THE MEUSE/HAUTE-MARNE
UNDERGROUND RESEARCH LABORATORY

A scientific research tool

to study the deep geological disposal of radioactive waste
The Meuse/Haute-Marne Underground Research Laboratory (MHM URL): a scientific tool

The Law of 30 December 1991 entrusted upon Andra to be responsible for one of the research areas on the future of high-level and long-lived (HLLL) radioactive waste. In that framework, the Agency assesses the feasibility of a safe and reversible disposal system for HLLL radioactive waste in deep geological formations.

HLLL waste results primarily from nuclear power-generating stations. On 31 December 2004, this waste represented 0.2% of the total volume of waste being produced in France and 91.7% of the total radioactivity. Currently, waste packages are stored on their production sites, pending a sustainable industrial management solution. The two main specificities of HLLL waste are the following: it produces heat and it contains HLLL radio-elements that may migrate out from the package over the long term. Those specificities must be taken into account in the design of any future deep geological repository.

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Designed as a comprehensive scientific tool, this underground laboratory contains no radioactive waste and, in accordance with the licensing decree, will never be used for radioactive waste disposal. Scientists use the laboratory to study a 155-million-year-old clay-rock layer with a view to qualifying such a geological formation for the safe and reversible disposal of HLLL waste.

Andra’s MHM URL does not form only a physical structure, located 500 m deep underground, but constitutes also as a scientific tool for which every phase represents a further step towards a better understanding of the rock, starting with the surface survey, continuing with the development of excavation methods and their actual application, up to rock instrumentation with data recording and interpretation.

The Meuse/Haute-Marne Underground Research Laboratory staff includes 100 employees, as well as 250 other workers dealing with excavation operations.

Operating and experimentation costs are estimated at 16 million euros per year.

From 1992 to 2006, 375 million euros were required for the construction and operation of the MHM URL.
Basic Safety Rule

Published in 1991 by the Nuclear Safety Authority, the Basic Safety Rule RFS III.2.f describes the required criteria for siting any deep geological repository, as follows:

- No seismic risk over the long term;
- No significant water circulation within the repository;
- A suitable rock for structure excavation;
- Containment properties for radioactive substances;
- Located deep enough to protect the waste against various aggressions;
- No exceptional recoverable resources in the vicinity.

Several rock formations have the required properties to comply with this basic safety rule.

From 1994 to 1996, Andra studied the geology of several districts which applied for the implementation of underground laboratories in clay and granite formations.

The northern sector of the Haute-Marne district and the southern sector of the Meuse district constitute a simple geological domain within the Paris Basin and consist of a succession of quasi-horizontal layers of limestones, marls and clay rocks. The latter were deposited at the bottom of ancient oceans some 155 million years ago. Geological surveys conducted on the boundaries between both districts confirmed the potential of a stable and homogeneous clay-rock layer located at a depth varying between 420 and 550 m: the Callovo-Oxfordian argillite.

Following a public inquiry and with the approval by the government and public authorities, Andra was granted the license to construct and operate an underground laboratory on the Bure commune.

MILESTONES

<table>
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<th>Year</th>
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<tr>
<td>1992</td>
<td>Definition of the required knowledge to design a suitable repository</td>
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<td>1993</td>
<td>On the motion of local communities and on the basis of geological criteria, selection of potential sites in four districts for the implementation of an underground research laboratory</td>
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<td>1994 - 1996</td>
<td>Geological survey of one granite site in the Vienne district, and of two clay sites in the Gard district and on the border straddling the Meuse and Haute-Marne districts, respectively</td>
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<td>1997</td>
<td>Public inquiry and consultations of local communities for the implementation of an underground research laboratory</td>
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<td>1998</td>
<td>Selection, by the Government, of the Meuse/Haute-Marne site, definition of the scientific programme, selection of the repository concepts proposing a large spectrum of technical solutions</td>
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<td>1999 - 2006</td>
<td>Construction of the laboratory at Bure, sinking of shafts and implementation of experiments, furthering of knowledge on the Callovo-Oxfordian layer</td>
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<td>2000 - 2004</td>
<td>Geological surveying while sinking the shafts, and drilling of new boreholes</td>
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<td>2001</td>
<td>Publication of an interim status report on acquired scientific and technical data (Dossier Argile 2001)</td>
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<td>2002</td>
<td>Review of the 2002-2005 scientific programme and selection of repository concepts (packages and disposal cells)</td>
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<td>2003 - 2004</td>
<td>Drilling of complementary boreholes on the MHM URL site and within a 20-km radius</td>
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<td>2004 - 2006</td>
<td>Excavation operations in the argillite formation and in-situ experiments in the shafts and drifts</td>
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<td>2005</td>
<td>Completion of the auxiliary shaft at a depth of 490 m</td>
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<td>2005</td>
<td>Opening of a drift at a depth of 446 m from the main shaft, and experiments</td>
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<td>Since 2005</td>
<td>Opening of two drifts at the main level (490 m), and experiments</td>
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<td>2005</td>
<td>Submission by Andra to the government of the final version of Dossier 2005, confirming the feasibility of an underground repository in the Callovo-Oxfordian argillite formation with a reversibility rationale</td>
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<td>Since 2006</td>
<td>Installation of the shaft final head-frames</td>
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<td>2006</td>
<td>Adoption by the Parliament of the Planning Act related to sustainable management of radioactive materials and waste, which notably describes Andra’s future missions and orientations</td>
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Surface geological surveys

