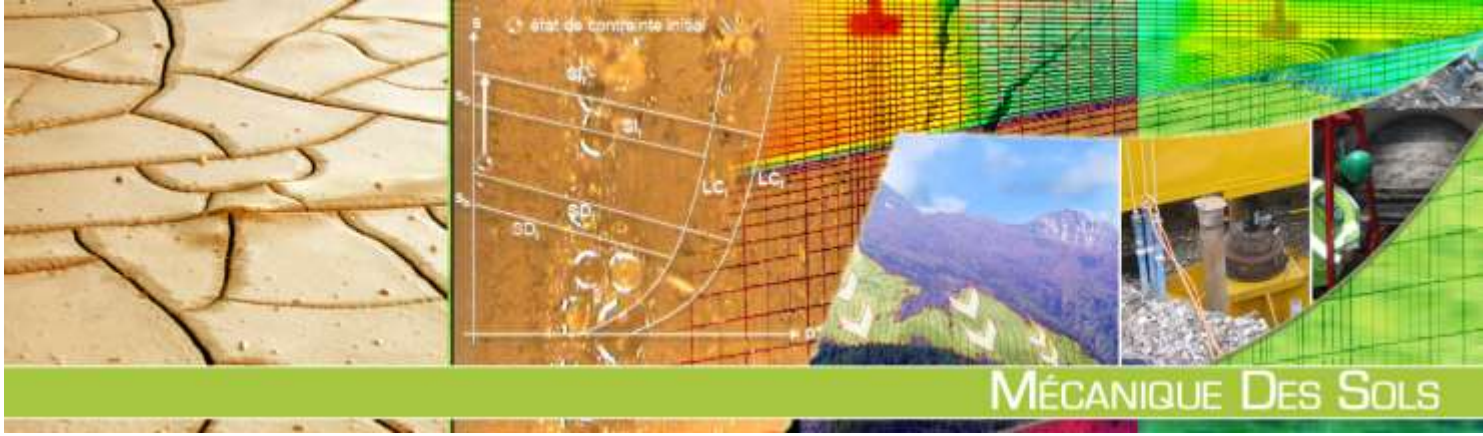

Bentonite Mechanical Evolution - BEACON Initial Workshop
19 and 20 June 2017 - Lithuanian Energy Institute, Kaunas, Lithuania

Some insights on the swelling pressure development of compacted bentonite upon wetting and its long term evolution

Olivier Cuisinier and Farimah Masrouri

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General approach at LEMTA

How to « control » the swelling mechanisms, and evaluate their impact on swelling pressure?

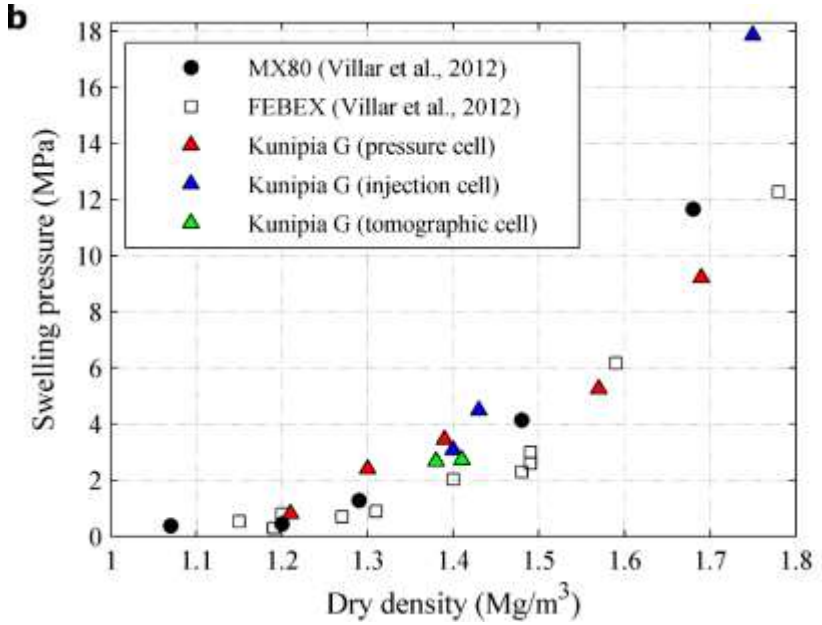
- Use of different wetting fluids:
  - Aqueous solutions with different ionic strength➔ crystalline swelling + osmotic swelling
  - methyl methacrylate (MMA) ➔ crystalline swelling only
- Combination of different suction controlled methods :
  - Vapor equilibrium ➔ total suction, vapor
  - Osmotic method ➔ matric suction, liquid water

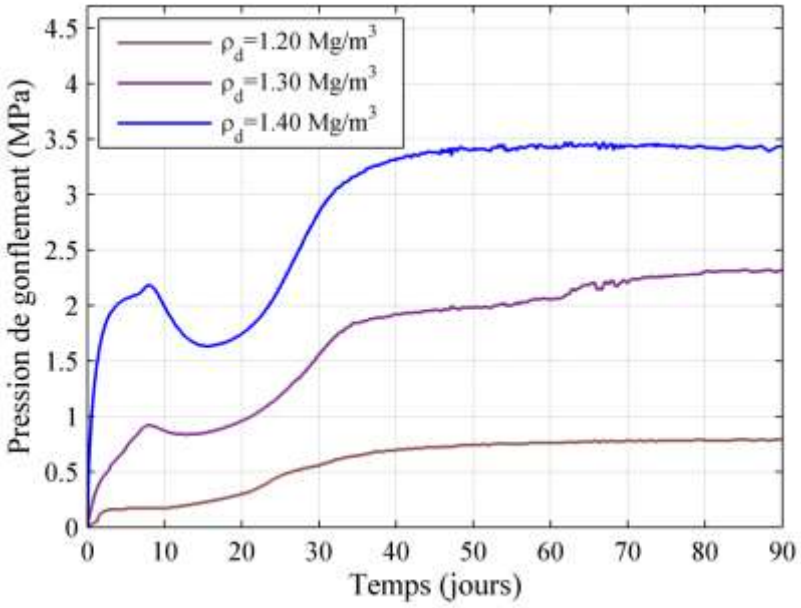
How to investigate microstructure reorganisation and swelling pressure development?

- Combination of different techniques for multi-scale investigations
- Key objective: same sample at different scales

Multi-scale investigation of the swelling clay material properties upon wetting

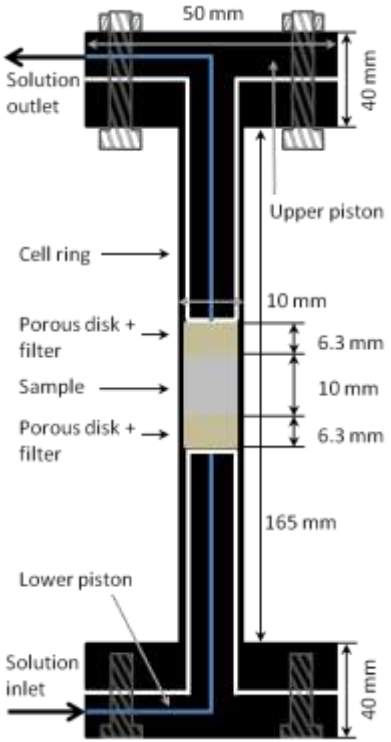
- Studied material: Kunipia-G
  - Na-smectite (95% Montmorillonite)
  - Significant interagregate porosity

