Investigating gas transfer processes in argillaceous media in the framework of nuclear waste disposal

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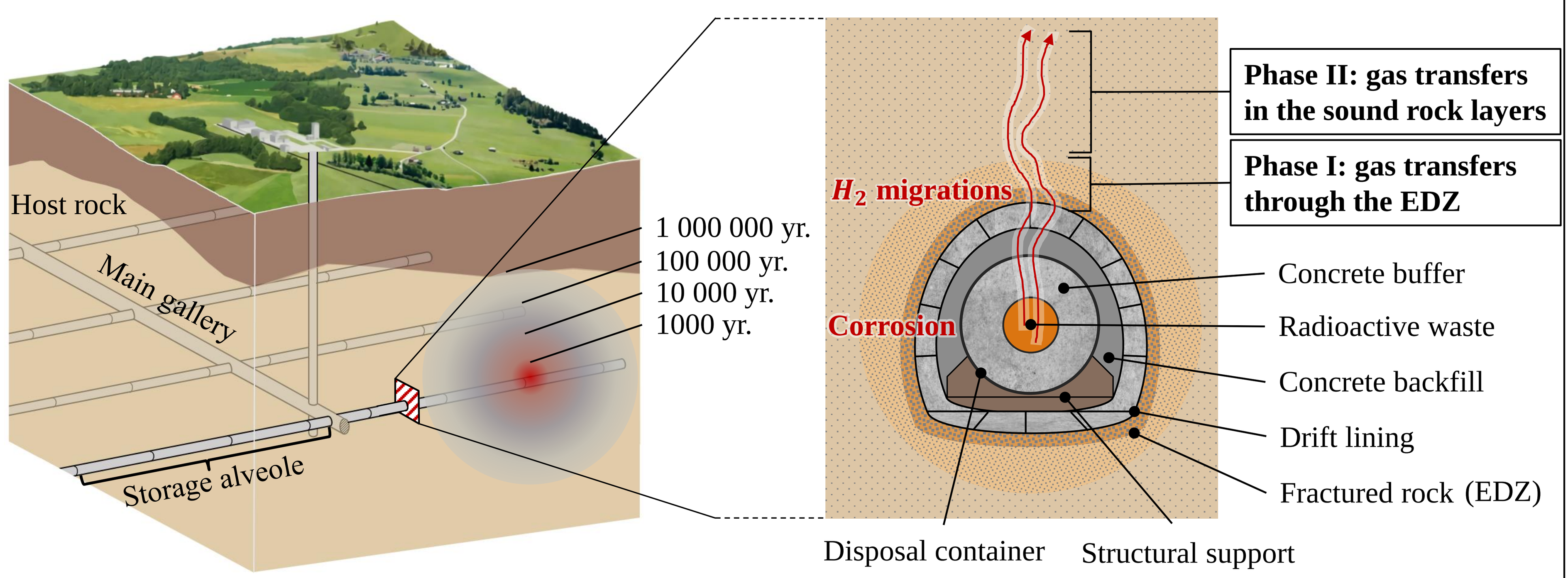
Contextualisation

