Andra's Strategy and Approach for Management of Uncertainties in Post-Closure Safety of Geological Disposal

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A common protection objective

Objective assigned to any radioactive waste disposal facility :

- Protection of humans being
- Protection of the environment

→ Short and long term

Safety covers all of the measures taken in design, building, operation and monitoring to prevent risks.

Immediate and deferred protection of humans and the environment constitute the fundamental objective assigned to any radioactive waste disposal facility

Andra's Post Closure Safety Approach : Key steps

Input data | Qualitative analyses | Quantitative assessments

Strategy - Context

- Framework and Safety Strategy
- Regulatory Framework/Reference Guidance

Data input – Assessment basis

- Inventory Waste package characteristics
- Site Characteristics
- Design of disposal packages and the facility
- Functions Required
- Scientific Knowledge

Post closure safety assessment

- Post closure safety/analysis of uncertainties (Qualitative Safety Analysis)
- Normal Evolution Scenario ↔ Altered Evolution Scenarios
- Impact of Normal Evolution Scenario and Altered Evolution Scenarios (Indicators)

Compliance with the objectives to be reached

Post closure safety

Challenging Issues

- Management of uncertainties and events
- Development of Scenarios
  - NES: certain or very likely situations
  - AES: hypothetical situations including human intrusion
- Assessment of Impacts (dose, complementary indicators)

- Evaluate the robustness of the repository by exploring
  - Possible malfunctions of the components of the repository (package, cover, sealing, etc.)
  - Human inadvertent intrusion
    - Check that uncertainties are managed either by technical components or by scenarios (NES and related sensitivity analysis / AES)
- Evaluate the safety indicators for each selected scenario,
  - Compliance with protection objectives
  - Check that the performances of the design components are reached to ensure safety functions
- Contribute to give a feed-back for research and design
  - Measures in terms of design

Post closure safety : Type of Uncertainties and Events

- Uncertainties on the Repository Project input data
  - Waste inventory and characteristics
- Uncertainties regarding the characteristics of the components:
  - Inaccuracy of measurement techniques
  - Relevancy of using documentary data (if not accessible through measurement)
  - Control of scale changes (sometimes limited number of samples)
  - Underlying model for defining processes (e.g., Kd notion), etc.
- Uncertainties on the processes governing the evolution of the repository :
  - Thermal, Hydraulic, Mechanical, Chemical, Radiological, Bacteriological and Gas (THMCRBG) behaviour
  - Validity limits of the model(s) used to represent them
  - Validity limits of the models over long timescales, etc.
- "Technological" uncertainties or implementation of technologies
- External events
  - Earthquake, flooding, climatic conditions
  - Intrusions

Post closure safety - Managing uncertainties and events

Qualitative Safety Analysis

On the base of an inventory of all uncertainties

- Explores possible dysfunctions of the repository components (waste package defects, seal failures,....)
- And examine if it can:
  - Affect its capacity to fulfil a safety function
  - Have an influence on the ability of another component to fulfil a safety function

Managing uncertainties

By design :

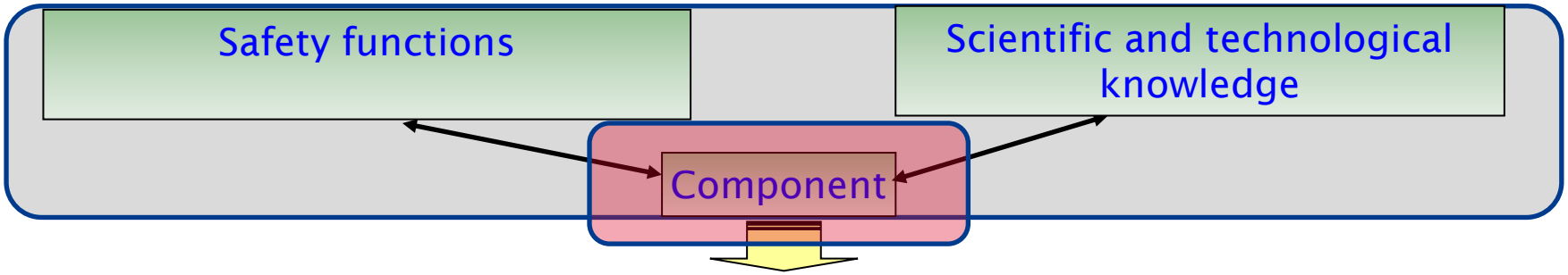
- Specific or generic measures

By definition of calculation cases in scenarios:

- Through conservative choices or sensitivity analysis in the normal evolution scenario
- Or through the definition of calculation cases in altered evolution scenarios (and their sensitivity studies)

QSA Methodology – Input data

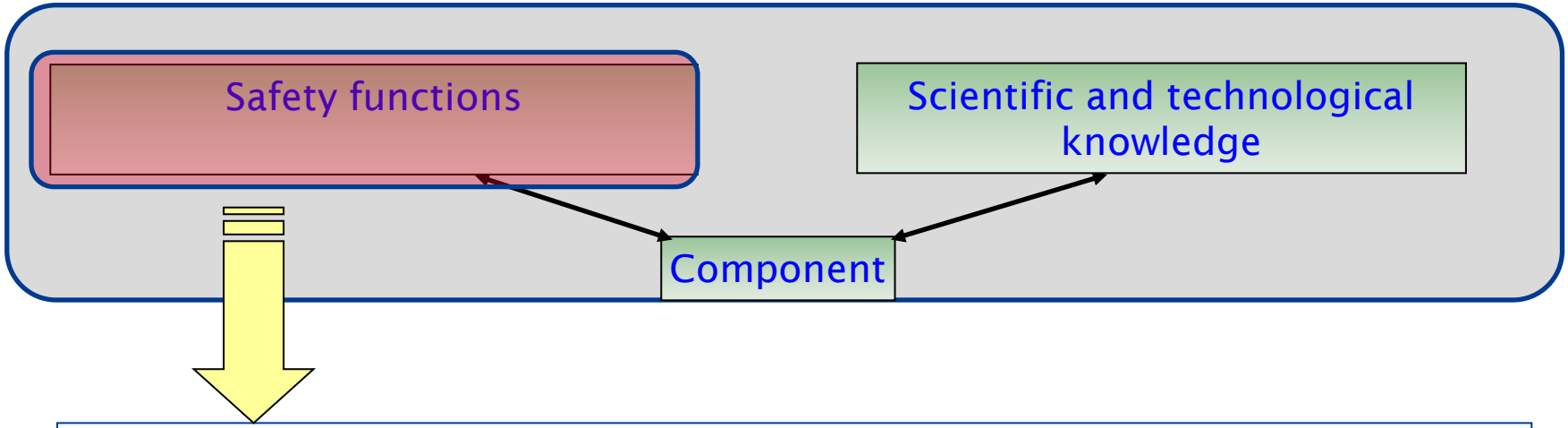
- The QSA is performed component by component
  - + *Allows the connection between safety function and scientific and technical knowledge with the associated uncertainties*



- Components contributing to the performance of one or more safety functions
  - + *Engineered component or pre-existing components (ex: waste)*
  - + *Uncertainties on those component are susceptible to significantly alter their ability to realise the expected performance of the function*
- Component not directly involved in the realisation of safety function but required for quantification.
  - + *May be important for quantification of the impact (ex: biosphere)*
- All components whether they contribute to safety functions or not, may induce perturbations
  - + *Have to be included in the analysis*

QSA Methodology – Input data

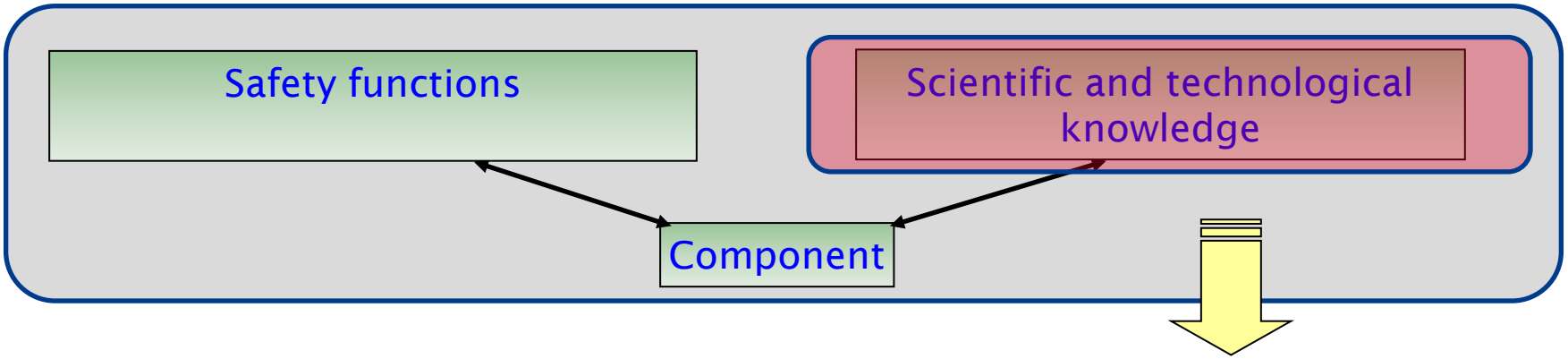
- Analysis of uncertainties component per component



