A pragmatic methodology to abstract the EDZ around tunnels of a geological radioactive waste repository. Application to the HG-A experiment in Mont Terri.

A. Alcolea, U. Kuhlmann (TK Consult AG)
P. Marschall (NAGRA)
B. Lanyon (Fracture Systems Ltd.)
A. Lisjak, G. Grasselli, O. Mahabadi (Geomechanica Inc.)
R. de La Vaissière (ANDRA)
H. Leung (NWMO)
H. Saho (BGR)

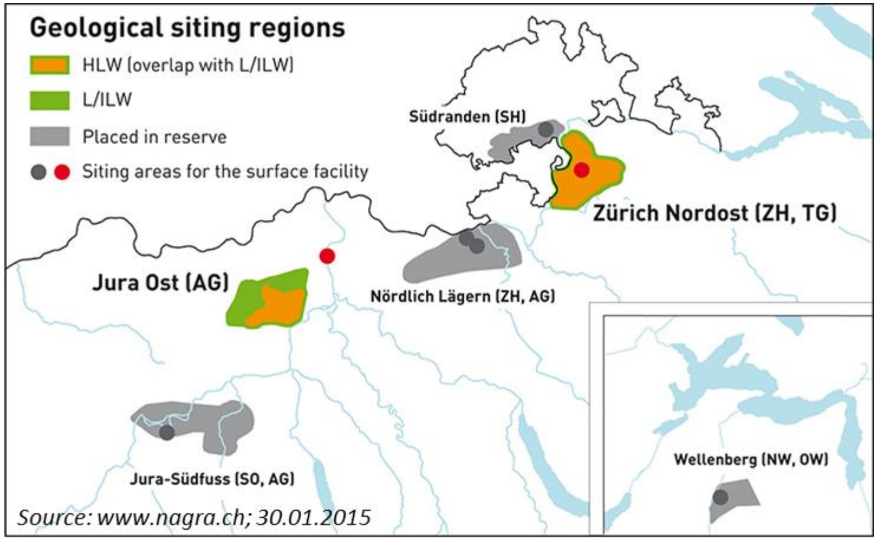
Outline

- Context
  - *Radioactive waste in CH*
  - *The need for abstracted models*
- Methodology
- Application. HG-A experiment
- Concluding remarks

6th International conference on Clays in Natural and Engineered Barriers for Radioactive Waste Confinement, Brussels, Belgium

1. Context. Radioactive waste in Switzerland

- **Sites for the disposal of radioactive waste in CH. Target = OPA**



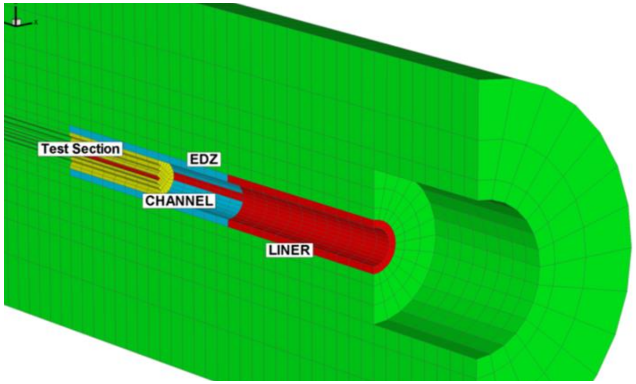
- **Provisional Safety Analysis (SA) on long term repository induced effects:**

  - pH plume back-fill of L/ILW caverns.
  - accumulation and release of repository gases.
  - heat emission of HLW canisters.
  - Excavation Damaged Zone (EDZ) around back-filled structures.

