Full Scale 3D-modelling of the Coupled Gas Migration and Heat Dissipation in a Geological Repository for Radioactive Waste in the Callovo-Oxfordian Clay

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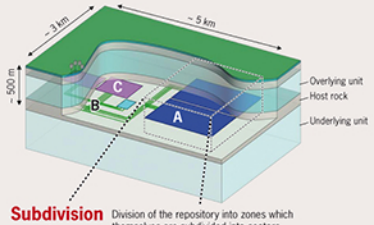
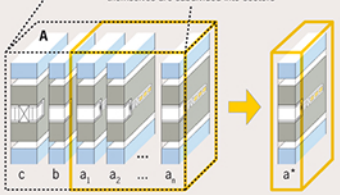
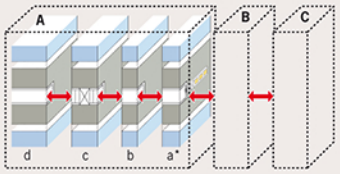
Approach: Division into zones, subdivision into repetitive sectors, multiplication & connection



Subdivision Division of the repository into zones which themselves are subdivided into sectors



Multiplication Aggregation of repetitive and symmetrical sectors by multiplication of volumes, areas and extensive state variables ($a_i \times n = a^*$)



Connection Complete repository model through connection of all individual sectors (a*, b, c ...) and all individual zones at drift interfaces (Basic assumption: mass transfer between sectors only along drifts)

A **sector** is a 3D block representing a repetitive part of the repository (e.g. a tunnel section, a shaft, an emplacement cell) embedded in the host rock and the over- and underlying units.

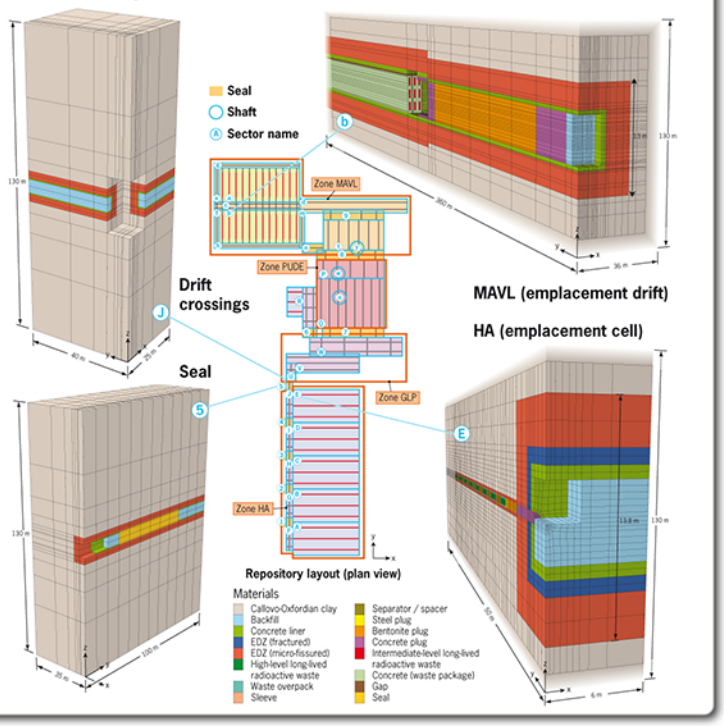
For the calculations, a sector is discretised as a TOUGH2-MP compatible mesh which represents the detailed geometry of the different materials (e.g. clay, bentonite).

Processes considered

- Two-phase (gas, liquid) flow using the concept of relative permeability/capillary pressure
- Mass transport of water and hydrogen by advection and diffusion
- Heat transport by advection and conduction

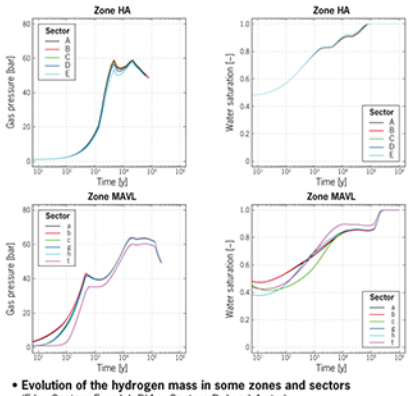
Layout and discretisation

- Individual 3D discretisation of different zones and sectors in the repository
- Geometrical representation from centimeter to kilometer scale