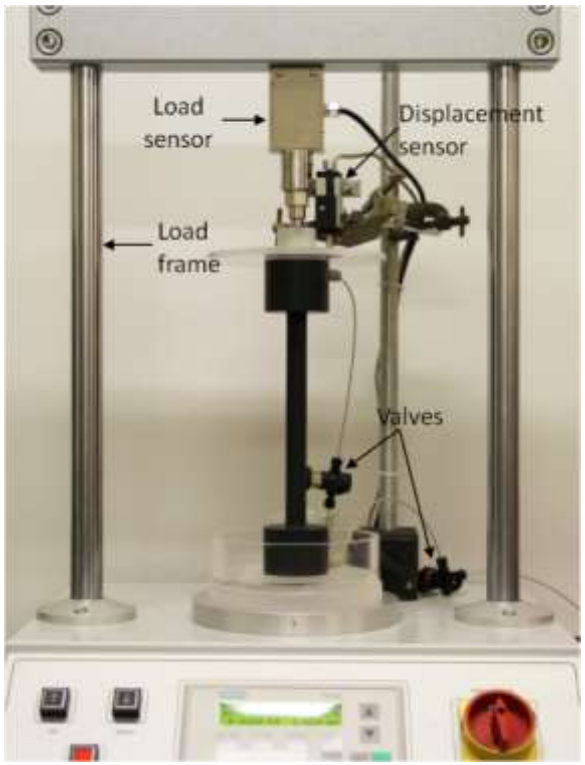




New tomographic oedometer cell

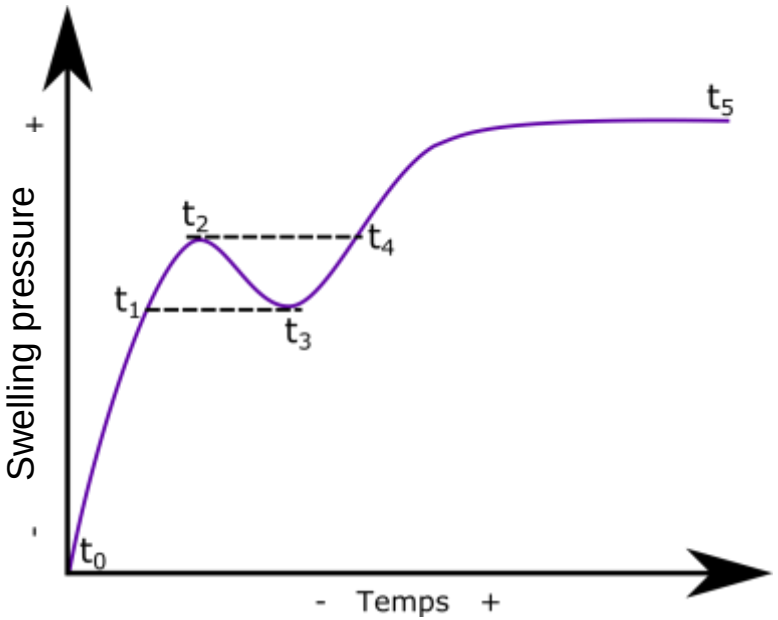
–Material with high mechanical properties, and transparent to X ray
– Dimensions of the cell adapted to the space available in the tomograph
– Sample size : diameter = 10 mm; height = 10 mm ➔ spatial resolution 5 µm



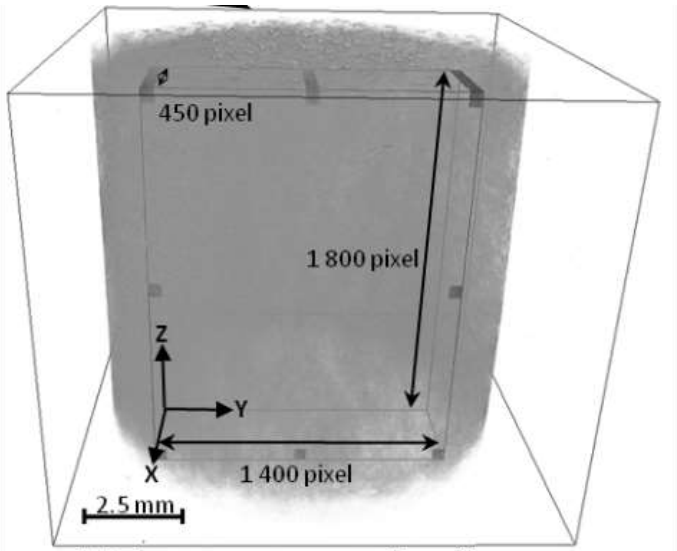


Global strategy

- Swelling pressure monitoring
- Analysis of macroporosity at several stages of swelling



Intermediate scanning of the sample

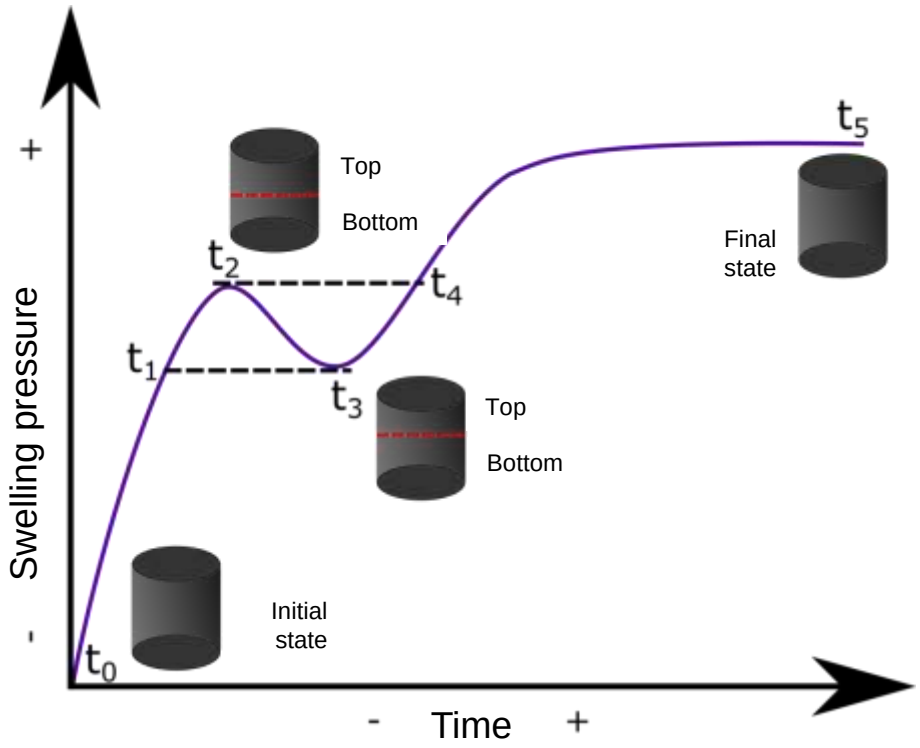


Vertical profile of porosity (spatial resolution 5 µm)

➔ Investigation of macroporosity and swelling pressure on the same sample

Global strategy

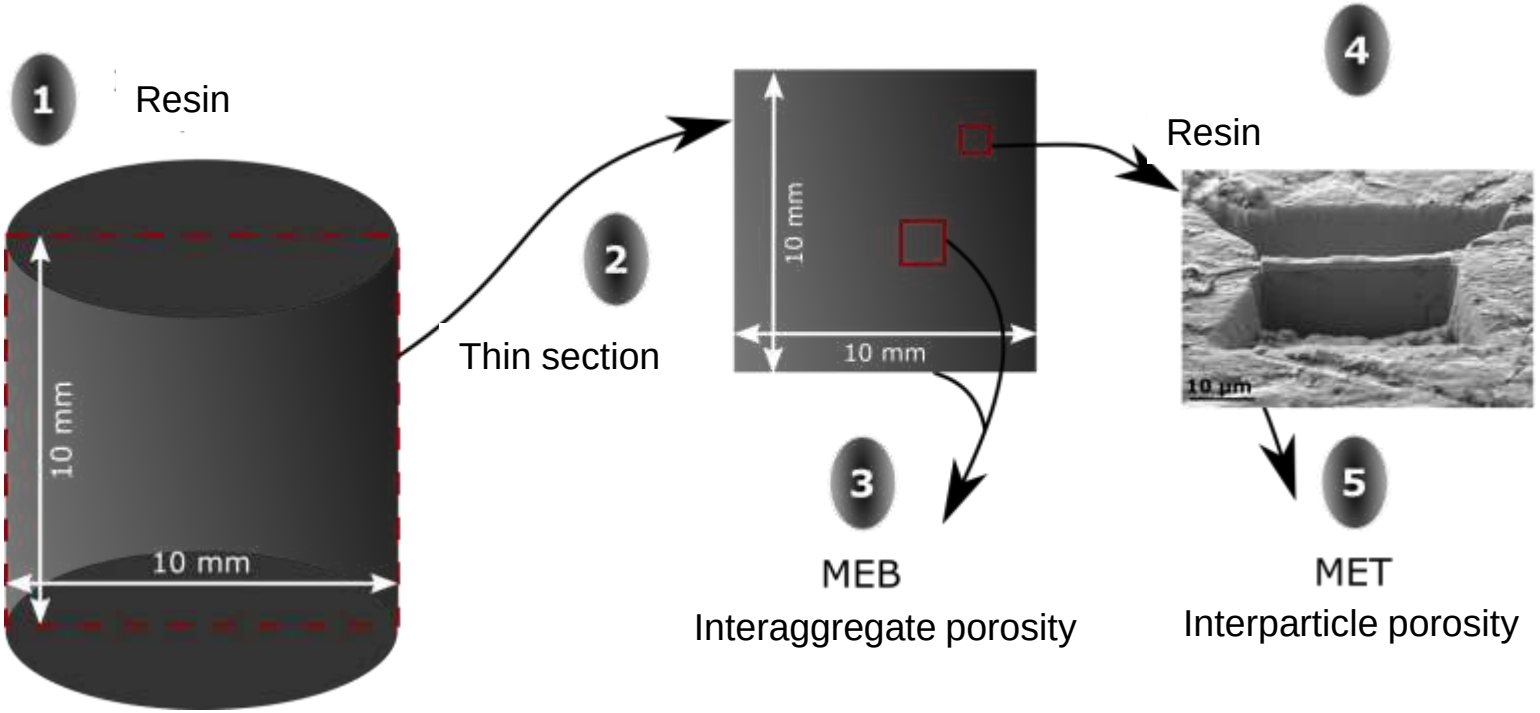
•Analysis of interparticles porosity at several stages of swelling with N2 and Ar adsorption