Before undertaking its own investigations, Andra relied on the previous studies carried out by other organisations concerning the sector, including the French Geological Survey (Bureau des recherches géologiques et minières - BRGM) and oil companies. The terrain, geological maps and regional seismic profiles were carefully examined and provided valuable information on the nature and geometry of the subsoil, as well as on the presence of potential faults (i.e., shallow and deep fractures in the rock formations due to the movements of the Earth's crust). Deep boreholes were then drilled in order to measure the mechanical and chemical properties of the intersected formations, especially their water permeability and their radionuclide diffusion and retention properties.

Once a series of large-scale-exploration boreholes were drilled into the geological formations, a geophysical campaign took place in 1999. It consisted in sounding the subsoil with vibrator trucks emitting seismic waves and provided a three-dimensional stratification profile of the MHM URL site.

Lastly, a hydrogeological monitoring system and a seismic-listening network were set in place.

Such exploratory work confirmed that the thickness of the 155-million-year-old Callovo-Oxfordian clay formation exceeded 130 m, was regular in shape and presented a remarkable horizontal homogeneity and extremely low permeability. For instance, it would take about 10,000 years for water to migrate over a distance of 1 cm within the rock. Furthermore, no fault with a vertical throw over 5 m was detected either in the Callovo-Oxfordian formation or in its overlaying geological formations.

Argillites consist mainly of clay minerals, but also contain quartz and carbonates that enhance considerably their mechanical strength. They form a grey stone that is compact, homogeneous and dry to the touch.

On the MHM URL site, argillites spread at a depth ranging from 420 to 550 m (130 m thick).

They result from the sediments that settled at the bottom of the ancient sea that covered the region some 155 million years ago during the Callovian and Oxfordian Ages on the scale of geological times, which means during the Jurassic Period of the Secondary Era.
Experiments conducted during excavation and underground

Shaft-sinking operations, followed by the drilling of boreholes from the experimental drift at a depth of 445 m helped to analyse metre by metre the structure of the rock and its response when excavated or drilled. They also provided full-scale data on the mechanical behaviour of the rock.

Since August 2005, a new phase of experiments has been launched in the main drifts of the laboratory (-490 m level which corresponds to the median part of the Callovo-Oxfordian formation). Their main purpose is to collect geomechanical, geochemical and thermal data, especially in the latter case with regard to the reaction of the rock under temperature increases. These data are used to validate the migration models of radioactive elements in the rock through the studies being conducted on water convection and on the diffusion of dissolved elements. Those studies also help to characterise the intensity and extension of the damages induced by drift-excavation operations. The overall set of collected data allows testing potential techniques designed to limit the impact of those damages.

Approximately 130 boreholes were drilled from the experimental drifts, and 1,400 sensors were installed in order to measure:

- deformations under the effect of natural strains (overburden pressure, tectonic thrust);
- pore-water pressures;
- permeability properties;
- diffusion properties, by using radioactive tracers*;
- retention properties.

Sensors are connected to data-recording systems available for direct consultation in the drift or from the surface.

* Radioactive tracers consist of chemical elements that are representative of those contained in HLLL waste packages. A few micrograms (one millionth of a gram) of those tracers are injected in the rock through a borehole while previously a large number of sensors has been installed around. After a given recording time, this borehole is over-cored in order to obtain the overall rock sample throughout which the tracers were disseminated. This sample is then analysed to provide the diffusion profiles of the radioactive tracers.
Favourable characteristics of Callovo-Oxfordian clay

On the Bure site, the Callovo-Oxfordian clay is located under a 400-m layer of limestone and marly rock. The overburden pressure (exerted by the weight of those overlying formations) has compacted the rock and strongly reduced its porosity. Due to the resulting low quantity of water contained in the rock, the mechanical strength is enhanced in comparison to argillaceous rocks currently found on surface.

