Belgian programme
on radioactive waste management

Ten years of continuous monitoring of the heater test

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07-11-2025

27th Exchange Meeting

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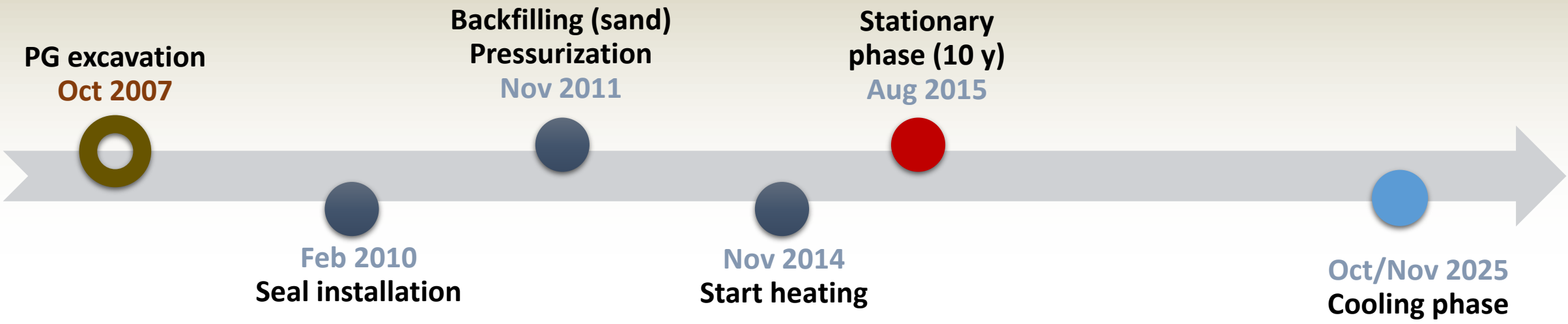
But the monitoring story started 20 Years Ago



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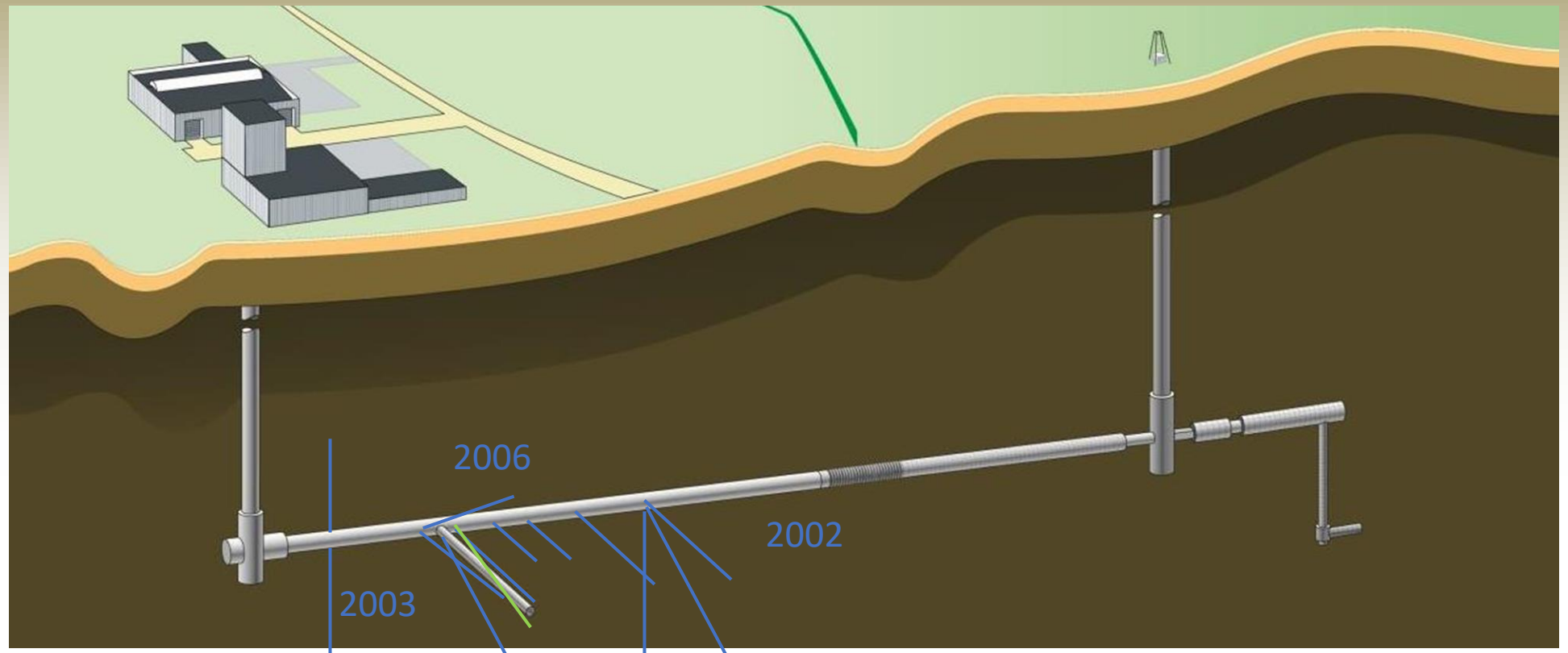
Monitoring – essential part of PRACLAY Tests

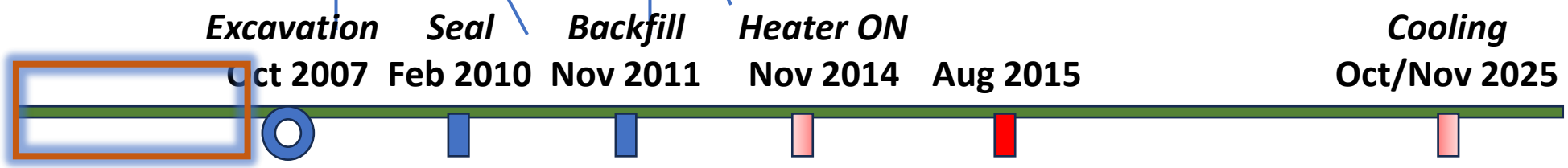
- Scientific
  - Do the observations match our predictions? Do we understand the system?
  - Upscaling from smaller heating tests (e.g. ATLAS)
  - Continuation of previous steps (gallery excavation,…)
- Technical
  - Daily follow-up / maintaining test parameters
- Operational Safety
  - Unforeseen risks due to elevated temperatures and pressures?
- Strategic added value
  - What and how to monitor in repository-like conditions

Which components are monitored ?