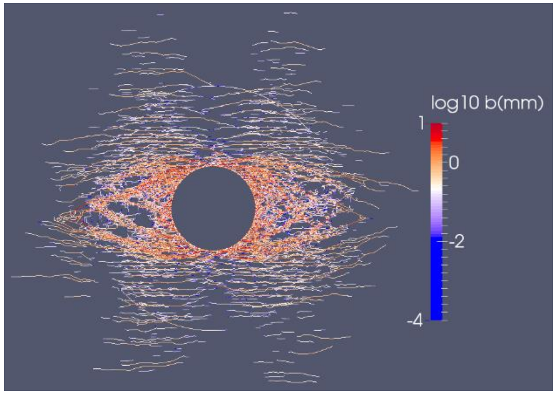
TK Consult AG
Hallenstrasse 10
8008 Zürich (Switzerland)
Tel: +41 (0)44 / 310 14 70
email: tkc@tkconsult.ch
web: www.tkconsult.ch

1. Context. The need for abstracted models

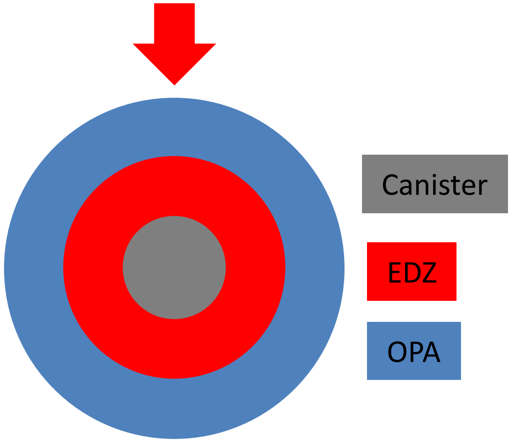
- Traditional THM models not wellsuited to Safety Analysis either due to simplicity (e.g., piece-wise homogeneous) or complexity (long model runs, etc.).



Lanyon et al. (2009)



Alcolea et al. (2014)



- SA demands models that are:
  - Simple and fast
  - Plausible
  - Heuristic, based on physical processes
  - Validated

- Prior work (EAGE Porto, 2014): EDZ abstraction methodology.

Hallenstrasse 10
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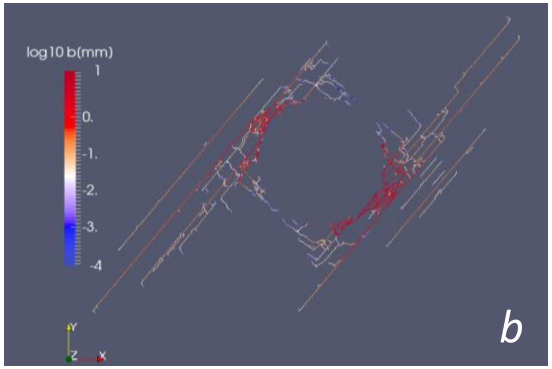
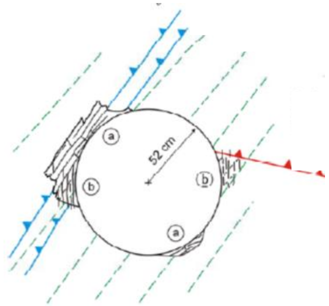
2. Methodology. Upscaling

