RESEARCH ON DEEP GEOLOGICAL DISPOSAL IN FRANCE:
Results and perspectives

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Resarch and Development Divsion

Blue Ribbon Visit
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Methodological underground laboratories

Research and analysis

- Analyses and characterisation
- Modelling
- Engineering

Site work

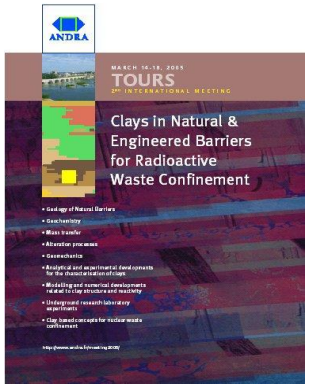
- Surface surveys
- Drilling
- Underground Research Laboratory

- Nearly 100 associated laboratories
- 8 laboratory groups
- Partnerships with leading research organisations

National and international scientific involvement

European Commission framework programmes (FP 5, 6, 7)
Ecoclay, Modex-Rep, Esdred, NF-Pro, Funmig, ,Modern, Forge…
More than 20 programmes

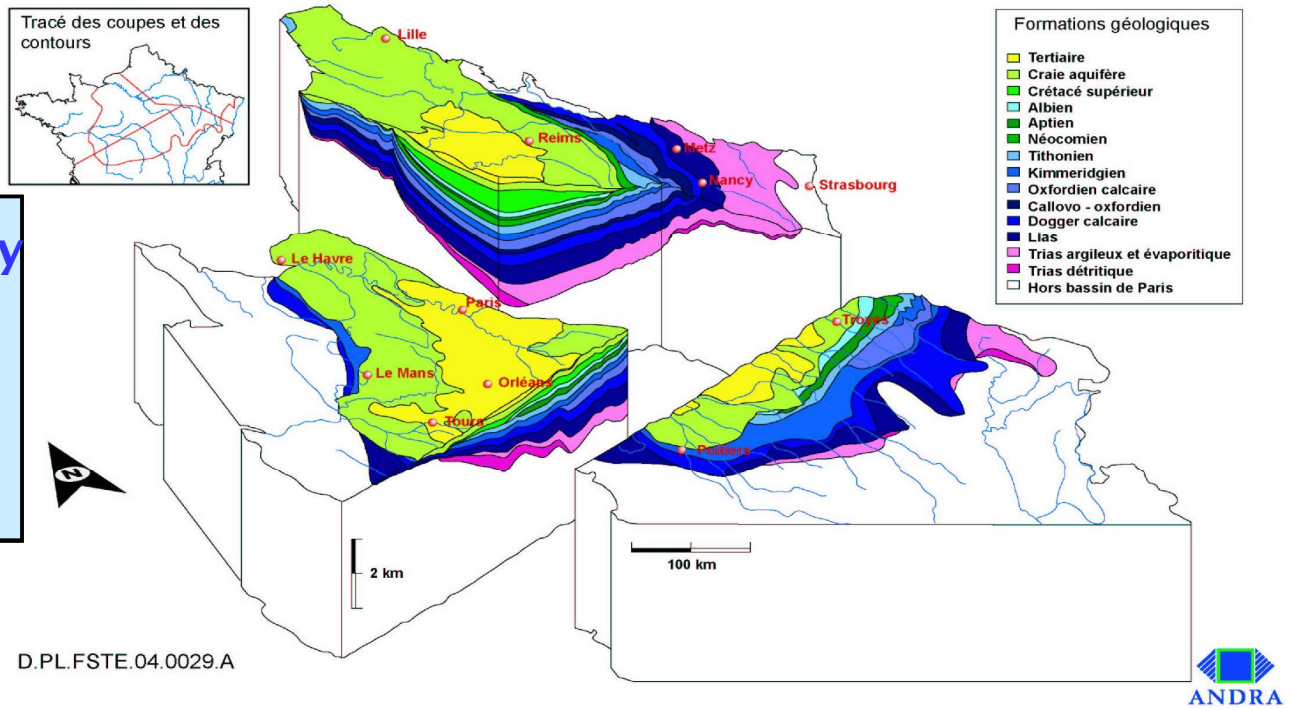
Implementing Geological Disposal of Radioactive Waste Technology Platform (IGD-TP)



- ~10 doctoral and post-doctoral research students per year
- 70 theses presented
- ~ 40 grade A publications per year
- 4 international meetings on clays in natural & engineered barriers for radioactive waste confinement (450-500 participants)