- Focus on the Boom Clay host rock
  - Perturbations (near field)
  - Overall temperature and water pressure distribution (incl. far field)
- PRACLAY Gallery → source term
  - Also defines the boundary conditions of the test
  - Operation of the heater test
    - Safety related : large volume of heated and pressurized water
- Seal as the most critical component
  - Large pressure (and temperature) gradients

The first monitoring boreholes (2002 – 2006)





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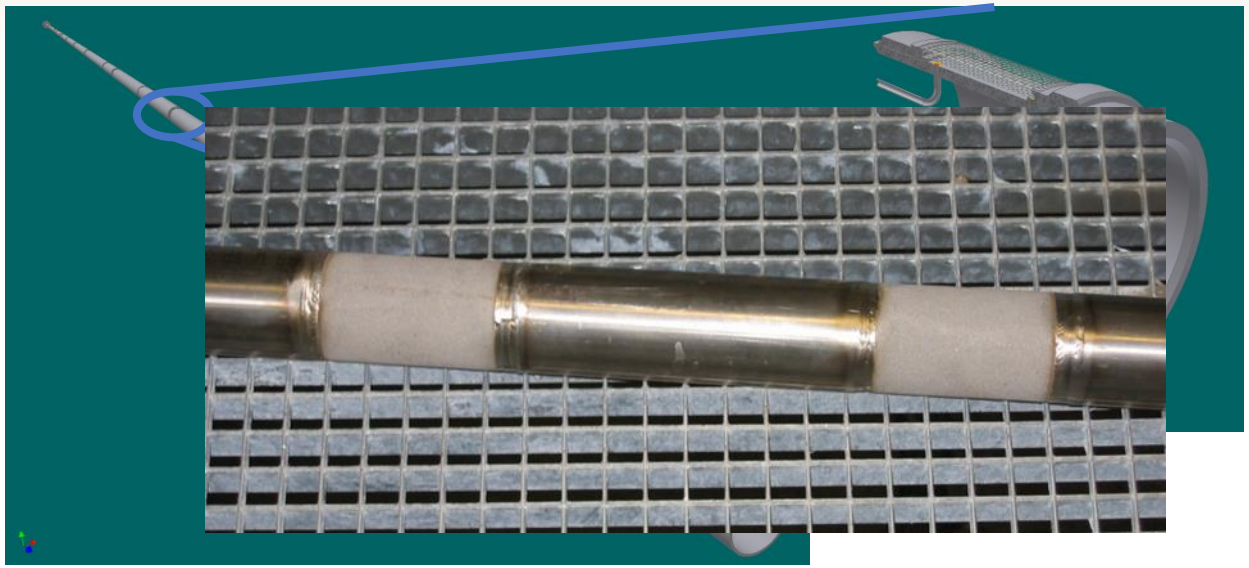
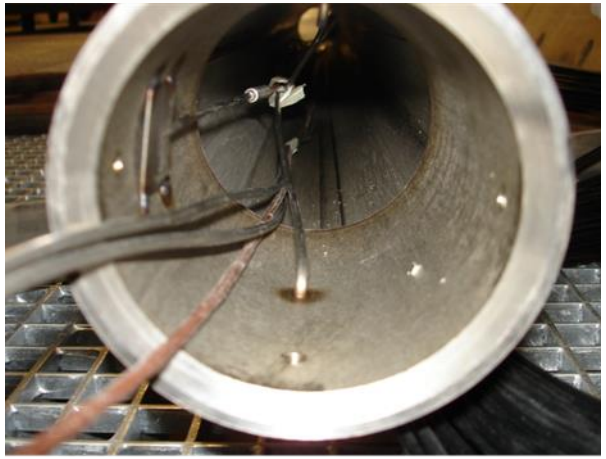
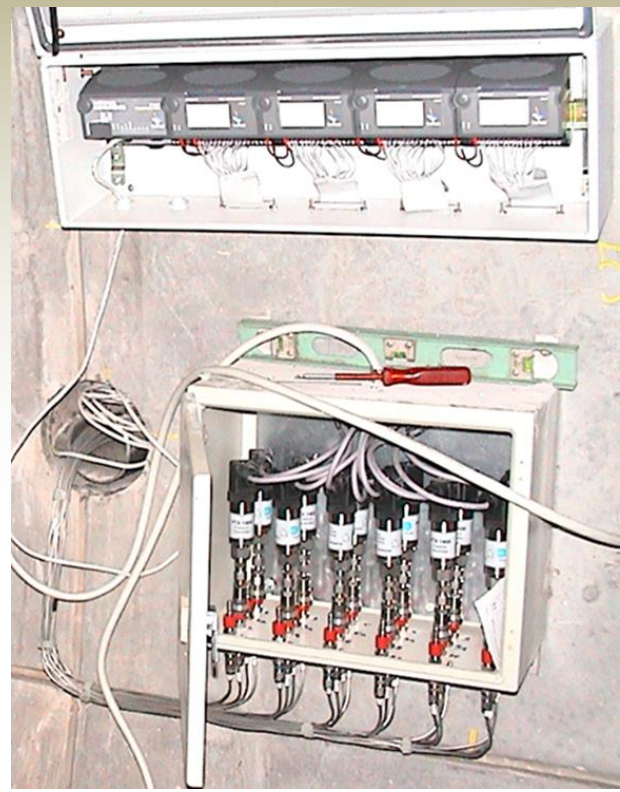
Multifilter piezometer boreholes → back-bone of monitoring network

- What? Piezometer measures pressure of the porewater
- How?
  - Filters integrated in borehole casing to collect porewater
  - Porewater led to pressure sensors by capillary tubes

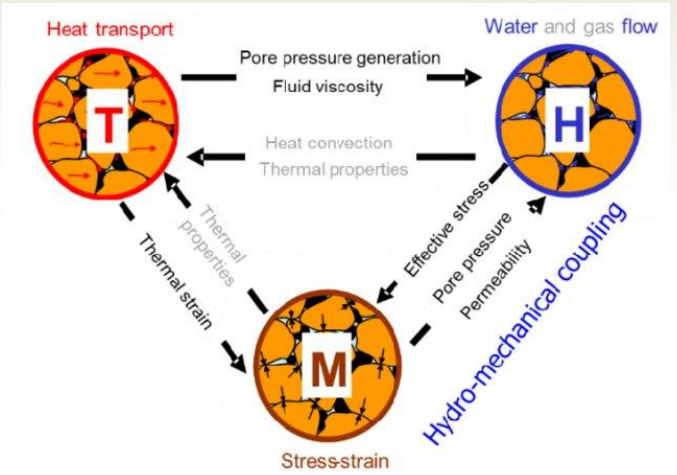






Multifilter piezometer boreholes → back-bone of monitoring network

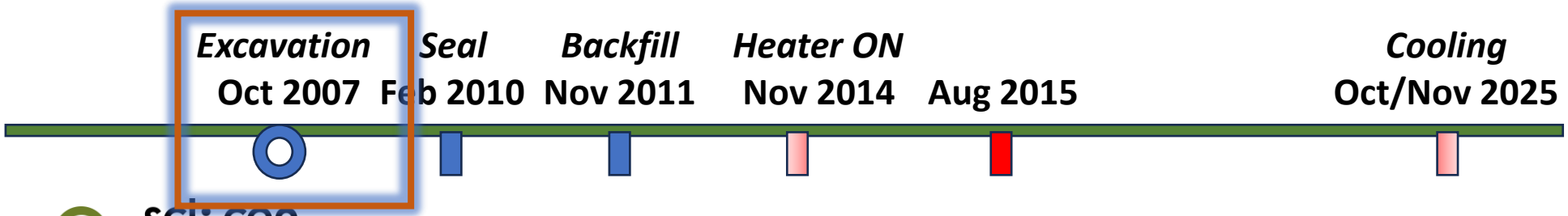
- Why?
  - porewater pressures are an excellent indicator for variety of phenomena (coupled behaviour)
  - versatile instrument: in addition to pressure monitoring
    - permeability measurement, sampling, on-line monitoring
  - long-term reliability
    - proven performance of in HADES conditions
      - several set-ups > 30 y operating
    - pressure sensor remains accessible (calibration, replacement)



