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Babylon: R&D program for French Bituminized Waste Products acceptability in deep geological repository

Pierre Vigneron, Jean-Baptiste Champenois, Paul Jourda, Celia Alameda Angulo, Sylvie Granet, Stéphan Schumacher

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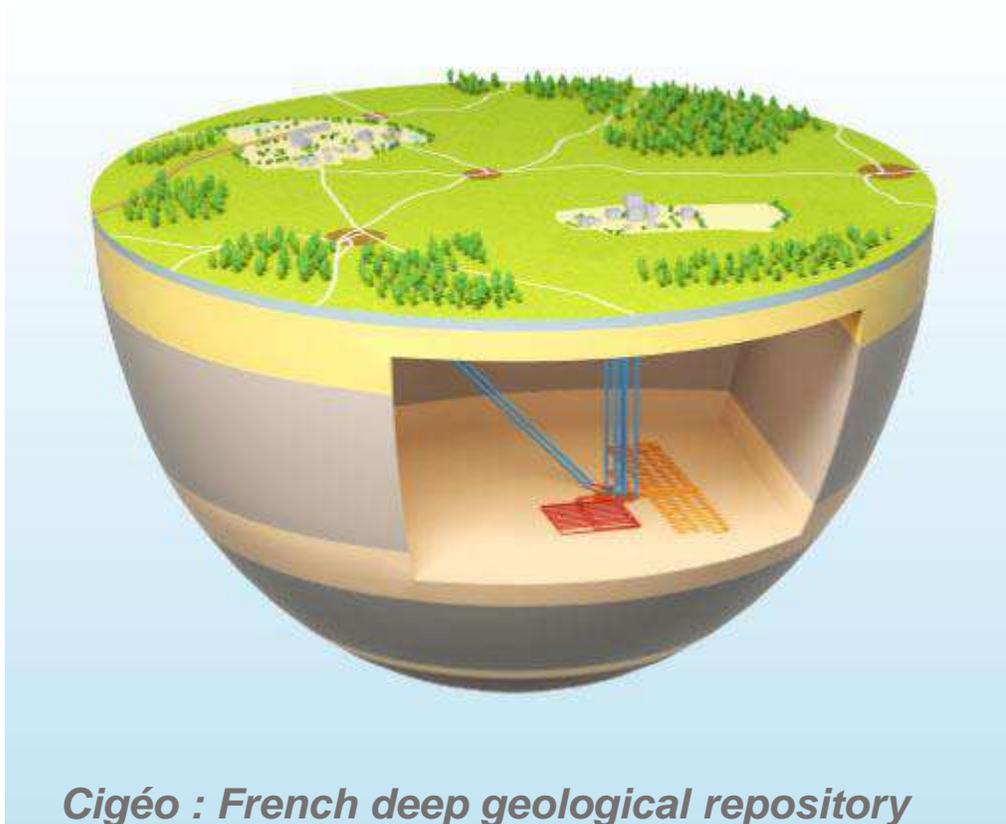
The logo for CEA (Commissariat à l'énergie atomique et alternative) features the lowercase letters 'cea' in a white, rounded, sans-serif font. A thin green horizontal line is positioned below the letters. The logo is centered within a white square that is itself centered on a red background.The logo for Orano consists of a stylized yellow circular graphic made of multiple overlapping lines, resembling a globe or a sun. Below this graphic, the word 'orano' is written in a bold, black, lowercase sans-serif font. The logo is centered within a white square that is itself centered on a red background.The logo for EDF (Électricité de France) features a stylized orange flower-like symbol with five petals. To the right of this symbol, the letters 'edf' are written in a bold, blue, lowercase sans-serif font. The logo is centered within a white square that is itself centered on a red background.The logo for ANDRA (Agence nationale pour le traitement et le stockage des déchets radioactifs) features a stylized green leaf-like shape on the left, with a yellow arc below it. To the right of this graphic, the word 'ANDRA' is written in a blue, uppercase sans-serif font. The logo is centered within a white square that is itself centered on a red background.

