Long-term Simulation of THM coupled Behavior in the Heater Emplacement experiment at Mont-Terri Underground Research Laboratory

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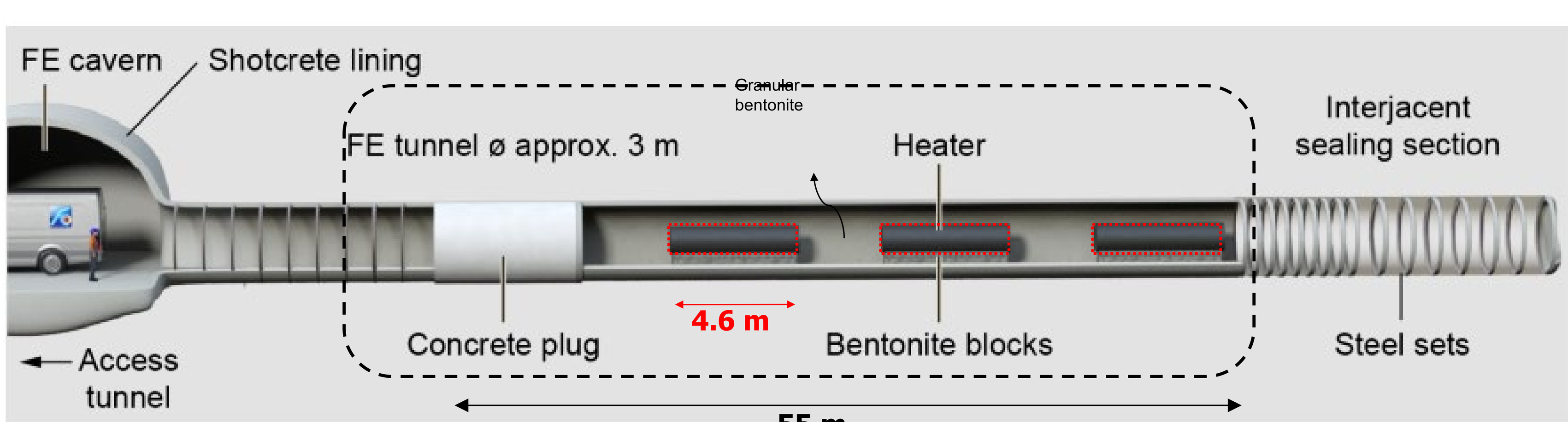
Introduction

Especially in the engineered barrier system in the high-level radioactive waste (HLW) disposal system, complex thermo-hydro-mechanical (T-H-M) coupled behavior affects the performance of buffer material and host rock. Numerical simulation is an effective method to predict the long-term behavior of the complex coupled behavior, but validation and verification are essential for ensuring the simulator's reliability.

As a part of the DECOVALEX (DEvelopment of COupled models and their VALidation against EXperiments) Project, an international joint research for developing a numerical model for thermo-hydro-mechanical-chemical coupled behavior in the high-level radioactive waste disposal system, we performed a series of T-H-M coupled numerical simulation based on the full-scale heater emplacement experiment performed at Mont-Terri underground research laboratory in Switzerland. The T-H-M simulation results in the bentonite and host rock are presented in this study.