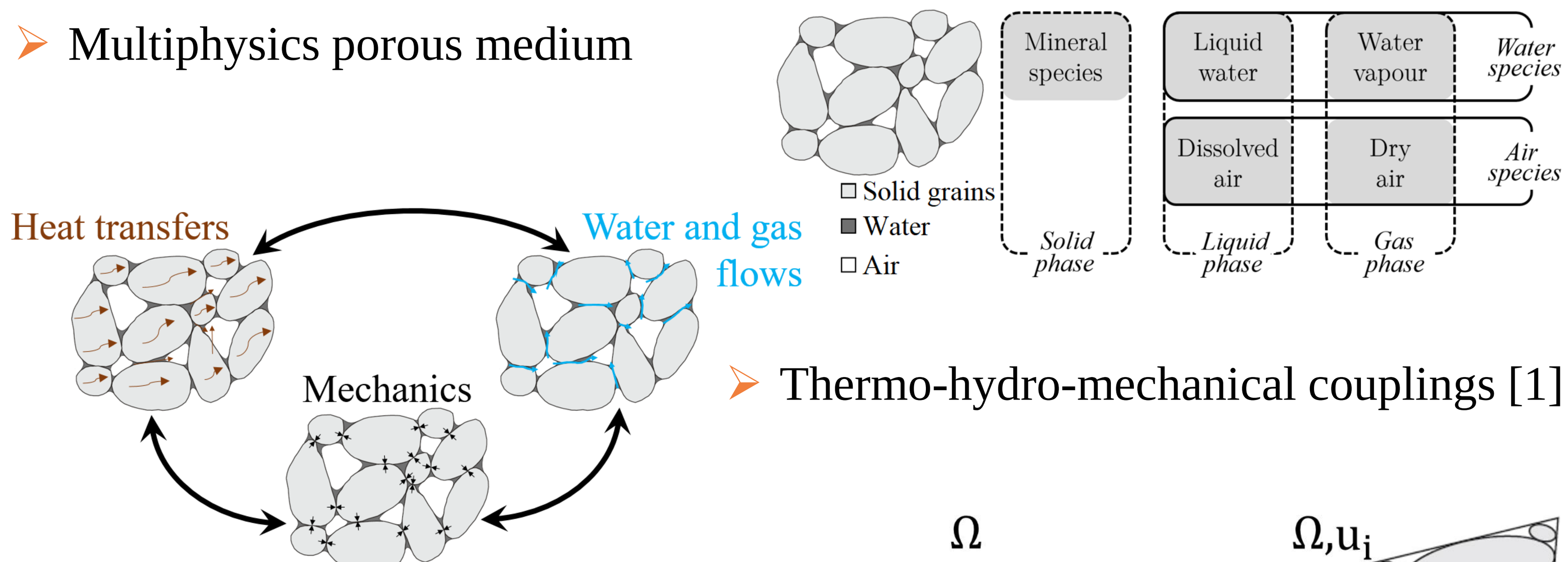
- Deep geological nuclear waste storage
- Multi-barriers confinement concept



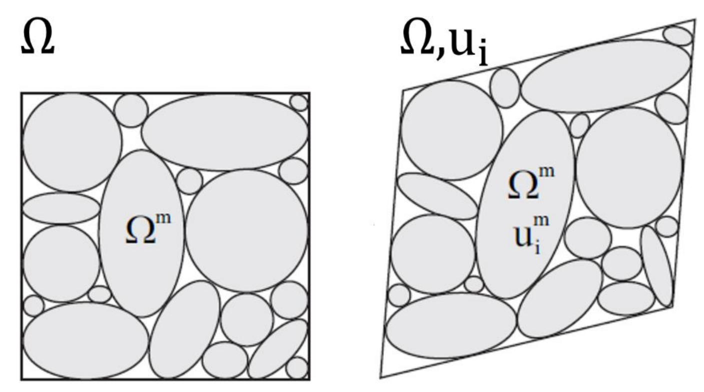
Goal: gas transfers modelling in
- Excavation Damaged Zone → **Phase I**
- Sound rock layers → **Phase II**

Phase I – Principle

- Multiphysics porous medium

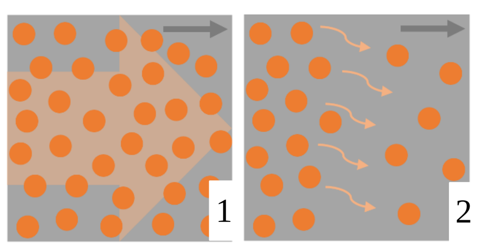


- Thermo-hydro-mechanical couplings [1]
- Strain localisation [2]
  - ↳ 2^{nd} gradient model: kinematics enriched with microstructure effects

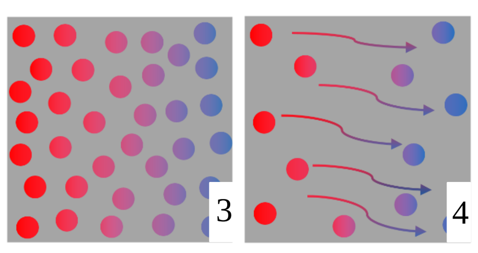


Phase I – Balance equations & constitutive model

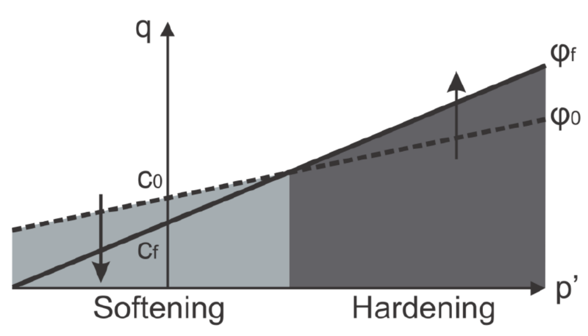
- Balance of momentum for the mixture
  - ↗ Microstructure effects
  - ↘ Kinematic constraint
- Water mass balance
- Air mass balance
  - ↗ Advection (1) — Darcy's law
  - ↘ Diffusion (2) — Fick's law