DE LA RECHERCHE À L'INDUSTRIE

Babylone: R&D program for French Bituminized Waste Products acceptability in deep geological repository

GLOBAL 2022, July 6 - 8 2022, Reims, France

P. Vigneron, J-B Champenois, P. Jourda, C. Alameda Angulo, S. Granet, S. Schumacher



Cigéo : French deep geological repository

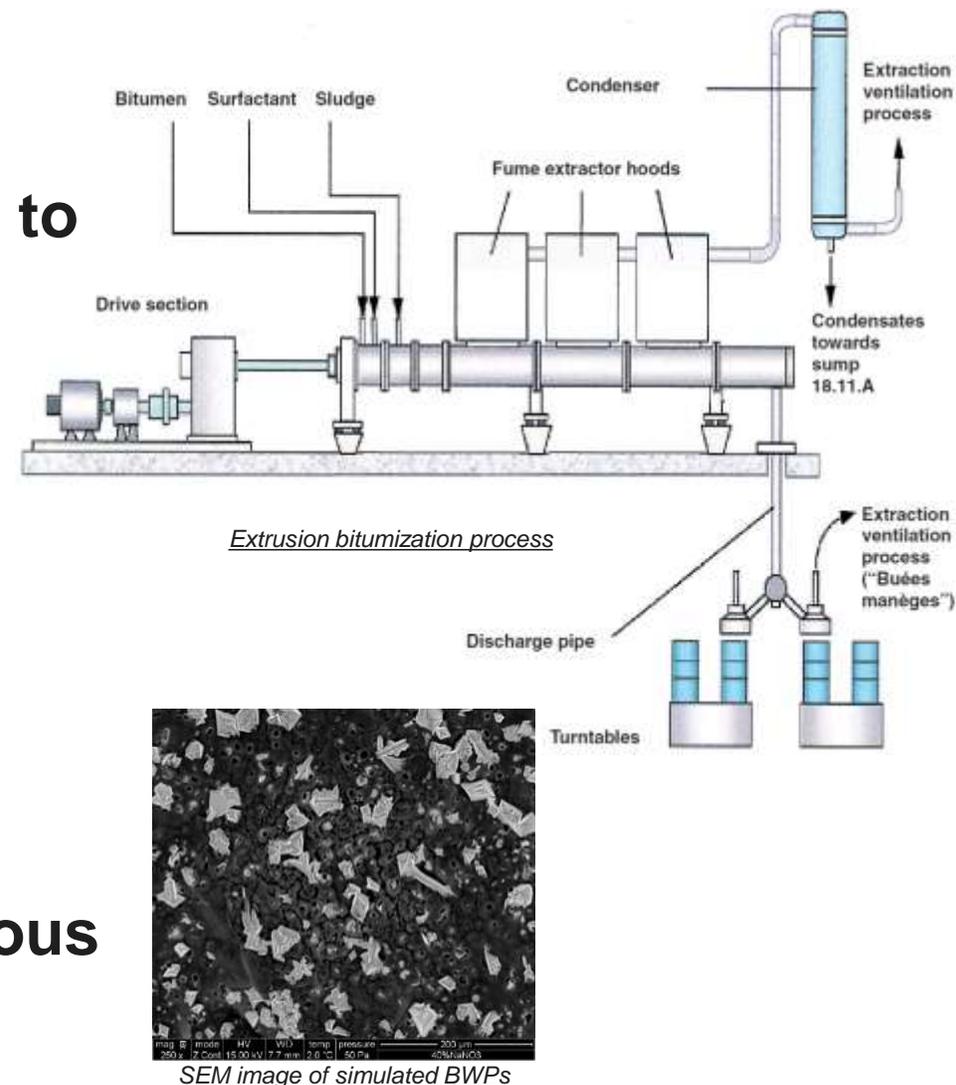
► Introduction

► Babylone R&D program

- BWPs thermal reactivity
- BWPs thermal behaviour
- BWPs long-term behaviour in repository

► Conclusion

- ▶ **Production started in the 1960's and still goes on**
 - Waste characteristics evolve over time
- ▶ **Issued from co-precipitation sludges related to reprocessing nuclear spent fuels**
- ▶ **Several inorganic reagents**
 - Co-precipitation salts: $\text{Fe}(\text{OH})_3$, BaSO_4 ...
- ▶ **Specific bitumen quality: 70/100**
- ▶ **Produced by extrusion to have an homogenous mixture**



