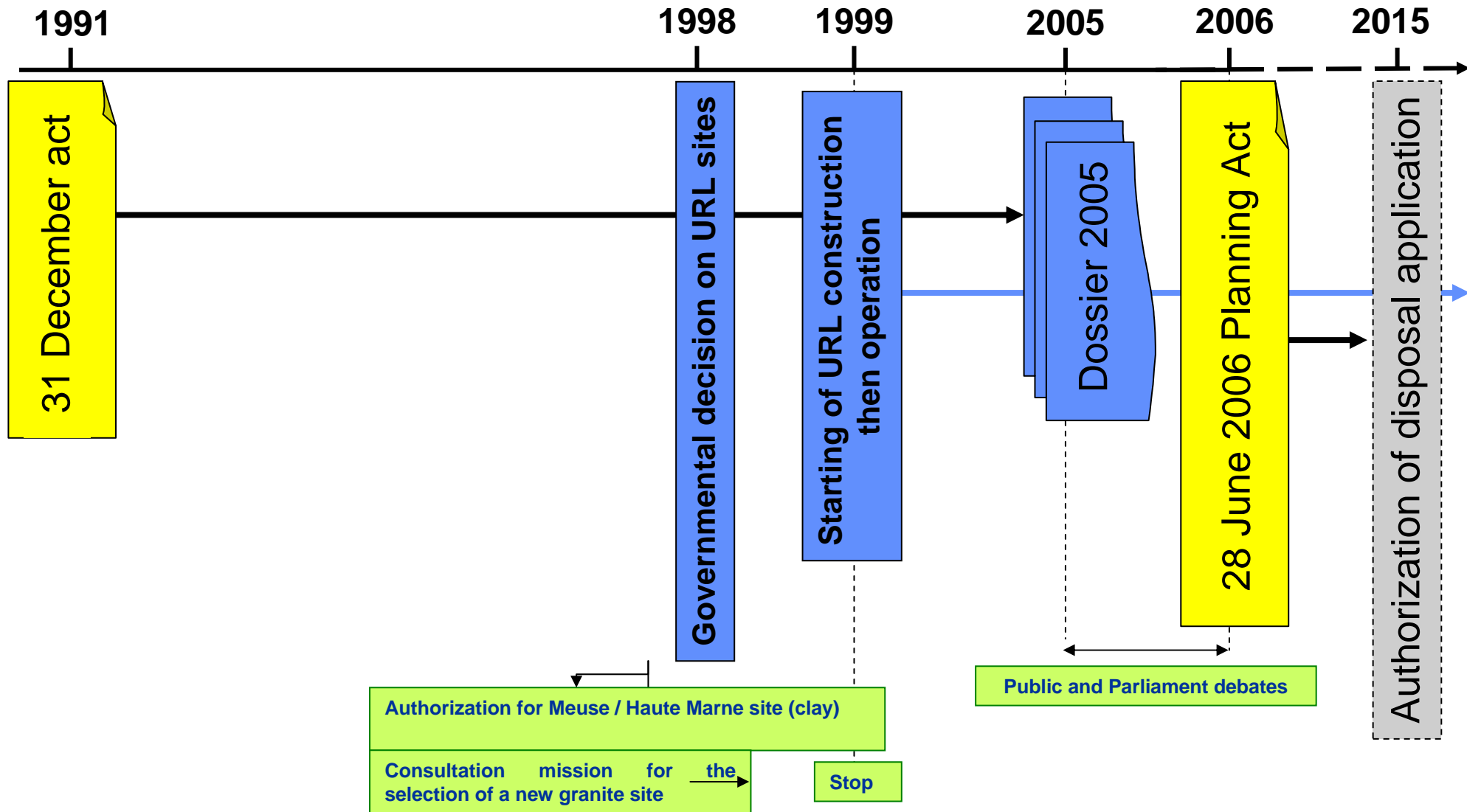

The French experience: an outline of the Andra research programme

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The French step-wise process on ILLW and HLW management



Main results of the dossier 2005

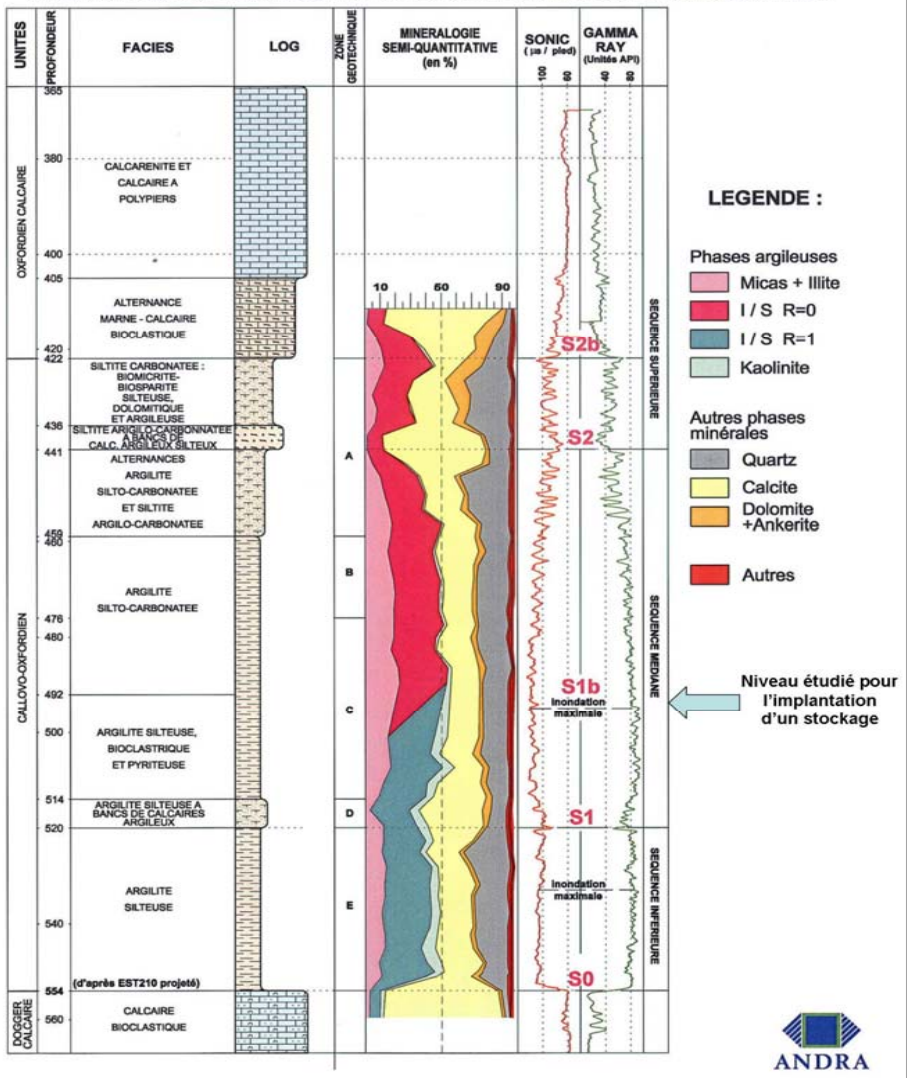
- A robust inventory was produced, able to cover various industrial options
- We have a good understanding of most of the waste packages to be taken into account
- A classification was made and is used as the basis for the studies
- Spent fuel, which is not considered to be waste, was envisaged on an exploratory basis