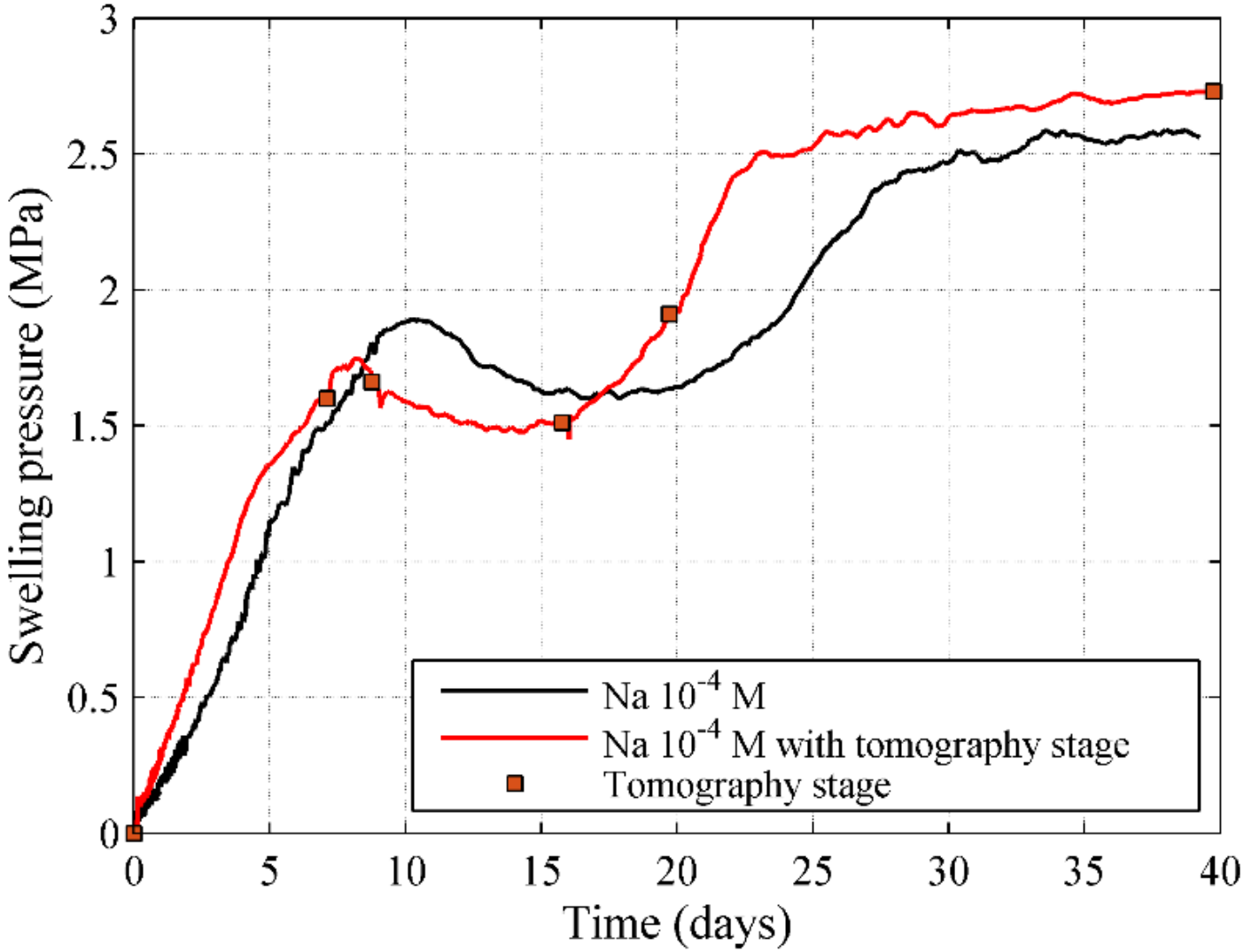
Textural properties (specific surface, number of unit layers per particle, etc.)

Global strategy

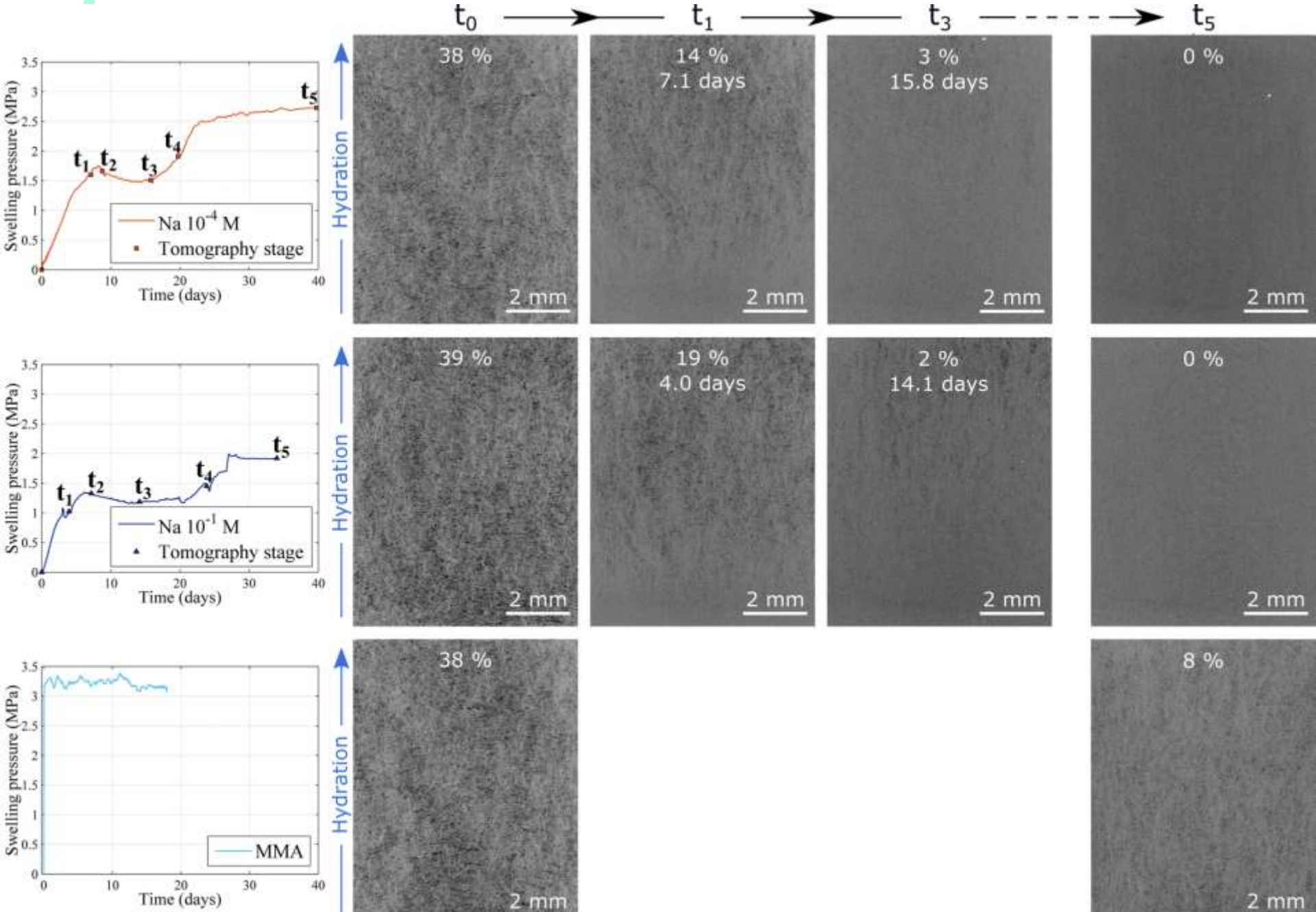
- Interaggregate porosity ➔ MEB
- Particles ➔ MET