- Per component , data relative to the safety function
  - + *Identification of safety function*
  - + *Level of performance*
  - + *Period during which the performance of the function has to be available*

QSA Methodology – Input data

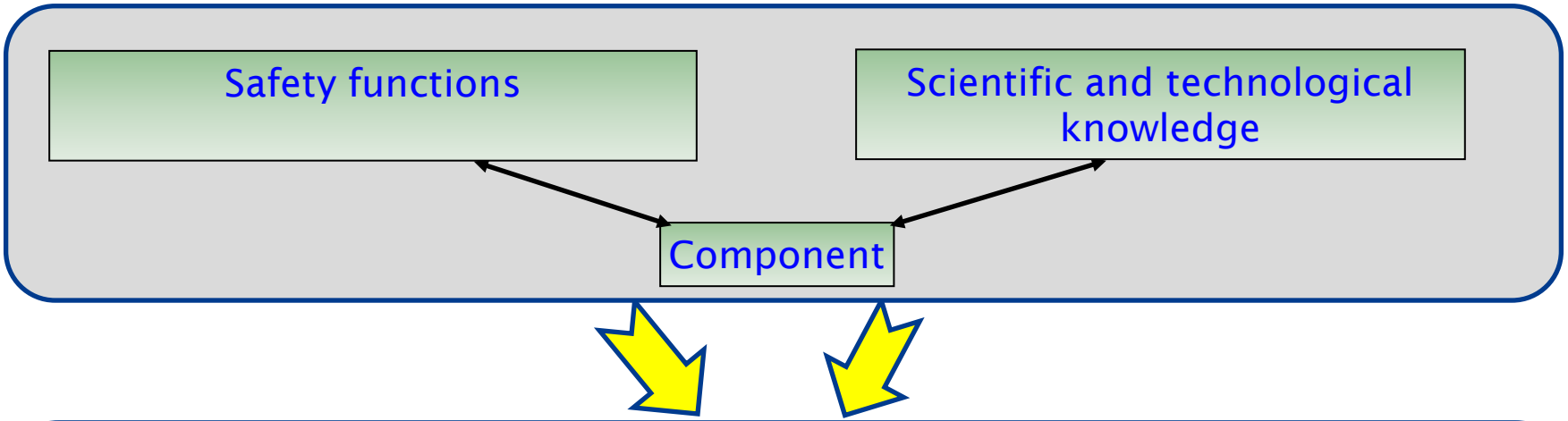
- Analysis of uncertainties component per component



- Data relative to the design of each disposal component
  - + *Description of the disposal system, implementation, location in the disposal*
  - + *Uncertainties taken into account if relevant regarding technological aspects (quality assurance…)*
- Data relative to scientific knowledge (Phenomenological Analysis of the Repository Situation (PARS))
  - + *Component Characteristics, Thermal (T), Hydraulic (H), Mechanical (M), chemical (C), radiological (R), bacteriological (B) processes and gas (G), Models/parameters and associated uncertainties*
  - + *Coupling of processes and associated uncertainties*
  - + *Interactions with surrounding components*
  - + *Evolution over time*
  - + *External probable events (e.g. climatic and geodynamic evolutions)*

QSA Methodology – Analysis

- Analysis of uncertainties component per component



- And examine if it can:
  - + *Affect its capacity to fulfil a safety function,*
  - + *Have an influence on the ability of another component to fulfil a safety function,*
  - + *Modify the environment of the component in such a way that it can influence the manner in which the component fulfils its functions.*

