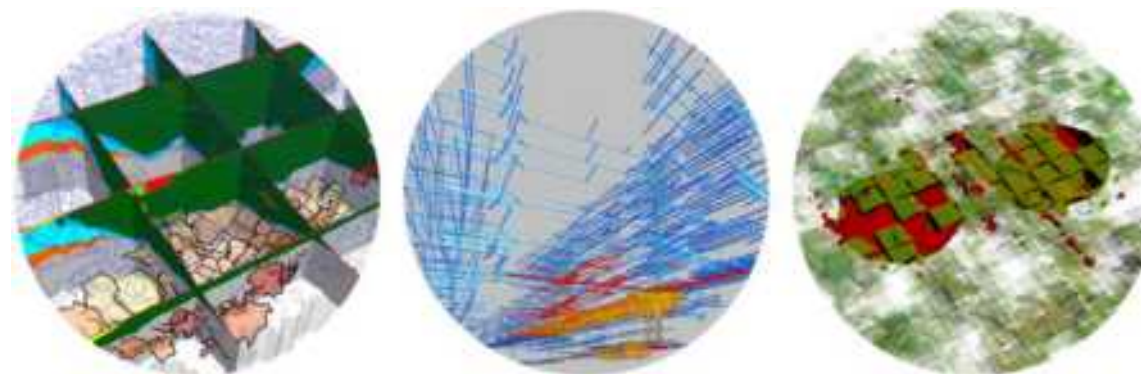




West Virginia Mine Drainage Task Force Symposium &
15th International Mine Water Association Congress
April 21–26, 2024 | Morgantown, WV, USA

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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²Fraunhofer IEG, Bochum, NRW, Germany

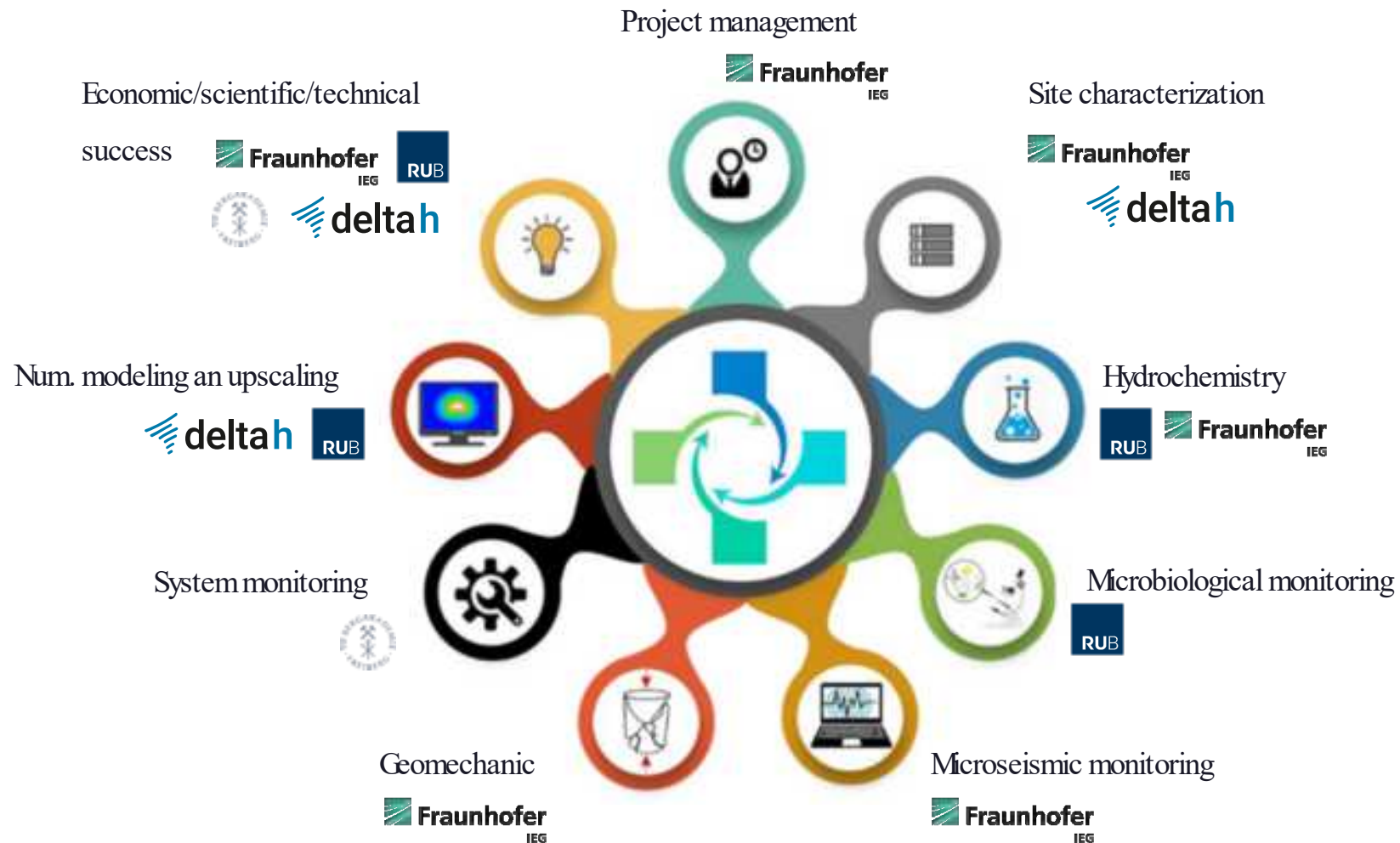
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In cooperation with:



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





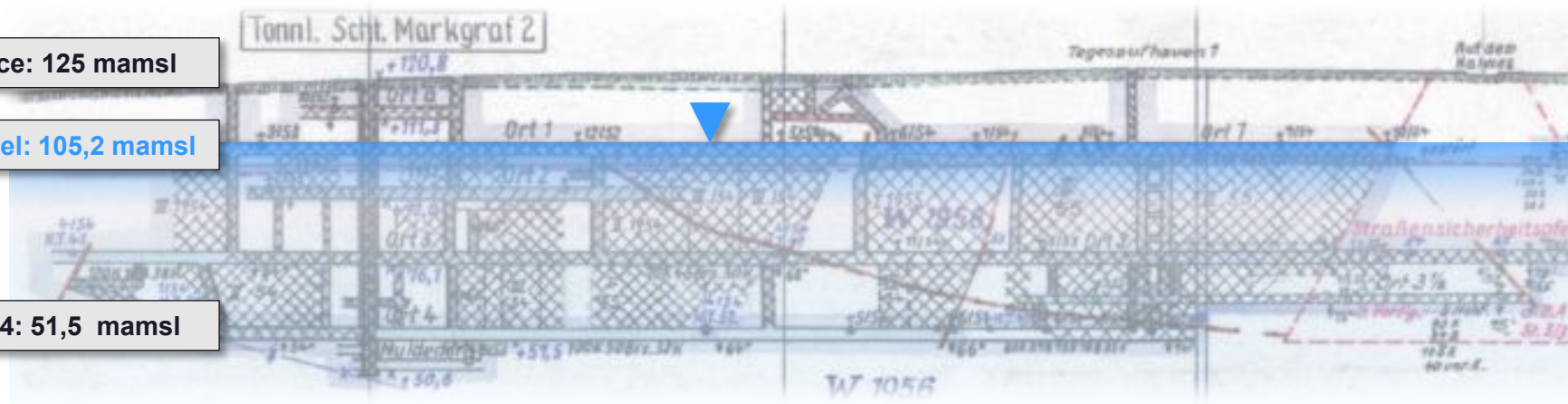
West

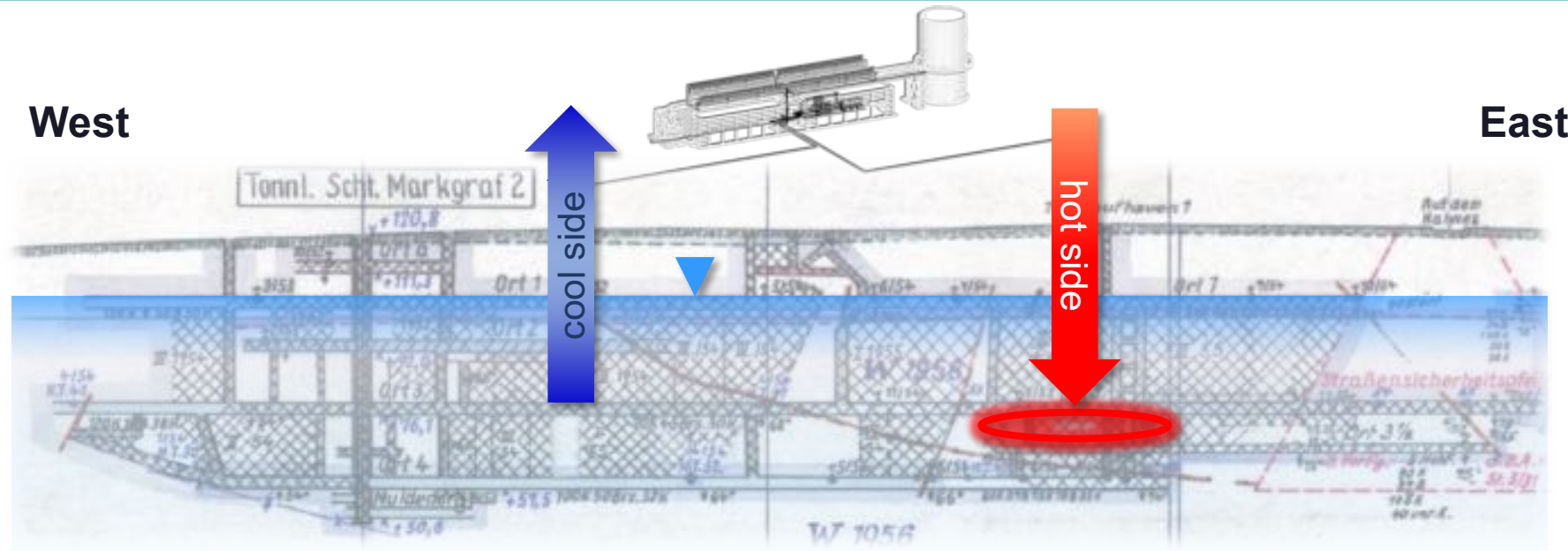
East

Surface: 125 mamsl

GW-level: 105,2 mamsl

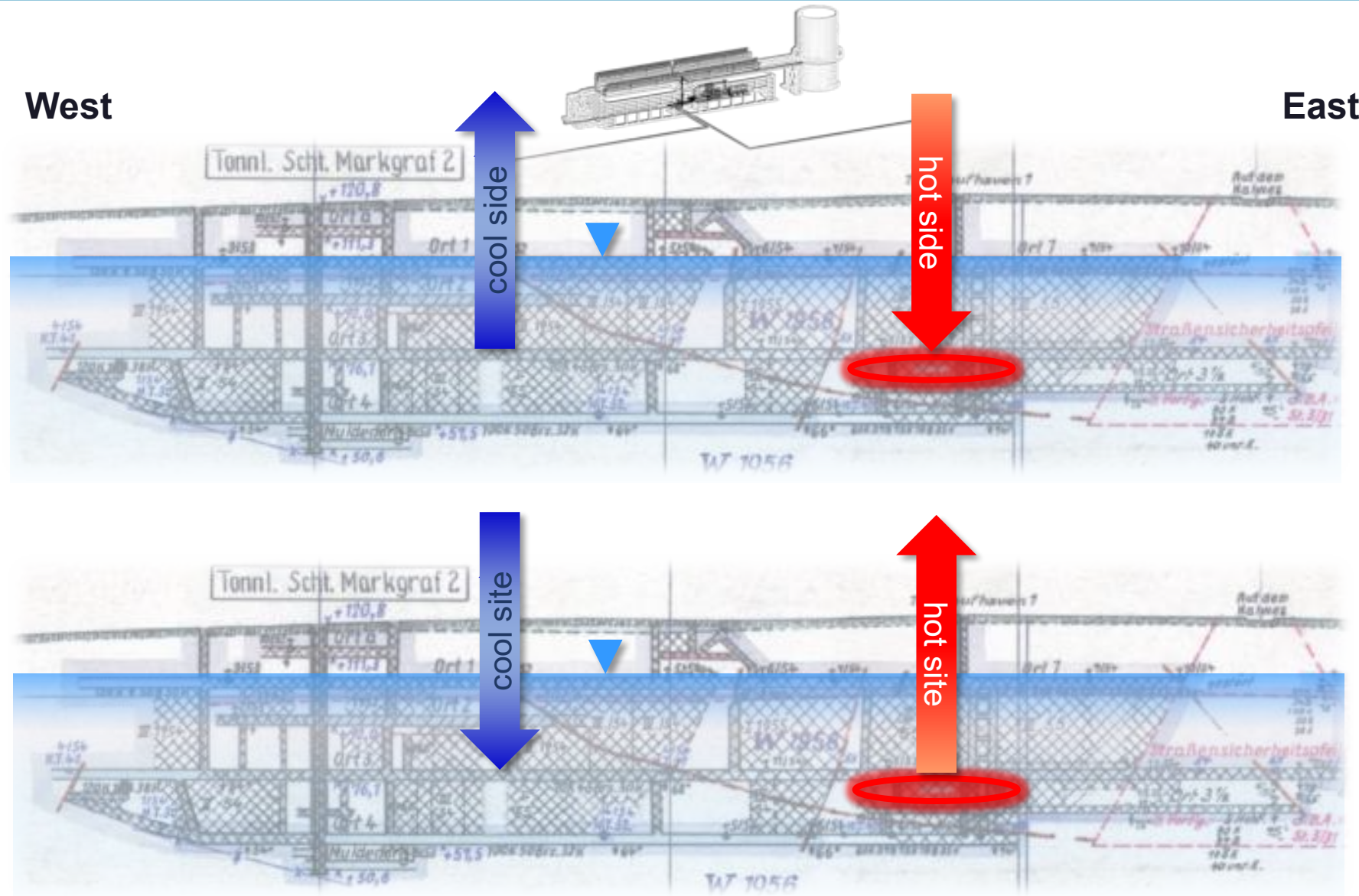
Level 4: 51,5 mamsl



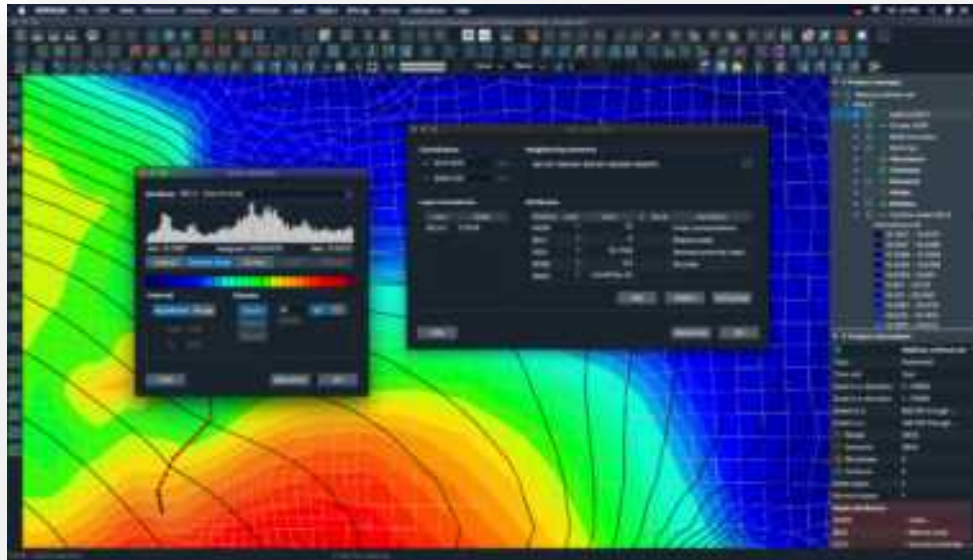


Summer:

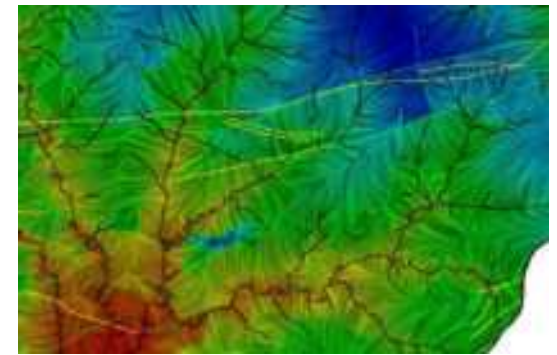
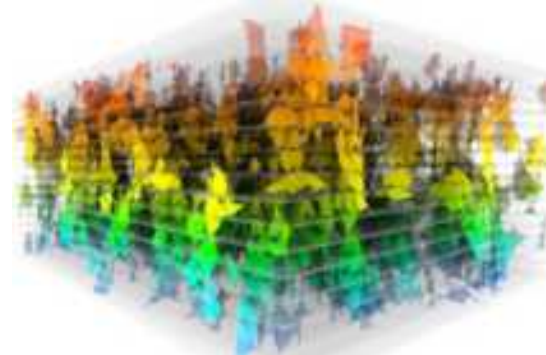
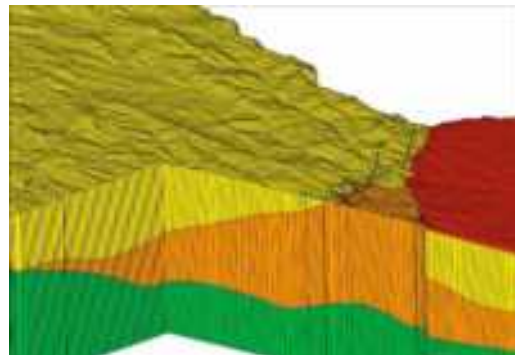
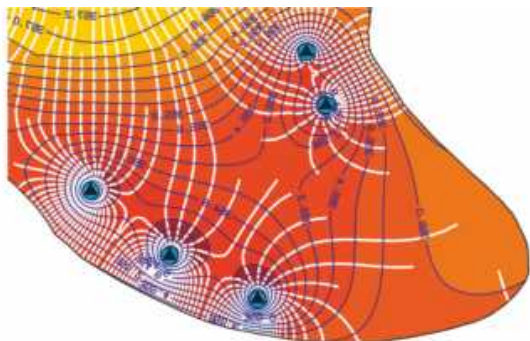
- solar thermal charging

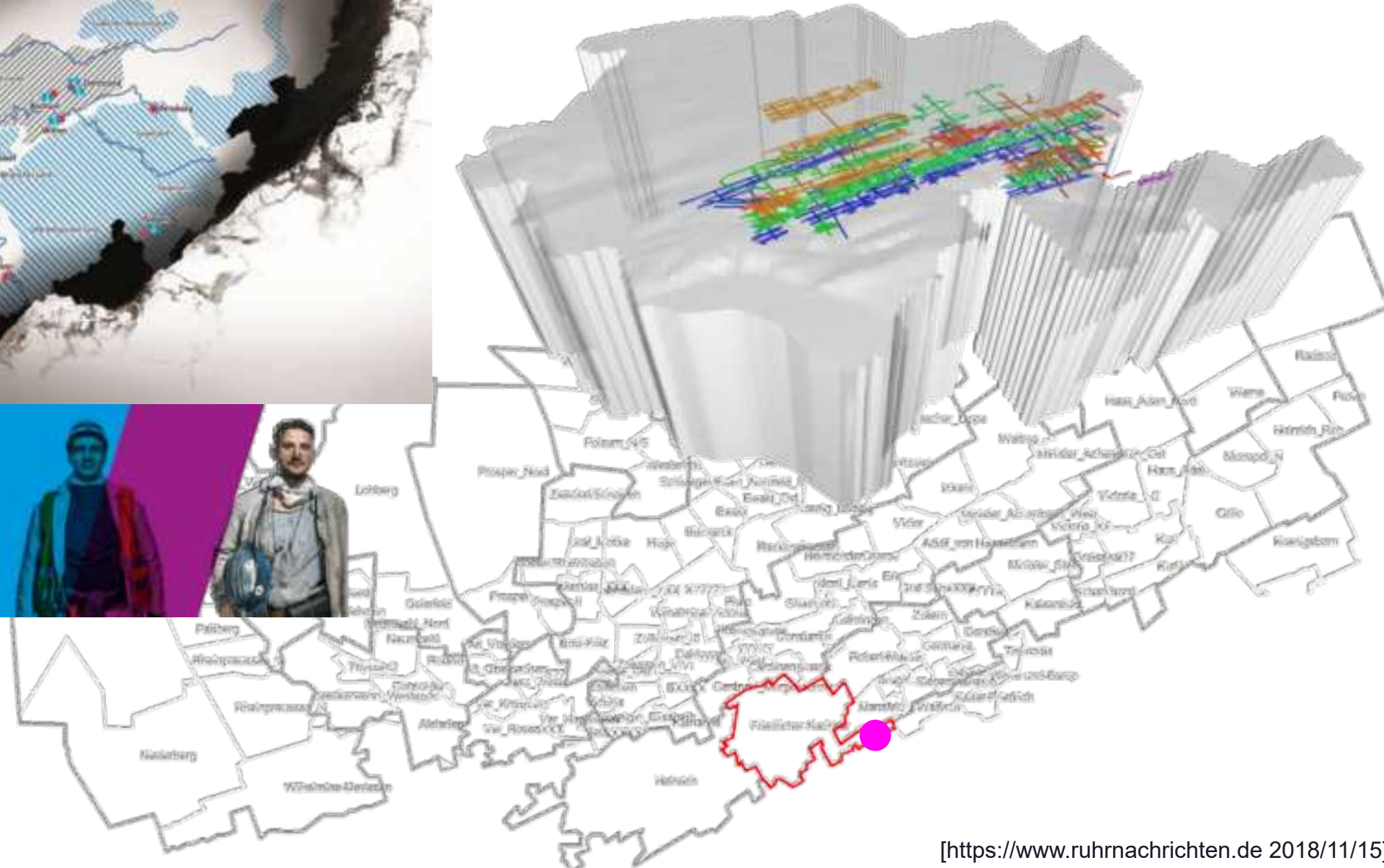
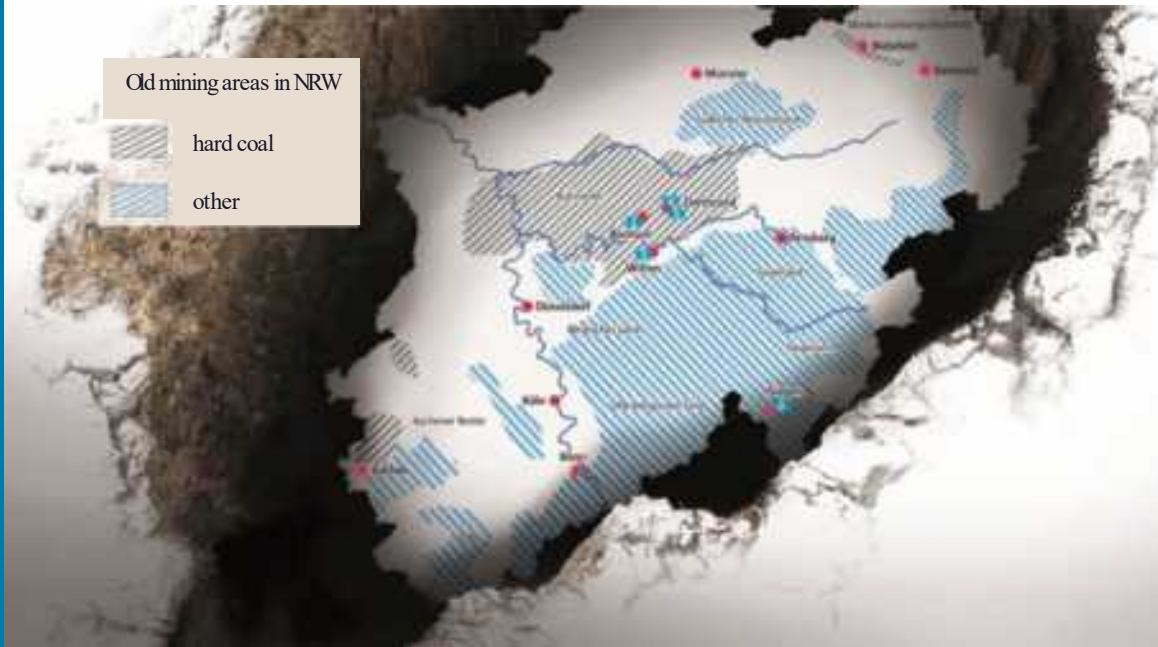


