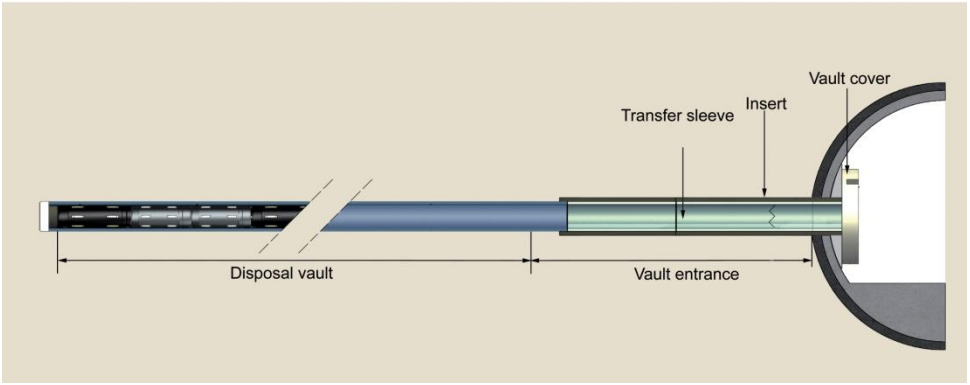
LUCOEX WP3 status

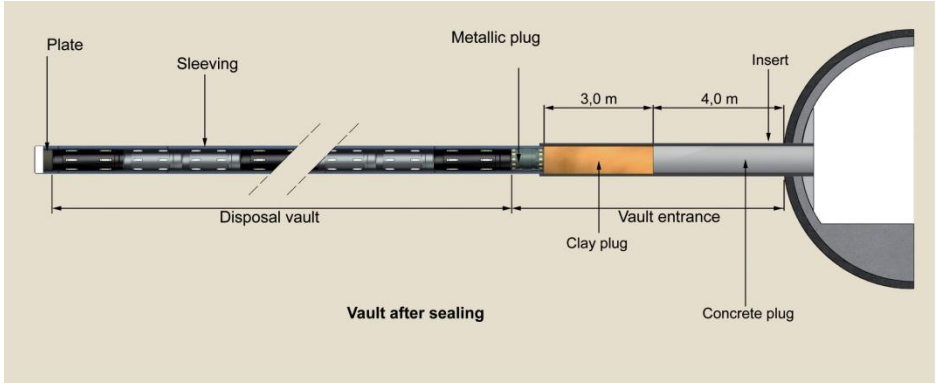
Oskarshamn – 13/05/2014

Concept of disposal cells for long life and high level activity wastes (HLW)

Horizontal micro tunnels, about 700 mm in diameter, cased with steel casing (sleeve and insert)

- Usable part ("body" part) at least 30 m long used for containers disposal,
- Head part 10 m long used for cell sealing
- End steel plug (base plate) and shield steel plug





→ Definition of a demonstration program at the Bure URL to test the feasibility of construction and the behaviour of such disposal cells

Full scale demonstrator – phase 3

The main objectives of phase 3 full scale demonstrator are:

- test the making up of the cell (head & usable part) and of different equipments into the cell (base plate and shield plug),
- verify the suitable working of the head insert to absorb the thermal dilation of the sleeve in the body part,
- provide data on the sleeve behaviour under thermal loading,
- verify the design of the cell head to limit thermal gradients on the drift wall,
- study the THM behaviour of the interface between rock and sleeve, and of the surrounding rock (not included in LUCOEX).

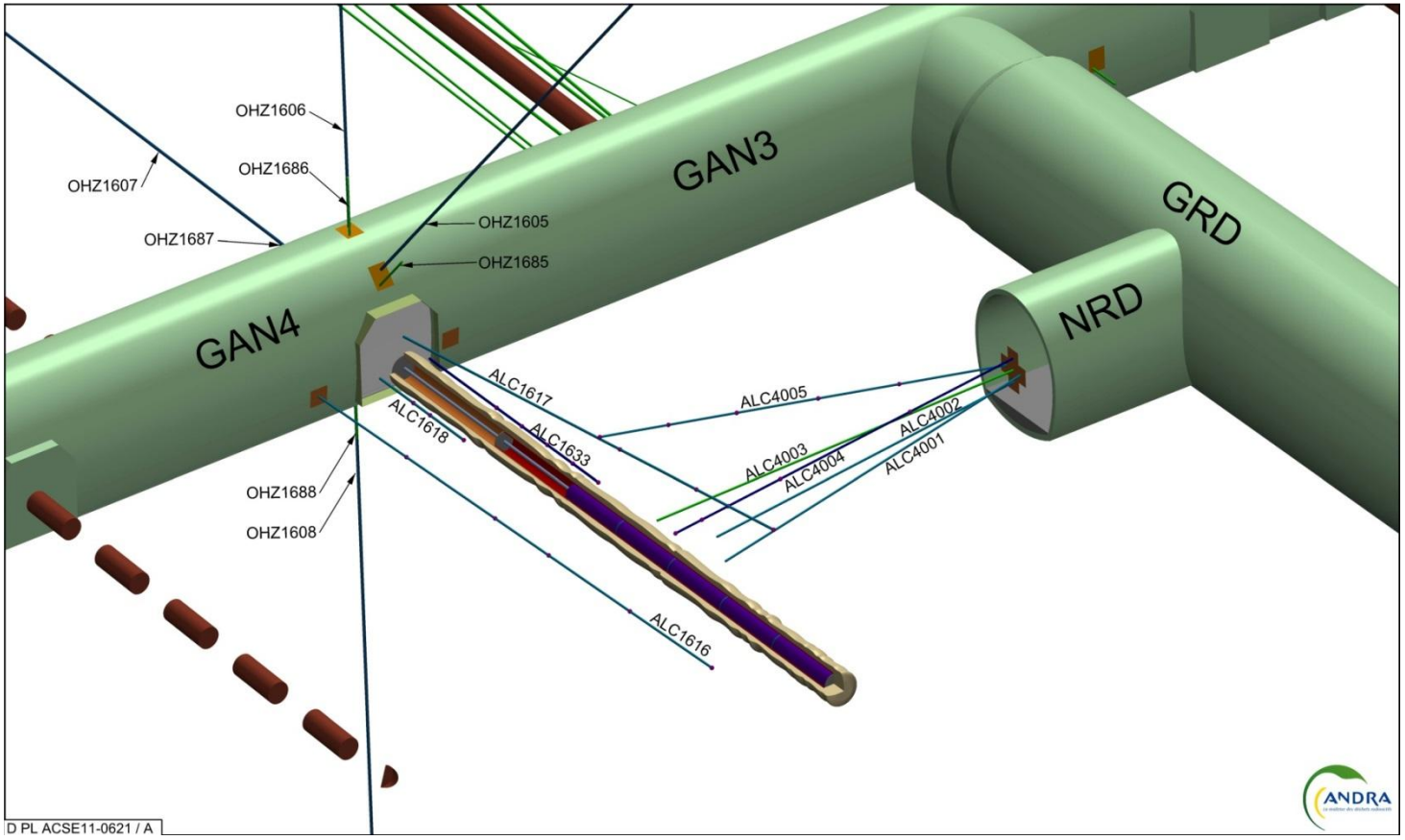
→ back experience of the former phases used to optimize the design

Demonstration cell characteristics

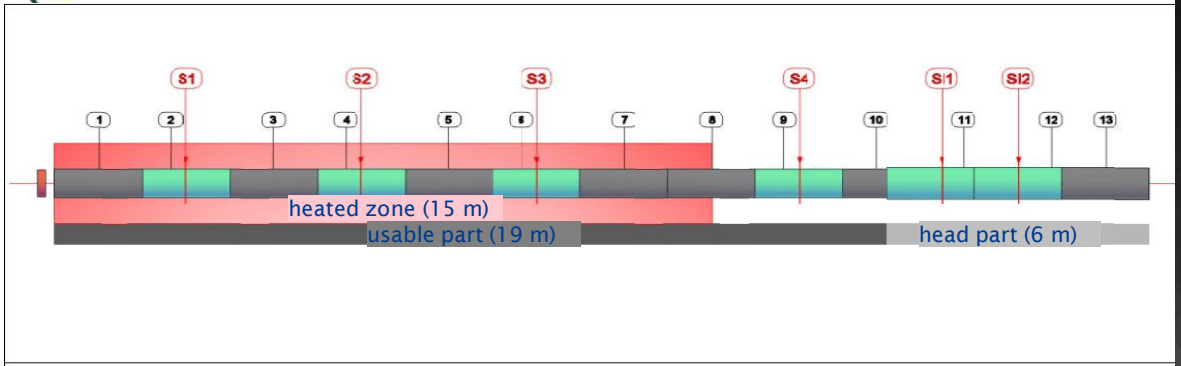
25 m long micro tunnel:

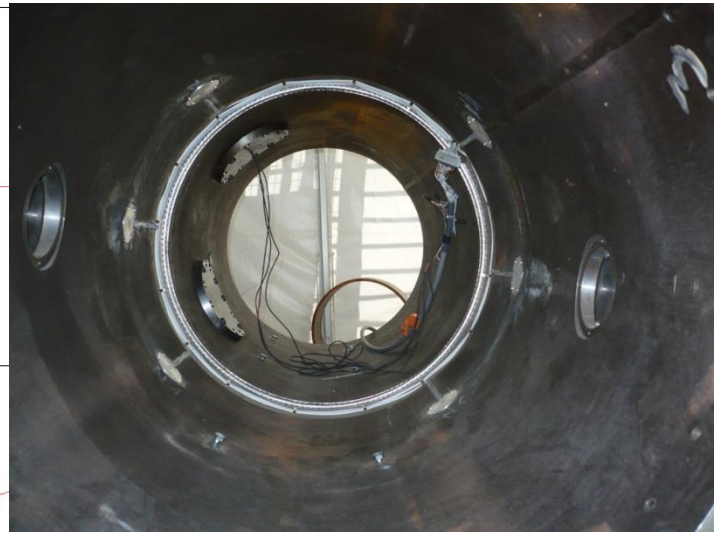
- Usable part excavated 750 mm Ø, steel sleeve 700 mm Ø, length 19 m
- Head part excavated 791 mm Ø, steel insert 767 mm Ø, length 6 m
- Base plate, shield plug and insert cover plate