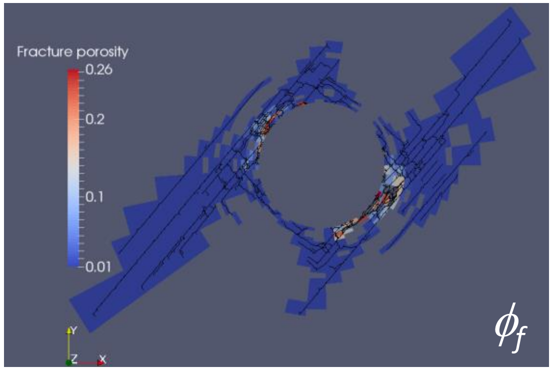
Element j, V_j

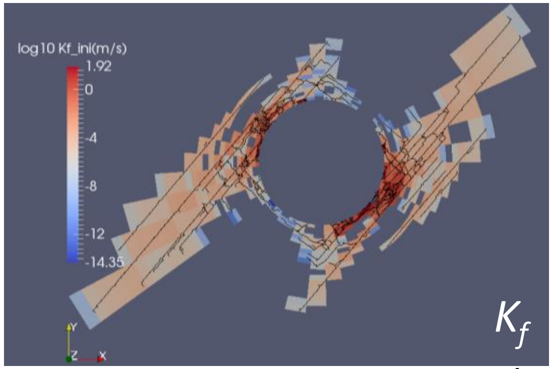




FEMDEM

$$\phi_f^j = \frac{\sum_i b_i L_i^j}{V_j}$$

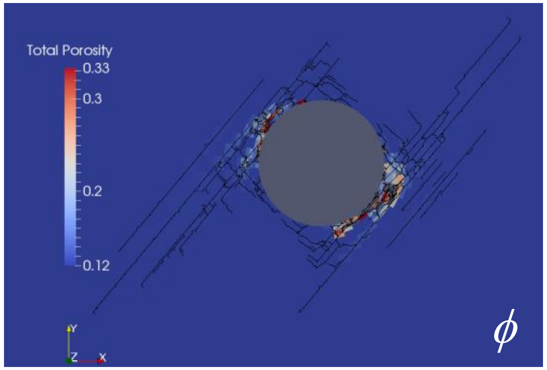


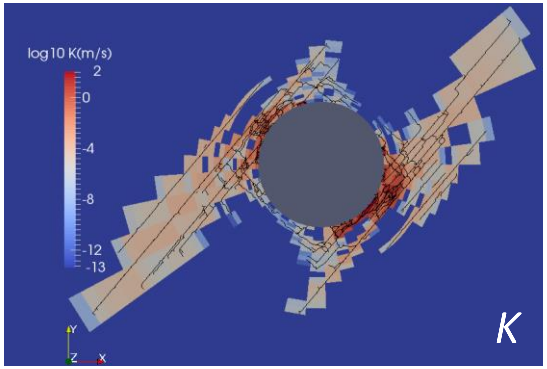


$$T_f = \frac{\rho g}{12\mu} b^3 \qquad K_f^j = \frac{\sum_i T_i L_i^j}{V_j}$$

FRACTURES

$$\phi = \phi_f(1 - \phi_m) + \phi_m$$





$$K = K_m + K_f$$

COMPOSITE

TK Consult AG
Hallenstrasse 10
8008 Zürich (Switzerland)
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web: www.tkconsult.ch

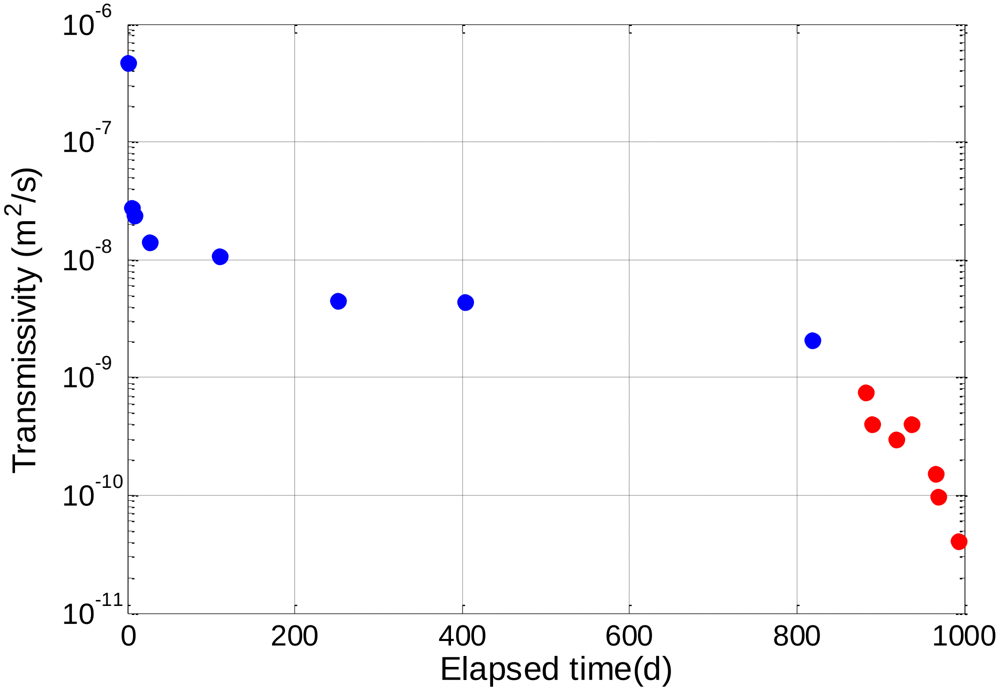
2. Methodology. Temporal evolution of parameters

