SCIENTIFIC INVESTIGATION IN DEEP BOREHOLES AT THE MEUSE/HAUTE MARNE UNDERGROUND RESEARCH LABORATORY, NORTHEASTERN FRANCE

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ABSTRACT

From 1994 to 1996, the preliminary investigation carried out by Andra, identified a sector favourable for hosting a laboratory in argillaceous Callovo-Oxfordian formation which has a thickness of 130 m and lies more than 400 m below ground level. In November 1999 Andra began building an Underground Research Laboratory (URL) with a 3D seismic survey over 4 km². From 2000 to 2004, large programs of boreholes were carried out on site and on the sector in order to define the characteristics of formations, to improve the regional geological and hydrogeological knowledge and to provide an accurate definition of structural features in Callovo-Oxfordian argillites and Dogger limestones.
These drilling programs have provided a fine characterization of the argillites on the laboratory area and a good correlation of geological properties at a sector scale.

1 Choice of Eastern France

ANDRA is in charge of analyzing the possibility of implanting a reversible nuclear waste disposal in deep geological formations. With this aim it has undertaken the construction of an underground laboratory in the eastern part of the Paris Basin. This region, with a geological history running over 365 million years and historically known to be stable, had been generally identified (Figure 1).

Figure 1. Geological structure of the Paris basin

The building of the Meuse/Haute-Marne underground research laboratory is conducted through the implementation of a scientific and technical approach, based on the knowledge acquired during the preliminary borehole drilling phases.

2 Research activities in the sector between the Meuse and the Haute-Marne (1994 to 1996)

The objectives of the preliminary investigation phase were to verify the characteristics of the selected host formation (argillites of Callovo-Oxfordian age) and the parameters of the surrounding rocks, particularly the hydrogeological parameters of the Oxfordian and Dogger formations. This investigation was carried out over a sector identified by an exhaustive analysis of prior geological survey data, 2D seismic profiles and borehole drilling operations.

In late 1994 and early 1995, two deep cored boreholes were drilled (Figure 2). Borehole HTM102 (1100 m deep), entirely cored from the Kimmeridgian to the Lias, was extended (rotary) to attain the first levels of the Triassic formation. In borehole MSE101 (922 m deep), located 15 km northwest of borehole HTM102, only the argillites formation has been cored.

From mid-1995 to mid-1996, 4 deep boreholes were drilled for hydrogeological (rotary method) and geomechanical (cored) investigations, three in the laboratory site and a fourth one 3 km southeast of the site.

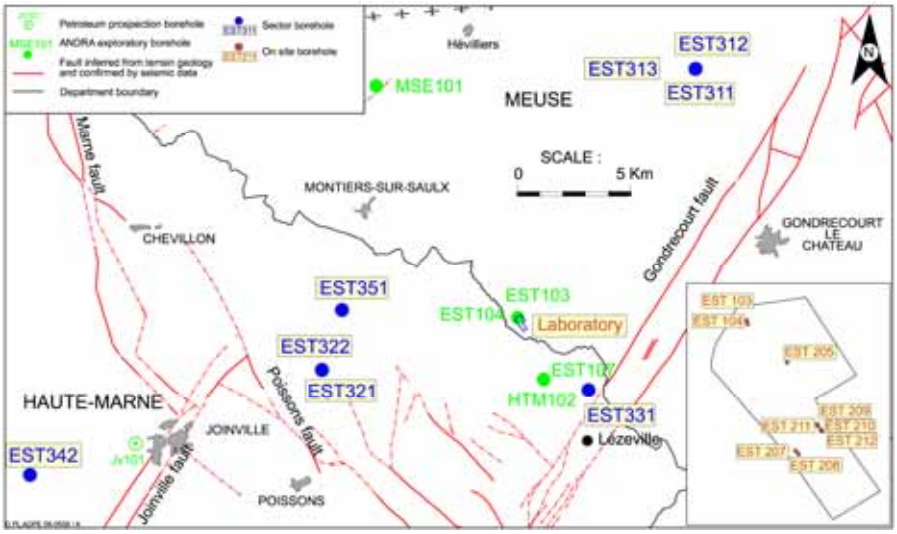

Figure 2. Location of the preliminary, sector and on-site boreholes

From 1994 to 1996, Andra identified through its preliminary investigation an area favourable for hosting a laboratory on the sector south of the Meuse and north of the Haute-Marne departments. In this sector the 130 m thick argillaceous Callovo-Oxfordian formation, lying at more than 400 m depth, has a very low permeability.