The Paris Basin

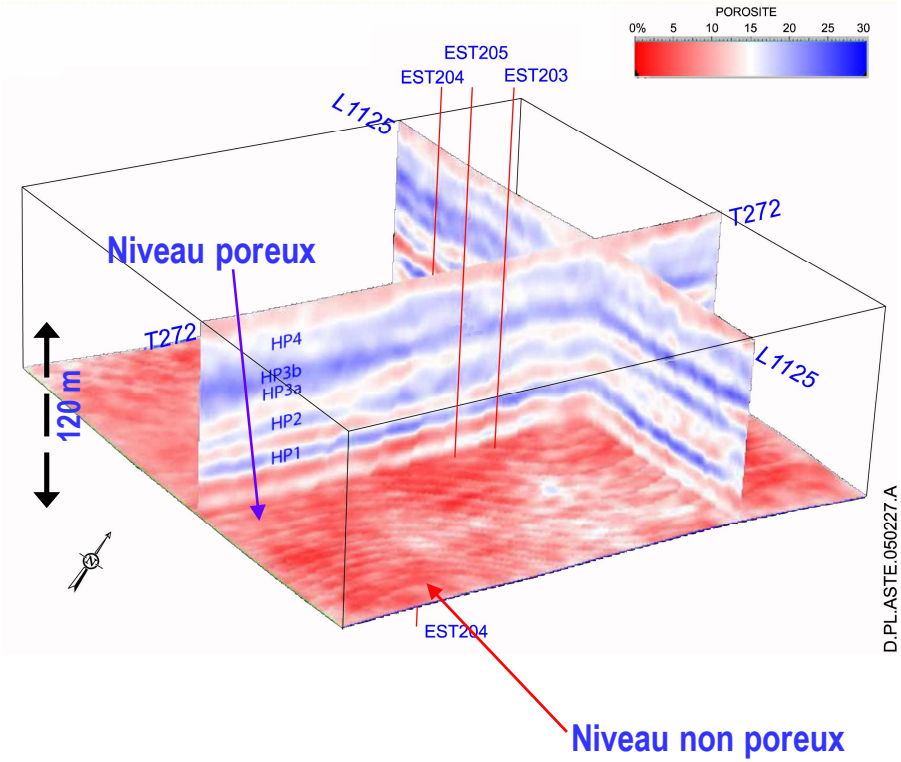
- 3000 m thick secondary and tertiary sedimentary series (250 Ma)
- Area of 250 000 Km²



- Very well documented geological framework (petroleum and water exploration)
- Classical structure (cup shape)
- Well-known structural framework
- Continuity of sedimentary sequences

Characterisation of the geological medium: Site investigations in figures

- In addition to the study of the existing former 68 boreholes, more than 40 specific boreholes with 25 km drilled and 3800 m cored in the Callovo-Oxfordian formation – use of oil industry deviated borehole drilling techniques for sub-horizontal surveying – 50,000 samples taken
- Specific 2D and 3D (45 km²) seismic campaign on the site – 1300 km of additional seismic lines acquired from the oil industry and studied



- ~3500 sensors in and in the vicinity of the underground laboratory
- 900 metres of drift at level 490 metres

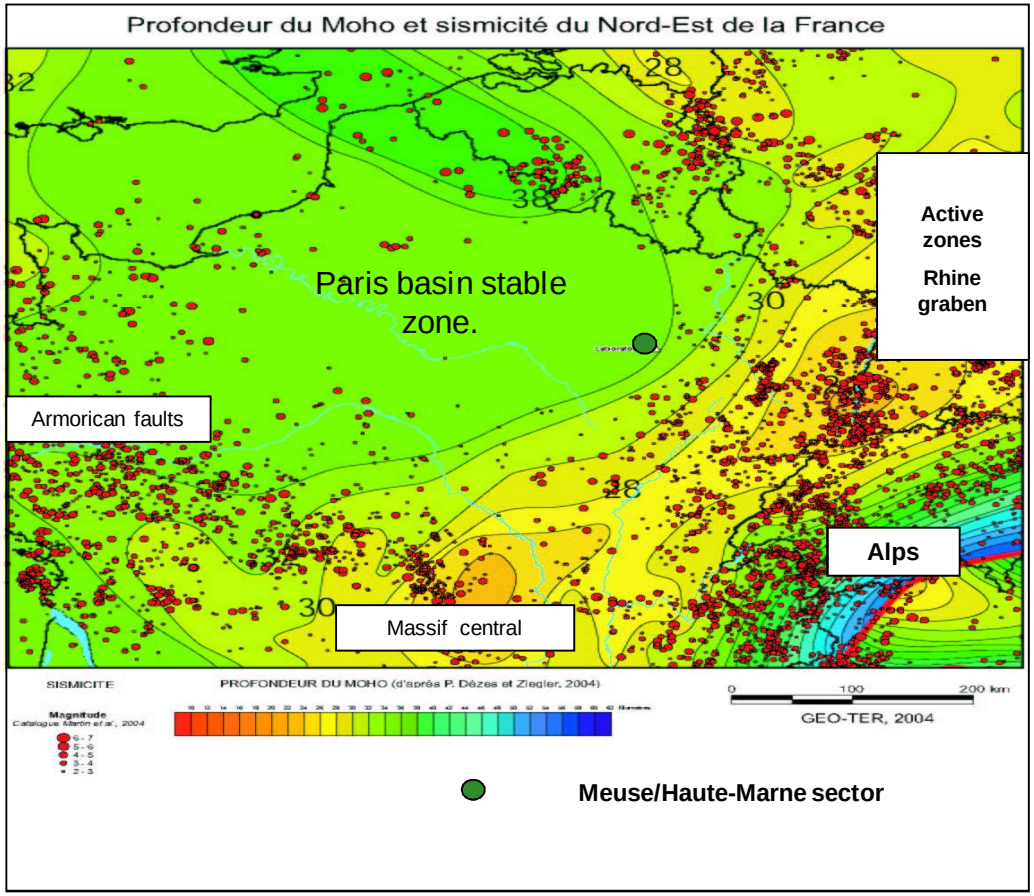
A stable zone with a simple geological structure

