



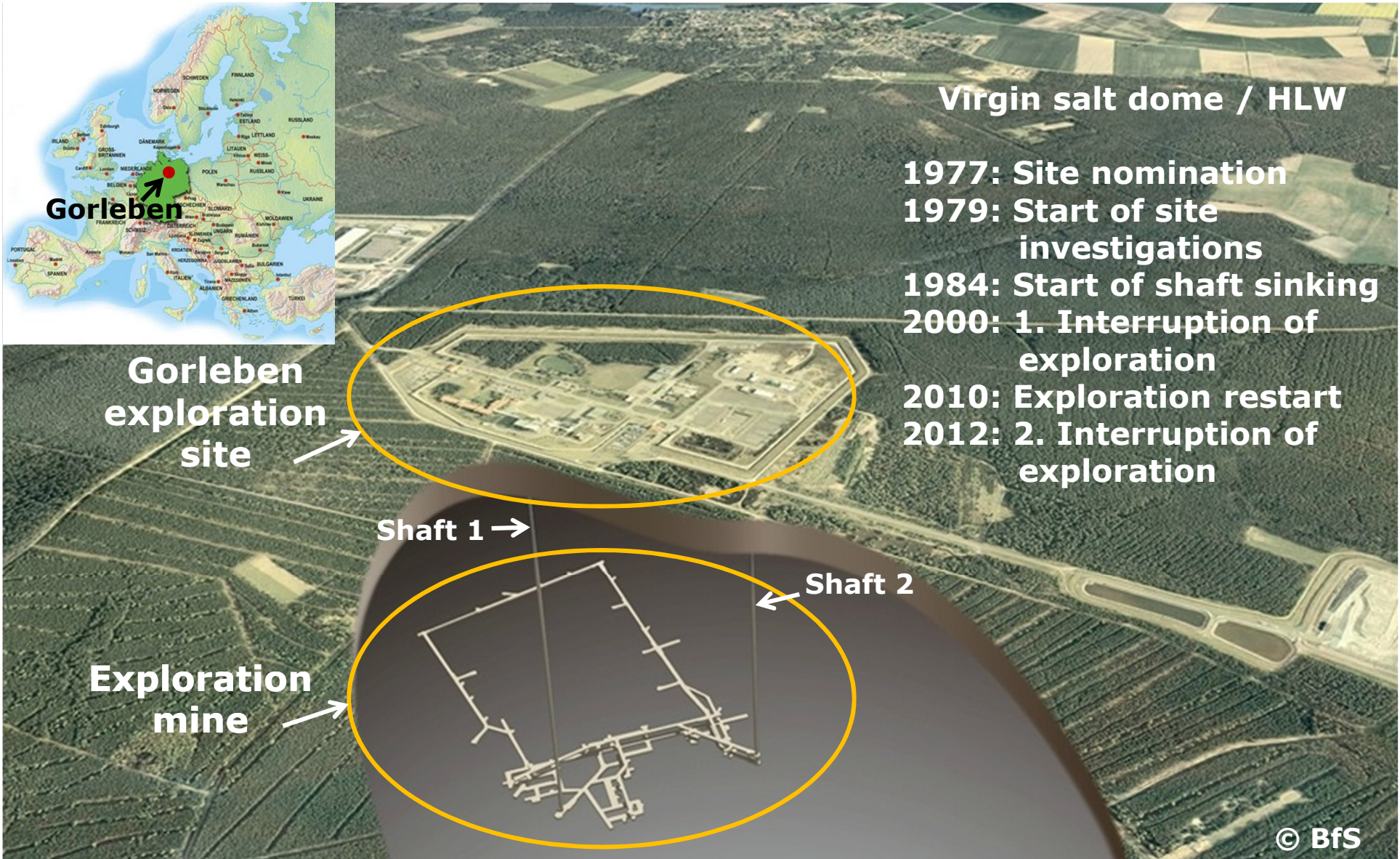
# Geoscientific Exploration of a Candidate Waste Disposal Site in Rock Salt

- Exploration of the Gorleben Site
- Geothermal Borehole Measurements and Numerical Modelling

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Hannover, Germany

Böker 200905

# Gorleben Site



Virgin salt dome / HLW

- 1977: Site nomination
- 1979: Start of site investigations
- 1984: Start of shaft sinking
- 2000: 1. Interruption of exploration
- 2010: Exploration restart
- 2012: 2. Interruption of exploration

Gorleben

Gorleben exploration site

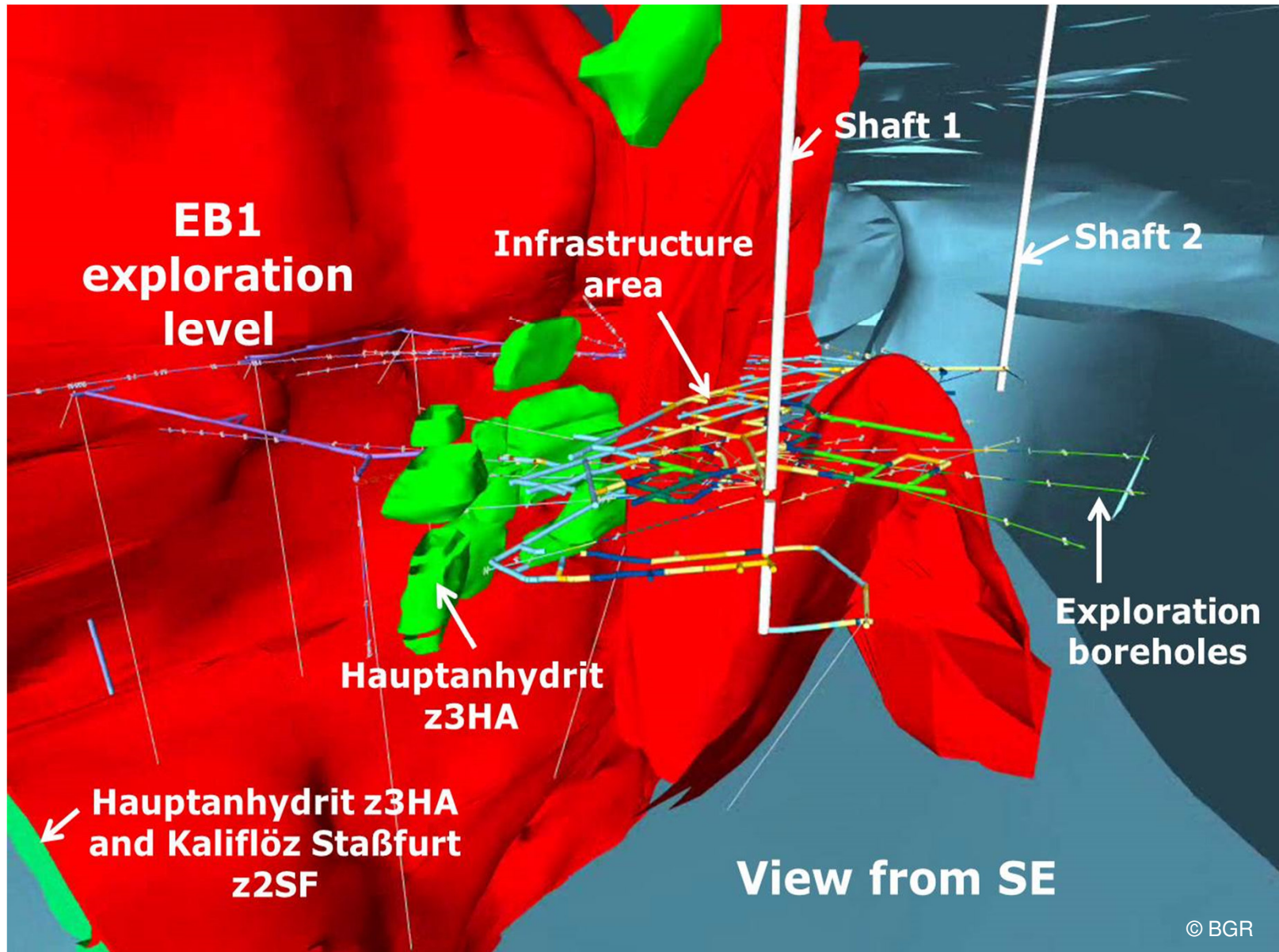
Shaft 1

Shaft 2

Exploration mine

© BfS

# Gorleben - 3-D view of the EB1 exploration level



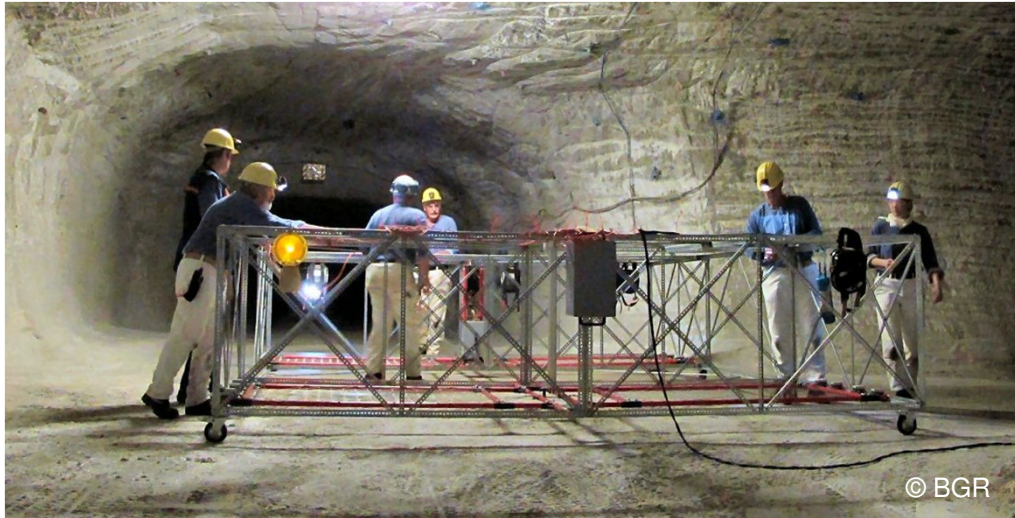
# Geoscientific Exploration of the Gorleben Site

