OVERVIEW OF THE DISPOSAL FEASIBILITY ASSESSMENT IN MEUSE/HAUTE-MARNE: INTEGRATION OF GEOSCIENTIFIC DATA IN THE SAFETY CASE, METHODOLOGY AND ORGANISATION, JUSTIFICATION OF THE PROCESSES AND MODELS, CHOICE OF THE DATA

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The Dossier on Disposal Feasibility Assessment in Meuse/Haute-Marne (Callovo-Oxfordian Clay layers), which was submitted by Andra to the French Government in June 2005, is the result of a long way from the Preliminary Geoscientific Survey in 1994 to the Safety Case. An iterative approach was used, three iteration loops were organised between acquisition of knowledge, architecture and design, safety studies and analysis with milestones in 1996, 2001 and 2005. At each step, the acquired geoscientific data was used to refine the disposal design and then was integrated to the safety case. During raw data acquisition and interpretation, each value and model were discussed and presented in technical reports with its uncertainties of all kind (e.g. ranges of porosity and permeability, uncertainties on head values, etc…).

From the raw geoscientific data, a first integration work (putting together measurements, results of modelling, lines of arguments) provided conceptual and phenomenological models which were the basis for description of the evolution of the repository (Phenomenological analysis of repository situations, PARS).

Predicting the phenomenological evolution of the repository and its geological environment over a one million-year timescale may initially appear a risky enterprise. In this respect, the hundred-year to multi-century timescale of the repository's operational, observation and reversibility period seems easier to grasp by the layman, in particular via the feedback on the behavior of underground engineered structures that has been generated by civil engineering and mining sources for decades. However, the "one million years" unit of time is commonly used in the earth sciences and astronomy. Scientists in these fields are accustomed to characterising and predicting sometimes complex phenomenological processes, or at least their trends, over time scales much longer than a million years. In this broad context, predicting the phenomenological evolution of the repository and its geological environment is a relevant exercise. The approach is based on the very principle of a repository in a deep geological formation and the design options proposed for the repository.

In regional terms, the fact that a geological environment has been stabilised over a period of several millions or tens of millions of years implies that significant internal geodynamic changes may not need to be considered for the analysis period. Locally, in the particular area under consideration, the Callovo-Oxfordian layer has simple geometric characteristics and a geological history that is straightforward and largely free from disturbances. It is also characterised by its very limited exchanges of matter with its environment and by interactions between fluids and rocks (i.e. solids) that are the result of early processes that occurred tens of millions of years ago, at least. This stability, combined with the layer's uniformity and intrinsic properties mean that the studied geological system's characteristics can be established using existing scientific and technical means. The geological environment's past behavior and properties provide a solid foundation for predicting its evolution over the next million years. In particular, the choice of a deep geological formation as the site of the repository means that the formation and therefore the repository are unsaturated from the effect of surface changes, allowing these properties to remain intact over time.

The work of (geosciences, engineering components) data integration and description of evolution from operating period over one million years was performed by an integrated team mixing scientists from different fields (geology, hydrogeology, geochemistry, two phases (water-gas) flows multi-components in porous media, radionuclides chemistry, chemistry, mechanic, geo-mechanic, numeric…). This principle allowed complementary, independent, consistent, and crossing points of view, in order to achieve as much as possible and reasonable both exhaustivity and different level of arguments. The inventory of the assumed phenomena with time and associated models was made for the different disposal components, underlining uncertainties in term of occurrence of each phenomenon or its exact chronology.

So an important part of integration work was to put in perspective processes in time and space, including uncertainties, in particular taking in reference radionuclide release and transfer from waste packages to biosphere. This can be illustrated for the geological media by the deep attention paid on geodynamic and climatic evolution processes and theirs consequences on the THMCR properties of the Callovo-Oxfordian clay layer and its surroundings formations, in particular water flows (directions, velocities, localisation of outlets) and solute transport pathways and processes. The depth of the Callovo-Oxfordian clay layer puts it out of reach of the thermal, mechanical or chemical phenomena induced by geodynamic evolutions.

