IRSN
INSTITUT
DE RADIOPROTECTION
ET DE SÛRETÉ NUCLÉAIRE

Enhancing nuclear safety

IRSN'S RESEARCH STRATEGY FOR RADIOACTIVE WASTE

Safety of Intermediate and High Level Waste

PRP / Waste and Geosphere
24 September 2015
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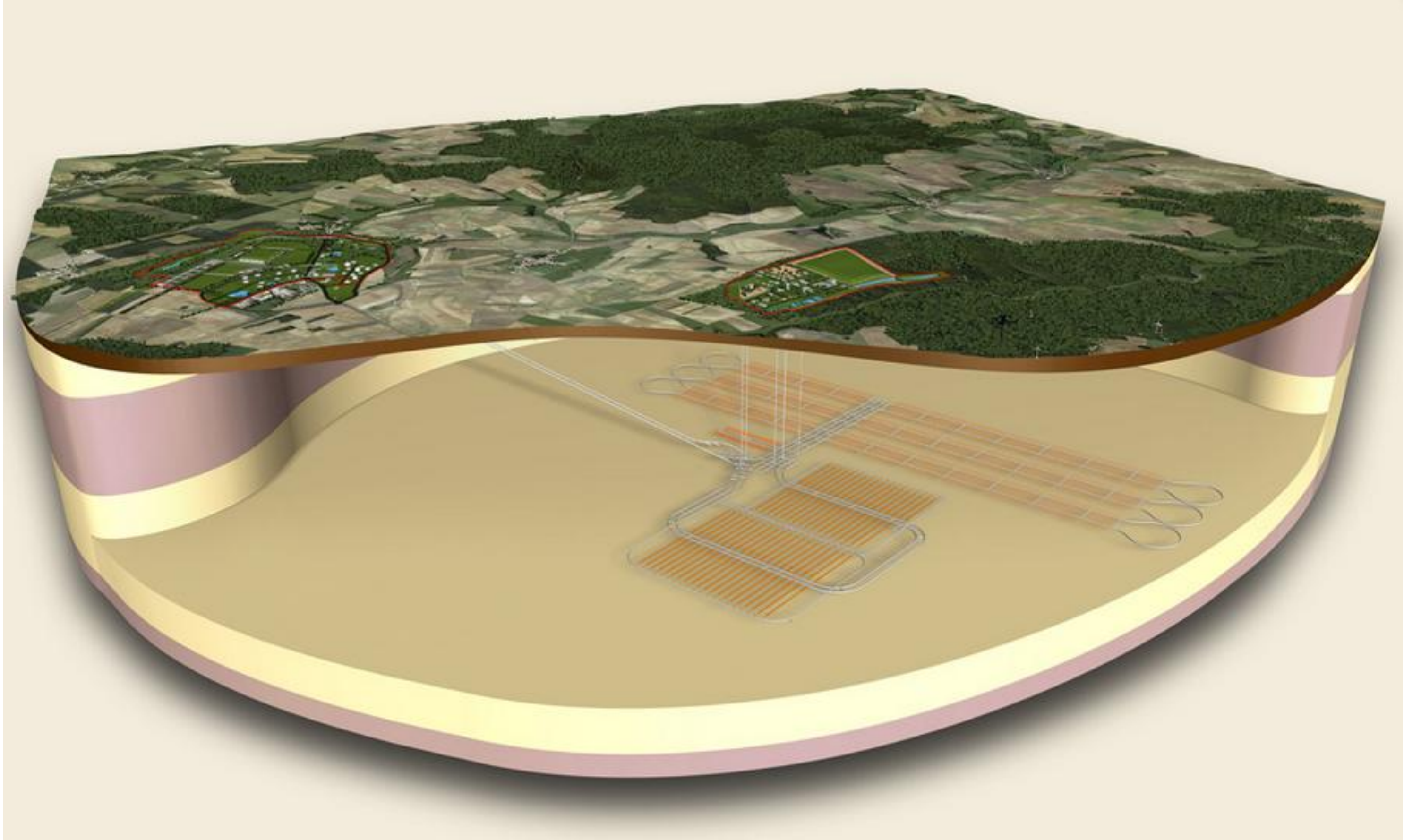
OUTLINE