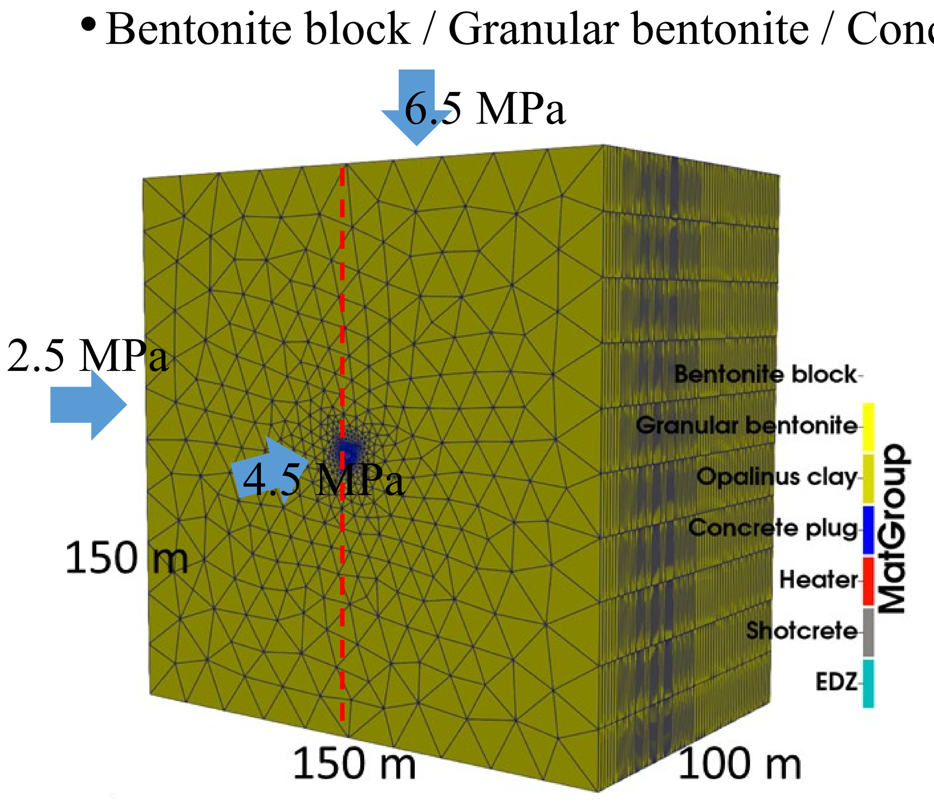
FE experiment

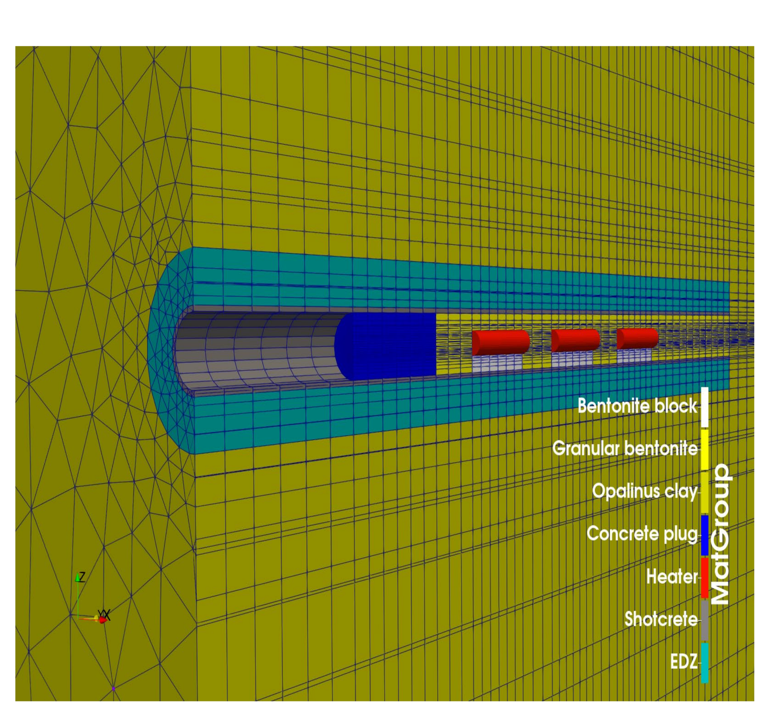
- **Full-scale Emplacement (FE) experiment at the Mont Terri URL**
  - Replicates the emplacement tunnel of Nagra's reference repository design at 1:1 scale.
- **Objectives of the experiment are:**
  - To investigate SF / HLW repository-induced **THM coupled effects** of the host rock
  - To verify the **technical feasibility** of constructing an emplacement tunnel
  - To **optimize the bentonite buffer** material design and production
- **Scheme of the experiment**