- Geological exploration



Drill cores of the Gorleben site

# Geoscientific Exploration of the Gorleben Site

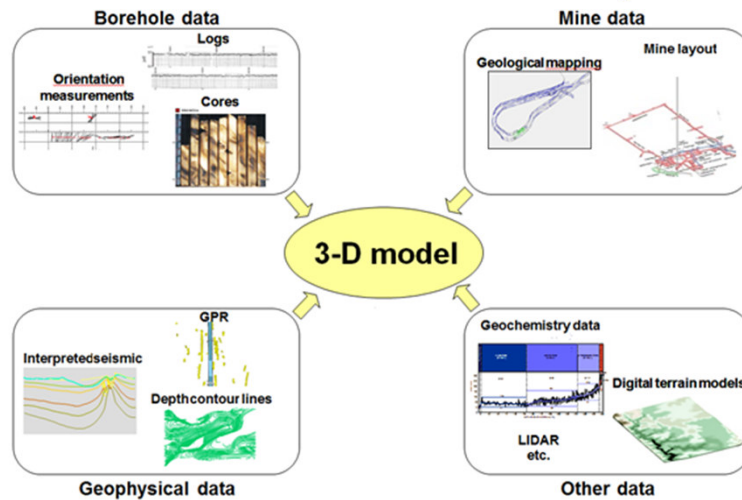


- Geological exploration
- Geophysical in-situ investigations



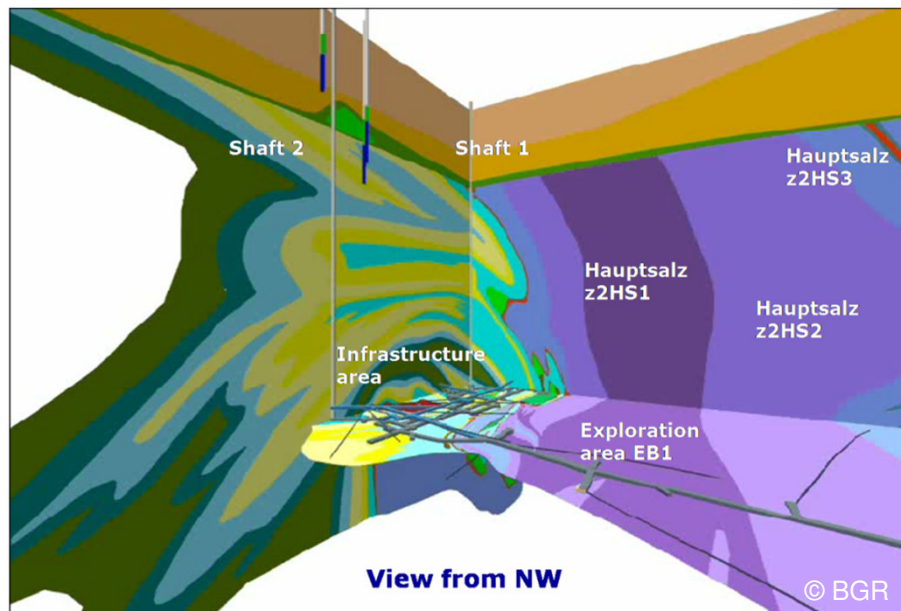
**GPR measurements in the wall of a drift at the 840-m level**

# Geoscientific Exploration of the Gorleben Site



Methodology of geological 3-D modelling

- Geological exploration
- Geophysical in-situ investigations
- Geological modelling



Geological 3-D model of the Gorleben exploration area

# Geoscientific Exploration of the Gorleben Site



Rock sample of the Gorleben site

- Geological exploration
- Geophysical in-situ investigations
- Geological modelling
- Laboratory tests

# Geoscientific Exploration of the Gorleben Site



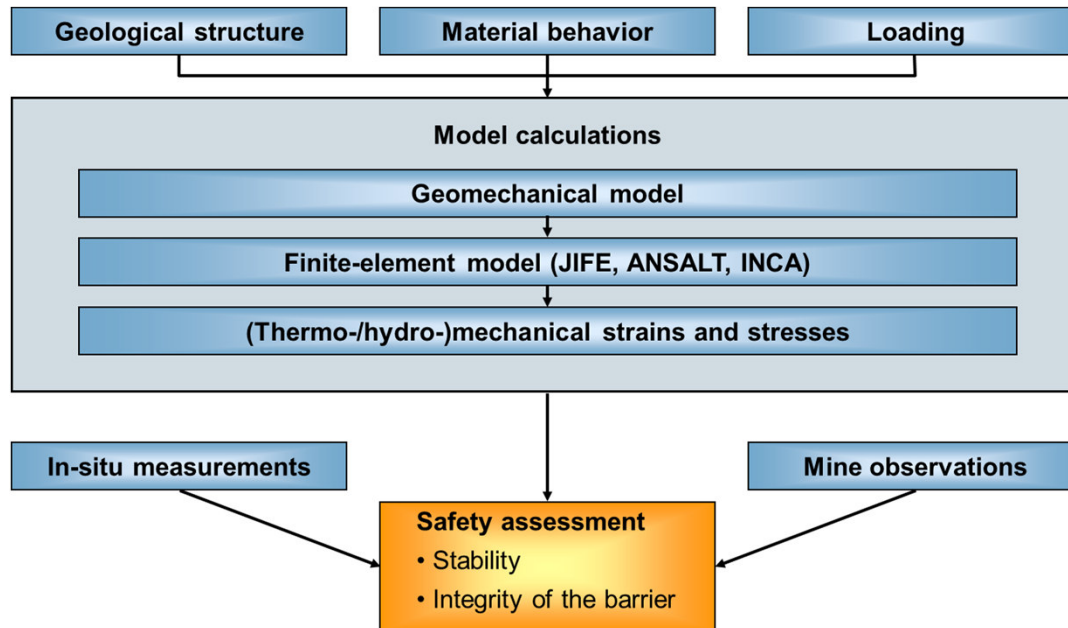
Installation of an extensometer at the 840-m level

- Geological exploration
- Geophysical in-situ investigations
- Geological modelling
- Laboratory tests
- **Geotechnical in-situ measurements**



# Geoscientific Exploration of the Gorleben Site

## Methodology of geomechanical modelling

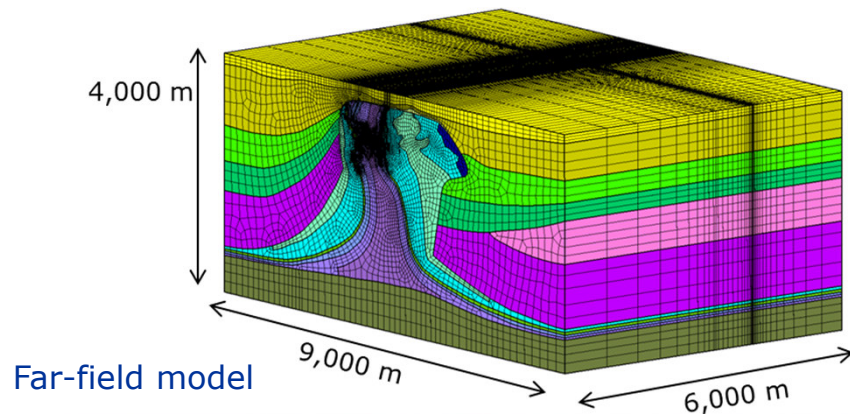
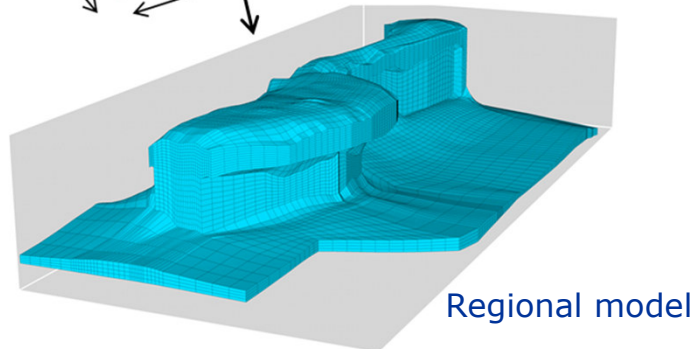
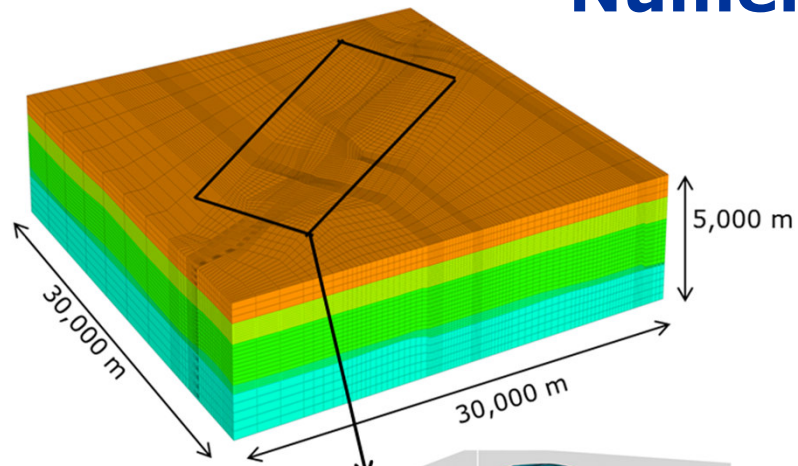