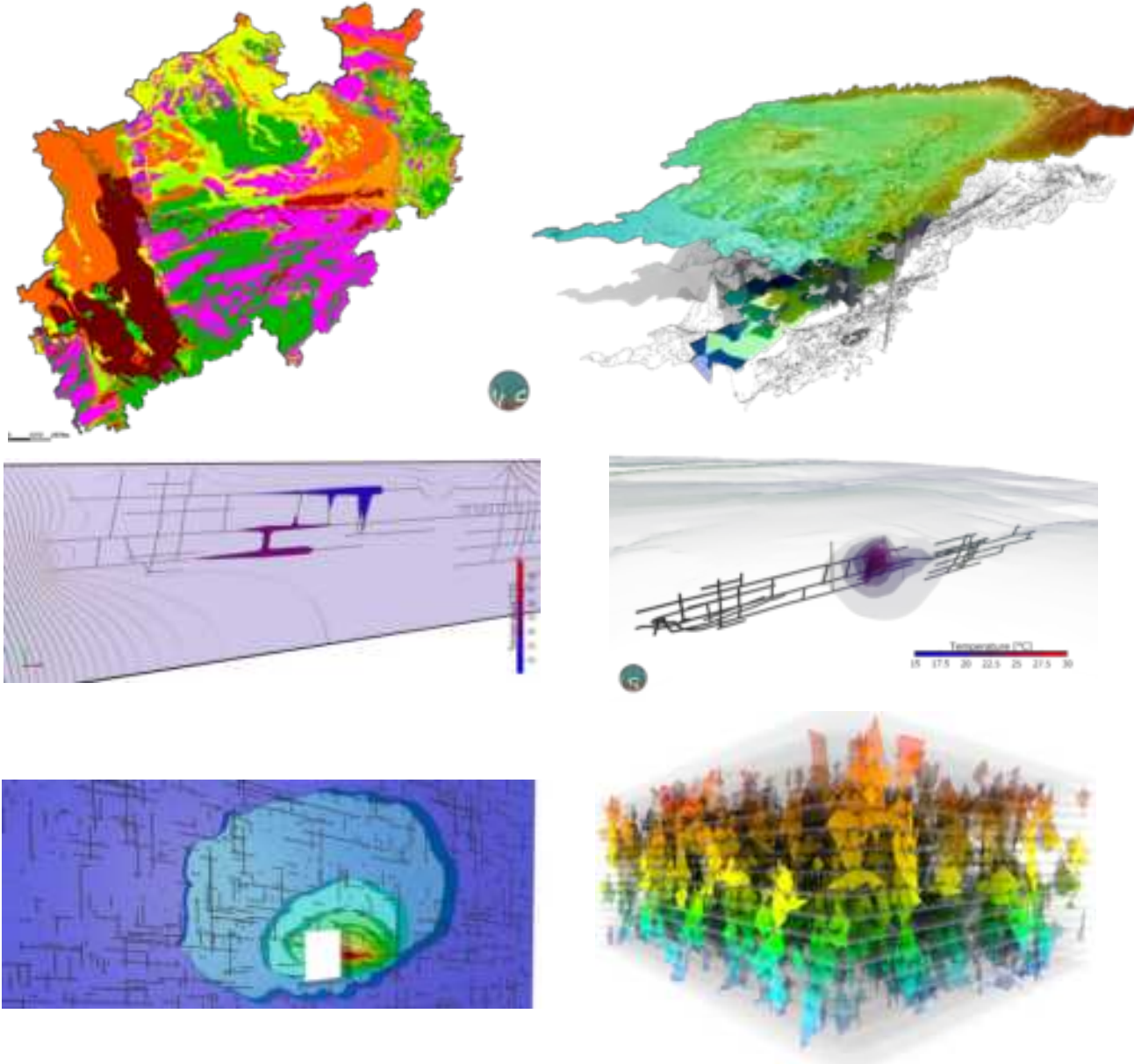
SPRING – Simulation of Processes in Groundwater