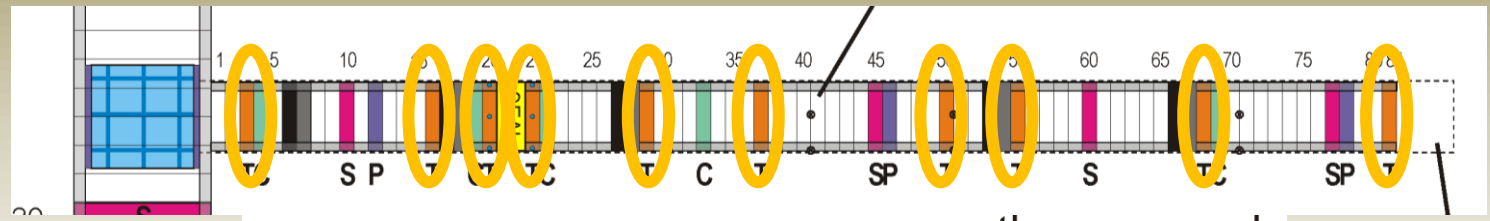
Installation in boreholes up to 45 m deep

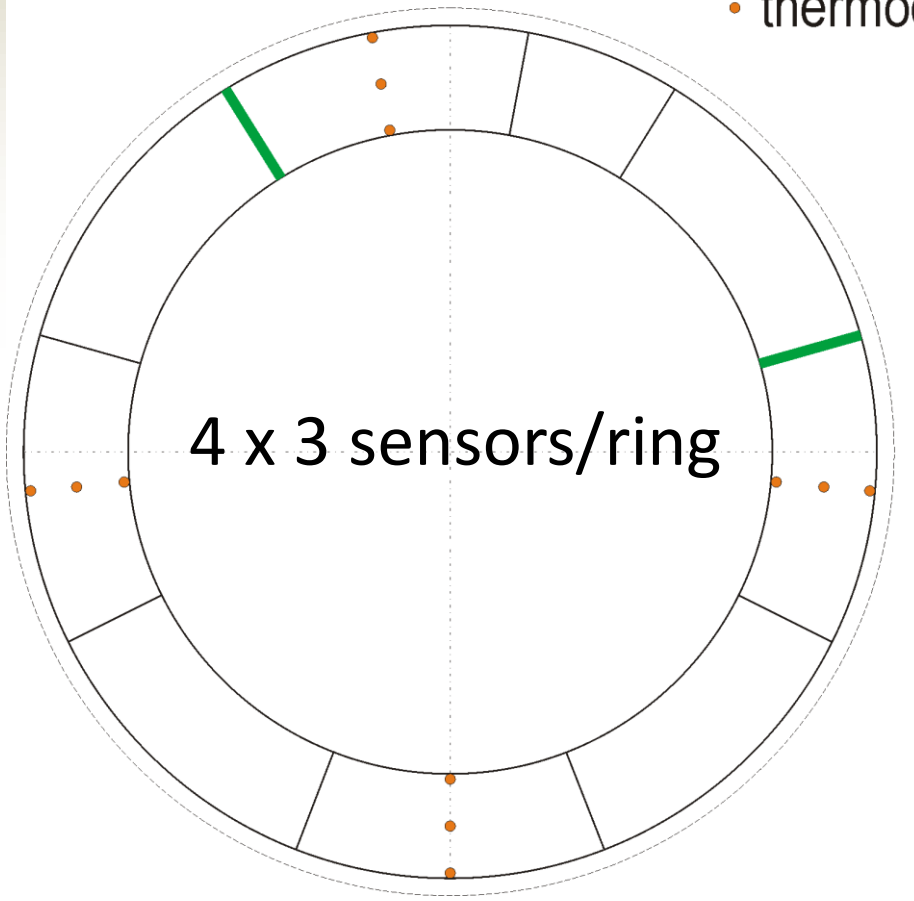
Instrumented segments for the PG lining (2007)

- Thermal conditions
  - Temperature (gradient) across lining
- Mechanical load on the lining
  - Embedded strain gauges
  - Pressure and load cells
  - Convergence measurements (invar wire extensometer)
- (Steel specimen for corrosion analysis)

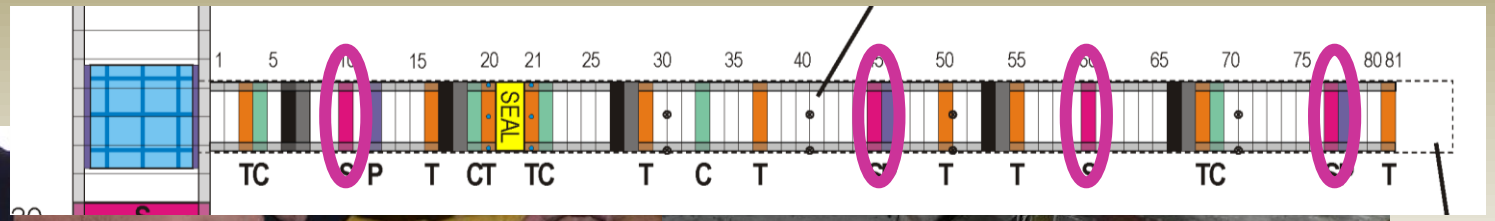


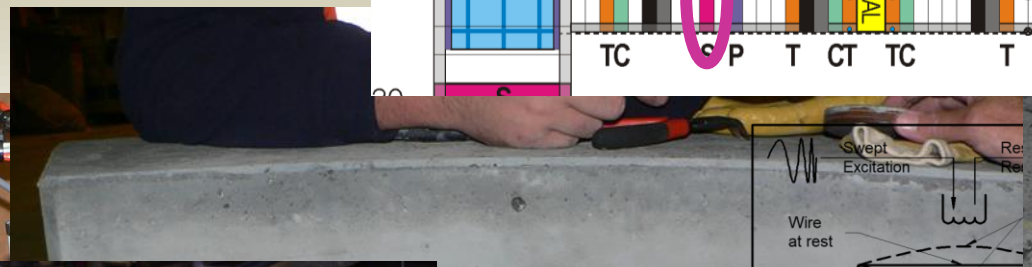
Ten rings instrumented with thermocouples