- Geological exploration
- Geophysical in-situ investigations
- Geological modelling
- Laboratory tests
- Geotechnical in-situ measurements
- Numerical modelling

# Numerical modelling

## Objectives

- Analysis of the long-term barrier integrity under thermal loading caused by HLW disposal (several disposal concepts, borehole emplacement, drift emplacement)
- Analysis of the thermomechanical response of the salt dome to ice age scenarios
- Model calculation to interpret and evaluate in-situ measurements and mine observations



# Gorleben Site Description, Parts 1 to 4



Description of the Gorleben site  
Part 1:

Hydrogeology of the  
overburden of the  
Gorleben salt dome



Description of the Gorleben Site  
Part 3:

Results of the geological surface  
and underground exploration of  
the salt formation

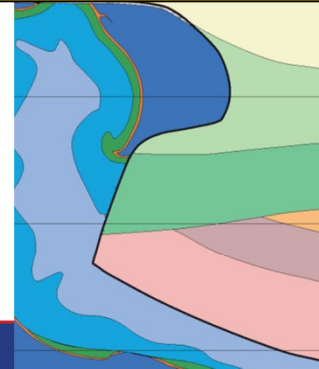
**Free download (english version):**

[http://www.bgr.bund.de/EN/Themen/Endlagerung/Aktuelles/2011\\_06\\_21\\_aktuelles\\_gorleben\\_engl\\_Part1bis4\\_en.html](http://www.bgr.bund.de/EN/Themen/Endlagerung/Aktuelles/2011_06_21_aktuelles_gorleben_engl_Part1bis4_en.html)



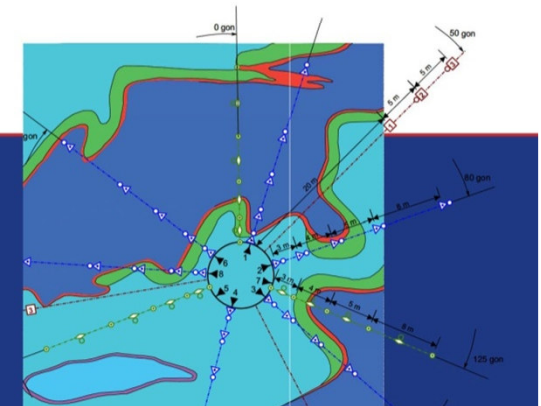
Description of the Gorleben site  
Part 2:

Geology of the overburden  
and adjoining rock of the  
Gorleben salt dome



Description of the Gorleben site  
Part 4:

Geotechnical exploration  
of the Gorleben salt dome

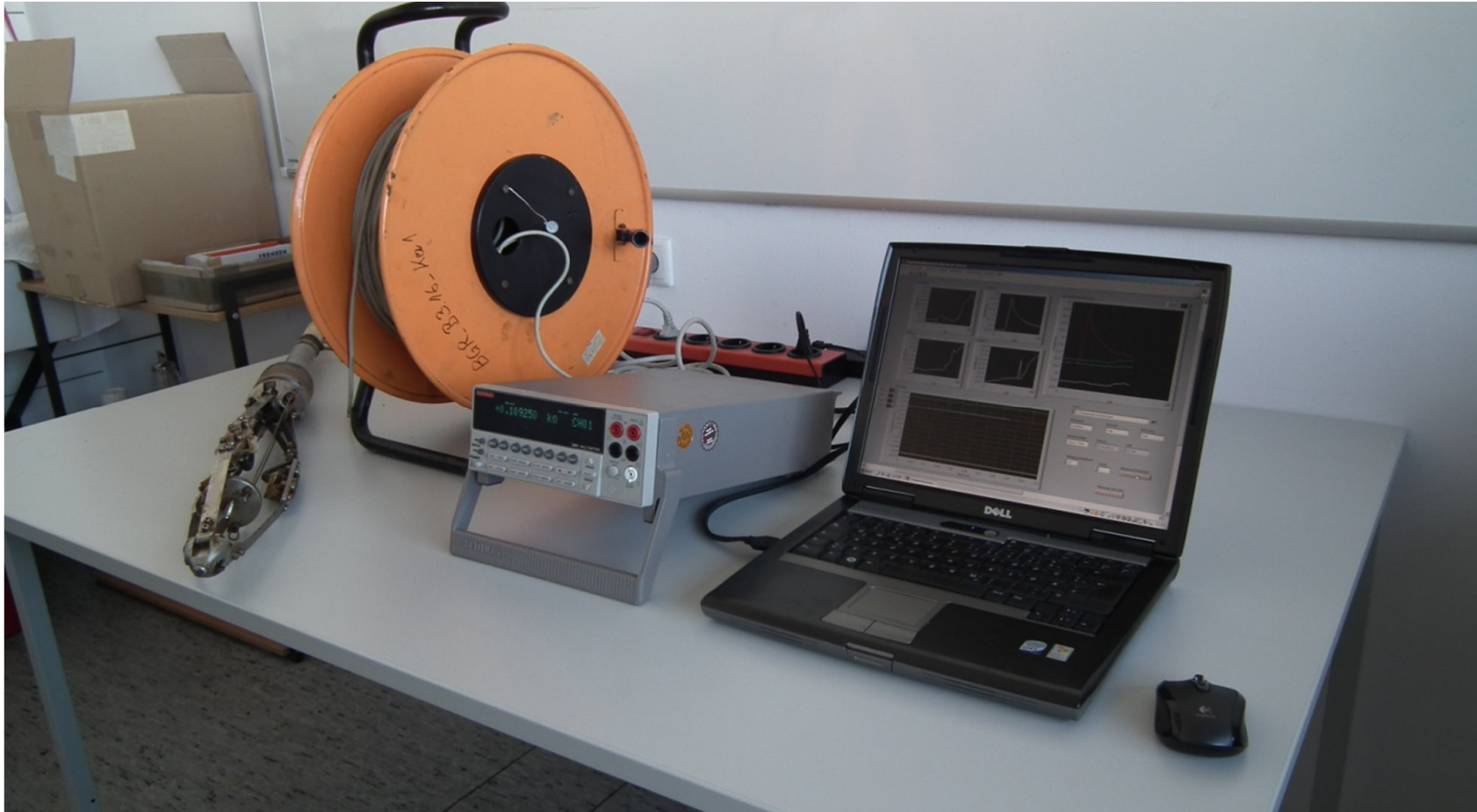


# Geothermal Borehole Measurements and Numerical Modelling

# Objectives of Geothermal Measurements

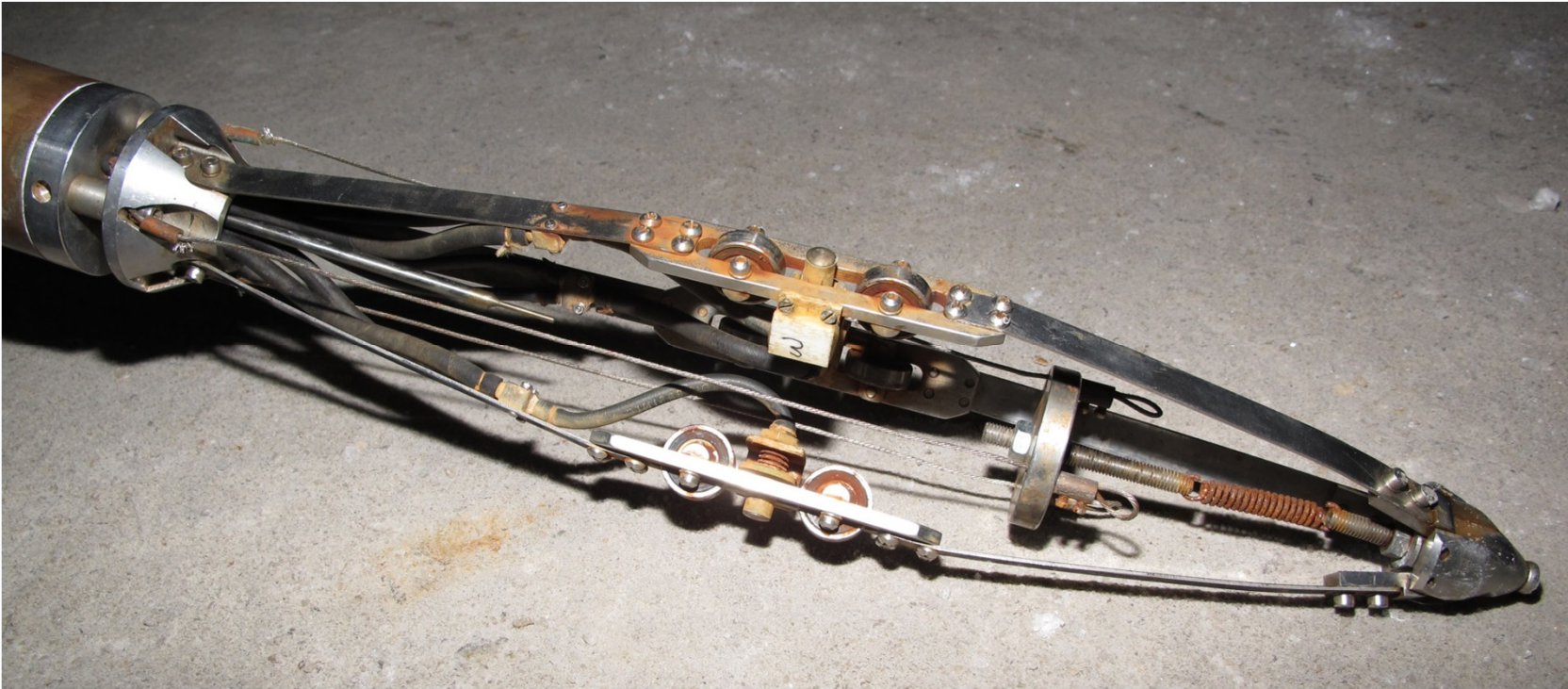
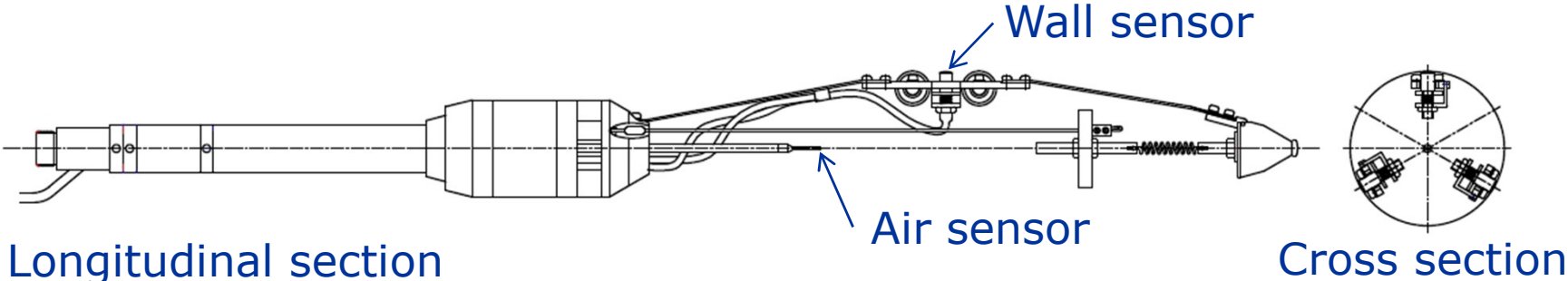
- Investigation of excavation and ventilation effects within the exploration area EB1 and the infrastructure area
- Spatial-temporal cooling of the wall of the drifts and disruption of the natural temperature field
- Characterisation of the temperature field in the near-field of the exploration area EB1
- Database for the evaluation of further geotechnical measurements

