# CLAYS IN RADIOACTIVE WASTES CONTAINMENT: EXPECTED ROLE AND STRATEGY FOR DATA ACQUISITION

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## Expected role in the radioactive waste disposal concepts

The properties of the clay barriers, natural or engineered, are mobilised to protect waste packages against natural aggressions and to reduceslow down the flux of potentially released radionuclides to the biosphere.

Regarding natural clay formations, the main relevant properties are the following:
- low water permeability associated with the hydrogeological context, to limit the water flux around the waste packages and to control the advective velocity within the formation as well as the underground installation;
- chemical reactivity and buffer effects to limit the chemical disturbances induced by the repository, in particular to ensure maintenance of reducing conditions;
- retention and sorption capacity to retard migration of released radionuclides.

Low water permeability is determined mainly by the texture of the clays included in the material, particularly the geometry (pore size and connectivity) of the porosity and the structure of the double layer around the clay minerals. The presence of minerals like pyrite or organic matter can exercise a feedback control over the redox , and carbonates buffer the pH. Sorption or ion exchange are more favourable in smectites. From these points of view, the Jurassic argilites studied in the Meuse/Haute-Marne underground research laboratory is well adapted to meet these expectations: clay fraction comprises 30 to 50% of the total amount with mixed-layer illite/smectite, calcite makes up 20 to 40%, and components such as pyrite or organic matter being less than 5%.

In HLW disposal concepts, potential buffer material are used to provide a robust diffusive medium around packages in order to control the physical and chemical conditions in the near field of the wastes. Because this material must resist high deformation rates (related to potential high temperature increase, packages collapse, etc.), plastic and swelling clays are considered.

The low water permeability of clay materials used to seal the repository makes it possible to limit the flux of radionuclides migrating along the access drifts and shafts. To ensure hydro-mechanical integrity of the seals and close contact with the rock, clays possessing a swelling capacity are required.

For buffer and sealing materials, the purest possible clay minerals are sought (generally smectites, in order to achieve high swelling pressures).

Some constraining characteristics of the host formation are to be taken into account in the design of the deep underground installations, including a logic of disposal process reversibility. The first characteristic that must be considered is the immediate and long term mechanical behaviour, so as to ensure on one hand the accessibility and safety of the underground openings during excavation, waste package transfer/emplacement, and

observation, and on the other hand the ability to seal these openings after operation. Besides the dimensions and permeability of the excavation disturbed zone around sealed underground cavities have a significant impact on the performance of the sealing system.
Another significant characteristic of the host formation is its porewater chemistry for insuring a constant and predictable chemical environment for the waste packages and engineered barrier systems.
Constraints related to the thermal dimensioning of the repository are to be considered for both clay buffer material and clay rock. These constraints address the thermal conduction of clays, taking into account variations in their resaturation rate. Another concern is the evolution of clay mineralogy when subjected to heating by certain wastes because of possible long-term effects on retention capacity, chemical reactivity and mechanical properties, in particular the swelling capacity of clays used as buffer material.

**Strategy developed for data acquisition**

Data acquisition makes it possible to progressively design disposal concepts, model their evolution at various time scales, taking into account interactions between clay and the other materials, and finally assess the performance and safety of the concepts. The strategy is different for the argilites and for the engineered clays, but in both cases it has to cope with the very strong water/rock interactions which are the consequence of the clay properties.

Considering the Callovo-Oxfordian formation, the data acquisition follows a progressive upscaling process in space and time to determine its actual properties. It takes into account their specific characteristics. Therefore it is needed at first to work at small scale (generally on core samples) in order to be able to identify and quantify separately the involved processes. Subsequent research must include large in situ scale experiments or eventually mock-up, if possible. The underground research laboratory will play a major role in this phase, particularly to observe and monitor the geomechanical behaviour of the formation during excavation. These experiments give access to all coupled phenomena under realistic system boundary conditions and heterogeneity at a metric scale.
The URL experiments designed to examine transport processes or chemical disturbances will allow observations of effects reaching only a few decimeters into the argilite. Determination that the process kinetics observed at experimentally observable time and space scales are valid over long time periods should rely on the study of analogue processes which have been acting within the Callovo-Oxfordian (or other similar geological formations) for tens thousands of years.
For the purposes of repository Performance Assessment, the information acquired at the Meuse/Haute-Marne URL site must be transposed to a larger scale (pluri-decakilometric). This final phase of up-scaling is based on the geological conceptual model of the host formation deposition and historical evolution which can explain their confinement properties and geomechanical characteristics.

For buffer or sealing materials, the data acquisition will allow inference of the needed properties from their design-demanded role. It will then be assumed that available material properties can be adjusted to meet the design and physico-chemical specifications, even if they are subjected to thermal or chemical disturbances.

The final objective is a comprehensive modelling of the clay behaviour in the different successive states of a repository and of its geological environment (including both the operational and post-closure periods of the repository, up to about one million years).