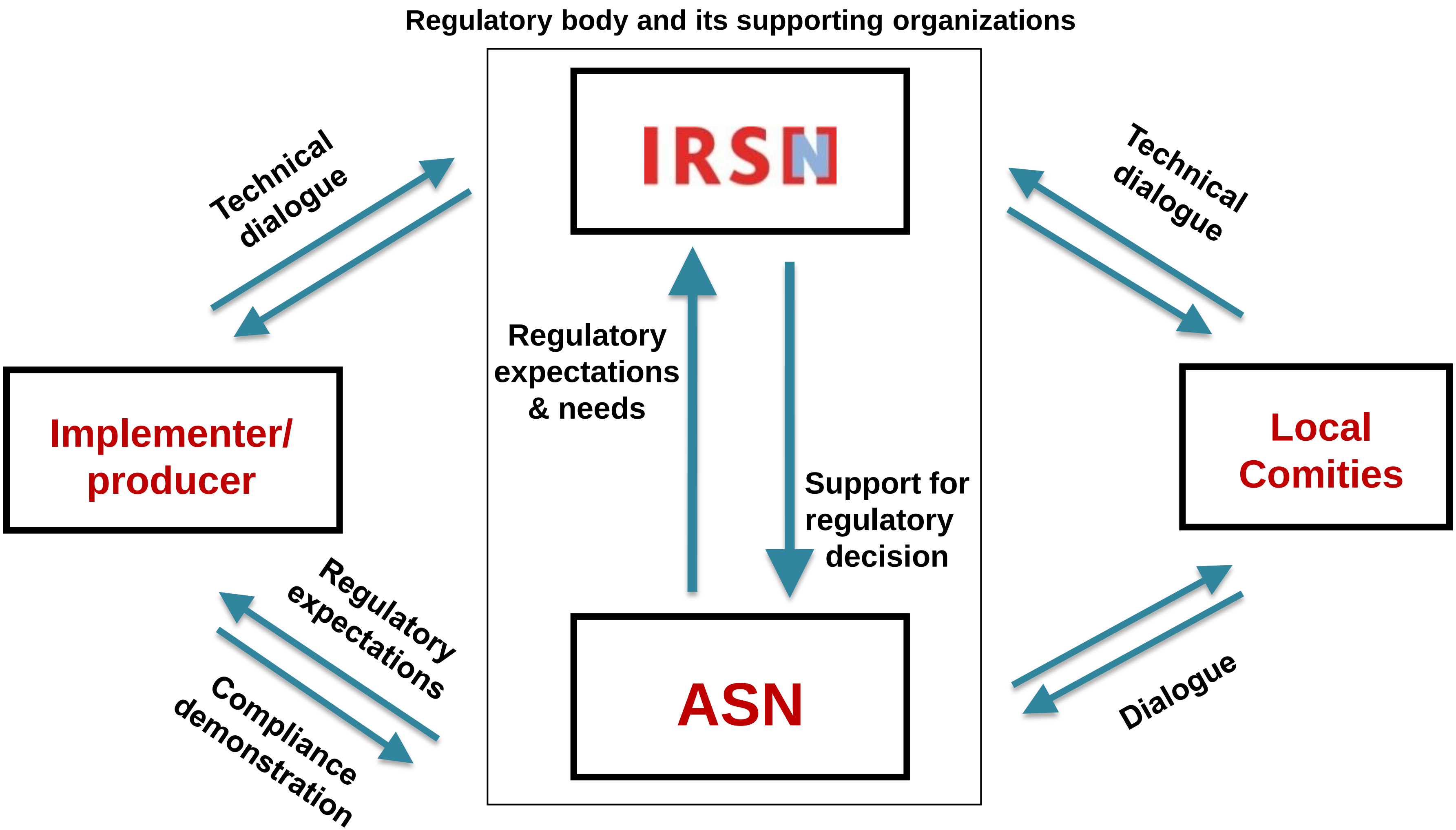
- Context : why and what kind of R&D?
- R&D program overview
- R&D illustrating examples
- Some perspectives

VIEW OF THE FUTURE FRENCH DGD (CIGEO, ANDRA)

Host-rock: claystone in the east of the Parisian Basin

Depth > 500 m





The expertise function and its interactions

Rationales for Independent R&D in support to Expertise Function

- when there is a need for investigating specific safety issues that require an independent knowledge from the reviewer to perform a contradictory review and check assumptions taken by the implementer with respect to safety,
- analysis of uncertainties and sensitivity of processes to containment capabilities,
- issues that are not considered (or not sufficiently) by the implementer, and require a particular attention from the reviewer

Independant R&D/scientific capabilities to assess…

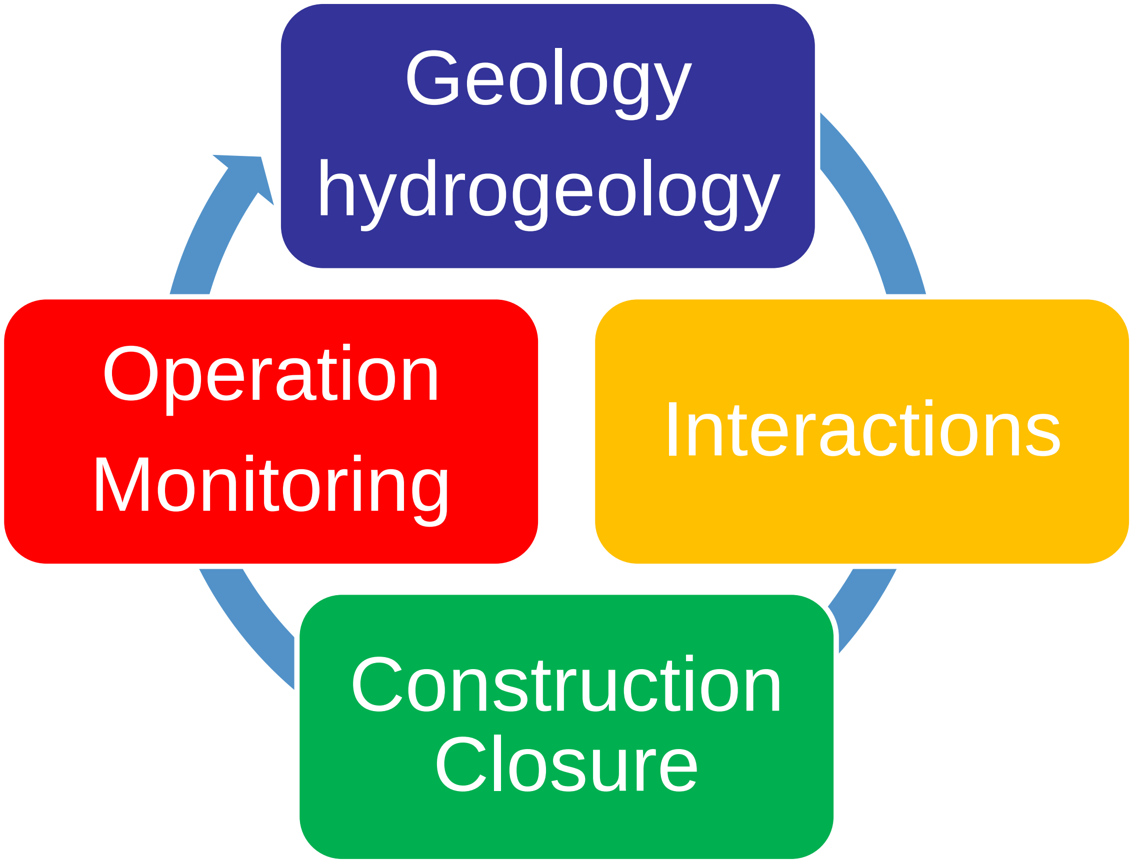
- The quality of the data
- The description of processes
- The quantitative evolution in space and time

…on which rests the safety of DGD

3 complementary tools

- Surface laboratoy
- In situ experiments in Tournemire URL (+ Mont Terri)
- Computer codes

