Overall idea of HomoBento

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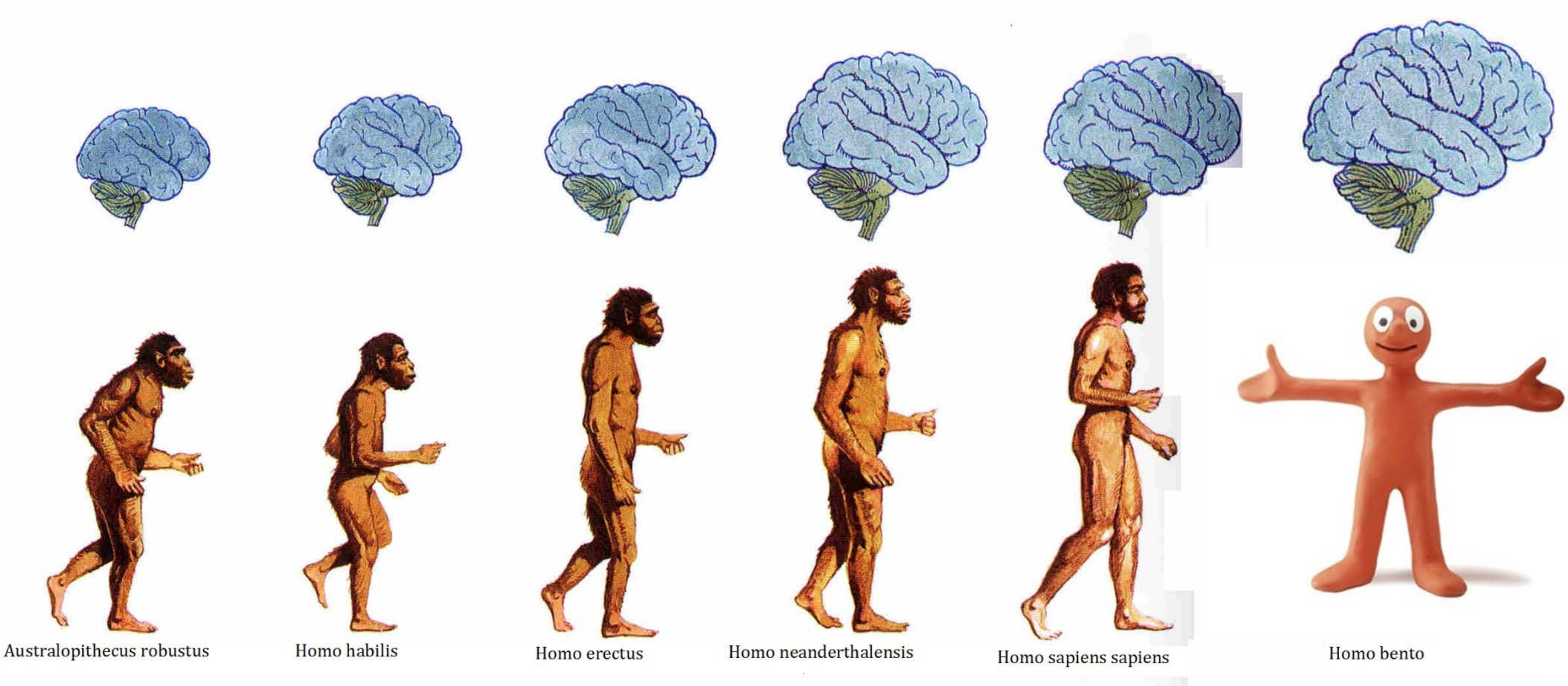


Overview

- Rationales
- Work in other projects
- Available experimental data
- Potential experiments
- Modelling issues
- Summary

Rationales

Safety assessments assumes a homogeneous bentonite material density distribution with a minimum dry density of 1.45 gcm^{-3} at full saturation. This may be an optimistic approach that needs to be verified.