Resaturation of fractures :

(1) Δp>0, from p_{atm} to p_h -> decrease of σ_n' -> fracture closure -> K_f and ϕ_f decrease

(2) Matrix is clay rich -> swelling. K_m and ϕ_m increase

Overall, reduction of EDZ transmissivity



Nagra, 2004

TK Consult AG
Hallenstrasse 10
8008 Zürich (Switzerland)
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web: www.tkconsult.ch

2. Methodology. Temporal evolution of parameters

At each time step:

(1) Calculate fracture aperture from pressure (effective stress) :

$$b(t) = b_0 - \frac{1}{b_0 K_{n0} \Delta p(t)^{\alpha-1} + 1}$$

Modified Barton-Bandis' model

α: closure rate

(2) Recalculate fracture transmissivity and porosity and upscale to grid: K_f and ϕ_f

(3) <u>Assuming that total porosity ϕ does not change in time</u>, calculate ϕ_m:

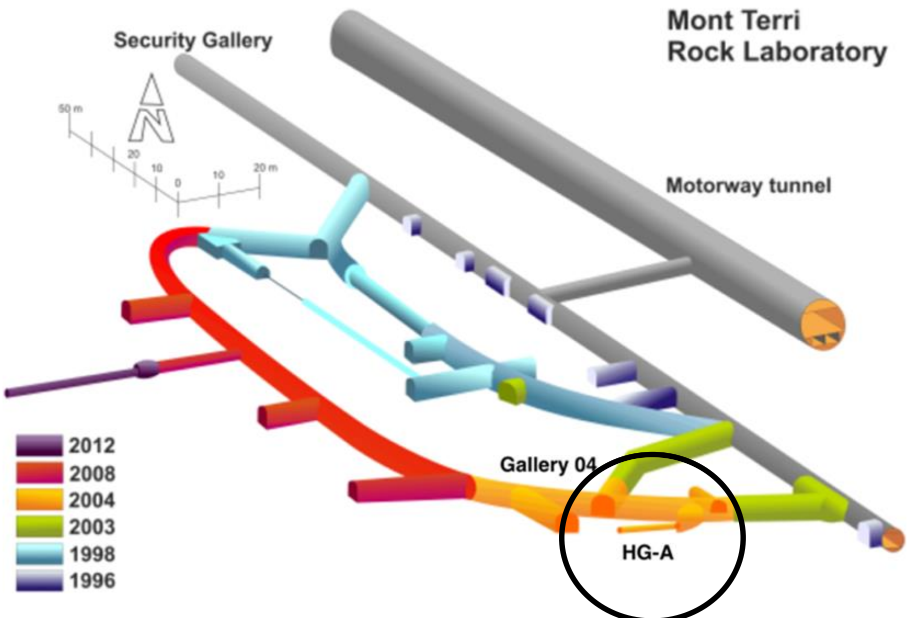
$$\phi_m = \frac{\phi - \phi_f}{1 - \phi_f}$$

(4) Calculate Km from ϕ_m using Kozeny-Carman equation:

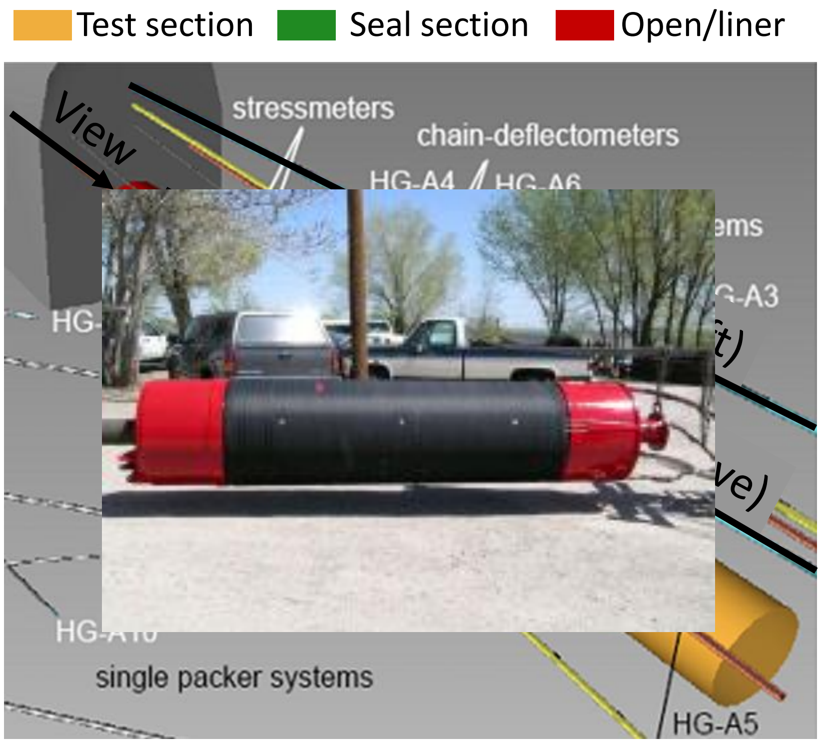
$$K_m(t) = \frac{\phi_m(t)^3}{(1-\phi_m(t))^2} \cdot \frac{\rho \cdot g}{\mu} \cdot \frac{{d_{10}}^2}{180}$$

(5) Recalculate total $K = K_f + K_m$ and simulate pressure with updated fields

3. Application. HG-A experiment in Mont Terri



Lanyon et al., 2014



Analysis	Reference
Response to excavation	*Marschall et al., 2006 and 2008*
Test section saturation and hydraulic testing	*Lanyon et al., 2009*
Gas testing	*Lanyon et al., 2014*

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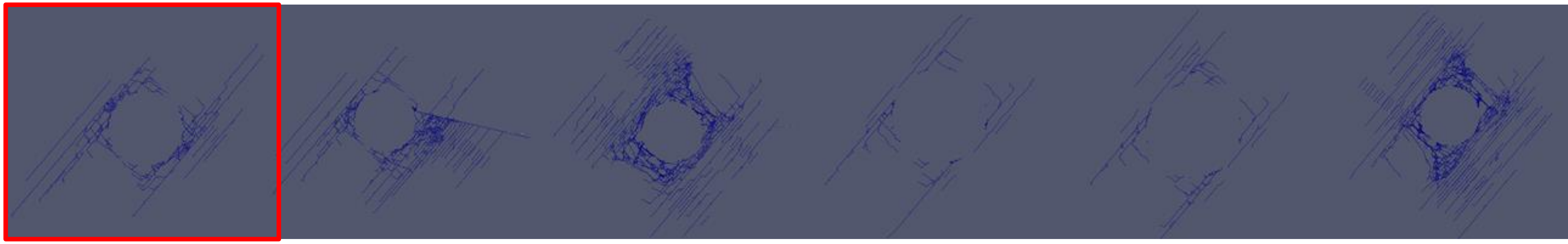
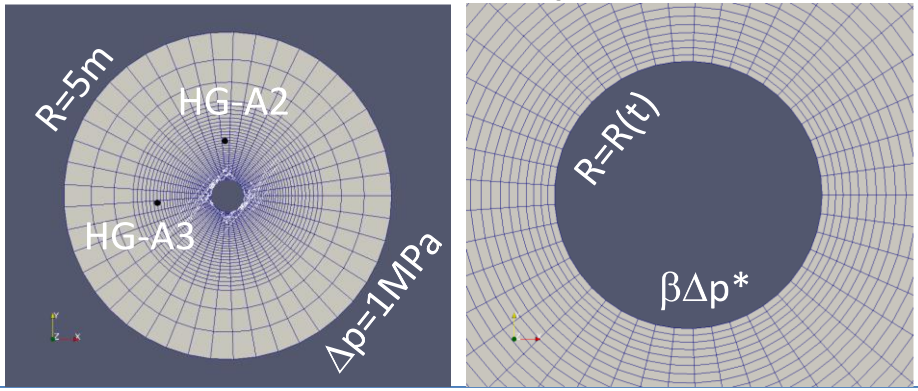
3. Application. HG-A experiment in Mont Terri

