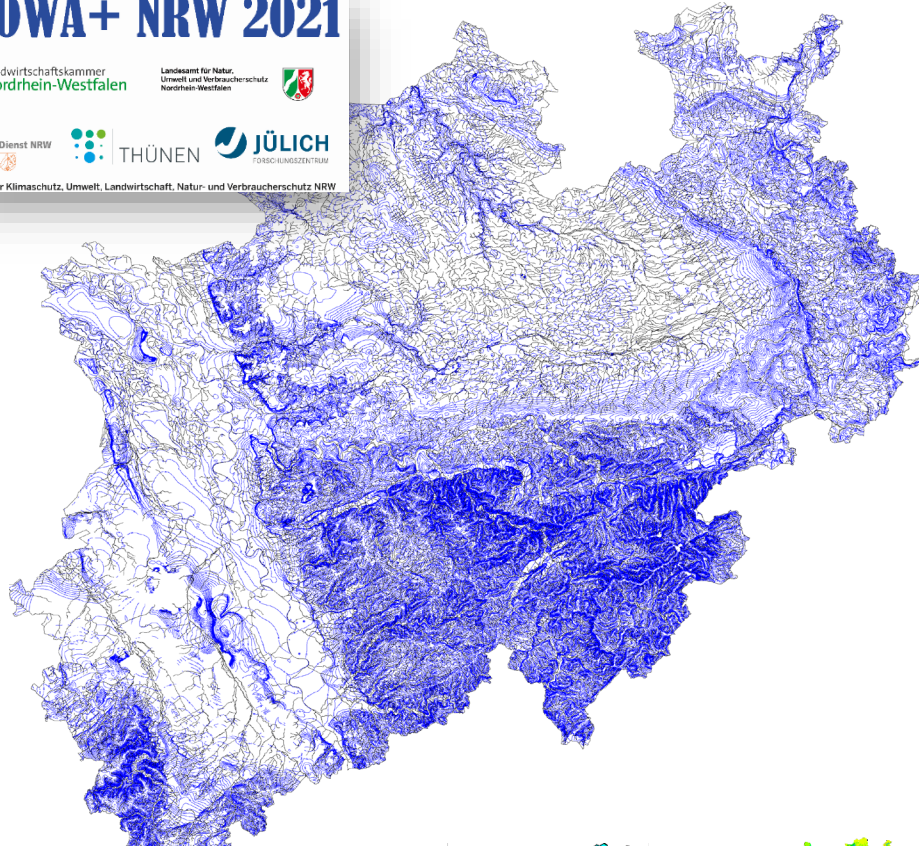


complexity

- Regional
- Site
- Detail

## Groundwater model NRW

### GROWA+ NRW 2021



GW-recharge, GW-measuring, Layer thickness, hydraul. cond. (calibrated), free GW-surface

## „Muensterland Cretaceous Basin Model“

Leitmarktagentur.NRW

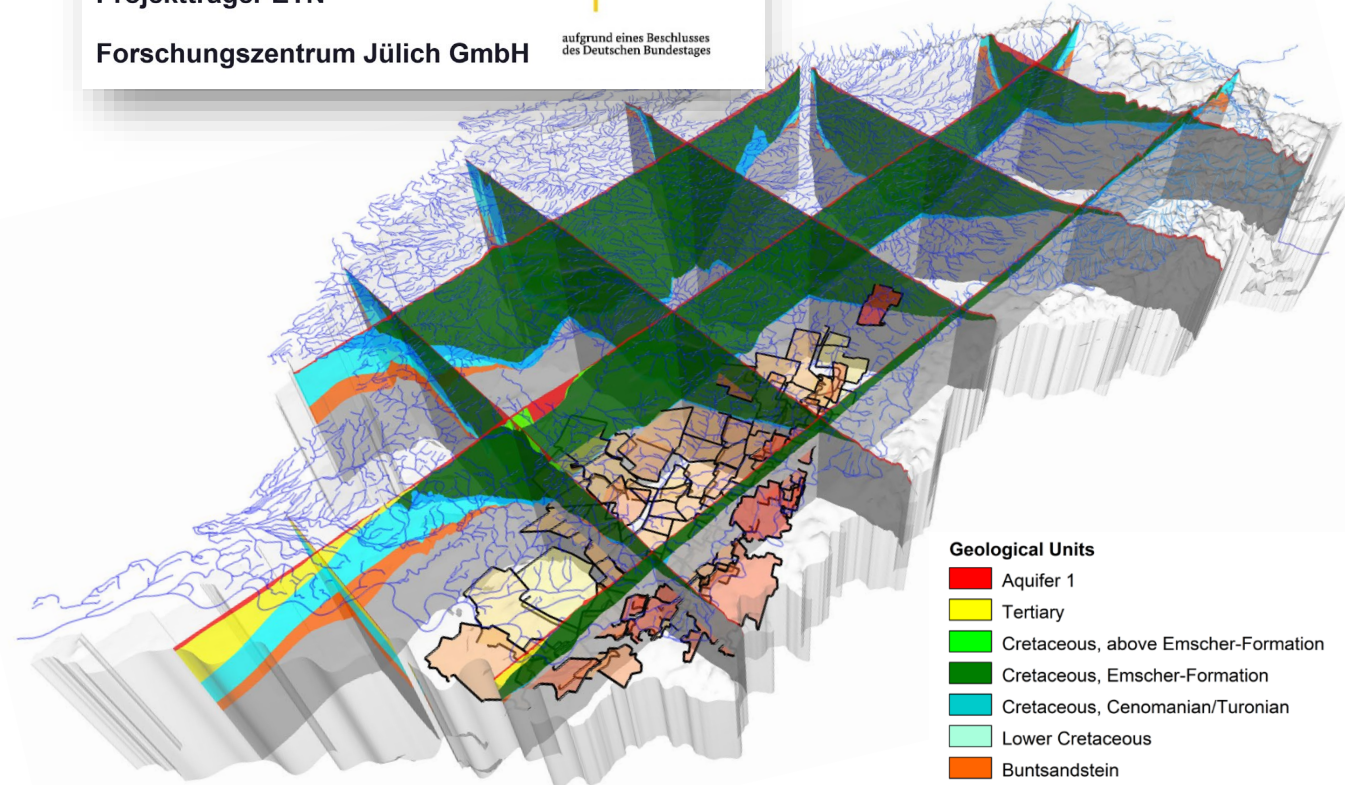
Projekträger ETN

Forschungszentrum Jülich GmbH

Gefördert durch:



aufgrund eines Beschlusses des Deutschen Bundestages

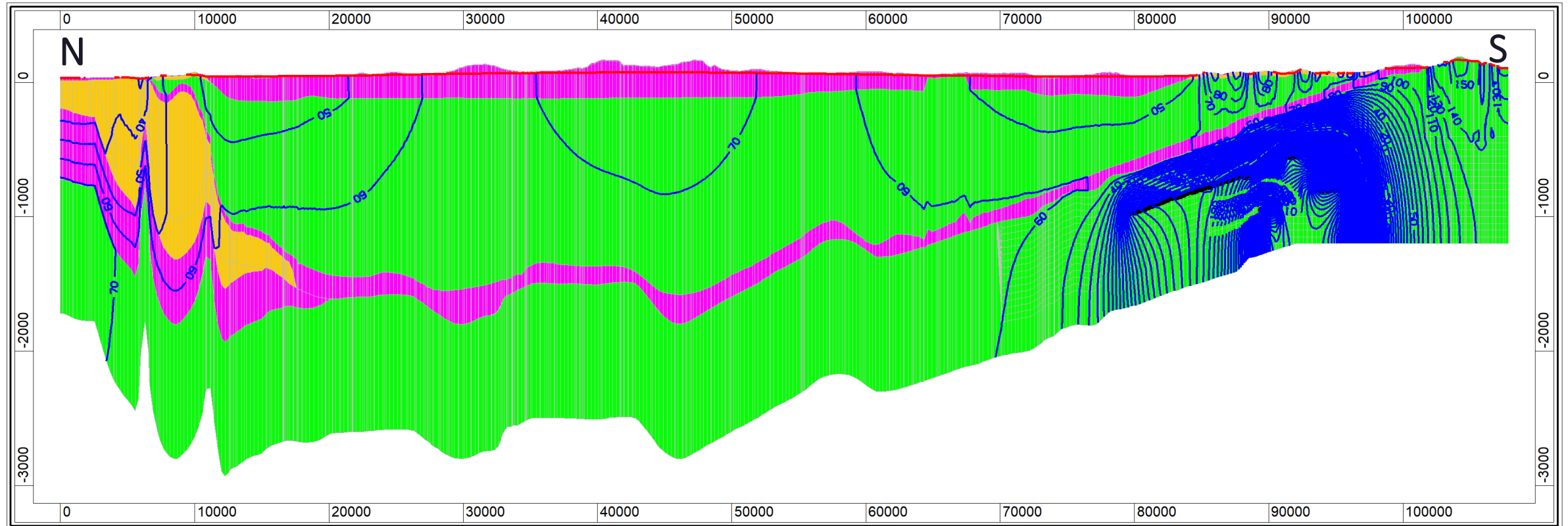


- Geological Units**
- Aquifer 1
  - Tertiary
  - Cretaceous, above Emscher-Formation
  - Cretaceous, Emscher-Formation
  - Cretaceous, Cenomanian/Turonian
  - Lower Cretaceous
  - Buntsandstein
  - Zechstein (Upper Permian)
  - Carboniferous