- **Site investigations in figures**

- In addition to study of the existing former 68 boreholes, 27 specific boreholes with 2300 metres of clay core-samples (4200 metres cored) – use of oil industry deviated borehole drilling techniques for sub-horizontal surveying – 30,000 samples taken
- Specific 2D and 3D seismic campaign on the site – 1300 km of additional seismic lines acquired from the oil industry and studied
- Surveying while shaft sinking (with instrumentation) - 40 metres of experimental drift instrumented (level 445 metres) with 1400 sensors in and in the vicinity of the underground laboratory
- 550 metres of drift at level 490 metres

Callovo-Oxfordian argilites main characteristics

(Profondeurs à l'aplomb du puits d'accès du laboratoire - Données géol. EST103/104 et 210 proj. - Minéralogie d'après EST207)



Thickness

~130 m

Age

155 MA (Callovo-Oxfordian)

Clay minerals

40-45 %

(Kaolinite, Illite, I/S R0 & R1, Chlorite)

Carbonates

22-37 %

Quartz

20-30 %

Pyrite

1-2 %

Org. M.

1 %

Porosity

15-18%

Permeability

10^{-14} - 10^{-12} m/s

Diffusion (D_e)

$\sim 10^{-11}$ m²/s

Pore size

20-30 nm

- **Very low permeability** (Darcy velocity of several cm in 100 000 y)
- Significant **retention** properties
- **Precipitation** of actinides in the near field (low Eh, water chemistry)
- **Diffusion**: few 10^5 years to diffuse through the 50 m thick argilite pile (mobile radionuclides)

A stable zone with a simple geological structure

- Stable zone – Paris basin

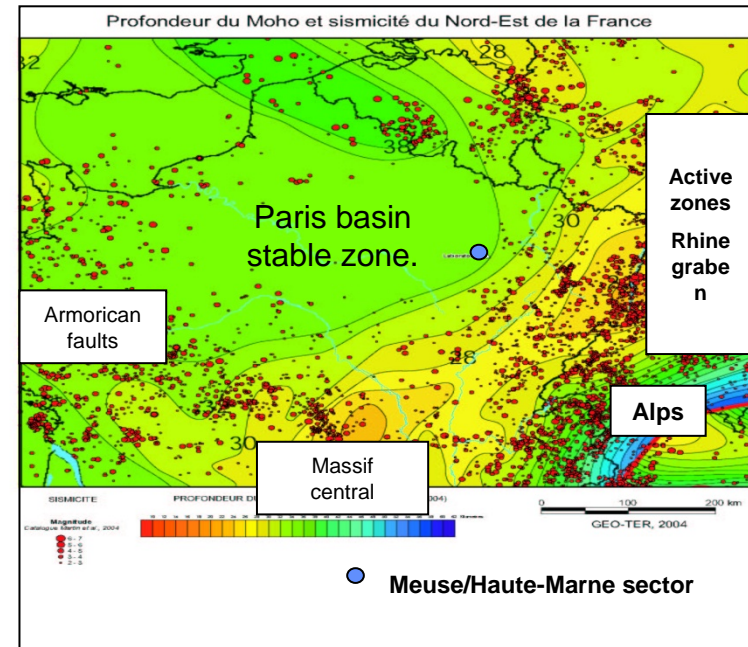
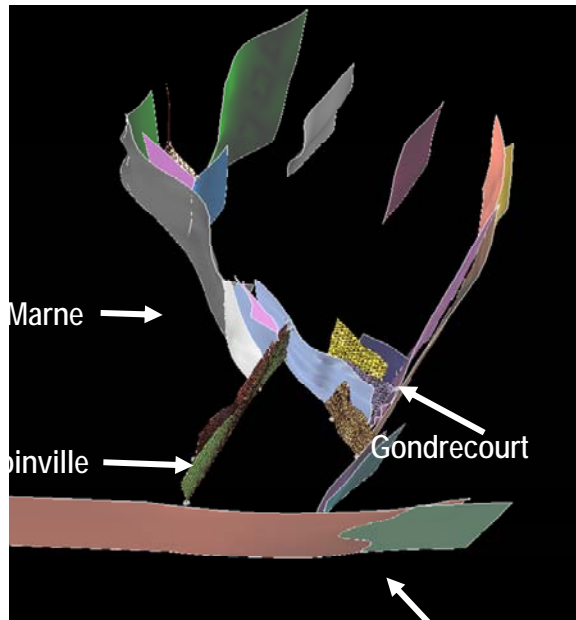
- Sedimentary basin with flat structural strata