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





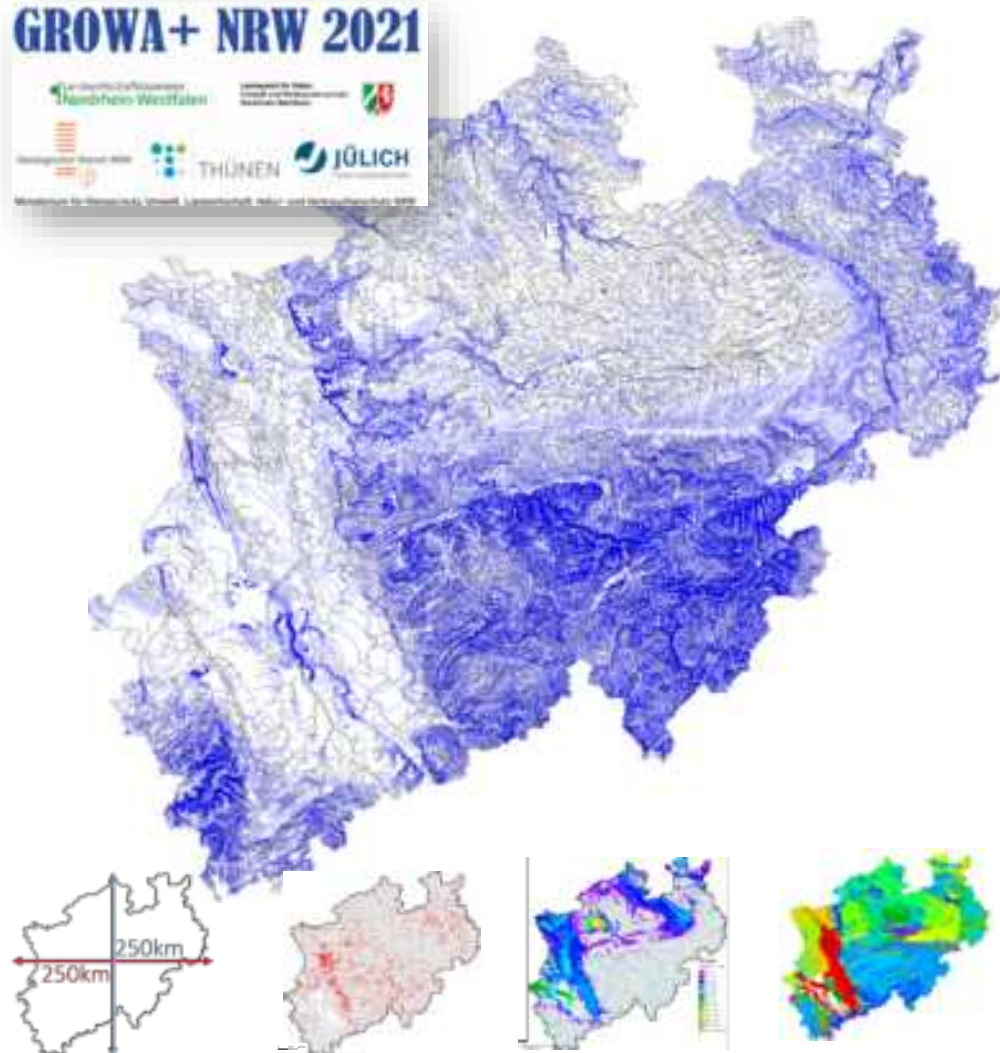


- Regional

- Site

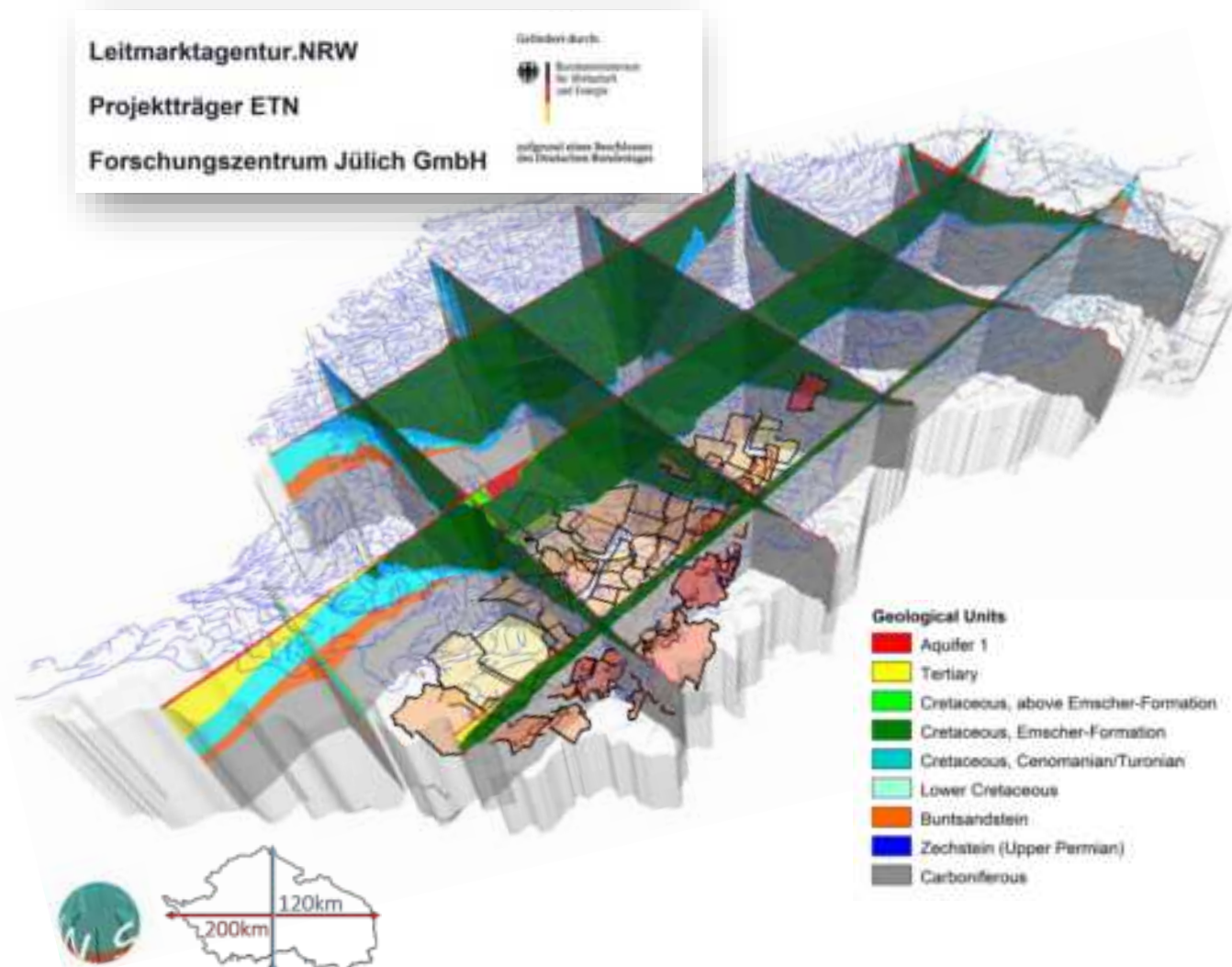
- Detail

Groundwater model NRW

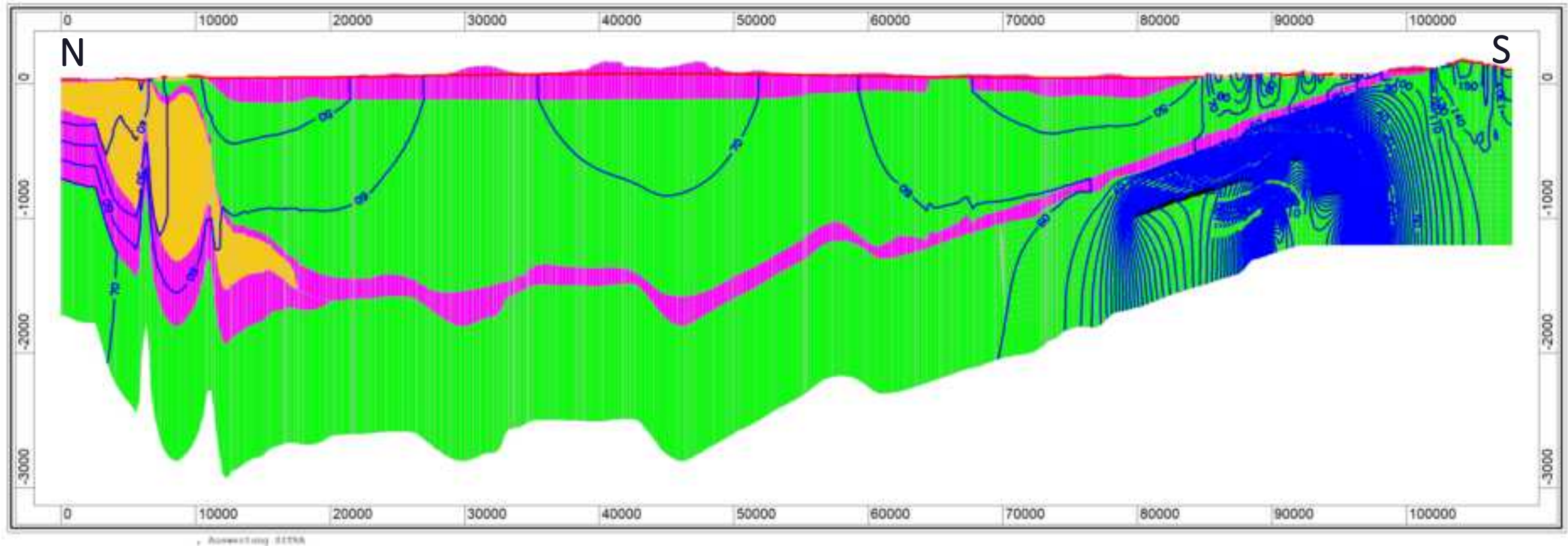


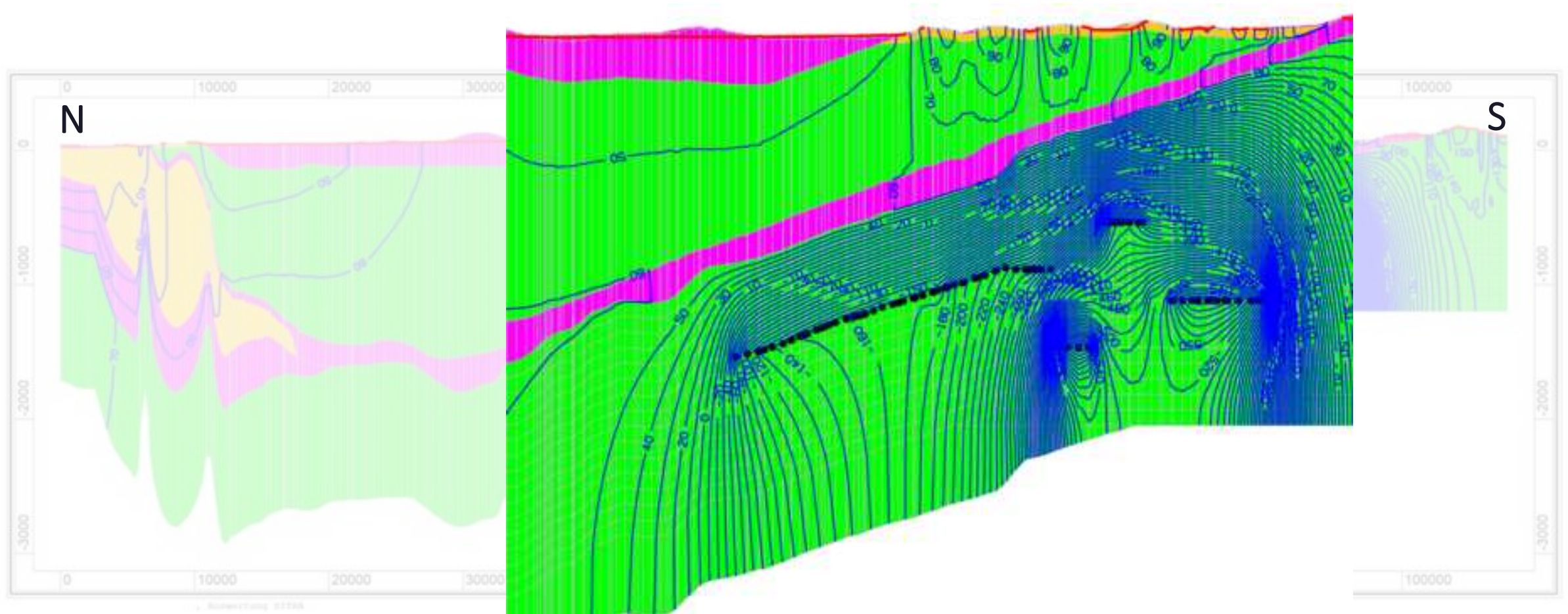
GW-recharge, GW-measuring, Layer thickness, hydraul. cond. (calibrated), free GW-surface

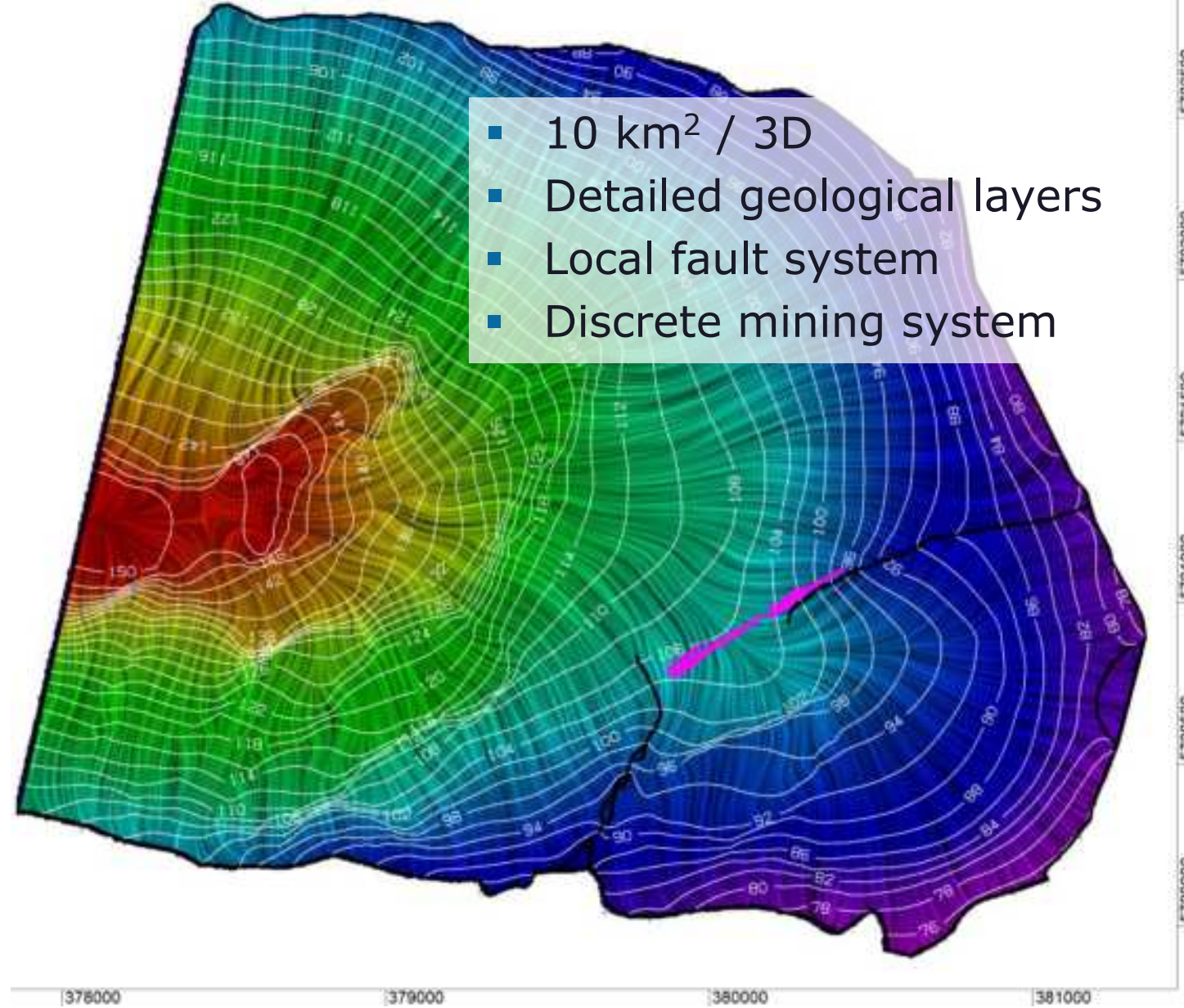
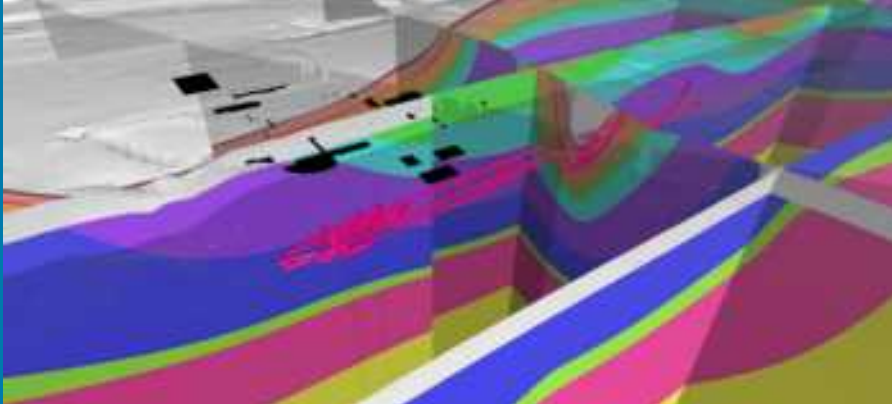
„Muensterland Cretaceous Basin Model“

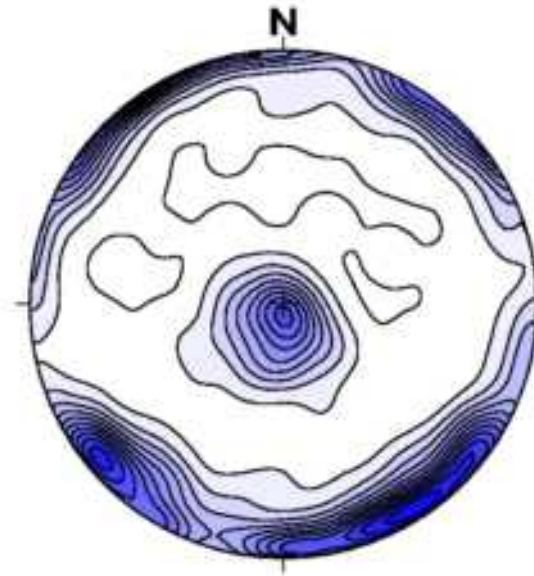


Geological layers, influence of mine drainage as boundary condition for site model







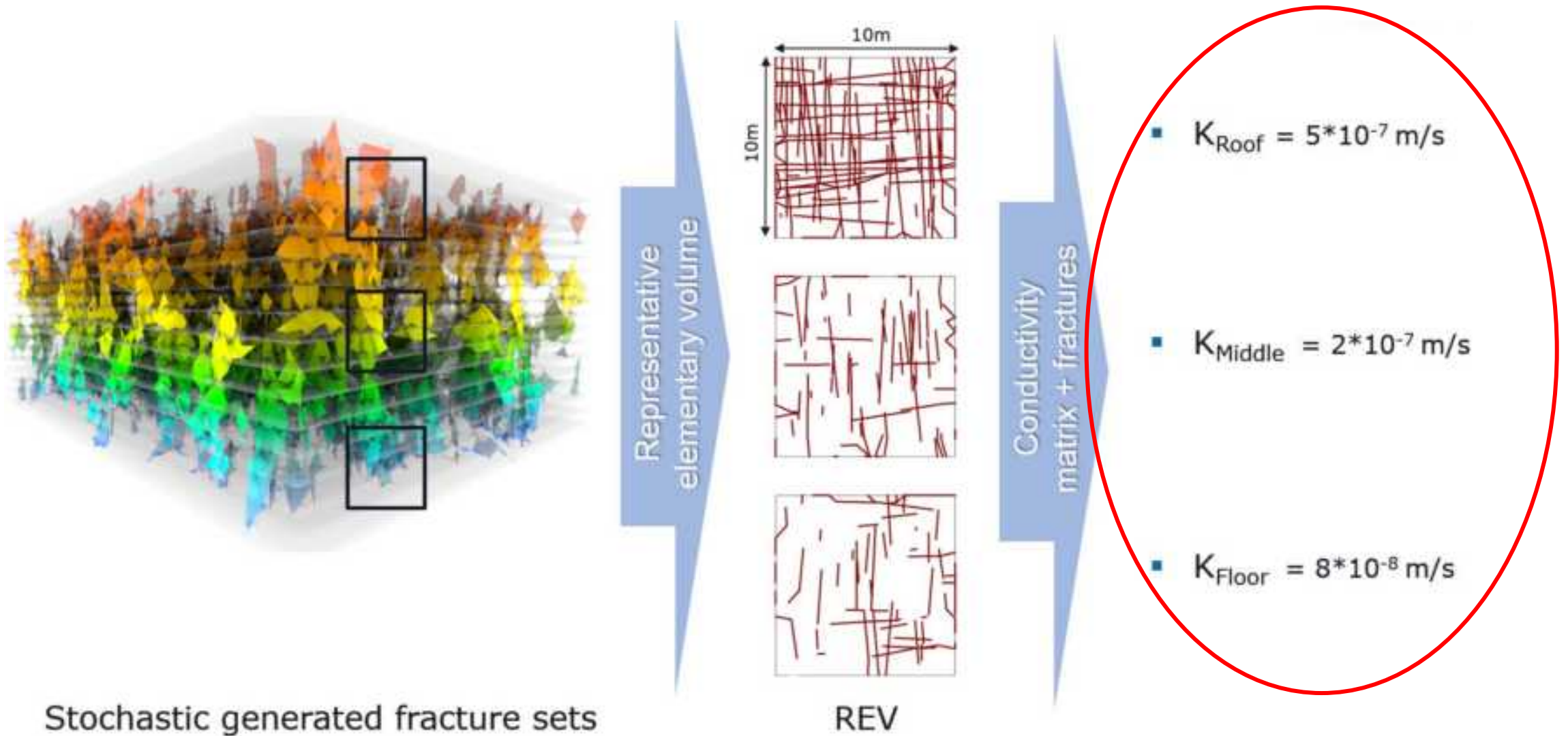


Measured fractured sets:

- Fracture orientation
- Fracture size
- Fracture density
- Aperture

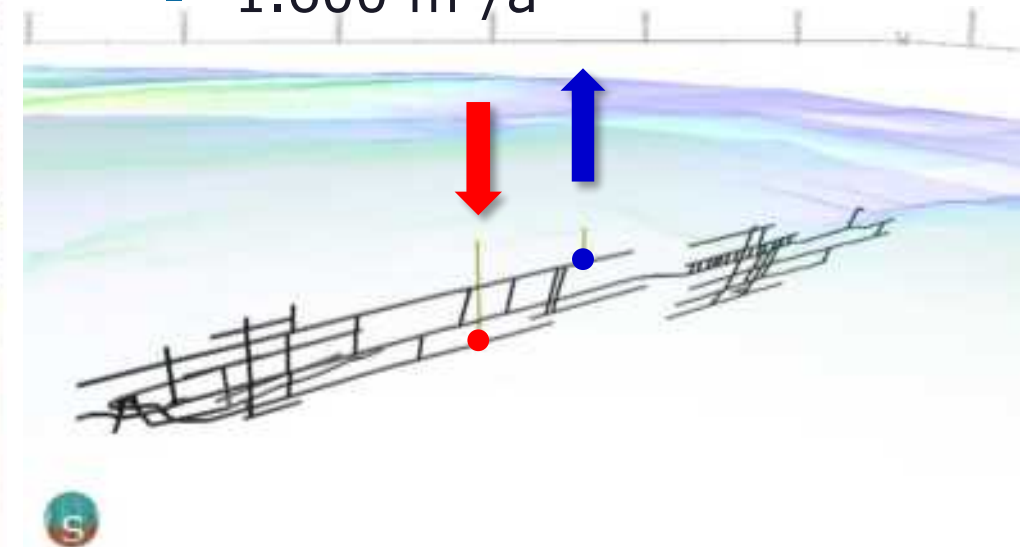
cluster	orientation in space	spherical angle Q	spherical variance s	concentration parameter k
I	$(a, f) = (274^\circ, 88^\circ)$	8.2°	0.95	16
II	$(a, f) = (71^\circ, 6^\circ)$	8.2°	0.95	17
III	$(a, f) = (309^\circ, 4^\circ)$	12.3°	2.35	16

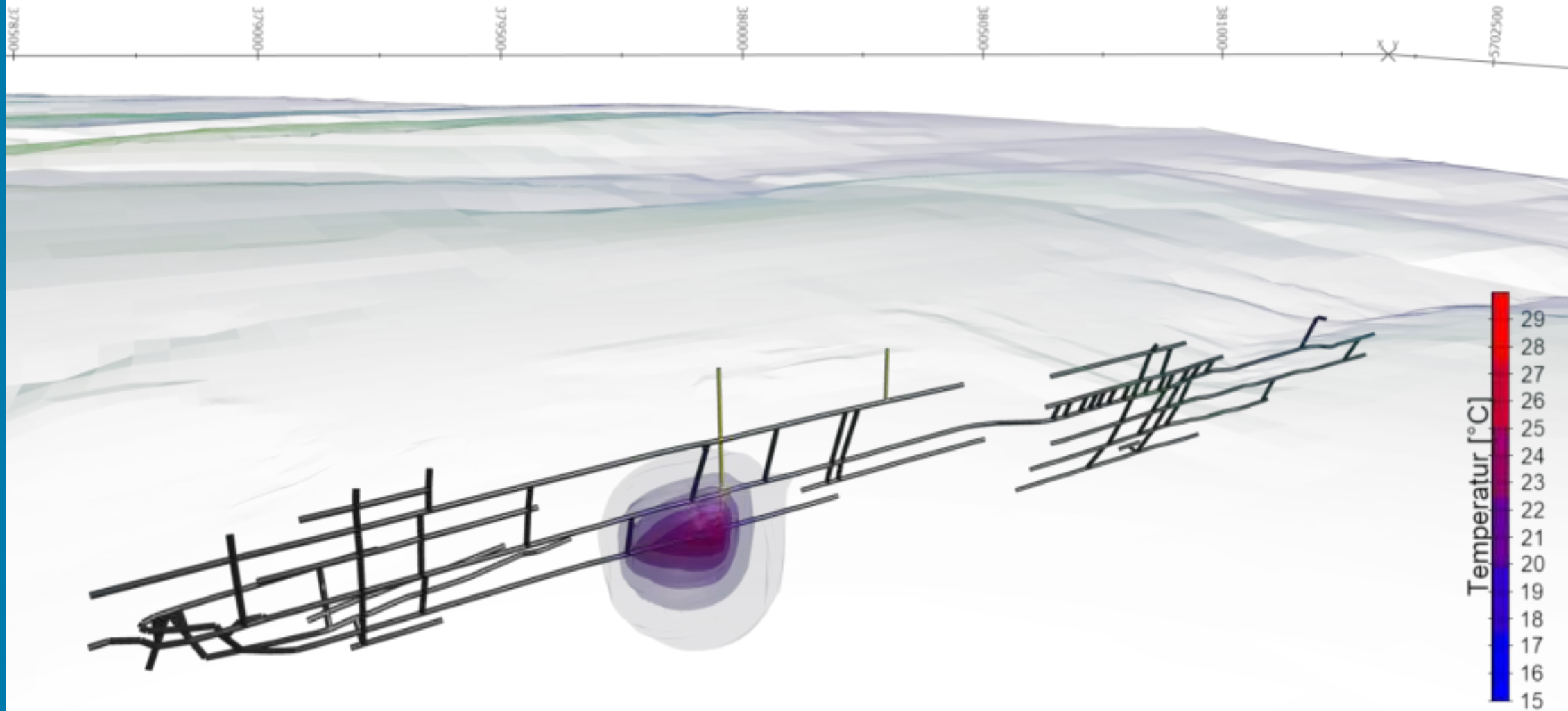
*Calculation and Mesh Generation of a Three-Dimensional Matrix-Fracture-System
Christoph König, Britta Rosen University of Bochum, Germany*





- Steady state
(flow and heat transport)
- MI1 cool site Ort 1
- MP1 hot site Ort 4 (35°C/95°F)
- 1.600 m³/a

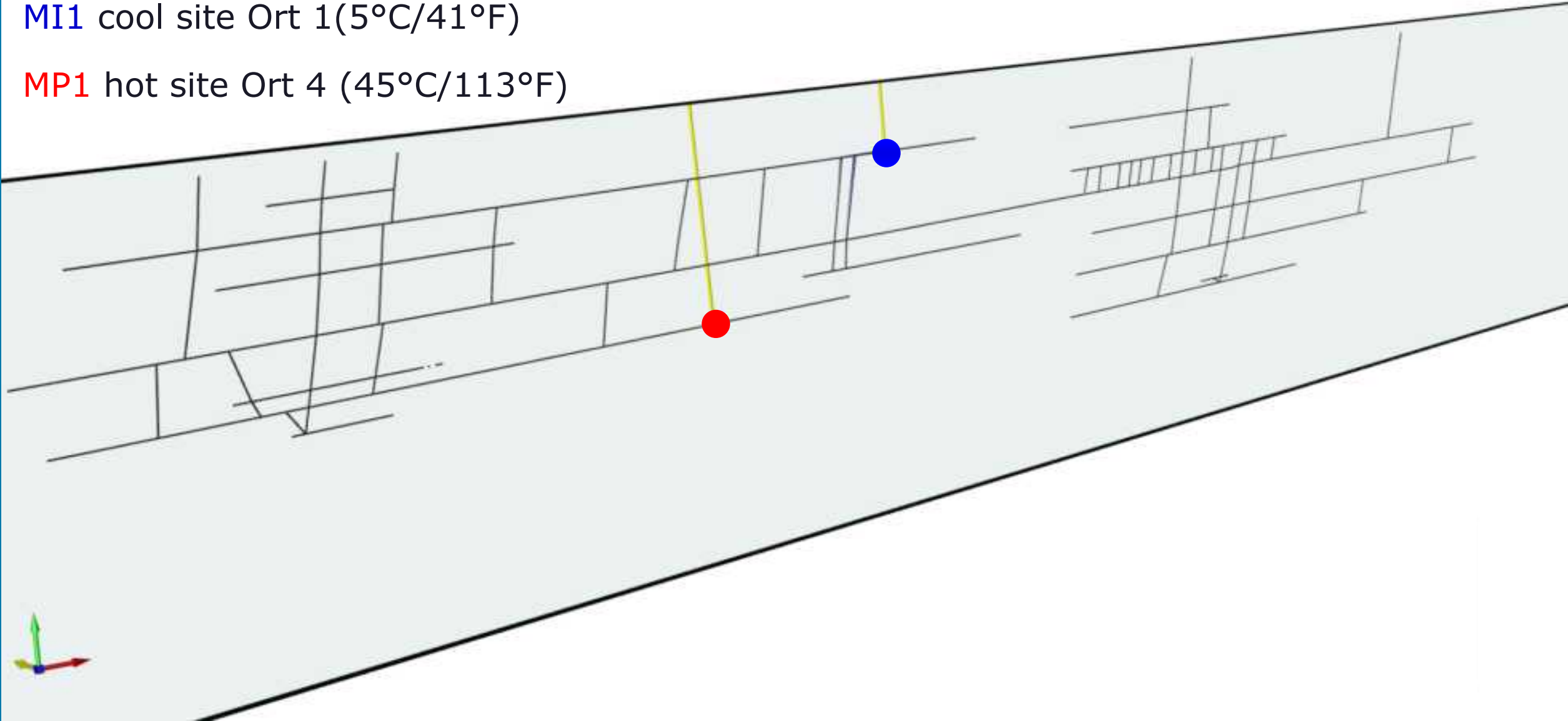




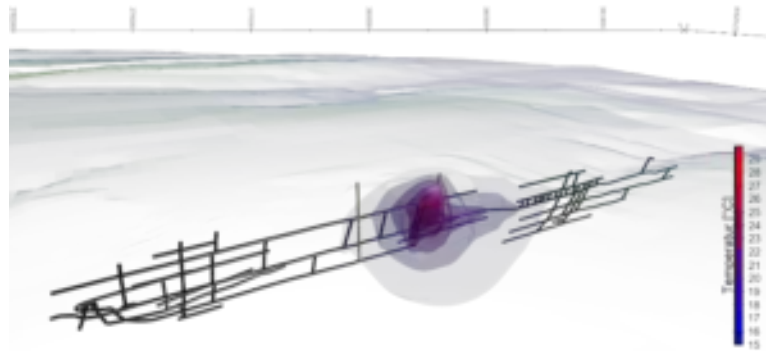
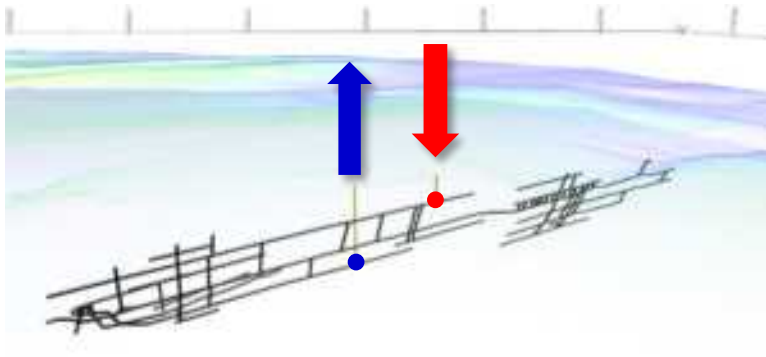
Transient calculation (flow and heat transport)

MI1 cool site Ort 1(5°C/41°F)

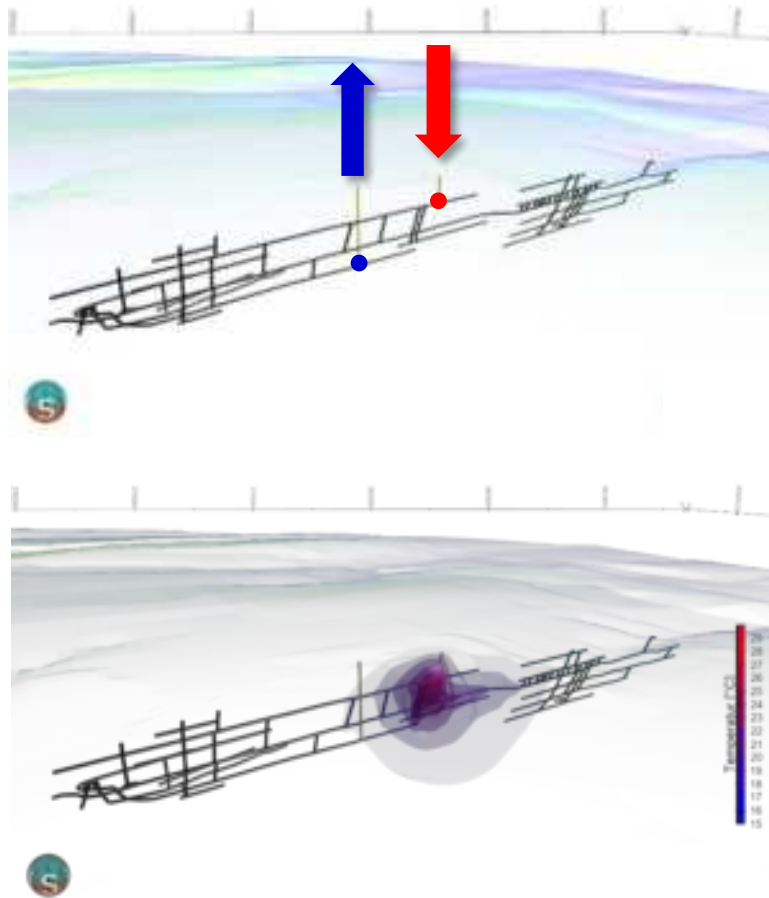
MP1 hot site Ort 4 (45°C/113°F)