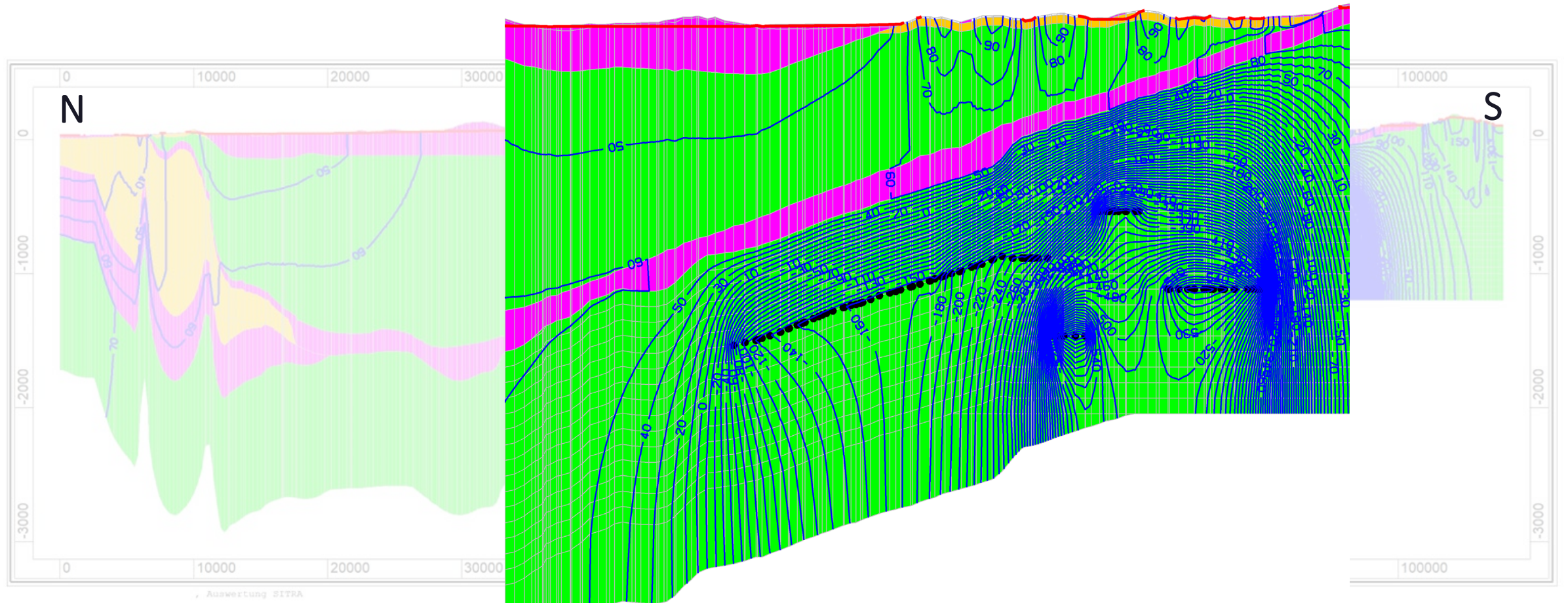


Geological layers, influence of mine drainage as boundary condition for site model

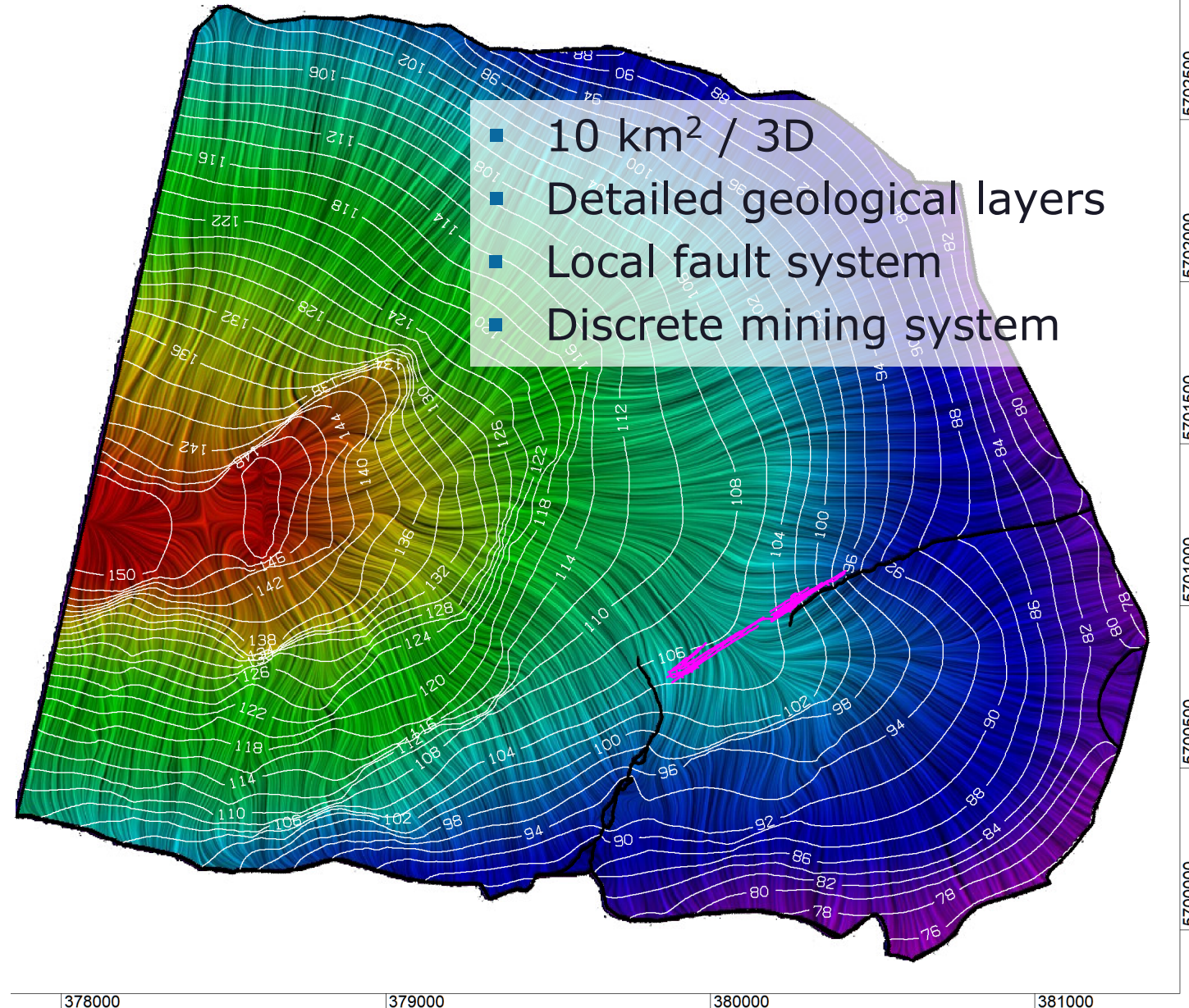
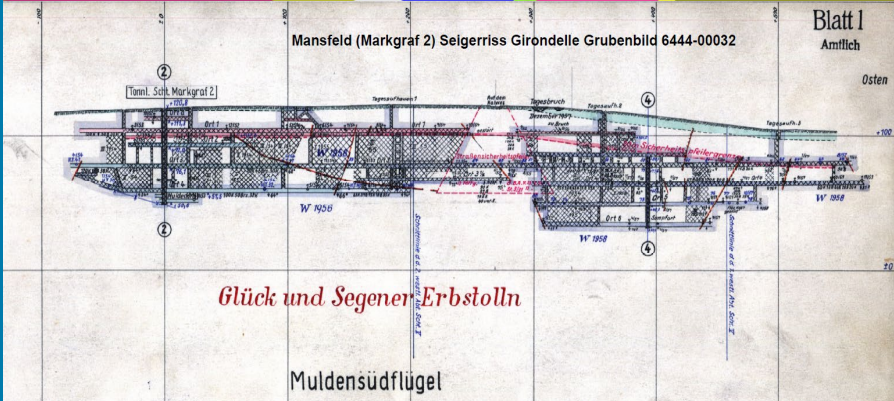
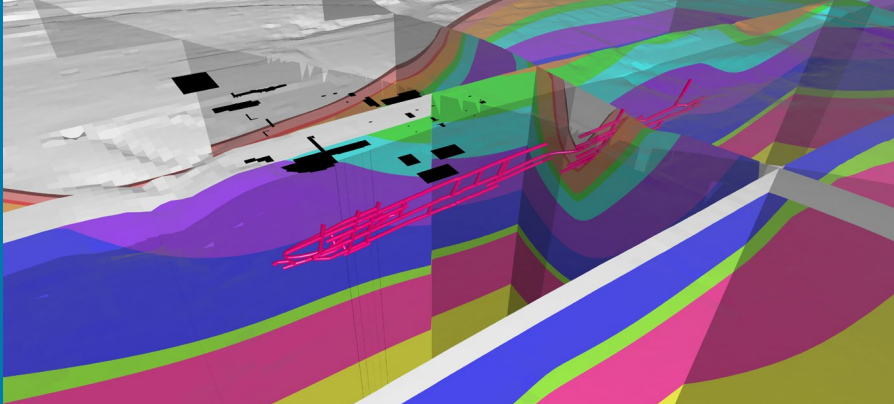
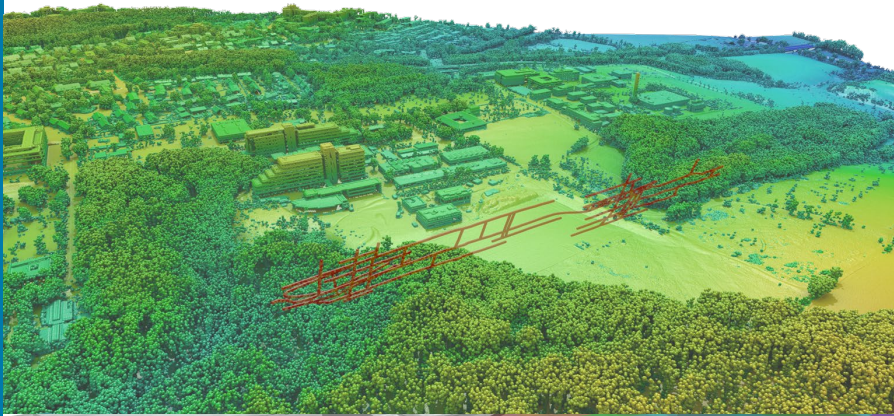




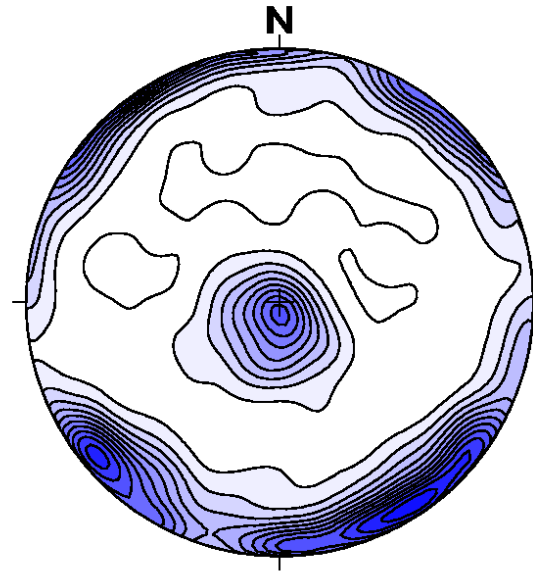
, Auswertung SITRA









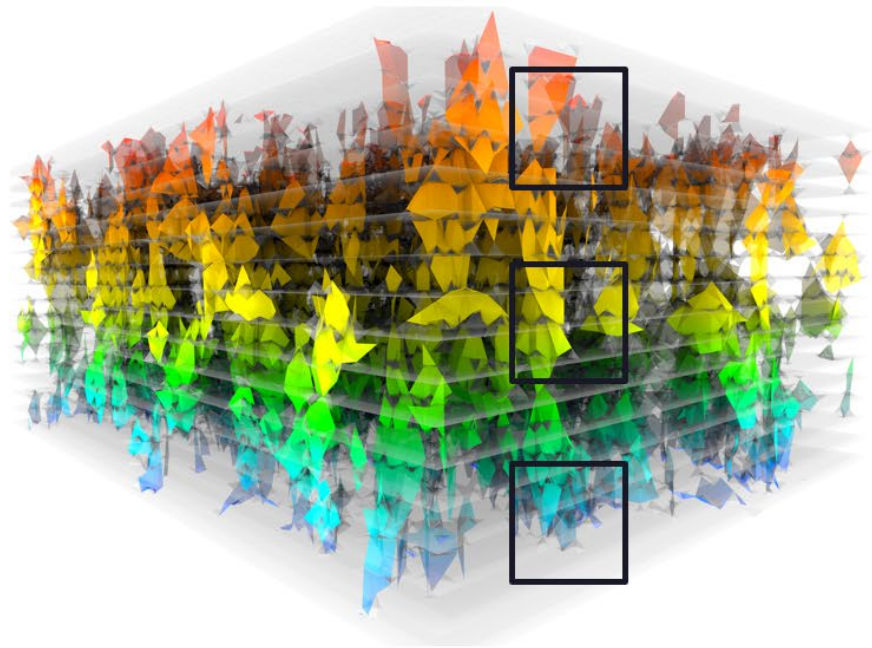


Measured fractured sets:

- Fracture orientation
- Fracture size
- Fracture density
- Aperture

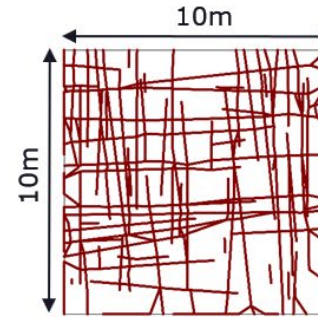
cluster	orientation in space	spherical angle Q	spherical variance s	concentration parameter k
I	(a,f) = (274°,88°)	8.2°	0.95	16
II	(a,f) = (71°,6°)	8.2°	0.95	17
III	(a,f) = (309°,4°)	12.3°	2.35	16

*Calculation and Mesh Generation of a Three-Dimensional Matrix-Fracture-System  
Christoph König, Britta Rosen University of Bochum, Germany*



Stochastic generated fracture sets

Representative elementary volume

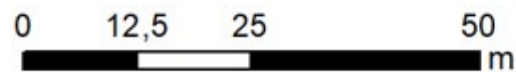
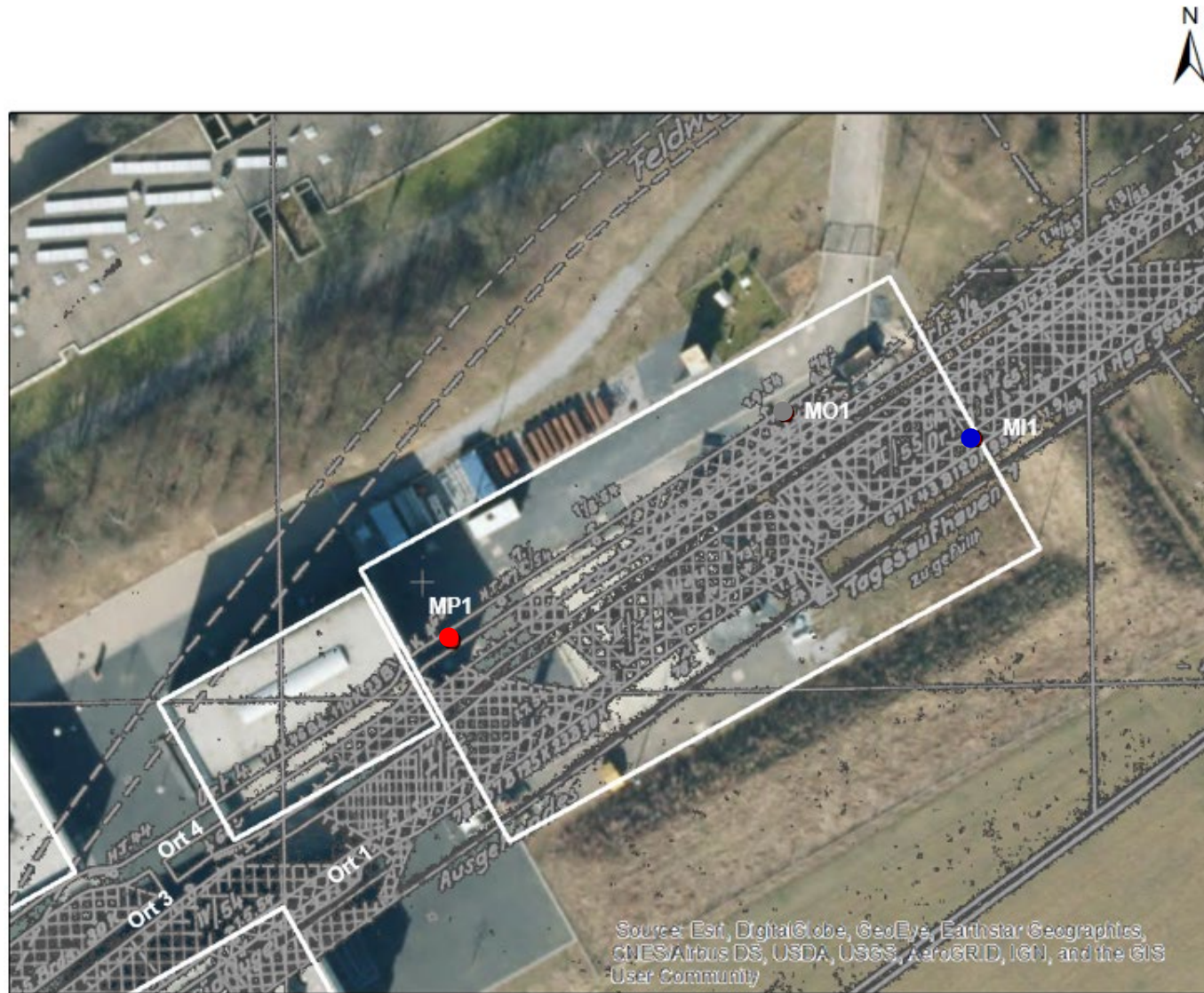


REV

Conductivity matrix + fractures

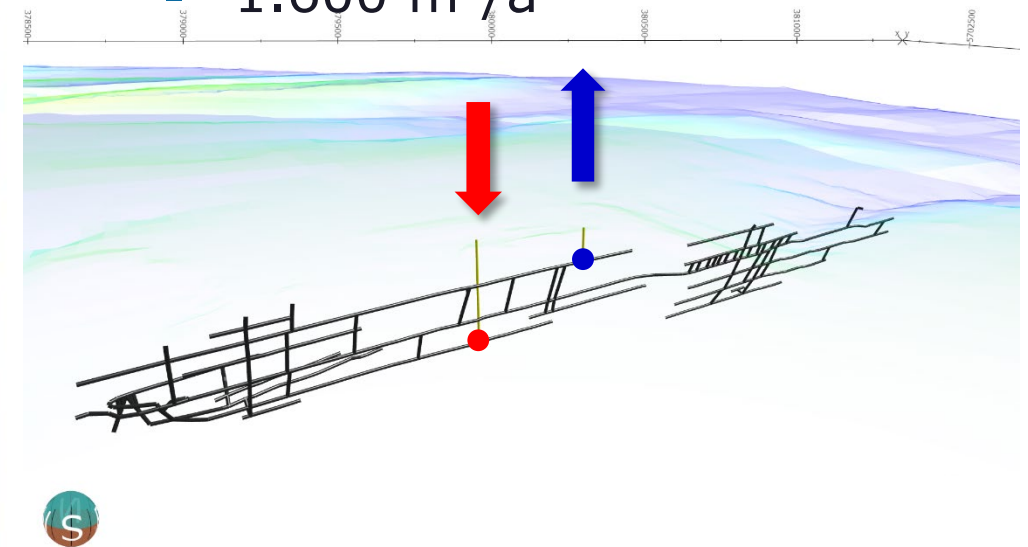
- $K_{\text{Roof}} = 5 \cdot 10^{-7} \text{ m/s}$
- $K_{\text{Middle}} = 2 \cdot 10^{-7} \text{ m/s}$
- $K_{\text{Floor}} = 8 \cdot 10^{-8} \text{ m/s}$





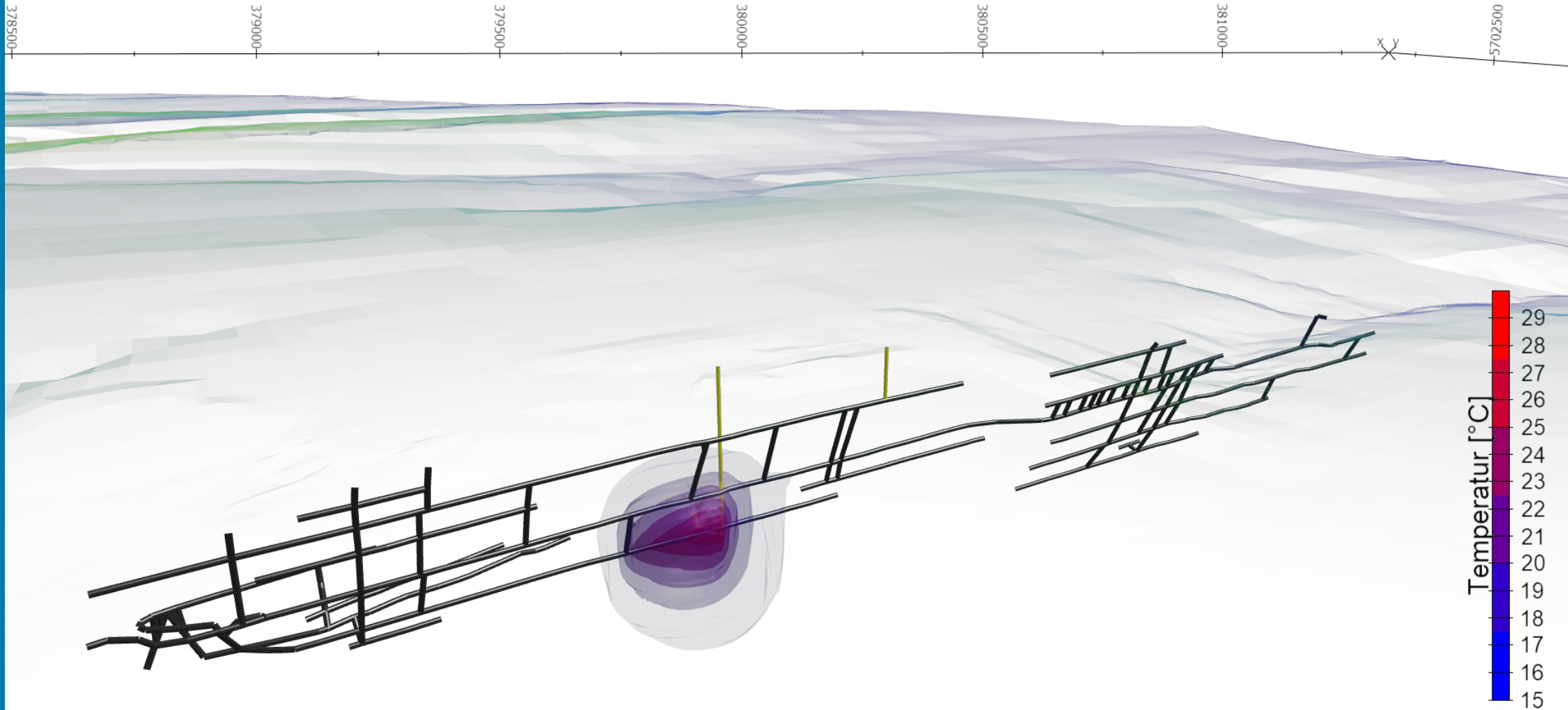
● geplante Bohrungen (neu)