After 10 years of investigations, Andra has achieved its research objectives. The acquired data clearly show that the Callovo-Oxfordian clay formation of the Meuse/Haute-Marne site has favourable characteristics for the implementation of a deep geological repository for HLLL waste:

- a stable geological environment with very low probability of seismic events;
- a regular, homogenous and fault-free clay layer over a large area;
- the low permeability of the Callovo-Oxfordian formation with slow and very slight water circulations within the surrounding formations;
- the capability of the clay to trap and retain radioactive substances over long timescales (at least about 100,00 years);
- the capability of the rock to withstand various mine-extraction operations involving structures measuring several metres in diameter;
- the compatibility of the characteristics of the Callovo-Oxfordian formation with the reversibility rationale of the disposal;
- a very low impact of engineered materials (cement, concrete, metal, etc.) which is limited to the immediate vicinity of the structures. These materials contributes in part to the safety and the reversibility of the disposal system;
- the possibility to transpose the results achieved in the MHM URL to the neighbouring 250-km² zone;
- the absence of any exceptional recoverable natural resources (such as oil, water, ores, geothermics, etc.).

The results of Andra’s investigations on deep geological waste disposal were gathered in a report entitled Dossier 2005. It contains two sets of documents: the first one deals with clay and is based on the studies conducted at the Meuse/Haute-Marne Underground Research Laboratory, whereas the second deals with granite. The final version of Dossier 2005 was submitted to the Ministers of Industry and Research in December 2005. The report was reviewed by the National Review Board, the Nuclear Safety Authority and a group of international experts placed under the aegis of the OECD Nuclear Energy Agency.
A broad national and international scientific mobilisation

Andra has developed a large number of partnerships in France, notably with the French Geological Survey (BRGM), the French Atomic Energy Commission (CEA), the National Scientific Research Centre (CNRS), the Paris School of Mines, the French Petroleum Institute (IFP), National Institute for Industrial Environment and Risks (Ineris), the National Polytechnic Institute of Lorraine (INPL) and approximately 100 laboratories. The Meuse/Haute-Marne Underground Research Laboratory is hosting, for instance, several experiments performed by the CNRS’ ForPro Group focusing on deep geological formations. Andra also relies on several methodological laboratories where other experiments were designed, validated and carried out before being implemented in the Meuse/Haute-Marne Underground Research Laboratory. Most of the countries equipped with nuclear power plants are studying the feasibility of disposing of their HLW waste deep underground. Therefore, Andra has been also involved in various international cooperative projects with its Belgian, German, Spanish, Swedish and Swiss counterparts, and is currently working with the European Commission and the International Atomic Energy Agency (IAEA).

Prospects

Following the publication of the Dossier 2005, the French Government drafted a bill concerning the future of HLW radioactive waste. This bill, voted by the Parliament as the 28 June 2006 Planning Act concerning the sustainable management of radioactive materials and waste, recognises deep geological disposal as a valid reference solution and prescribes Andra’s future research orientations in the scientific, technical and industrial fields, together with the associated deadlines. Before considering the implementation and operation of such a radioactive waste repository, Andra must therefore fulfil the following requirements:

- refining its knowledge about the geological formation over several years;
- proposing a location for the repository in the 250-km² zone close to the Meuse/Haute-Marne Underground Research Laboratory, known as the “transposition zone”;
- testing disposal cell prototypes and technological demonstrators*, in some cases in-situ underground.

The Planning Act of 28 June 2006 concerning the sustainable management of radioactive materials and waste prescribes two deadlines:

- 2015, for the review of the licence application concerning the implementation of a repository (after public debate);
- 2025, for commissioning that repository, would the corresponding licence be granted.

The decision to license a deep geological repository will only be taken after a vote by the Parliament regarding reversibility conditions.

* Technological demonstrators consist of various equipment (disposal cells, robots, package mock-ups, over-packs, etc.) designed to determine the overall characteristics of the repository: dimensions, operating procedures, materials, etc.
Some of ANDRA’s publications are available in English.

**Essential Series**

In a few pages, documents in the Essential Series provide simple and illustrated explanations with a view to furthering knowledge on radioactive waste and ANDRA.

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**Periodical Series**

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**Discovery Series**

Videos, CD-ROMs, synthesis images and comic strips... are worth more than a thousand words. The Discovery Series uses vivid illustrations to explain to a foreign public the underlying principles of radioactive-waste management.

**Science and Technology Series**

Taking stock of current knowledge, presenting ongoing research as well as the Agency’s methods and approaches constitute the objectives of the Science and Technology Series. Intended for a specialised public, it provides various syntheses and monographs published under the direction of ANDRA or in partnership with other scientific organisations.

**Report Series**

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**Industrial Practices Series**

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