From siting to operation



Geology / Hydrogeology

2005	2009	2013	2015
Feasibility file	Technical options	Site choice Public debate	Licensing application

Transfers in the host-rock — Scientific watch

Strategy for detailed site characterization, fractures detection — Scientific watch

Conceptual hydrogeological site model (deep water flows) — Scientific watch

Modelling with homemade computer tool of RN transfer in the disposal and surroundings for long term containment

Long term evolution (correlation fracture/seism, geoprospective)

Interactions

2005	2009	2013	2015
Feasibility file	Technical options	Site choice Public debate	Licensing application

HM phenomena & host-rock behaviour
(EDZ,characterization & prediction, time-evolution)

Scientific watch

Physical-chemical environments on corrosion of carbon steel components
Released iron on physical-chemical properties of clayey materials

Alteration of swelling & confining properties of clayey materials upon the alkaline plume

Alteration of containment properties of nuclear waste packages

Construction / closure

2005 — Feasibility file

2009 — Technical options

2013 — Site choice Public debate

2015 — Licensing application

Modelling of seals with homemade computer code

Influence of main parameters of seal/plug on the performance of swelling clay cores, at long-term

In altered situations (loss of mechanical confinement)

Modelling of H2 pressure and extension

Mechanical impact during hydraulic transient phase

Operation / monitoring

2005	2009	2013	2015
Feasibility file	Technical options	Site choice Public debate	Licensing application

Fire hazard : to adapt fire computer code to characteristics of underground fire

Alteration of chemical & mechanical properties of concretes upon multi-ionic attack from the clay pore water

Effectiveness of monitoring devices

NUCLEAR WASTE PACKAGES PERFORMANCE

- Conditioning the wastes should therefore be thought with a view to confining the radionuclides in the two following ways:
  - ✓ complete isolation of the wastes from the environment (water leaching) during a given period (a performance that can mainly be reached by use of a metal container),
  - ✓ limitation of the release of the radionuclides once the container is degraded (the presence of a confinement matrix slows the release of radionuclides present in the wastes).

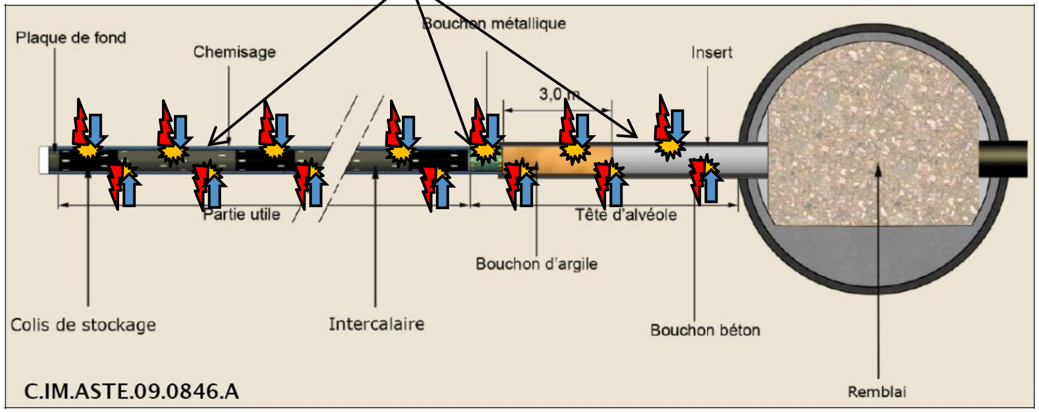
- Safety issue: corrosion, radiolysis, lixiviation, impact on RN release
  - ✓E.g. : cementitious matrix performance under radiation (radiolysis effect)
  - ✓ Major hazard investigated: Hydrogen formation
    - » Risk of explosion
    - » Cracking by increase of H_2 pressure

CEMENT PACKAGES RADIOLYSIS

- In order to simulate the radiolysis of the cement material
  - Irradiation of cement sample with alpha beams, gamma rays
- Objectives :
  - Radiolytic products yields
    - ✓ e.g. : H2
  - Microstructure evolution under radiation : cement phases evolution,
    - ✓ risk of lost of mechanical properties
  - Formation of organic species by carbonate radiolysis
    - ✓ Increase of radionuclide mobility (e.g. plutonium)

CONTEXT

Carbon steel (overpack, insert)

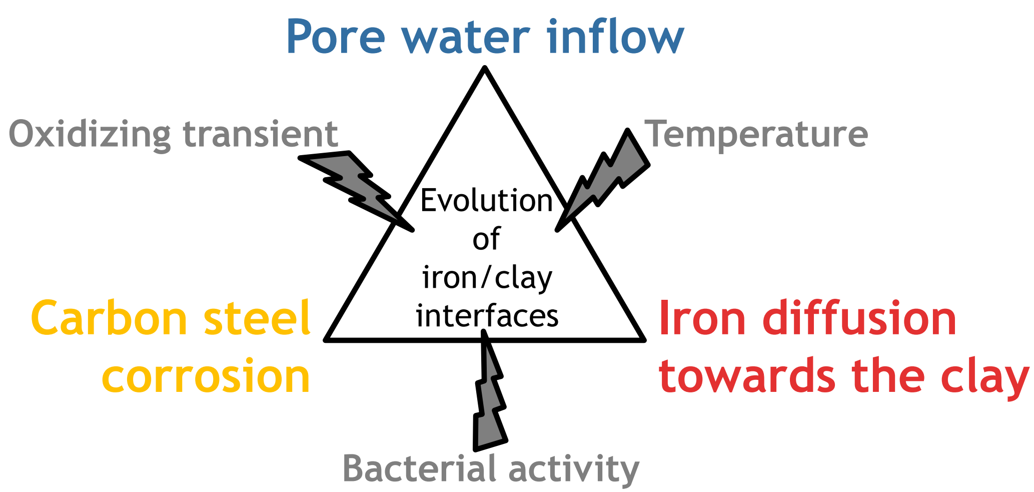


HLW cell after closure (Andra, 2009)

?