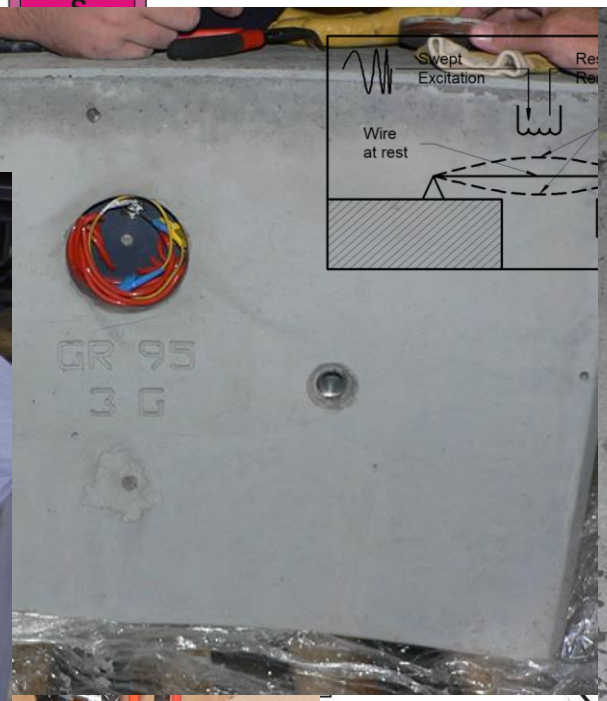


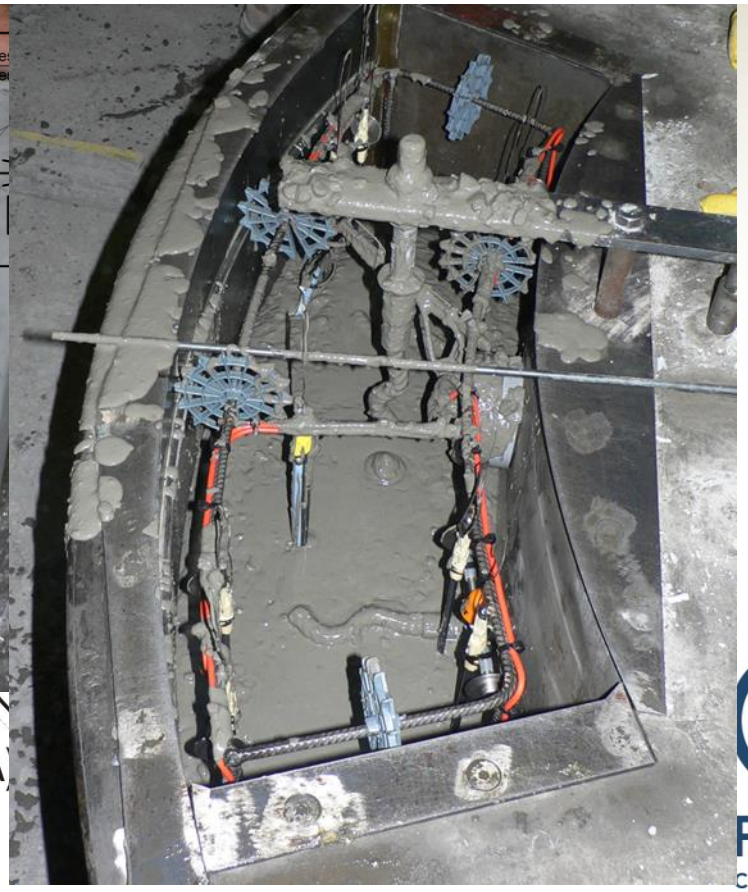


Four rings instrumented with strain gauges









vibrating wire SG

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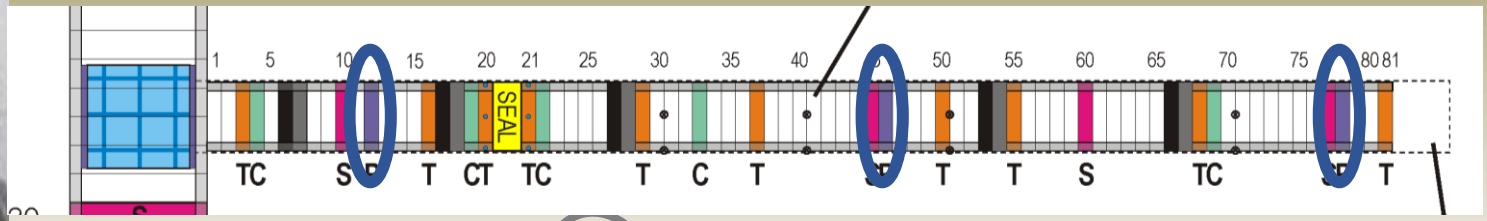
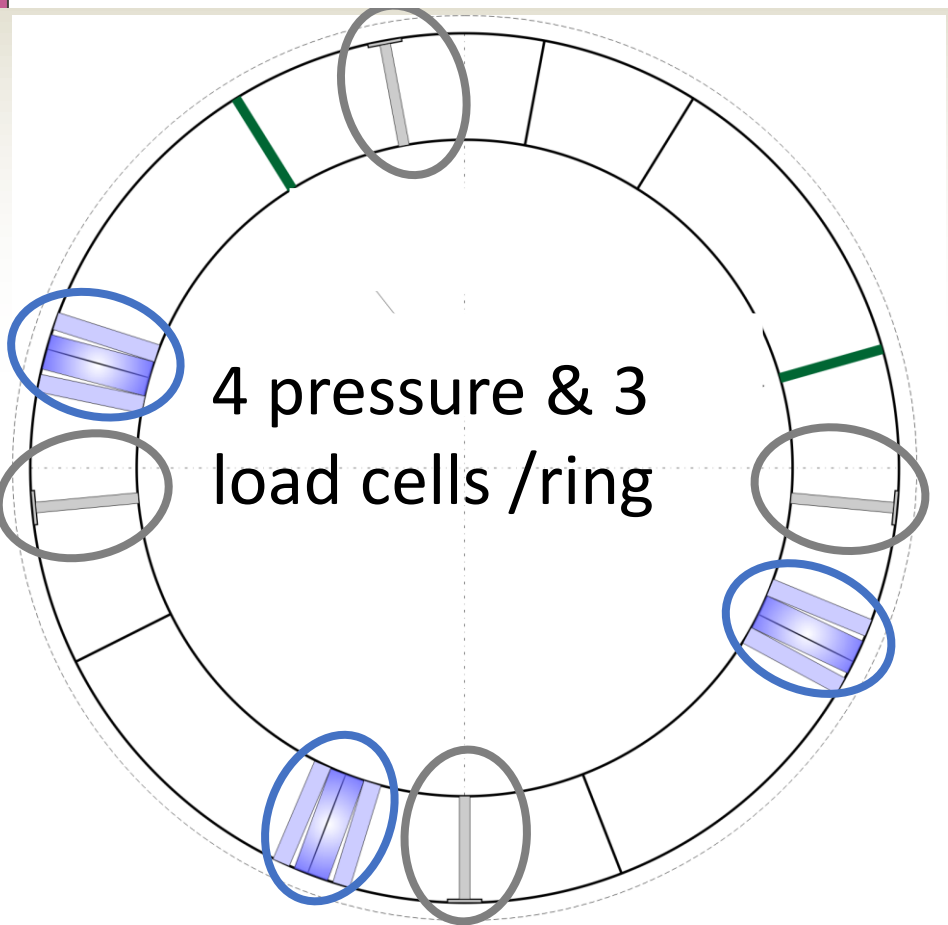
Pressure and load cells in three rings