- Meuse Haute-Marne sector

- No detectable neotectonic activity
- No significant local seismic activity

On the scale of the study zone

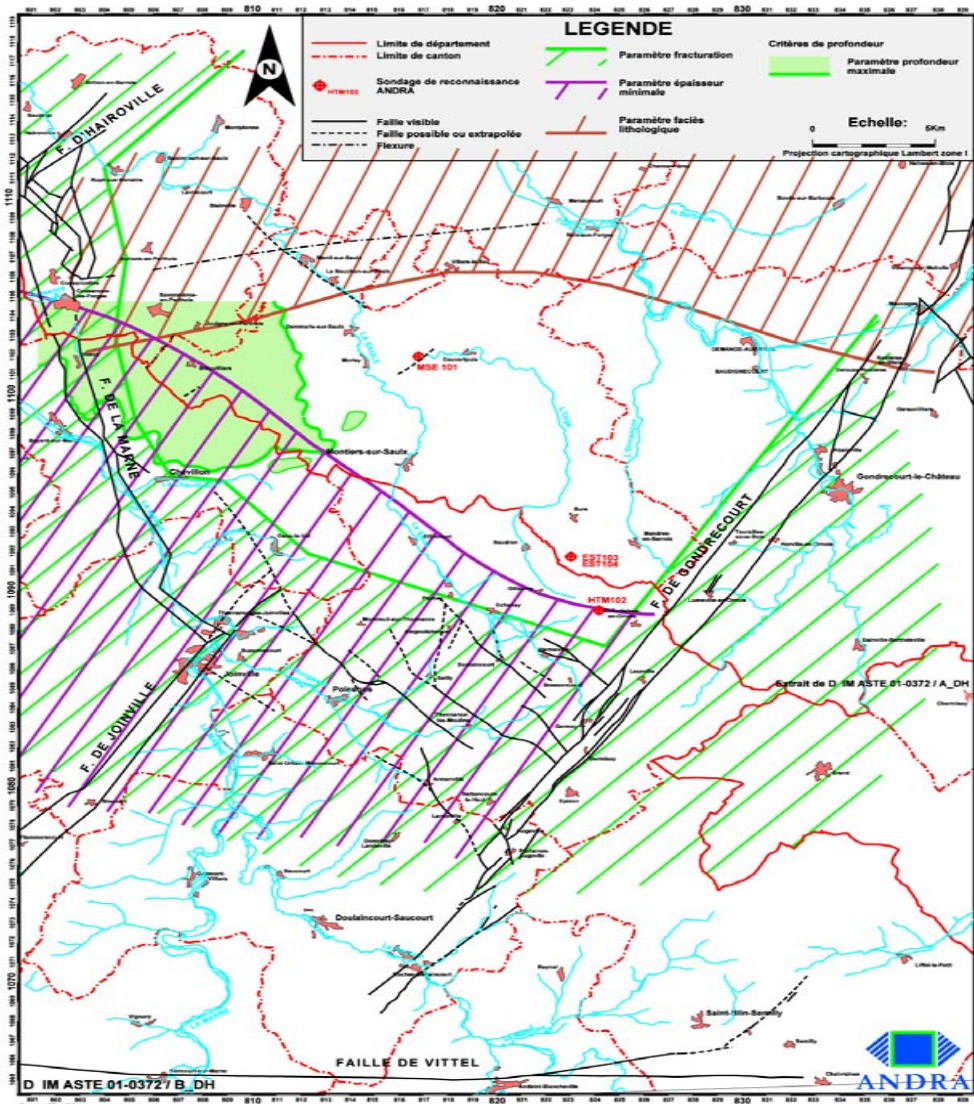
- A structural framework known as of 1994
- Very slight fracture density outside the regional faults



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

Transposition zone of results acquired in the laboratory

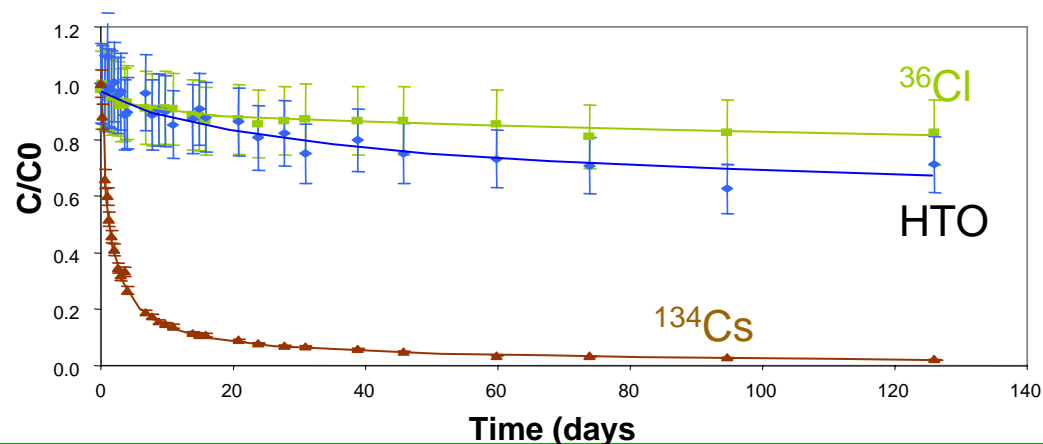


- definition of criteria for ensuring properties of the potential host formation similar to those of the laboratory zone

- identification of a zone of about 250 km² around the underground laboratory

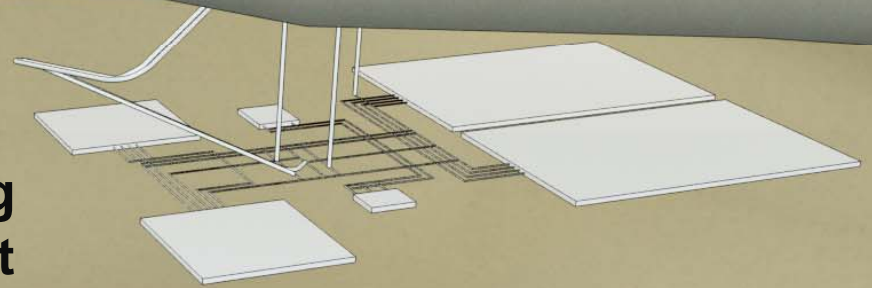
Acquired knowledge of the geological medium