Two safety issues:

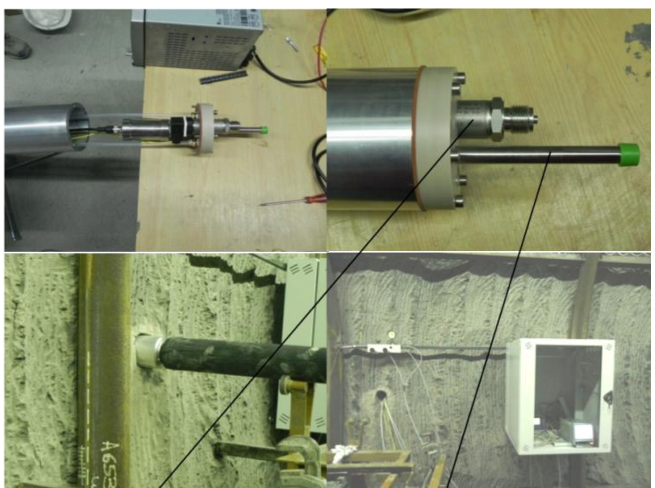
- Impact of physical-chemical environments on corrosion of carbon steel components?
- Impact of released iron on physical-chemical properties of clayey materials?



OBJECTIVES OF THE IN SITU TESTS

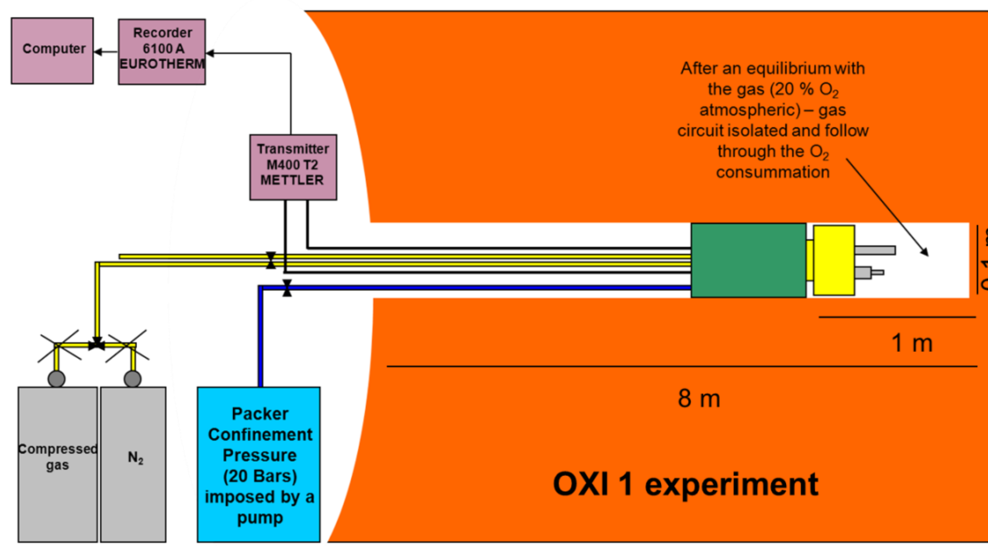
- **Measure the rate of oxygen consumption upon reaction with:**
  - Clay host-rock only (pyrite oxidation)
  - Both host-rock and carbon steel powder (pyrite and iron oxidation)

- **Design & emplacement**
  - Stainless steel devices coated with resin
  - Emplaced after drilling under inert atmosphere



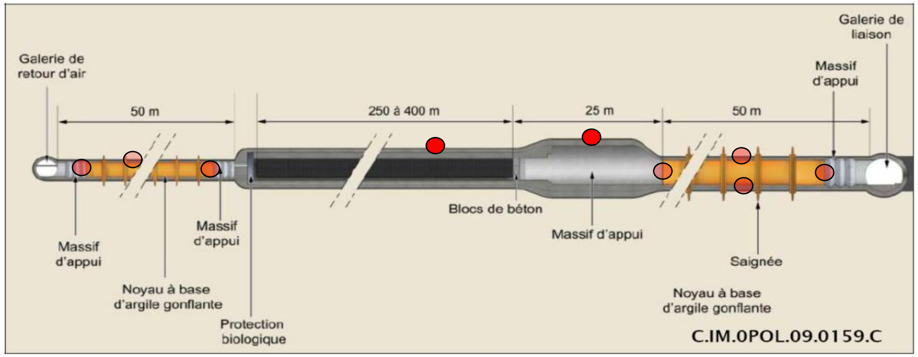
Probe P_{tot} *in situ*

Optical probe *in situ* O_2

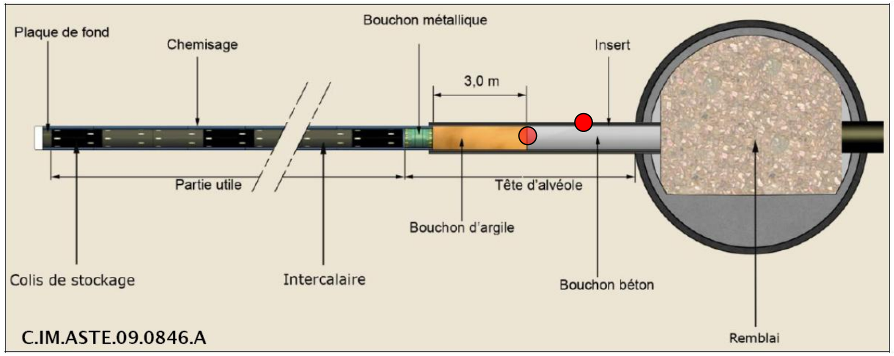


CONTEXT

Concrete-based structures in contact with clayey materials (argillite, bentonite)