- Mixture energy balance:
  - ↗ Conduction (3) — Fourier's law
  - ↘ Convection (4)

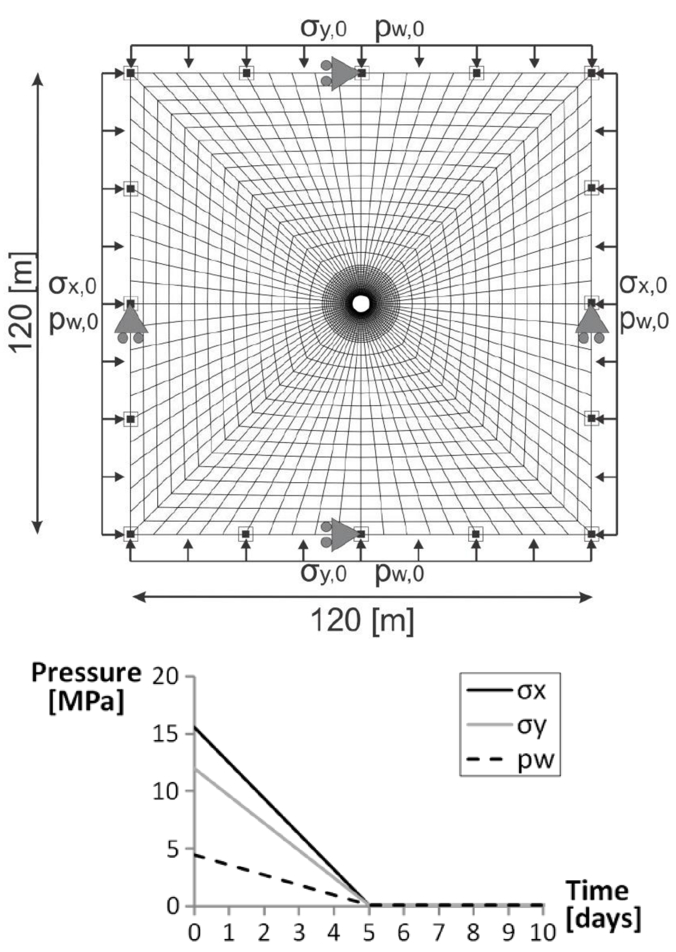


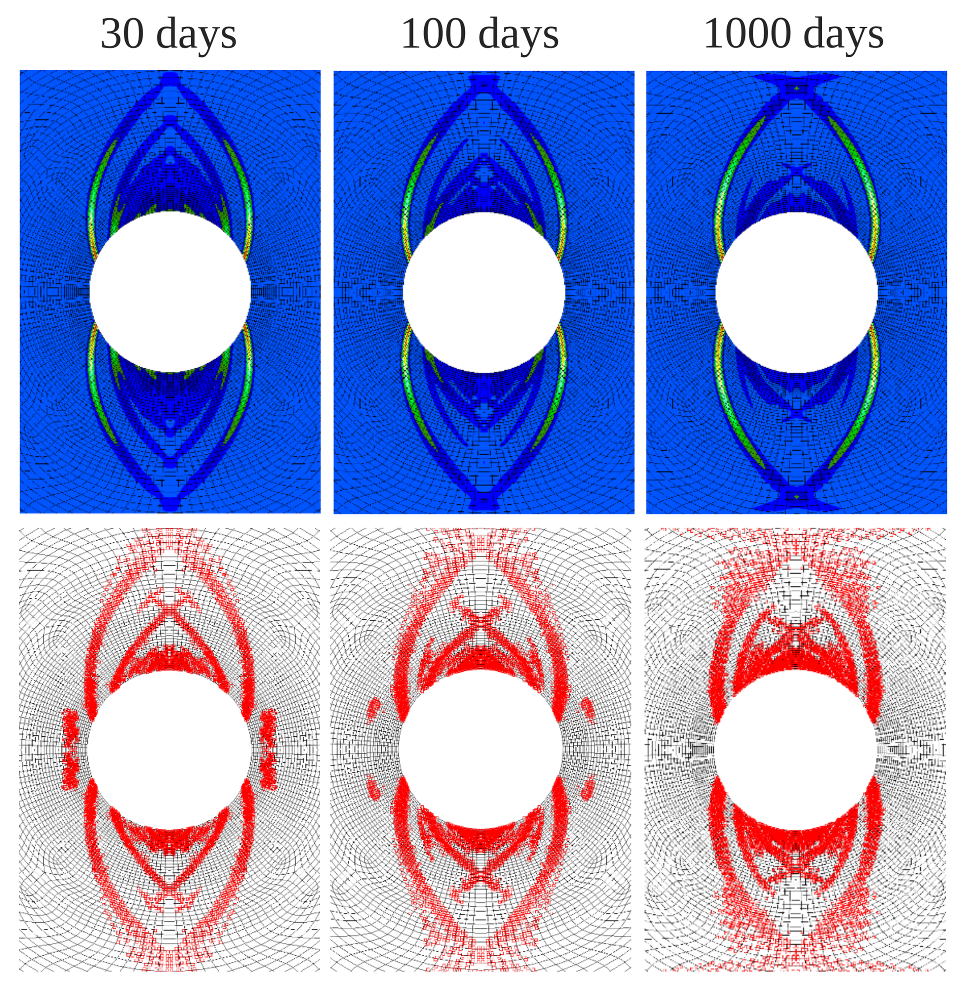
- Elasto-plastic internal friction model
  - ↳ Drucker-Prager yield surface, with φ hardening and c softening