A method applied within the framework of the 2005 file
(D 2005, Safety Assessment Volume – Chapter 6)

QSA– Datasheet

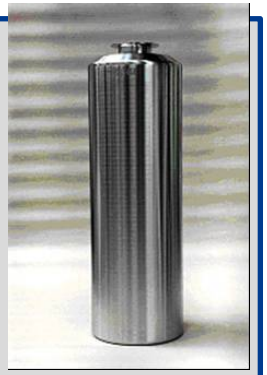
Illustration D2005

- Production of Datasheets :

  One per component
  - Collection and treatment of uncertainties

- Production of a summary table
  - Global analysis, identification of failure modes
  - Analysis of uncertainties in a coupled manner
    - » *Possible combination of uncertainties which could lead to altered situations undetected by the individual analysis of uncertainties*

Component



1. Safety functions of the component and associated performances

2. Design measures

3. Component characteristics
   - + *TH(G)MC(B)R processes, evolution and coupling*
   - + *Models and parameters (variability and uncertainties)*

4. Environment of the component – Potential interactions
   - + *Internal interactions induced by other components of the disposal*
   - + *External events*

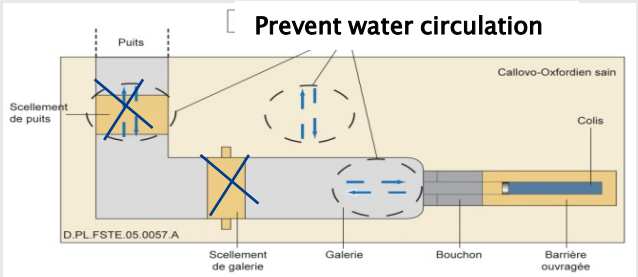
5. Summary of uncertainties and their management

Conclusions

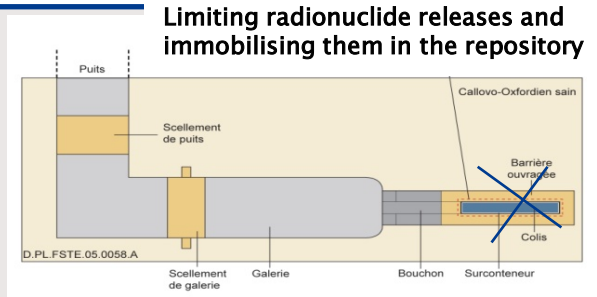
QSA : A systematic method to manage uncertainties *(Comparison with FEP databases)*

Three Altered-Evolutions Scenarios associated to QSA (from D2005)

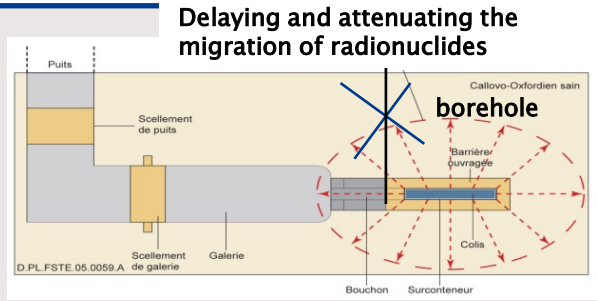
- "Seal-failure" scenario
  - Failure of shaft or galleries seals, or of all seals.
  - Sensitivity studies at the containment parameters of the EDZ, seals, etc.



- "Package-failure" scenario
  - Failure of all or part of over-containers for vitrified waste.
  - Sensitivity study to test the influence of the hydraulic transient.

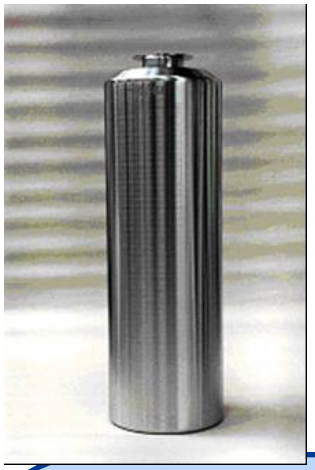


- "Borehole" scenario
  - Different locations, one or two boreholes.
  - Sensitivity studies to the characteristics of the EDZ (K), of packages, etc.