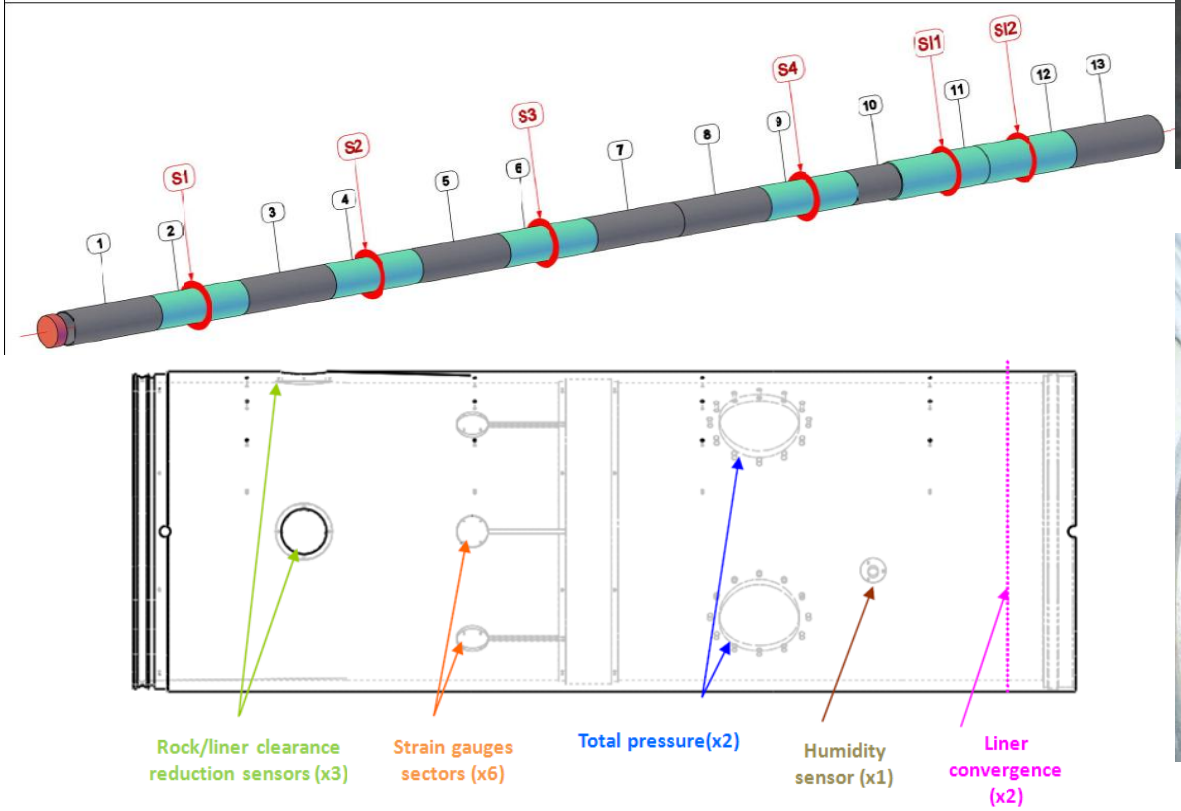
Heating carried out between 10 and 25 m depth, up to 90°



Casing instrumentation (Egis Géotechnique)

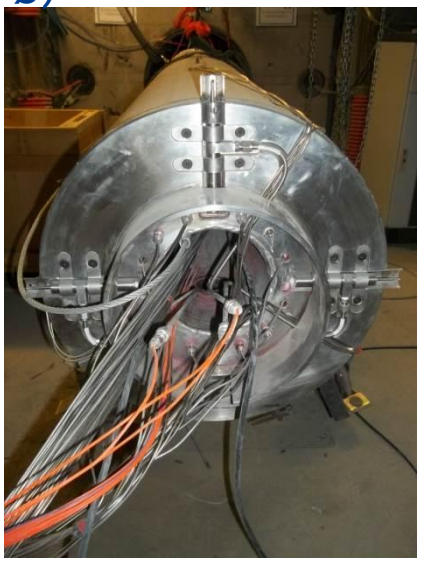






Heaters (Aitemin)

5 elements 3 m long – 50 cm ø)



Body part's head plate

Base plate

Insert cover plate

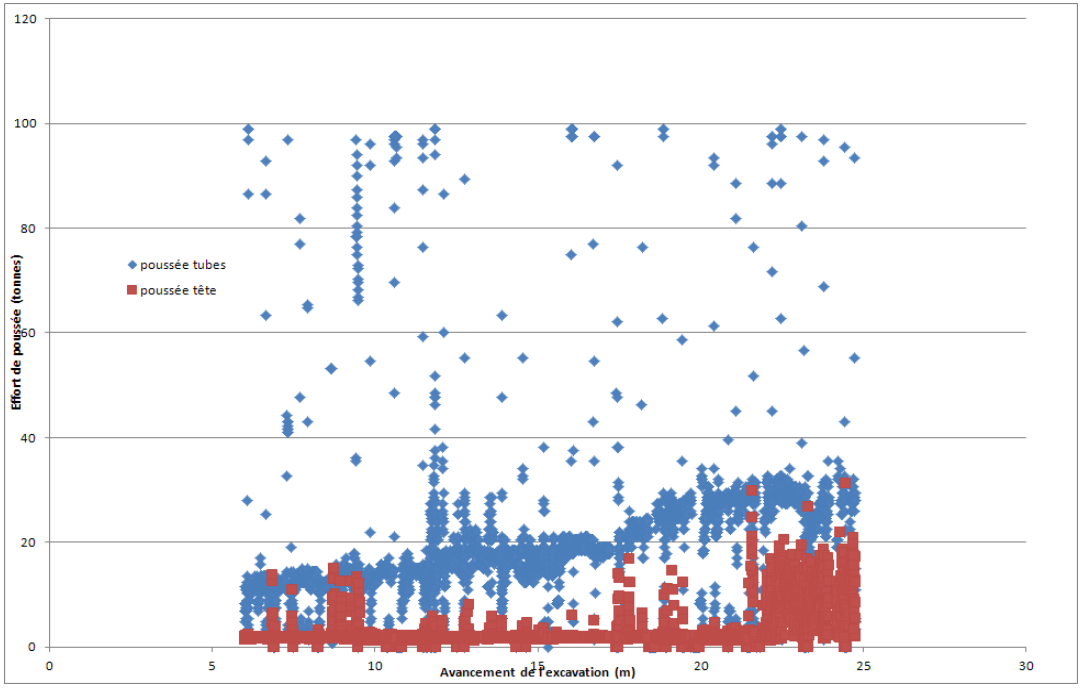
Cell demonstrator excavation (CSM Bessac)

Excavation from 23rd to 31st October 2012.

- Cell head excavation (5,5m in rock) in 16 hrs (0,35 m/hr),

- Body part excavation in 2 phases:
  - to PM 24,3 in 40 hrs (0,46 m/hr), then broken piece on drilling machine;
  - excavation of the last 50 cm by reverse rotation (ø 60 cm, then liner pushing), final PM 24,8.

Thrust effects on the liner (sleeve and insert) staid limited (< 40 tons)

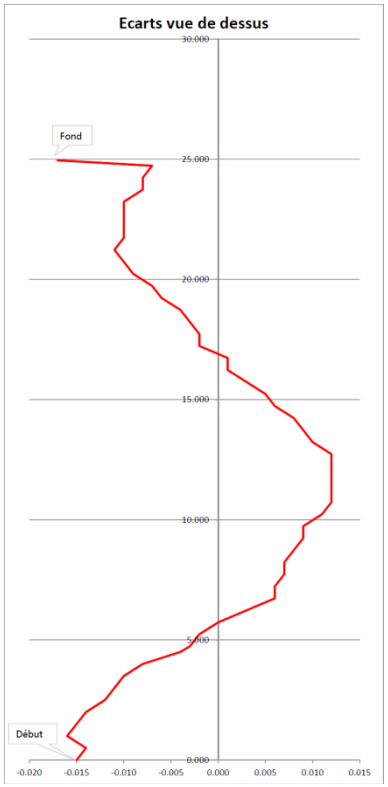


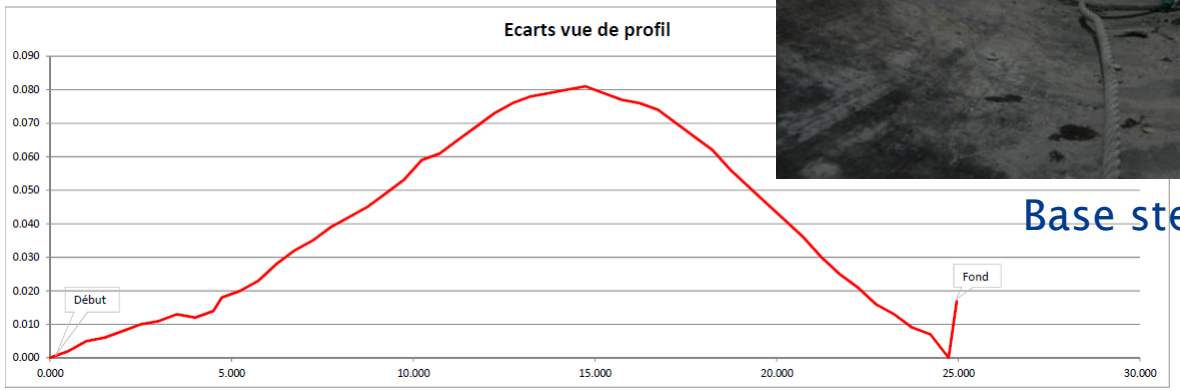
Cell demonstrator excavation (CSM Bessac)

Small deviation to theoretical trajectory:

3 cm in horizontal plane

8 cm in vertical plane

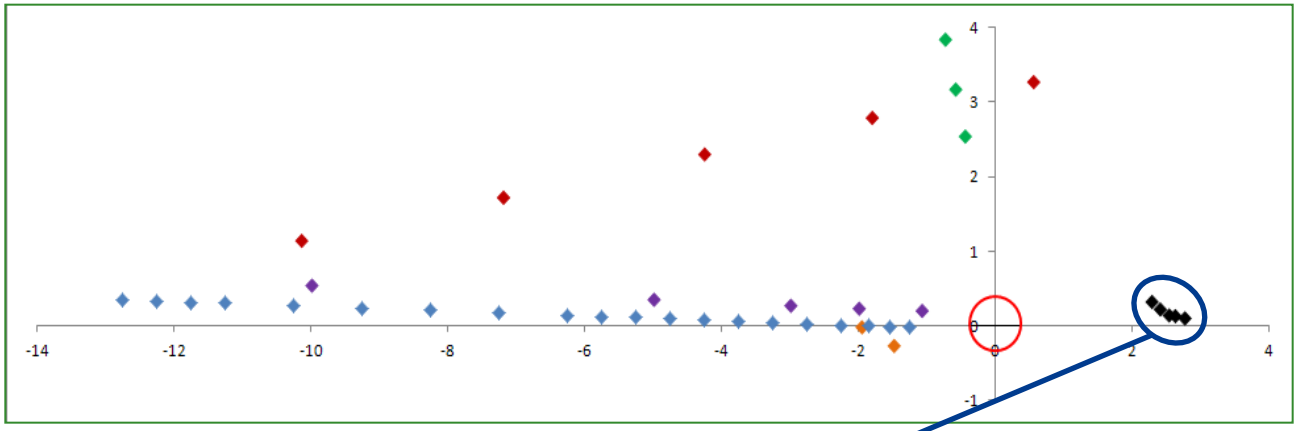


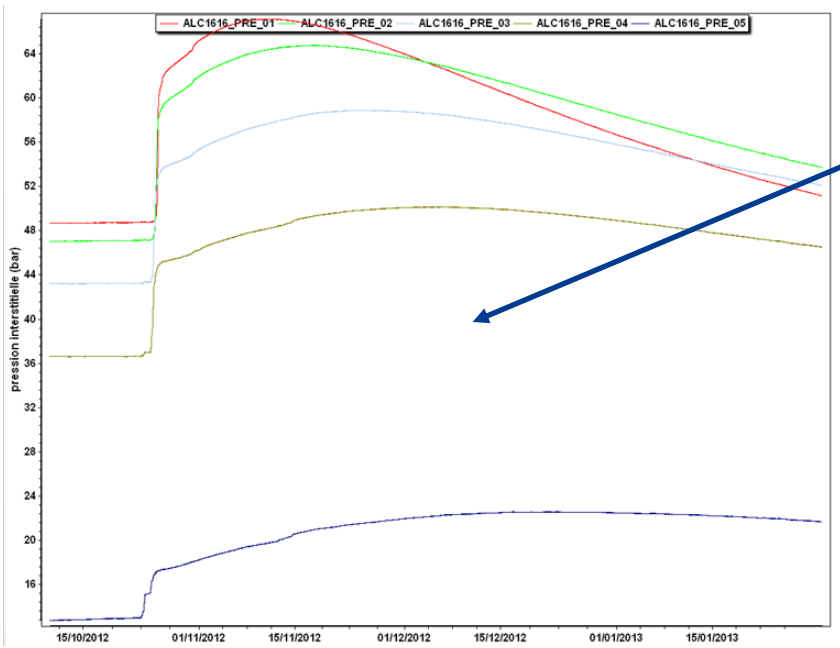


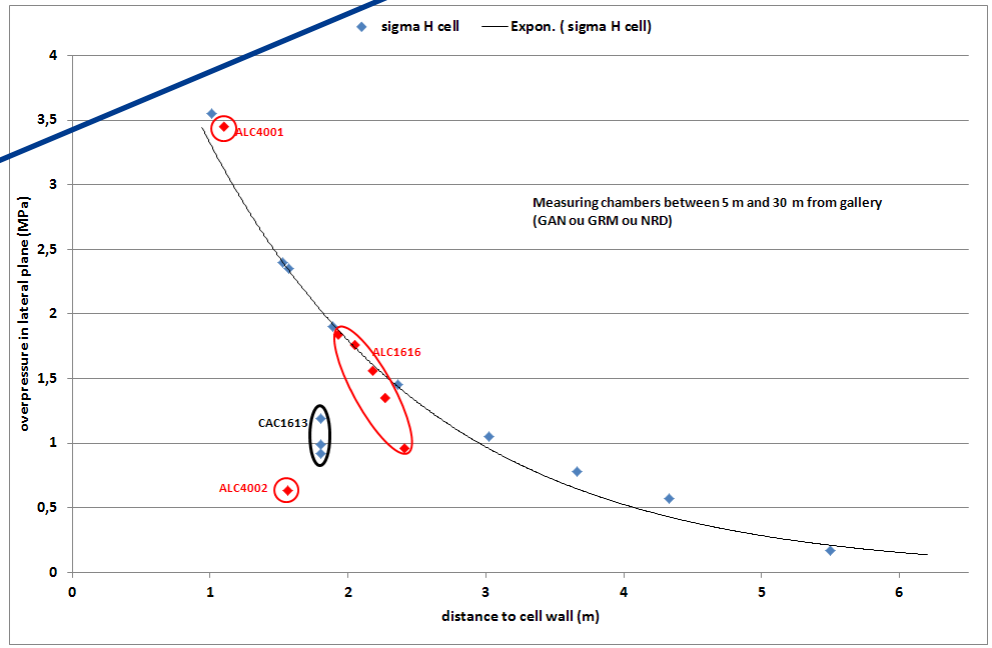
Base steel plate

HM impact of excavation

Location of measurement points around the cell demonstrator





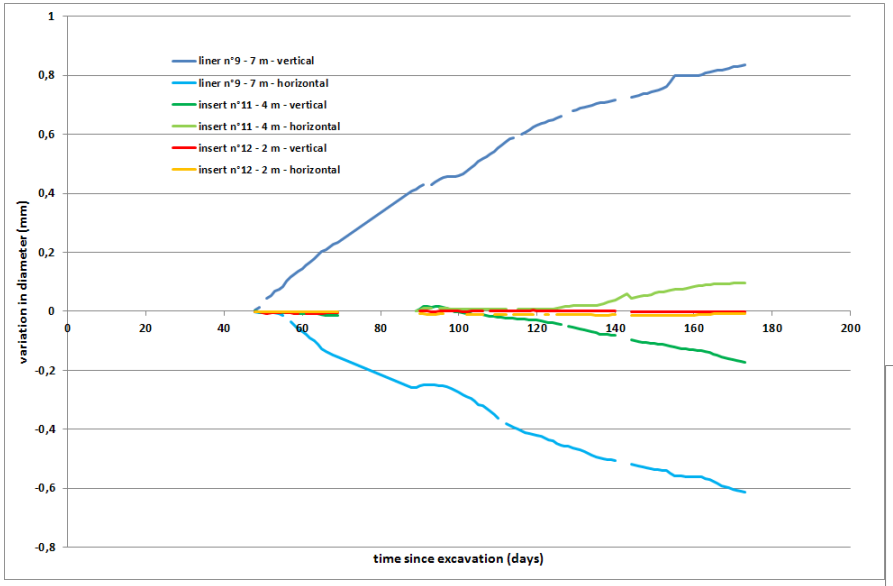


Strong overpressure in horizontal plane

Excavation HM impact consistent with former phases

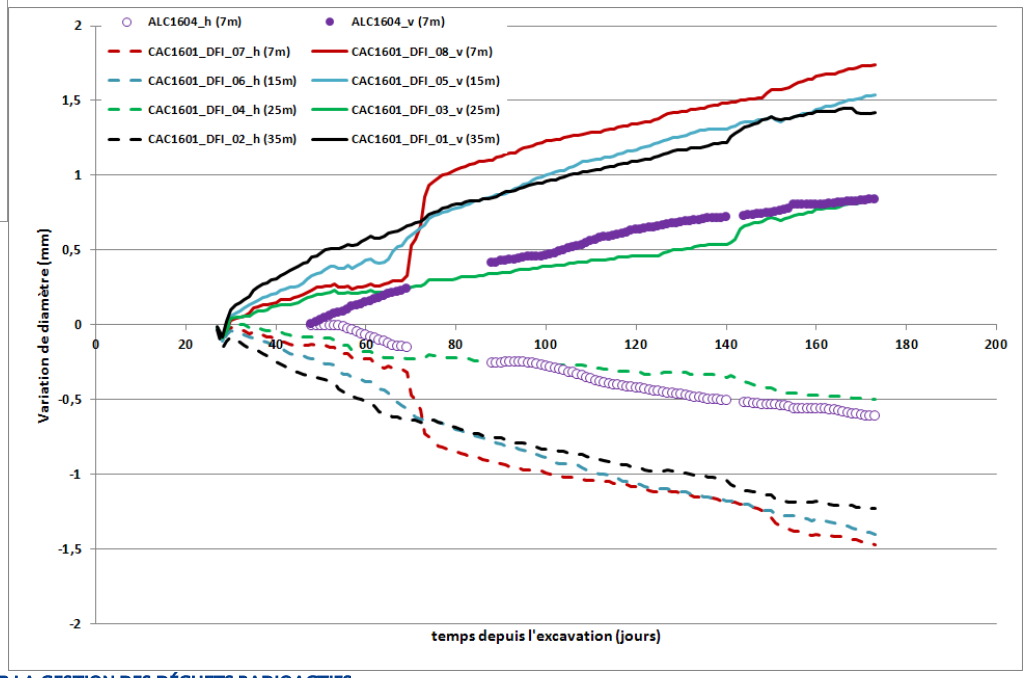
Sleeve and insert behavior before heating

Sleeve and insert diameter variation induced by cell wall convergence



Deformation starts immediately once the sensors are installed

→ contact rock/sleeve through breakouts spalling, rubbles



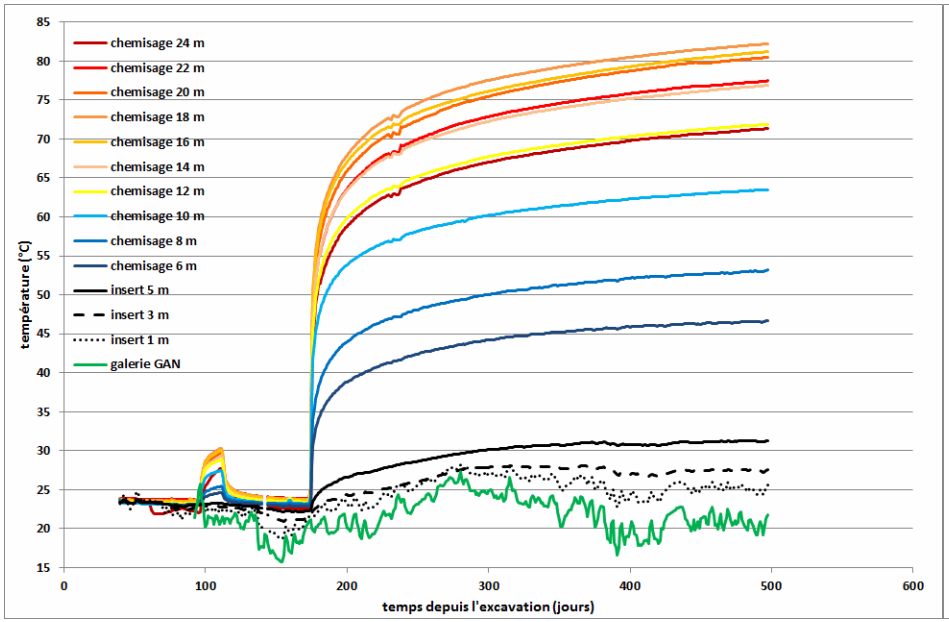
→ Consistent with what was observed in the former phases

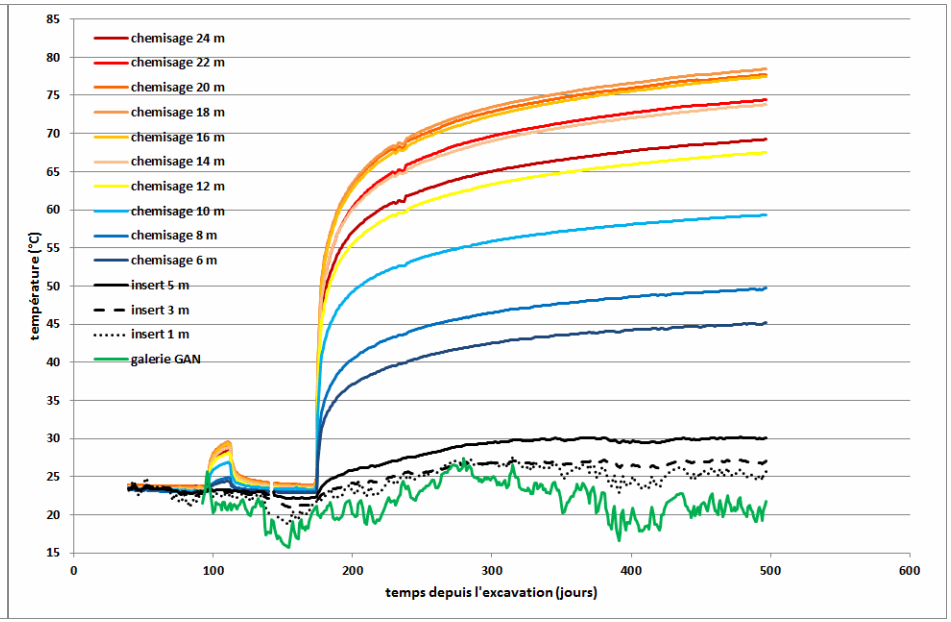
Heating phase

Heating test at very low power (33 W/m) from 31st January to 15 February 2013.