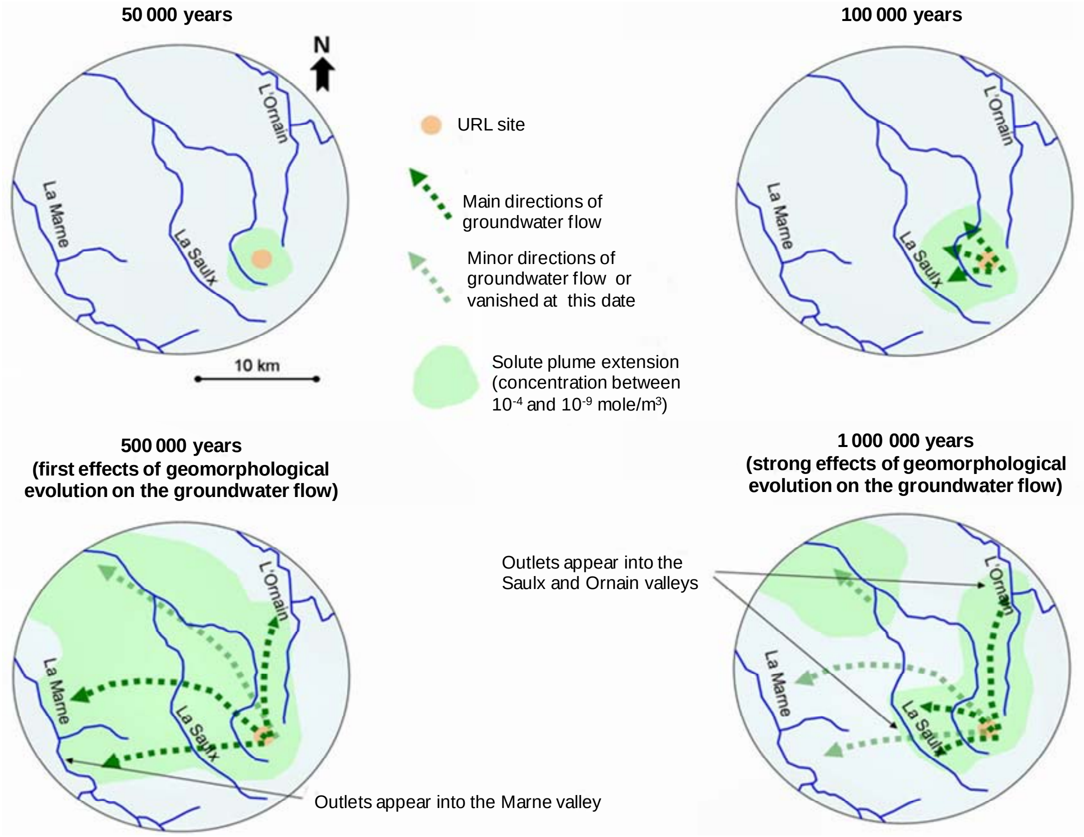
From the hydraulic aspect, it was noted that evolutions affecting the hydraulic head in the surrounding formations will gradually change the conditions at the limits of the layer over the next million years. The vertical hydraulic head gradient through this layer will therefore increase from a maximum value of 0.2-0.3 $m.m^{-1}$ in the transposition zone at the present time to 0.4-0.5 $m.m^{-1}$ in a million years' time This gradual change, which will only be perceptible from around the 500 000-year mark, will however remain minor and the diffusion phenomenon will still be the dominant mode of transfer in the Callovo-Oxfordian over the entire period. This time is much higher than the time scale of transfer within the Callovo-Oxfordian for mobile radionulides (^{129}I).

