FROM THE FEASIBILITY ASSESSMENT TO THE LICENSING APPLICATION: ORGANISATION OF THE DATA ACQUISITION, HOW TO DEAL WITH METROLOGICAL LIMITS, UNCERTAINTIES AND PROJECT MILESTONES; HOW FAR MUST WE GO?

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The research work summarised in the "Dossier 2005 Argile" has provided detailed information on each of the repository components but also on the determination, the analysis and the assessment of the main phenomena which are occurring within the repository. Their detailed representation associated with proposed repository architectures allowed the processing of the data in order to assess the robustness of the repository and to see how it would meet safety requirements.

Through various indicators, the analysis showed that the three main safety functions "preventing water circulation", "limiting radionuclides release and immobilising them in the repository" and "delaying and attenuating radionuclide migration" were effectively fulfilled by the proposed system in both normal and much more penalising situations.

The PARS as well as the QSA already facilitated a systematic identification of uncertainties, then allowing covering them either trough cautious hypothesis, penalising or conservative representation of some phenomena or components, sensitivity studies or altered evolution scenarios. Subsequently, the safety analysis revealed some residual uncertainties and margins for potential progress which will provide useful orientations for future research developments.

While the safety analysis conducted reveals that the repository appears to be robust in all the configurations envisaged with respect to its safety functions, both CNE and safety authority evaluations focus on the necessity to provide more comprehensive and realistic modelling of the behavior of the repository (both exploitation and post-closure periods) and of the radionuclides. For example, it is requested not to consider the perturbed zone (EDZ) as a "dead zone" the characteristics and properties of which are set to zero in terms of transport. Similarly, when Andra constructed its safety case, an envelope "hypothesis" for conducting calculations led to consider the repository as fully saturated as soon as its closure. It has been asked to Andra to present for the next dossier a phenomenological approach of the hydric transient taking into account the gas production and migration issues but also the potential consequences of reversibility.

Those recommendations led to set up a scientific programme for the 2008-2012 period that aims at improving the representation of repository evolutions over time, extract the relevant parameters for monitoring during the reversibility phases, reduce the parametric uncertainties and enhance the robustness of models for performance calculations and safety analyses. A few points that appear to be major design factors in the context of this scientific programme deserve to be mentioned by way of example:

- The long-term behaviour of disposal packages and their contents.

- The consistency with the experimental and demonstration programmes implemented in the Bure underground laboratory.
- The continuous links to be established with the input data requirements of the simulation programme.
- The efforts to enhance the representation of phenomenology and various transients (primarily thermal, mechanical and hydraulic) over the first millennia. Scientific progress will have to set out to provide the elements needed to characterise the reversibility phase and provide input to the repository monitoring and observation programme (sensors, data transmission facilities, etc.).

In parallel both safety analysis outcomes as well as evaluators recommendations led Andra to initiate the re-evaluation of the repository architectures especially by taking stock of the margins and uncertainties identified in the "Dossier 2005". Medium and high waste cells deigns, accesses to the repository (ramp or shaft), general architectures of the storage zones as well as the type of materials used constitute the major engineering issues to be dealt with.

In terms of milestones, a step-by-step approach has been preferred in order to fit with the expectations of the national plan for the management of radioactive materials and wastes. The Andra will provide in 2009:

- A range of safety options for the design of the repository.
- The reversibility related options.
- The needs for storage complementary to the repository project and relating options.
- A proposal for a limited area in view of detailed survey for the repository location.
- Supporting documents (geological survey and modelling; design options).

However, such requirements, that frequently request research developments that are at the frontiers of actual science, imply a dedicated organisation of the research programme. For each major research topic, different questions have been addressed in order to dimension the efforts to conduct:

- Up to what extent should we improve the representation of processes?
- What type of development does that implies?
- As far as uncertainties increase over long time frames, when do we stop?
- More generally, how far should we go? What is reasonably accessible? What is beyond the current science limits? And above all, what is really needed?

In the following sections, three examples will be developed in order to illustrate the questions that were addressed when constructing the research programme for the next four years.