Stable zone – Paris basin

- Sedimentary basin with flat structural strata

Meuse Haute-Marne sector

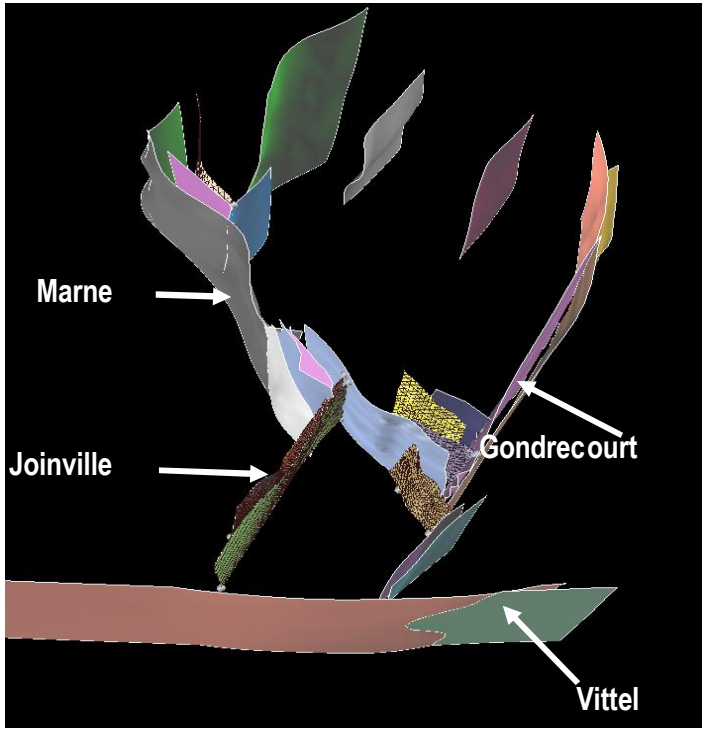
- No detectable neotectonic activity
- No significant local seismic activity



A well-defined structural regional framework

On the scale of the study zone:

- A structural framework known as of 1994
- Very slight fracture density outside the regional faults

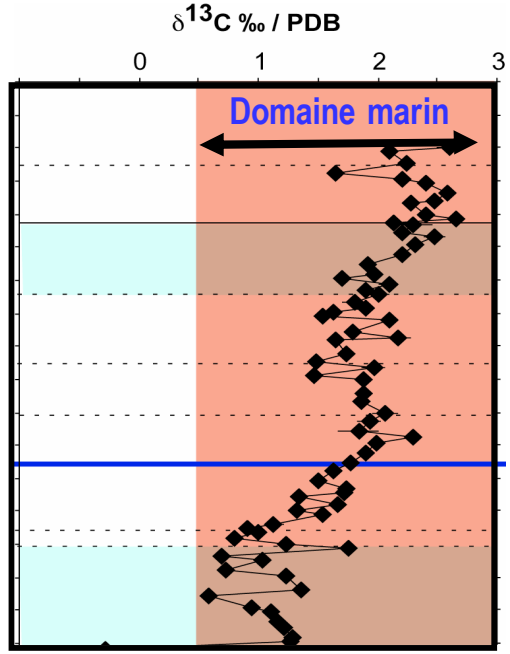


On the laboratory site:

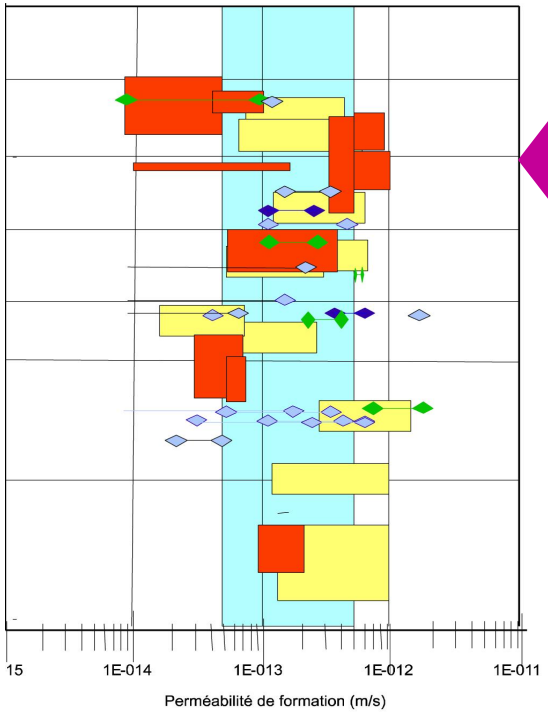
- No vertical throw faults ≥ 2 m detected by 3D seismic campaign over 4 km²
- 4 directional boreholes, 1377 m of coring: 38 micro-breaks without movement and without influence on the hydraulic properties.