French BWPs have been produced on 2 sites:

- ▶ La Hague: interim storage of ~ 13 000 drums

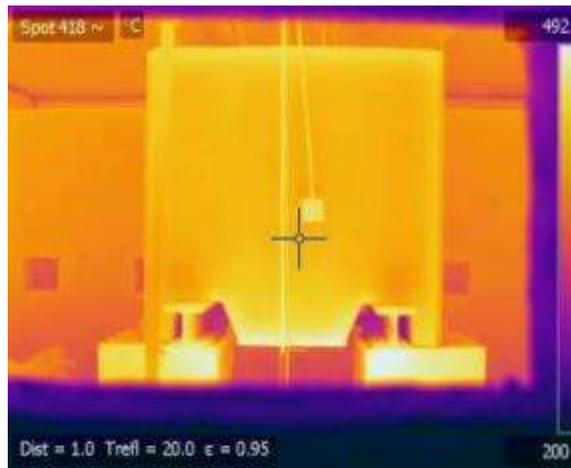


- ▶ Marcoule: interim storage of ~ 62 000 drums

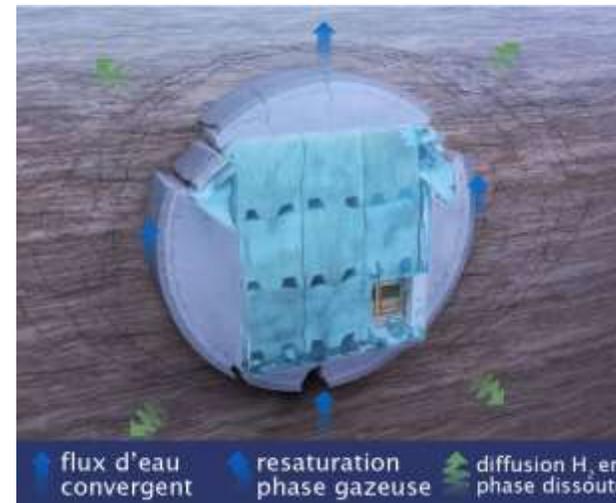


2 main issues to be tackled:

- ▶ During the exploitation period: BWPs behaviour subsequent to thermal stress (fire case)
- ▶ Over the exploitation period: BWPs long-term behaviour (~ 100 000 y) when water will resaturate disposal cells



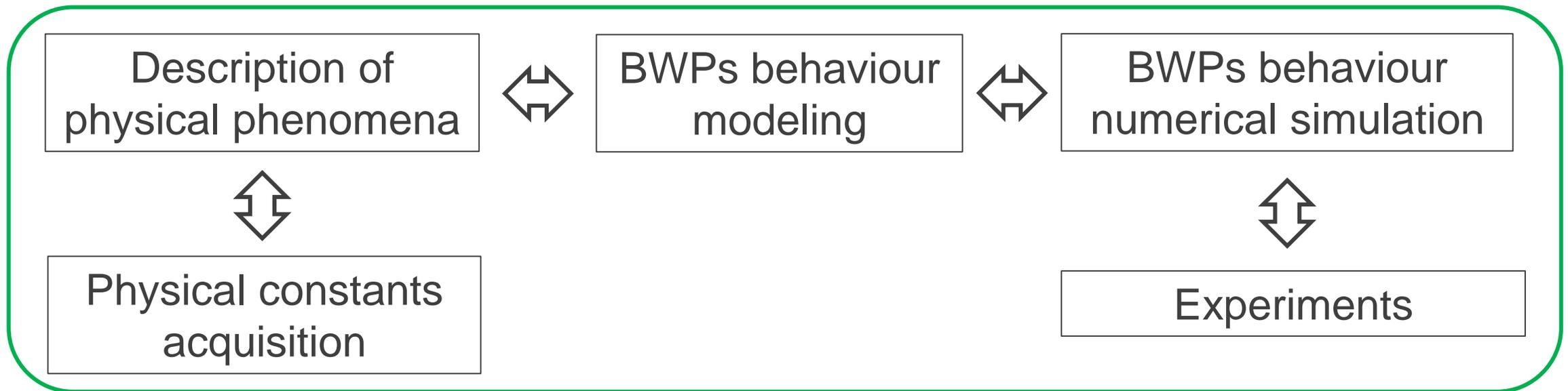
Heating in an oven of a concrete container filled with simulated BWPs drums