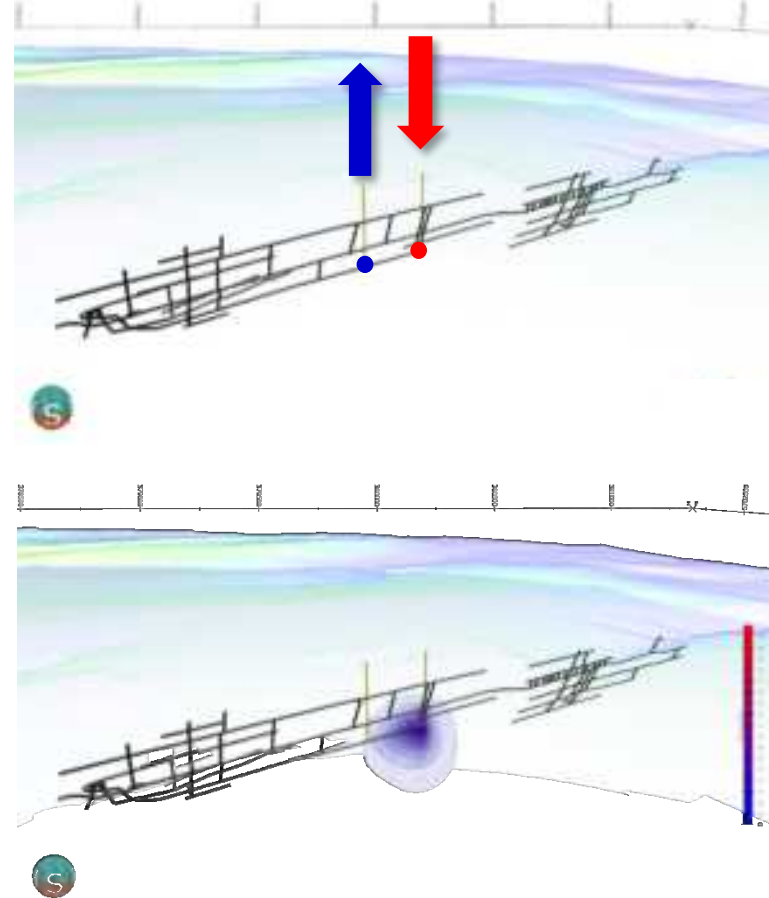
Scenario B



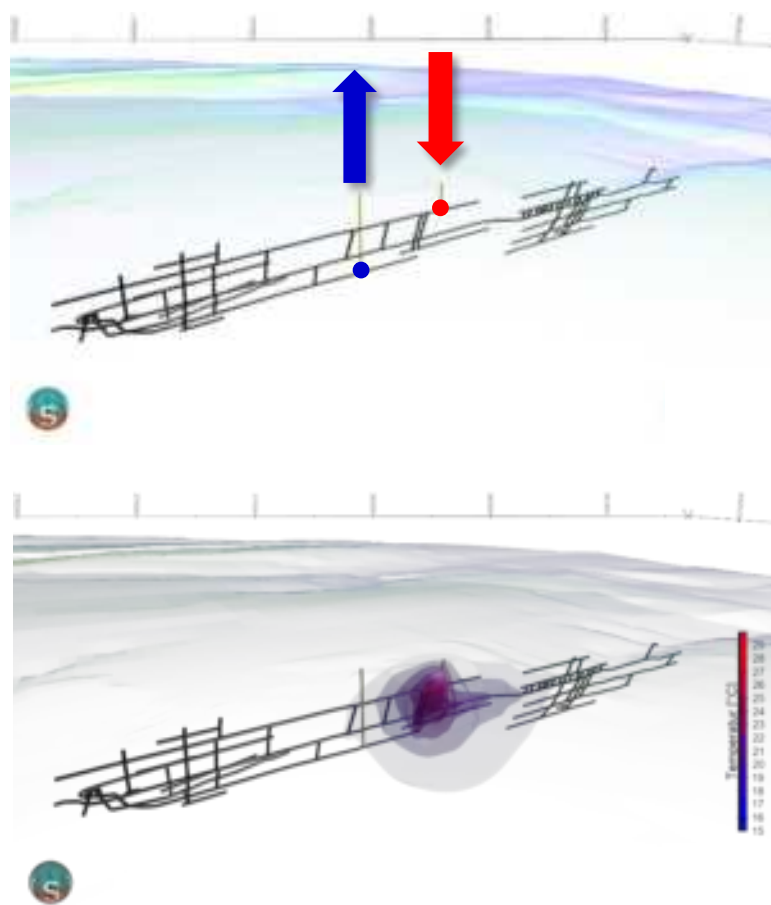
Scenario B



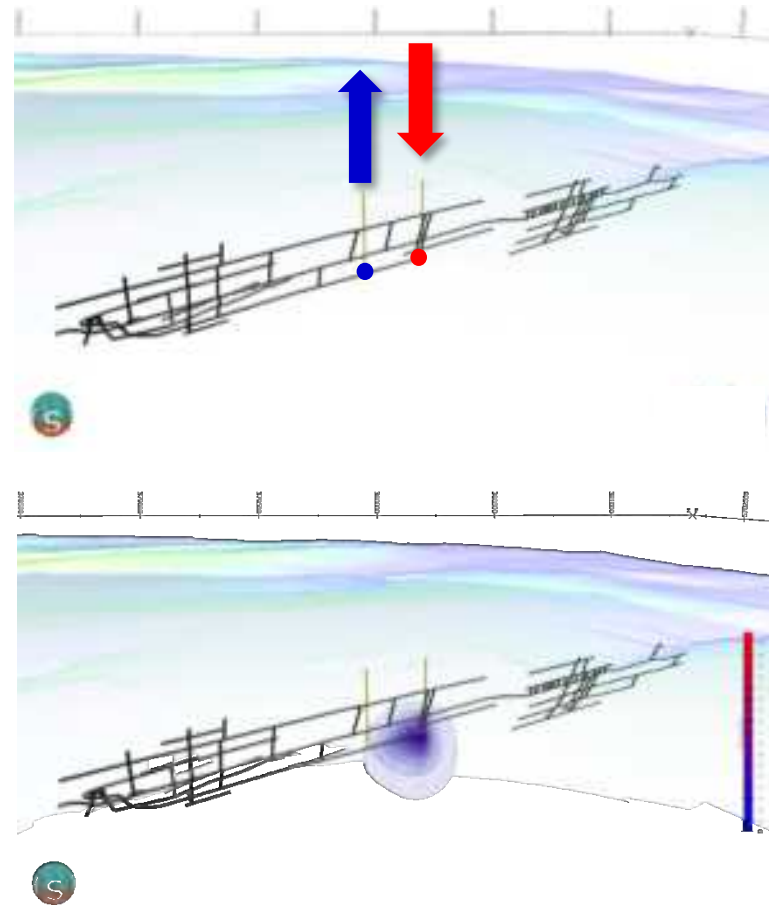
Scenario C



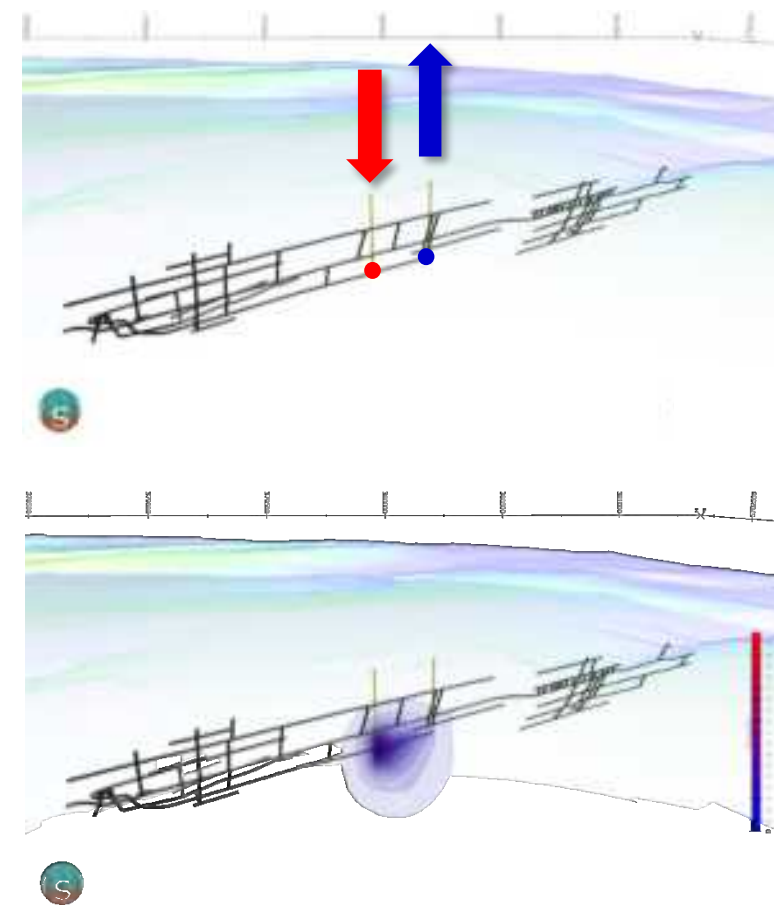
Scenario B

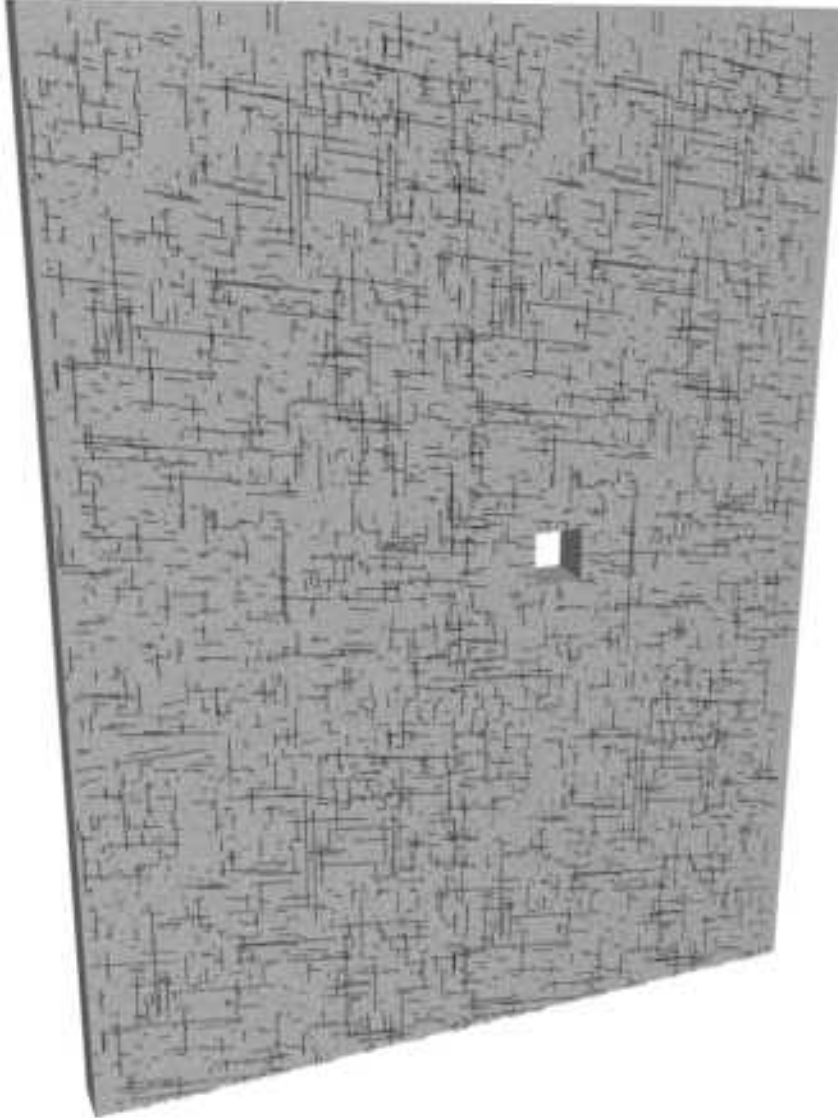


Scenario C

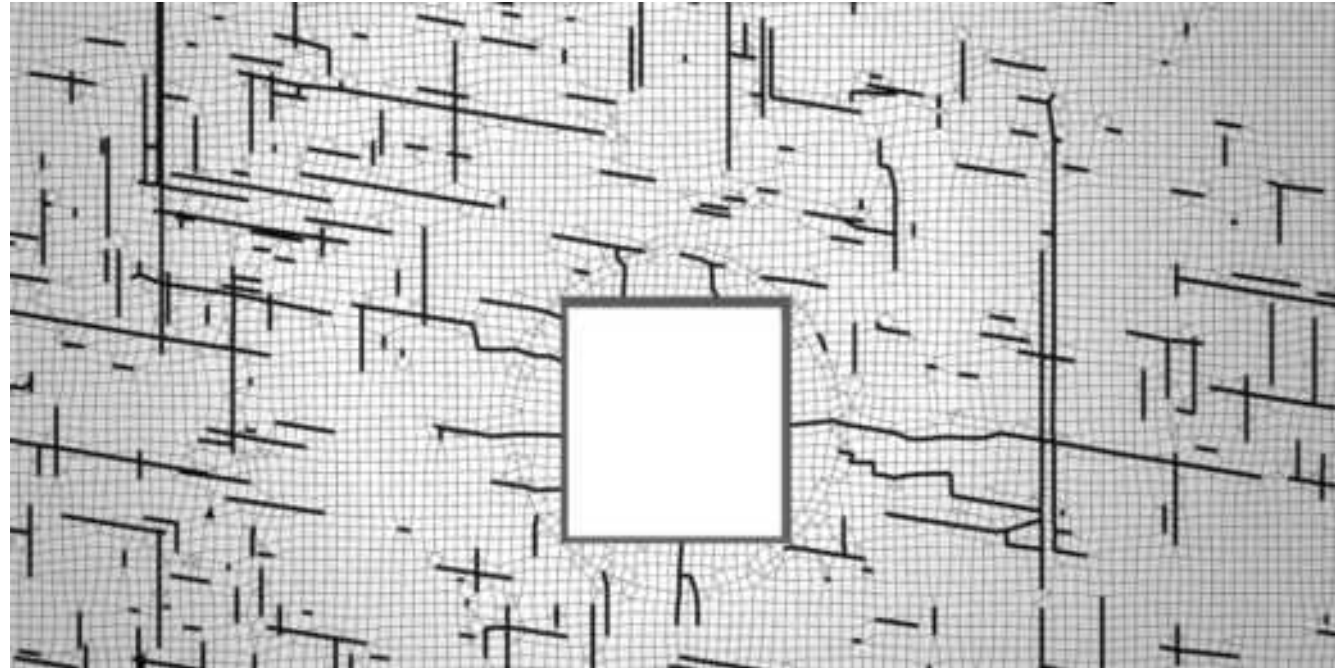


Scenario D

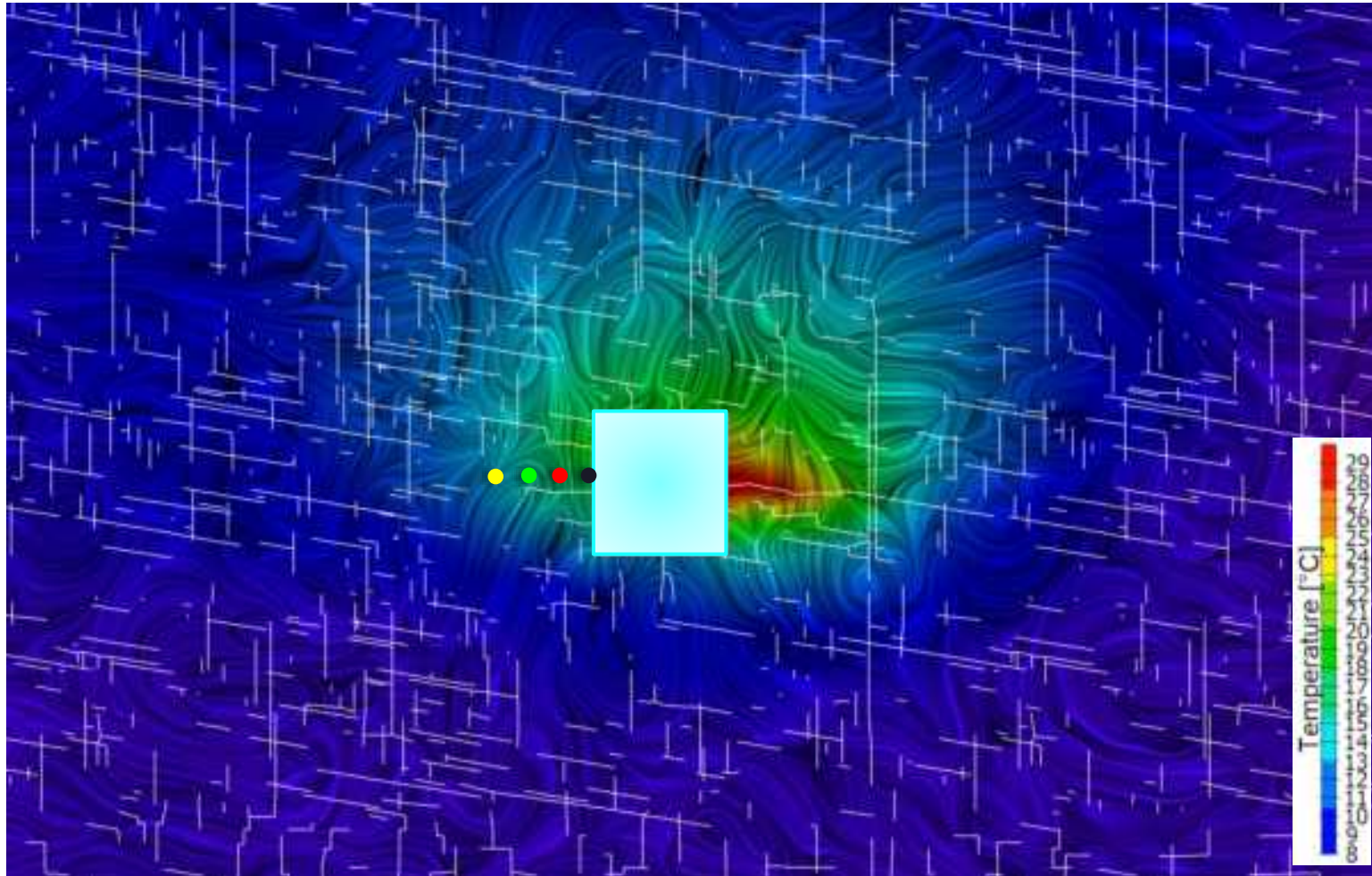




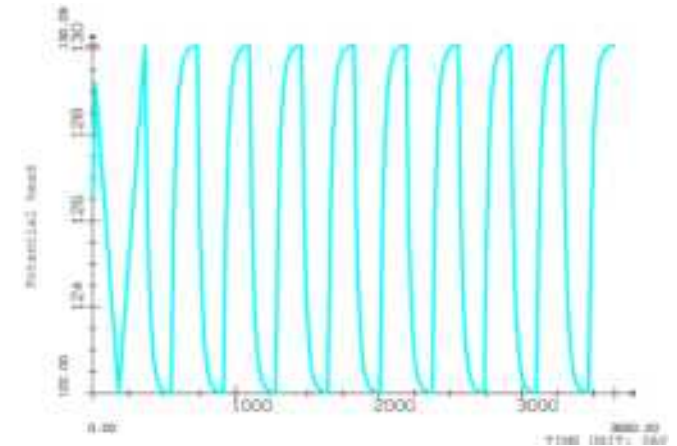
- 2D-vertical model
- 30x40 m