Very favourable physico-chemical characteristics of the Callovo-Oxfordian formation

- Geological thermometer indicating a maximum paléotempérature around 45°C (data from a 2000m deep borehole)
- Almost no diagenetic transformation after 120 Ma



- Very low permeability measured insitu comparable to that determined on cored samples
- High clay mineral content
- Mineralogical homogeneity
- Total porosity averaging 15% with half corresponding to bound water
- Small sized pores (average 50 nm)



- Reducing conditions limiting the solubilization of radionuclides
- Stong sorption capacity of clay minerals
- Slow transport processes dominated by diffusion
- For the mobile radionuclides (I, Cl, Se) a maximum concentration at the boundaries of the COX after 250 000 years

Preparing the HL & IL-LL Waste Disposal: Siting the disposal facilities

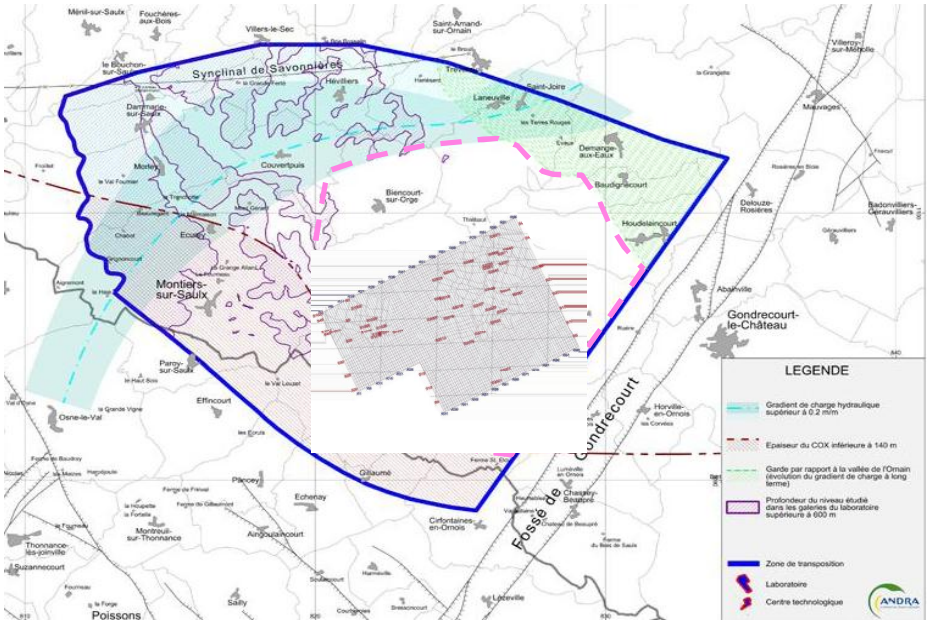
Detailed geological investigations in the 250-km² transposition zone (2007-2008)

2D seismic lines:174 km

14 boreholes: 350-m to 2000-m depth

Definition of a restricted area (100 km²) for siting based on new detailed geological information about:

- thickness of the clay formation
- depth of the clay formation
- hydraulic gradient



Proposing a 30-km² zone of interest for an in-depth survey

3D seismic survey in Spring 2010

Understanding the repository system

The knowledge acquired covers

- the waste packages
- the architecture
- the geological medium

→Need to understand the history of the repository over time, linked to the interaction between the above three aspects

A tool providing the space and time description of the repository and its environment (the concept of phenomenological analysis of repository situations PARS/APSS) in other words the history of the repository:

- analysis data to understand the influence of the various phenomena and identify the key aspects
- input data for numerical modelling and simulation of the phenomena and their couplings (representation and simulation tools)
- support for the safety approach by providing a simple and prudent basic representation of the repository