Main heating phase at 220 W/m started on18 April 2013

→ 90°C in 2 years on the sleeve

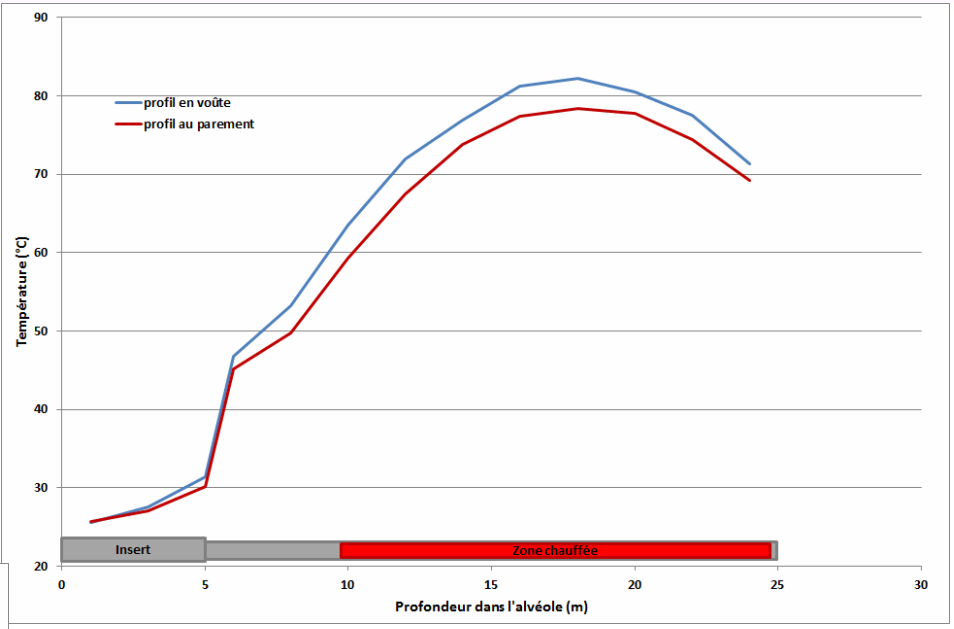


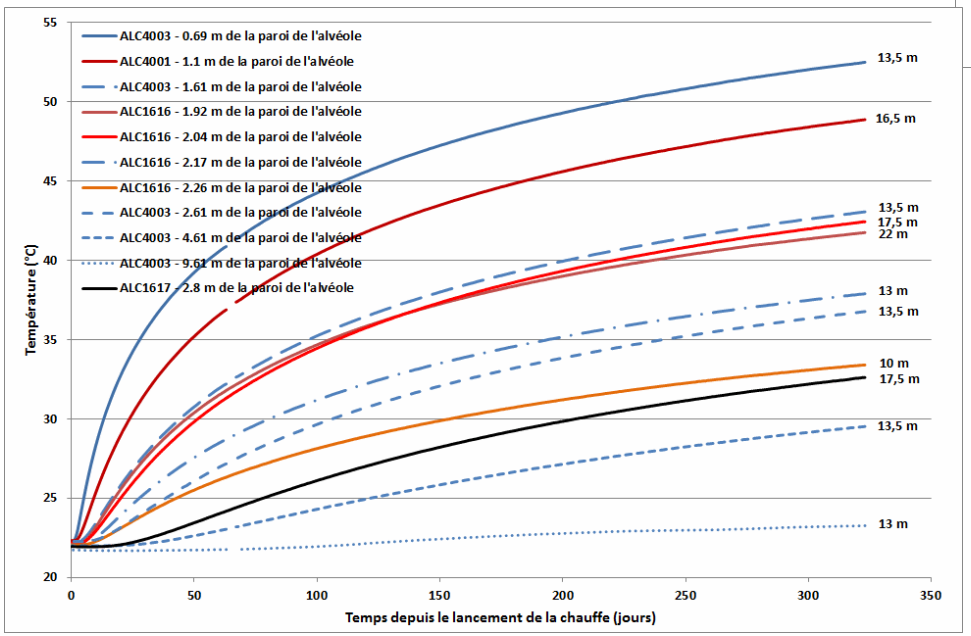


T° profile at the vault about 4°C > T° profile on the side → influence of rock contact

Heating phase

Temperature profile along the cell: T° centered on 18 m depth (center of the heated zone)



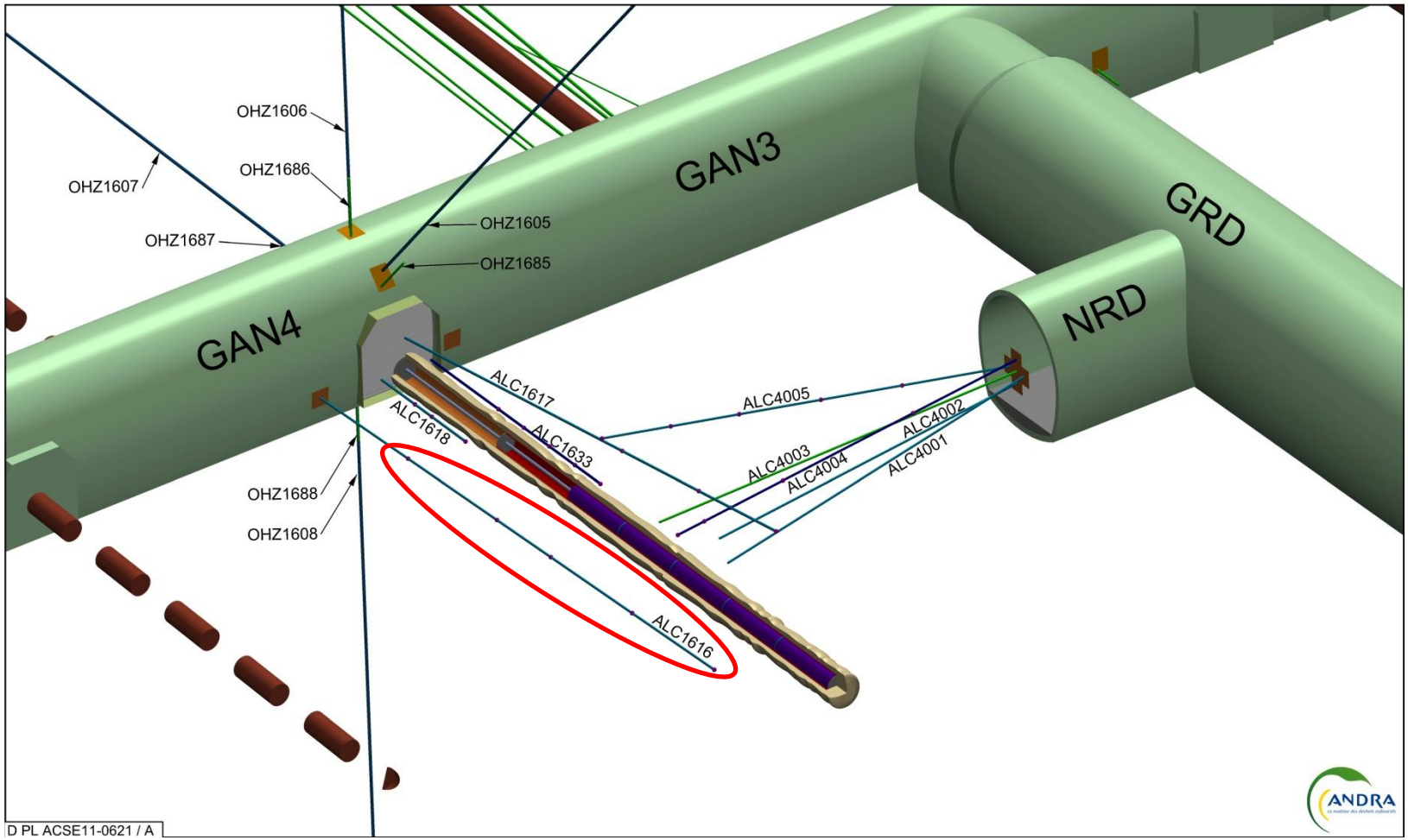


At a given distance from cell wall, temperature higher in the middle of the heated zone.

At a given distance from the cell wall, temperature higher in horizontal than in vertical plane.

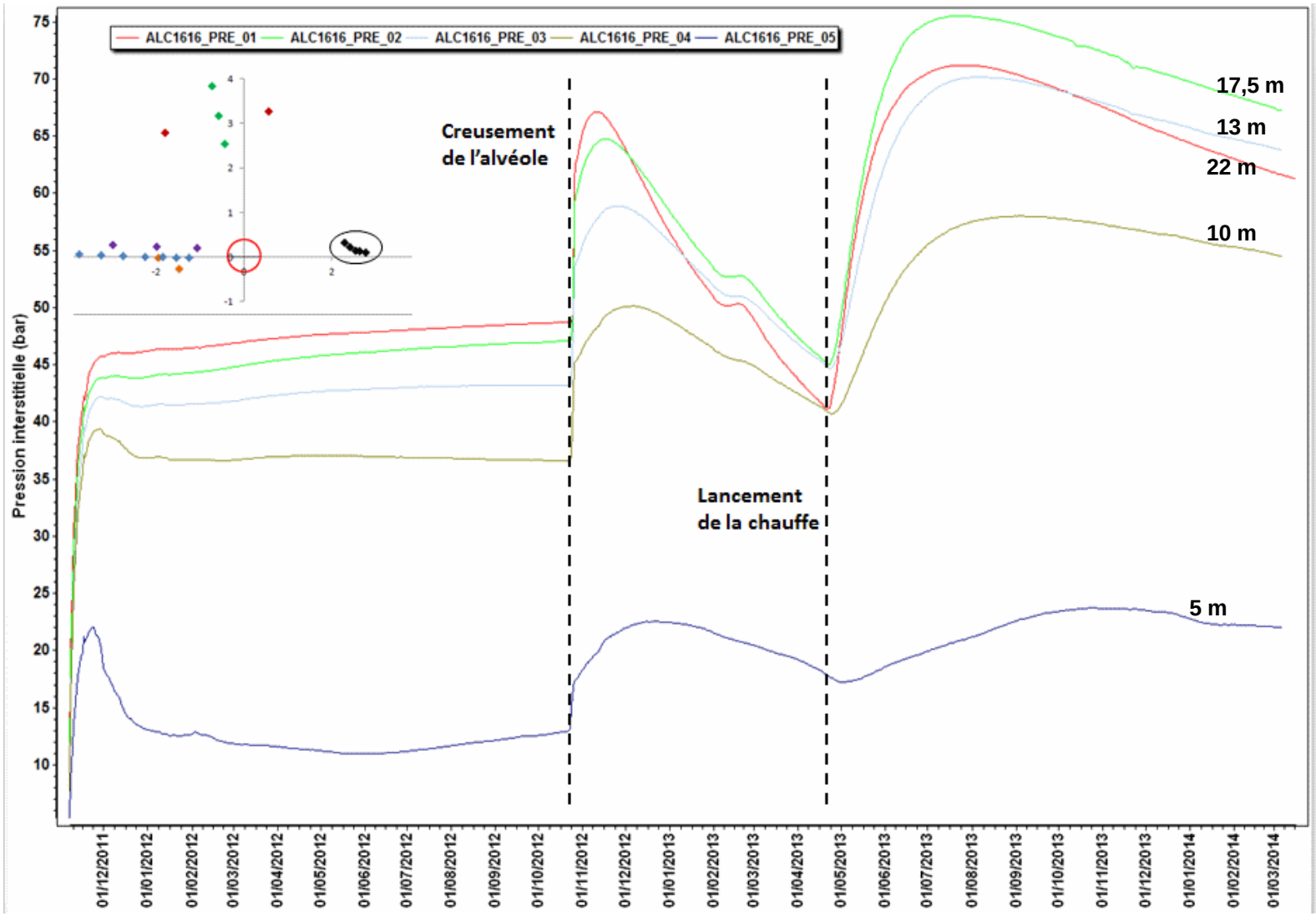
THM impact on the rock mass – pore pressure