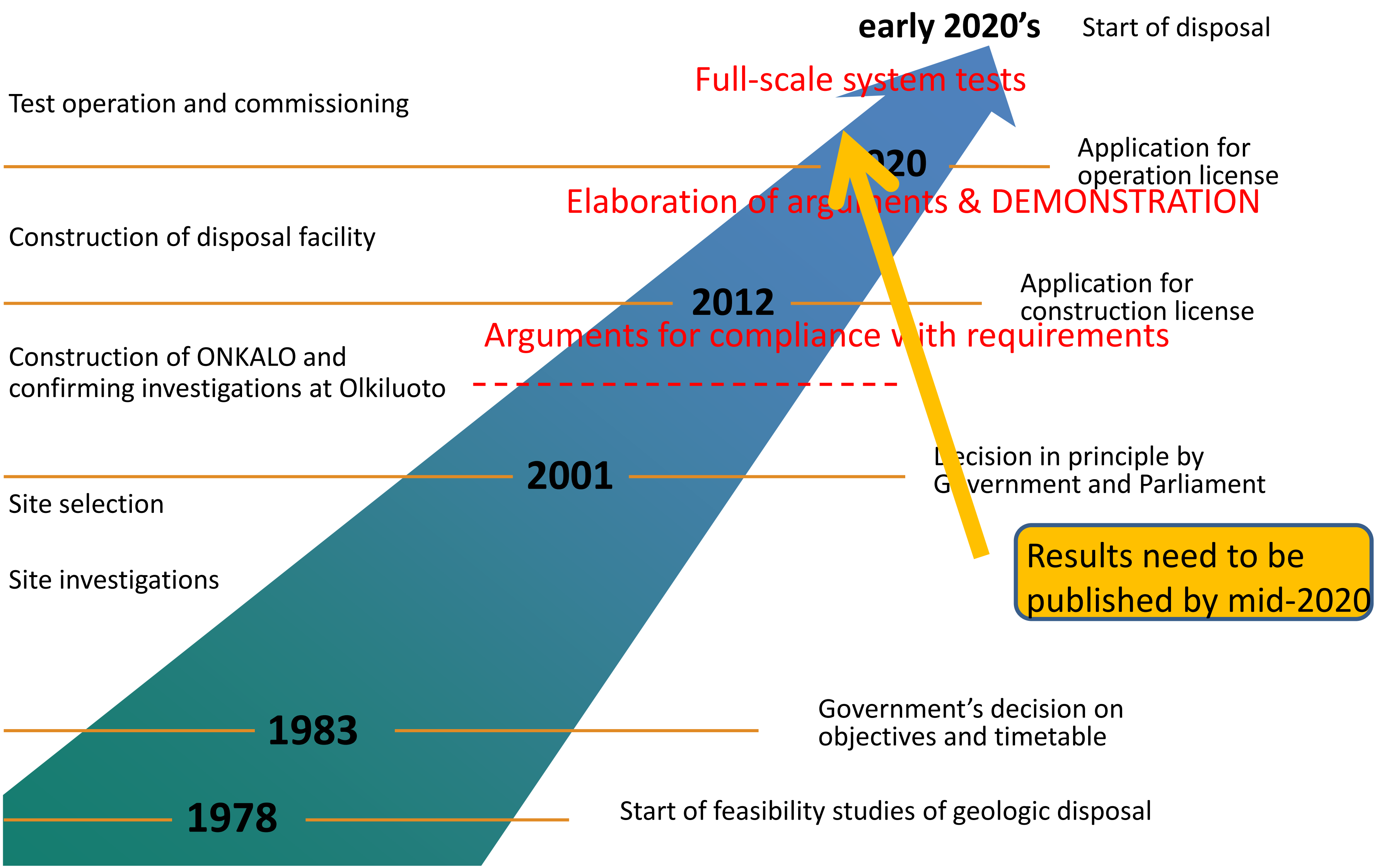
To fulfill this requirement, **it is assumed** that:

1. **Initial material property** differences vanish through resaturation (e.g. blocks and pellets)
2. **Backfill process** induced heterogeneities vanish with resaturation (including technical gaps)
3. **Heterogeneities induced through the nearfield evolution** disappear with resaturation (including chemical interactions at all interfaces)

But based on experimental evidences homogeneity is never fully achieved, thus following questions become pertinent for safety assessment:

1. What phenomena and processes are expected in backfilled repository sections that could be detrimental to safety and that are caused by a heterogeneous backfill?
2. What degree of backfill/buffer homogeneity is needed to ensure long term safety?
3. If heterogeneities are detrimental to the long term safety, how can these be limited or avoided?