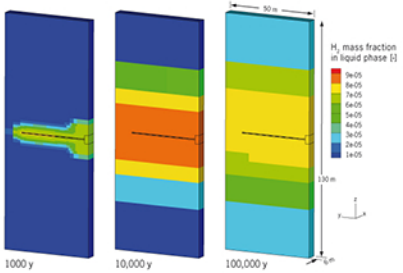


Example results from TOUGH2-MP, EOS5

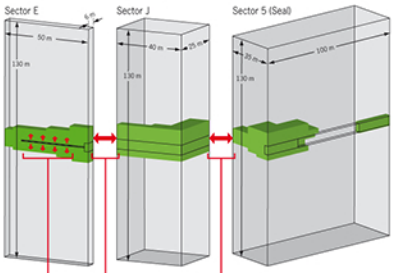
- **Evolution of pressure and saturation in backfilled drifts at various locations in the repository**



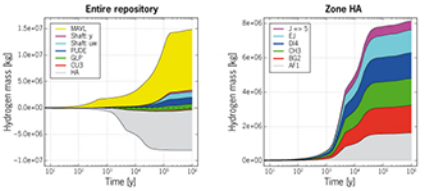
- **Evolution of the hydrogen mass-fraction in the liquid phase in Sector E**



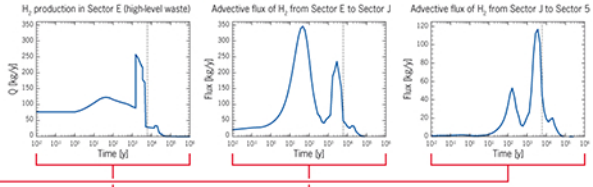
- **Spatial distribution of the gas saturation (>1%) after 6000 years**



- **Evolution of the hydrogen mass in some zones and sectors** (EJ = Sectors E and J, DI4 = Sectors D, I and 4 etc.)

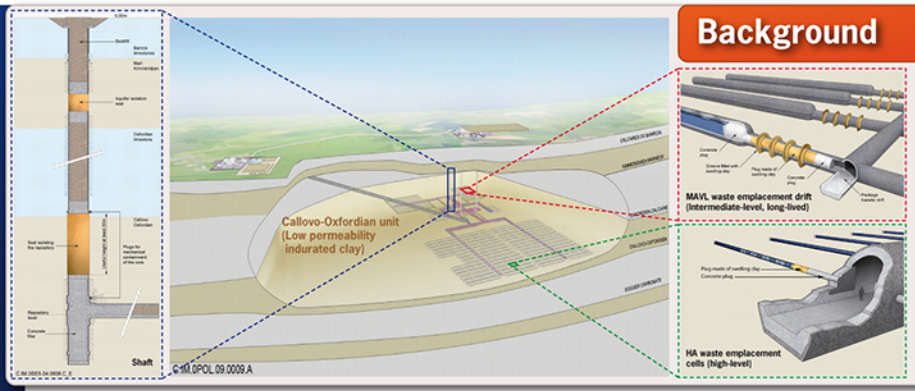


- **Evolution of advective gas fluxes: Sector E → Sector J → Sector 5**



Benefits of the approach

- Efficient method for the modelling of the coupled flow and transport of hydrogen and heat on the scale of an entire repository while simultaneously considering small scale structures
- Modular approach together with Python-script implementation offers high flexibility with respect to impact assessments for changes in the repository design, such as:
  - different configurations of the repository layout
  - different degrees of geometrical detail (e.g. different mesh discretisations)
  - different waste configurations (e.g. different heat and gas emission rates)
  - parameter studies



Background

- Hydrogen is produced in the HA cells and MAVL drifts in the post-closure phase mainly due to corrosion of steels and metal alloys for several 100'000 years.
- The generation of hydrogen and its migration through the backfilled repository in gaseous or dissolved form contributes to pressure build-up.
- Temperature rise due to heat generating wastes further enhances pressure build-up.
- Excessive pressure build-up may contribute to the deterioration of the barrier system.

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Nantes 2010: Clays in Natural & Engineered Barriers for Radioactive Waste Confinement, 4th International Meeting, March 29th-April 1st, 2010

Reference: Poller A., Enssle C.P., Mayer G., Croisé J., Wendling J., 2010: Repository-scale modeling of the long-term hydraulic perturbation induced by gas and heat generation in a geological repository for high and intermediate level radioactive waste – Methodology and example of application. Submitted for publication in Transport in Porous Media, special issue TOUGH2 Symposium 2009