Horizontal plane



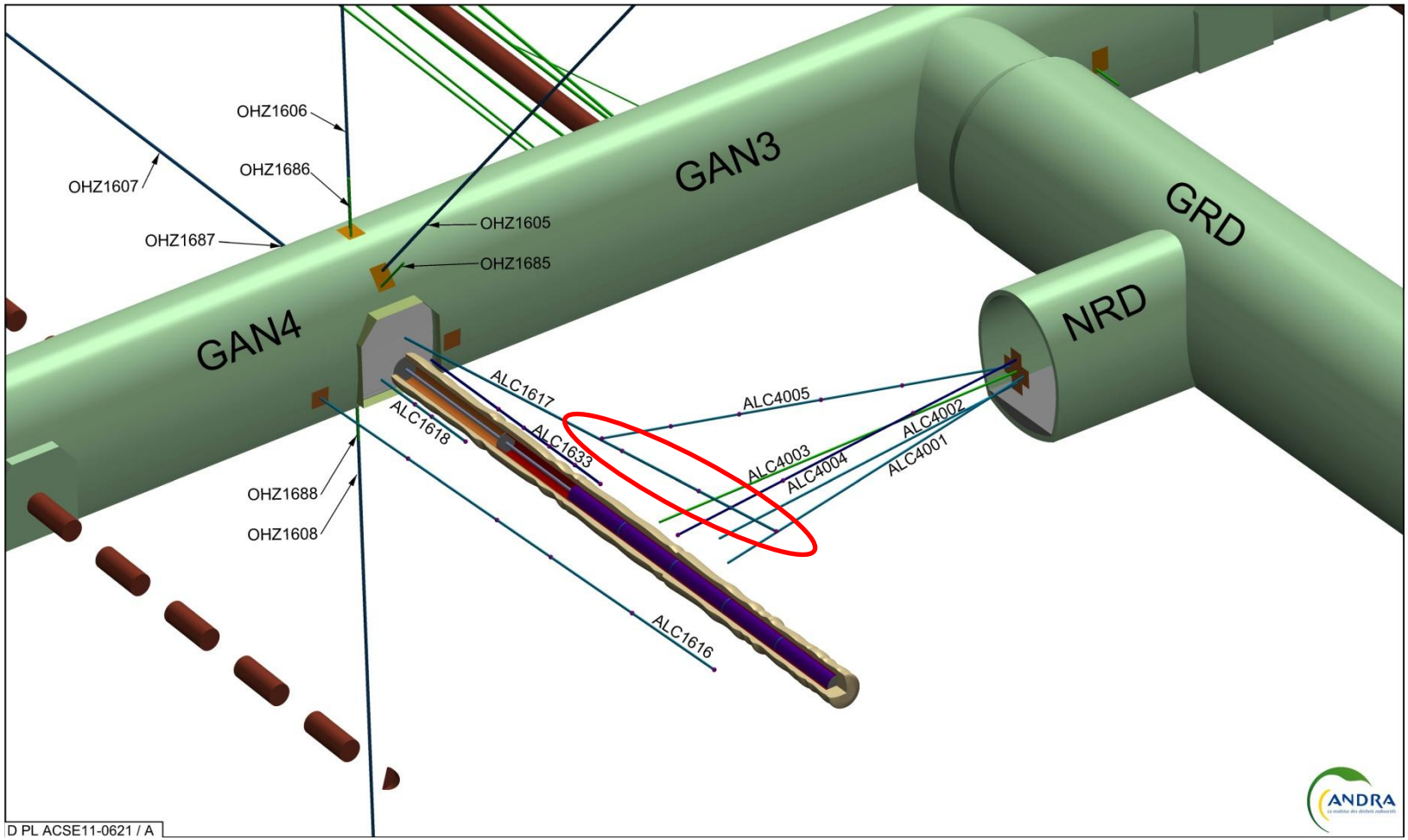
THM impact on the rock mass – pore pressure

Measuring points between 1,9 and 2,4 m from cell wall, 5 to 22 m depth from access drift



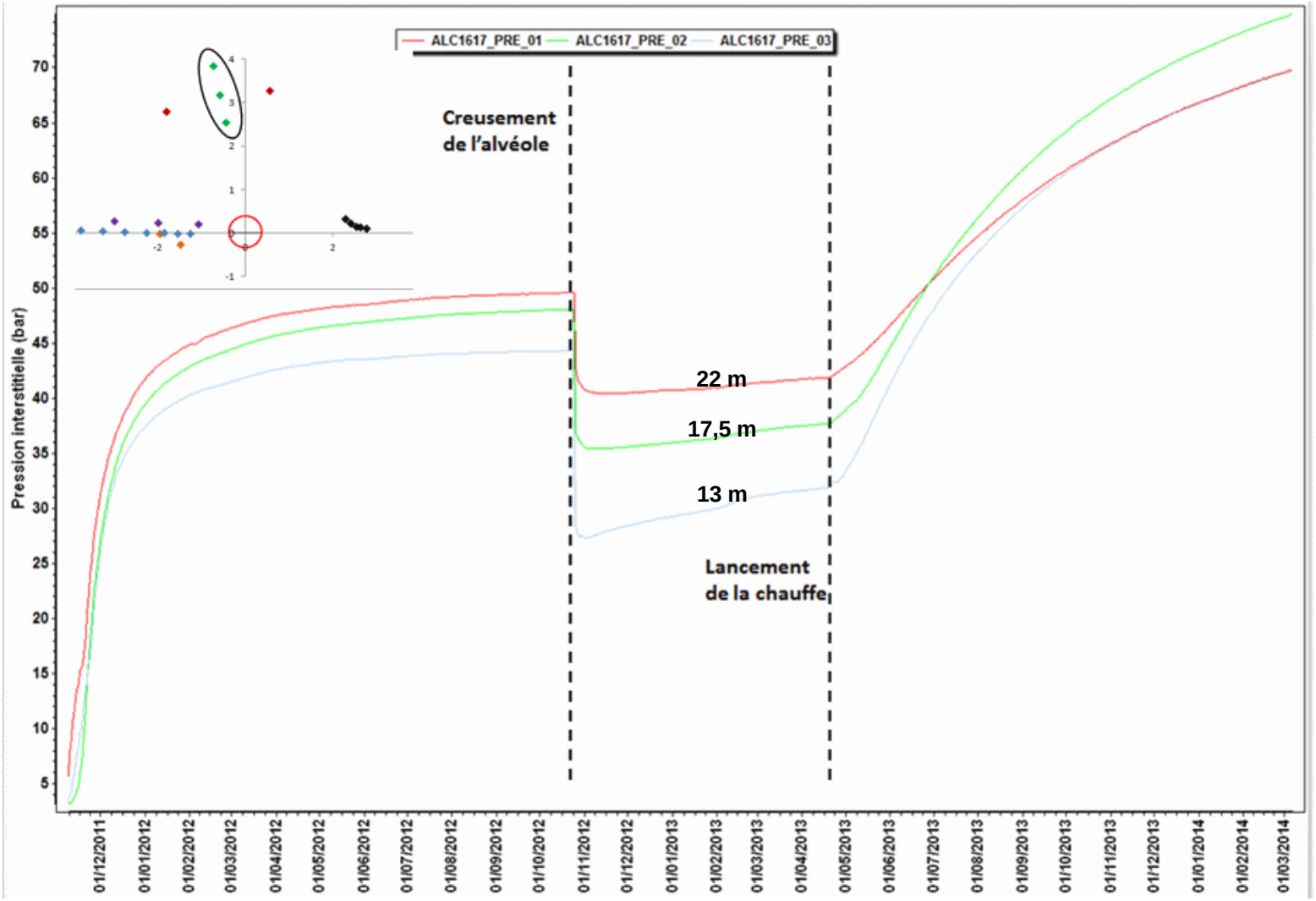
THM impact on the rock mass – pore pressure

Vertical plane



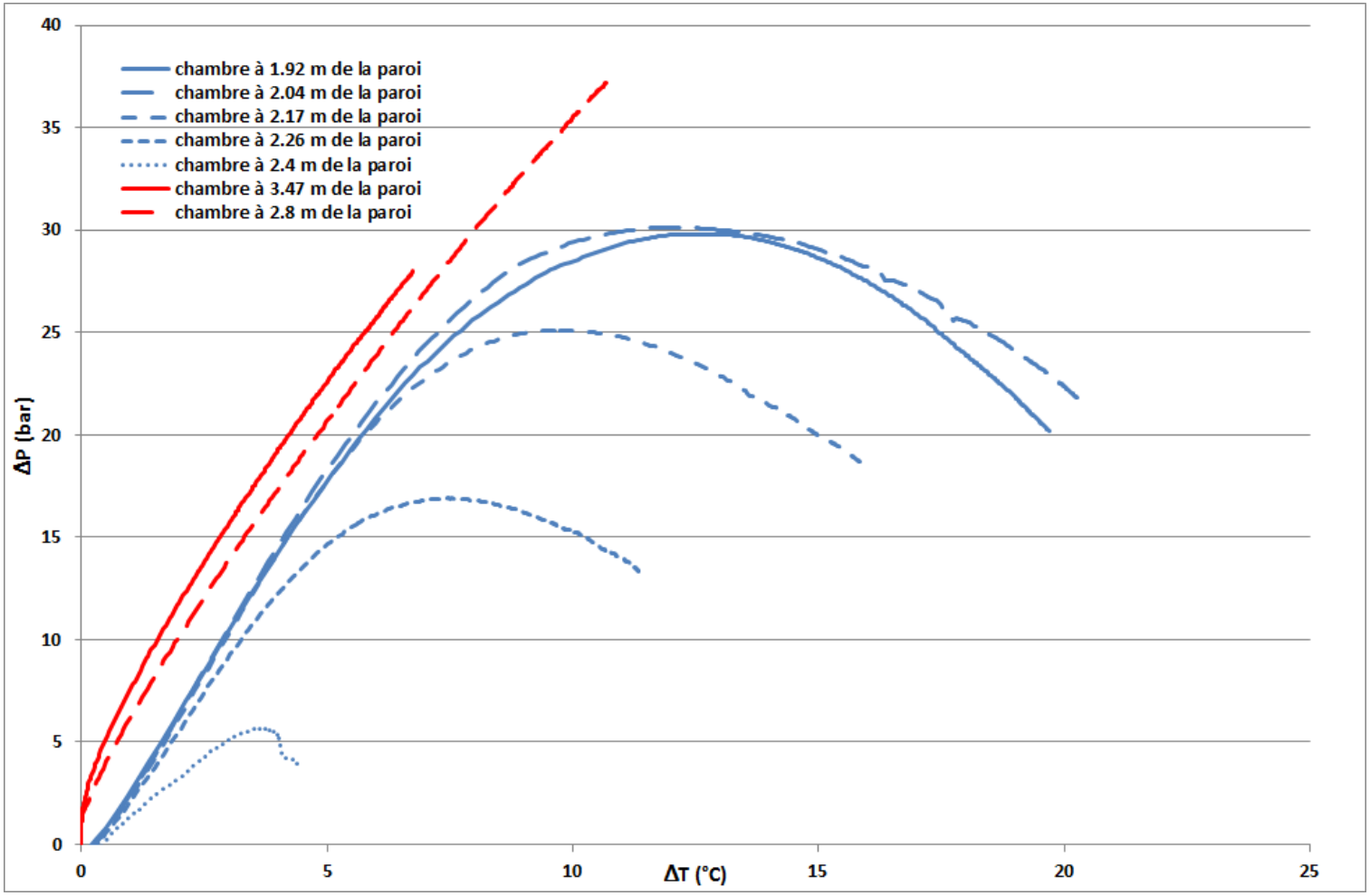
THM impact on the rock mass – pore pressure

Measuring points between 2,2 and 3,5 m from cell wall, 13 to 22 m depth from access drift