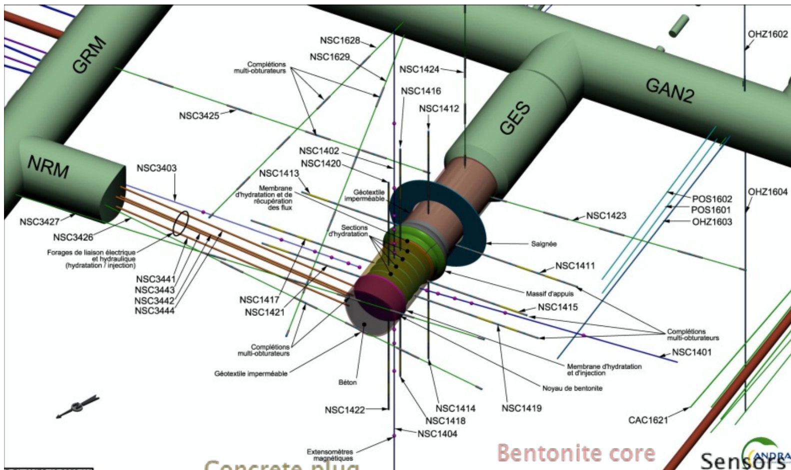
Schedule – Posiva

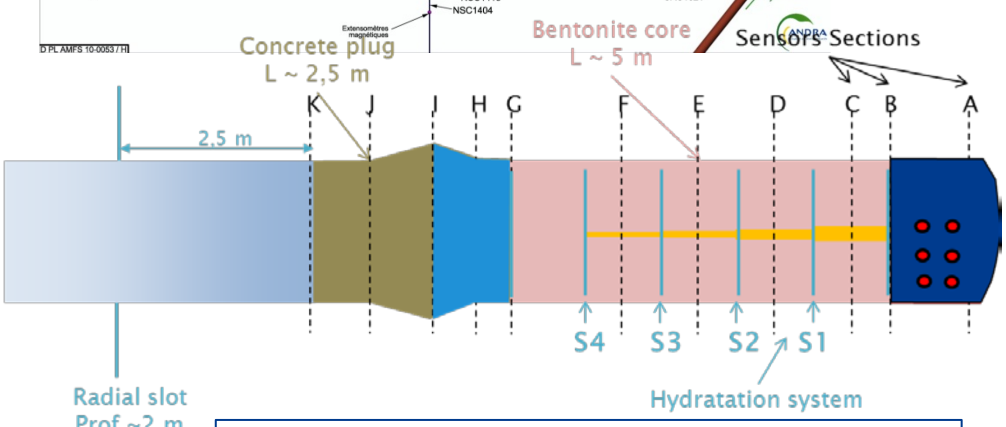


AVAILABLE EXPERIMENTAL DATA

NSC a large scale sealing experiment

Sand/bentonite bricks
Seal of 5 m long 4,6 m diameter
Pellets/powder mixture to fill interface between host rock and bricks