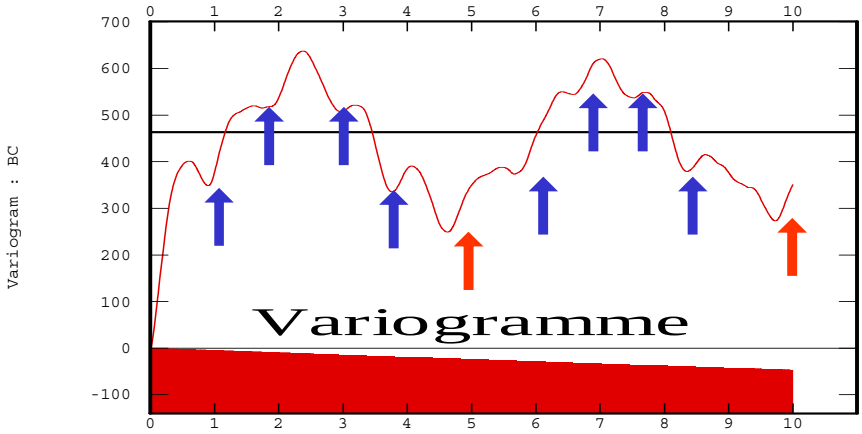
Siting

In order to facilitate the step by step siting of the repository, Andra has planned since 1994 a more and more detailed investigation programme that includes up to 2006:

- 27 specific boreholes with 2 300 metres of clay core-samples
- Specific 2-D and 3-D seismic campaign on the site
- Surveying while shaft sinking; 40 metres of experimental drift at level 455 metres and 550 metres of drift at level 490 metres.

In 2005, the interpretations of classical well logs led to consider the possible occurrence of sedimentation hiatus that could induce consequences on the properties of the host formation. In order to confirm or set aside the occurrence of hiatus, evaluate their duration and their precise location and verify that they don't have any consequence on the properties of the formation, the Fullbore formation Micro-Imager (FMI) with a vertical resolution of de 0.5 cm (instead of 20 to 25 cm minimum for classical well logs) was used. This facilitates detailed geostatistical treatments to be performed and allows a deposition cyclicity of less than 1 m to be detected (Figure 1). It has been shown that this high frequency cyclicity was corresponding to astronomic cycles such as eccentricity (95 Ky at Jurassic times) and obliquity (38 Ky). Cyclicity anomalies correspond to hiatus or low sedimentation rate periods, the duration of which is evaluated. It is also shown that hiatus do not induce lithological discontinuities, and then consequences on rock properties are not expected.

Figure 7. **Deposition cyclicity reconstruction using conventional well logs (plurimetric cyclicity detection: red arrows) and FMI (inframetric cyclicity: blue arrows)**



Conceptual model for transfer processes

Based on numerous experimental data Kd values for major radionuclides of interest have been obtained. Besides, *in situ* and surface laboratory experiments allowed obtaining consistent results on diffusion parameter values. Conclusions were then drawn on anionic exclusion and the strong sorption capacity of cations which were then introduced in PA calculations.

However some major questions remain especially concerning the up- (or down-) scaling:

- Can the differences in macroscopic transfer properties observed in clay-rich compacted materials for non-sorbing anions, HTO and sorbing cations be explained in terms of "mechanism-based" model(s)?
- Can models developed to explain data obtained at different space-time scales be made coherent?