3 On-site boreholes (2000)

In March 2000, to monitor the influence of the drainage on the Kimmeridgian and Oxfordian formations of the shaft access, hydrogeological boreholes were drilled on the laboratory site using an inverse circulation method

For the Oxfordian formation, two boreholes (EST201 and EST203 - 420 m deep) have been equipped with five measuring chambers, thereby supplementing boreholes EST103 and EST104 located north of the laboratory site. For the Kimmeridgian formation, one borehole (EST202, 150 m deep) has been equipped with three measuring chambers (Figure 2).

In mid-2000, two geological exploratory boreholes were cored in the main and auxiliary shafts axis in order to define the characteristics of the formations to be taken into account for shaft sinking. A large program of scientific, hydrogeological and geomechanical measurements was therefore undertaken. In the EST205 borehole, an oil base mud was used to core the Callovo-Oxfordian argillites in order to achieve a better core recovery and carry out geomechanical tests (micro-hydraulic fracturing tests between 460m – 500m)

4 Scientific boreholes at sector scale (2003)

A drilling program was carried out on a large sector (about 2 000 km²) around the laboratory in order to improve the regional geological and hydrogeological knowledge, enhance the hydrogeological model, identify the lateral variation of the host formation and perform permeability measurements.
Throughout this sector (Figure 2), 8 boreholes were drilled on 5 platforms chosen for the acquisition of permeability and cinematic porosity fields in the rock structures surrounding the Callovo-Oxfordian, Oxfordian and Dogger formations.
The inverse circulation drilling method was used to drill the Oxfordian and Dogger carbonated formations, above and under the argillites formation, and more specifically for coring in the argillites.

The scientific program included:
- a detailed geological survey to acquire a lithological profile and identify possible sedimentation gaps in the Callovo-Oxfordian formation,
- hydrogeological and geochemical measurements in the carbonated formations (Oxfordian, Dogger) to obtain uncontaminated water and gas samples.

This information was used to define an equivalent transposition zone relevant for applying the results obtained.

5 Formation exploration borehole campaign (2003-2004)

The 2003-2004 on site drilling program consisted of seven deep boreholes, four of them deviated (up to 10° from the horizontal plane) to obtain an accurate definition of structural features in the Callovo-Oxfordian argillites and Dogger limestones, and the geological variability of the host formation at the laboratory scale (Figure 3). The objectives of the other drillings were to identify the natural stress properties of the host layer and to perform the first in-situ measurement of the diffusion of radioactive elements in the argillites. The drilling methods implemented were the inverse circulation drilling or polymer mud coring in the carbonate formations, the oil base mud coring in argillites and the air or nitrogen coring for the diffusion test in the argillites (EST208).

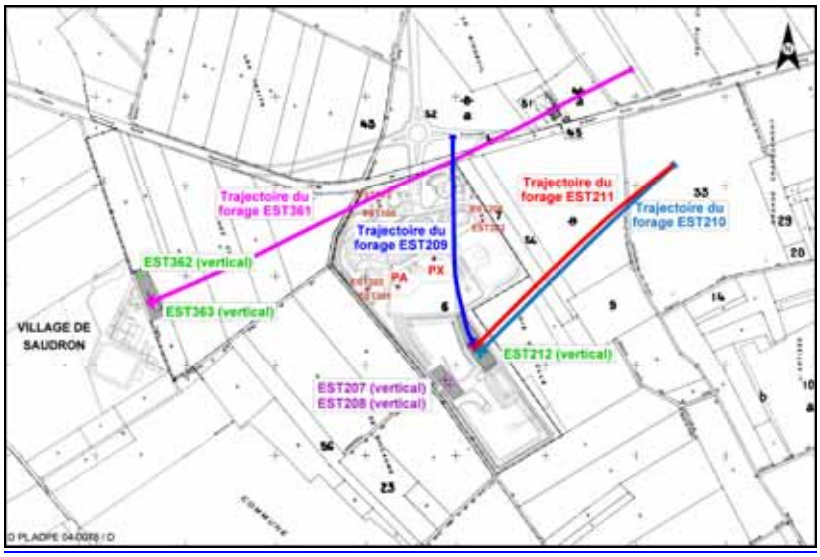

Figure 3. Location and trajectories of the directional boreholes drilled on the Bure site

The first program unit (geophysical and hydrogeological purpose) consists of one vertical borehole EST212 and two oblique directional boreholes (EST210 and EST211). Two EPG electromagnetic transmission pressure sensors were installed in EST212 and one in EST211.
The second program unit (geological and geomechanical purpose) consists of one oblique directional borehole (EST209) and one 1494 m-long sub horizontal borehole (EST361). A third borehole EST363 (vertical) was equipped with an EPG sensor.
The third program unit (measurement of the diffusion of radioactive elements) consists of two vertical boreholes, EST207 and EST208.