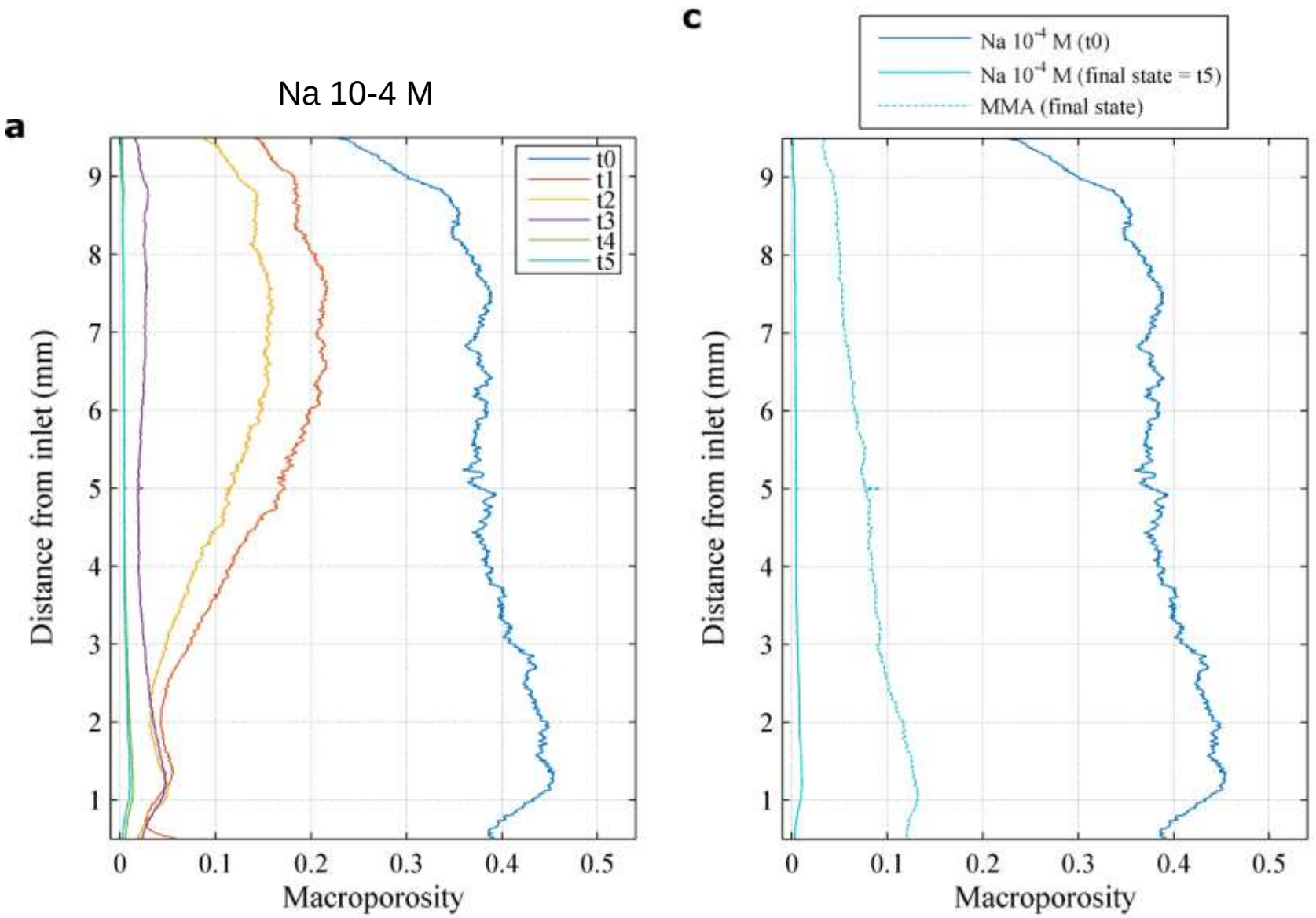
Swelling pressure development



Macroporosity (>5 µm) vs swelling pressure



Macroporosity reorganisation upon wetting

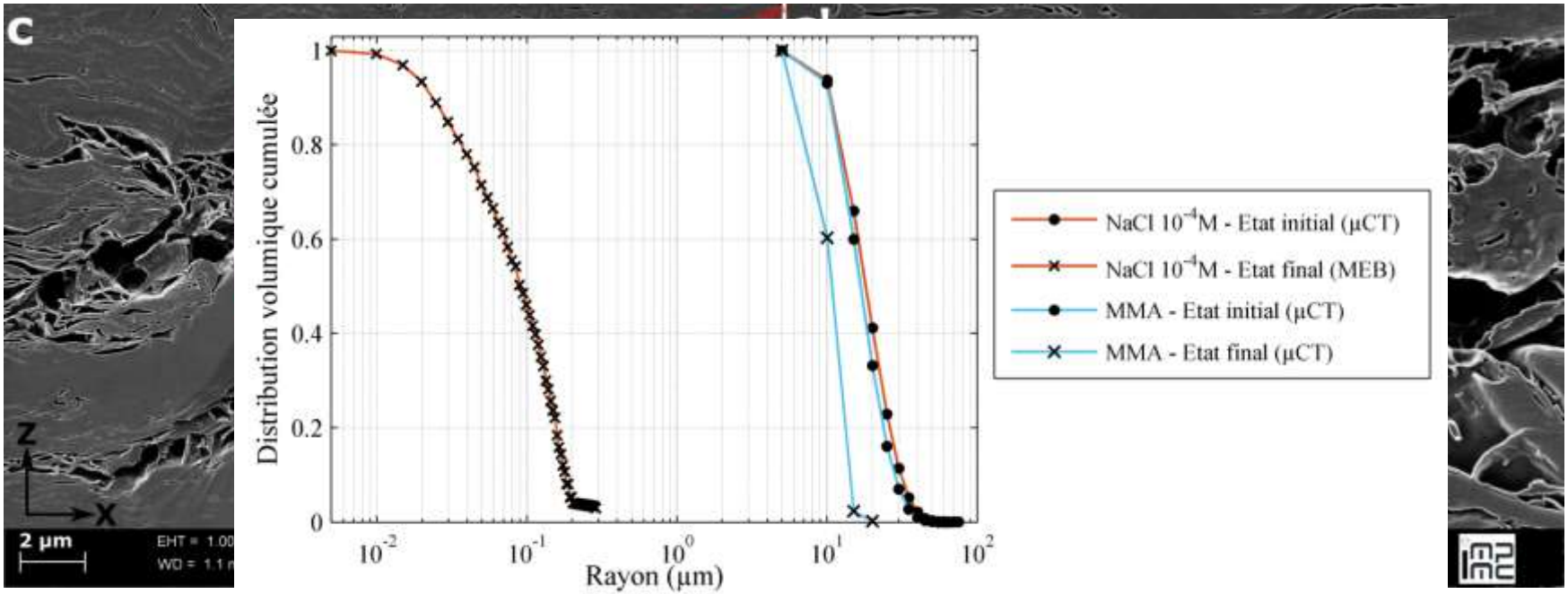


Comparison with SEM investigation

Interaggregate porosity at the final (NaCl 10^{-4} M)