- Steady state  
(flow and heat transport)
- MI1 cool site Ort 1
- MP1 hot site Ort 4 (35°C/95°F)
- 1.600 m<sup>3</sup>/a





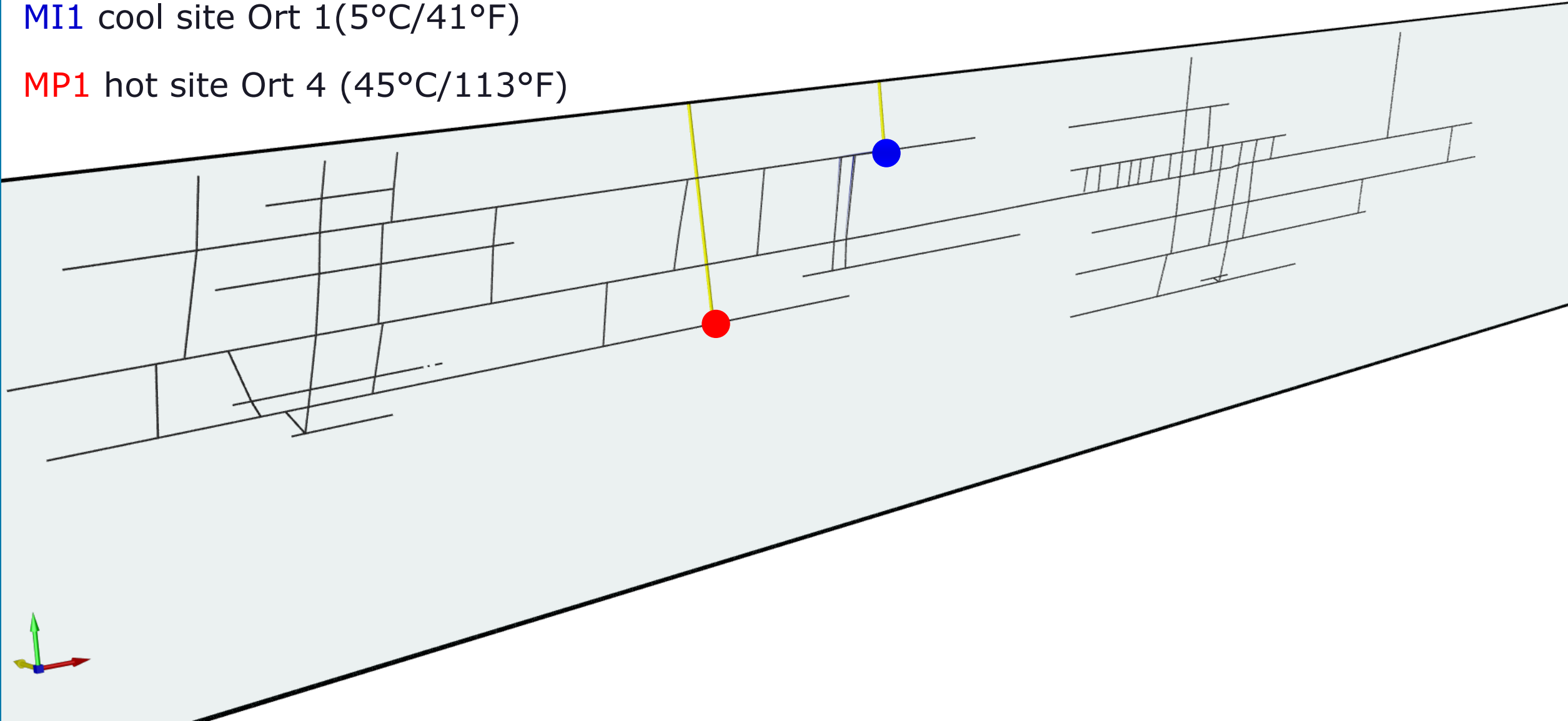
# Steady state temperature distribution



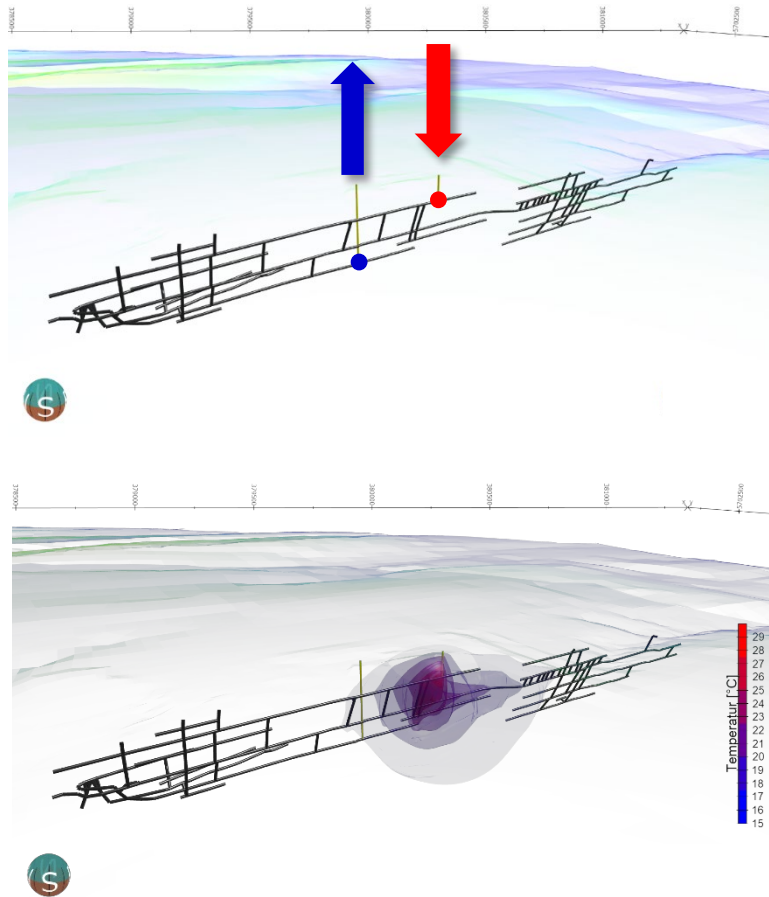
Transient calculation (flow and heat transport)

MI1 cool site Ort 1 (5°C/41°F)

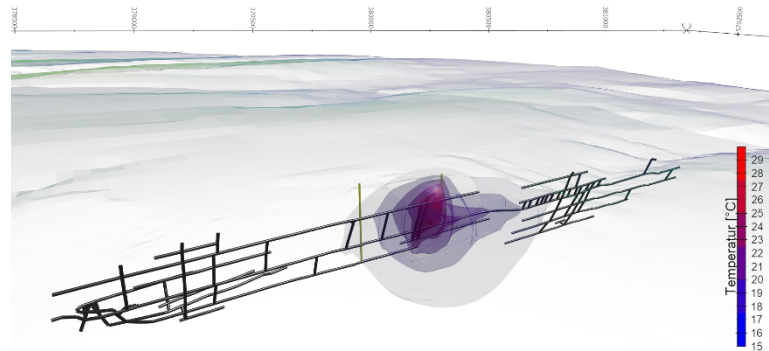
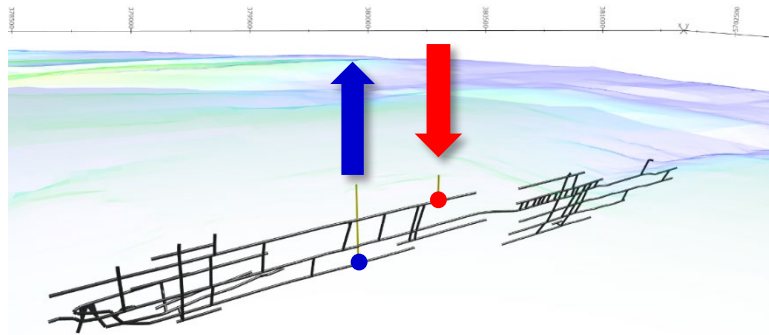
MP1 hot site Ort 4 (45°C/113°F)



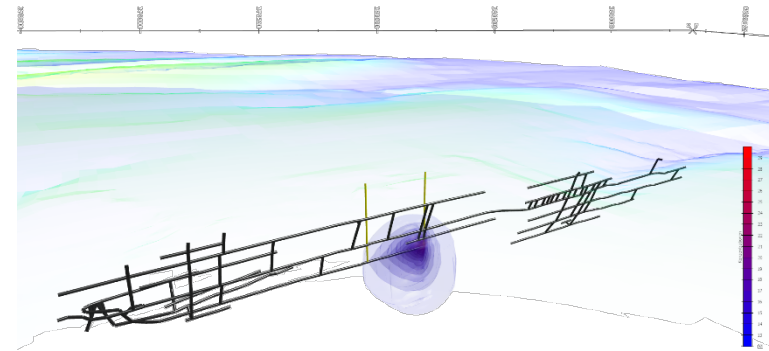
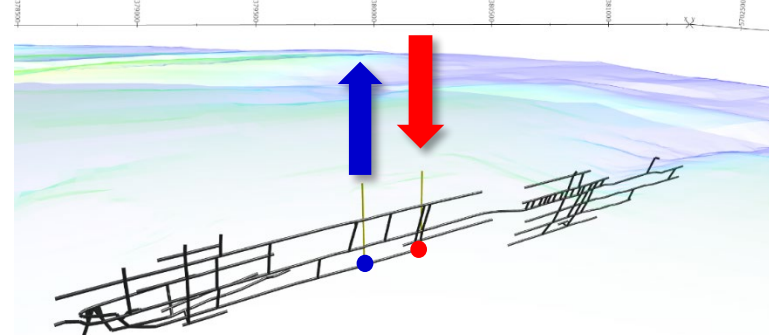
## Scenario B