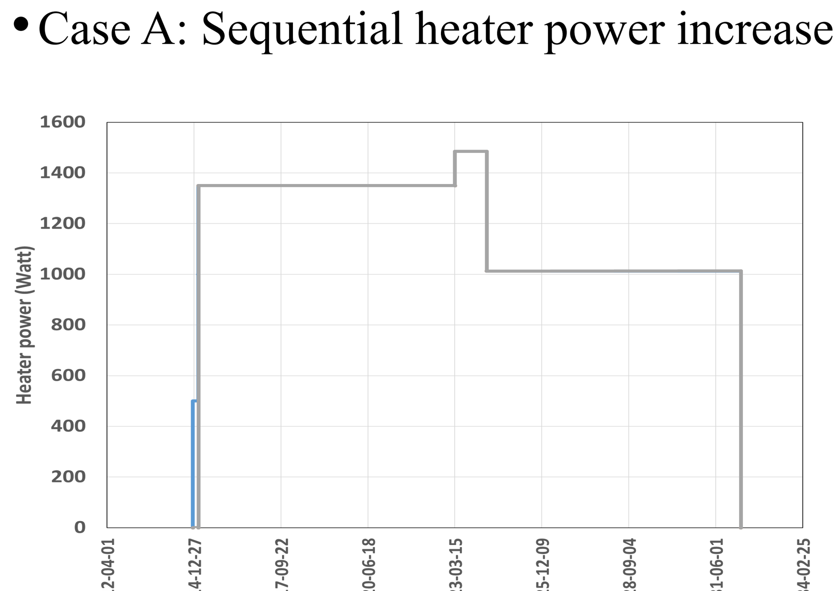
Numerical model

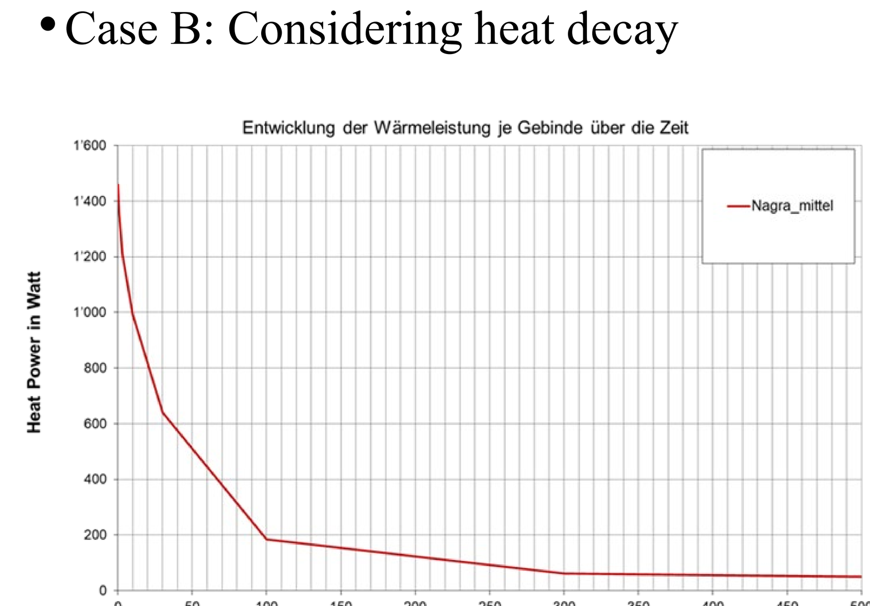
- **Numerical model**
  - Node: 65,000 / Element: 124,000
  - **OGS-FLAC** simulator
  - Prism shape mesh using Gmsh
  - Domain: 150 m x 150 m x 100 m
  - Boundary conditions: constant normal stress
  - Three heaters are modeled with pedestals.
  - **T-H-M anisotropy** of the host rock was considered.
  - **Richards flow model** for the **two-phase flow** analysis
  - Bentonite block / Granular bentonite / Concrete plug / Shotcrete / EDZ / Heater / Rock