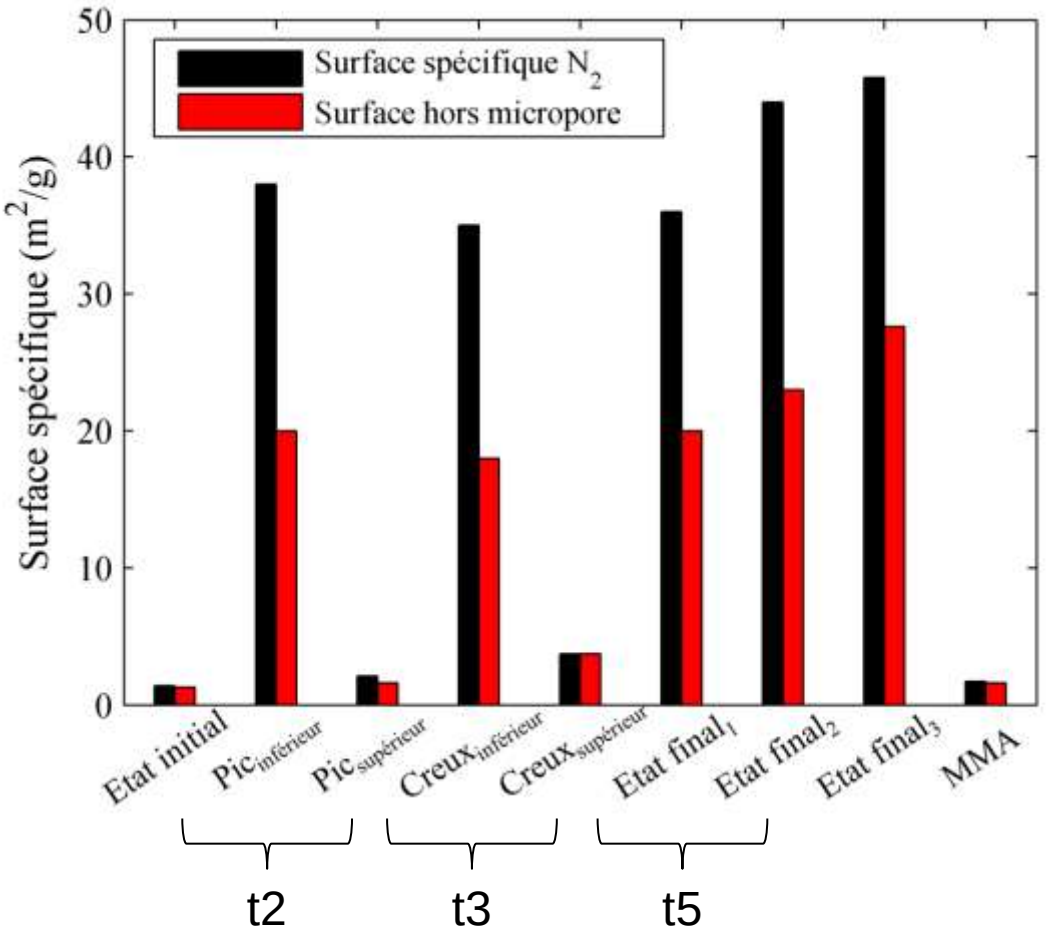
– pore radius of 0,2 µm

→ Difference with µCT due to resolution

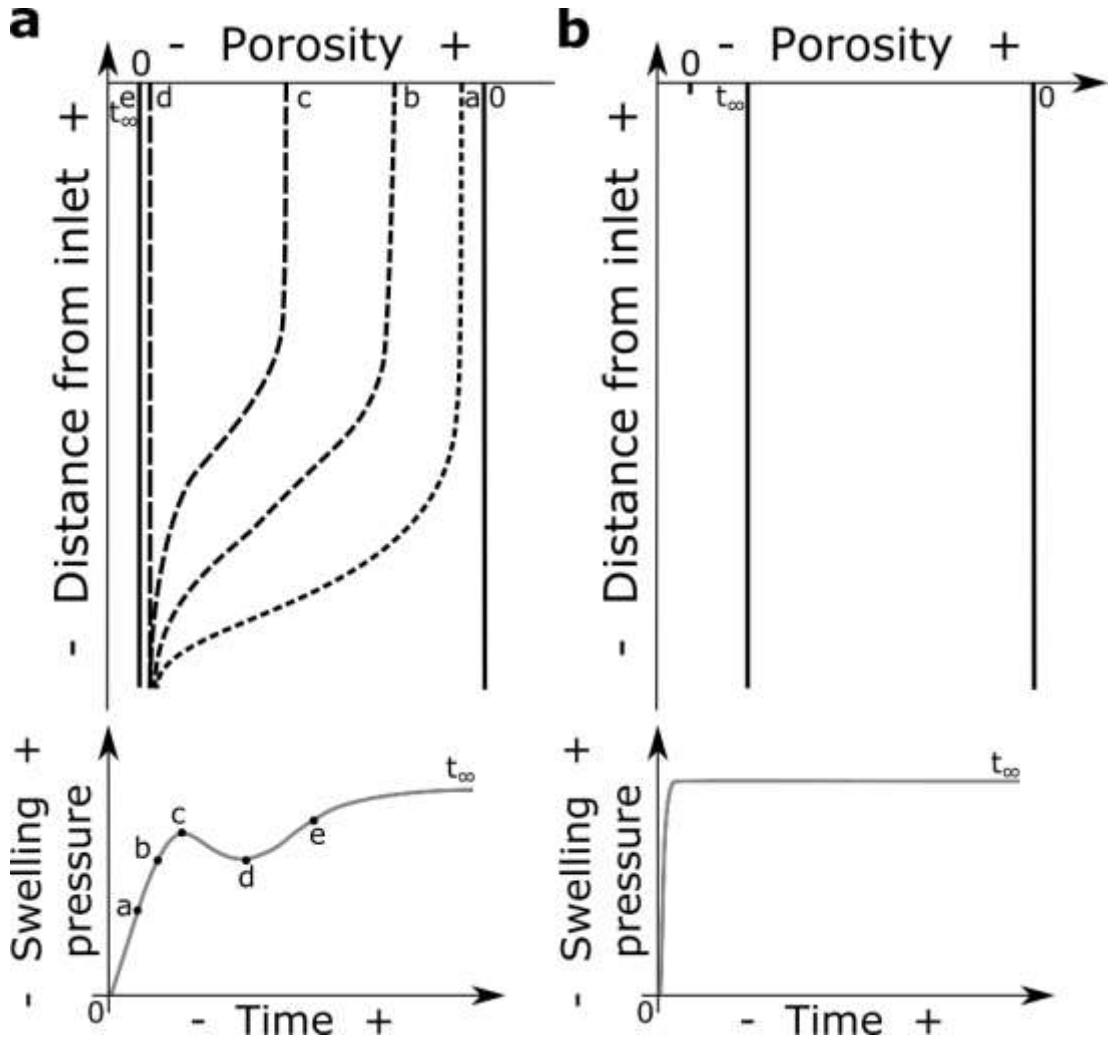


Interparticle porosity

- During hydration (N2 adsorption)
  - NaCl 10^{-4} M : upward reorganisation with an increase in interparticle porosity
  - MMA : similar to initial state (only crystalline swelling)



Conclusion



How to control the hydration process?

General strategy at LEMTA

How to « control » the swelling mechanisms, and evaluate their impact of swelling pressure?

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- Combination of different suction controlled methods :
  - Vapor equilibrium ➔ total suction
  - Osmotic method ➔ matric suction

How to investigate microstructure reorganisation and swelling pressure development?

