Lessons learnt from excavating the clayish Callovo-Oxfordian host formation at Bure URL and excavation technologies considered for the future Cigéo DGR

LUCOEX Conference – Oskarshamn, June 2015

F. Chauvet & al.

Bure URL

Andra (*French public body in charge of disposal of radio-active waste*) is working for a long time in order to find a good (and acceptable) solution for the disposal of:

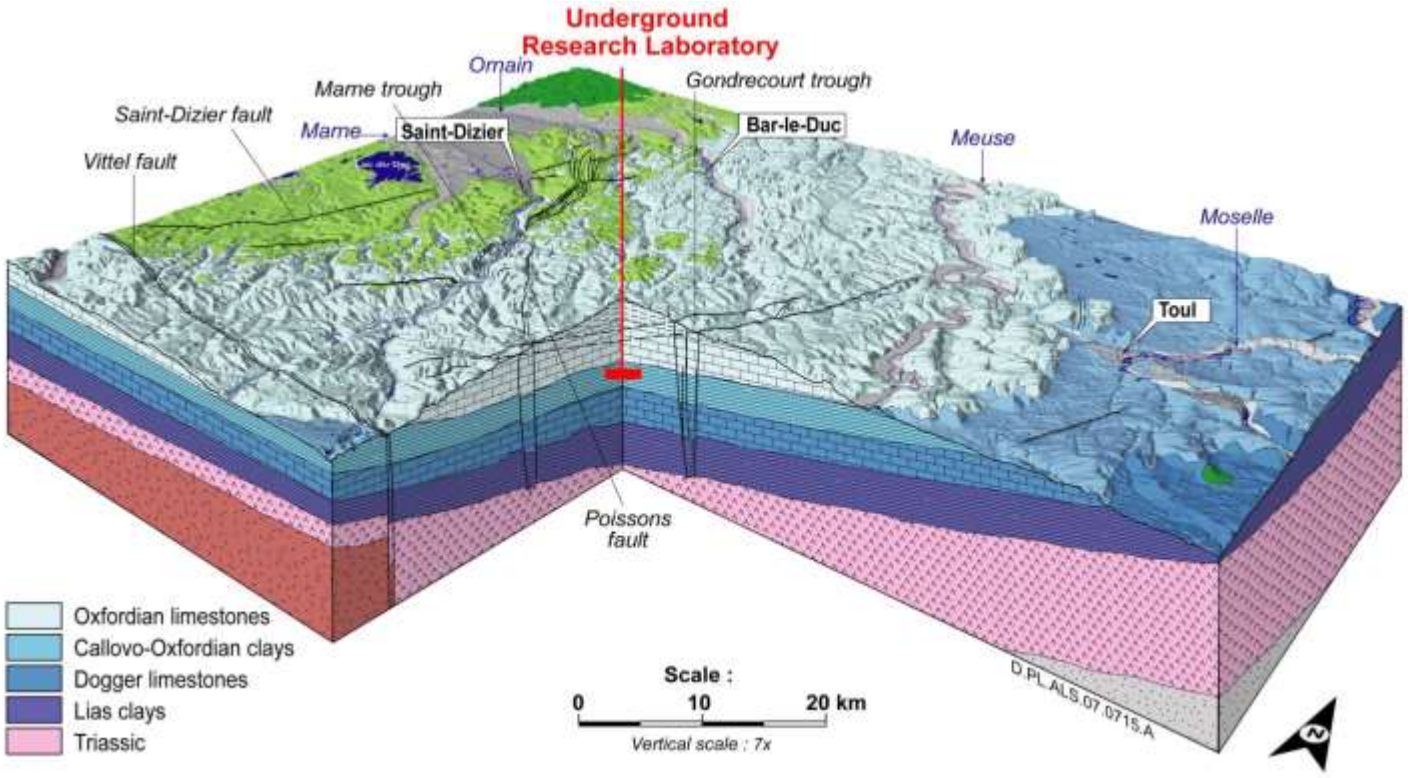
- High level radioactive waste (say HL)
- Intermediate long lived radioactive waste (say IL)

After the first phase of conception, and extensive discussions about the geological host formation capable to receive such HL and IL waste on the long term, it was found that Callovo-Oxfordian host formation could be well adapted to such a disposal, due to high water-tightness and self-healing qualities of this rocky clay.