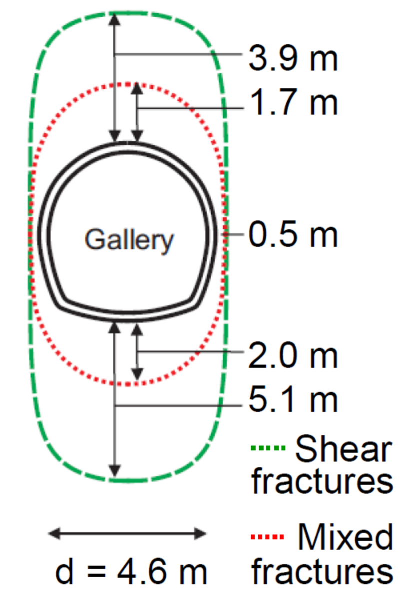


Phase I – Numerical modelling

- 2D plane strain state, HM simulations: Excavation of the Callovo-Oxfordian claystone







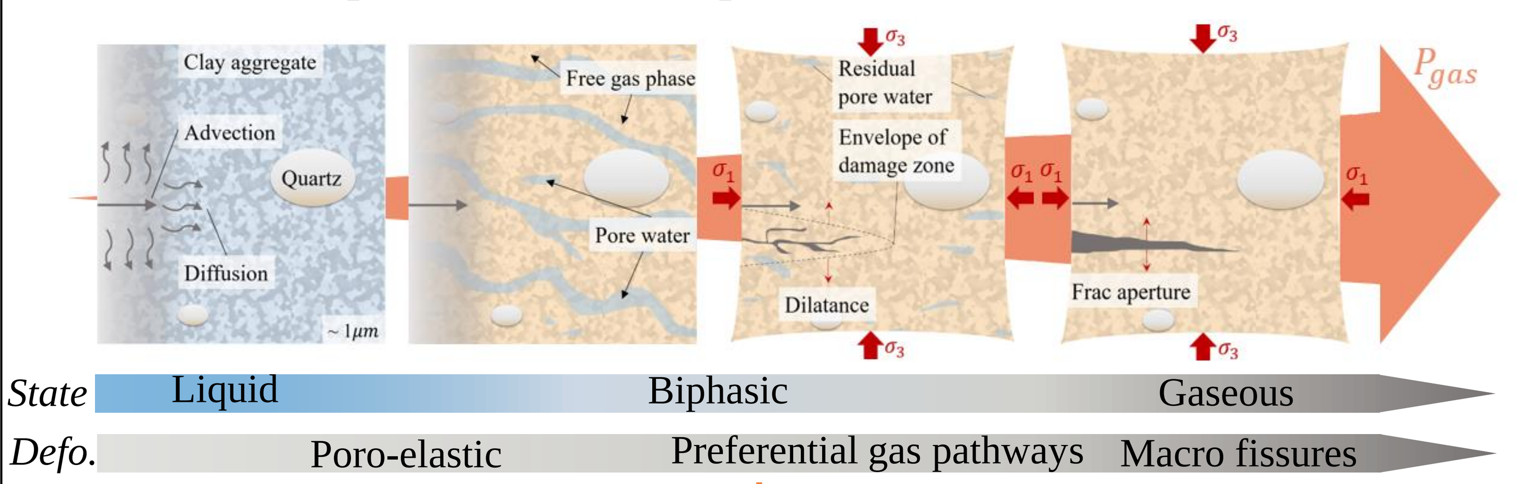
Total deviatoric strain (up), plasticity zone (down), in situ [3] measurments (right)

