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CENTRE D'ÉTUDE DE L'ÉNERGIE NUCLÉAIRE

SEALING/HEALING in Argillaceous Media: Laboratory Tests Results

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Experimental Programme (1): Permeameter cell tests

- Artificial planar fracture through the sample
- Testing of the chemical component in the self-healing (self-sealing) process using different injection fluid compositions in constant volume conditions en monitoring K evolution
  - Boom Clay (soft plastic clay)
    - Synthetic Boom Clay Water (SBCW)
    - Idem in oxidized conditions
    - Evolved cement water
  - Opalinus Clay from Mont Terri (indurated clay)
    - Low saline Pearson water
    - High saline Pearson water (still running)
    - Low saline evolved cement water
- µCT scans taken at regular intervals to visualize the sealing process

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Experimental Programme (2): Isostatic cell tests

- Testing of the combined chemical and mechanical components in the self-healing process using controlled isostatic and effective stress conditions
  - Two tests per clay type (Boom Clay and Opalinus Clay)
  - Drilling of a hole through the axis of the cylindrical sample
    - Boom Clay: 60 and 120 mm diameter
    - Opalinus Clay: 2.5 (still running) and 4 mm diameter
  - Monitoring of the permeability evolution

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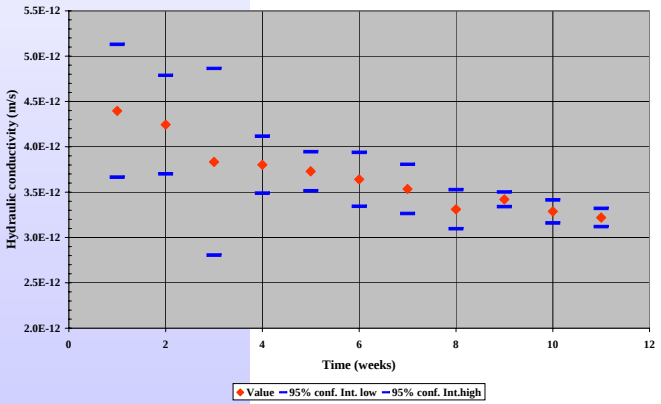
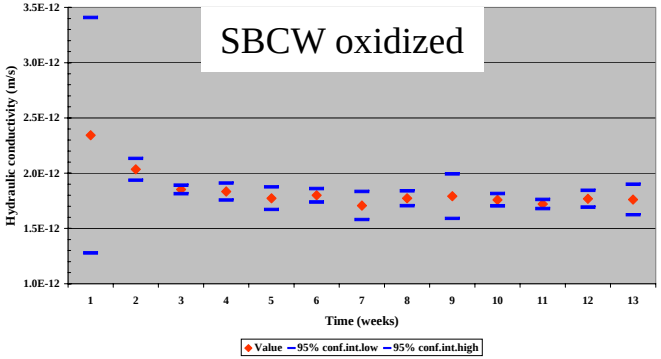
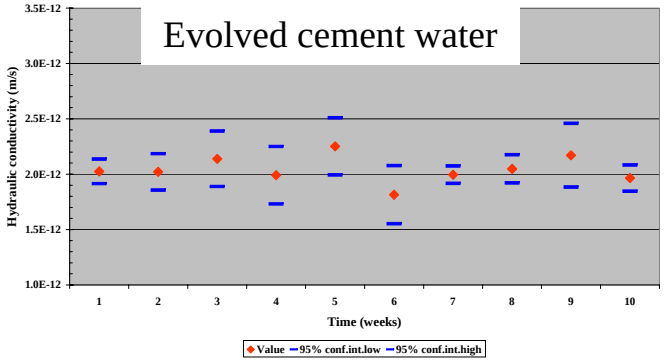
Permeameter Cell Tests: Boom Clay (1)

- A slow self-sealing is observed when SBCW in normal and oxidized condition is injected
- A fast self-sealing is observed when evolved cement water is injected