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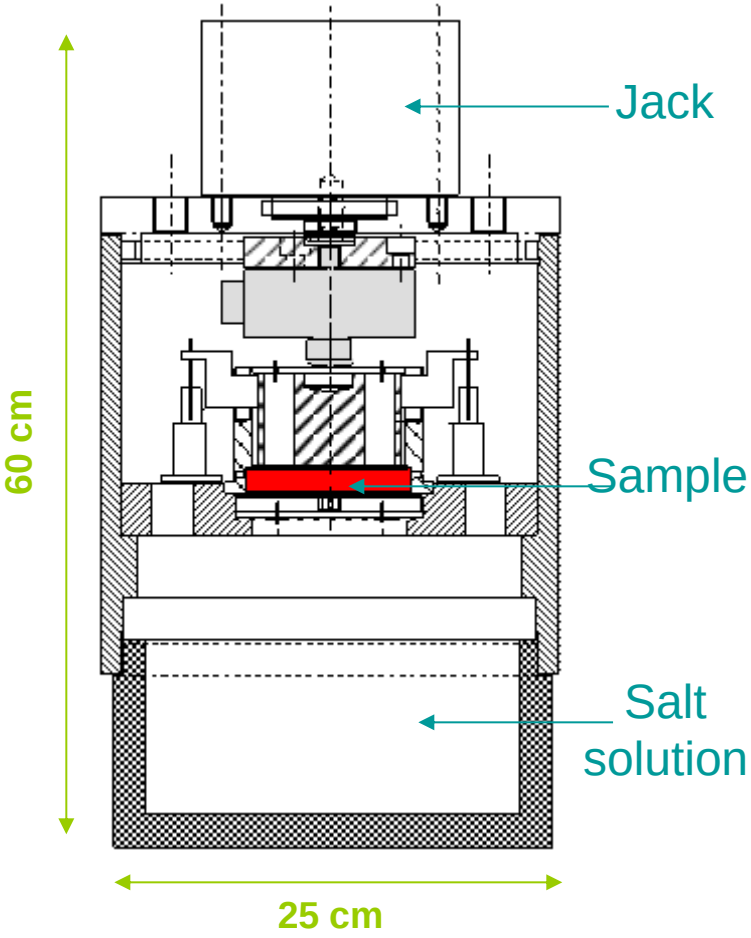
- Key objective: same sample at different scales

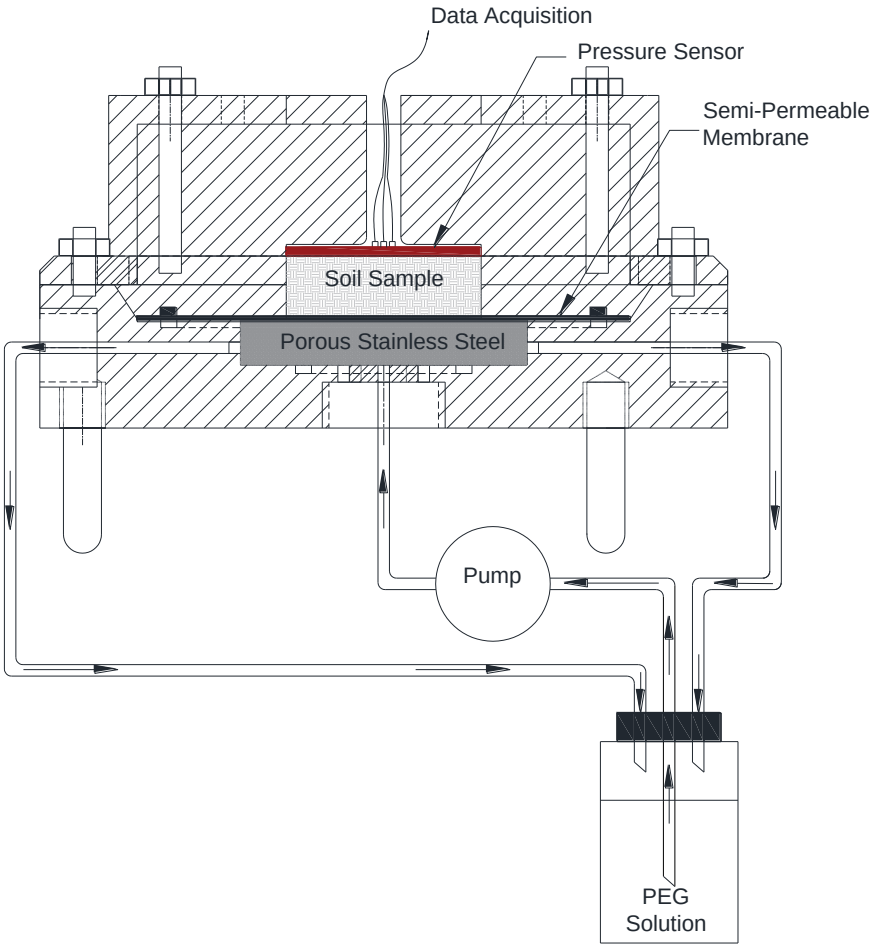
Suction controlled methods

- High suction range (>3,5 MPa) : salt solutions



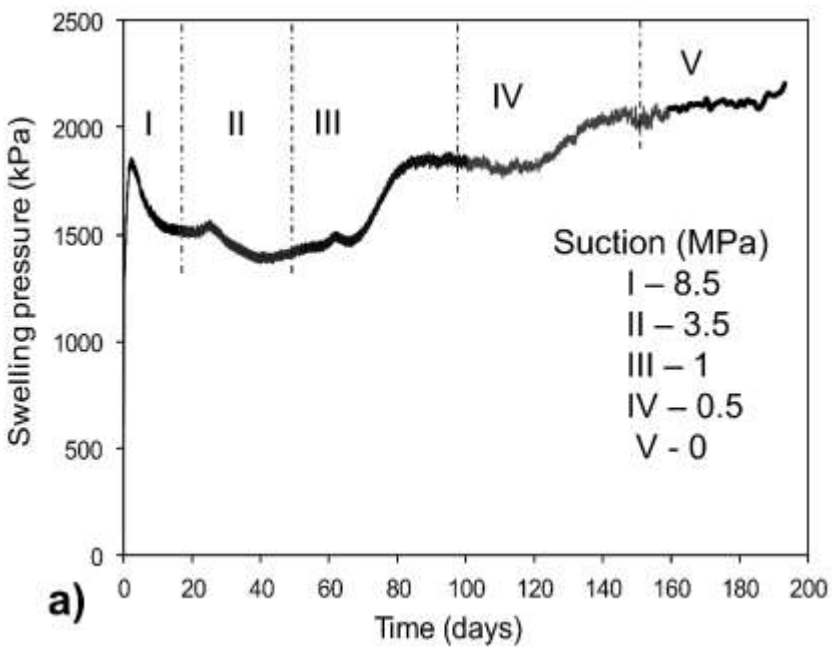
Suction controlled methods

- Low suction range (< 10 MPa): osmotic method
- New device to guarantee constant volume condition