- Known deposit conditions indicating a geological environment that has been stable for millions of years
- Strata with a simple, regular geometry
- A homogeneous clay stratum covering a large surface area
- No faults identified
- Well-known hydrogeology of the sector
- Transport processes dominated by diffusion



Engineering work completed

- Definition of a simple and robust concept for each type of waste
- Availability of realistic options taking advantage of the properties of the geological medium
- Design engineering studies confirming the basic feasibility but without aiming at technological optimisation



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

Scenarios studied and dose evaluations

- Normal evolution scenario
- Altered evolution scenarios
 - Container/overpack failure
 - Seal failure
 - Intrusive borehole drilling
 - Heavily degraded operation
- Nearly 7000 calculation cases run using the Alliances simulation platform

- In a normal evolution scenario, the doses related to the various types of waste are one or more orders of magnitude lower than the limits specified in the RFS, calculated in penalising conditions (boreholes close to the repository)

- Sensitivity analyses indicate the predominant effect of the host formation

- Altered evolution scenarios show dose rates also lower than the RFS limits, including in heavily degraded conditions

- Favourable characteristics of the Meuse Haute-Marne site
 - Robust and realistic disposal concepts taking advantage of the favourable geological conditions
 - Safety assessments which confirm the feasibility approach
- **Basic feasibility is confirmed by the knowledge acquired and the analyses conducted**

National Review Board (CNE); IRT Peer Review, OECD/NEA; ASN ; Andra's Scientific Board

- **Transposition zone**
 - Detailed survey of the transposition zone in order to select the implementation site of repository structures
- **URL activities**
 - Continuation URL investigations and studies
 - Implementation of a demonstrator programme in order to verify the performance of repository equipment and to test the reversibility of concepts
 - Long-term experiments (diffusion)
 - Effectiveness of plug
- **Reversibility**
 - Demonstrate technically the repository's management and reversibility
 - Limit reversibility in time through stepwise management

- Scope of the draft law: **all radioactive materials and waste**
- 2 Principles:
 - **for the protection of human beings and the environment**
 - **responsibility of current generations with regard to future generations**
- A national management plan for radioactive materials and waste, defined by a decree, updated every three years, and tabled before Parliament.

The 2006 Planning Act

- ✓ Principles of the national management plan for radioactive materials and waste (defined by a decree, updated every three years).
- **the quantity and toxicity of waste must be reduced, notably by processing or conditioning spent fuel and radioactive waste**
- **radioactive materials and waste pending storage or disposal must be stored in dedicated facilities**
- **after storage, any ultimate radioactive waste that is unsuitable for disposal in surface or shallow facilities for nuclear-safety or radiation-protection reasons must be disposed of in a deep geological repository**
- ✓ Foreign radioactive materials and waste
 - **prohibited** disposal of foreign radioactive waste in France;
 - importation of spent fuel and radioactive waste strictly limited to processing and research, or to transfers between foreign countries;
 - **processing** of foreign radioactive materials in France subject to published **intergovernmental agreements** and the return of radioactive waste to foreign producers

The 2006 Planning Act - Strategic orientations for investigations

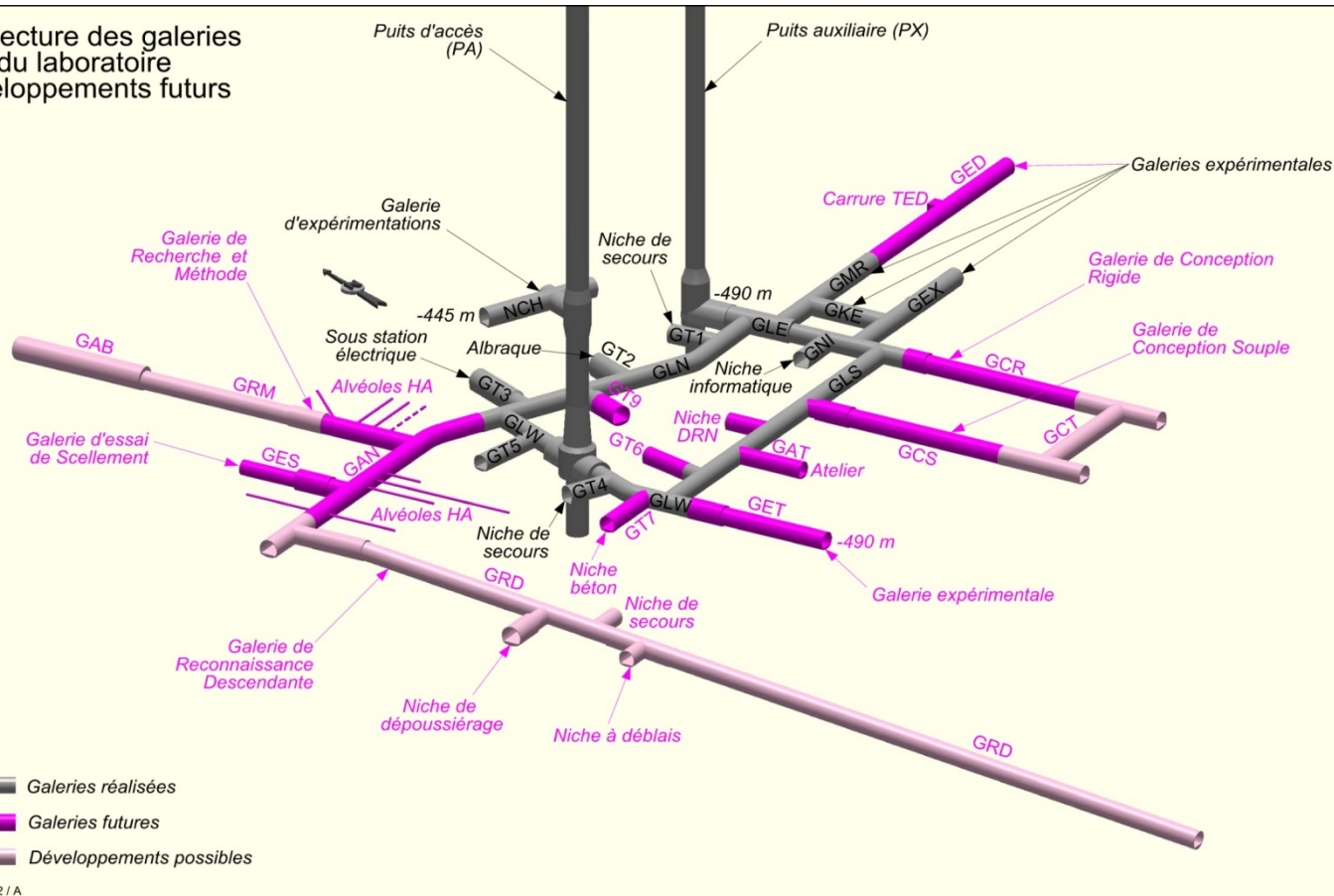
- Storage: to perform investigations and studies needed to create new facilities or to back fit existing facilities by 2015
- Disposal: to prepare an authorisation application in 2015 for a scheduled commissioning in 2025
- Advanced partitioning/transmutation: investigations to be furthered within the framework of the Generation-IV Programme; commissioning of a prototype in 2020