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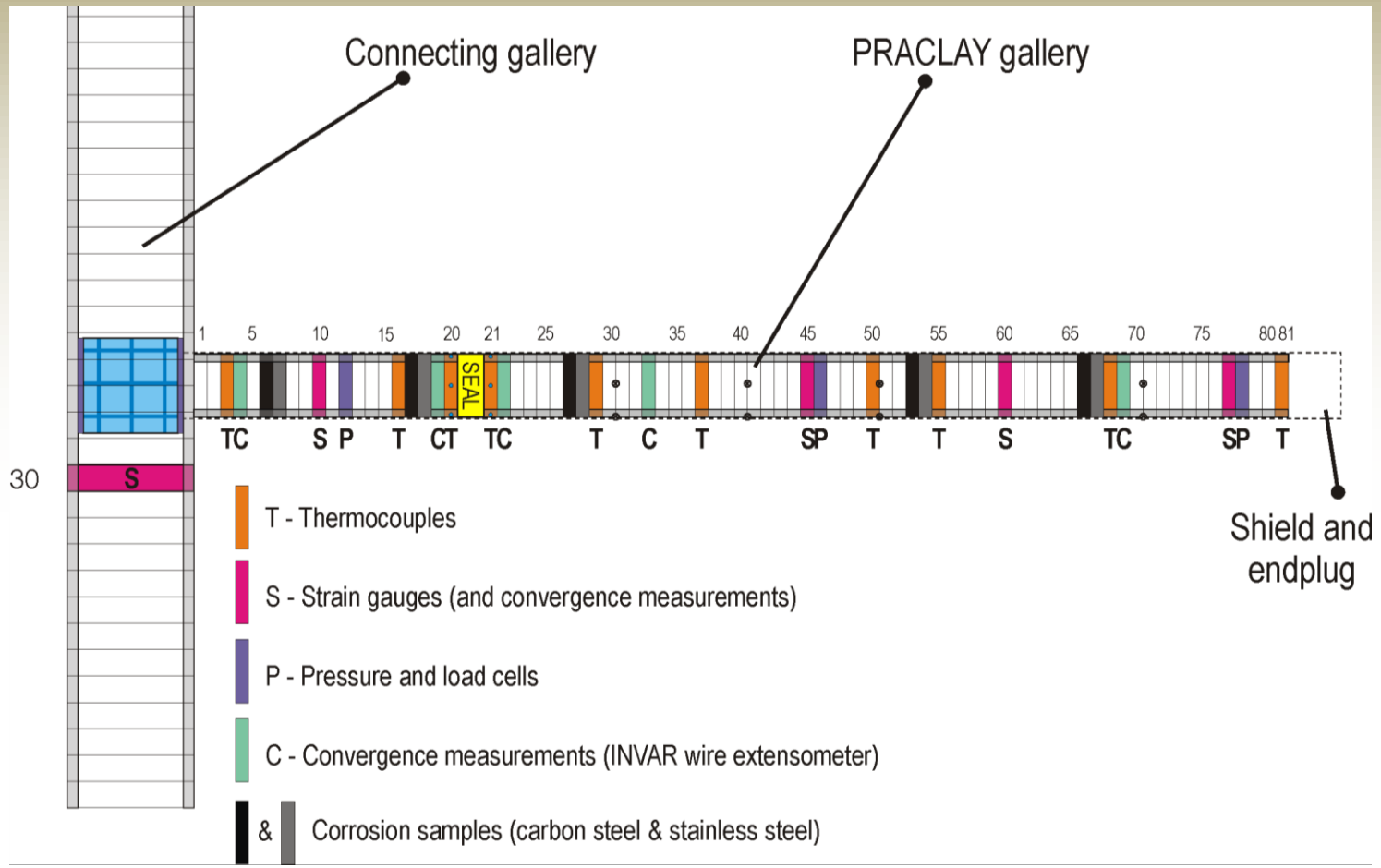
Resulting in > 300 sensors in the PG lining



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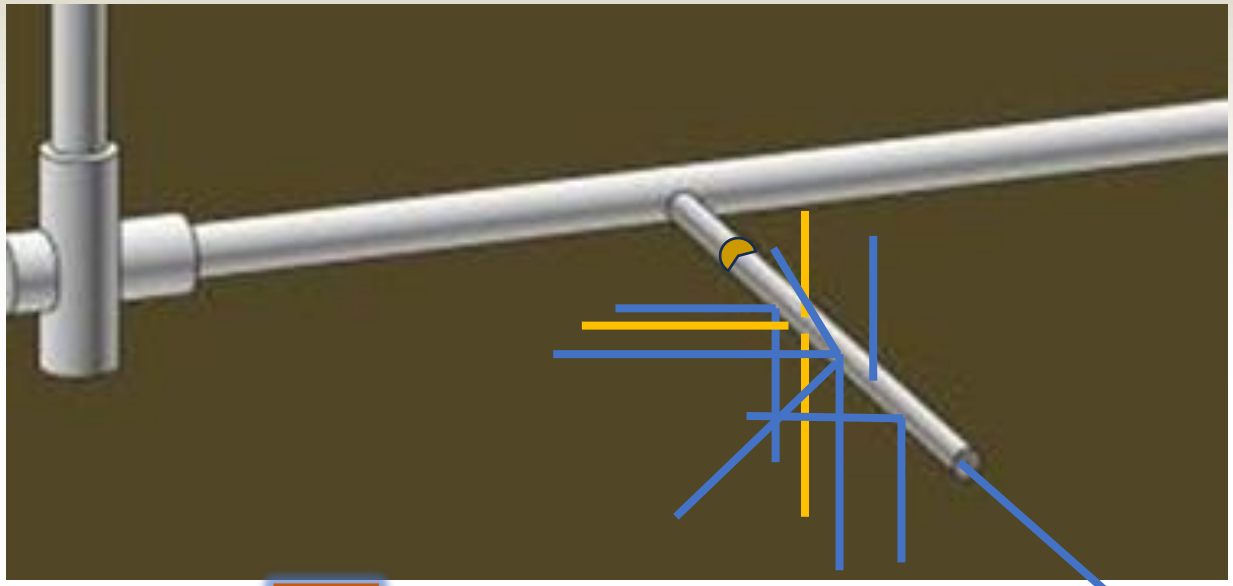
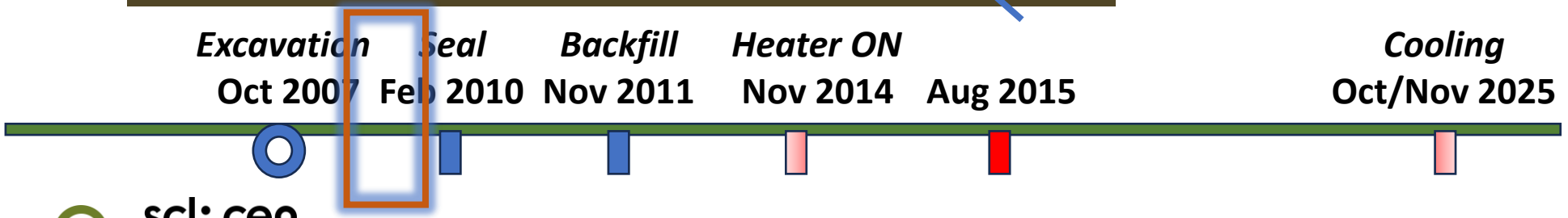
Observation boreholes from the PG (2009)