SBCW

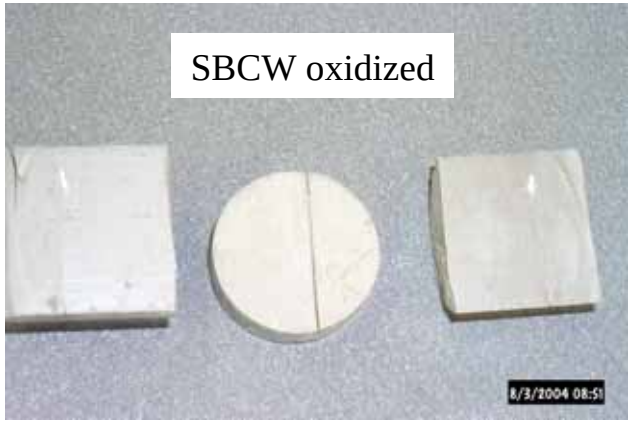


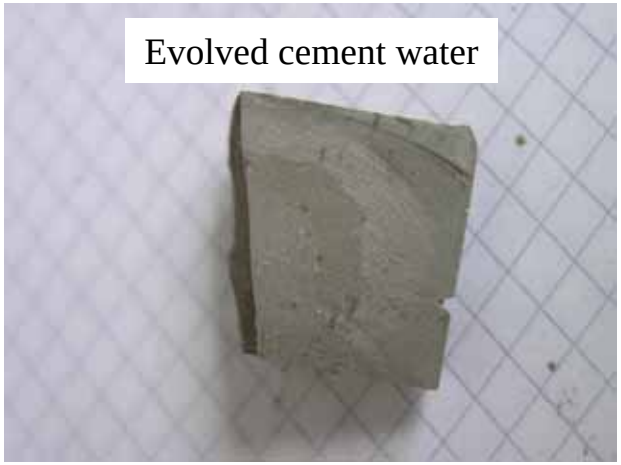




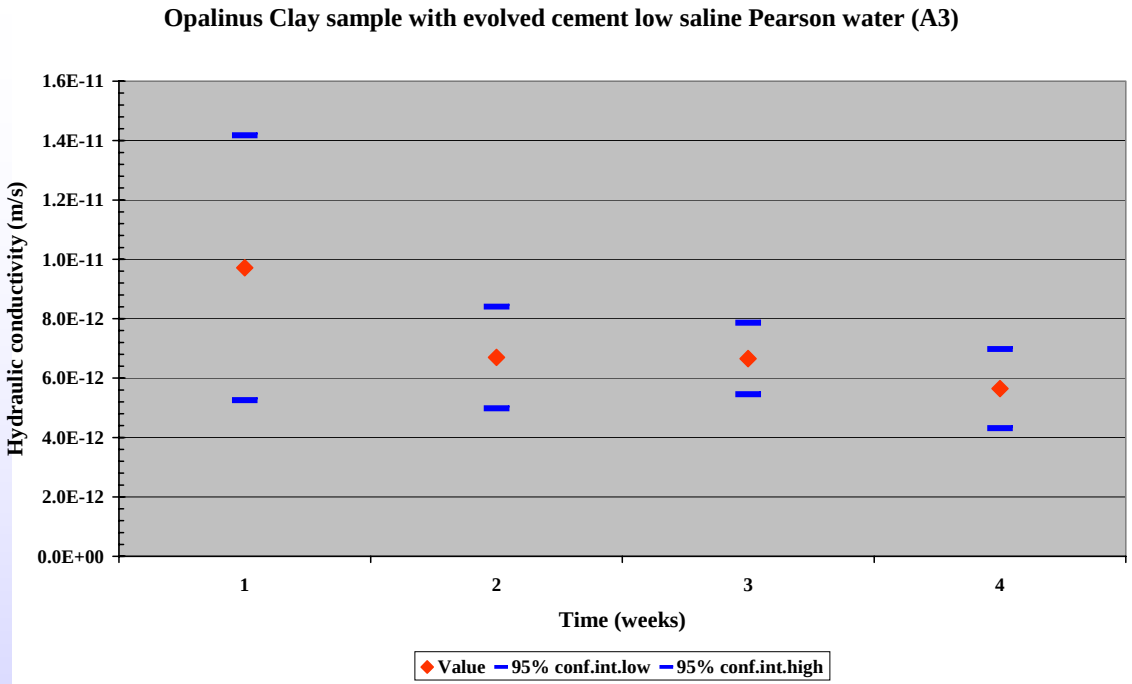
Permeameter Cell Tests: Boom Clay (2)

- Though the hydraulic properties seem to be restored, the mechanical properties are not. The best cohesion is obtained with the injection of evolved cement water. SEM micrographs show only clay minerals present in the original fracture: no cementation (cf presentation M. Van Geet together with µCT scans)