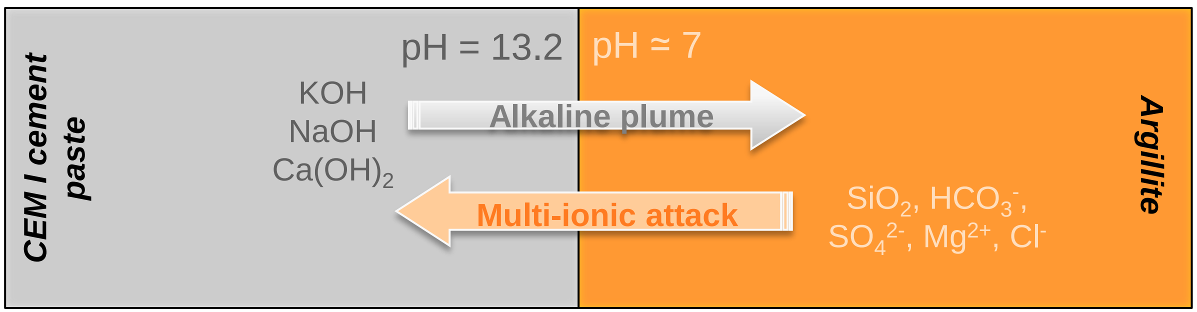
IL-LLW after closure (Andra, 2009)



HLW cell after closure (Andra, 2009)

Cement vs. clayey materials: 2 materials with highly contrasted chemistry

at 25°C :



Open issues:

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- Effectiveness of low-pH cements usage vs. CEM I? Effect of temperature (up to 70°C?
- Alteration of swelling & confining properties of **clayey materials** upon the alkaline plume?
- Alteration of chemical & mechanical properties of **concretes** upon multi-ionic attack from the clay pore water?

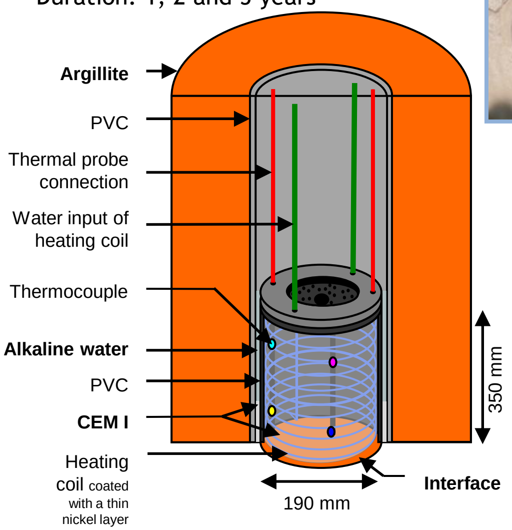
OBJECTIVES OF THE TESTS

- Cement (CEM I & low pH) / argillite interactions under T°:
  - Mineralogical perturbations
  - Effect on transport properties (diffusion)

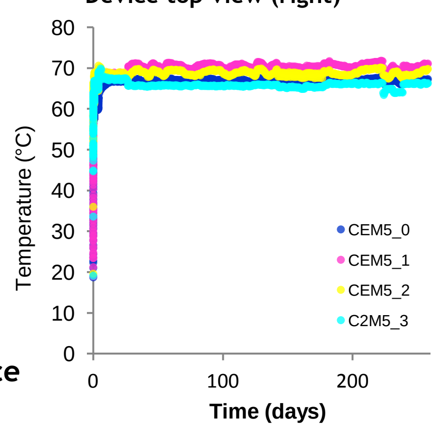
CEMTEX in situ

- 6 experiments under saturated conditions (3 CEM I and 3 low-pH cement pastes) and prescribed temperature (70°C)
- **In situ casted concrete**
- Duration: 1, 2 and 5 years

Polished borehole in argillite (left)
Heating coil (center)
Device top view (right)



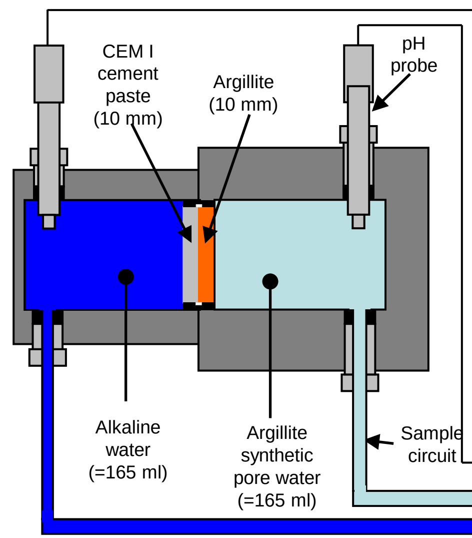
CEMTEX in situ borehole device



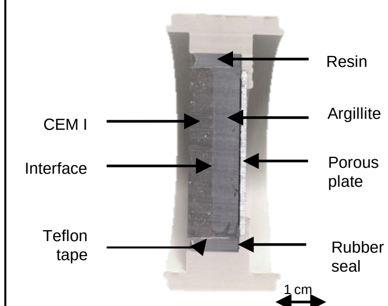
Continuous thermal monitoring

CEMTEX lab

- Dedicated diffusion cells designed to reproduce cement paste/argillite interfaces in saturated conditions
- **Pre-casted concrete**
- Cells emplaced into a thermal chamber to prescribe 70°C