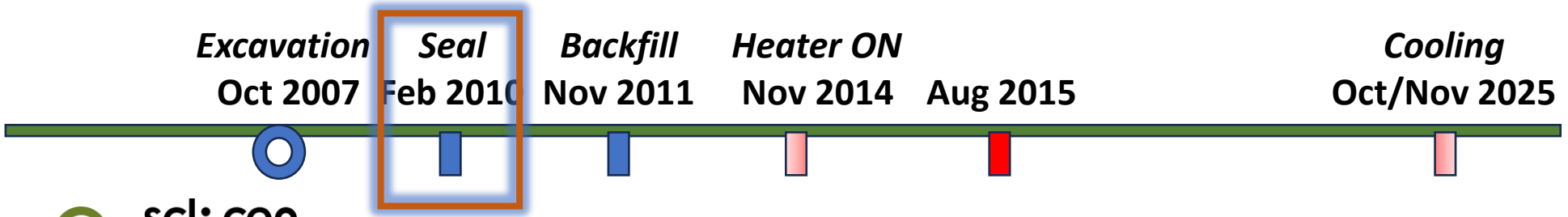
- Additional borehole piezometers (10) to add radial sensing points
- Three extensometer boreholes to monitor displacements



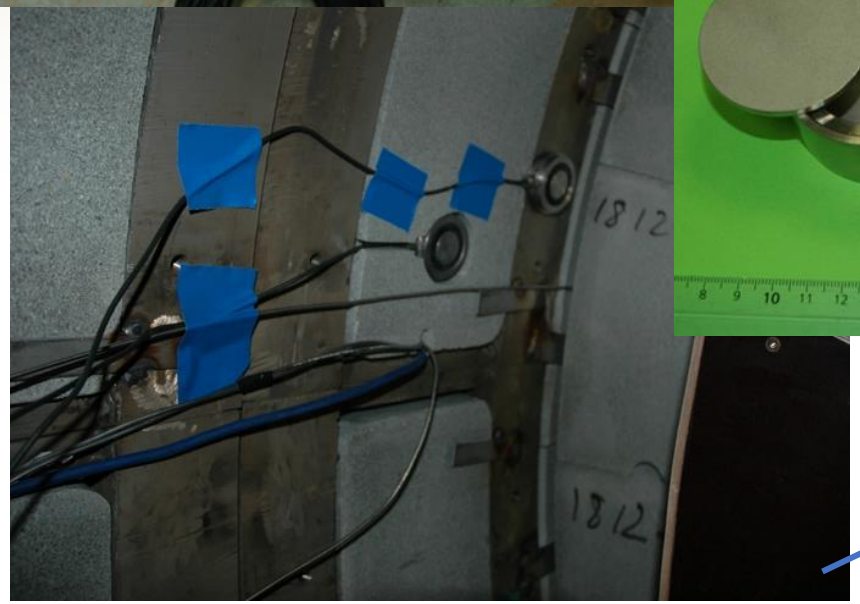


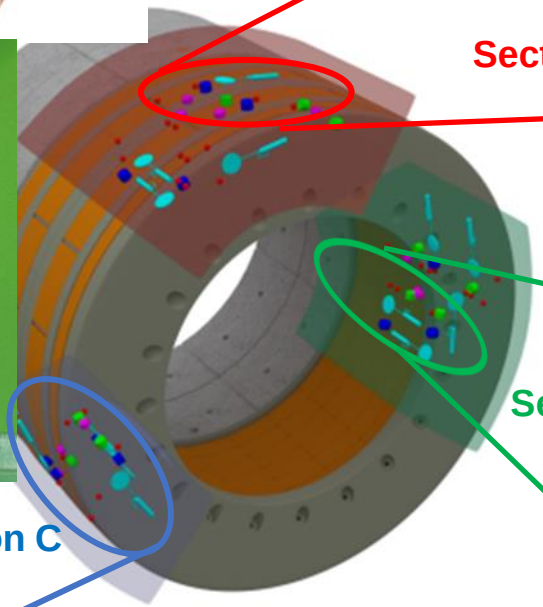
How is Seal performance monitored ? (2010)

- Critical component in the P
  - Undrained conditions for th
  - High porewater pressure an
- Hydro-mechanical monitori
  - Check swelling of bentonite
  - Through moisture content –
- Temperature and pore pres



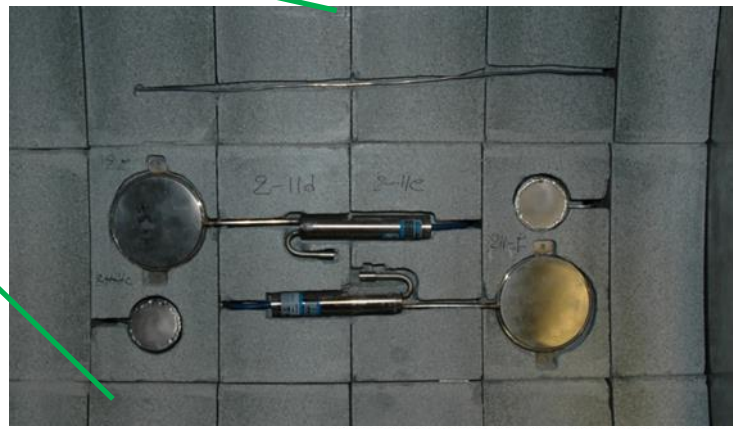
Seal sensors clustered in three sections





Section A

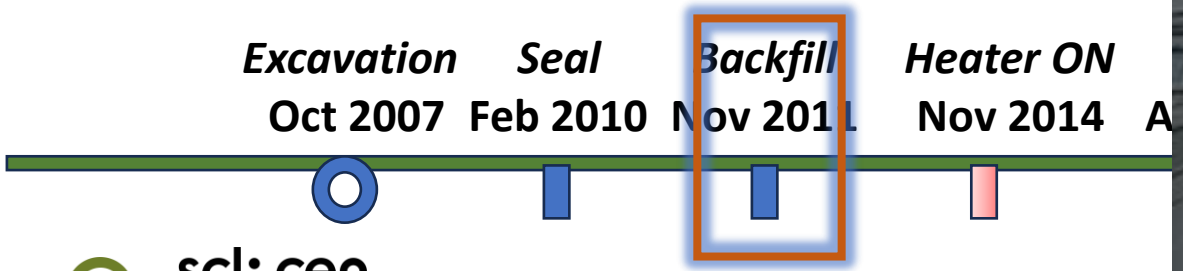
Section B



Section C

PG interior / backfill sensing

- Temperature
  - Check heater cables
- Water pressure
  - Uniform pressure along the gallery backfill