6 Hydrogeological results

The hydrogeological properties were acquired through specific tests, using innovative techniques developed in collaboration with our Finnish partners.
Head disturbances in the Oxfordian formation caused by shaft sinking began on 26 November 2001 when a drilling, intersected a porous and identified level 24 m from the sole of the main shaft, thereby triggering the drawdown process.

The permeabilities of the Callovo-Oxfordian formation (Figure 4) measured in boreholes EST212, EST211 and EST363 confirm the values determined for the host formation during previous campaigns, namely its very low permeability (5.10-13 m/s).

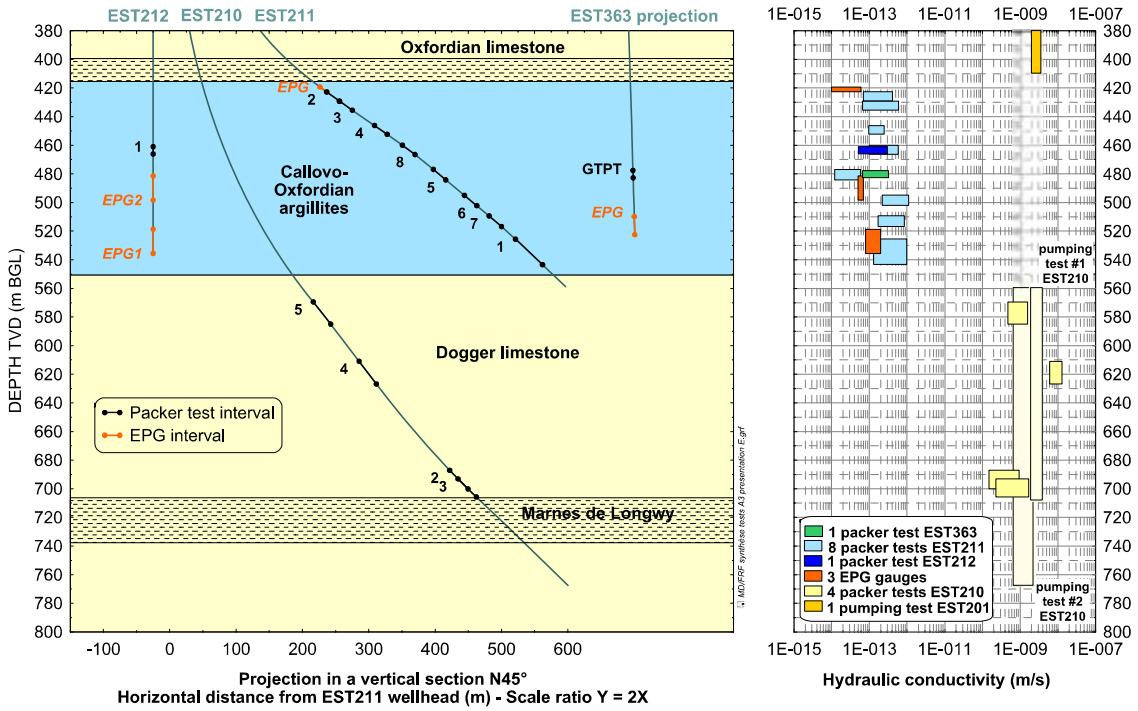

Figure 4. Results of permeability measurements in the host formation

7 Geological results

In the sector identified, the results of the geological survey and the interpretation of the intersected facies lead to the following conclusions regarding the geometry of the formations:

- The Oxfordian formation displays a slight decrease in thickness towards the northeast, in accordance with the regional palaeographic scheme. The transition from a carbonated platform system (towards the east) to a more open basin (towards the west) during the lower Oxfordian is confirmed.
- The Callovo-Oxfordian formation displays an increase in thickness (Figure 5) from the southwest towards the northeast (100 to 160 m, respectively), ranging from 135 to 138 m on the site.