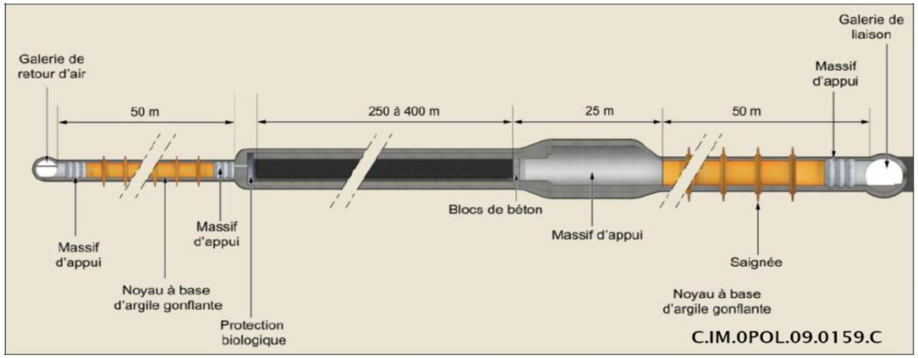
Diffusion cell

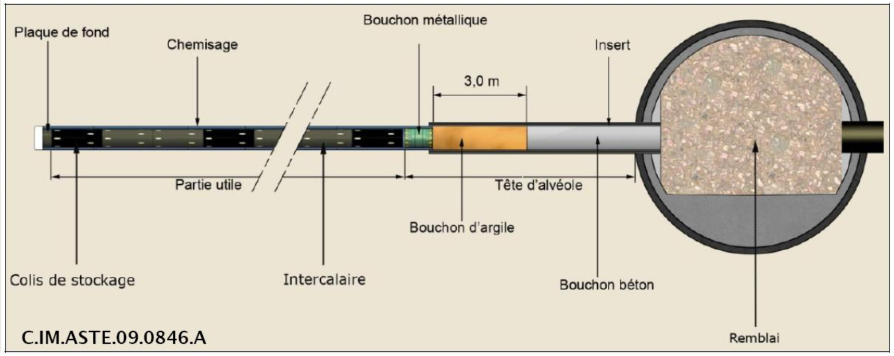


CEMTEX Labo sample

CONTEXT

- Numerous seals (bentonite based) foreseen to close the DGR





Objectives of the in situ tests

Influence of main parameters with respect to the overall hydraulic performance of swelling clay cores, at long-term:

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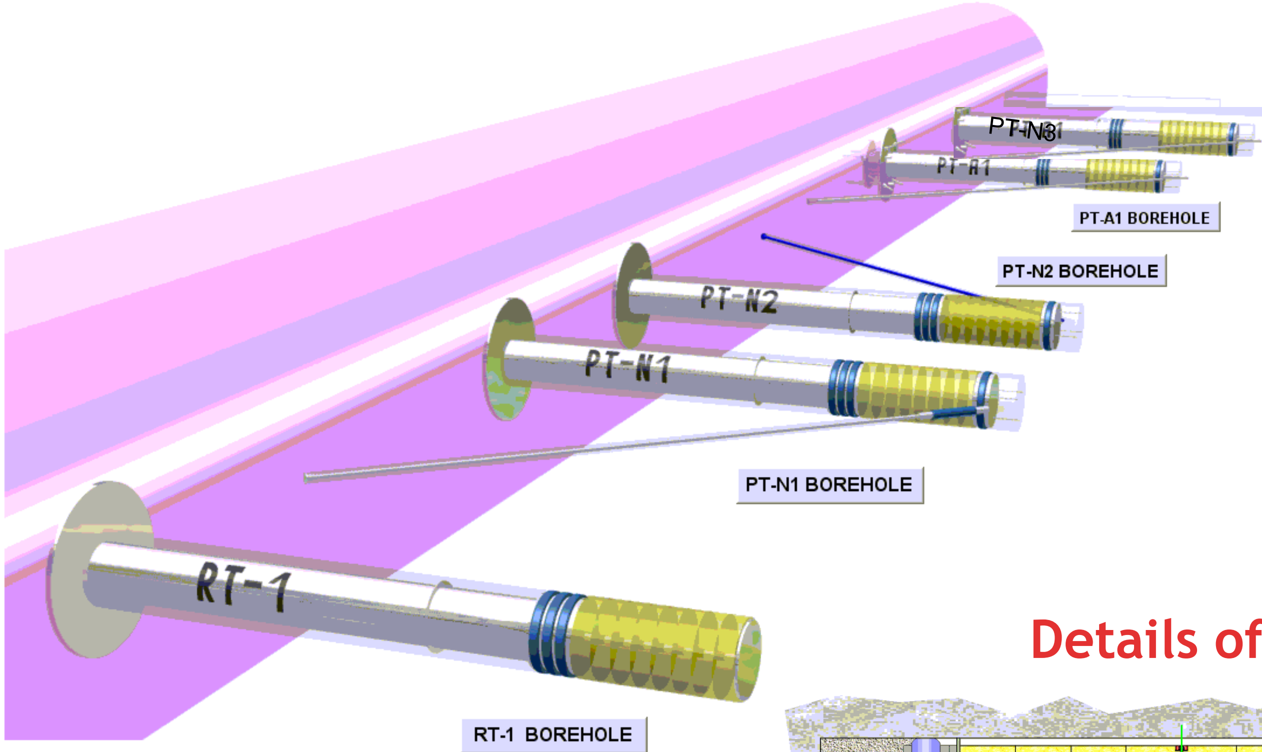
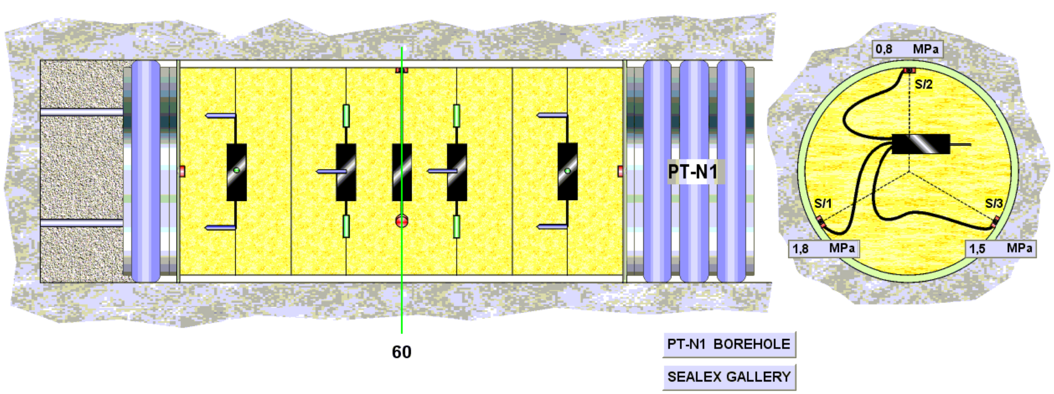
- In nominal situations for different core compositions (pure MX80, sand/MX80 mixtures)?
- For different technological choices (impact of intracore geometry, construction joints)?
- In altered situations (loss of mechanical confinement)?