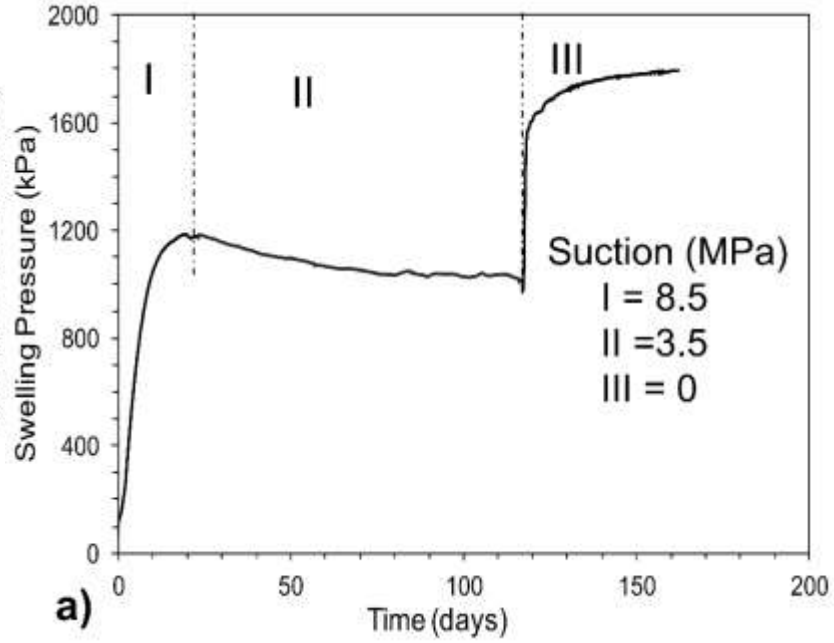


Hydration of Georgia bentonite

Osmotic

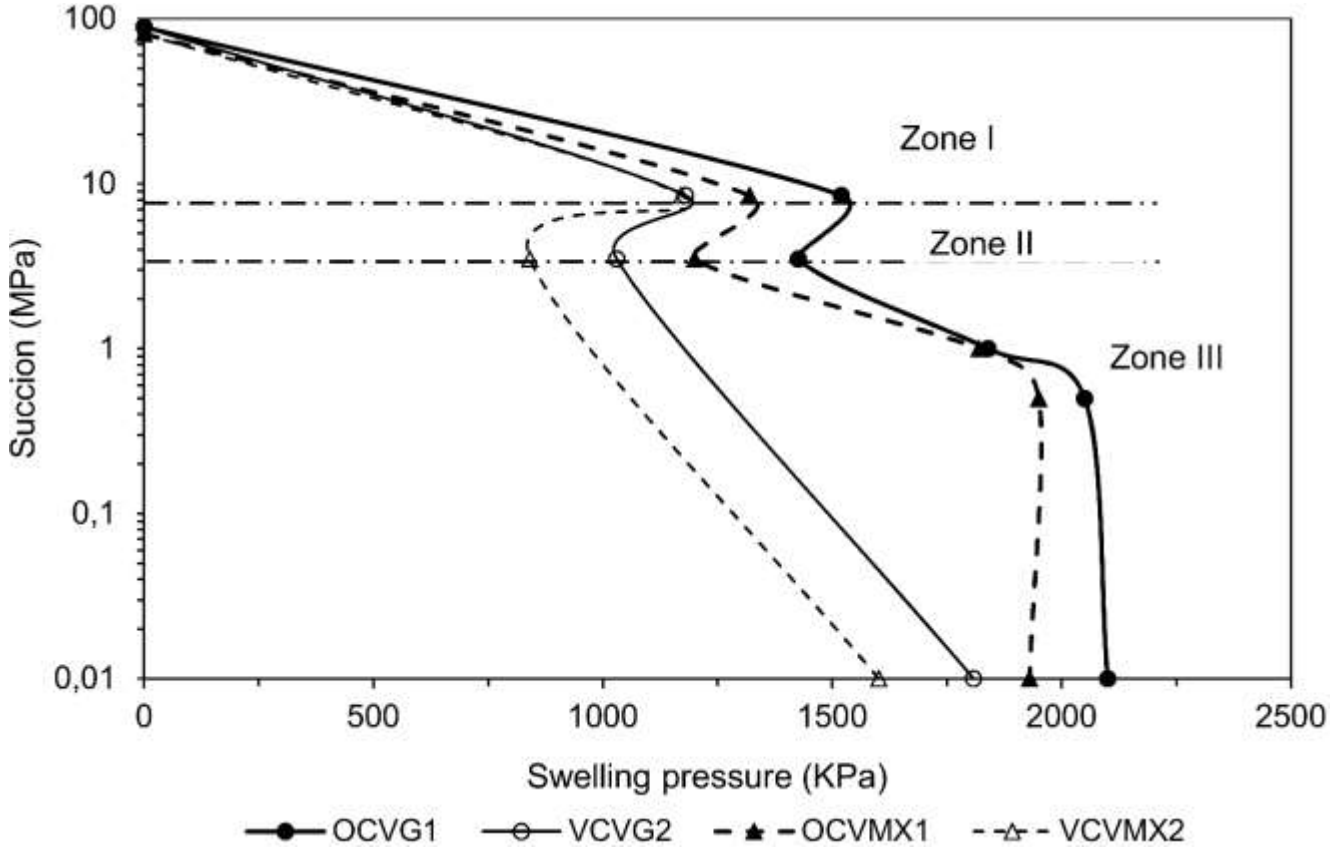


Vapor equilibrium



Stress path dependancy of the final swelling pressure

Suction vs swelling pressure



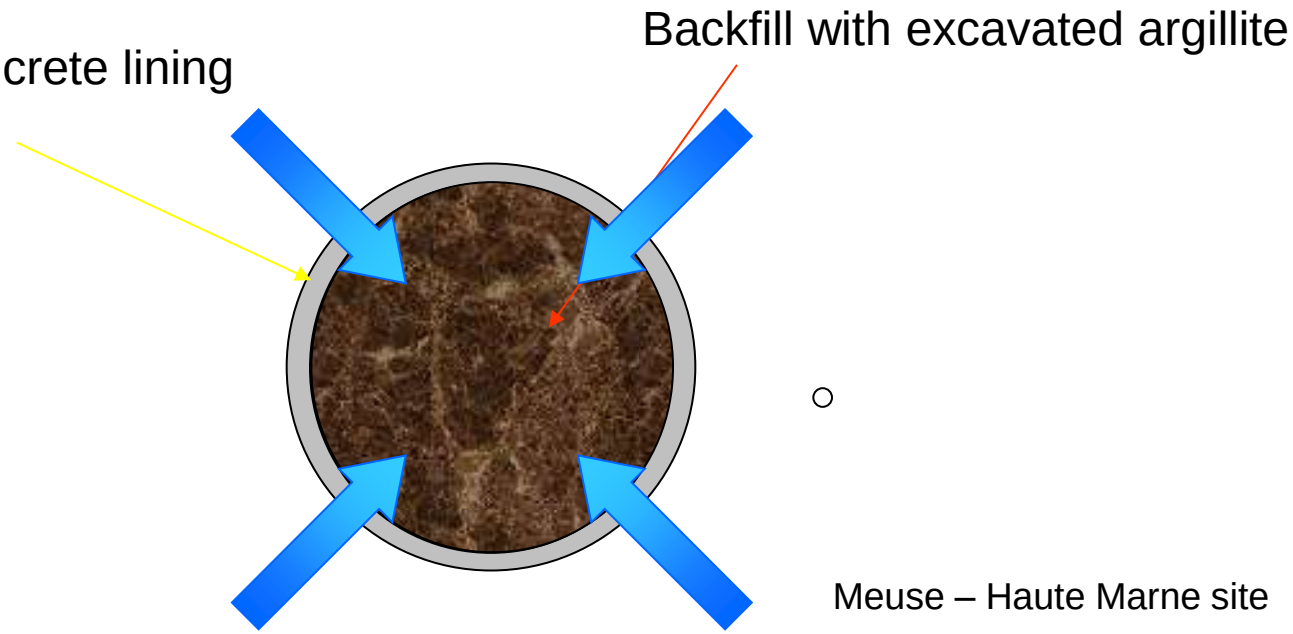
Hydration path dependancy of the final swelling pressure

Questions:

link with hydration processes?

microstructural reorganisation?

Ageing of compacted expansive soil



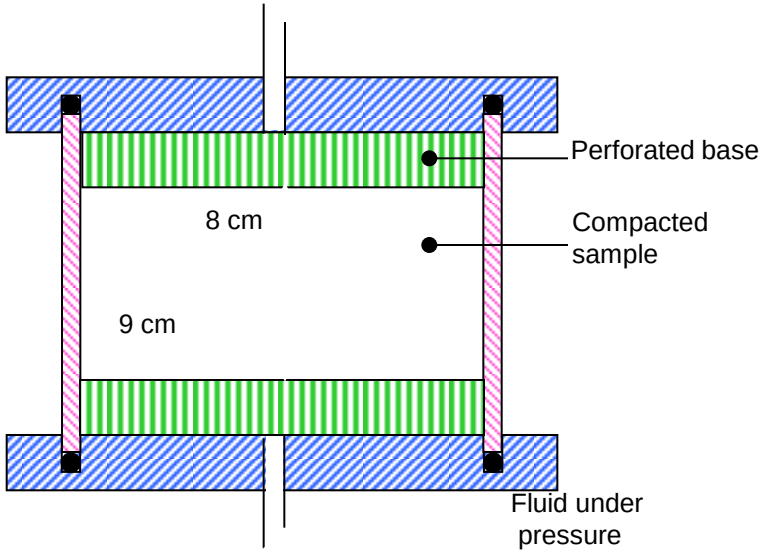
Saturation of the backfill by alkali-rich and high-pH water (concrete degradation)

Consequences of this high-pH water on the behaviour of the backfill (compacted argillite) in the very long term?
➔ study of chemo-mechanical couplings !

