Development and Demonstration of monitoring strategies and technologies for geological disposal

Modern2020

Rock Mechanics Monitoring At Olkiluoto, Finland. Case Study: Monitoring Strategy Of Repository Temperature Evolution

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safe solutions for radioactive waste

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Rock Mechanics Monitoring at Olkiluoto

Purposes and processes of rock mechanics monitoring

- Purposes:
  - ✓ defining baseline
  - ✓ monitor stability of Olkiluoto during construction phase => constructability in point of view of rock mechanics
  - ✓ safeguards (only microseismic network)
- Following processes are monitored during construction phase:
  - ✓ Stress redistribution
  - ✓ Tectonic bedrock movements
  - ✓ Reactivation of existing fractures, formation of new fractures
  - ✓ Isostatic uplift
  - ✓ Seismicity
  - ✓ Thermal evolution
- Monitoring network composed by
  - ✓ microseismic network
  - ✓ GPS-stations
  - ✓ precise levelling
  - ✓ extensometers
  - ✓ temperature measurements inside boreholes
  - ✓ visual observations

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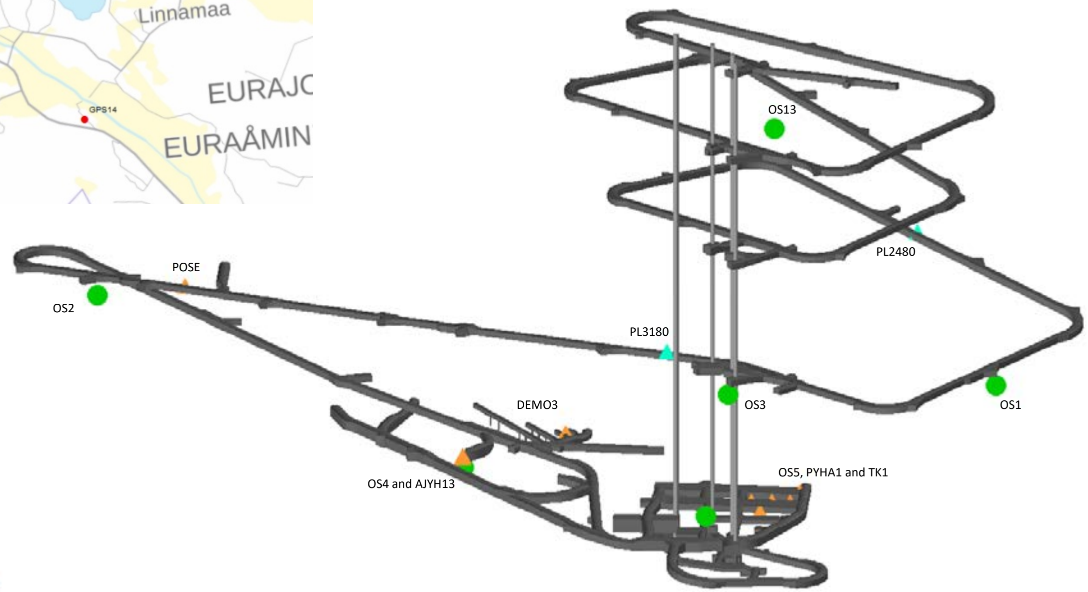
Rock Mechanics Monitoring at Olkiluoto

Rock mechanics monitoring network in Olkiluoto in 2019 at surface (left image) and underground (right image).



The network is composed by GPS stations (red points), microseismic stations (blue on surface and green underground), extensometers (orange and turquoise triangles). Only precise levelling bolts are missing from the images

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M2020 D2.2 test case: Safety functions and EBS

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	Canister monitoring	Buffer monitoring:	Backfill monitoring
In operation phase:	QA/QC in design (material; physical, chemical and geometry), manufacturing and operation	QA/QC in design, manufacturing and operation - Initial state mineralogy - Initial state chemistry - Initial state geometry - Initial state density (dry and bulk) - Initial state water content - Initial state pore structure	QA/QC in design, manufacturing and operation - Initial state mineralogy - Initial state chemistry - Initial state geometry - Initial state density (dry and bulk) - Initial state water content - Visual observation of the deposition tunnel plug face - Analysing and measuring any leakage water coming through the deposition tunnel plug or from plug-rock interface
In full-scale and/or in-situ test:	Canister geometry at installation and dismantling	Mineralogy at installation and dismantling Chemistry at installation and dismantling Geometry at installation and dismantling Density (dry and bulk) at installation and dismantling Water content at installation and dismantling Pore structure at installation and dismantling Swelling pressure (sensors)	Mineralogy at installation and dismantling Chemistry at installation and dismantling Geometry at installation and dismantling Density (dry and bulk) at installation and dismantling Water content at installation and dismantling Swelling pressure (sensors) Relative humidity (sensors) Piping and erosion (visual observation in dismantling)
Throughout construction and operation:	**Other monitored parameters with indirect relation to canister, buffer and backfill**		
	Groundwater flow and chemistry		
	Additional monitored parameters with indirect relation to canister and buffer		
	Seismicity (incl. potential rock displacements)		
	Temperature		