From the structural point of view, no structures were intersected in the cored sections of the Callovo-Oxfordian formation (only joints or fissures were encountered in the carbonated facies).

The mineralogical results for the various boreholes confirm the mineralogical composition of the host formation, which contains 30 to 55% clay minerals, associated with 20 to 30% carbonates, 20 to 35% quartz and a small percentage of subordinate minerals. The lateral variation of the mineralogical composition is very low.

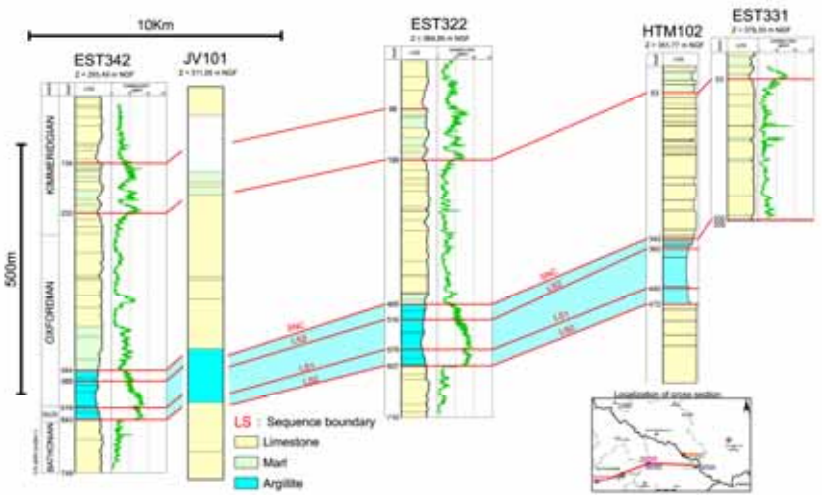

Figure 5. East-West lithological cross section of the sector

8 In situ stress profile

The various geomechanical measurement campaigns conducted in the framework of the survey borehole campaign in the Callovo-Oxfordian formation (boreholes EST209 and EST361) and Dogger formation (EST210) have (Figure 6):

- confirmed the amplitude of the minor horizontal component (σh) in the argillites
- made it possible to measure directly the amplitude of the minor horizontal stress in the Dogger formation
- yielded the anisotropy ratio of the horizontal stresses in the argillites
- shown that the maximum principal stress corresponds to the major horizontal stress (σH) in the Callovo-Oxfordian formation

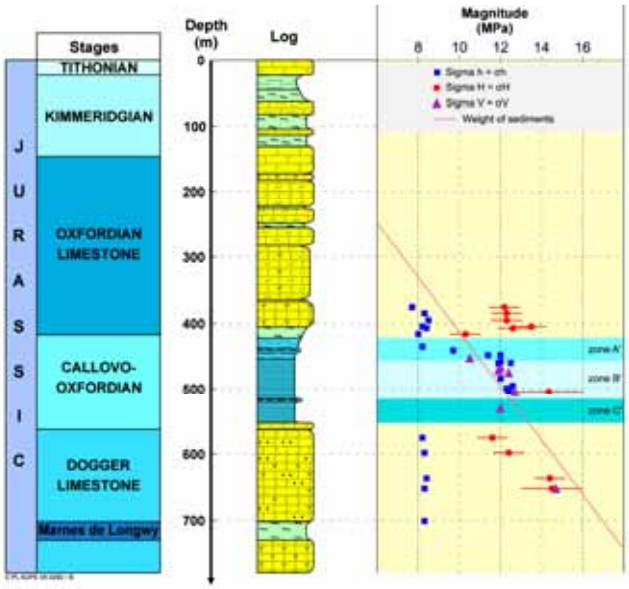

Figure 6. Stress values measured in-situ in the boreholes

9 Conclusions

These drilling programs (27 boreholes, 11 873 m of drillings, 4432 m cored) have provided a fine characterization of the physical and chemical properties of the argillites on the laboratory area and a good correlation of geological properties at sector scale. Based on these results, a transposition zone of 200 km² with similar characteristics has been delimited. During the next phase starting in 2007, a drilling survey will be carried out over the transposition zone to acquire the same accurate knowledge over the entire area of interest to ANDRA .