Ageing of compacted expansive soil

- Circulation cells:

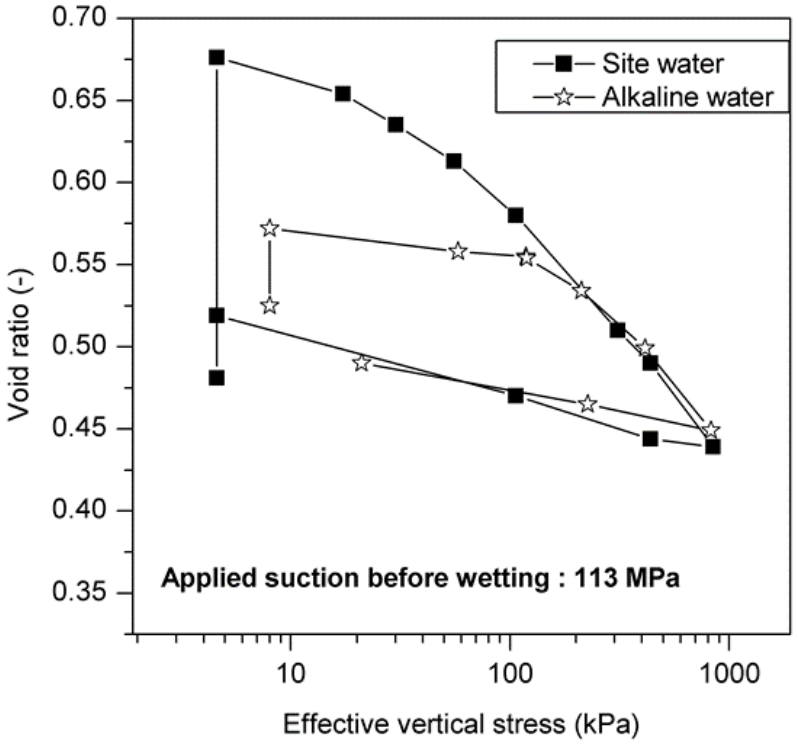
PVC
T = 20 or 60°C
i ≈ 50
Saturated in $Ca(OH)_2$

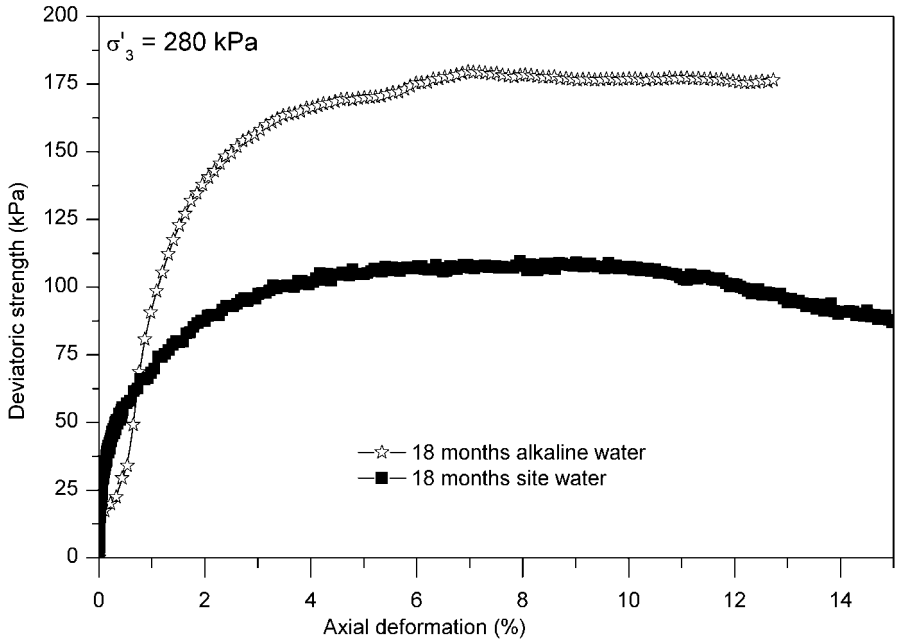


- Principle:
  - ➔ circulate high-pH fluid (pH ≈ 12.5) through **compacted** material at 60°C up to 12 months
  - ➔ No swelling

- Experimental investigations:
  1- microstructure determination: mercury intrusion porosimetry
  2- mechanical study: CU + u triaxial tests

Impact of alkaline fluid circulation (18 months)

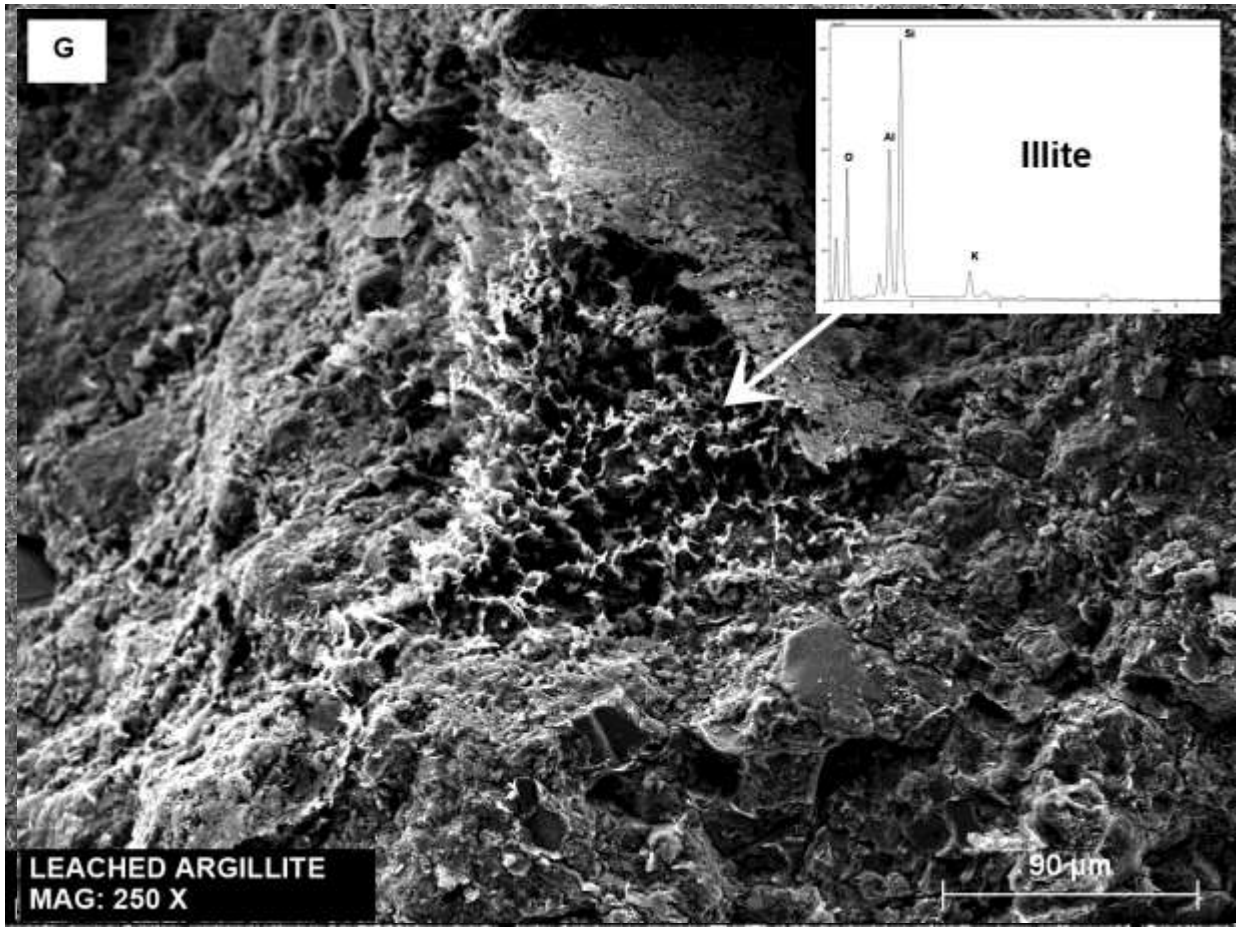




Loss of swelling properties

Gain of strength (mainly friction – no cohesion increase)

Impact of alkaline fluid circulation (18 months)



Dissolution of smectite + illitization process

→ loss of swelling properties

→ increase of friction angle

Synthetis of work at LEMTA

- Several studies performed to :
  - Analyse the microstructure reorganisation upon wetting and swelling pressure development
  - Perform suction controlled hydration and monitor swelling pressure development
  - Investigate the impact of agressive fluids on mechanical performances
- Perspectives
  - Suction controlled tomographic oedometer cell
  - Imposition of different boundary conditions (two fluids) and impact of swelling pressure
  - …

Acknowledgments

http://lemta.univ-lorraine.fr/comp_thmc_sols.html

Some references

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Thank you for your attention

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