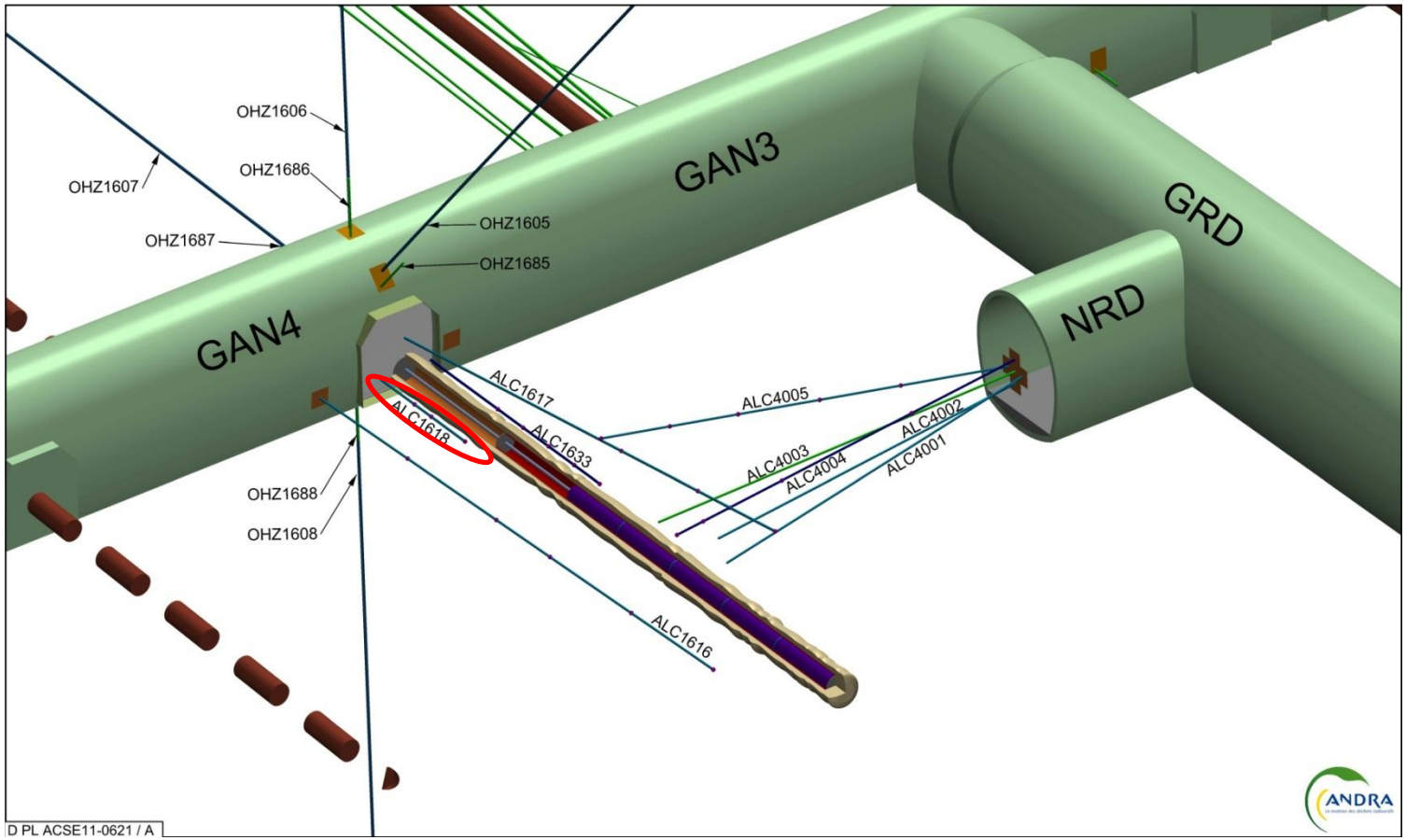
THM impact on the rock mass – pore pressure

At a given distance from the cell wall, thermal induced overpressure peak reached later in the vertical plane (relative to horizontal plane) than previously observed on small scale THM experiment. → Heaters are not centered in the cell in the vertical plane.

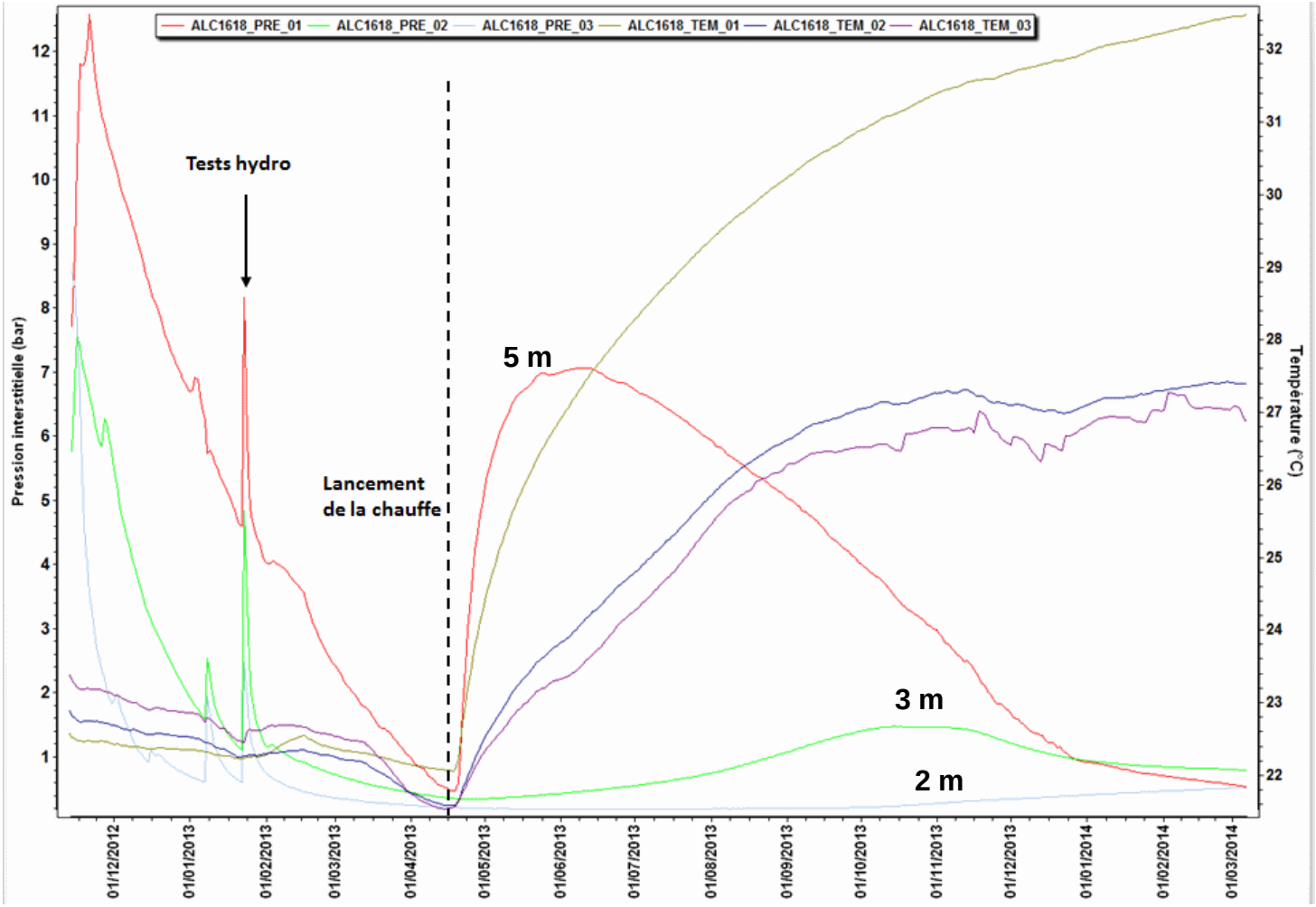


THM impact on the rock mass – pore pressure

Along the insert (cell head)



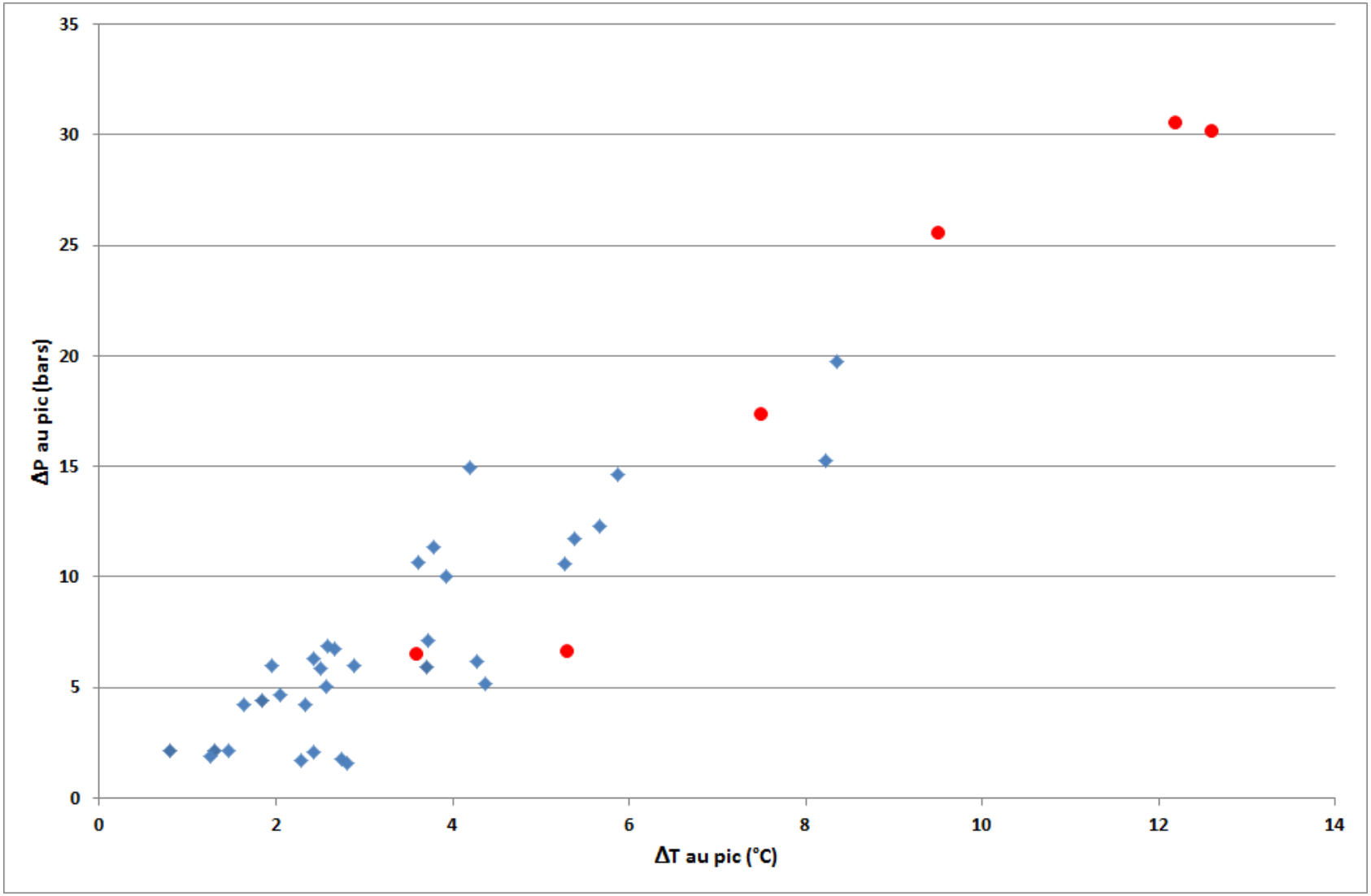
THM impact on the rock mass – pore pressure



→ Influence of EDZ from the access drift.