Localisation bands during excavation: Chevron fractures concentrated around the gallery due to the anisotropic stress state

Fracturing pattern as *in situ*

Phase II – Principle

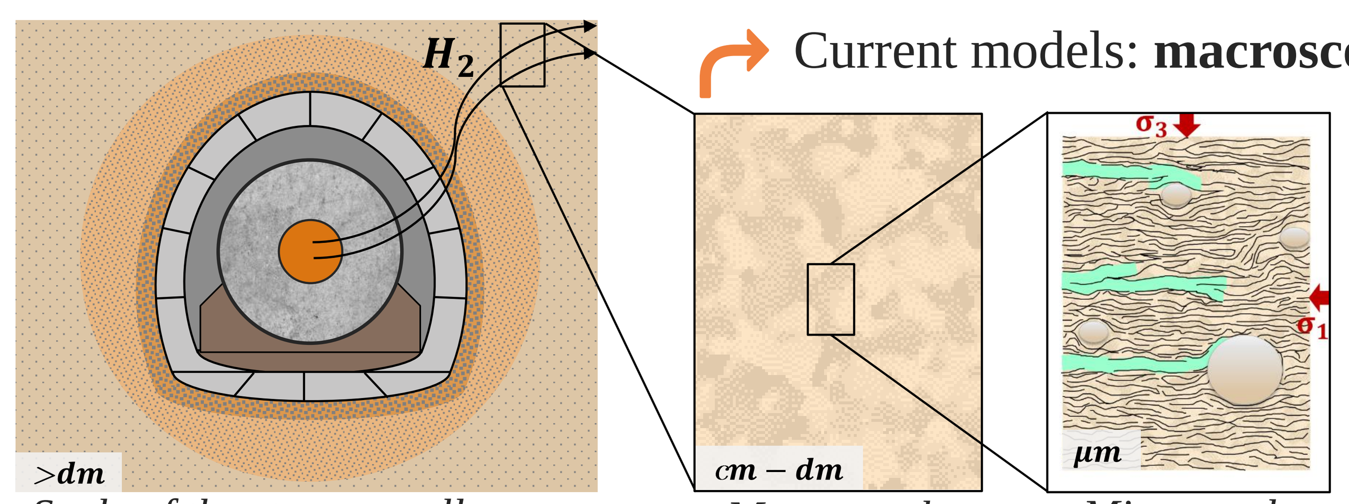
- Gaz transfer processes in low-permeable media [4]



↳ Barrier function of the host rock is affected

Phase II – Methodology

- Development of a **multi-scale model** of gas flows in low permeable soils



Scale of the storage gallery — *Macro-scale* — *Micro-scale*

↱ Current models: **macroscopic** approach → complex laws

→ FE^2 method:
complexity + HM effects of the **microstructure**
↓
simplified laws

1. Hydraulic microscopic model
- REV: Capillary network model; No mechanical influence
- Numerical implementation
- Comparison to existing models

2. Hydro-mechanical microscopic model
- REV: Influence of mechanics; Hydro-mechanical couplings
- Numerical implementation
- Sensitivity analysis

3. Hydro-mechanical macroscopic model
- Experimental campaign: influence of capillary network on gas migrations
- Implementation of the model through the FE^2 method
- Experimental validation

4. Applications
- Modelling of *in situ* gas injection tests
- Modelling of a nuclear waste storage gallery

Conclusion

1. The impact of gas migration on the repository components is a crucial issue
2. In the fractured zone: development of a 2^{nd} gradient THM model to reproduce simultaneously the fluid flows mechanisms and the strain localisation process
3. In the low-permeable sound rock: development of a multi-scale model to take into account the effects of the microstructure on the macroscopic flow

References

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