# Measuring Equipment

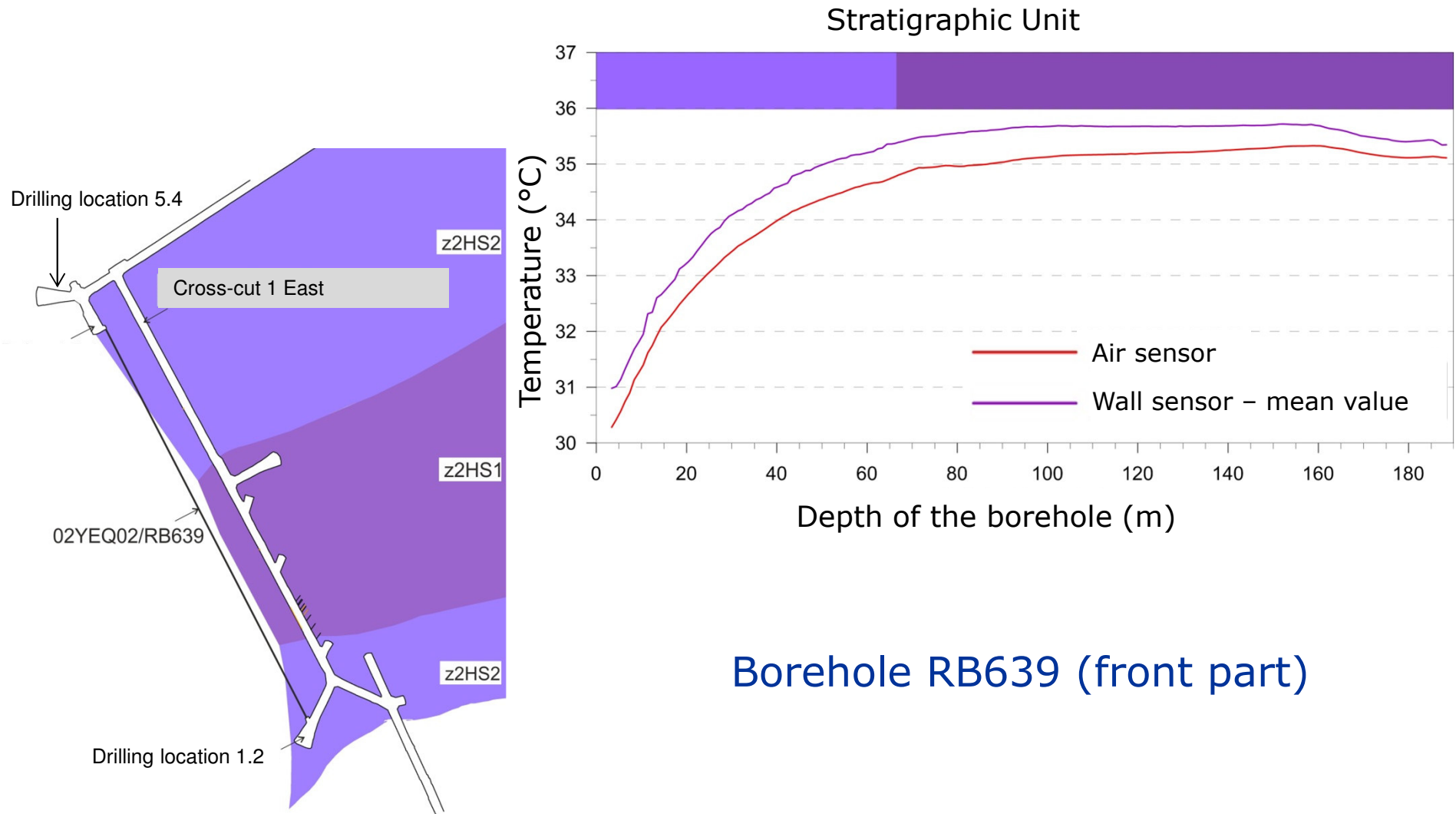


Full temperature logging system comprising sensor head, measurement cable on drum, digital voltmeter and laptop

# Sensorhead



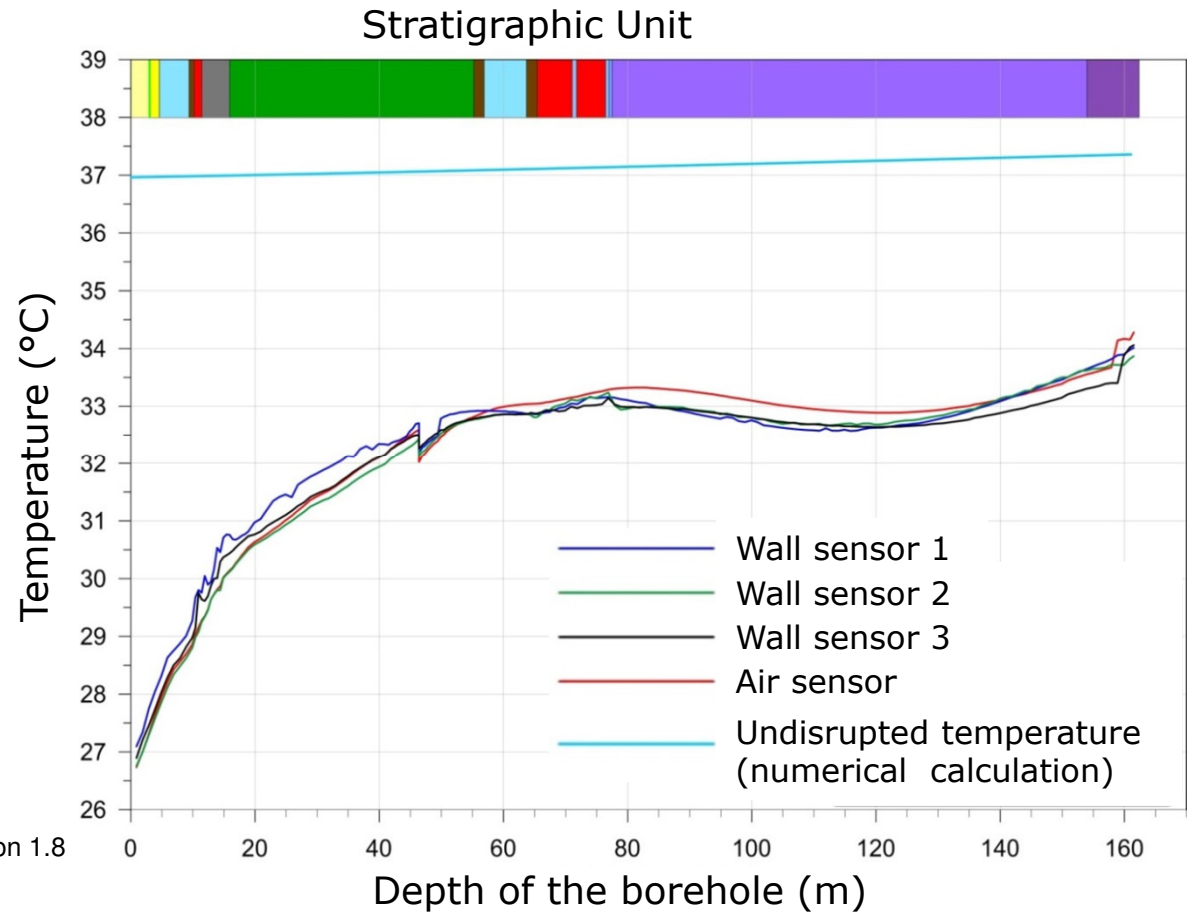
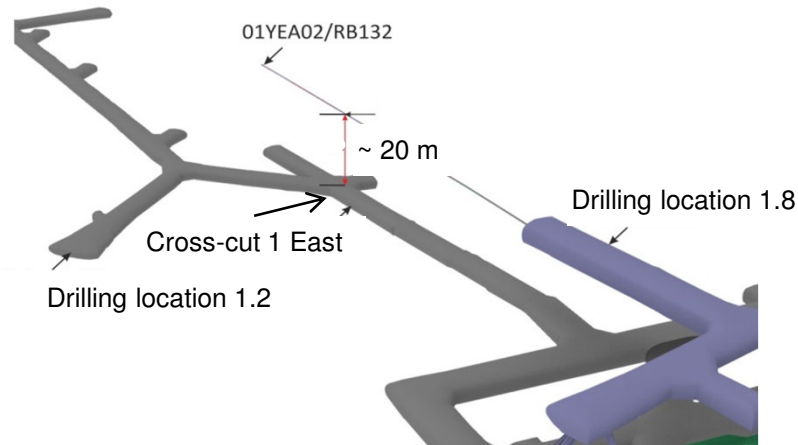
# Characteristic Measuring Results