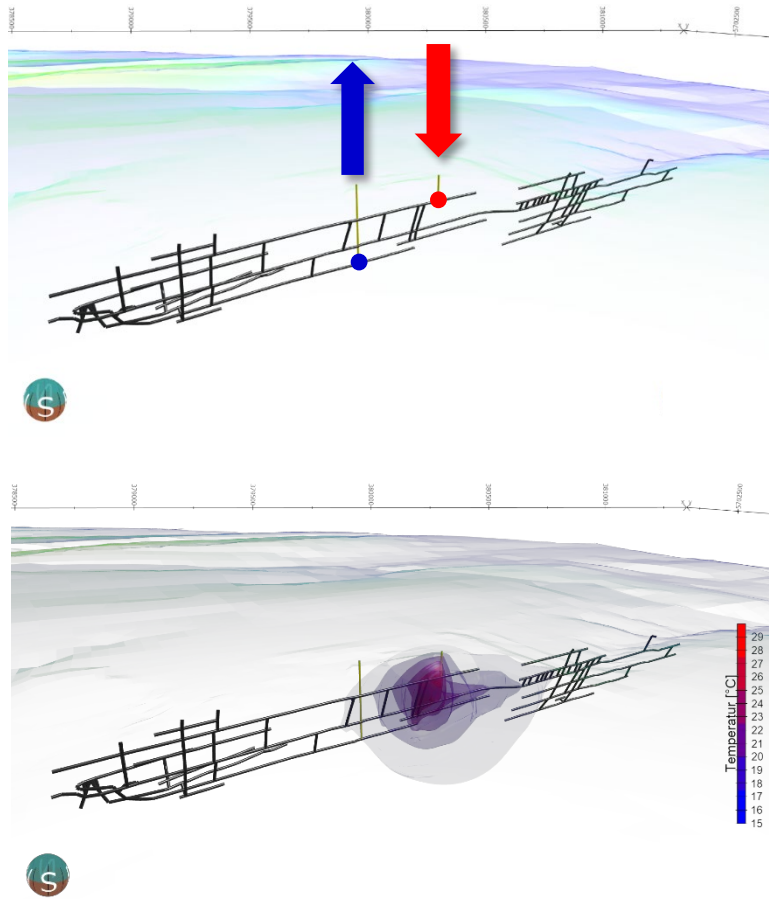
## Scenario B



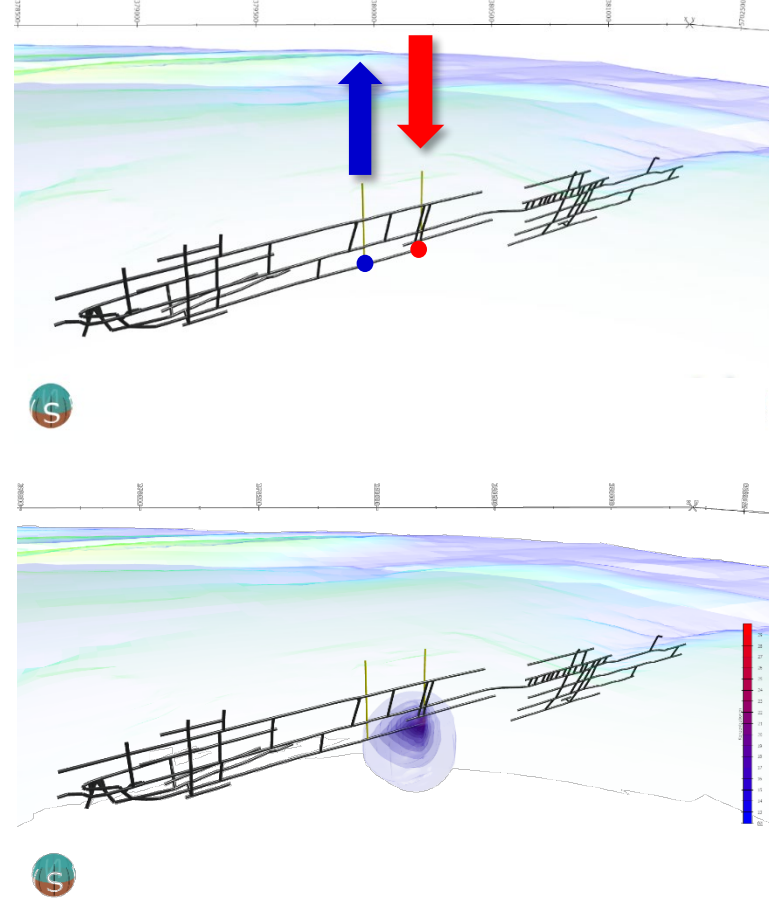
## Scenario C



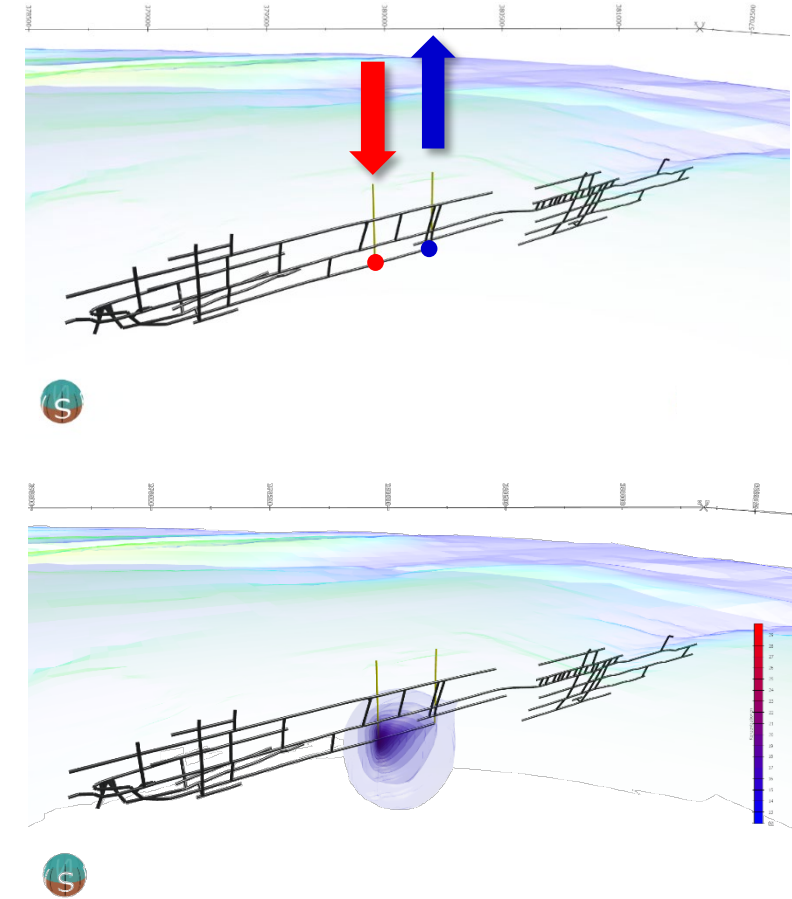
## Scenario B



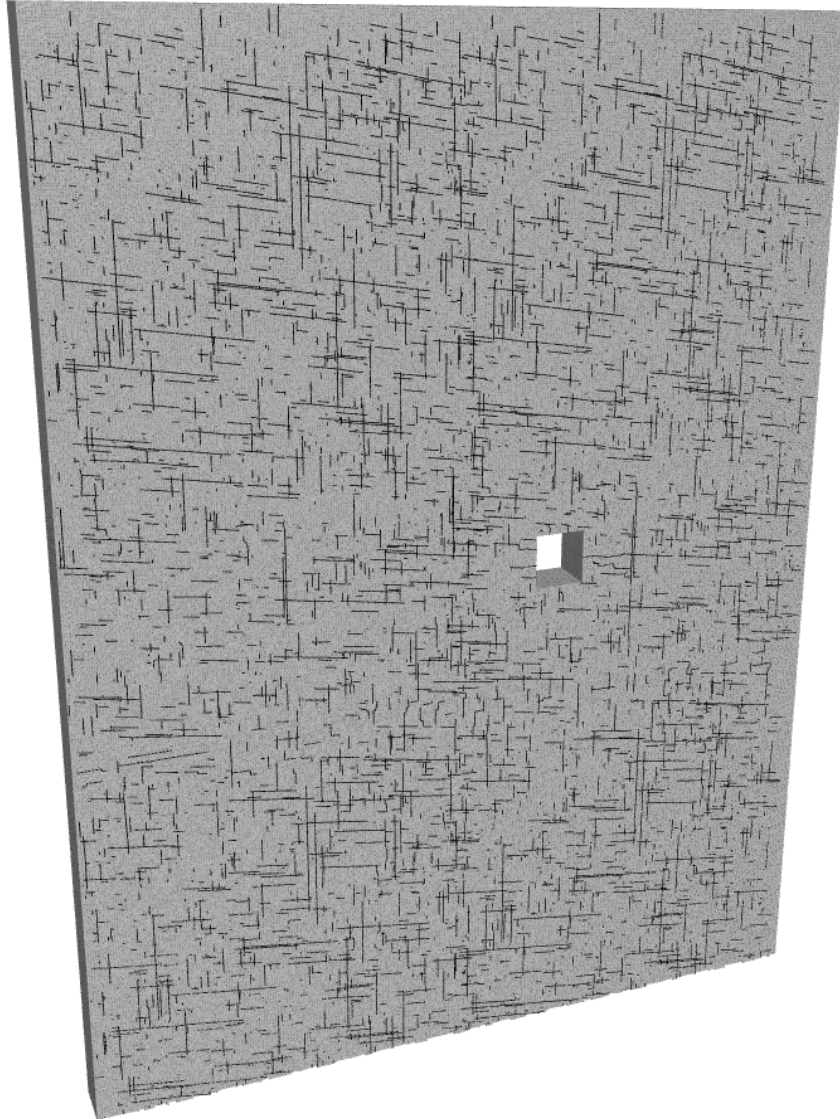
## Scenario C



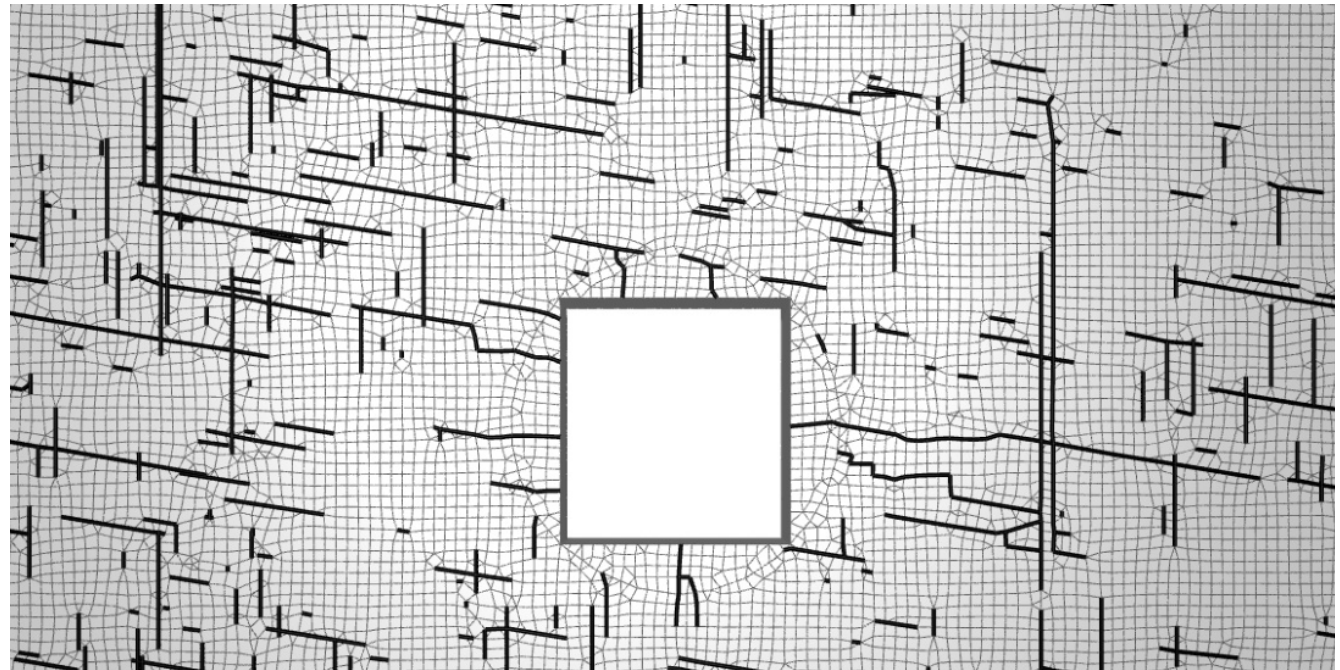
## Scenario D





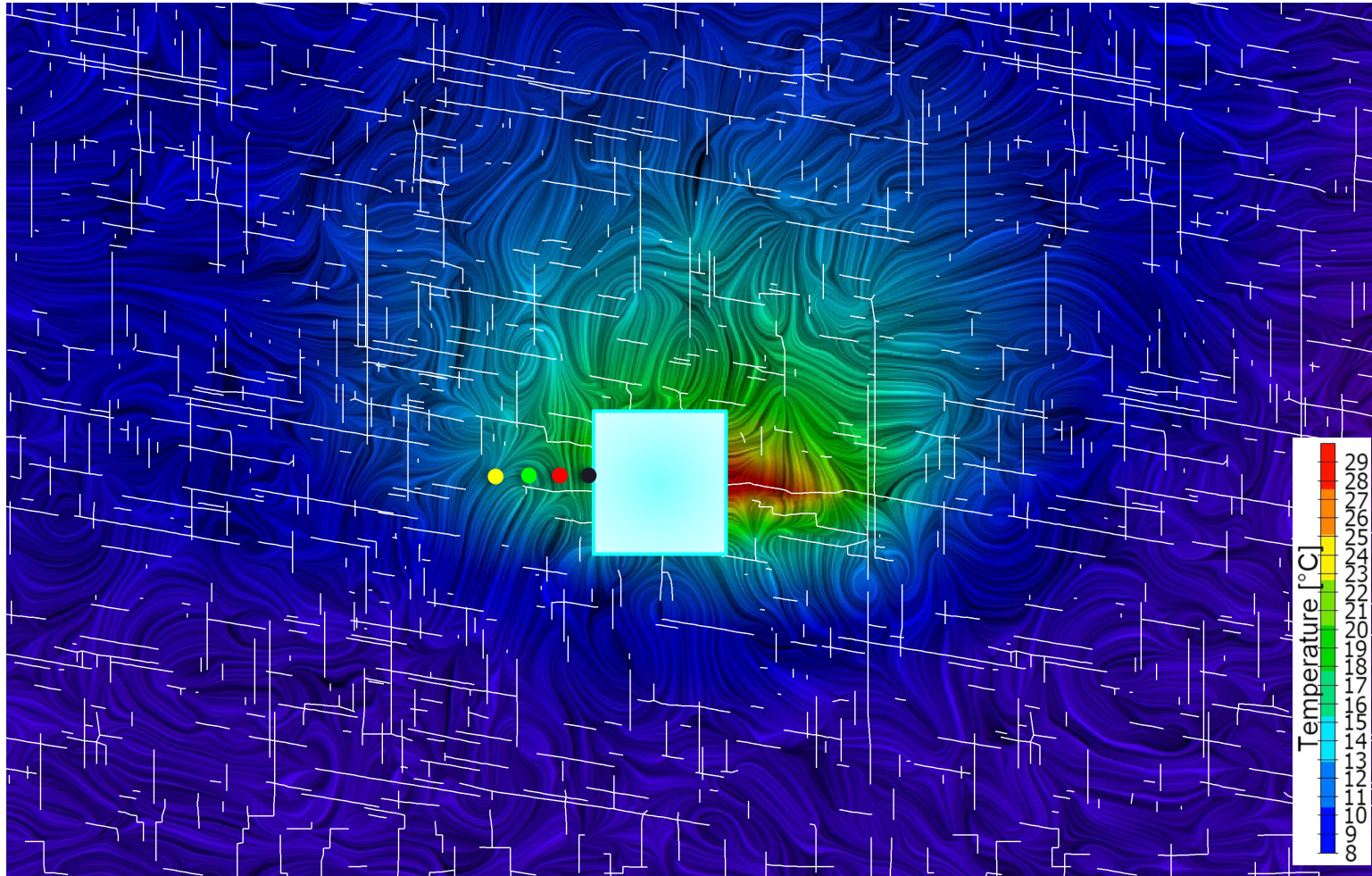


- 2D-vertical model
- 30x40 m