This formation is present at Bure, where an Underground Research Laboratory (URL) was designed, then built. Since 1999, Andra has been studying this host formation (COX) in order to qualify it for the future Cigéo repository.

Bure URL

General situation of Bure URL, and geological 3D block-diagram of Meuse – Haute Marne site



Bure URL

1. Geological setting

North of Haute-Marne district and South of Meuse district form a simple geological domain of the Paris Basin, comprising a sequence of near horizontal limestone layers, marls and argillaceous rock layers, deposited at the bottom of former oceans, some 150 millions years ago.

2. Geological faults

The detailed studies of geophysical profiles of the sector have shown that the tectonic deformations affecting the region have been mild and essentially limited to Gondrecourt fault system and Marne River fault system. In the area between above faults, the COX layer is even and planar.

Bure URL

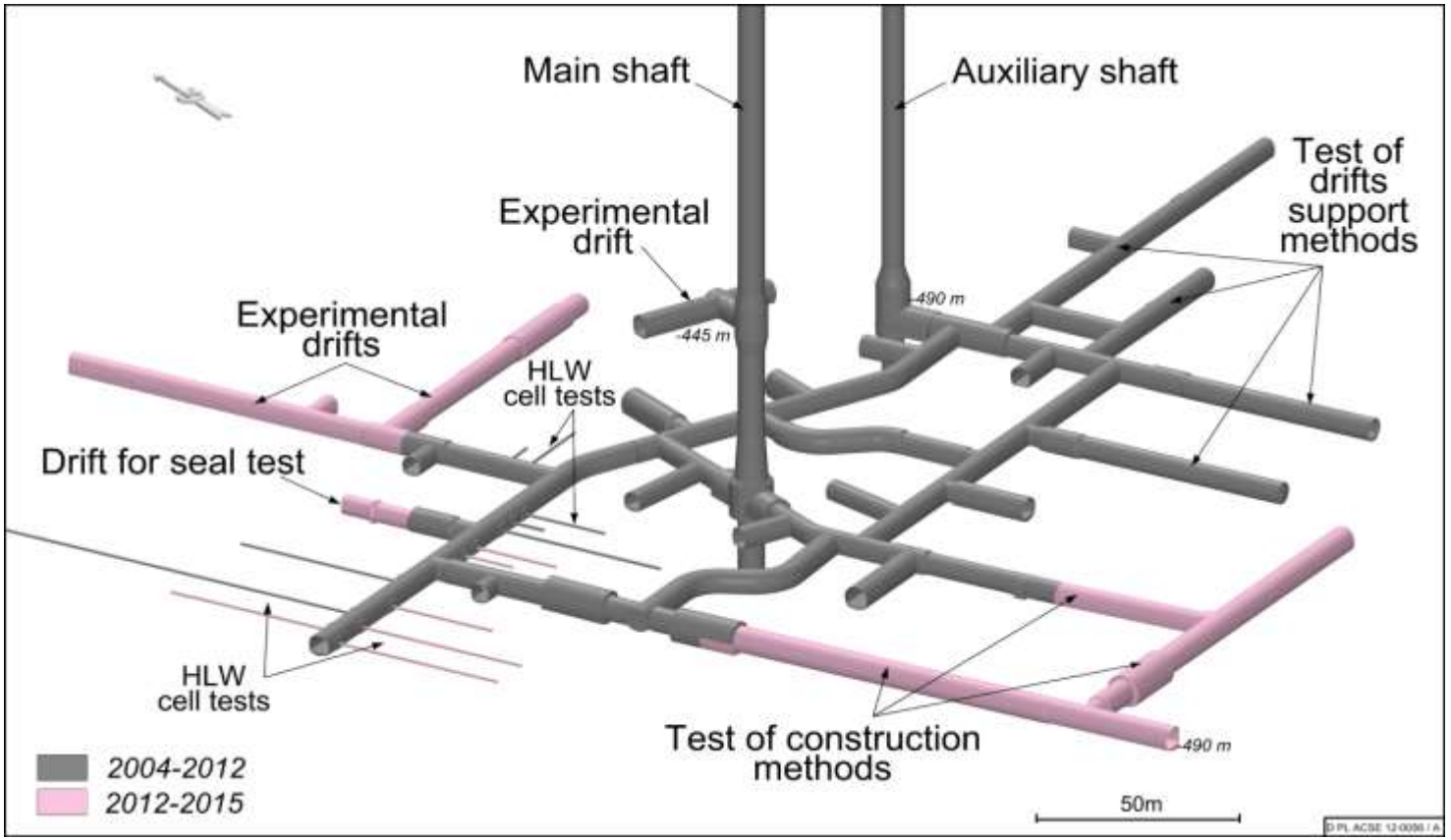
3. Laboratory architecture

The URL infrastructure includes :