THM impact on the rock mass – pore pressure

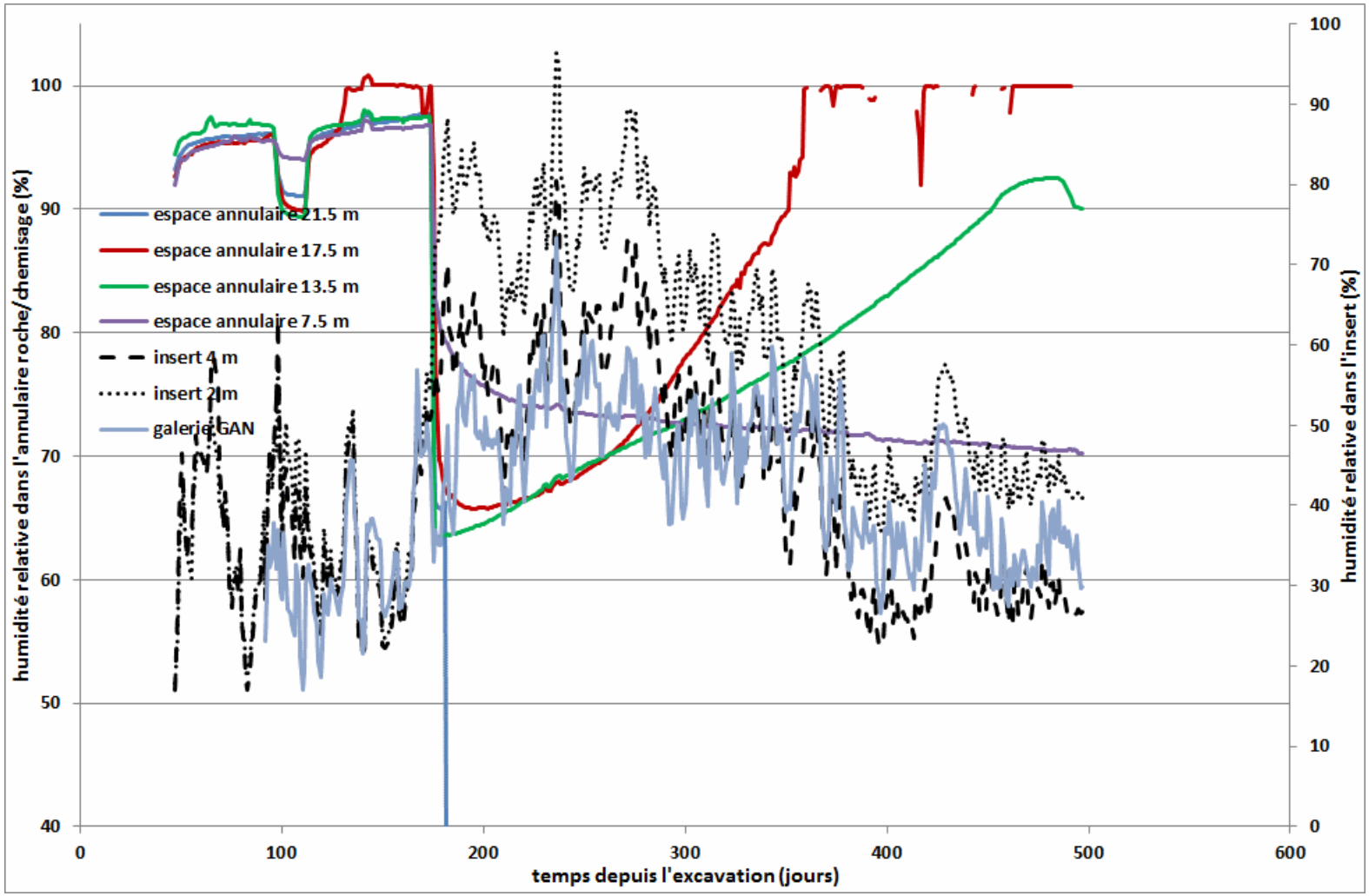
ΔP/ΔT correlation consistent with small scale THM experiment.



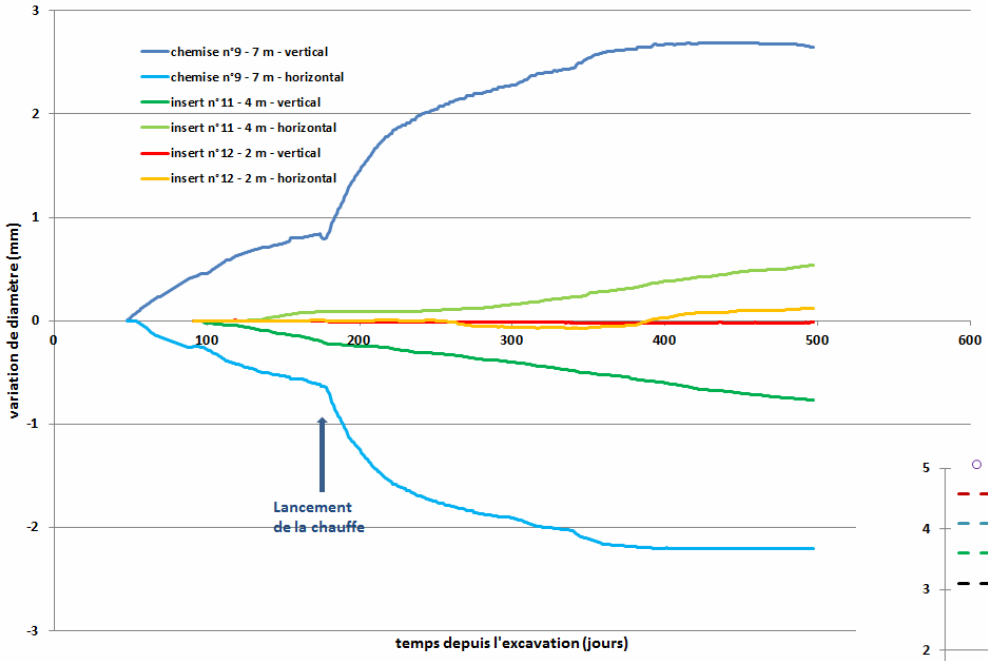
Relative humidity in the cell

Strong and quick desiccation induced by heating, then slow resaturation in the heated zone. Outside the heated zone, desaturation continues.

In the insert, opposite effect. Influence of access drift but also humidity transfer ?



Sleeve TM loading – diameter changes



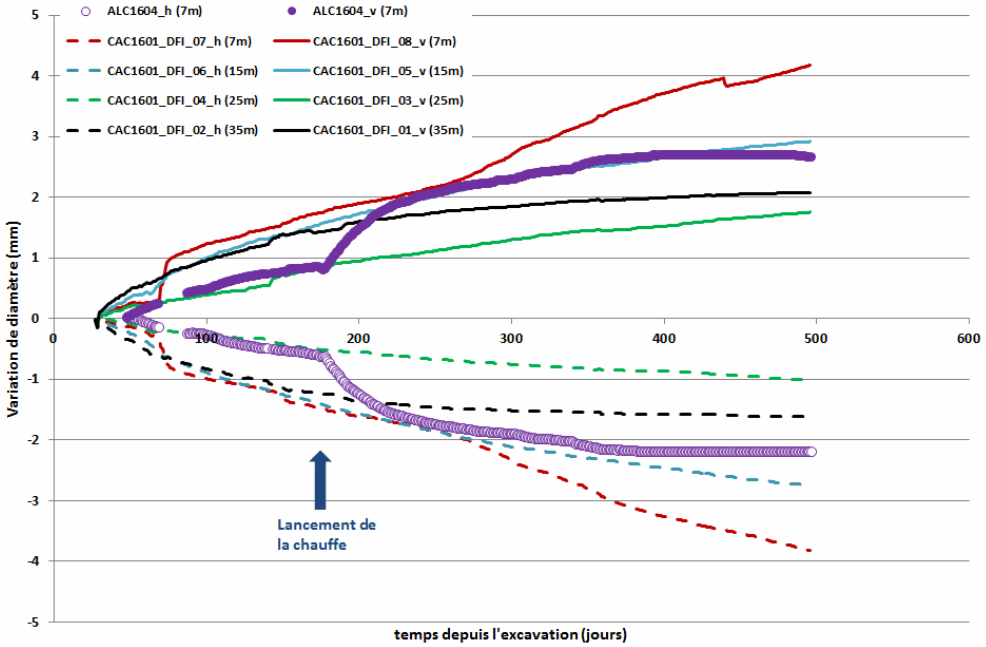
Initial behavior (before heating) consistent with what was observed in former phases.

Increase of deformation and deformation speed induced by heating.

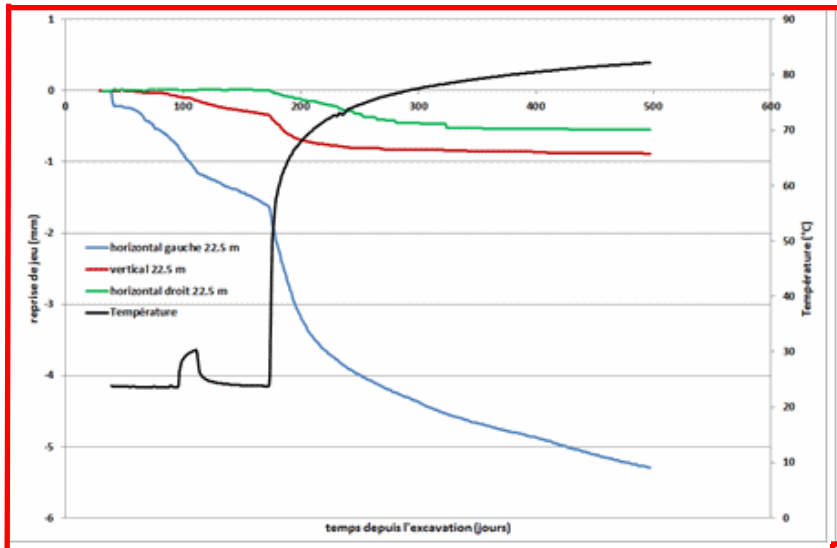
Deformation stopped at the vault ➡ annular space at least partially filled (presence of rubbles probably below the sleeve, annular space thus lower at the vault).

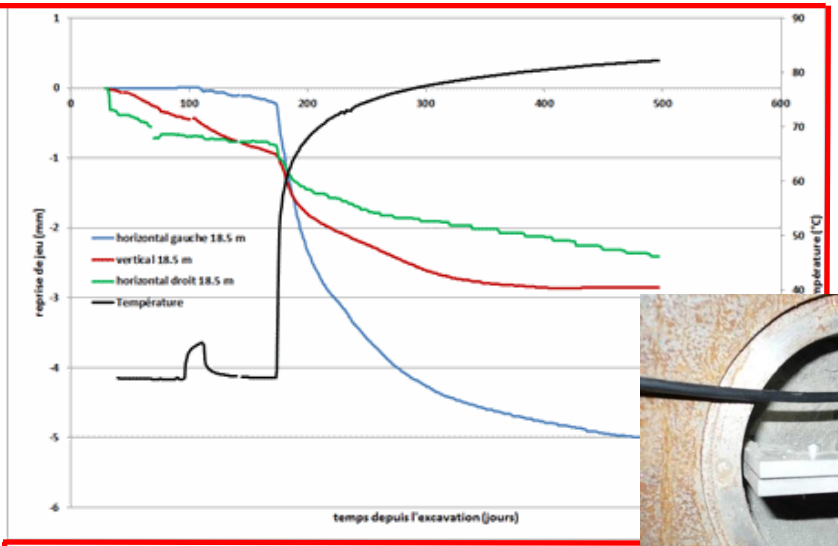
Opposite behavior of the insert at 4 m depth, also observed on annular space-filled cell demonstrator.