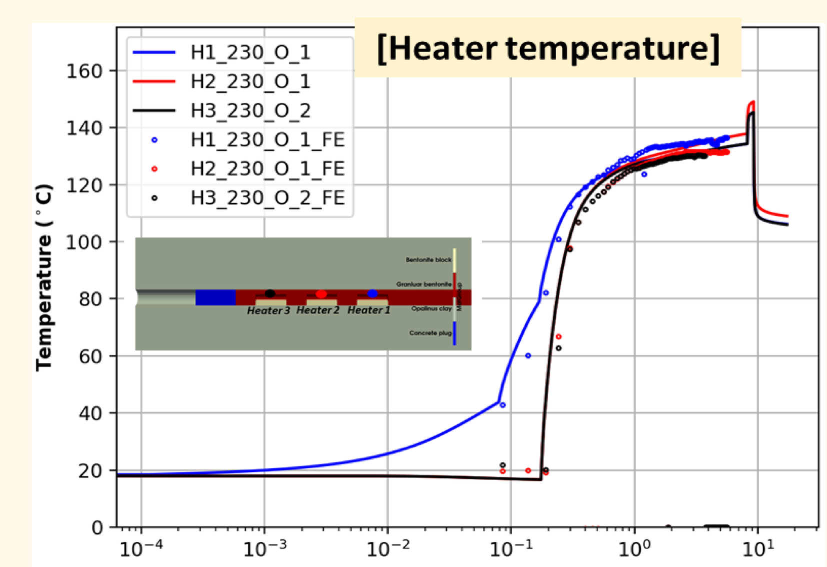
- **Heating scenario**
  - Case A: Sequential heater power increase
  - Case B: Considering heat decay