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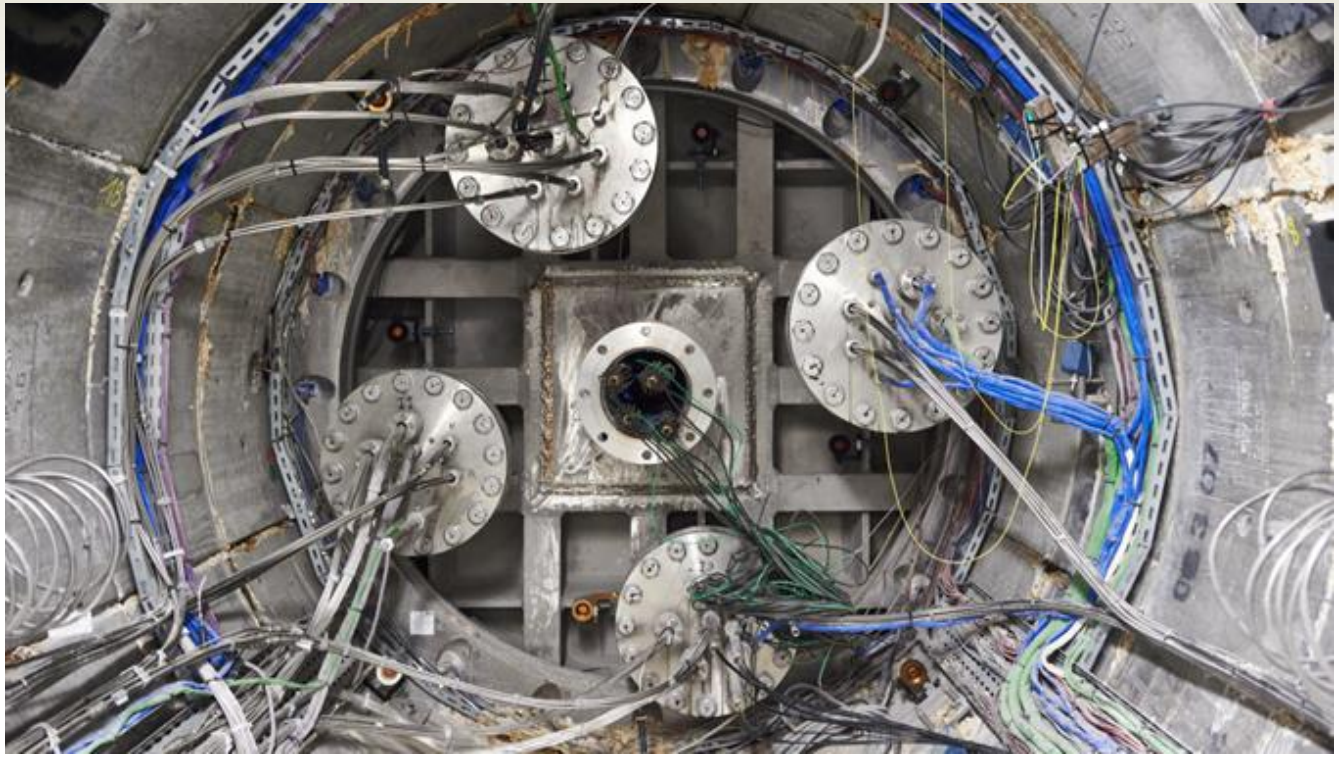
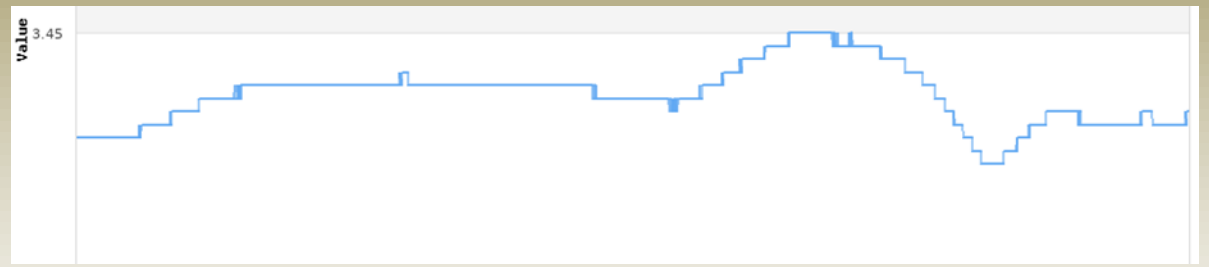
Cabling & Seal feed-through for many sensors

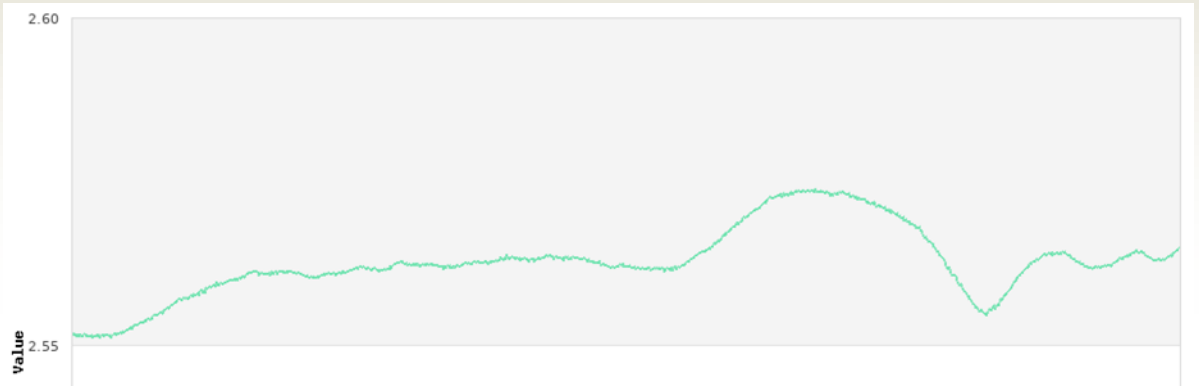
- Challenging operational conditions
  - cabling and junctions subject to elevated water pressure and temperature
  - watertightness



Upgrading of the monitoring set-up to prepare for the cooling

- Data acquisition replacement
  - e.g. higher measurement resolution
- Inclinometer replacement
  - Improved measurement technology →
- Longer time spans
  - equipment becoming obsolete