Borehole RB639 (front part)



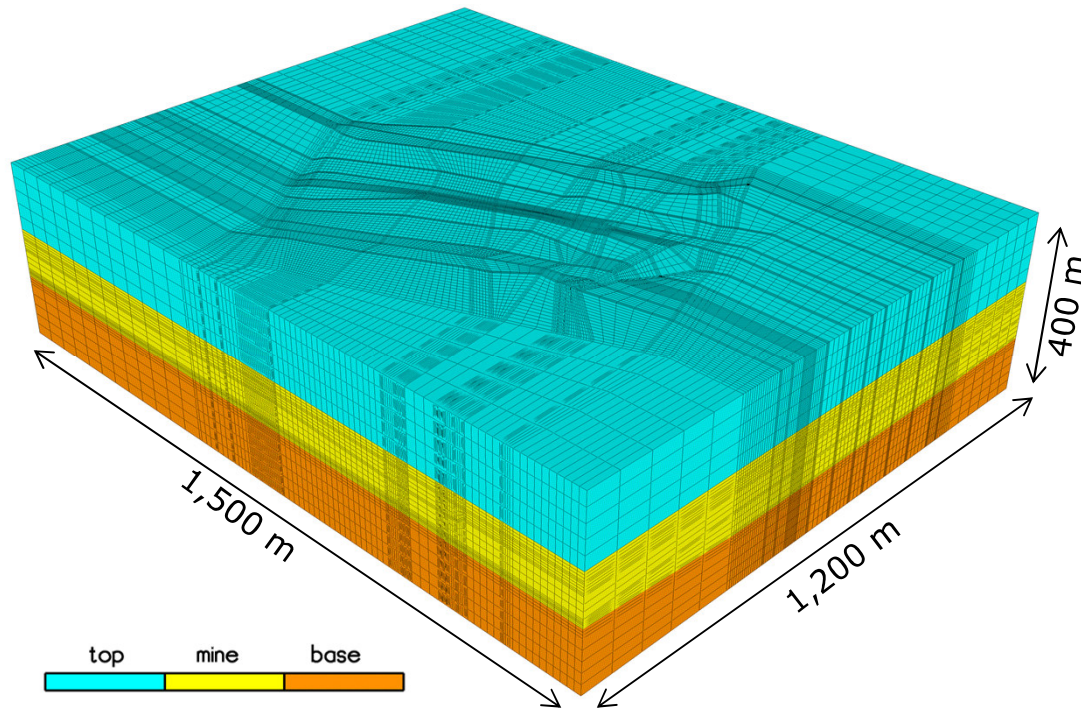
# Unusal Measuring Results



Borehole RB132

# Numerical modelling

# Near-field 3-D Model of the Gorleben Exploration Site



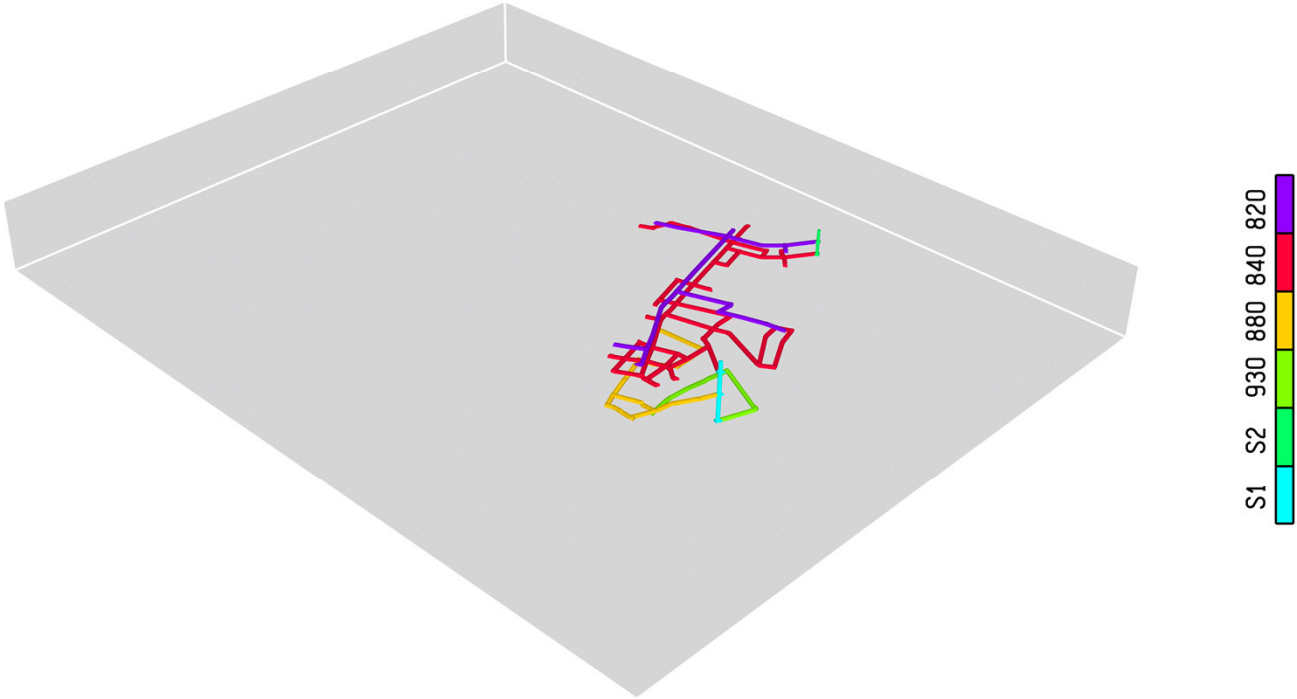
Complete model (View from SE to NW)

- Model size: 1.5 x 1.2 x 0.4 km
- Approx. 600,000 Hexaeder-Elements
- Code: JIFE

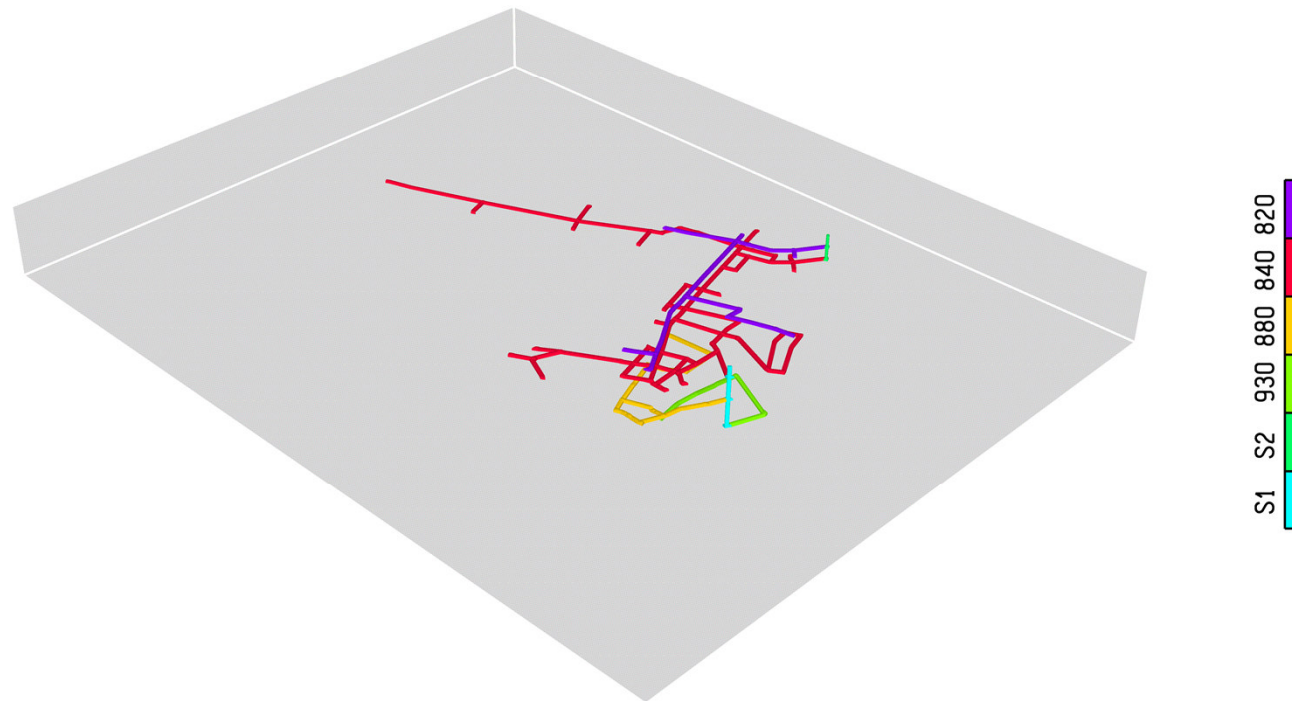
## Objectives:

- Thermal calculations to analyse the cooling-off of the surrounding rock of the drifts caused by ventilation
- Prediction of a realistic time and space dependent distribution of the temperature field within the exploration area
- Consideration of
  - exploration mine with the adjoining host rock
  - successive excavation of drifts and boreholes

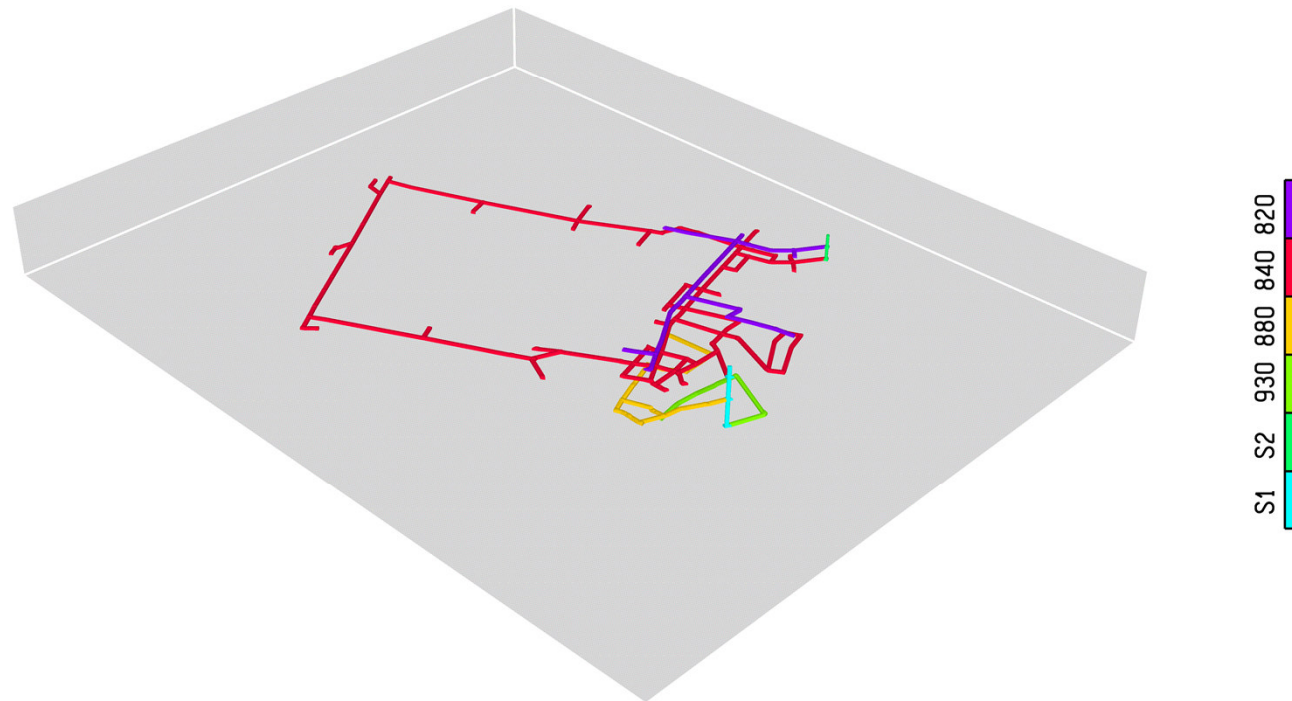
# Excavation Status 1998



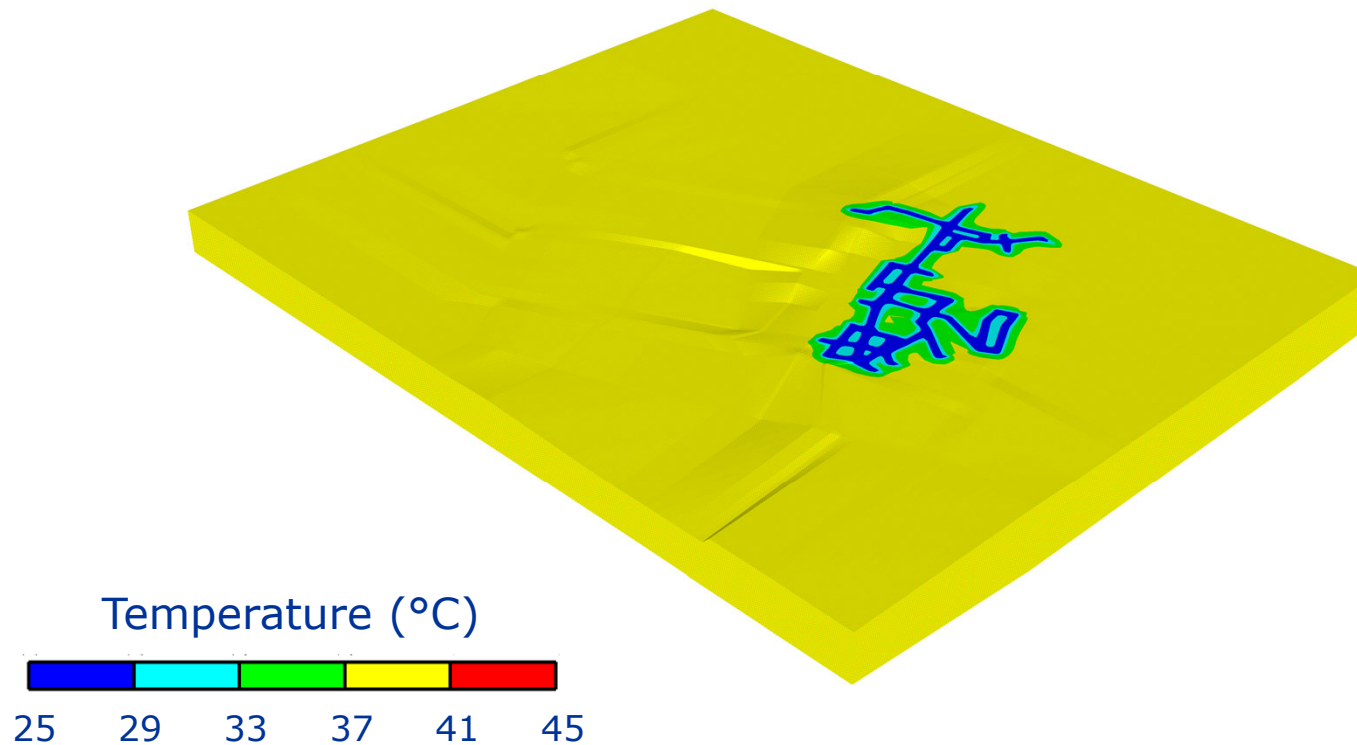