Parameters to be monitored to verify safety functions of canister, buffer and backfill (Table 5-2 from Posiva's test case in D2.2 of M2020).

In Posiva's test case made for deliverable D2.2 of the Modern2020- project, temperature was identified to be a parameter that has indirect relation to canister and buffer and that it needs to be monitored throughout construction and operation

↓

Temperature influences on the water (re)distribution, the chemical alteration and the swelling pressure of bentonite

↓

Thus the bentonite safety functions, protecting the canister, can not be guaranteed

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Case study: Monitoring strategy of repository temperature evolution

Temperature monitoring in a final repository

- Radioactive decay of spent nuclear fuel will continue throughout the entire operational phase of the repository. Consequently, excess heat from the deposited canisters will flow on to the surrounding barriers, while also inducing temperature and thermal stresses increase in the rock barrier.
- The heat flow from the deposited canister has been identified to affect the following factors:
  - ✓ the stability repository openings
  - ✓ the safety functions of EBS barriers
  - ✓ ageing of tunnel reinforcements
- In order to monitor the preservation of safety functions of the EBS barriers temperature evolution can be used as a proxy. The most important design requirement relates to the bentonite clay buffer and backfill, stating that the temperature of the installed buffer shall stay below 100˚C

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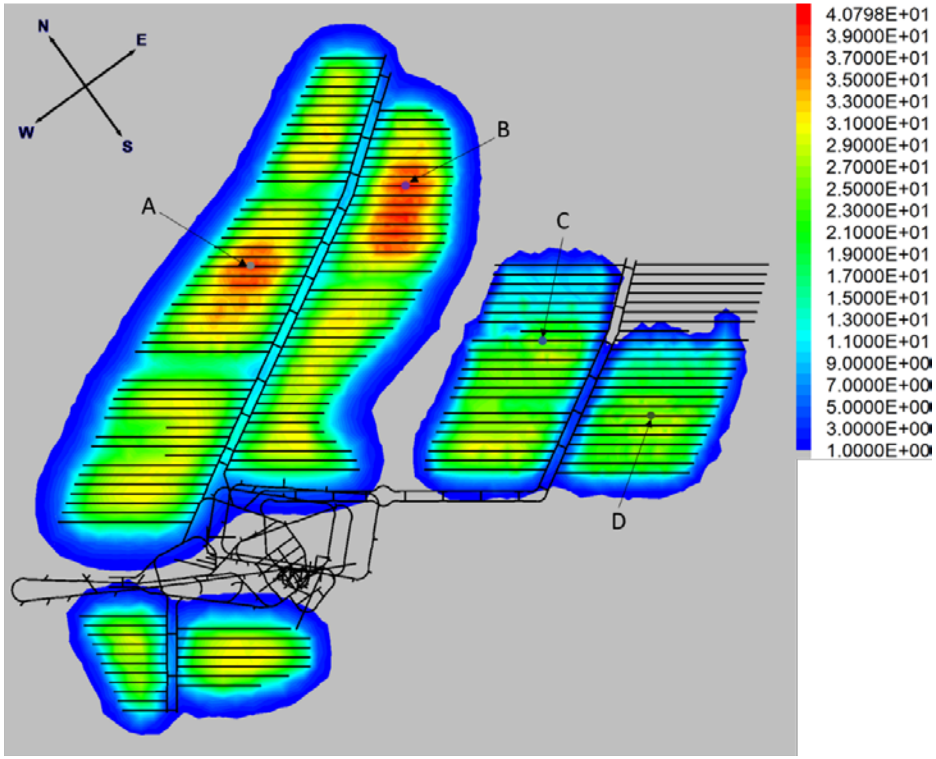
Case study: Monitoring strategy of repository temperature evolution

Strategy of monitoring thermal evolution

- Thermo-mechanical modelling of the repository temperature evolution by Clay Technology AB
  - ✓ Predictive model highlights the areas where maximum temperature are reached
  - ✓ In addition, estimates of the timing of the maxima can be established
  - ✓ Model set up is simplified, to consists of perfectly intact and elastic matrix. No effect of flowing fracture network of deformation zones are taken into account.