⇒ Andra is now in charge of both Disposal and Storage

- Research assessment by an independent commission
 - broadened membership (international, human sciences);
 - annual report to be tabled before Parliament and made public.
- Local Information and Oversight Committee (CLIS)
 - overall follow-up, information and consultation mission concerning research on the management of radioactive waste, and especially on deep geological disposal
 - headed by an official appointed by the Presidents of the General Councils of the relevant departments
 - possibility to hold hearings and counter-assessments

Underground laboratory development 2008-2014

Architecture des galeries du laboratoire Développements futurs



Continuation of ongoing experiments

- Mechanical strength of structures
- Thermal behaviour of formation
- Water and radionuclide transfers
- Water chemistry

New experiments

- Gas migration
- Bacterial populations
- Oxidation, desaturation
- Evolution of EDZ , self-sealing
- Behaviour of materials in situ (concrete, steel, glass)

Technological tests and demonstrators

- **Excavation and lining**

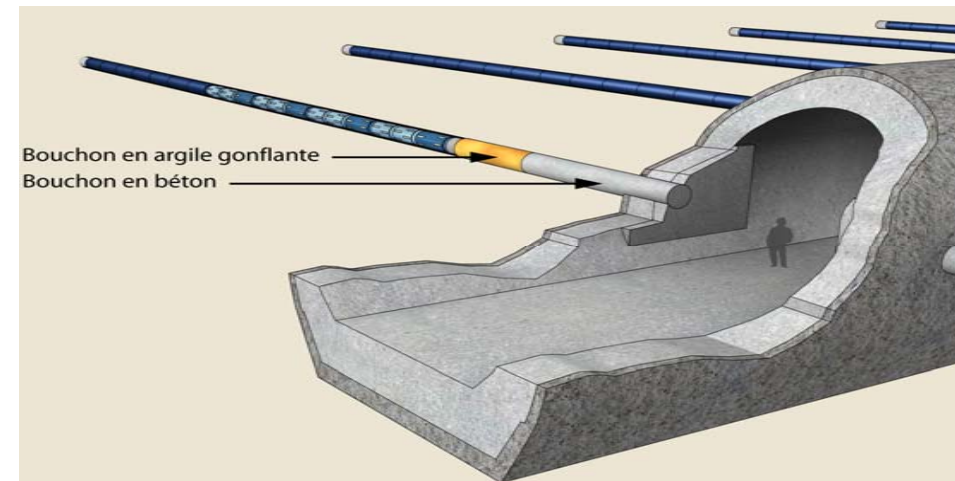
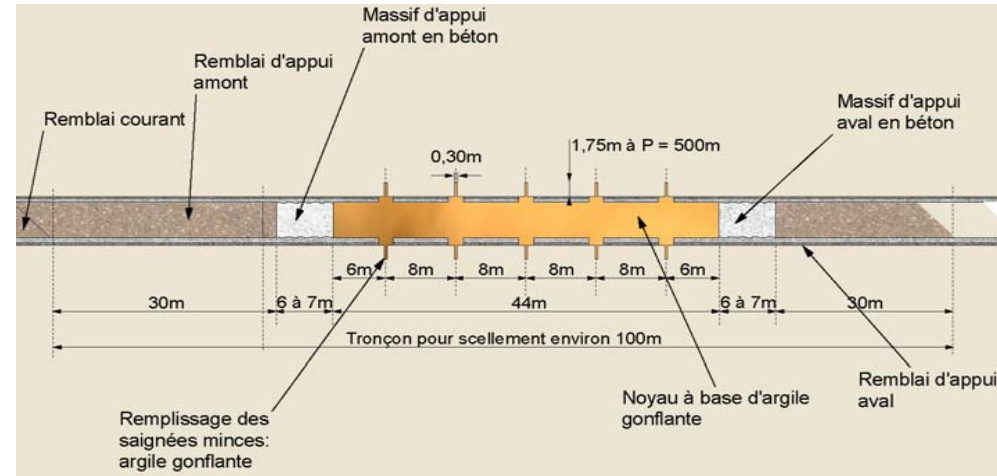
Excavation, support and durable lining (new drifts)

- **Technological tests and plugging/backfill demonstrators**

Preparation, construction, instrumentation, loading and long-term follow-up

- **Disposal cells**

- Demonstrators of disposal cells for HLLL waste (thermics, hydromechanics, stress; plugging operations, waste emplacement and retrieval)



Select a repository site

- Over the 2007-2008 period, a geological survey will be carried out on the transposition zone defined around the the Meuse/Haute-Marne URL (250 km²)
- Andra will propose in 2009 a restricted zone of interest (about 30 km²) for the continuation of research.
- Over the 2010-2012 period, a detailed survey (3D geophysics) will be carried out on the restricted zone of interest.
- Within the framework of the public discussion scheduled in the law, Andra will propose one or several proposals for the siting of the future repository.
- The site chosen in 2013 constitutes a major input for the DAC to be presented at the end of 2014.