Contrary to the Callovo-Oxfordian, the consequences of geodynamic phenomena on the transfer of solutes in the surrounding layers (Dogger and calcareous Oxfordian) are more pronounced. Generally, the successive 100 000-year glacial cycles cause transient, reversible disturbance. During glacial maximum periods, more or less continuous permafrost develops on the surface and the 0°C isotherm penetrates to a depth of approximately 300 m. This permafrost blocks infiltrations at the outcrops. At depth and at the site level, it is also likely to limit the flows in the more superficial aquifers (surface aquifers – Calcaire du Barrois (Tithonian) and Kimmeridgian carbonate intervals – and also the porous upper levels of the calcareous Oxfordian). The phenomenon of salt exclusion on freezing causes a gradual concentration of salt at the permafrost front, at an average depth of around 35 metres, much higher than the top of the calcareous Oxfordian in the transposition zone. These phenomena develop over short periods, approximately 20 000 years out of a 100 000-year cycle, which are minor compared with the transfer times in the surrounding formations (several hundred thousand years).

Their impact is therefore limited. The forthcoming glacial cycles may potentially be disrupted in terms of duration and amplitude by anthropic activities (massive greenhouse gas emissions) in extreme scenarios. This disturbance may prevent the return of glacial conditions to the site for the next 200 000 to 300 000 years and would disturb the amplitude of the following cycles up to 500 000 to

600 000 years hence. Over these periods, the transfer of radionuclides and toxic chemical elements is not likely to be disturbed by these transients in the case of anthropic disturbance. After the 600 000-year point, the effects of anthropic disturbance on the climate cycles would no longer be significant. On a million-year scale, the sequence of climate cycles causes the geomorphological evolution of the landscape. This evolution leads to a significant change in the calcareous Oxfordian hydraulic head field. Indeed, the outcropping of certain parts of this formation in the valley floor in zones downstream of the flow causes the present-day outlets (Marne Valley) to migrate or new ones (Ornain Valley) to appear. Such disturbances to the hydraulic head field will therefore lead to the disappearance of the present-day regional direction of flow to the centre of the Paris basin. These gradual changes will become perceptible from the 500 000-year point. The Dogger carbonate is less sensitive to this evolution as it is more distant from the outcrops and, on the scale of the next million years, transfers in this formation will therefore remain similar to the present situation.

Figure 4. **Progressive evolution of hydrogeology due to geodynamic on the Meuse/Haute-Marne site**



All theses geoscience data supported the safety models (normal and altered evolution scenarios) which were also constructed taking into account the capabilities of the available codes for calculations and the safety strategy. The geoscience data was then used to support the sensitive analysis studies for these scenarios, via a qualitative safety assessment, including a FEP cross checking. This allowed to verify that all uncertainties (including uncertainties outside the fields of geoscience data) are properly handled with regard to the safety functions.

The management of the uncertainties was carried out continuously, at all stages of elaboration of conceptual models. The first stage of management of uncertainties is a draw up of a general typology. Concerning geoscience information, it was distinguish (i) Uncertainties concerning intrinsic characteristics of a media, (ii) Uncertainties regarding the processes governing repository evolution, and (iii)

Uncertainties about external events, here mainly naturally occurring phenomena (climatic, tectonic events, erosion process,…) which are in principle predictable but often subject to great uncertainty in space and time. The conceptual models and associated data could be then described, for the use of the safety approach, as “phenomenological”, corresponding to the value best expressing the acquired data and reasonably covering possible variation in space and time, to “conservative” and “pessimistic” taking all the uncertainties into account.

For instance the hydrogeological model at present state was constructed with an evaluation of the impact of uncertainties on some key indicators as travel time or flow directions, using other set of data (like natural tracer data, paleo-hydrogeologic reconstruction,…) in order to assembly some lines of evidences, contributing to reduce uncertainties. The future evolution was then evaluated taking into account all the range of possible events in term of intensity or geographical extent. Finally, the result is an “envelope” view, giving an overall evolution, for which the uncertainties were analysed and quantified to provide a support for the safety analysis.

The traceability of models, parameters and especially uncertainties, from raw data to final assessment was supported by a systematic chapter on uncertainties, indicating how they are managed, in each technical document. This provides the basis of the analysis for the higher level documents.

The effectiveness of the overall method used by Andra has been underlined by the different reviewers of the Dossier 2005 and recommendations have been made for future development.