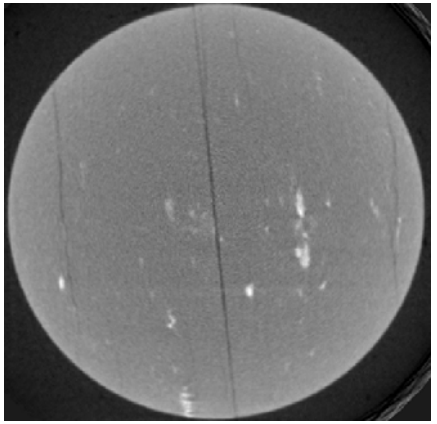
Permeameter Cell Tests: Opalinus Clay Mont Terri (1)

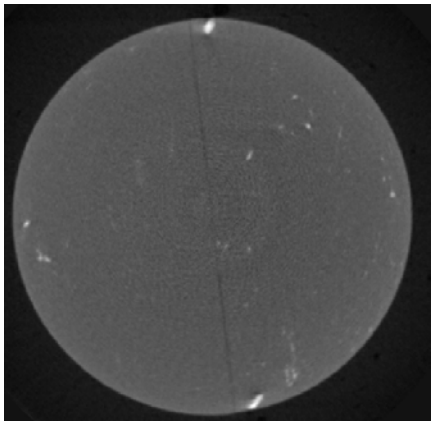


- A very moderate self-sealing (although not statistically significant) could be observed for the Opalinus Clay at the timescale of the lab test (1 month)

Permeameter Cell Tests: Opalinus Clay Mont Terri (2)

- The main fissure is still present, the peripheral faults could not anymore be detected with the µCT





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Isostatic Cell Tests: Boom Clay

- Two tests have been carried out on Boom Clay samples
  - Same original core
  - 6 and 12 mm centered drillhole at the installation
  - SBCW injected through the bottom of the sample (flow parallel to the orientation of the bedding plane)
  - The confining pressure is progressively incremented (starting at 0.1 MPa g) up to a final value of 4.5 MPa while the mean effective stress and mean pore water pressure are kept equivalent
  - The evolution of the hydraulic conductivity and of the consolidation are monitored