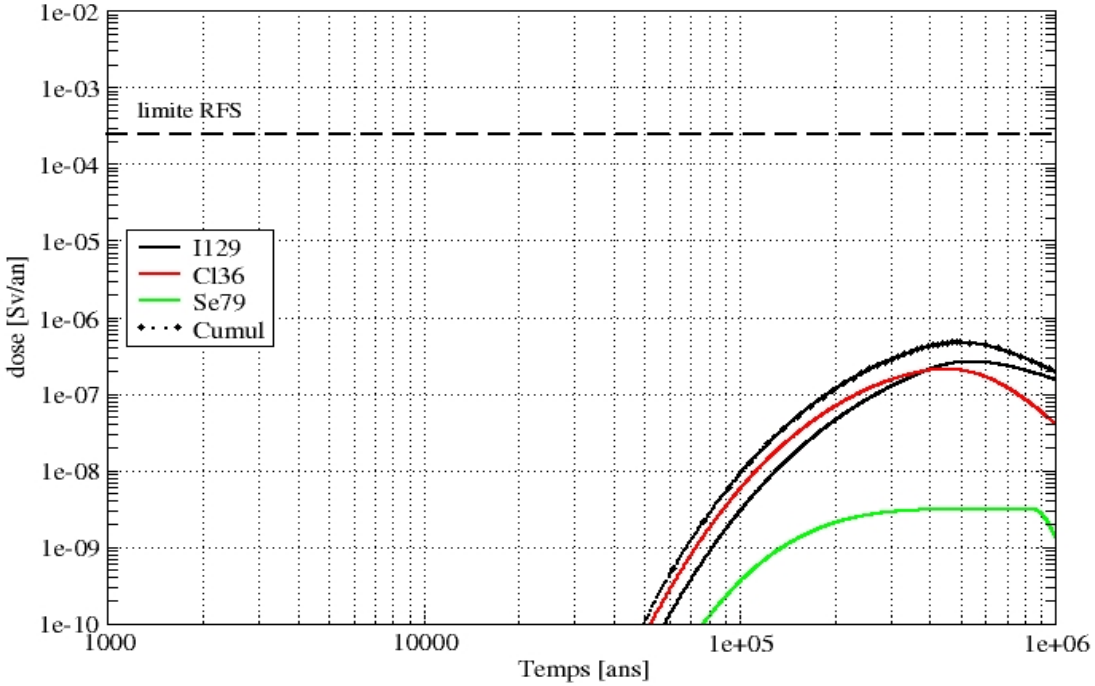
The analyses performed

- Test on the reliability of the various safety functions
  - Minimising water circulation: calculation of the Péclet number, flow passing through the structures versus the geological medium → In the most unfavourable cases, the predominant transport condition remains diffusion
  - Minimising radionuclide release → the packages and various barriers contribute to significant retention of the radionuclides
  - Retarding and attenuating migration → the structure of the geological medium ensures that limited quantities of only three mobile radionuclides are released after 200,000 years
- The combination of safety functions ensures the redundancy and robustness of the system, including in the event of failure

The safety analysis confirms the long term confinement potential of the formation

- Even when taking into account very conservative data and models and penalising conditions, the calculated doses are several orders of magnitude below the limit specified in the safety rules.

- sensitivity analyses together with probabilistic calculations clearly demonstrate the major role played by the geological formation.



- Results from scenarios introducing altered situations (components failure: overpack, seals…) also indicate doses lower than 025 mSv.

The scientific programme is centred on three thematics:

(i) control of the basic phenomenological processes,

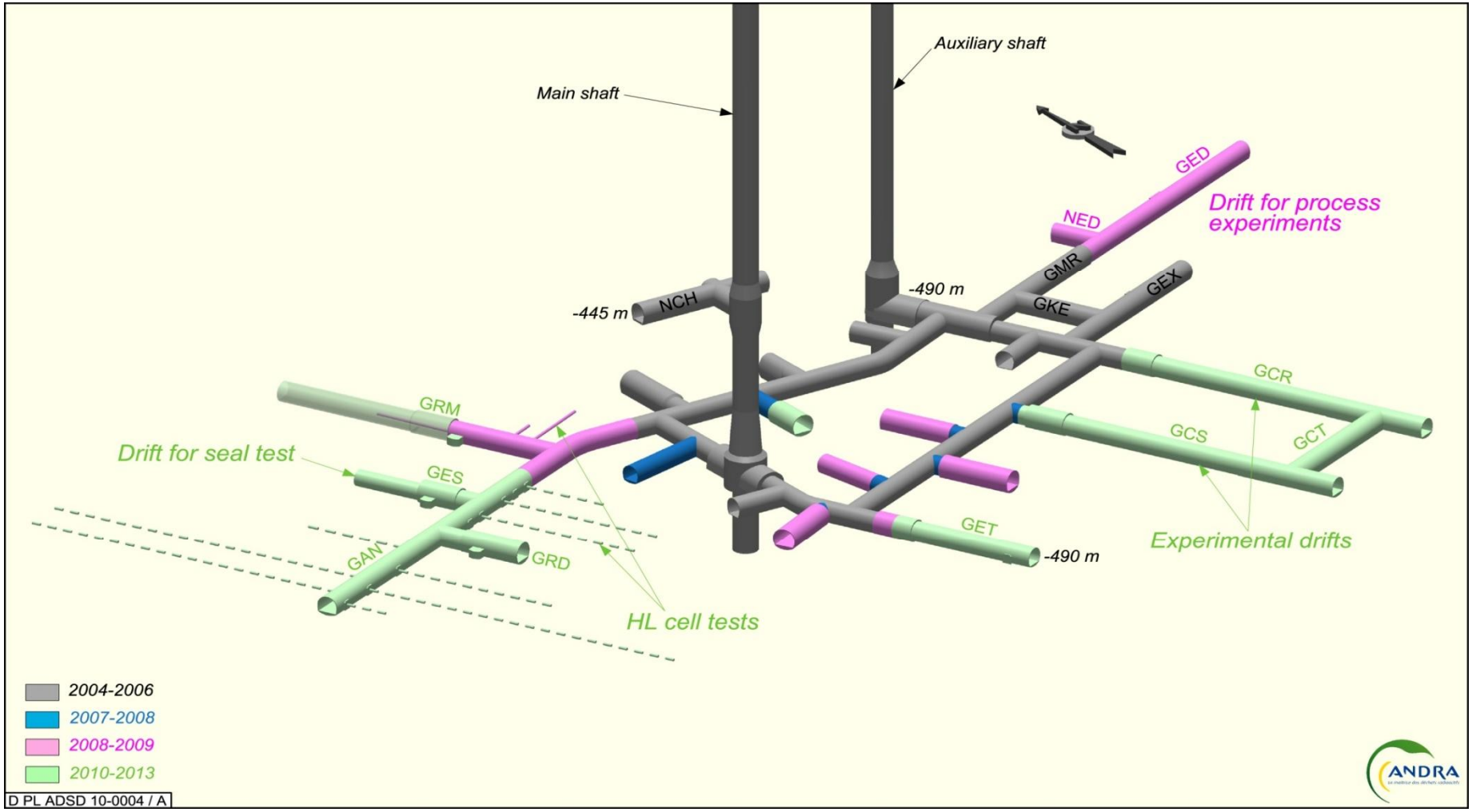
(ii) process coupling in the repository and with its environment,

(iii) data upscaling.