Survey around the underground laboratory

- **Surface survey**

- Boreholes: geometry of the formation; mechanical properties, water quality and datation

- 2-D seismic studies

- 3-D seismic studies over 30-40 km² (geometry of the formation, geological properties)

 - Step-by-step process for the siting of a geological disposal

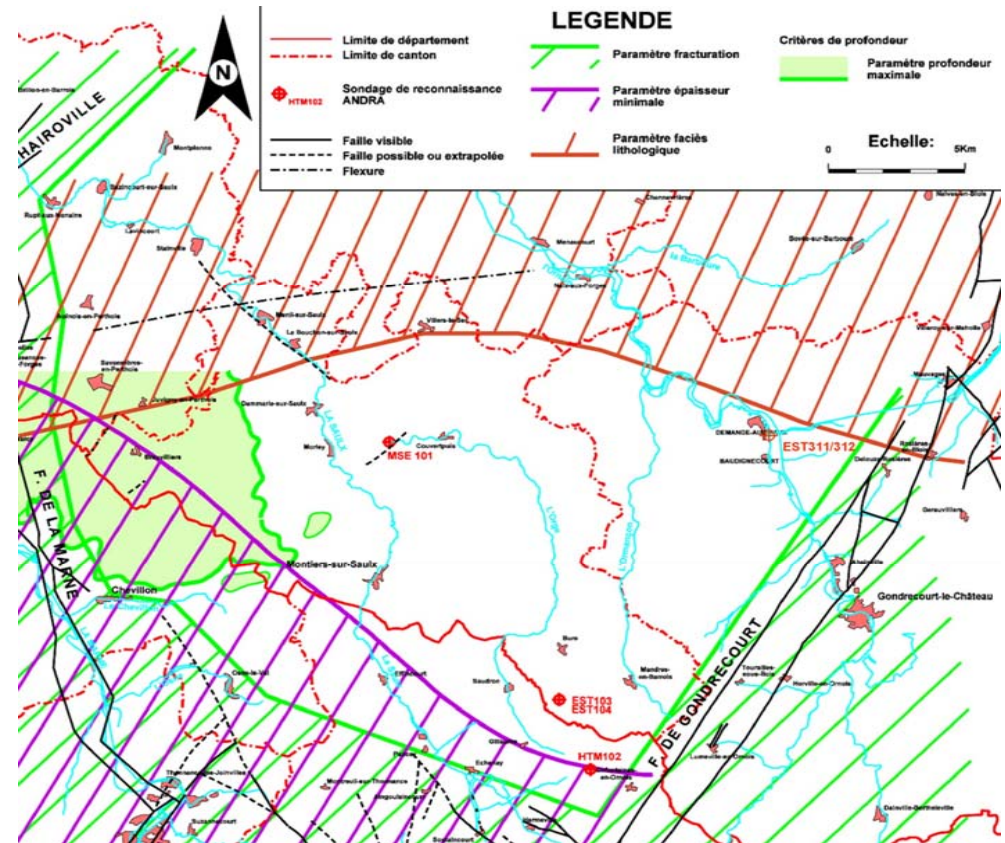
 - Hydrogeological modelling

 - Evaluation of the role of regional faults

 - Detection and characterization of possible minor faults

- **Surface environment characterization**

Long-term observation of soil, surface waters, climatic biosphere and social parameters for environmental studies



Delineation of a favourable implementation zone for a potential repository

Major research themes

- **Improved understanding of basic phenomena**
 - Behaviour of packages in repository conditions
 - Chemical evolution of radionuclides and transport
 - Gas production and transfers
 - Long-term mechanical evolutions of structures
- **Couplings between phenomena and at interfaces between repository components**
 - EDZ
 - Impact of thermics on mechanical and chemical properties
 - Hydraulic transient phase
 - THMC behaviour of disposal components
- **Validity of data at different scales**
 - Transposition of the data obtained in the URL to a larger area (mechanical and chemical properties)
 - Extrapolation of behaviour laws over the short and medium terms (geomechanical, chemical kinetics)

Consolidation and optimisation of engineering studies



- **Detailed studies on the processes and the components:**

HL and ML packages and cells

- **Detailed studies of overall architectures:**

- Precise definition of underground structures, in terms of their dimensioning, construction methods and equipment
- Surface nuclear facilities (reception and surface storage of packages, disposal package conditioning facilities, etc.)
- Transfer, emplacement and possible retrieval of disposal packages

- **Instrumentation technologies and measuring devices**

- **Operating safety studies**

Scalings (space, time)

- Implementation of geostatistic methods for the transposition of the data obtained in underground laboratory to a wider zone (mechanics, geochemistry)
- Extrapolation of the laws of short-term and medium term behavior (geomechanical, kinetic chemical)
- Details on the geometry and the petrophysic properties of aquifers (hydrogeologic modeling)
- the nano-micro-meso-macro relationships in the transfers processes
- Methods of homogenisation and decomposition of fields for performance assessment and safety calculations in the ALLIANCES platform.

The tools for the scientific policy

- Continuation of the partnerships with the scientific organizations and the academic institutions
- New orientations for the laboratories groups: cement, gases, glass-iron-argilites interactions, geomechanics, transport-chemistry, monitoring tools
- Implication in the FP6 programs(ESDRED, NF-PRO, FUNMIG, MICADO, PAMINA),
- Implication in the FP7 programs FORGE (gas generation and migration) RECOSY (Red-Ox), CARBOWASTE (graphite), and Modern (monitoring)
- Continuation of the policy of theses and post-doctorates
- The international conference Nantes 2010

Disposal Project for Low-level Long-lived Radioactive waste

Legislative and regulatory framework

- ✓ The **Planning Act of 28 June 2006** concerning the sustainable management of radioactive materials and waste establishes a research and study programme with a view to:
“developing disposal options for graphite and radium-bearing waste in order for a corresponding disposal facility to be commissioned in 2013”.