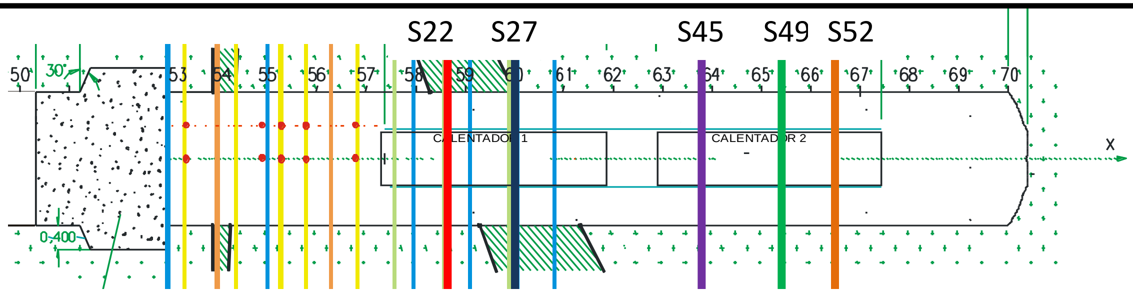


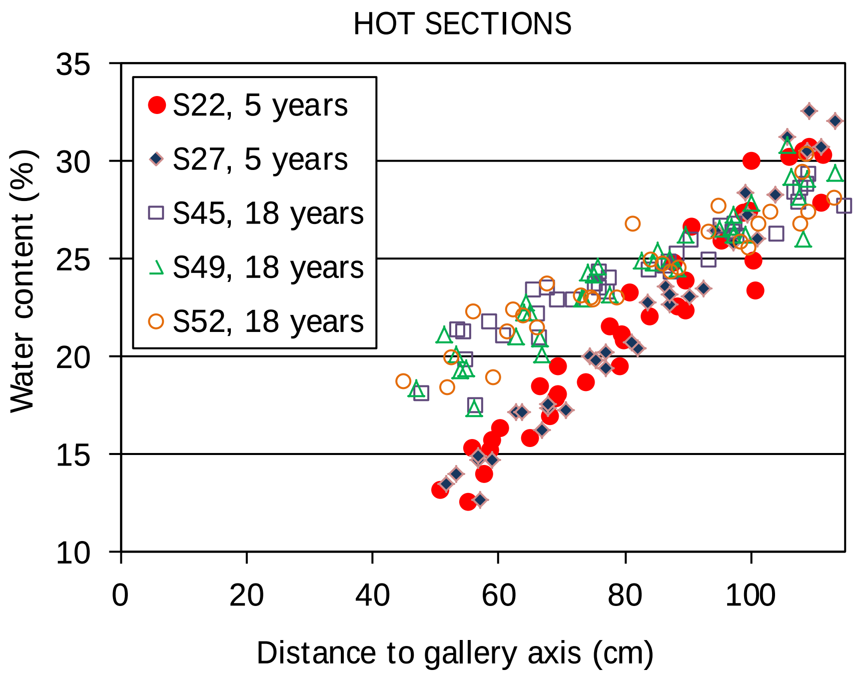
Hydraulic tests of interfaces 2017

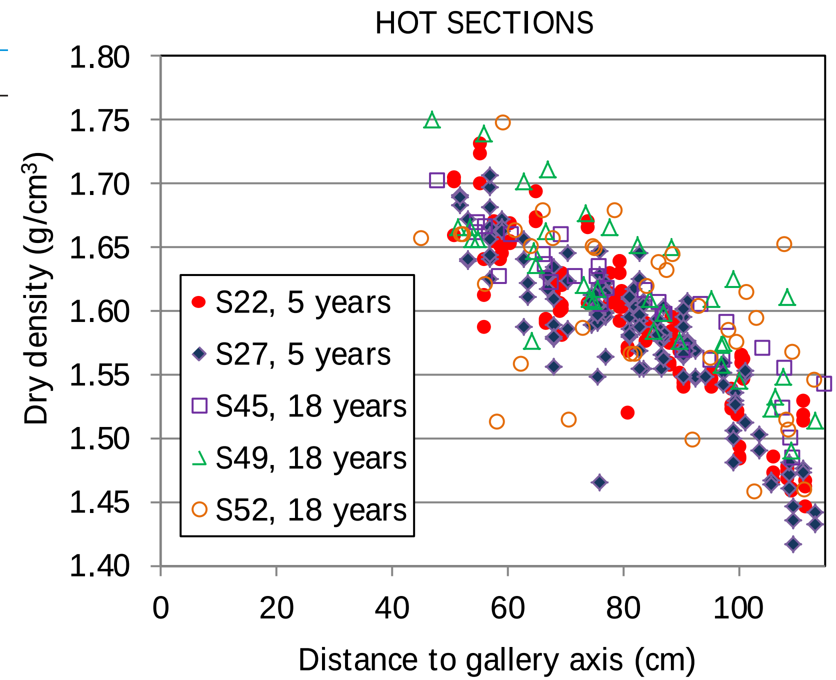
- 318 sensors in the bentonite core
  - Pore pressure :98
  - Load cells :76
  - RH (Capacitive 64, Psychrometer 64, FDR 16)
- 88 sensor in the concrete plug
  - Deformation 36, displacement 16
  - Pore pressure 20
  - tomography(INERIS) 16

Beginning of hydration: January 2014

COMPARISON PARTIAL DISMANTLING





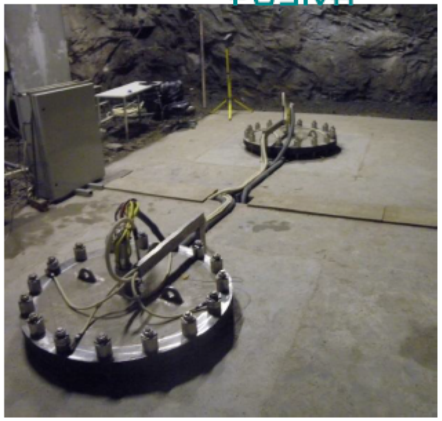


***w* (%)**	
S22: 22.6%	S45: 25.7%
S27: 22.6%	S49: 25.9%
	S52: 25.6%

***S_r* (%)**	
S22: 85%	S45: 98%
S27: 84%	S49: 99%
	S52: 98%

ρ_d (g/cm³)	
S22: 1.57 g/cm³	S45: 1.59 g/cm³
S27: 1.56 g/cm³	S49: 1.59 g/cm³
	S52: 1.59 g/cm³