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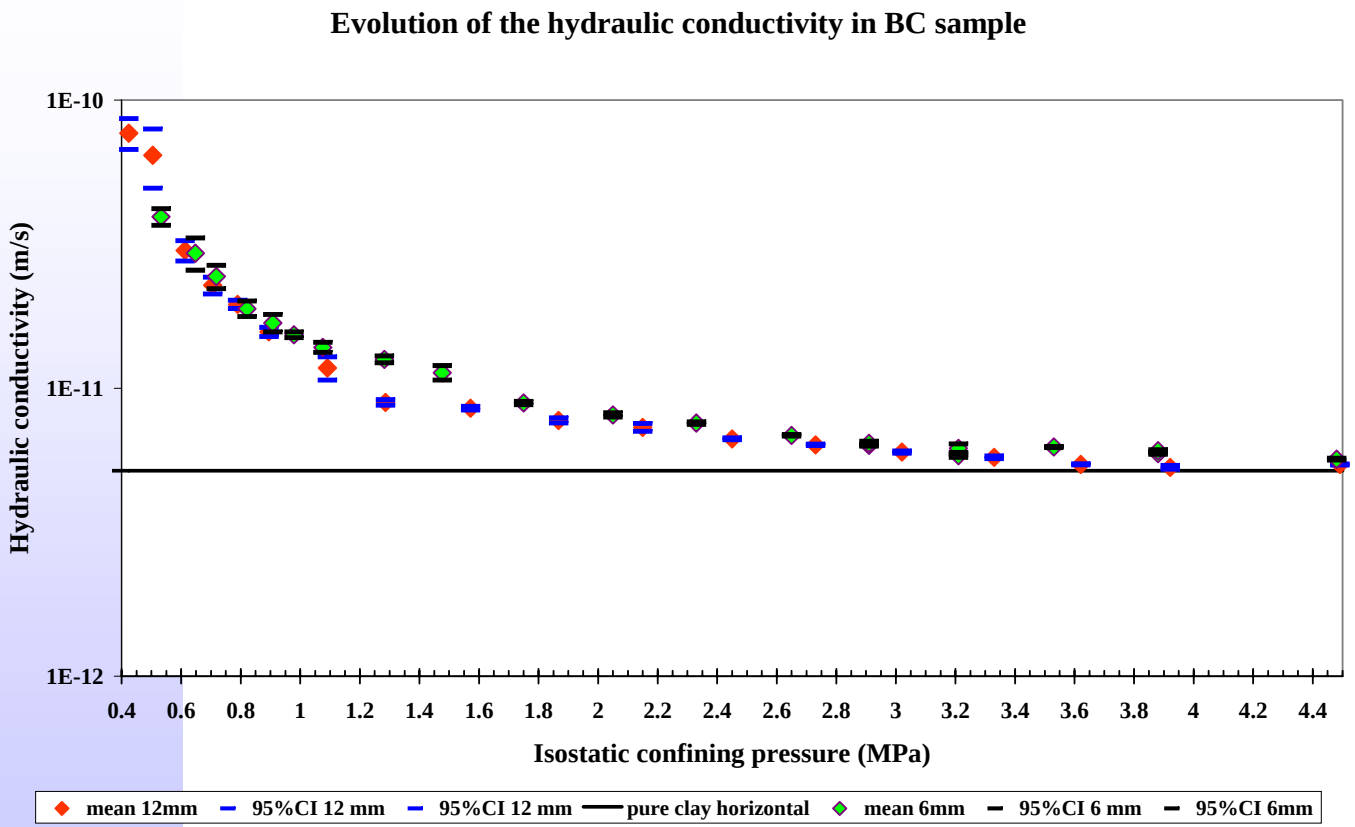
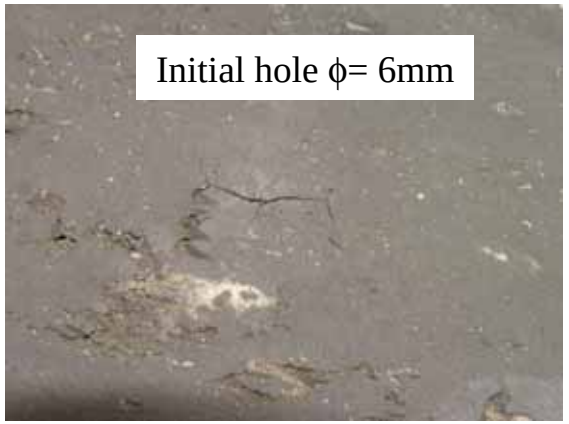
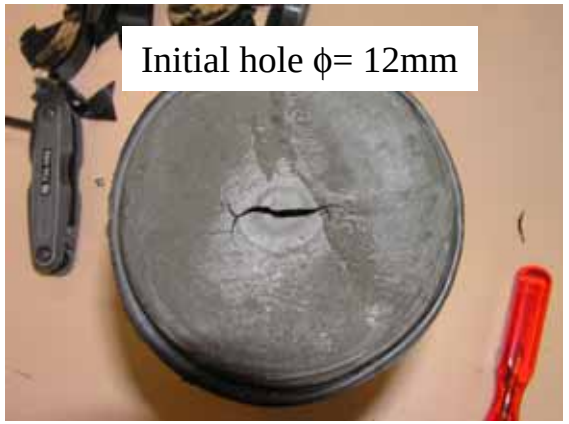
Hydraulic Conductivity Evolution of the Boom Clay Samples is similar



Pictures of the Samples Taken after the Dismantling Operation

- The decompression of the samples during the dismantling operation provoked the formation of a fissure throughout the sample in its centre en oriented in a // direction vs. The bedding plane
- Fissure dimension correlated with the initial hole dimension
- Discharge rate sample with initial 6mm hole: 5 hours
- Discharge rate sample with initial 12mm hole: 1 week





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Isostatic Cell Tests: Opalinus Clay

- Two tests have been carried out on Opalinus Clay samples
  - Same original core
  - 2.5 and 4 mm centered drillhole at the installation
  - Low saline Pearson water injected through the bottom of the sample (flow parallel to the orientation of the bedding plane)
  - The confining pressure is progressively incremented (starting at 0.1 MPa g) up to a final value of 4.5 MPa while the mean effective stress and mean pore water pressure are kept equivalent
  - The evolution of the hydraulic conductivity and of the consolidation are monitored

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No sealing observed for the sample with the larger hole diameter (4mm)

- The hole was still present when the sample was dismantled with similar dimensions as when installed. A direct connection between the sample boundaries could be established by permeability pulse tests and confirmed visually and by µCT scans