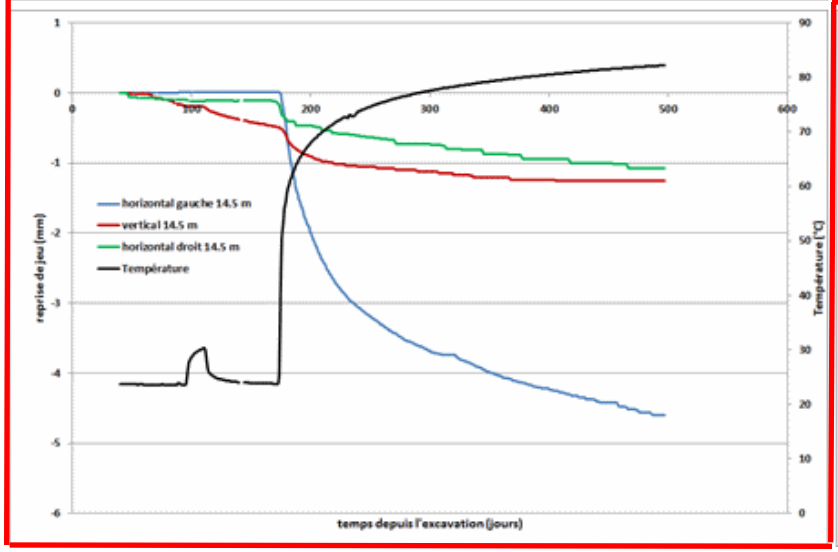
➡ influence of rock strength in contact with the insert (initial space lower, 12 mm in radius), more EDZ in the horizontal direction.

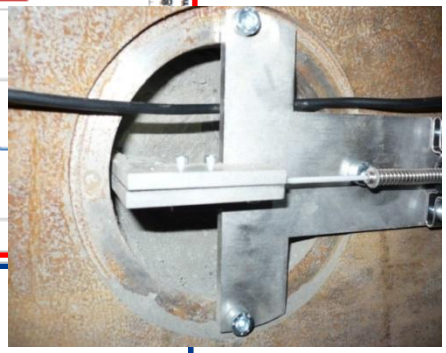


Sleeve TM loading – rock sleeve clearance reduction







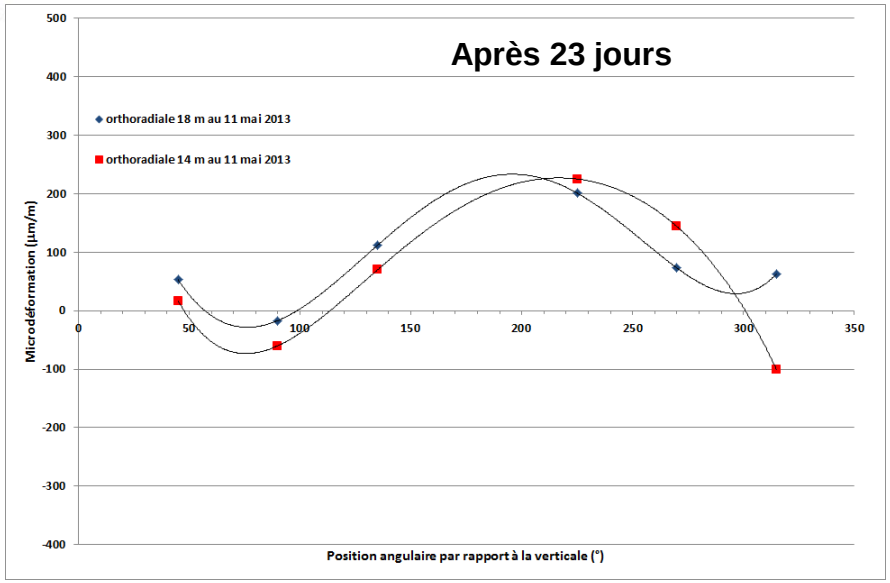


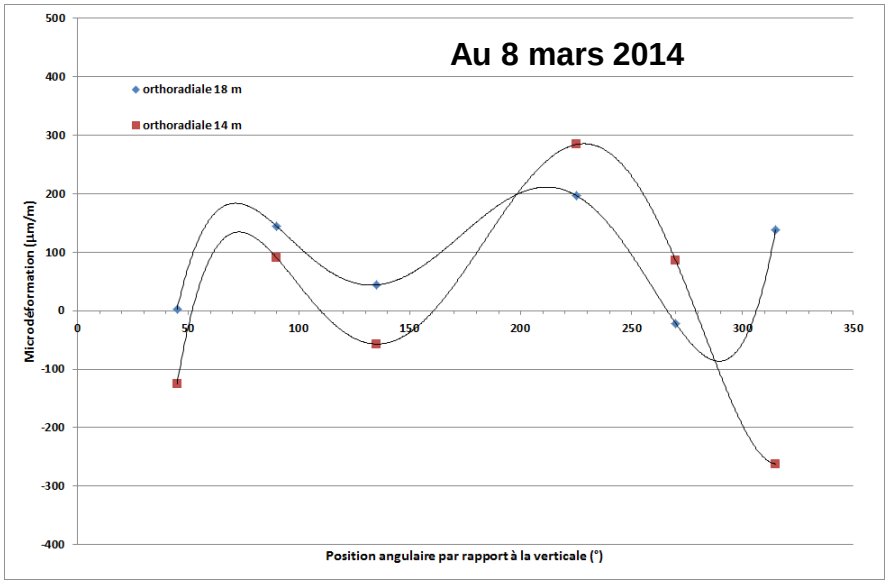
Clearance reduction more important at the left side.

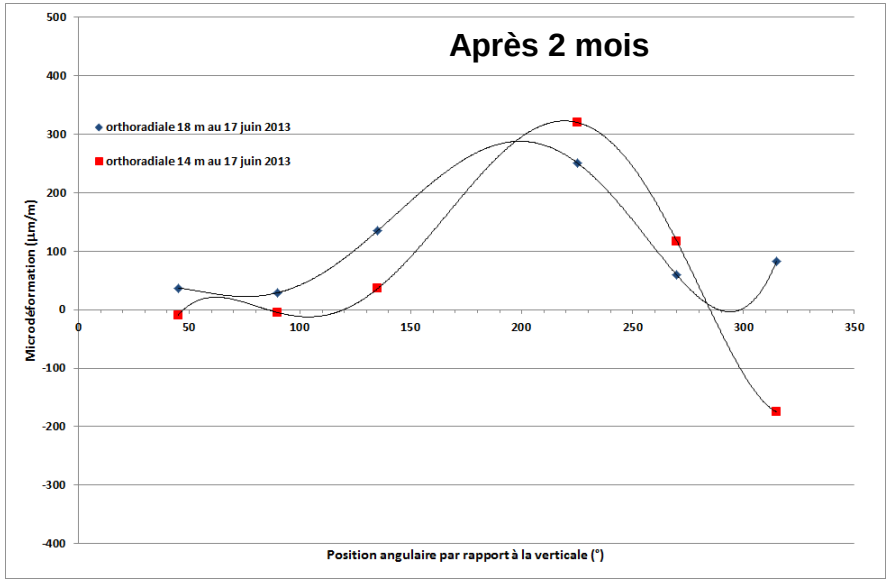
Up to now 5,7 à 7,4 mm clearance reduction in the horizontal plane, 0,9 à 2,8 mm at the vault.

Clearance reduction stopped at the vault at 18,5 m depth. ⟶ Annular space partially filled.

Sleeve TM loading – strain gages





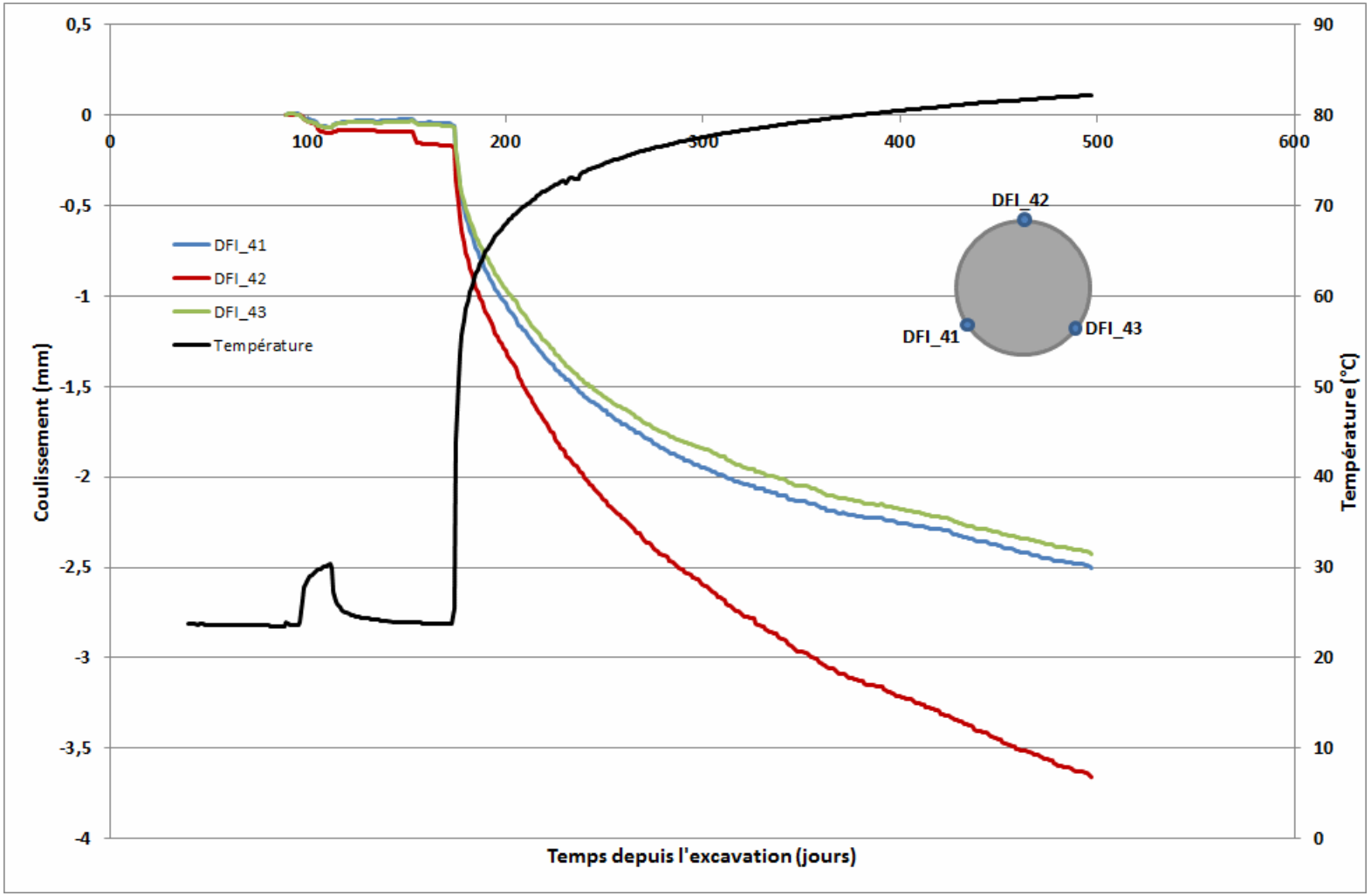


Axial deformation very small (< 100 µm): sleeve sliding in the insert so limited axial stress.

Ortho-radial deformations stay limited (< 400 µm).

Sleeve load globally horizontal, consistent with diameter changes.

Sleeve/insert sliding



Max sliding 3,5 mm, for a theoretical dilation of max 10 mm (homogeneous T° over the heated zone).

⟶ dilation also towards cell's end, and influence of cell wall convergence.

Conclusions

- A representative HLW cell has been successfully excavated and instrumented;
- After 1 year heating :
  - 2 to 3 types of sensors not adapted (total pressure, axial extensometer, fiber optics sensors on the heaters);
  - All other kinds of sensors (cell and rock mass) give good and consistent data;
- THM impact on rock mass pore pressure is consistent with small scale THM experiment; kinetics difference in the vertical plane;
- Sleeve deformation speed increased by heating, with TM loading globally horizontal ; contact at the vault after 400 days indicating the importance of spalling/rubbles filling the annular space;
- Sleeve sliding in the insert limited : sliding also towards the cell's end and influence of cell wall convergence.