# Excavation Status 1999



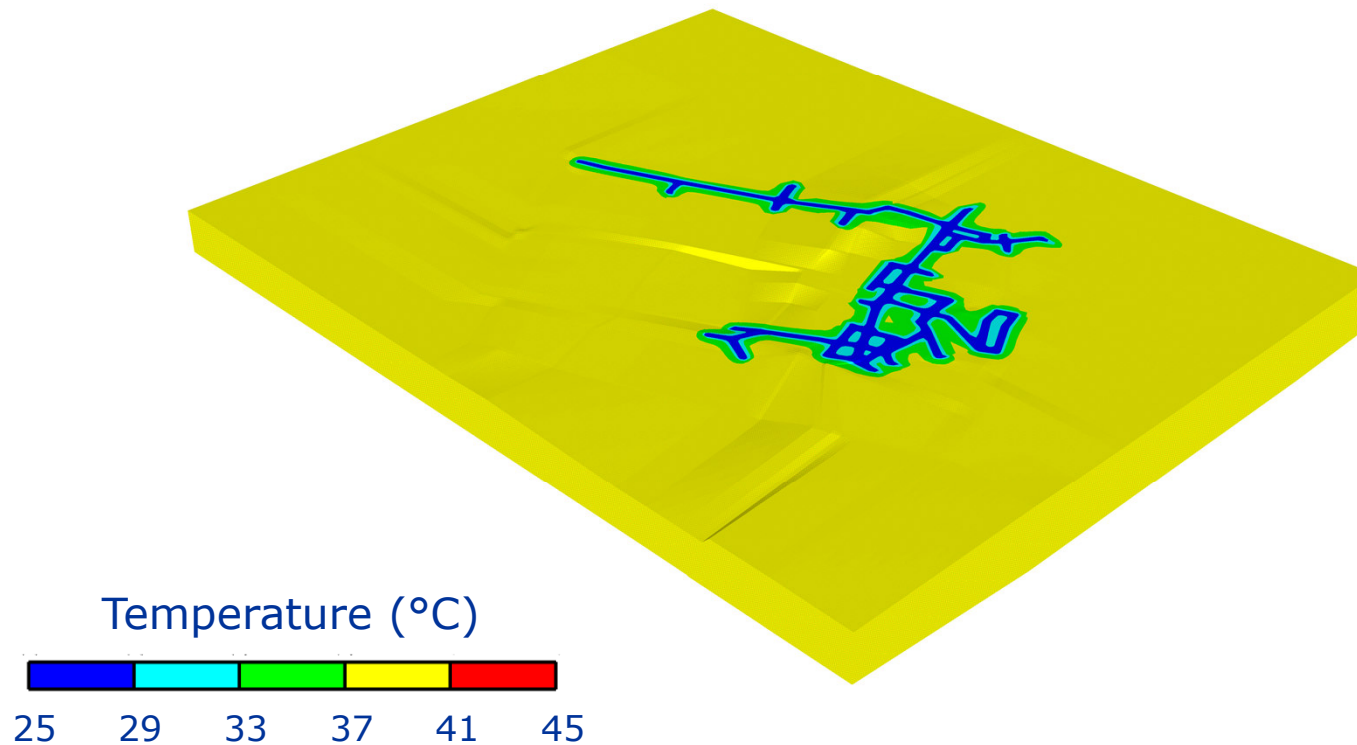
# Excavation Status 2000/2011



# Simulated temperature distribution at the 840-m level in 1998

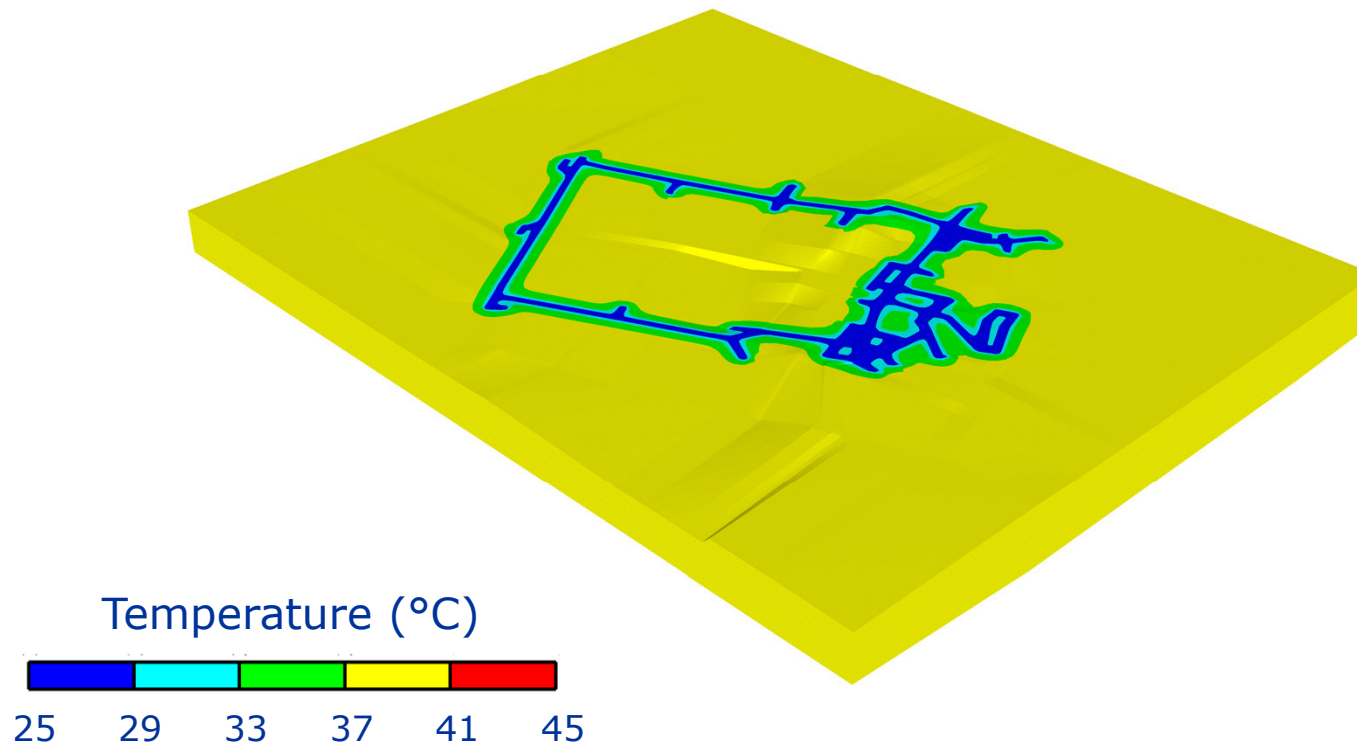


# Simulated temperature distribution at the 840-m level in 1999

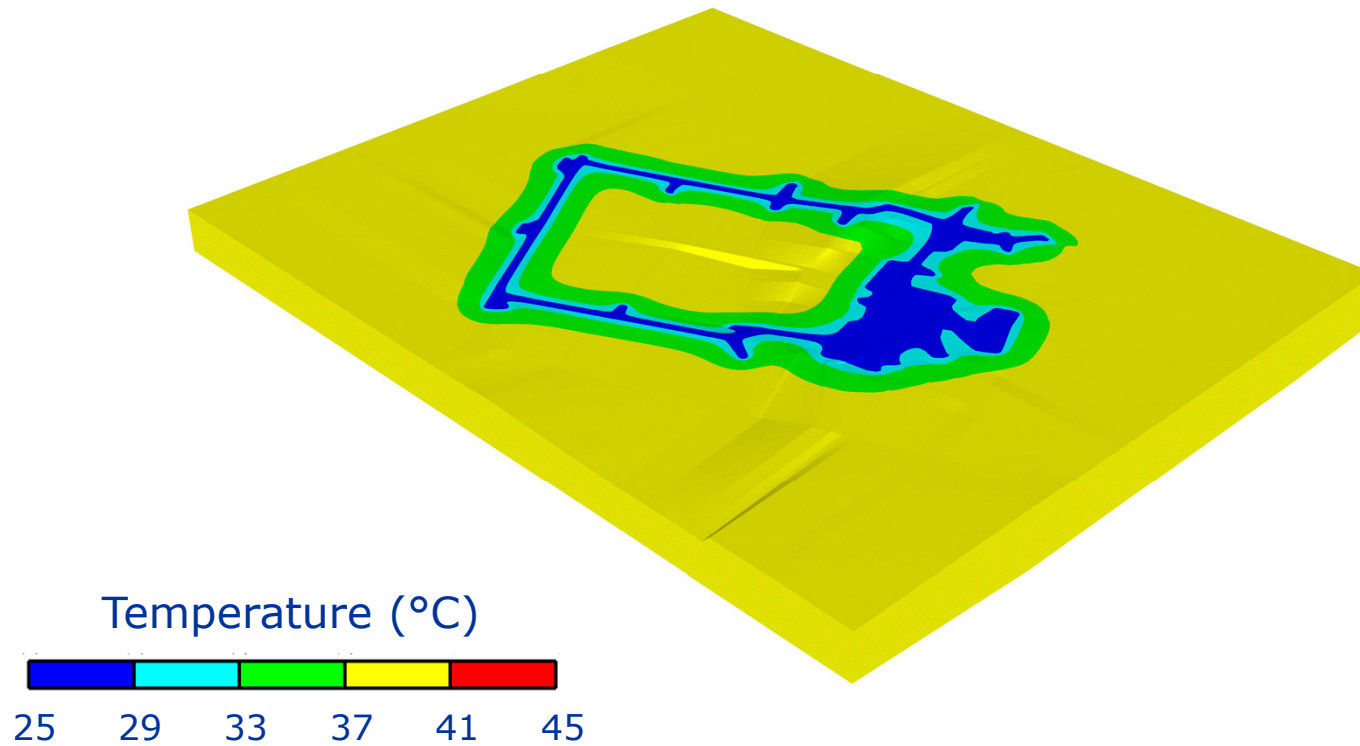




# Simulated temperature distribution at the 840-m level in 2000

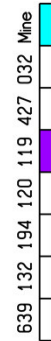
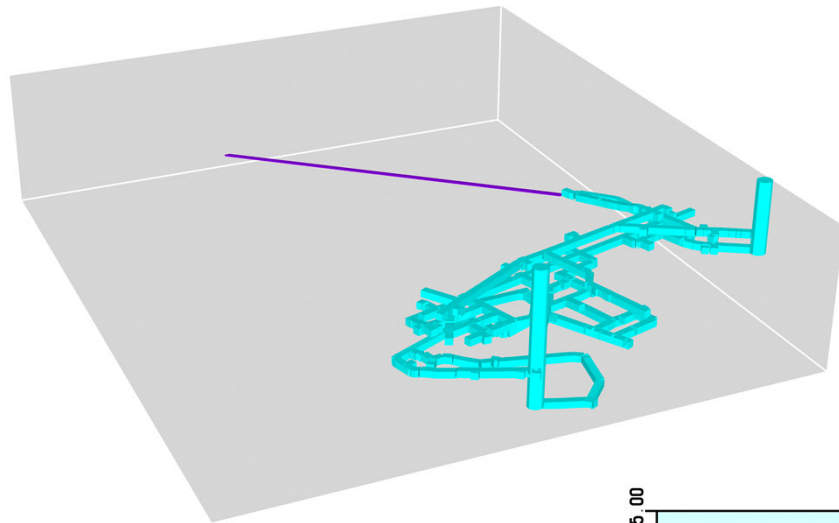