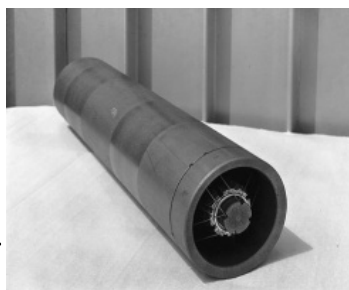
- ✓ The **Decree of 16 April 2008** sets forth relevant requirements for the National Management Plan for Radioactive Materials and Waste, as follows:
 - Graphite and radium-bearing waste shall be **stored pending the availability of a disposal facility**;
 - The disposal facility shall be **studied and design to accommodate graphite and radium-bearing waste. The possibility to take over other LL-LL waste shall also be investigated** (e.g., in the case of items containing radium, uranium and thorium with low specific activity, disused sealed sources), and
 - On the basis of local investigations, Andra shall submit by the end of 2009 an **analysis of suitable sites** for the implementation of a disposal facility.

Graphite Waste

- **Piles (dismantling): 81%** Bugey 1, Chinon A1, A2 and A3, Saint-Laurent-des-Eaux A1 and A2, G1, G2 and G 3



~ 23 000 t of graphite waste
(~ 100 000 m³ of conditioned waste)



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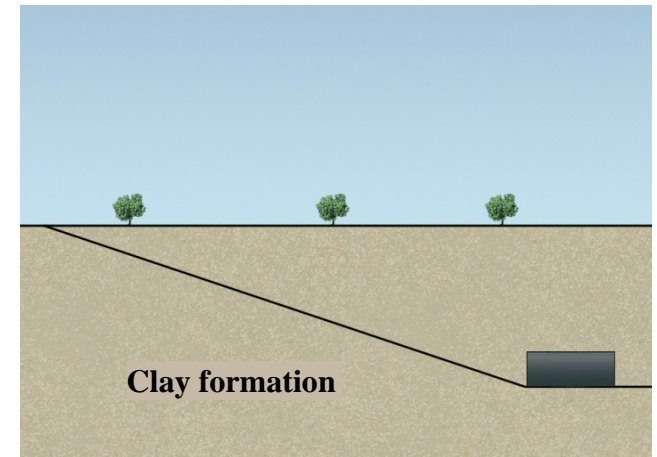
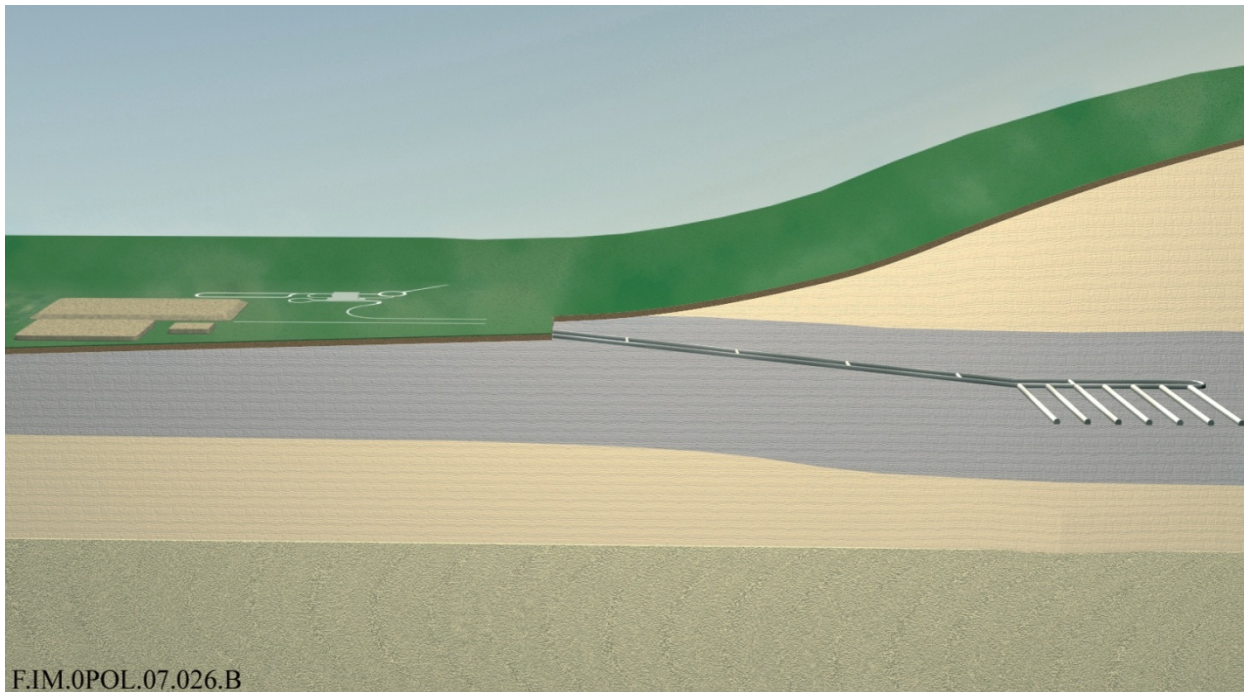
- **Sleeves and cores (operation): 18%**
Saint-Laurent-des-Eaux, Marcoule, La Hague

● Graphite-waste storage facilities

- **Various other waste resulting from CEA experimental reactors: 1%**

Disposal Solution for Graphite Waste

- Andra is studying a subsurface disposal design under an intact clay cover (at a maximum depth of 200 m)
- The architectures under investigation allow for various site configurations (slope, ramp access)