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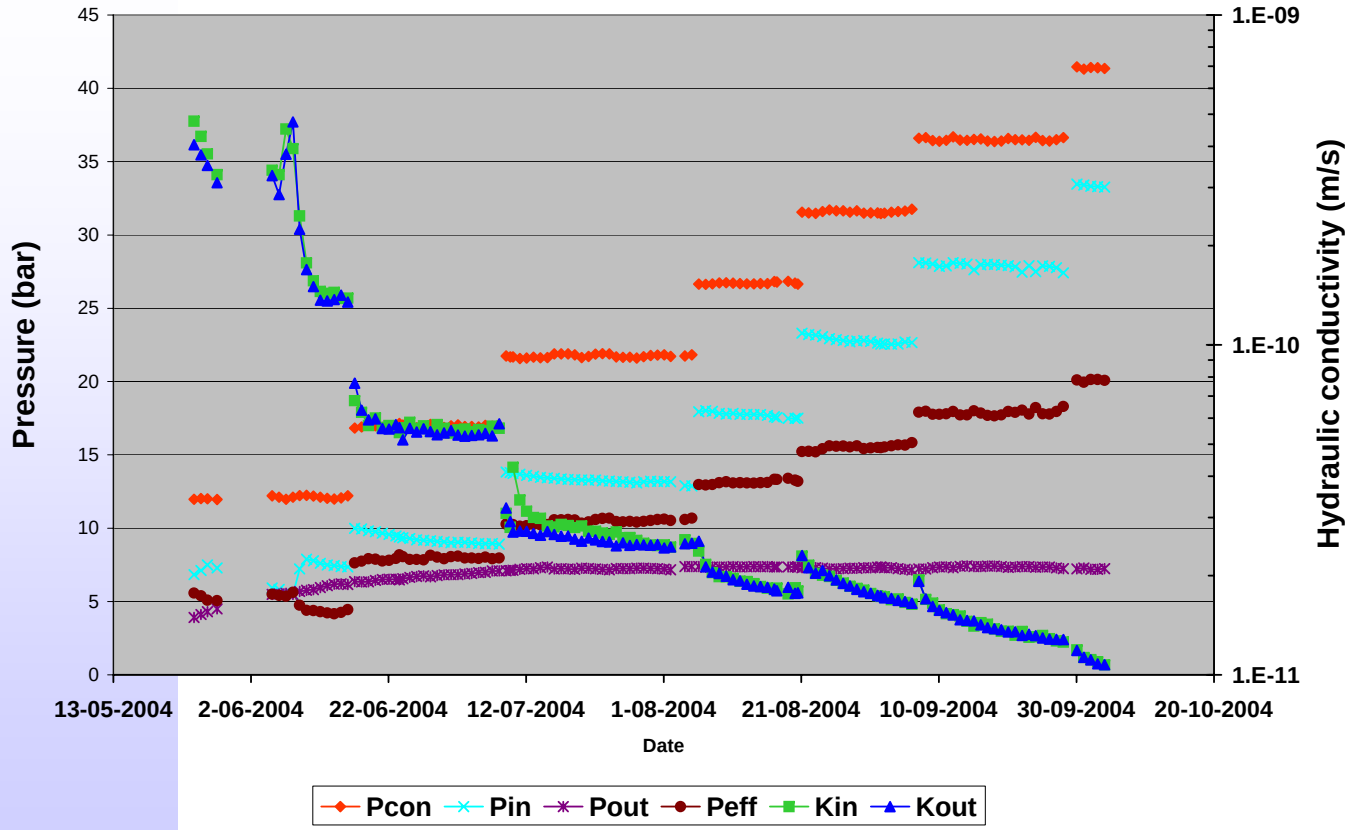
A Moderate Sealing Process could be Detected for the Sample with the Smaller Hole Diameter (2.5mm)



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Conclusions

- No perfect self-healing (restoration of hydraulic AND mechanical properties) could be detected for both argillaceous materials tested
- Lower density detected with µCT at the original hole location for Boom Clay
- The hydraulic properties were fully restored for Boom Clay (self-sealing)
- The effect of the chemical composition on the sealing of the clay samples could up to now only be detected when evolved cement water was injected through Boom Clay. The cohesion was increased though no cementation was observed.
- A very moderate self-sealing (chemical and mechanical) is observed for Opalinus Clay

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Recommendations

- The permeameter cell experiments testing the chemical component of the self-healing seem to be dependent on the experimental procedure (constant head/constant flow, “natural”/artificial fracture, boundary effects, …). A sensitivity study could complete the experimental data
- For these tests, the small fracture aperture (order of 100µm) implies at least three orders of magnitude difference in permeability to be detected on the integrated surface: tracer tests might give a better idea of the fault conductivity