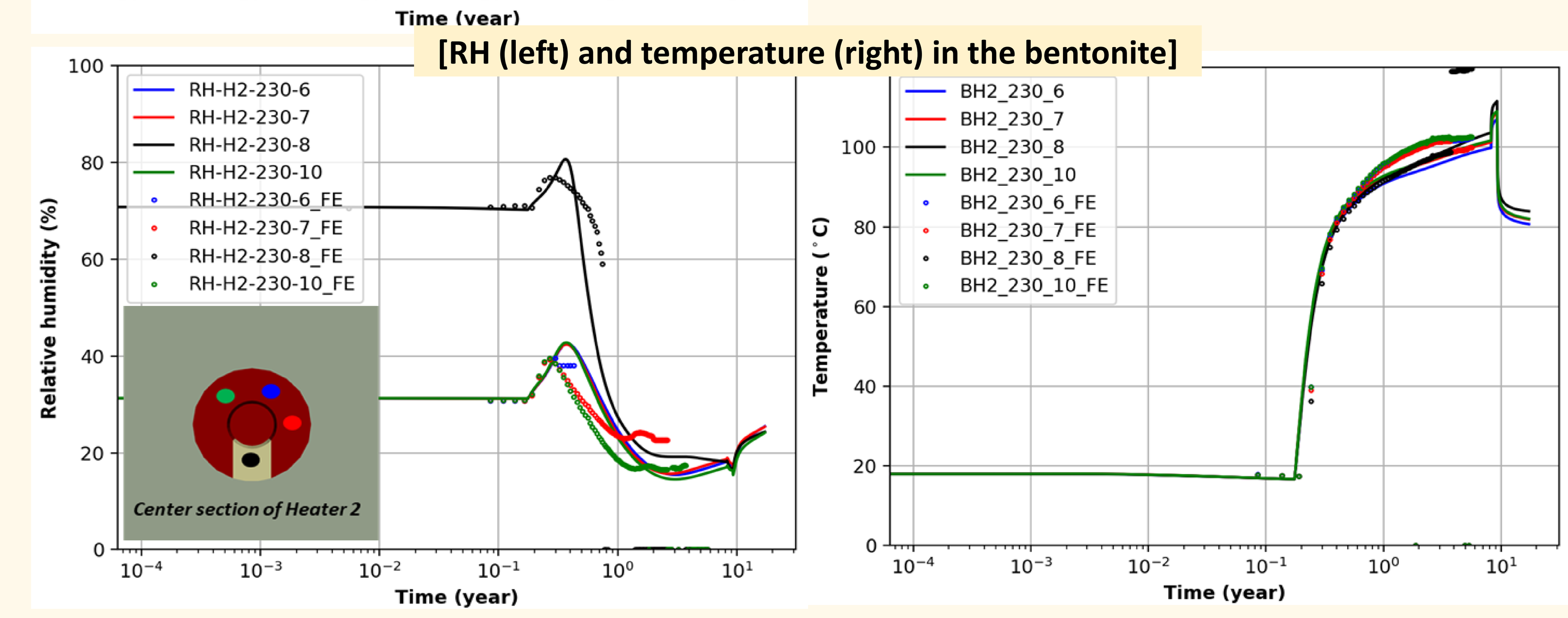


RESULTS

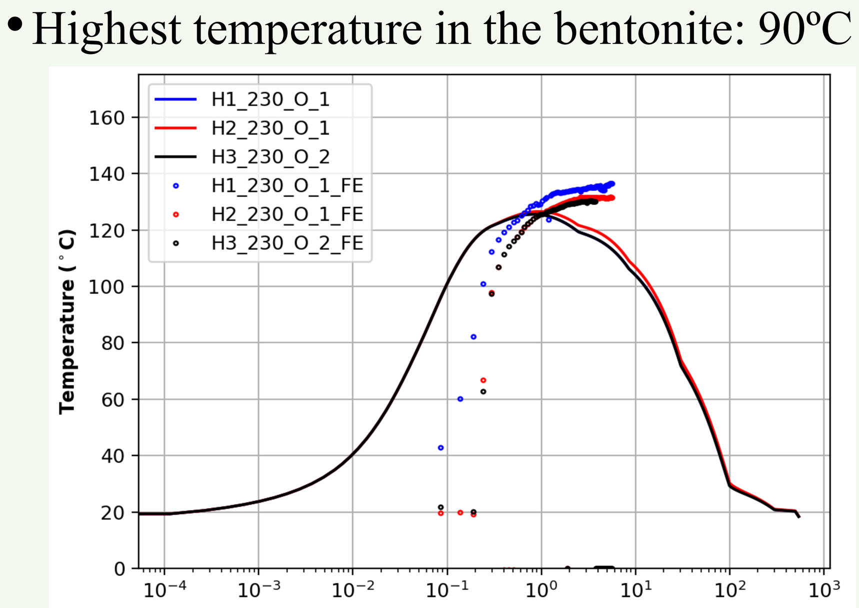
- **Case A: Sequential heater power increase (18 years)**
  - Extended heating plan: Based on Nagra's schedule for 18 years
  - Maximum temperature in the bentonite: 149ºC / depending on heater power schedule
  - Maximum temperature/pressure in the Opalinus clay: 35ºC & 2.5 MPa
  - Solid line: simulation / Dots: field-data