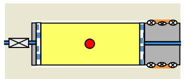
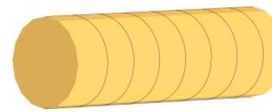
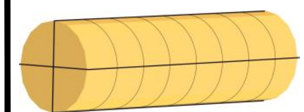
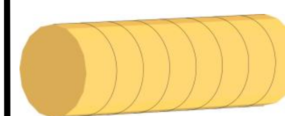
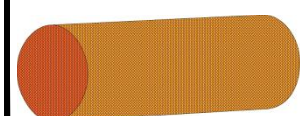
VIEW OF THE SEALEX IN-SITU TESTS



Details of PT-N1 test

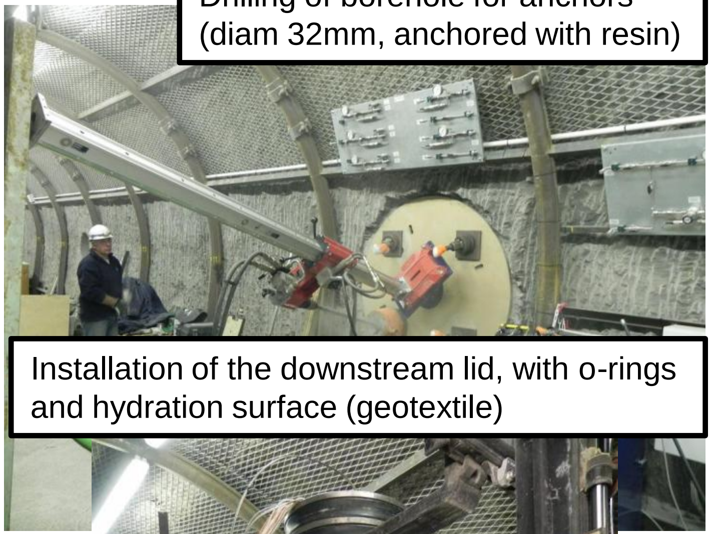


PROGRESSIVE EXPERIMENTAL PARAMETRIC APPROACH

	Reference Tests	Performance Tests	Intra-core geometry Core conditioning Composition (MX80/sand)	Core view	Altered conditions	Emplacement date
Base case	RT-1	PT-N1	Monolithic disks Precompacted (70/30)		No	12/2010 06/2011
Variations / Base case	-	PT N2	Disks + internal joints (4/4) Precompacted (70/30)		No	12/2011
	-	PT A1	Monolithic disks Precompacted (70/30)		Confinement loss	06/2012
	-	PT-N3	Pellets/powder In situ compacted (100/0)		No	01/2013
	-	PT-N4	Pellets/powder In situ compacted (100/0)		Confinement loss	*10/2013*

INSTALLATION OF RT-1 TEST (1/2)

Drilling of borehole for anchors (diam 32mm, anchored with resin)



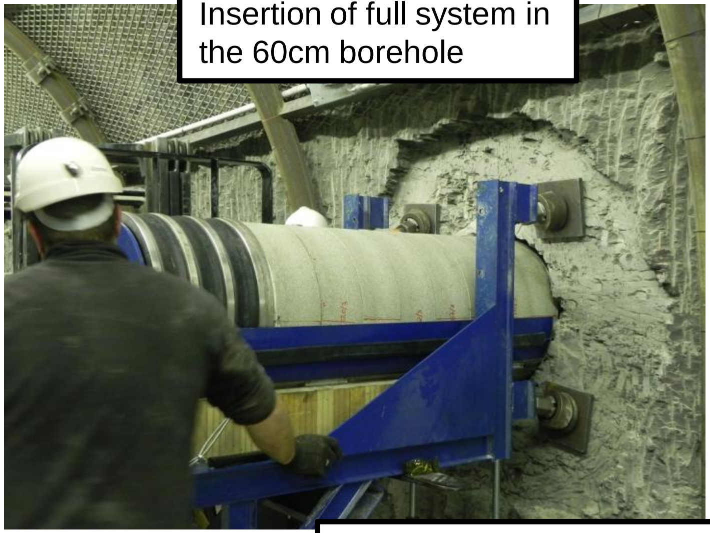
Installation of the downstream lid, with o-rings and hydration surface (geotextile)

View of one ring, with installed sensors (total stress, pore pressure, relative humidity)

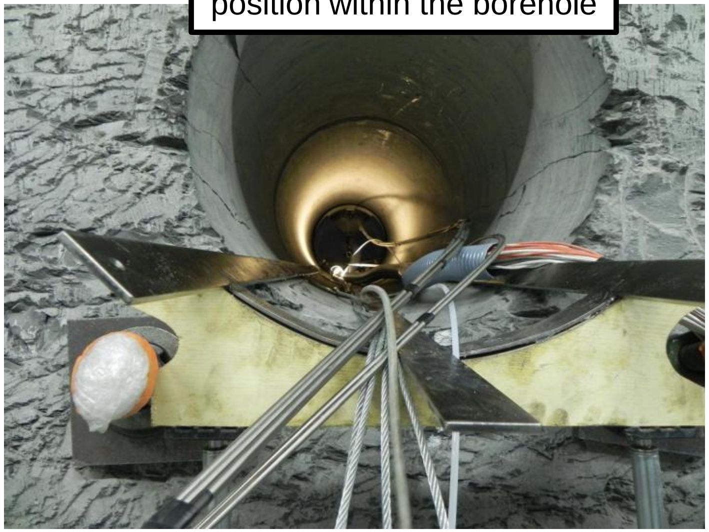
Rotation from vertical to horizontal position

INSTALLATION OF RT-1 TEST (2/2)

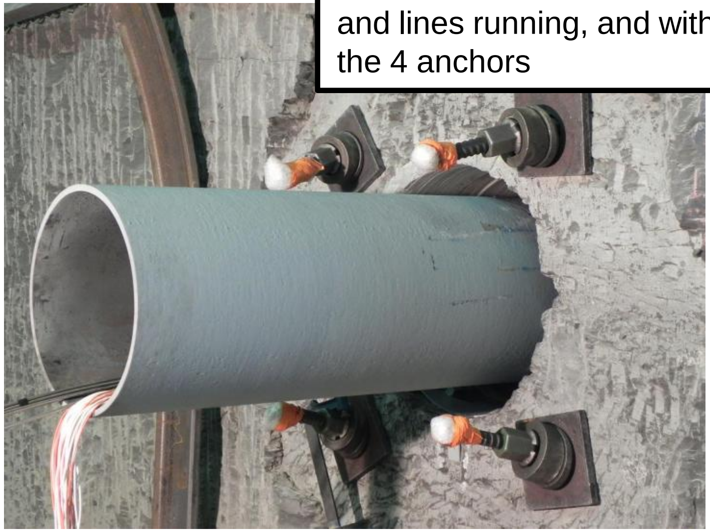
Insertion of full system in the 60cm borehole