- Constrains related to the strategy of monitoring results to following conditions:
  - ✓ where the temperature is predicted to increase at the earliest stage during the repository operation.
  - ✓ where maximum temperature changes are predicted.
  - ✓ where temperature changes are predicted to be minor.
  - ✓ Temperature increase should have sufficient lateral and vertical coverage, in the direction of predicted anisotropy (foliation).
  - ✓ Temperature changes should be monitored in locations relative to water bearing features
  - ✓ Long enough baseline monitoring for ambient temperature of the bedrock
  - ✓ easy maintenance of the instruments and continuous data collection
  - ✓ replaceable and reachable measuring devices



Bedrock temperature increase (> 1°C) at year 160 after deposition of first canister. Horizontal section from depth level -420 m. Coloured dots, marked with A, B, C and D, act as local maximum query points for obtaining estimate of the local temperature maxima.

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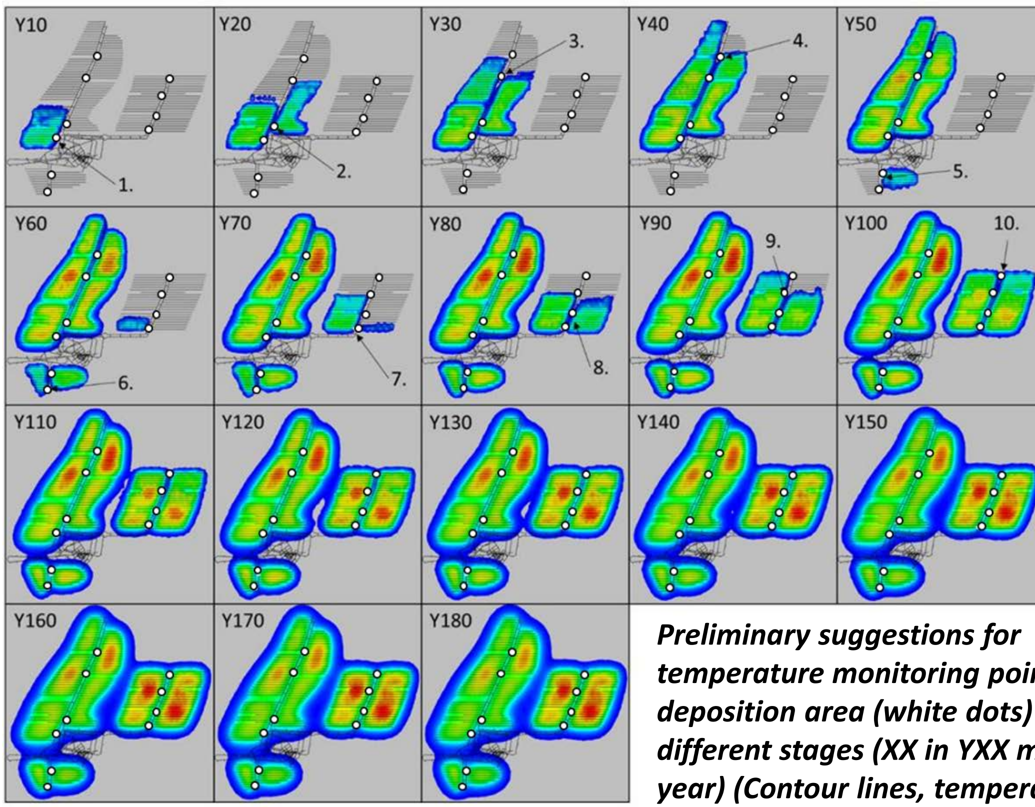
Case study: Monitoring strategy of repository temperature evolution

Suggested monitoring points in deposition area



Preliminary suggestions for temperature monitoring points in deposition area (white dots) at different stages (XX in YXX means year) (Contour lines, temperature increase > 1°C, horizontal section from level -420).