→ Confirming acquired data and reducing further the margins of uncertainty, as far as it can significantly support the robustness of safety and design options

The URL development

The scientific and technological programmes are supported by a thorough URL experimental programme.

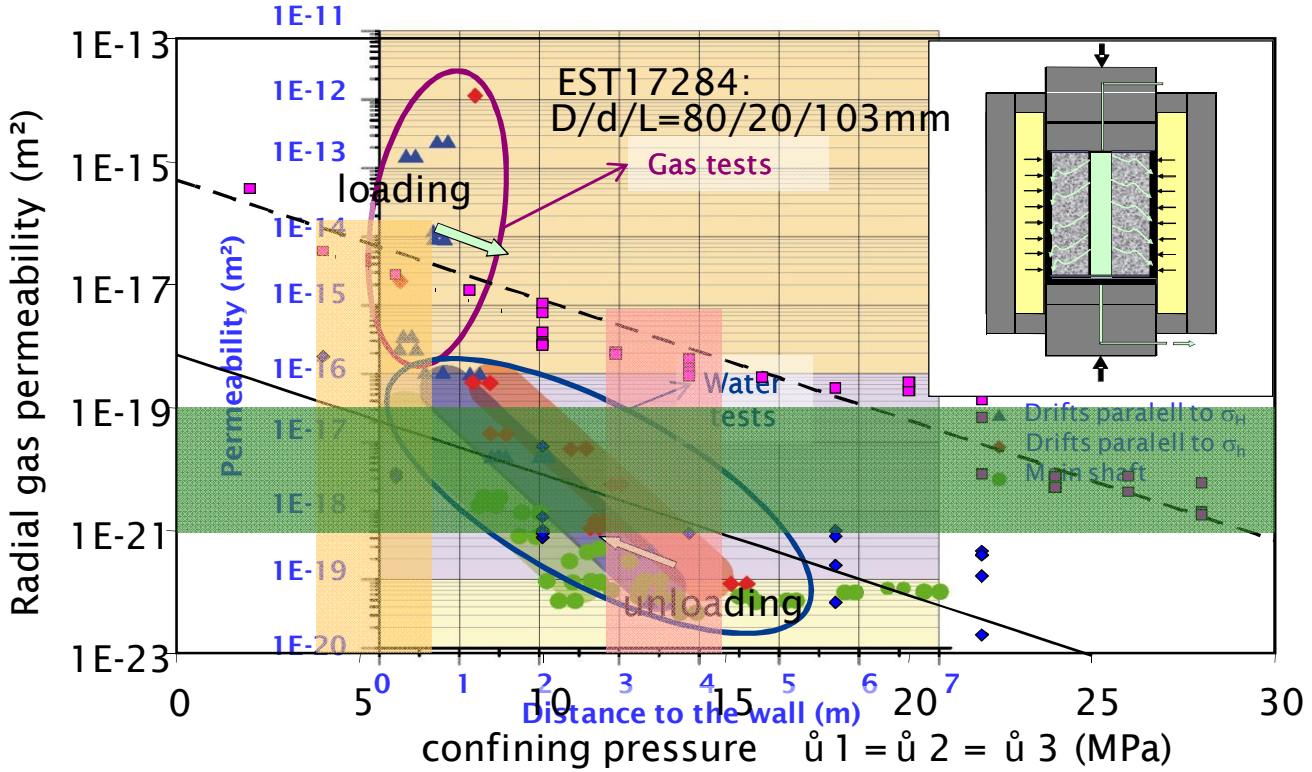


Characterization of EDZ properties

EDZ geometry, properties and self sealing data

New data are assessing the effect of self sealing. They have been acquired by a five year *in situ* multi-disciplinary investigation of the URL drifts.

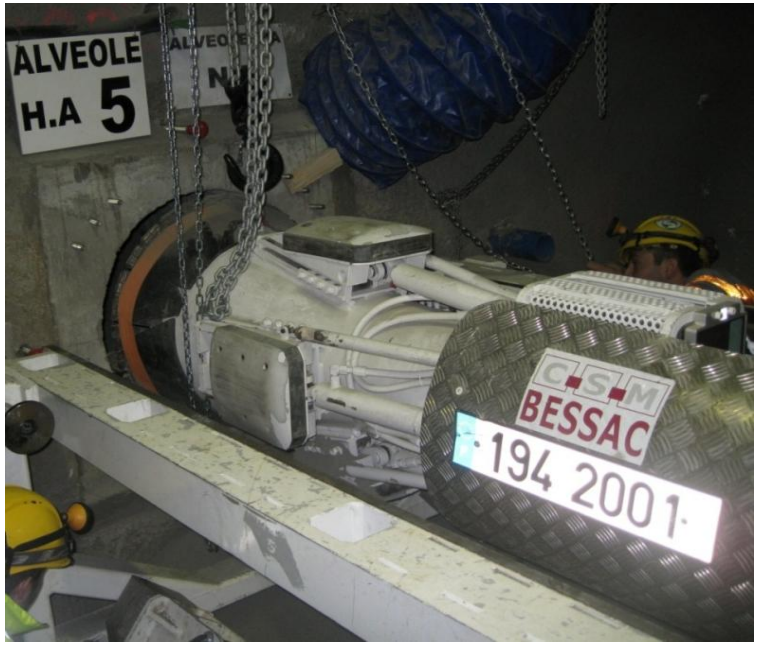
Complementary studies aim at studying its interaction with Rn migration and alkaline plume and consolidated by the shared conclusions of the EC NF-PRO Project.