Thank you

1. Example from D2005 - QSA Analysis of vitrified HA waste packages



» Safety functions of the component

❑ Limit the radionuclide and chemical toxic release and immobilise them in the repository"

+ *Limiting the aqueous alteration of the glass*

» Characteristics associated with the performance of safety functions

❑ Glass-dissolution model: pH, Vo, Vr, T, S, weight, [Si],

Uncertainties regarding the dissolution model of the glass during the thermal phase

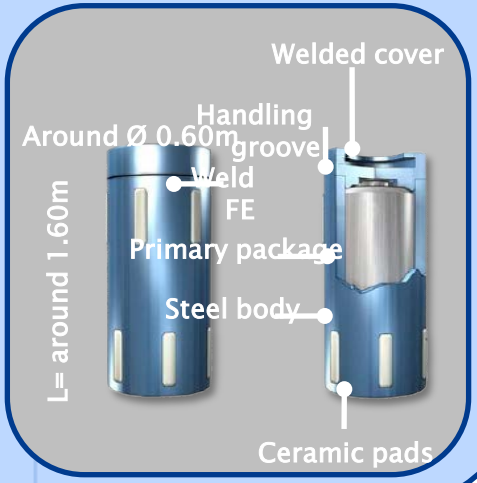
➢ *Effect on the safety function: "limit the radionuclide release and immobilise them in the repository"*

Management of the uncertainty by design measures

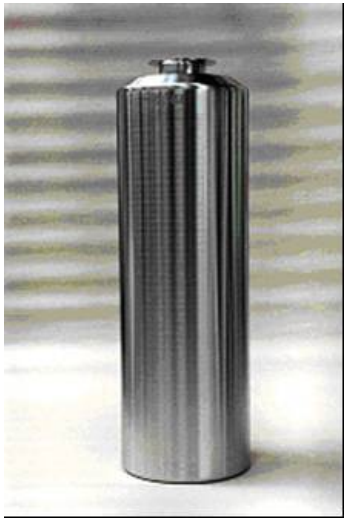
❑ Temperature limitation between cell

❑ Solution retained to ensure the function: Over-container

+ *Will prevent water to access the glass matrix during the thermal phase (50°C)*



2. Example from D2005 - QSA Analysis of vitrified HA waste packages



- Safety functions of the component
  - Limit the radionuclide and chemical toxic release and immobilise them in the repository"
    - + *Limiting the aqueous alteration of the glass*
- Characteristics associated with the performance of safety functions
  - Glass-dissolution model: pH, Vo, Vr, T, S, weight, [Si],

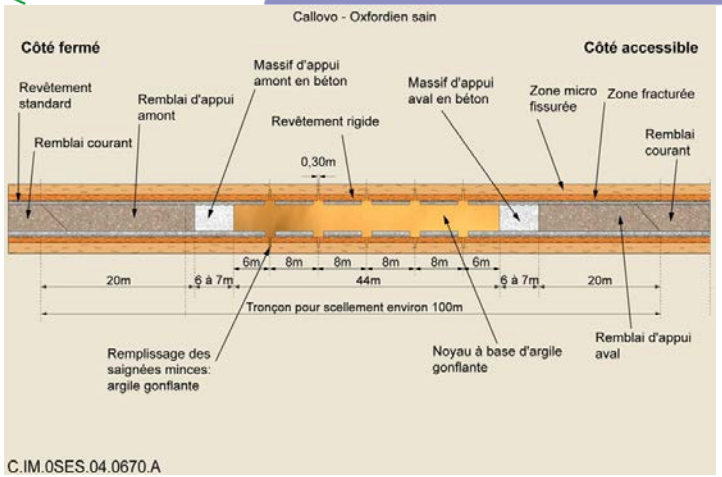
Uncertainties associated to those models/parameters

- *Effect on the safety function: "limit the radionuclide release and immobilise them in the repository"*

Management of uncertainty by sensitivity studies of the normal-evolution scenario

- + *Vo → Vr is a model providing significant experiment feedback, but underlying mechanisms remain to be understood → sensitivity study of the normal-evolution scenario*
- + *The surface accessible to water (S) is uncertain → sensitivity study of the normal-evolution scenario*

3. Example from D2005: QSA Analysis of galleries seal



- Safety functions of the component
  - Prevent the circulation of water
- Characteristics associated with the performance of safety functions
  - Low permeability seal (bentonite) + seal hydraulic cut-offs (of the EDZ)