- 30.000 1D-fracture elements

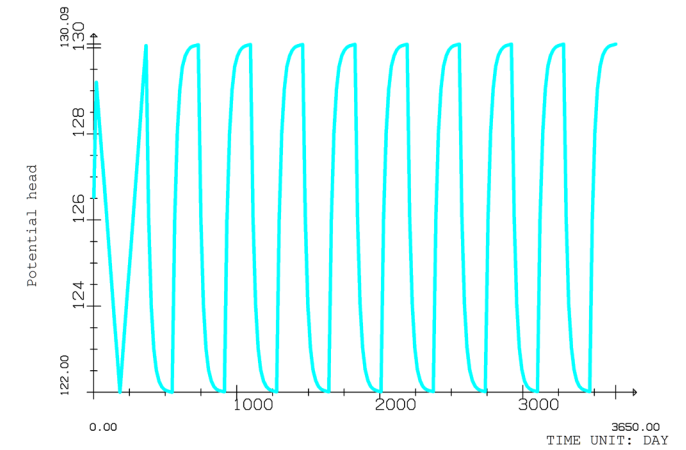




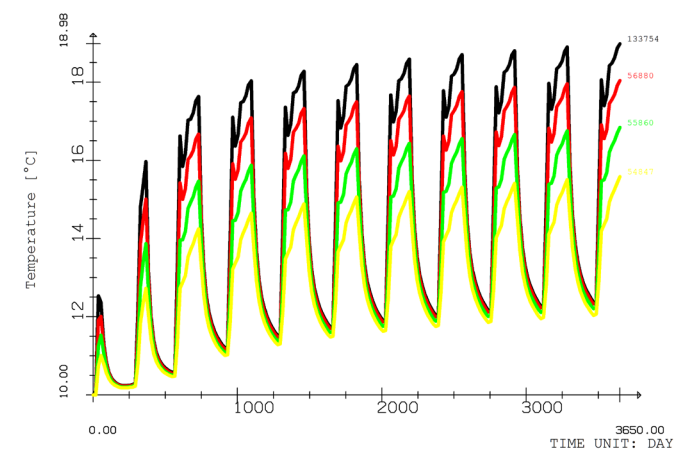
- Heat transport calculation
- Transient, 10-years



- BC mine: periodic potential head

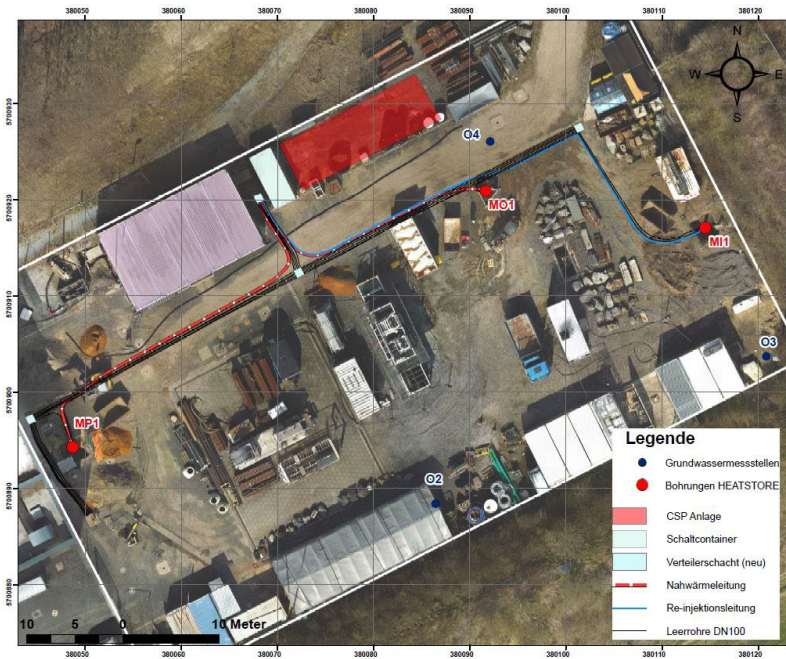


- Result: temperature









- Drilling to the mine
- Borehole development
- Installation of solar thermal system
- Commissioning