HLW cell tests – phase 1

Improving excavation technology:

- Boring efficiency
- Casing set up
- Geometry of the casing/rock gap
- EDZ induced by boring

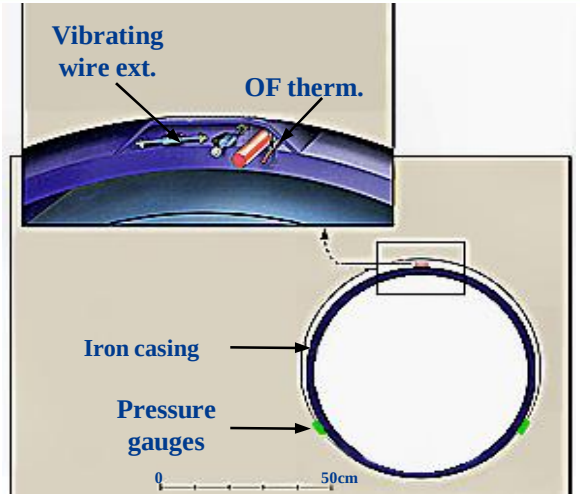


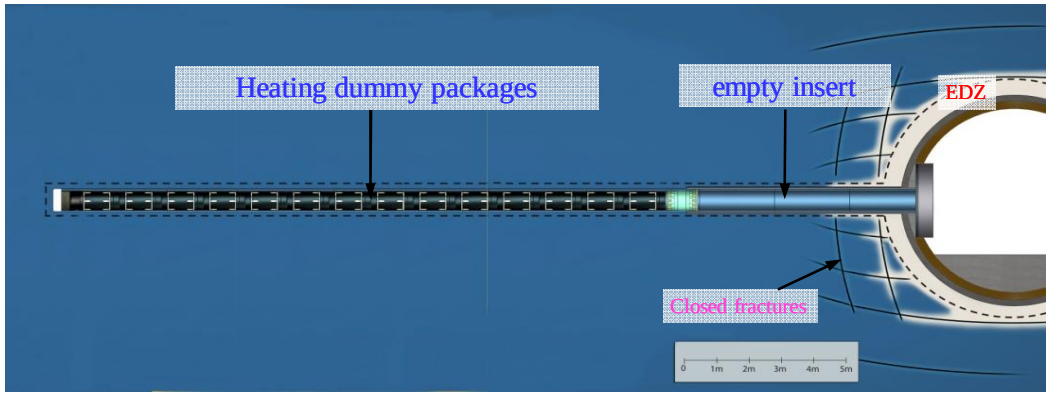
HLW cell tests – phases 2 & 3

Survey of HM condition evolution:

- at the interface argillite/casing (void reduction, water inflow...)
- Into the casing (O2 consumption, H2 production)

Test of monitoring system along a decade at least (2010)

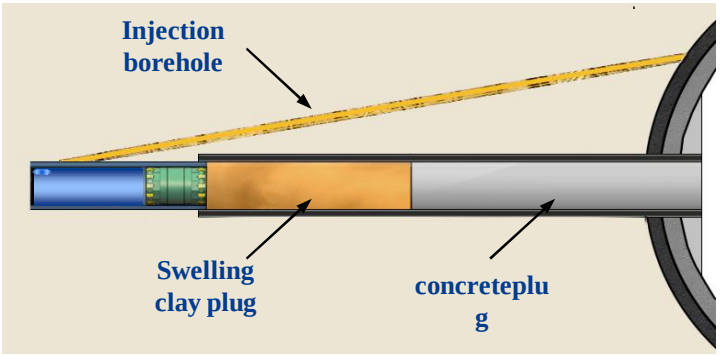




Full-sized reproducing of a HLW cell and follow up of its THM behaviour (from 2012)

Test of cell closing process (2012)