- **2 vertical shafts, 490m deep**
- **About 600m of technical drifts, dedicated to access, escape routes, power supply, safety shelters, mechanical maintenance, ventilation and water exhaust**
- **About 500m of experimental drifts, dedicated to all experiments for qualification of COX**

Bure URL

Overview of Bure URL architecture



Bure URL

4. Experiments

A lot of scientific experiments were performed in the Laboratory, including:

- **Geophysics**
- **Geomechanics**
- **Hydrogeology**
- **Geochemistry**
- **Corrosion**
- **Biology**
- **Radio-elements diffusion**
- **Temperature effects**

But the excavation of galleries has also brought a lot of knowledge about the behavior of the COX in different conditions of excavation.

Bure URL

5. Excavation methods used for construction of the URL

- Excavation of shafts: drill and blast (explosive)
- Excavation of drifts: hydraulic hammer or road header with classical sustainment with steel arches (rigid or sliding), anchor bolts, and shotcrete, then different kinds of lining (shotcrete, concrete cast in situ)
- Excavation of HLW horizontal cell (0.7m diameter): micro-TBM. The main problem encountered was the behavior of the steel casing placed at the rear of the machine. Spalling and convergence of the COX necessitate excavation to be quick, in order to avoid sticking of the casing against the COX.
- Experimental excavation: Tunnel Boring Machine (single head) and concrete precast segments for the lining.

All those methods have put in evidence advantages and disadvantages for each of the solutions, in the particular conditions of the COX.

Note: size of tunnels/drifts in the URL are close to half-size of the Cigéo tunnels/drifts, which are about 8m internal diameter.

BURE URL —› Cigéo

All that experience gained in the URL was then "injected" in the preliminary design of Cigéo underground structures.

The differences in dimensions, in use (Cigéo will be an industrial site) and in economic needs, between the URL and Cigéo, have guided Andra to some specific choice for excavation methods.

Before explaining the use of URL experience in excavating methods to Cigéo, a short description of Cigéo repository is necessary.

Cigéo

Cigéo mainly includes 7 main underground areas:

a) 2 ramps (inclined tunnels), 8m diameter and 4,4km long, in order to reach the COX layer. At the very beginning of site works, both inclined tunnels will be dedicated to construction of underground structures. Later, ramp will be specifically equipped for nuclear waste transportation only.

b) 5 vertical shafts, 6 and 8m diameter, and 500m deep. 3 shafts are dedicated to construction operations and 2 shafts are dedicated to nuclear operations only.

c) A disposal area for the intermediate long-lived waste packages (ILW), including 2 access galleries, 2 ventilation galleries and 50 disposal cells.

d) A disposal area for high activity waste packages (HLW0), which have thermally decayed and have a low temperature (less than 90°). This area includes 75 cells 0.7m diameter, 80m long.