KBS-3V 40% Scale Buffer Demonstrations

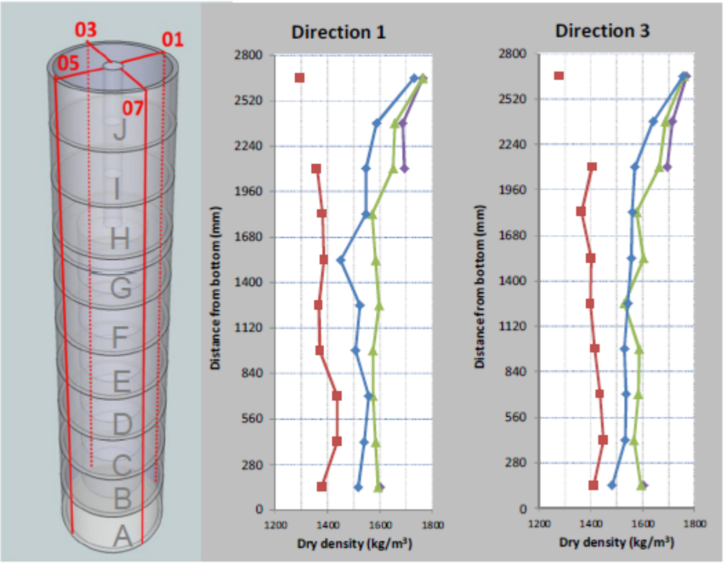


Project Schedule
- Site selection & Designing 2010
- Site preparation 2011 then Final installation 10/2011
- Monitoring 2011-> on-going
- Partial Dismantling 9/2013

Project Goals
- To perform medium-scale tests in underground conditions
- Learn how to plan, build and monitor tests at repository environment
- Get information from early phase processes of the bentonite buffer

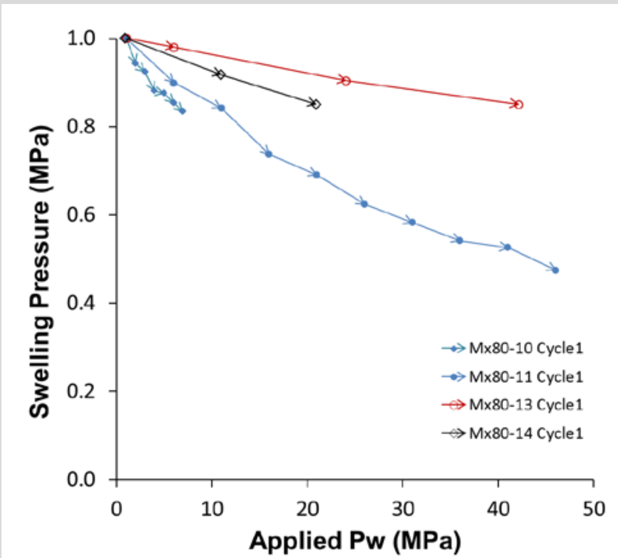
Test basic information
- Two test holes: 800 mm diameter, 3000 mm deep and 4 m from each other
- Buffer blocks, gap filling pellets and heating canisters

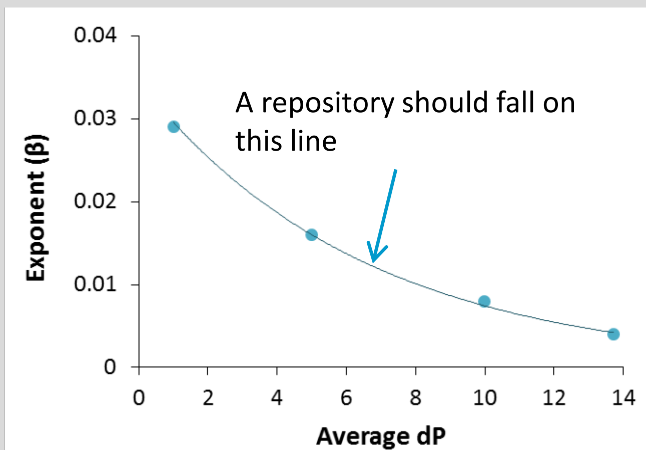
Dismantling
- One experimental test hole was opened and sampled after two years of testing
- A total of 361 water content measurements and 203 density measurements were done during the post-sampling laboratory assessments phase