Over 100 000 y : water resaturates disposal cells and hydraulic equilibrium is recovered

A complementary approach based on:

- ▶ Phenomenologic knowledge
- ▶ Modeling & simulation
- ▶ Experiments

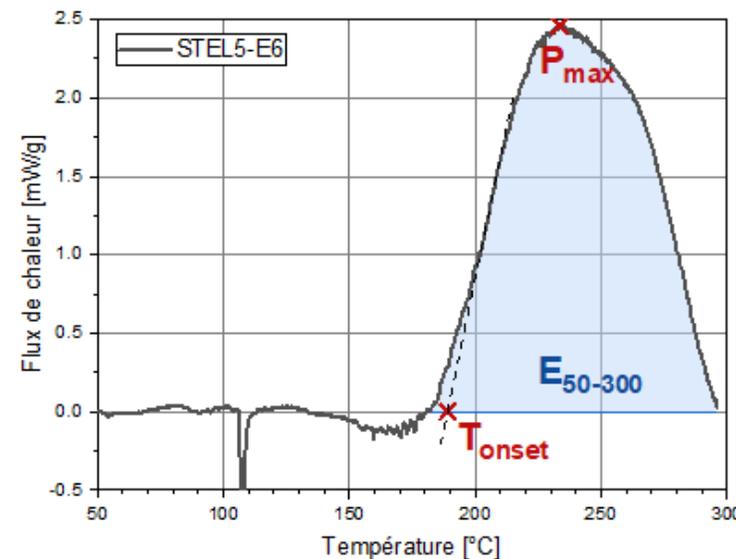


Partners : Andra, CEA, EDF, Orano

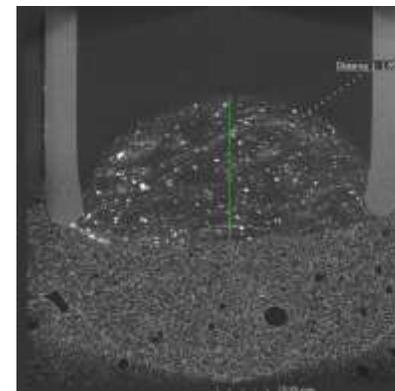
Duration : 2020 – 2026

3 Topics :

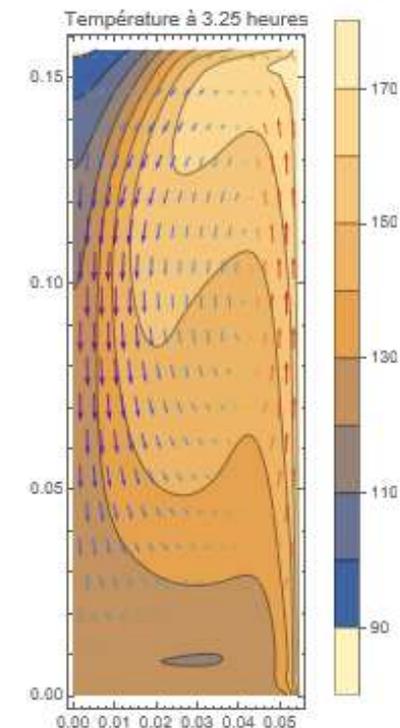
- ▶ BWPs thermal reactivity
- ▶ BWPs thermal behaviour
- ▶ BWPs long-term behaviour in repository