Cigéo

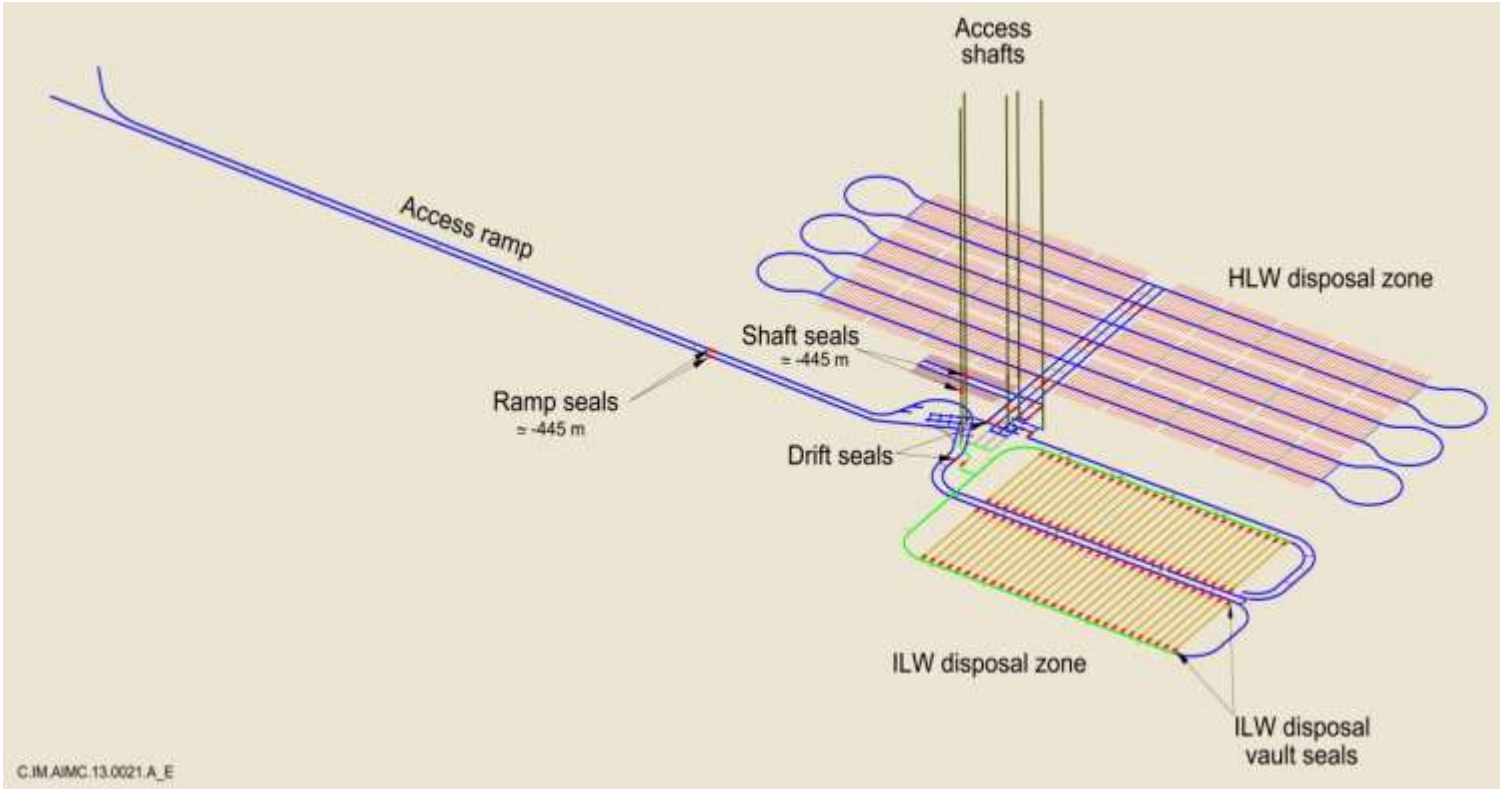
Cigéo mainly includes 7 main underground areas:

e) 6 disposal areas for high activity waste packages (HLW), which are presently too hot to be put in contact with the embedding rock. The total length of cells to be excavated is 148Km (1474 cells, diameter à.7m, 100m long).

f) Tens of connecting tunnels and technical rooms.

g) Service galleries, forecasted for construction purpose, for instrumentation purpose and for operation purpose.

General 3D view of Cigéo underground structures



Cigéo

A part of such a design results from a long period of conception, which involved requirement for nuclear safety, long term durability and protection, fire protection, and, in particular:

- **Civil engineering calculations.**
- **Integration of excavation methods.**
- **Integration of time constraints (the waste packages need to be disposed in time).**
- **Integration of cost requirements.**

Cigéo

Presently, excavation methods, forecasted for Cigéo, are the following:

1. **Inclined tunnels: Tunnel Boring Machine (full face) and the tunnel lining made of precast concrete segments. Both TBM will continue, after completion of inclined tunnels, and they will excavate, in the same way, both horizontal access tunnels (2,2 km long each) and potentially other galleries, if it is possible according to the general time schedule.**

2. **Shafts: drill and blast. Initially, the lower part (in COX) was forecasted to be excavated by means of hydraulic hammer. It appears, from geotechnical tests, that the "drill and blast" method is safer for the COX integrity.**

Cigéo

Presently, excavation methods, forecasted for Cigéo, are the following:

3. ILW disposal area : 50 cells will be excavated with Road Header Machine. Lining will be built with a first layer of shotcrete, then a second layer of concrete poured in place. An option remains open for the future, in case a TBM (single head) may be adapted to the work (multiple single vaults 500m long).