→ Uncertainties on EDZ

→ Emplacement of seal hydraulic cut offs

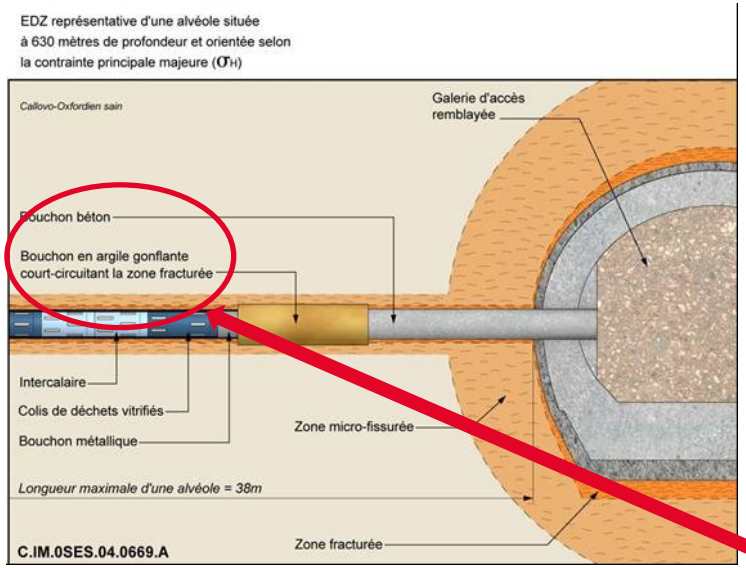
→ Technological uncertainty on the realisation of seal hydraulic cut offs

Management of uncertainties:

The Assumes that loss of rock confinement is not compensated by swelling of the bentonite bricks.

→ Addressed in the AES "Seal failure" by an ineffective swelling of the clay in the cut-offs, which are bypassed by a fractured EDZ.

4. Example from D2005 - QSA Analysis of the Callovo-Oxfordian host rock



- Safety functions of the component
  - Delaying and attenuating the migration of radionuclides
- Characteristics associated with the performance of safety functions
  - Favourable characteristics of the Callovo-Oxfordian (permeability, diffusion, retention properties, solubility)

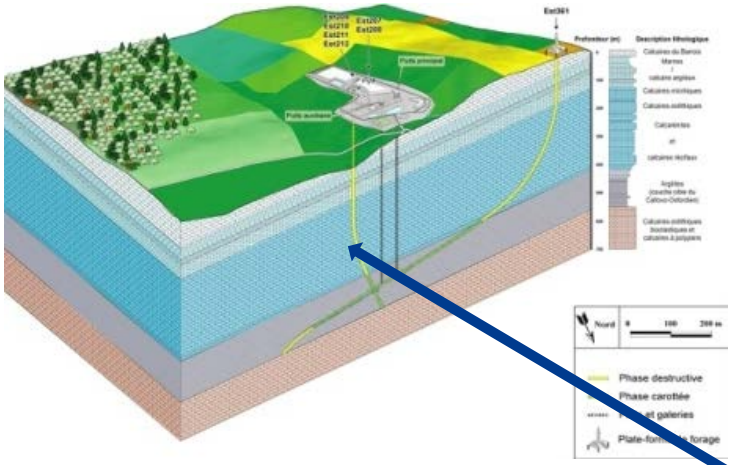
- Disturbances from the waste packages
  - *Heat produced by the waste*

Management of uncertainties:

+ *The heat produced by vitrified waste may interfere with the functions of the host rock (limiting and mitigating radionuclide migration)*

→ *Addressed by design: Limitation of temperature (<90°C)*

5. Example from D2005 - QSA Analysis of the Callovo-Oxfordian host rock



- Safety functions of the component
  - Delaying and attenuating the migration of radionuclides
- Characteristics associated with the performance of safety functions
  - Favourable characteristics of the Callovo-Oxfordian (permeability, diffusion, retention properties, solubility)

- External events
  - *Inadvertent human Intrusion due to a loss of the memory of the repository*

Management of uncertainties inadvertent human intrusion:

\+ *Influence of the uncertainty on duration of the memory*

On the long term → Addressed by AES Borehole at a reasonable date (after 500years as required by NSA)