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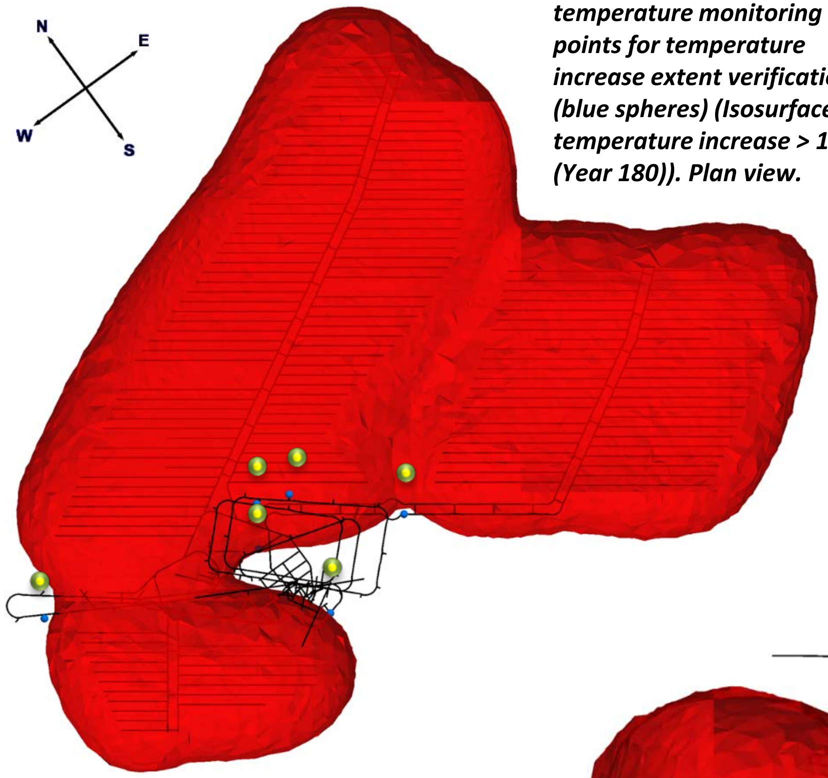
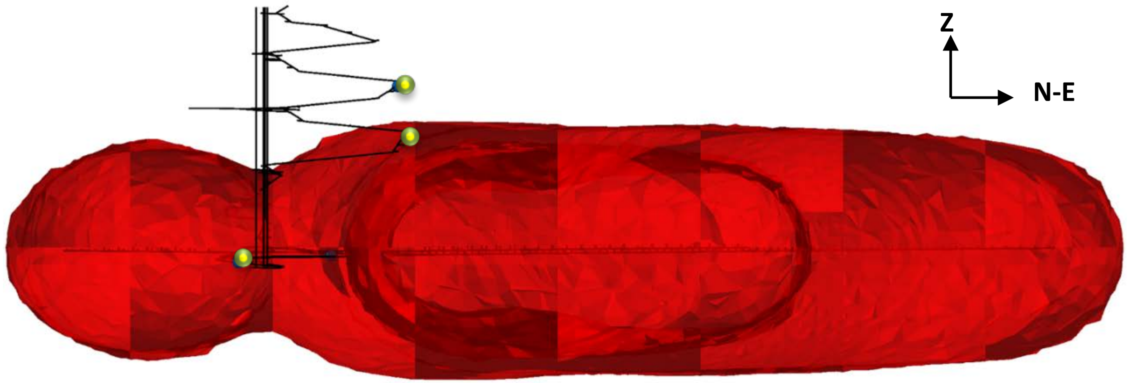
Case study: Monitoring strategy of repository temperature evolution



Preliminary suggestions for temperature monitoring points for temperature increase extent verification (blue spheres) (Isosurface temperature increase > 1°C (Year 180)). Plan view.



Preliminary suggestions for temperature monitoring points for temperature increase extent verification (yellow spheres) (Isosurface temperature increase > 1°C (Year 180)). View from South-West.

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Case study: Monitoring strategy of repository temperature evolution

Remarks

- Technical challenges on the monitoring instrumentation
  - ✓ limitations on foreign materials and tunnel closure
  - ✓ no instrumentations and boreholes allowed inside the deposition tunnels
  - ✓ ageing of instrumentation: possible conflict between datasets before and after instrumentation changes
- Time schedule
  - ✓ Establish a reliable baseline prior to deposition of first canisters
  - ✓ Coordinate monitoring advancement with canisters deposition
- Monitoring strategy in general
  - ✓ Based on predictions of the extent and magnitude of selected processes
  - ✓ Prediction needs to be validated continuously by observations on the field

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Establishing a monitoring strategy

Conclusions

- Formulation of suitable monitoring
  - ✓ **Identification** of the stage of the repository project => objective for extent and scope of the monitoring
  - ✓ **Using previously collected data sets** => undisturbed baseline and identify processes affected by construction and operational activities
  - ✓ **Predict** the extent and magnitude => identification the location of the largest changes, for monitoring point installation
  - ✓ **Long-term safety** for drillhole locations or foreign materials

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