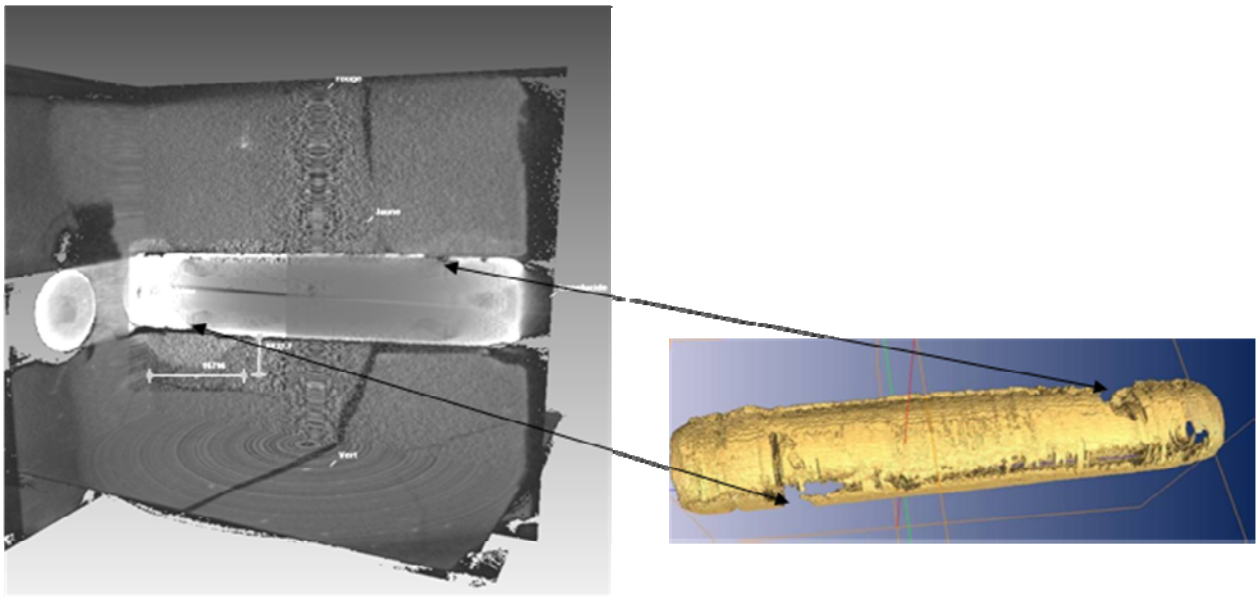
Mechanistic approaches are then required in order to provide additional explanations for the observed experimental results. Molecular dynamics applied to the electrical double layer theory and involving the anion exclusion volume and the surface diffusion coefficient allowed both the anions and cations distributions at the vicinity of clay surfaces and the nano-scale variations of the diffusion coefficient of cations to be calculated. This provides a new insight on the transfer mechanisms that is supposed to facilitate the coherency of the approaches conducted at different scales and on different materials.

Dimensioning: corrosion of metallic materials and their consequences

The modelling of the physico-chemical behavior of vitrified waste cells and the associated near field includes a management of uncertainties based on conservative values of parameters. Possible consequences of such models on other processes such as H2 production and migration are significant. More specifically, the corrosion rates of steels in an anoxic environment led to estimate the lifetime of C waste containers (> 4 000 years), while the extent (few cm) of the Fe/clay disturbance favoured the preservation of clay and argillite properties.

Except the gas issue, the corrosion processes were not a major concern for the evaluators of the "Dossier 2005".

Figure 8. **Integrated experiment glass/iron/argillite: results from tomography**



However, in order to improve the knowledge of the interactions occurring in a C waste cell and of their consequences on glass dissolution, it has been decided to carry an integrated R&D programme associating corrosion, iron-clay interactions and glass dissolution. It aims at contributing to the optimisation of architectures (thickness of steel overpack, gas source term,…), integrating the environmental conditions representative of repository situations and understanding the basic mechanisms even if conservative models are available.

It also necessitates complex integrated experiments (Figure 2) which have never been developed, including difficulties on conception, metrology and interpretations as well as the collaborative effort of research laboratories from different scientific communities.

At this stage of the programme, while the feasibility of the experiments has been demonstrated, preliminary results probably induce more questions than answers.

Concluding remarks

The three examples previously presented show that designing and weighting a scientific programme to move from feasibility to licensing may be tricky. The first example on siting shows that technological progresses may help confirming hypotheses supporting a 3-D geological model and its

consequences on the transfer properties of the host-rock. The second example lies on sophisticated scientific approaches which appear to be essential for improving our understanding of nano-scale phenomena which is probably useful for the consistency of the models designed at different scales and the detailed interpretation of experimental data. The last example corresponds to the temptation to go beyond the frontiers of science and to expect from researchers bound to different communities to combine their skills for solving a complex problem.

Those choices of developing such R&D programmes is in keeping with a process aiming at anticipating questions arising from public and evaluators even if the associated questions do not call the repository safety into question. They also correspond to the necessity to closely follow the progresses of science in order to increase confidence even if this require more and more sophisticated approaches to deal with difficult questions and may lead to an inadequate evaluation of the scientific limits.

Those examples also indicate that:

- Scientific improvements and the new data associated are not easily integrated into a safety case.
- There is a risk to obtain incomplete results in a limited time frame.
- Complex experiments may not be representative (time, environment…).

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