Radium-bearing Waste

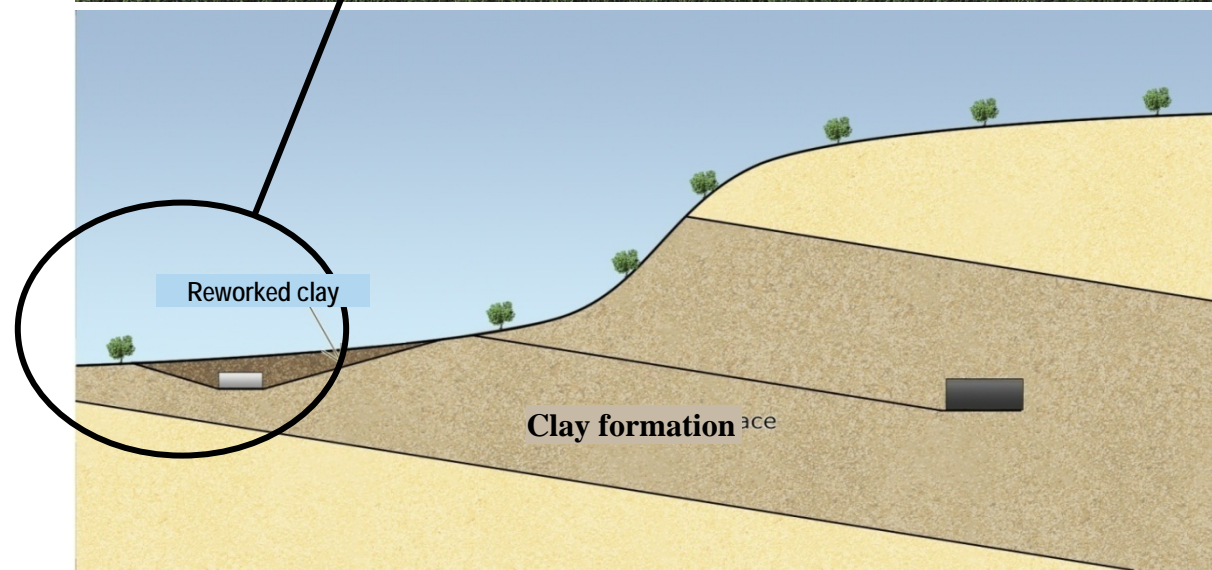
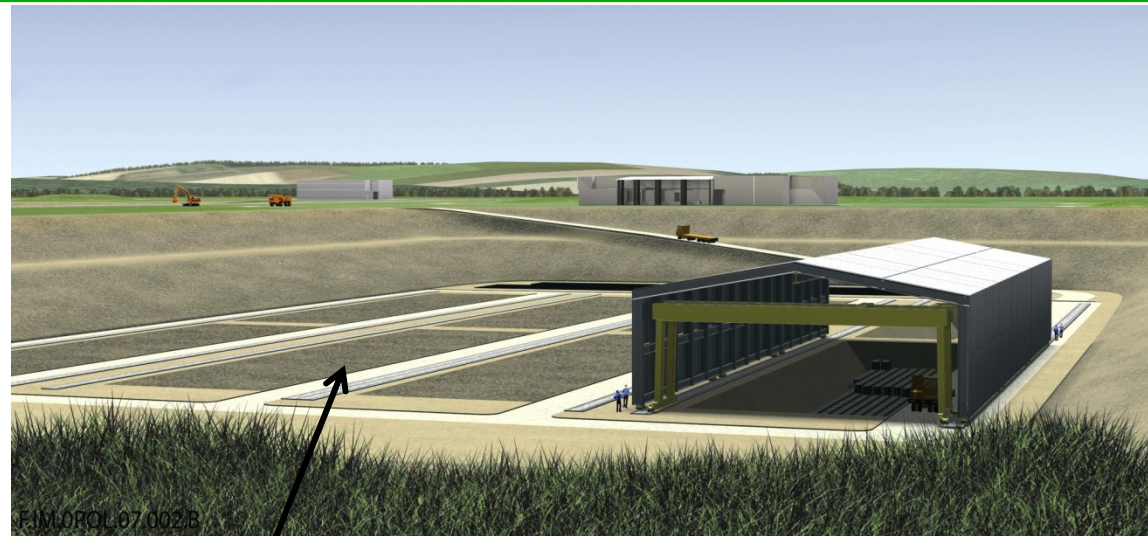
- Solid waste containing radionuclides from three natural radioactive families (Ra, Th, U and their daughter products)
- Radon exhalation



Disposal Solution for Radium-bearing Waste

Two disposal solutions are being investigated:

- together with graphite waste under an intact covering layer
- under a reworked covering layer close to another disposal facility



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Radium-bearing waste disposal facility

Graphite waste disposal facility

At the request of the government, Andra drew a realistic schedule for the project:

- Launching of the site-search phase in mid-2008
- Site selection: end of 2010
- Development of disposal solutions in preparation for the implementation-licence application in 2013
- Expected commissioning in 2019
- The schedule may be refined in 2009, during the update of the PNGMDR, in relation to the advances of the site-search phase

Site-search principles (1/3)

- ✓ A mechanism sponsored, validated and monitored by the State
 - An engagement letter from the Minister of State to the Chairman of Andra
 - Initial notification by the Minister of State to Prefects (to inform them about the mechanism and to ask them to relay the information to the Presidents of General and Regional Councils)
 - A monitoring committee led by the Ministry of Ecology, Energy, Sustainable Development and National Planning (MEEDDAT)

- ✓ An open approach based on a call for interest to mayors of all communes located on theoretically suitable geological sites for the implementation of a disposal facility in accordance with the criteria prescribed by the Nuclear Safety Authority [ASN]

Site-search principles (2/3)

- ✓ At the national level, the seriousness of the approach is warranted by several participating organisations and institutional representatives, including:
 - the Parliamentary Office for the Assessment of Scientific and Technological Options (OPECST);
 - the National Review Board (CNE); the Nuclear Safety Authority (ASN), and
 - the High Committee for Transparency and Information on Nuclear Safety.

- ✓ The following organisations were pre-notified about the site-search campaign:
 - the National Commission on Public Debates (CNDP); the Economic and Social Council, and the Working Group of the PNGMDR.

- ✓ In its outreach approach, Andra also intends to submit the project to groups, associations or organisations such as:
 - environmental associations; labour unions, and professional federations and networks.

Stepwise decision-making process

- End 2008 ⇒ pre-selection of zones, based on technical criteria (geology) and the interest of communities and their territory
- End 2010 ⇒ selection of the site, after local investigations and confirmation of the interested communes