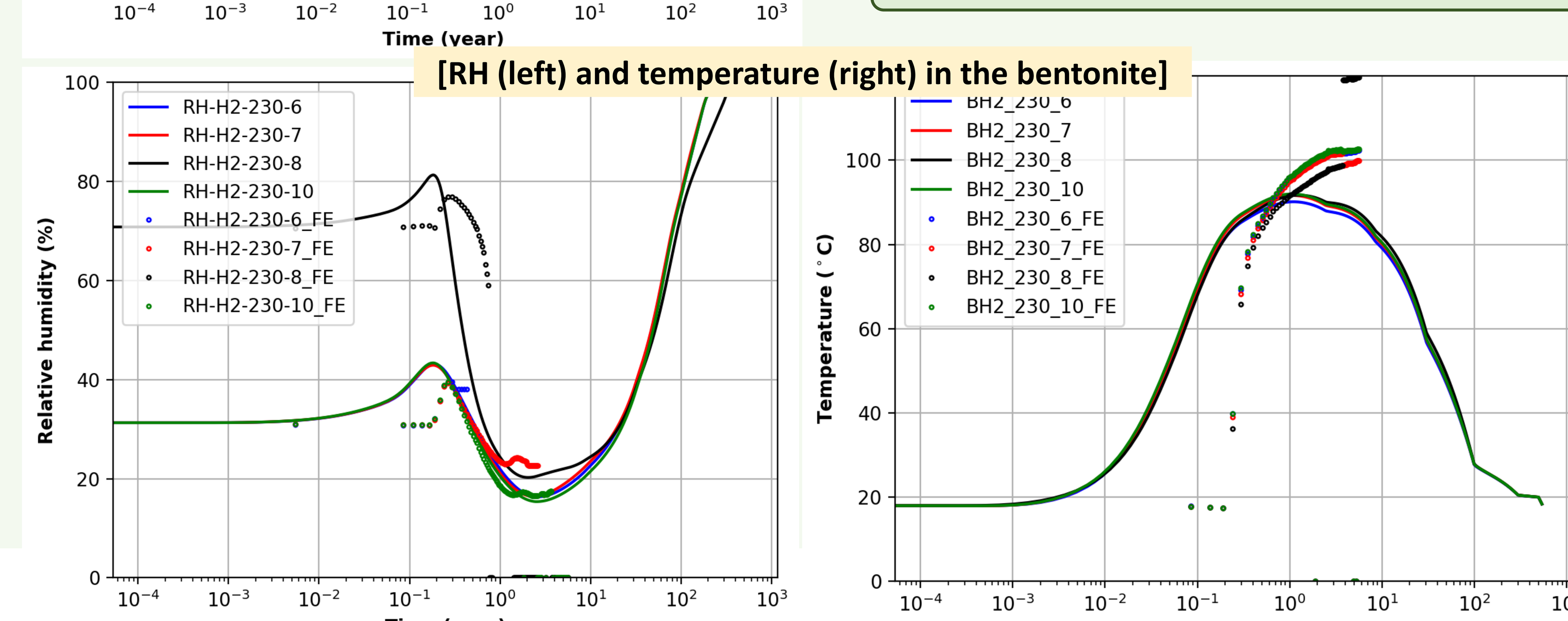
- Results in the bentonite:
  - ✓ Well-matched heater temperature following the heating schedule
  - ✓ Well-matched bentonite temperature
  - ✓ Well-matched RH
  - ✓ RH decrease due to heating & RH increase after temperature decrease due to water inflow effect



- **Case B: Considering heat decay (500 years)**
  - Maximum heater temperature: 126ºC at heater 2 after 1 year of heating
  - Bentonite fully saturation: 150 years after heating
  - Highest temperature in the bentonite: 90ºC after 1 year of heating



- Results in the bentonite:
  - ✓ Lower heater temperature due to lower heater power
  - ✓ Fully saturation of bentonite due to groundwater inflow
  - ✓ Faster saturation due to capillary effect
  - ✓ Temperature decrease in the bentonite due to saturation increase



CONCLUSIONS

- **OGS-FLAC** was applied for T-H-M coupled simulation of the FE experiment.
- **T-H-M anisotropy** of the host rock was well simulated with the **two-phase flow analysis**.
- THM simulation results matched well with the FE experimental data.
- The highest temperature was depending on the maximum heater power.
- Depending on the distance from the disposal tunnel, the dominant factor affecting the pressure gradient in the host rock was varied.

ACKNOWLEDGEMENTS

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