- 30.000 1D-fracture elements



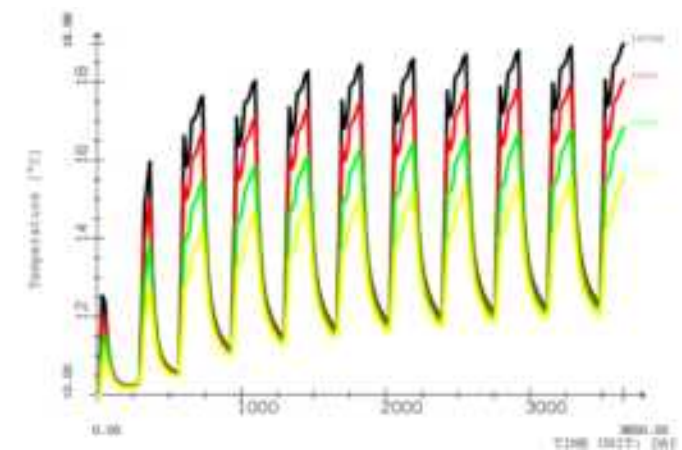
- Heat transport calculation
- Transient, 10-years

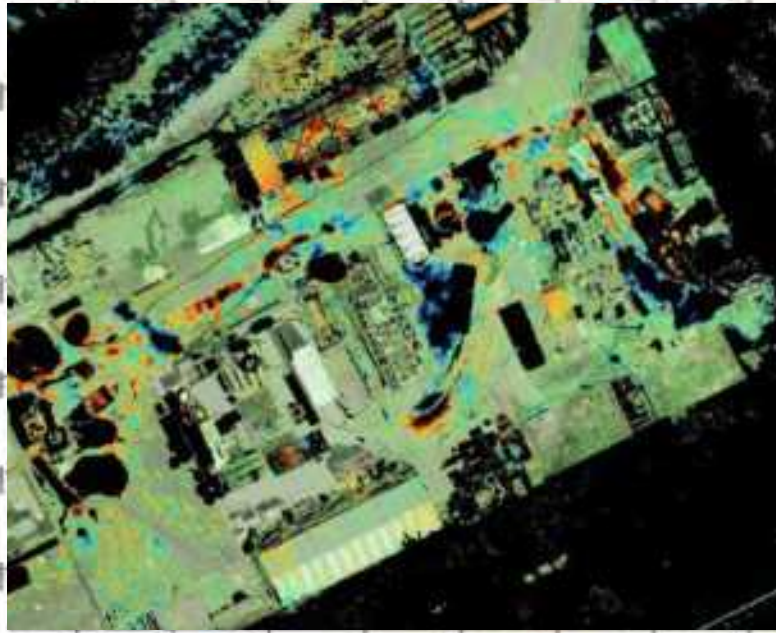


- BC mine: periodic potential head



- Result: temperature

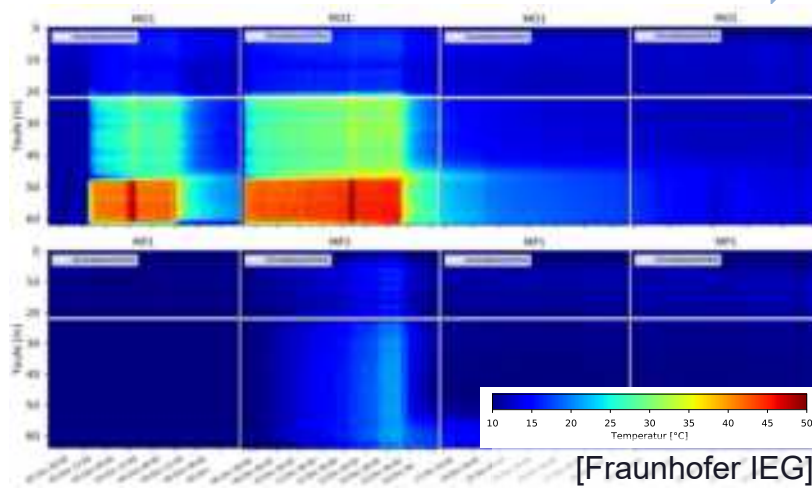
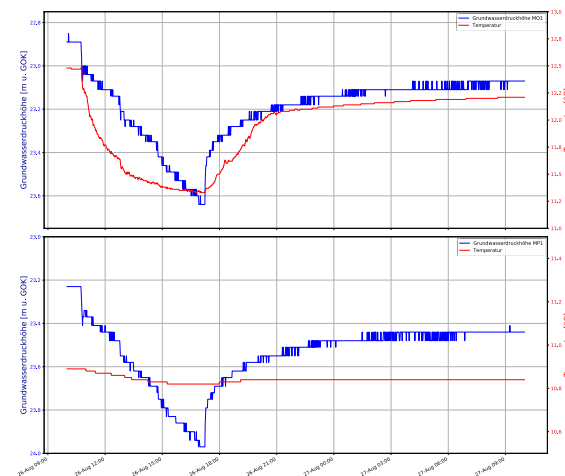




- Camera inspection
- Fiber optic evaluation
- Sampling
- Pump test
- Storage operation test
- Geomechanical monitoring