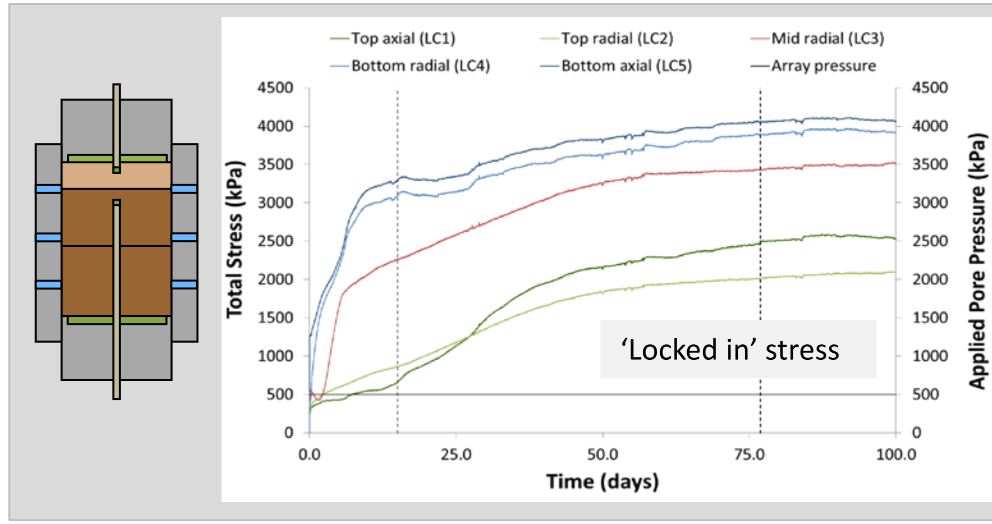
REFERENCE: *Posiva Working Report 2015-08 (Kivikoski et al)*

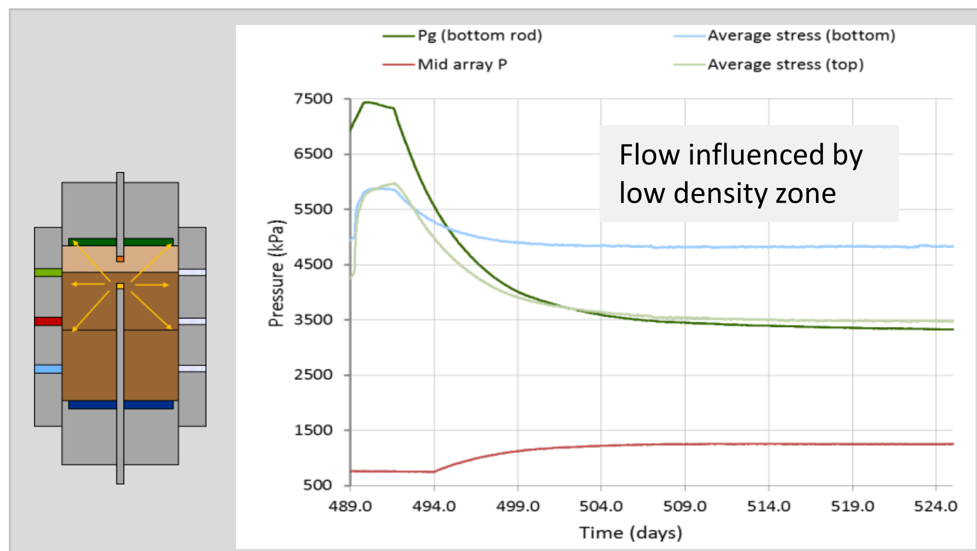
Laboratory experiments – homogenisation under different hydraulics gradients and coupling in dual density systems





$$\sigma = p_w + \pi_0 \, e^{-\beta p_w}$$





To be done: Saturation and mechanical properties for homoionic clays

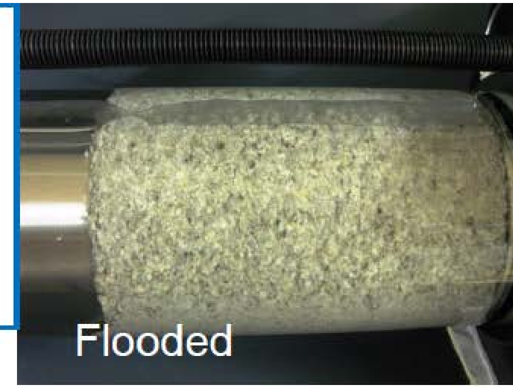
- Hydraulic conductivity
  - Triaxial high pressure chamber – up to 10 MPa
  - Cell without chamber pressure
- Swelling pressure
  - Cell without pressure chamber
- Saturation of homoionic clays:
  <u>THM PHYSICAL MODELS</u>
  - Cells developed within EU FP7 project DOPAS
  - Meaurement:
    - pressure and infiltrated water amount in the beginning of the sample
    - Swelling pressure on the end of the sample
    - Relative saturation in 9 observation points