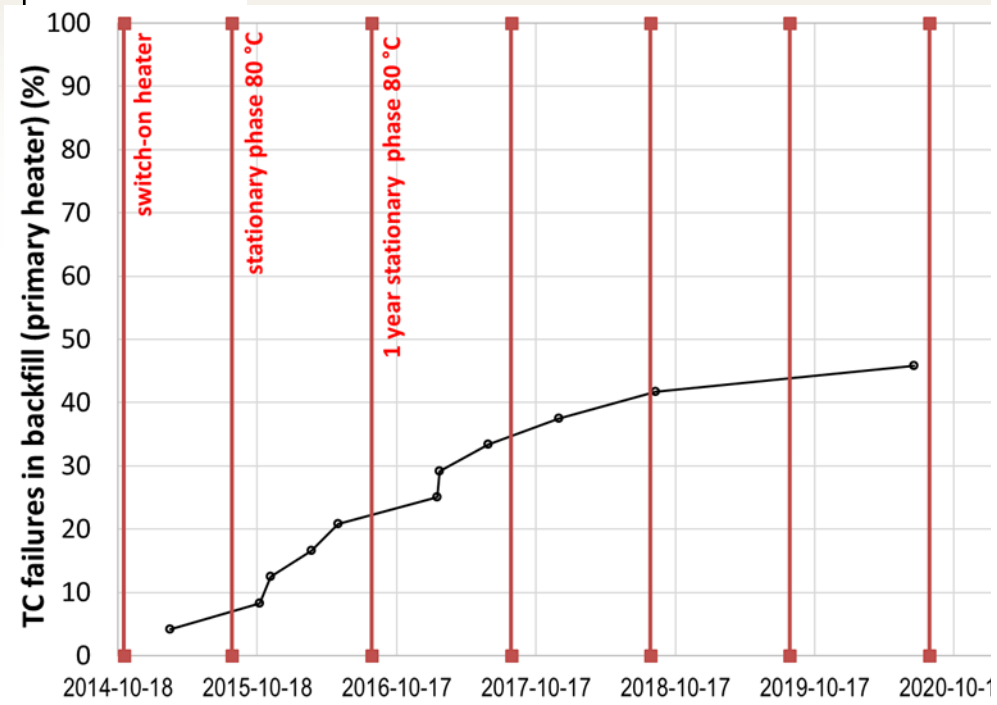


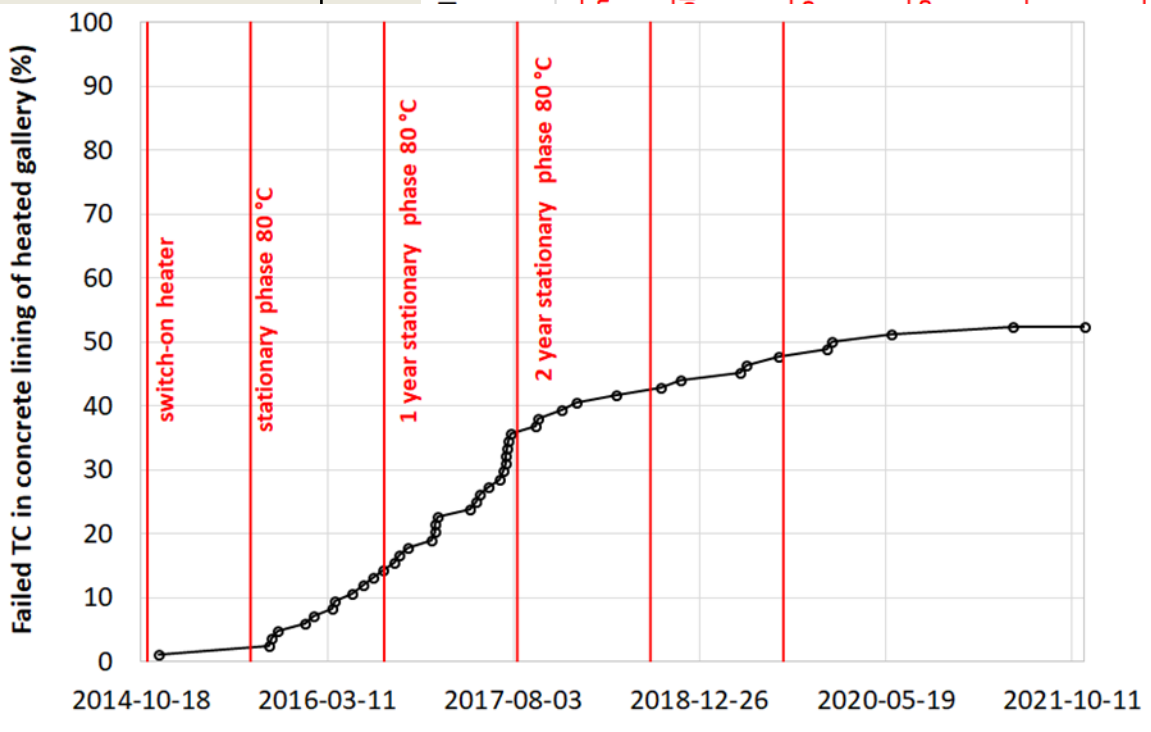
Important REX on sensor performance

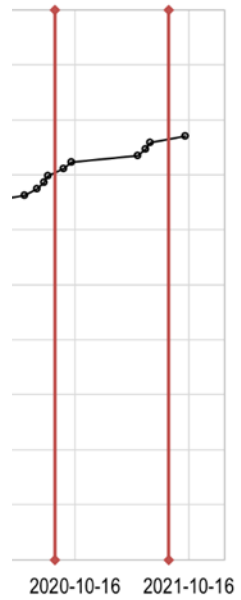
- Long-term sensing → experience for long-term operation
- Conditions in/around PG beyond standard geotechnical specifications
  - Elevated temperatures (> 80 °C) and water pressures (> 2.5 MPa)
- Extensive assessment has been performed on the different sensor types and installations

Thermocouple performance depends on location

	# TC sensors		# Failed	% Failed	
CG PIEZO	109		0	0	
PG PIEZO	83		64	77%	
LINING	120	*84**	44	37%	*52%**
HEATER	24		11	46%	







Main sensor performance assessment results

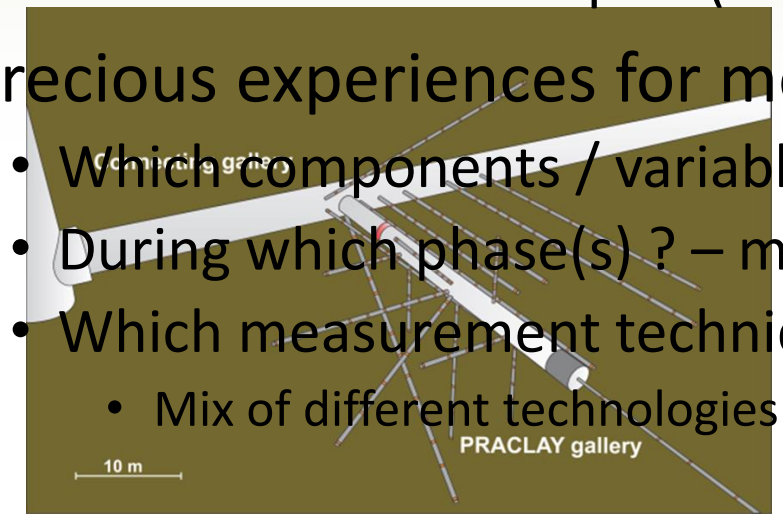
- Temperature and water pressure conditions
  - Avoid cable connections where possible
  - Extensive sensor testing
    - endurance (long-term) testing at relevant conditions
  - Less but more robust sensing points?

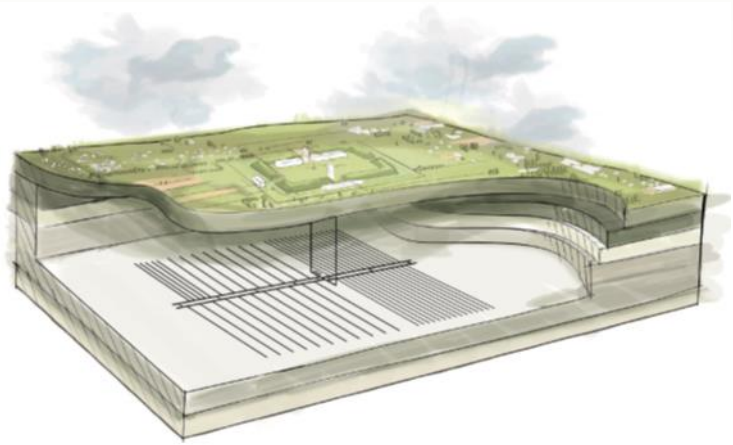
Conclusions

- An extensive and unique dataset has been generated
  - Data management including validation
- Input for design of repository monitoring

Monitoring perspectives

- Long-term monitoring technically feasible
- PRACLAY monitoring not a blueprint for repository monitoring
  - Different monitoring objectives
  - Non-invasive techniques (↔ monitoring boreholes)
- Precious experiences for monitoring s
  - Which components / variable
  - During which phase(s) ? – mo
  - Which measurement techniq
    - Mix of different technologies





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The heating stopped – monitoring continues

- Monitoring effects during cooling
- Dismantling
  → sensor analysis

… for 10 more years ?!