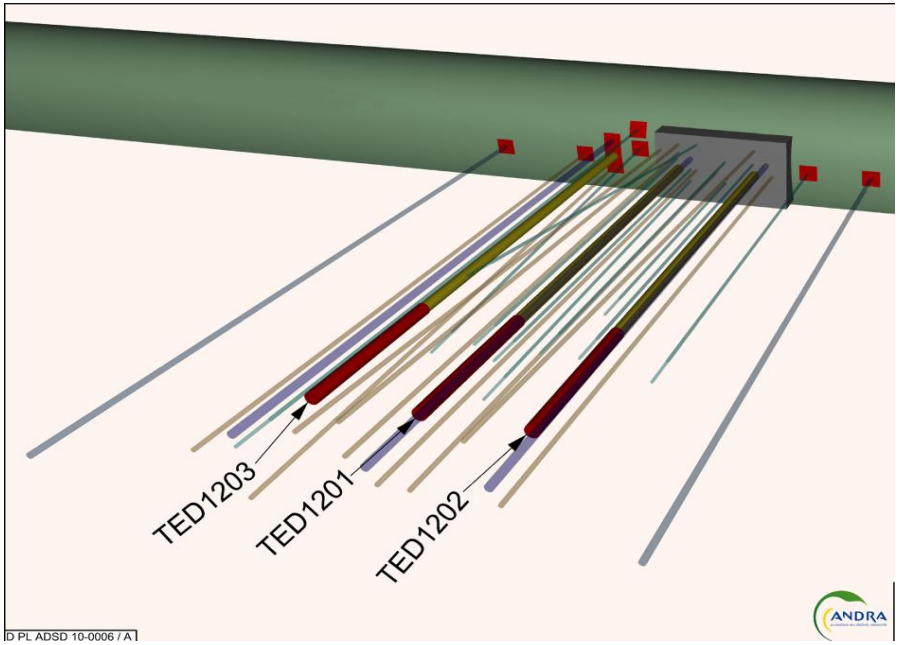
Fluid transfer experiment (water, then gas) by injection behind the plug (2013-2016)



Management of the interfaces and the couplings (1)

- **Implementation of THM coupling**
  by a new URL experiment (TED) :

  Assesment of boundary conditions and superposition of thermal fields using a multi-source heating



- **Comparison of newly formed phases at rock/concrete** (CEM I and V) interfaces under mechanical loading at 25 and 50°C:
  - higher carbonatation at the interface and into CEM I at 50°C, but only by around 100 µm.
  - precipitation of clay minerals as far as the concrete.

  ➡ Study extent to low-pH concrete

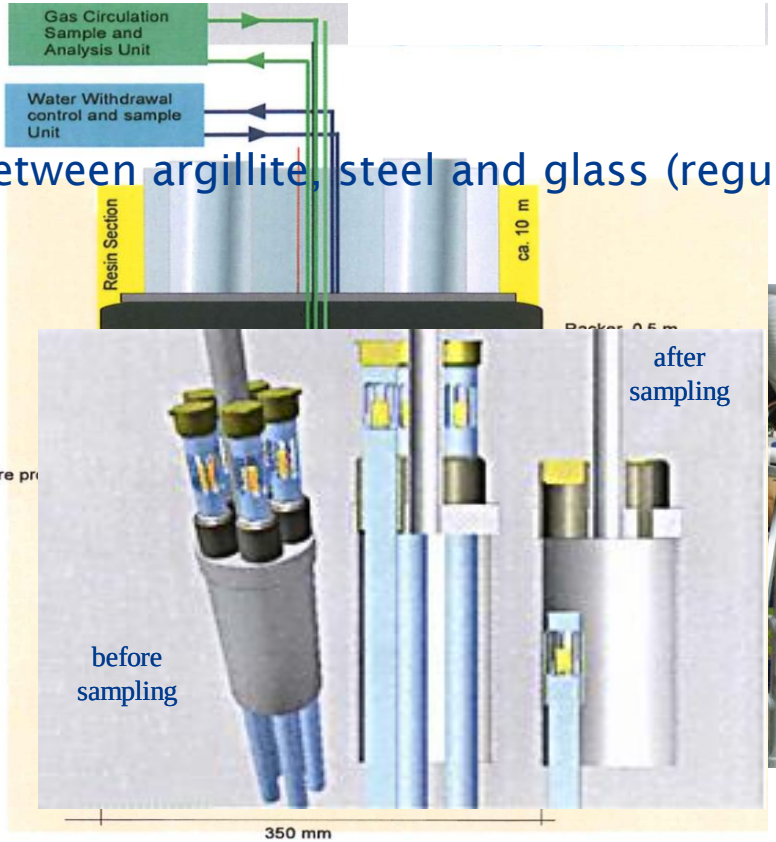
Management of the interfaces and the couplings (2)

Studying interactions between structures and/or packages materials and the argillite

Iron silicates and hydroxycarbonates have been identified as corrosion products in a disposal context ➔ assessing silicium sorption/coprecipitation on CP

- Innovative long term experiments installed in 2009-2010

e.g. survey of chemical interactions between argillite, steel and glass (regular sampling from now to 2030).



What future for the URL?

2015-2025

- Carrying on with perfecting the disposal processes during the first construction phase of the facilities, and before going progressively to cold testing then hot testing.
- Developing monitoring methods for the management of the reversibility

  ❑ 2025 : commissioning of the reversible deep geological disposal facility

After 2025

- Continuing with data acquisition on a long period (10 to 20 y),
- Verifying the life span and fiability of monitoring devices into the argillite.

  ❑ 2026-2035 : first exploitation decade of the disposal and preparation of the following period

Permanent objective:
Contribuing to the training of disposal staff for underground works and nuclear safety during exploitation as well as long term.