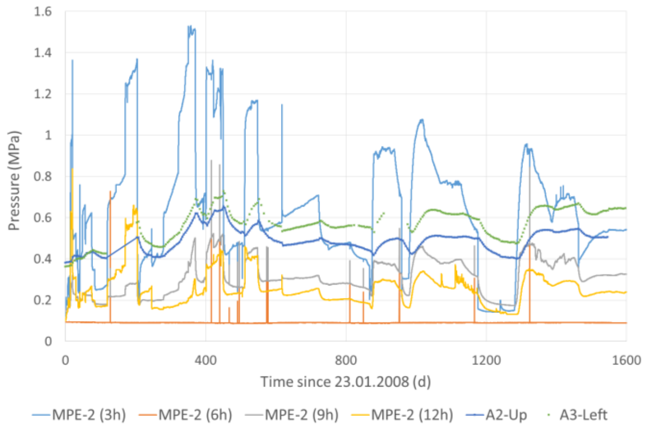
- Different FEMDEMS mimicking different local stress conditions



σ_1=6.5 Mpa	σ_1=6.5 Mpa	σ_1=6.5 Mpa	σ_1=6.5 Mpa	σ_1=5.5 Mpa	σ_1=6.5 Mpa
σ_3=4.5 Mpa	σ_3=4.5 Mpa	σ_3=4.5 Mpa	σ_3=4.5 Mpa	σ_3=5.5 Mpa	σ_3=6.5 Mpa
$\theta(\sigma_1)$=90º	$\theta(\sigma_1)$=90º	$\theta(\sigma_1)$=140º	$\theta(\sigma_1)$=50º	isotropic	isotropic
	Tectonic fault	Perp. bedding	Parallel bedding		

- Model discretization, boundary conditions and extent



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3. Application. HG-A experiment in Mont Terri

- Calibration parameters (not exhaustive search, but trial and error):
  - α, the rate of fracture closure. Low α = high rate of closure.
  - β, dampening factor mimicking:
    - the transfer of mechanical energy between megapacker and formation
    - skin effect
- Least squares minimization of misfit at HG-A2 and HG-A3. Model not aimed at fitting perfectly available measurements, but at “ressembling trends”. Instead, we seek a heuristic model that is simple, abstractable, based on empirical observations and that captures the physical nature of the phenomenon.
- Local stress conditions highly uncertain. This methodology also allows the selection of the best structural model.

3. Application. HG-A experiment in Mont Terri

Fits A-2

Fits A-3

3. Application. HG-A experiment in Mont Terri

- Animation of pressure and of K

3. Application. HG-A experiment in Mont Terri

- End members and abstraction of HG-A

4. Conclusions

- An abstraction methodology to go from extremely complex EDZ models to simple piece-wise heterogeneous models, wellsuited to SA.
- Sequential approach: mechanical simulations of EDZ formation and development, then decoupled hydromechanical simulations.