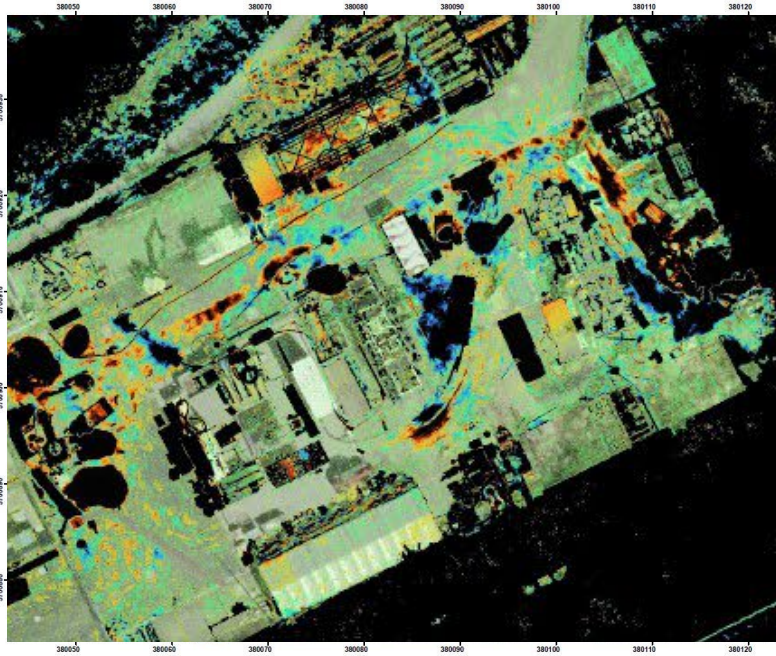
Summer 2020

Summer 2021



[Fraunhofer IEG]

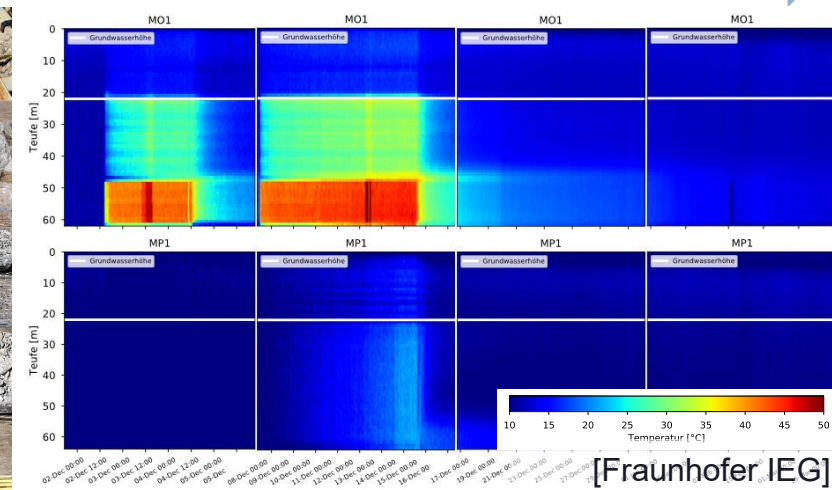
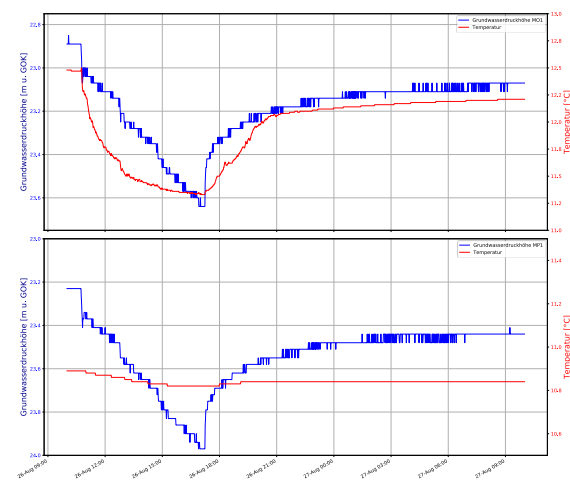


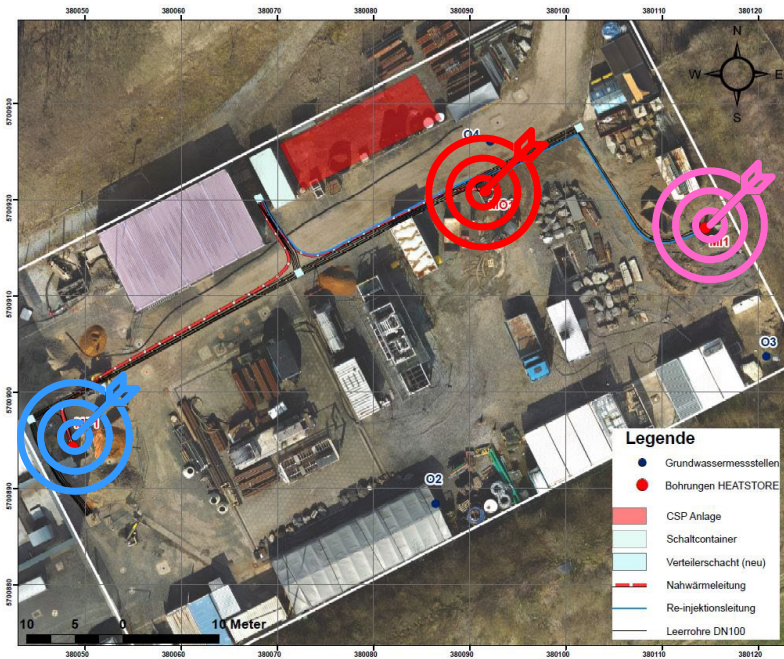


- Camera inspection
- Fiber optic evaluation
- Sampling
- Pump test
- Storage operation test
- Geomechanical monitoring

SPRING 2020

Summer 2022

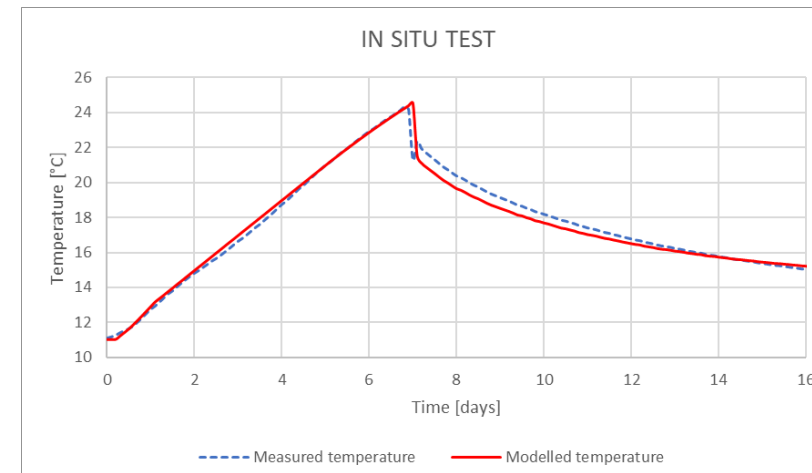
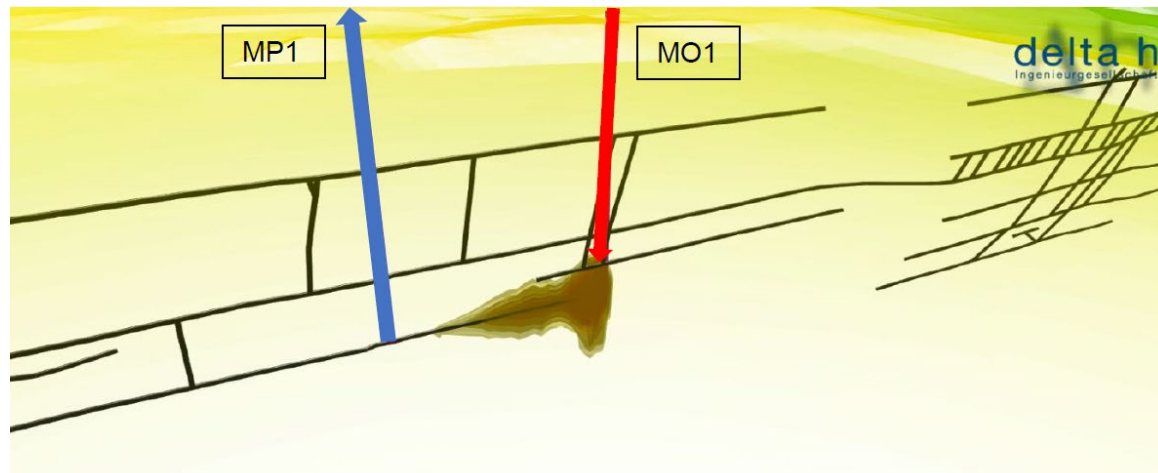




- MI1 well not productive
- Adjustment MO1-MP1 (Szenario C)
- Investigation of storage capacity
- → Coupling high temperature heat pump
- → Connection local heating network