Microcalorimetry measurement of simulated BWPs



Tomography image of simulated BWPs free leaching test



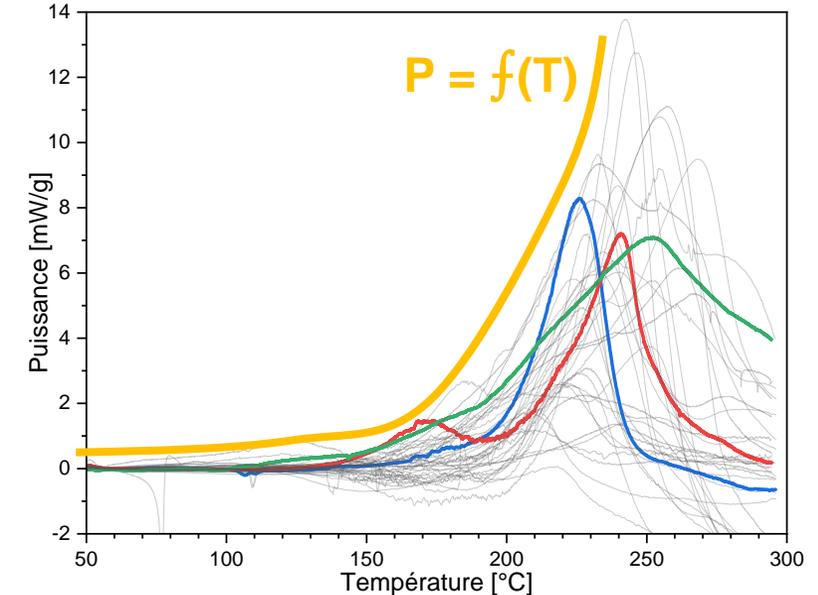
Thermohydraulic simulation of BWPs in a wall-heated 2L vessel

French BWPs described by 6 composition domains

Energy, Power and T_{onset} previously acquired with experimental designs

What is foreseen in Babylone:

- ▶ To assess uncertainties
- ▶ To establish envelope curves of chemical reactivity
- ▶ To figure out data on real BWPs by sampling drums in La Hague and Marcoule



*Example of superimposed thermograms
in order to define envelop curves*

Previously studies on just-made non-radioactive BWPs and conservative approach modeling based on conduction phenomenon

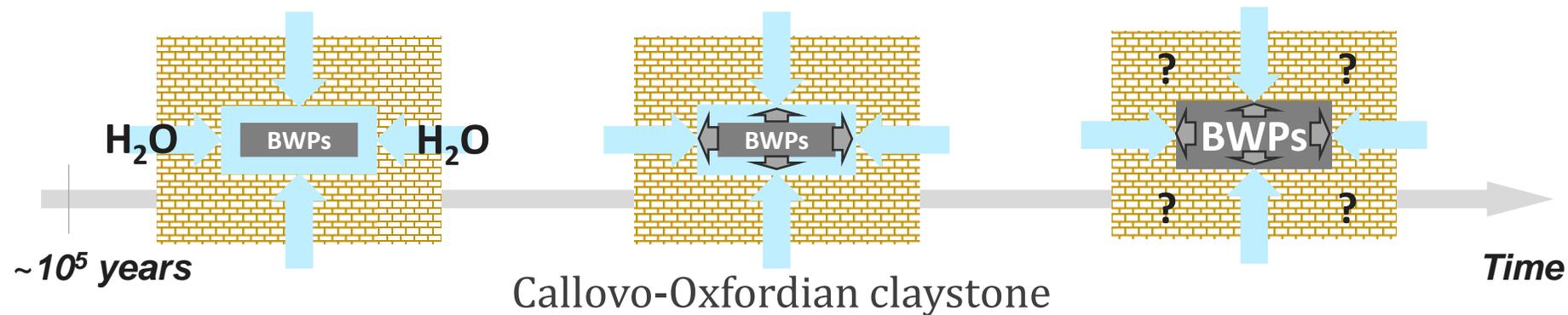
What is foreseen in Babylone:

- ▶ **To study the effect of radiolytic ageing on BWPs thermal behaviour:**
 - External irradiation of non-radioactive BWPs at different doses
 - Physico-chemical constants acquisition of these materials
 - Influence of the presence of H₂ gas bubbles
 - Influence of doses equivalent to 200 years ageing
- ▶ **To validate BWPs thermohydraulic modeling with thermal stress experiments on drum scale**