4. HLW0 disposal area: Road header Machine for the access galleries and micro-TBM for each of the 75 cells. Tests performed at Bure URL with 2 micro-TBM will continue in order to obtain a well-adapted machine for this specific work.

Cigéo

Presently, excavation methods, forecasted for Cigéo, are the following:

5. HLW disposal areas : similar methods than for HLW0 disposal area. Road header Machine for the access galleries and micro-TBM for each of the 1474 cells. Nevertheless, the beginning of this work is forecasted in year 2070. There is no need to decide now, and technology could evolve to allow best solutions. TBM (full face) could become the good solution for construction of access galleries.

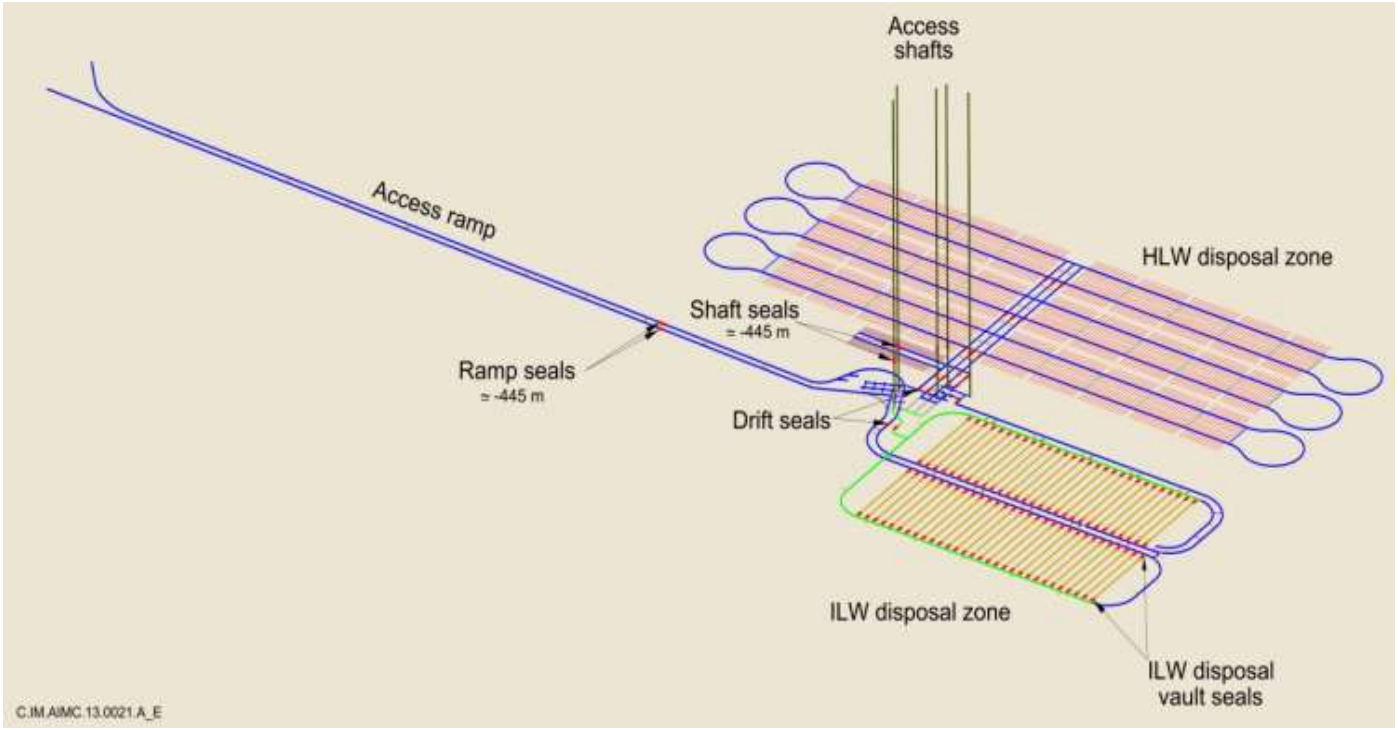
6. Connecting tunnels and technical rooms: due to the short distances to be excavated, hydraulic hammer seems to be the best solution.

Cigéo

Presently, excavation methods, forecasted for Cigéo, are the following:

7. **Service galleries : two different solutions remain possible, the choice depending on the length of the gallery, and on the time schedule (in relation with neighboring works). Road header Machine or hydraulic hammer.**

General 3D view of Cigéo underground structures



Thank you!