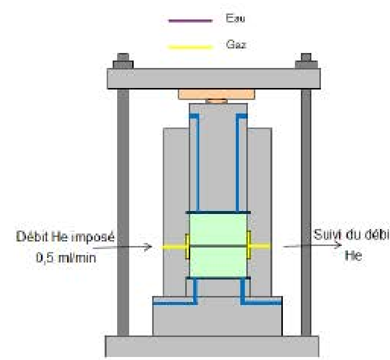
(FP7 EU project DOPAS)

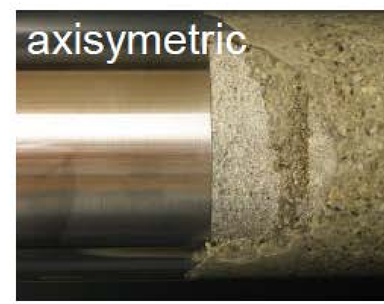
- Qualitative investigation of some specific points, using visual and smart experiments in glass vessels
    - Filling of gaps containing air or water or both : increase of pressure, delay of saturation time…
    - Study of different scenarios, defined with modellers
    - Pressures measurements during the tests
    - Density and water content performed after dismantling

- Influence of a gaz flow on gaps or joints closing, for choosen scenarios (existing equipment).

Some of these tests were reported by Rémi de La Vaissière within EC FORGE project (D3.38-R)







MODELLING ISSUES

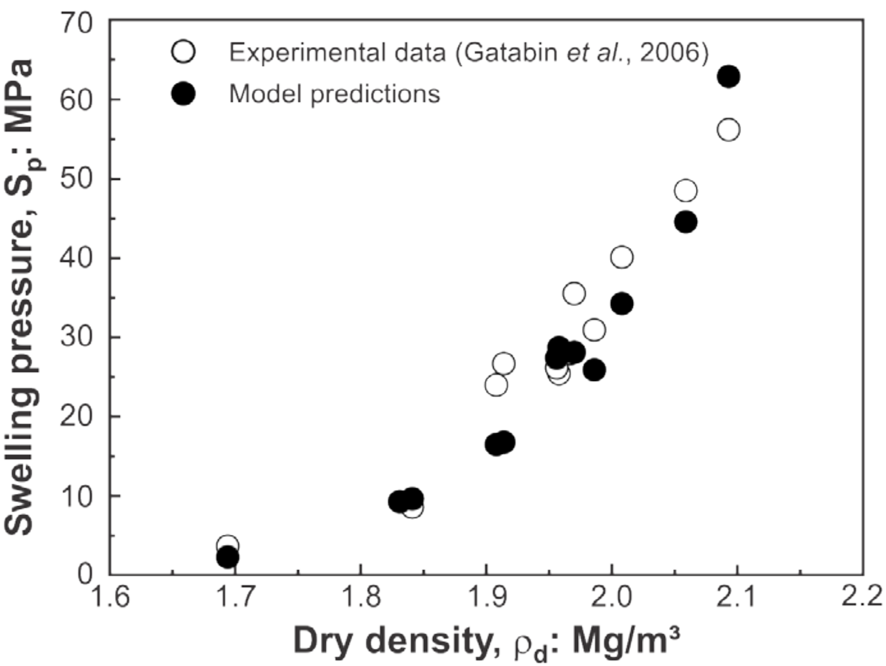
Objectives

- Process understanding requires research on:
  - Effects of initial fabric and its evolution
  - Role of thermal effects
  - Potential role of geochemistry
  - Very long term behaviour (creep)
  - Well-controlled laboratory tests over a range of conditions and scales are required
- Modelling
  - To develop predictive behaviour
  - Constitutive modelling of the bentonite (including large displacements)
  - Incorporation into coupled HM and THM formulations and codes
  - Ancillary (but important) developments: e.g. gap model
  - Application to laboratory and field cases (enhanced database with the dismantling of long term tests)
  - Application to case studies for the verification of performance