# Simulated temperature distribution at the 840-m level in 2011



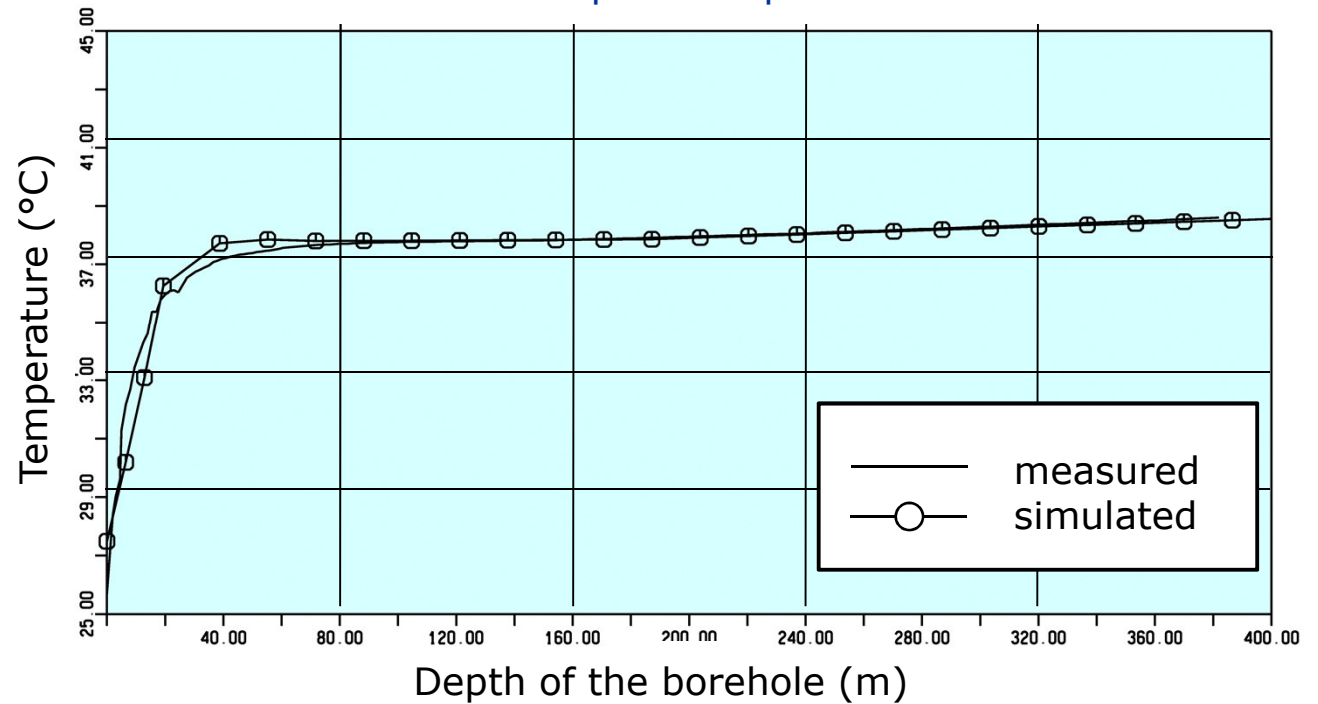
# Comparison of measured and simulated temperature profiles

# Borehole RB119 at the 840-m level



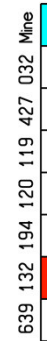
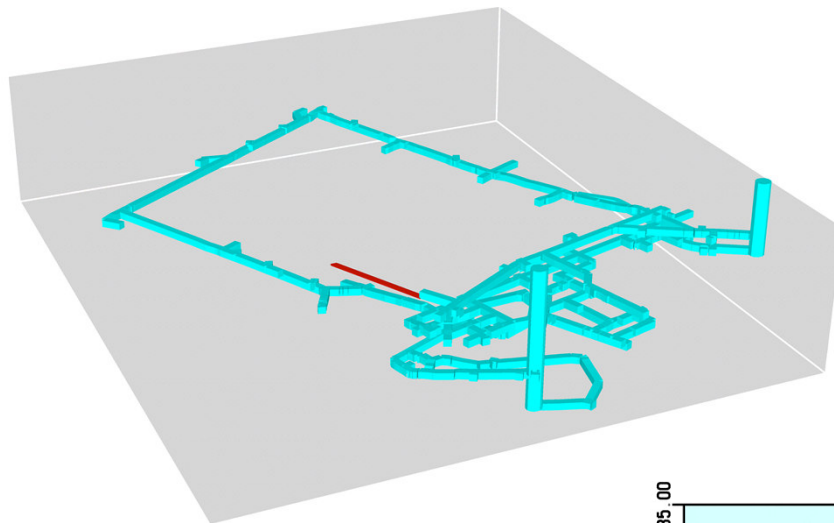
Temperature measurement  
in 1998

Temperature profil

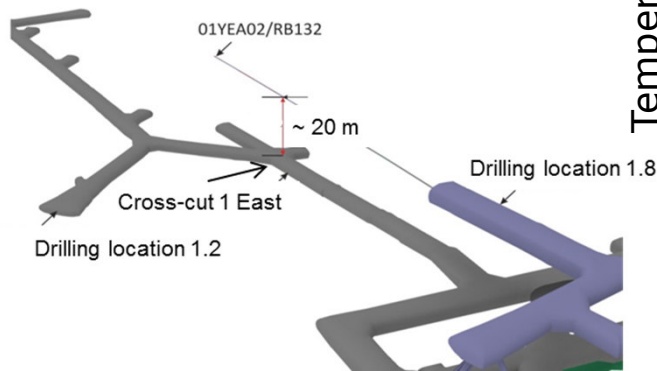
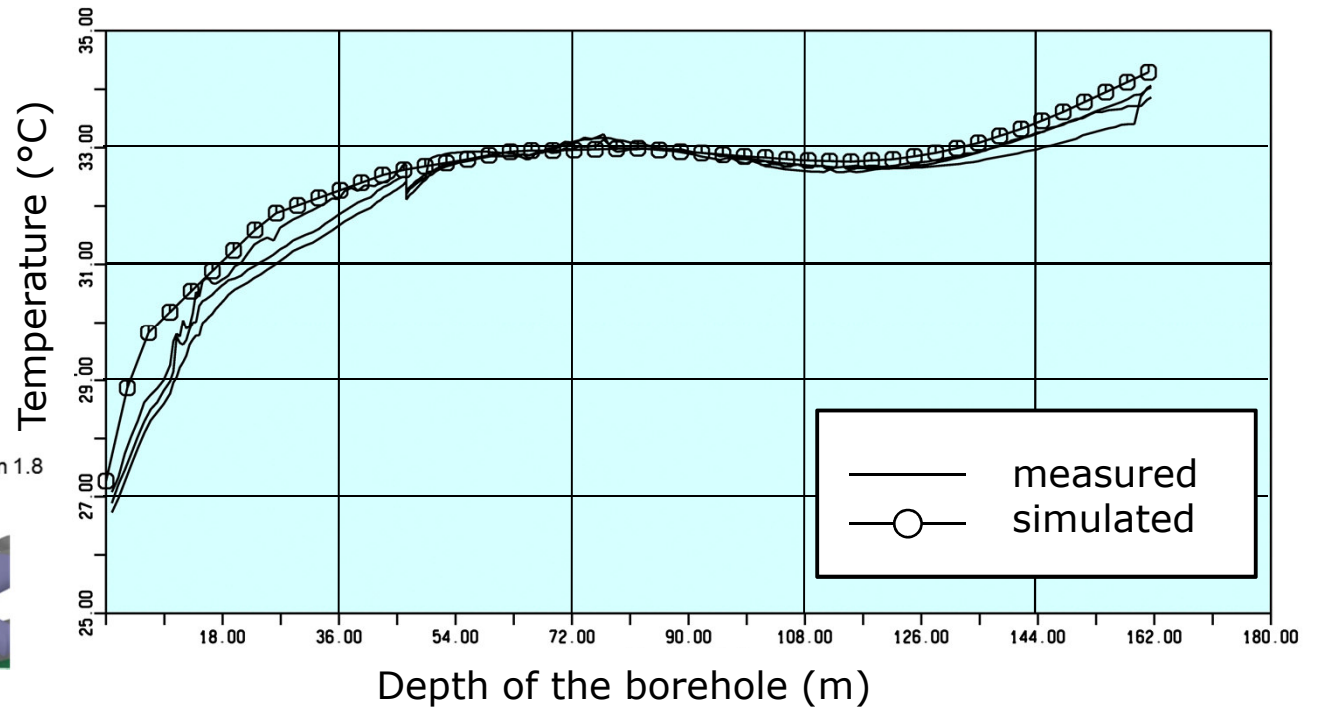


# Borehole RB132 at the 820-m level

Temperature measurement  
in 2011



Temperature profile



# Conclusions

- Geoscientific exploration of the Gorleben site
- Geothermal borehole measurements and numerical modelling
  - Temperature measurements in the Gorleben exploration mine as database for the evaluation of further geotechnical measurements
  - Spatial-temporal cooling of the wall of the drifts due to ventilation
  - Special case: unusual measuring results
  - Thermal model calculations to interpret and evaluate the temperature measurements
  - Over the entire excavation history, the comparison shows an excellent match between the measured and the simulated temperature profiles.

# Thank you for your attention!



ISRM Commission on Underground Research Laboratory Networking, Montreal, 10<sup>th</sup> May 2015