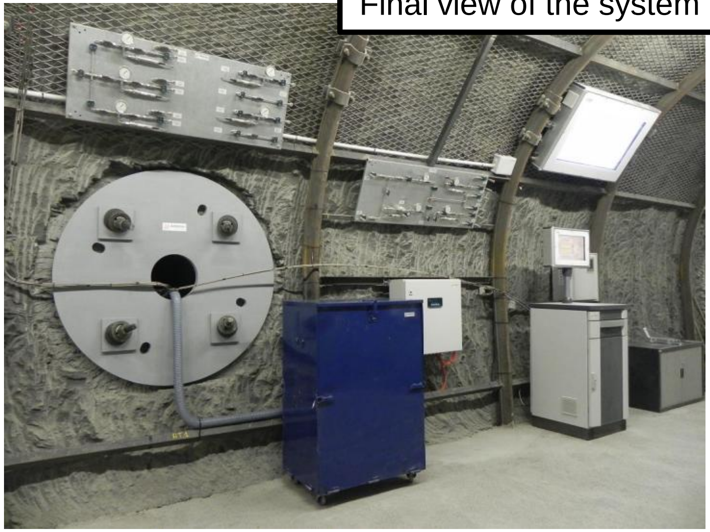
View of the final system position within the borehole



Central tube with all cables and lines running, and with the 4 anchors



Final view of the system



CONCLUSIONS AND PERSPECTIVES

R&D must be fruitful at the right time

- …when safety evaluations are performed by IRSN
- programs and priorities shift over time (less rock characterization, more operational safety issues, e.g.)

Conditions for implementing R&D

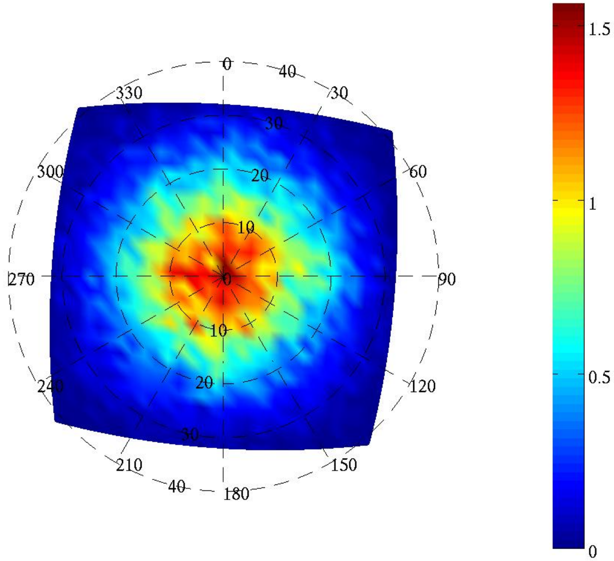
- internal skills + tools + funding
- cooperation with academics and other TSOs
- access of results to stakeholders

Important challenge *now*

- EU strategy for governance of joint programs: JOPRAD
- IRSN's contribution to an International SRA for Expertise Function (TSOs + nuclear safety authorities + civil society) : SITEX-II

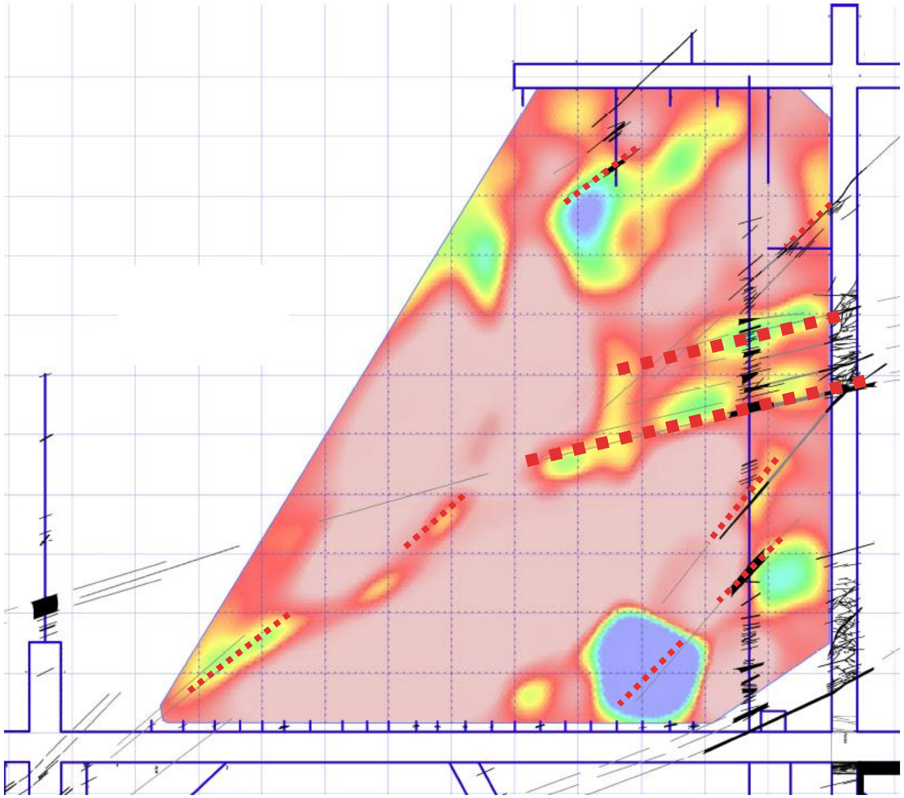
EXPLORATORY RESEARCH (1/2)

- Bio-corrosion (SRB, IRB & biofilms)
- Monitoring properties evolution via time series analysis
- Monitoring of density evolution via muons attenuation tomography



EXPLORATORY RESEARCH (2/2)

- Seismic tomography between underground works



P-waves velocity map