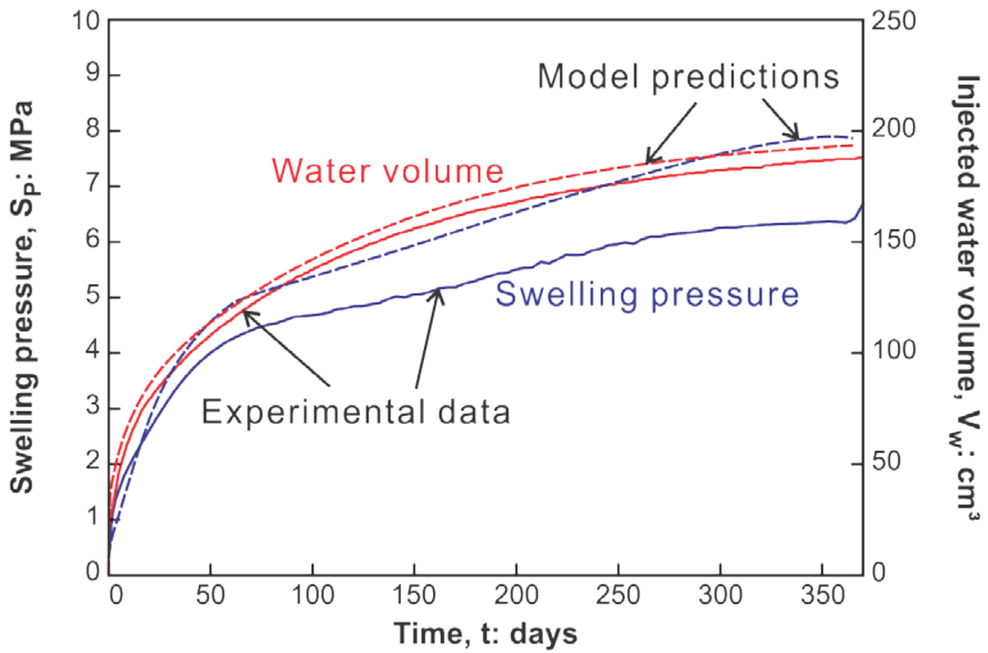
Mechanical aspects

- Elastoplastic model for partially saturated soils = “Extended” BBM

Swelling pressure tests



Infiltration test (BENTOGAZ2)



Experimental data: **70% MX-80 bentonite – 30% sand** - Gatabin et al.

New Project: HomoBento

- Core WG already formed:
  - ANDRA, Enresa, Nagra, Posiva, SKB, RWM, SÚRAO
- Working group discussion at IGD-TP 6th Exchange Forum
- If encouraged by IGD-TP, start-up meeting early 2016
- Potential workpackages:
  - Design and safety assessment
  - Benchmarking/code testing
  - Laboratory experiments
  - Conceptual and mathematical model development

Conditions

- Large amount of data already available
  - Key issue: evaluation of existing data
  - No operation of large- or field scale experiments included in project
- The objective of the modelling with respect to bentonite homogenisation would be
  - Achieve and demonstrate process understanding
  - Attain and demonstrate predictive capabilities
- Focus would be on the mechanical constitutive model that should exhibit irreversibility and stress path dependency and encompass:
  - Saturated and unsaturated material
  - Isothermal and non-isothermal conditions
  - Blocks and pellet-based materials
- The mechanical constitutive model incorporated in coupled HM and THM formulations would be applied to:
  - Well-controlled laboratory tests at different scales (process understanding)
  - Past and ongoing large scale field tests: EB, Febex, SEALEX, CRT…
  - Case studies for the verification of the performance of current designs for buffers, backfills, seals and plugs
- Long term homogeneity/heterogeneity may depend on creep behaviour
  - Laboratory tests (limited duration); fundamental micro or nanoscale studies may be required

Mechanical Homogenization in Bentonite (HomoBento)

- Currently considered in an optimistic way (full homogenization)
  - This has to be verified in the license processes
- Common issue in most programs
  - The working group had strong and common interests to contribute to the issue
- The conceptual understanding of homogenization is incomplete
  - Is the underlying physics correctly represented?
- Available numerical models are not able to predict experimental behavior
- Laboratory and field data is available
  - Possible to continue model improvement
- Strong benefit from a joint effort
- Off-spring from DOPAS, FORGE, LUCOEX and PEBS
- The number of interested partners could be ~30+
  - This includes WMO, TSO, Universities, Research organizations/companies
  - Will be a management challenge