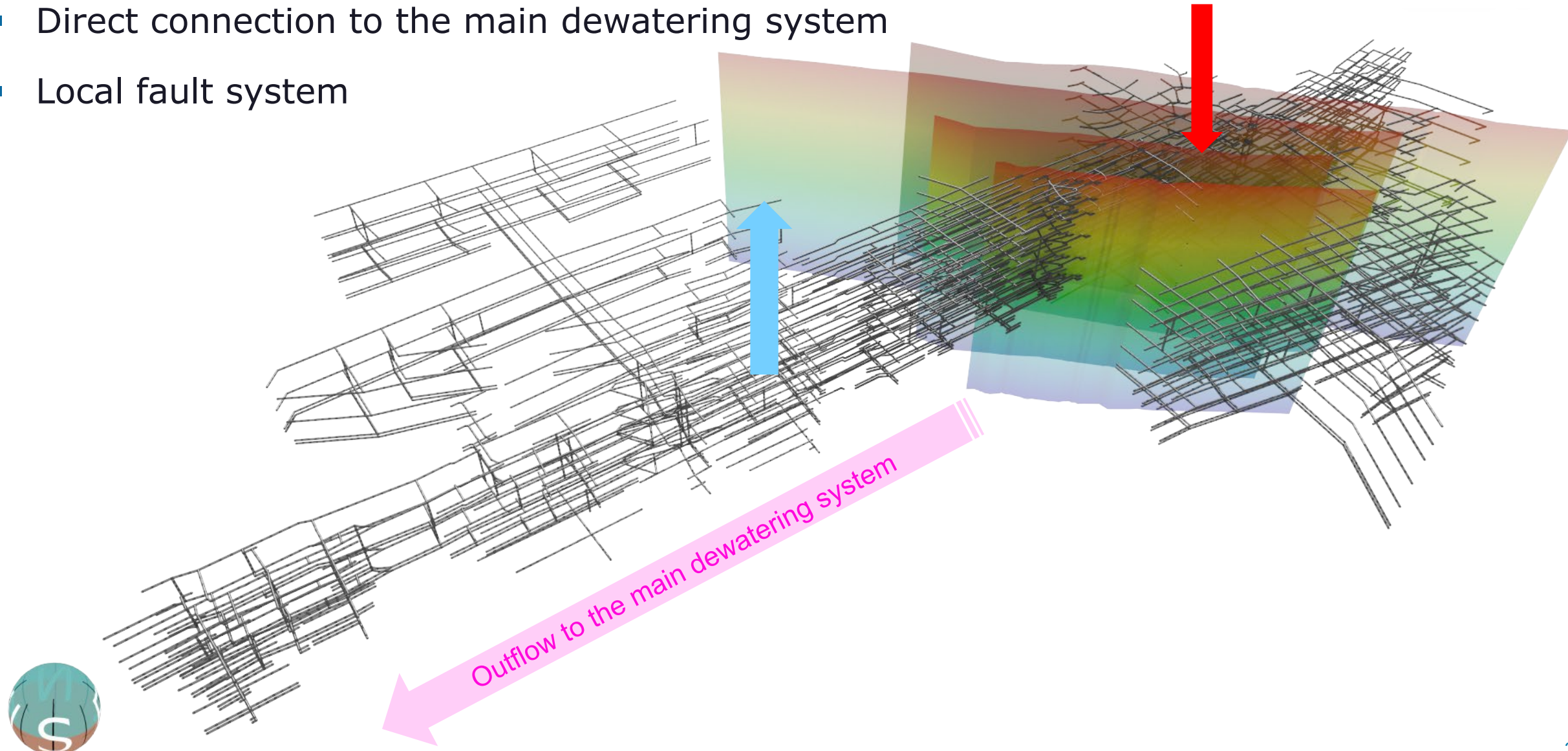
Summer 2022

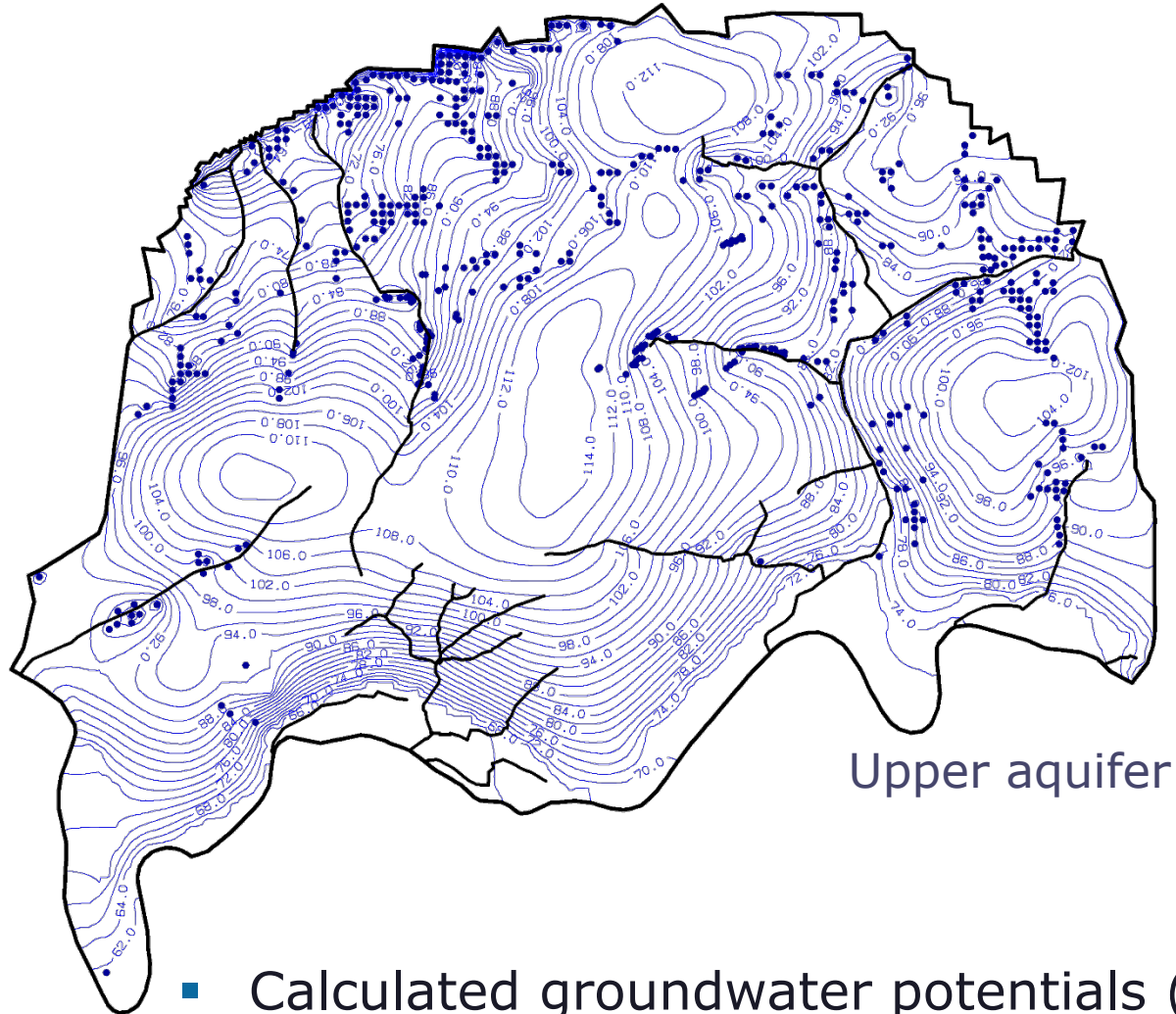
Winter 2022





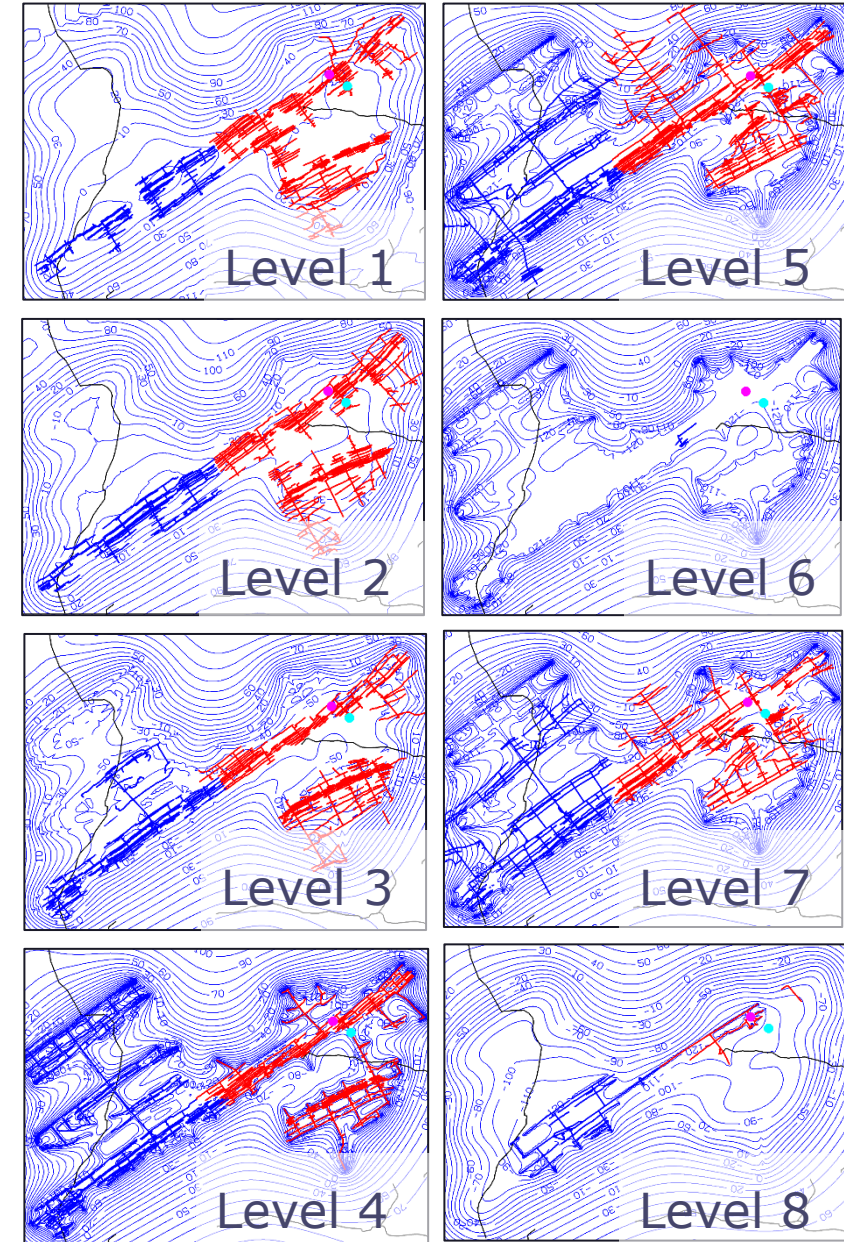
- Colliery Dannenbaum
- Direct connection to the main dewatering system
- Local fault system



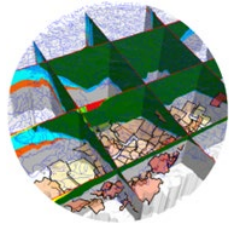


Upper aquifer

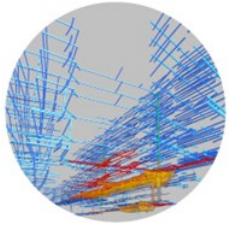
- Calculated groundwater potentials (steady state)
- Drainage areas



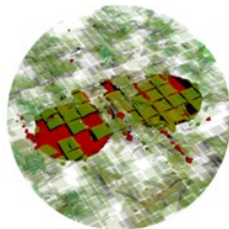




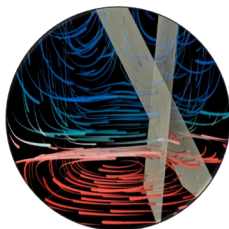
- Regional model with global mining system & flow regime  
→ boundary conditions



- Site models with refined geology & discrete mining system  
→ heat transport



- High-resolution detail models  
→ determination of input parameters



- TODO: more research  
→ geochemistry / density stratification / heat exchanger?

THANK YOU FOR YOUR ATTENTION

[ts@delta-h.de](mailto:ts@delta-h.de)



WINZER: Heat storage in coal mines of the Ruhr area (WINZER) is a project under the GEO:N "Geo Research for Sustainability" fund on the topic of "Digital Geosystems: Virtual Methods and Digital Tools for Geoscientific Applications".

In cooperation with: Fraunhofer IEG Bochum, Technical University Bergakademie Freiberg, Technical Thermodynamics (tTD), Ruhr University Bochum (RUB)  
Funded by: German Federal Ministry of Education and Research, Projektträger Jülich (PtJ)