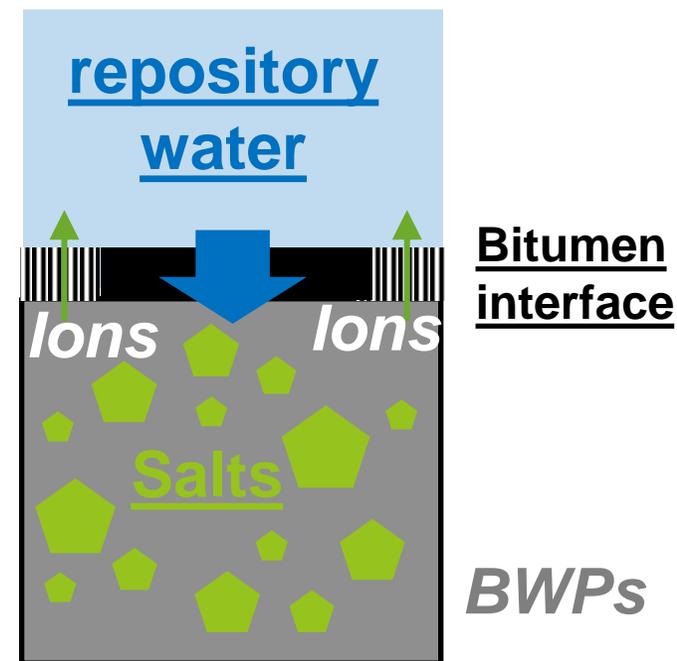


Example of 2L vessel for heating tests of simulated BWPs

BWPs long-term behaviour in repository



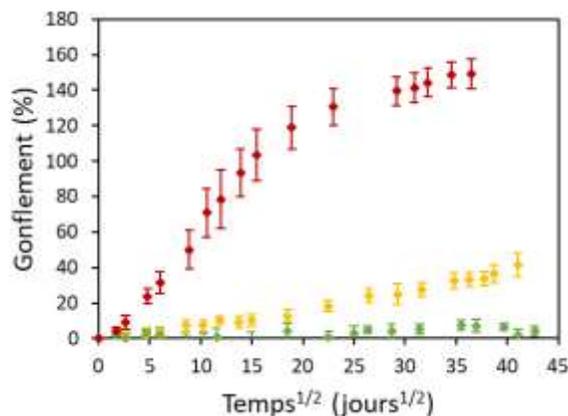
- ▶ Osmotic phenomenon → Water uptake
- ▶ Salts leaching
- ▶ Swelling



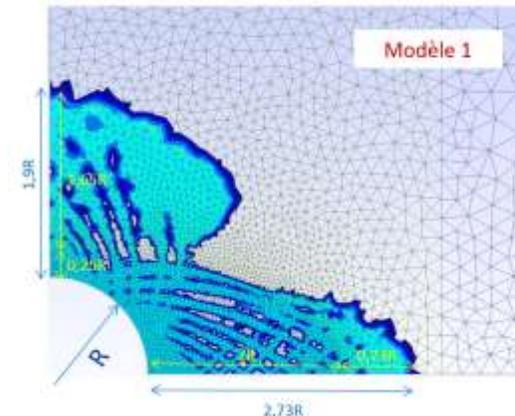
Previously conservative approach : maximum of the theoretical BWPs swelling pressure applied on the disposal cell wall and considered as constant in time

What is foreseen in Babylone:

- ▶ To collect experimental data related to leaching BWPs behaviour in volume- or stress-constrained conditions
- ▶ To build a hydromechanical model with these data
- ▶ To simulate Callovo-Oxfordian behaviour under BWPs swelling stress



*Free leaching tests:
Swelling of mono and bisalts BWPs*



*Example of claystone hydromechanical
simulation under BWPs swelling stress*

Andra, CEA, EDF and Orano have launched a R&D program on BWPs for a period of 6 years.

Its main objectives are:

- ▶ To confirm the design and implementation of disposal cells and to increase safety margins during the operation of disposal cells**
- ▶ To consolidate the safety assessment during BWPs disposal**
- ▶ To increase safety margins during BWPs disposal**

Thank you for your attention

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P. Vigneron¹, J-B Champenois¹, P. Jourda¹, C. Alameda Angulo², S. Granet³, S. Schumacher⁴

¹ CEA, ² Orano, ³ EDF, ⁴ Andra