SPRING 2020

Summer 2022

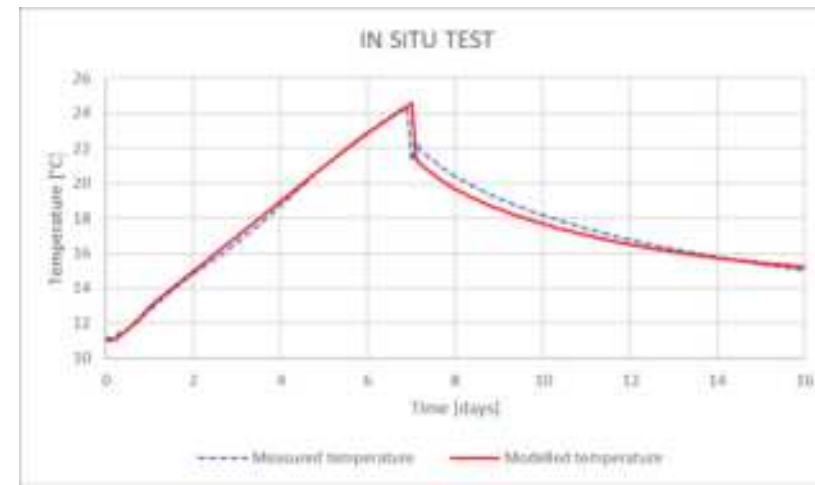
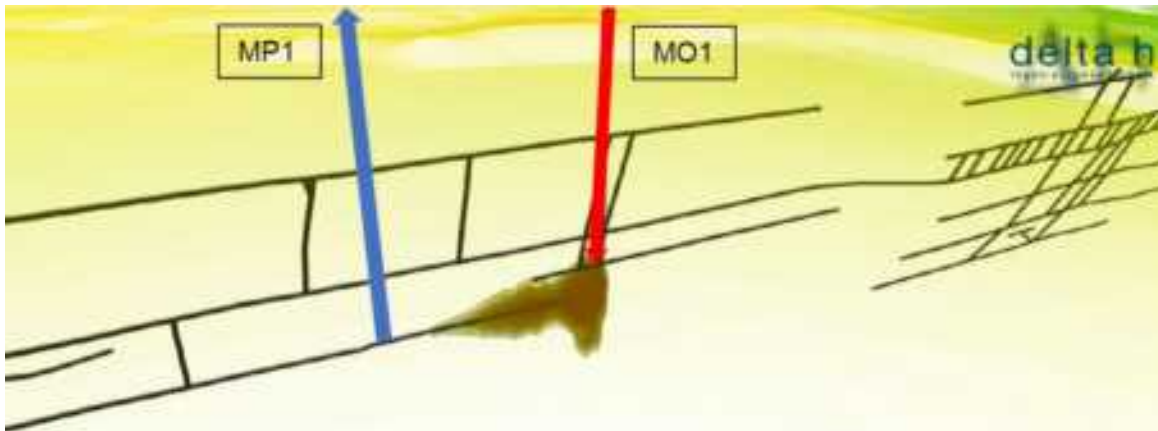




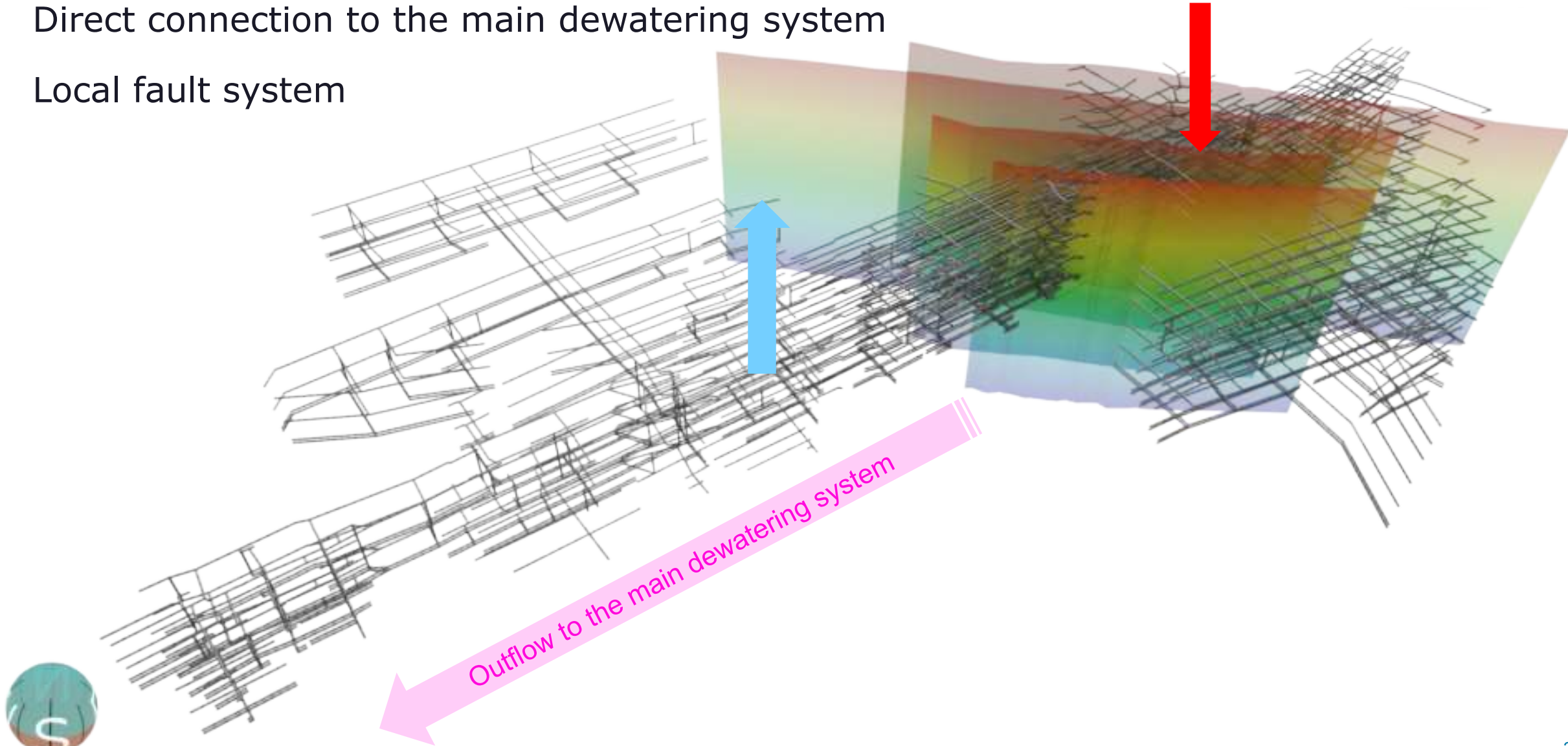
- MI1 well not productive
- Adjustment MO1-MP1 (Szenario C)
- Investigation of storage capacity
- → Coupling high temperature heat pump
- → Connection local heating network

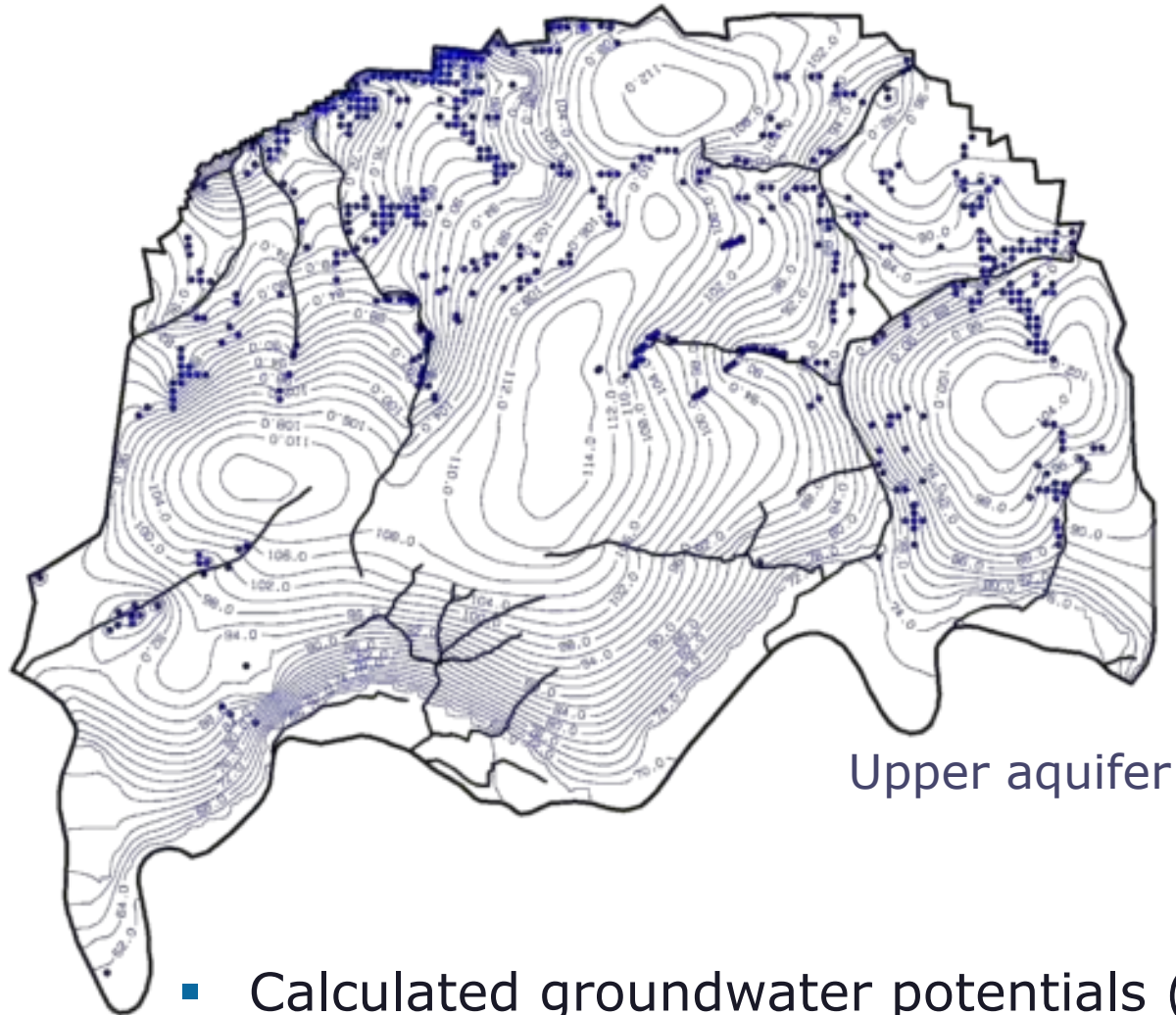
Summer 2022

Winter 2022



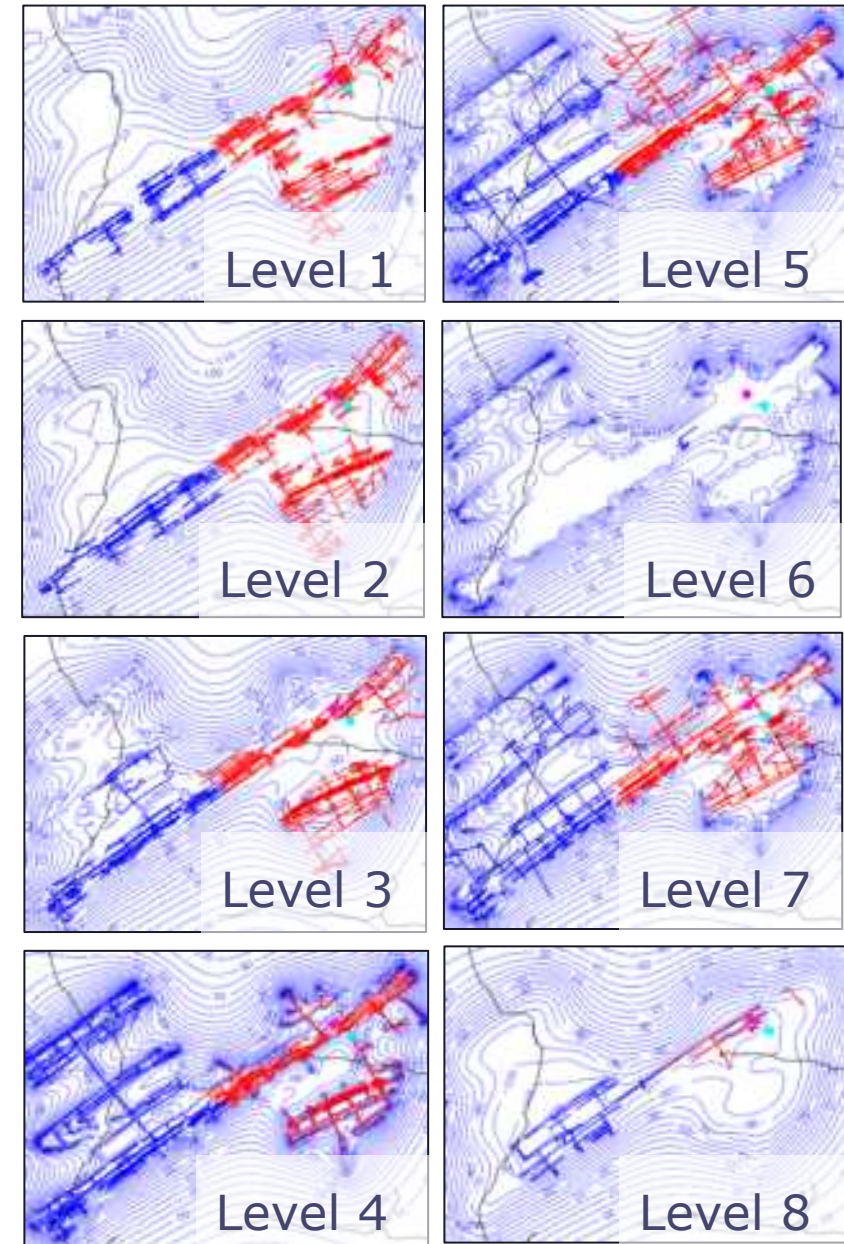
- Colliery Dannenbaum
- Direct connection to the main dewatering system
- Local fault system





Upper aquifer

- Calculated groundwater potentials (steady state)
- Drainage areas

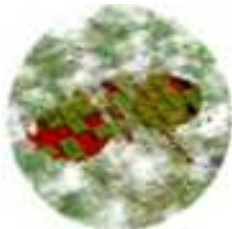




- Regional model with global mining system & flow regime
→ boundary conditions



- 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

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)