HYDROMECHANICAL MODELLING OF THE GAS TRANSPORT IN CLAY SAMPLES

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Introduction

The gas transport in the vicinity of a deep geological repository is controlled by different mechanisms. Among them advective-diffusive transport of dissolved gas and the formation of discrete fractures as preferred flow paths were examined in this study. To better understand the gas transport in clay, the finite element code OpenGeoSys-6 (OGS-6) was used to simulate two laboratory experiments. In the course of the work package GAS of the EURAD Project, several permeability models were used to evaluate the gas transport and coupling between hydraulic and mechanical response of the Opalinus Clay rock.

Numerical Model and Experiments

An axisymmetric 2D numerical model was used to numerically investigate the gas transport in Opalinus Clay (see Figure 1). Laboratory experiments were used to calibrate the models and determine the parameters. Table 1 shows the permeability models examined.

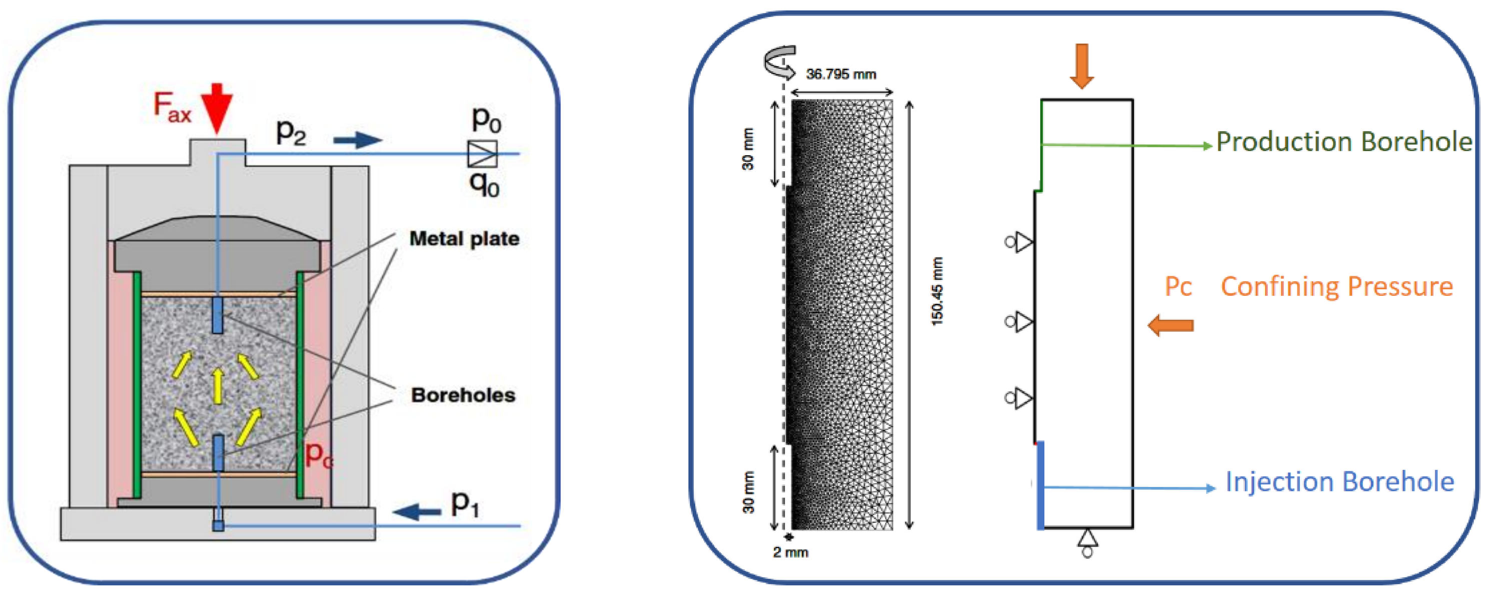

Figure 1. Sketch of laboratory experiment (left) and mesh of the numerical model (right) (Xu et al. 2013)

Table 1. Permeability models used in numerical simulations

1. Gas pressure dependent permeability $k = f(p_g)k_{int}^{ini}$	$f(p_g) = \begin{cases} (1 + a_1 p_g)k_{int}^{ini} & , p_g \leq p_{thr}\ [MPa] \\ (a_2(p_g - p_{thr}) + 1 + a_1 p_{thr})k_{int}^{ini} & , p_g > p_{thr}\ [MPa] \end{cases}$
2. Strain dependent permeability $k = f(\Delta\varepsilon_{vol})e^{b_1 \Delta\varepsilon^p} k_{int}^{ini}$	$f(\Delta\varepsilon_{vol}) = \begin{cases} 10^{b_2 \Delta\varepsilon_{vol}} & ,compaction \\ 10^{b_3 \Delta\varepsilon_{vol}} & ,extension \end{cases}$
3. Failure index dependent permeability $k = k_{int}^{ini} + < f - 1 > k_r e^{bf}$	$f = \begin{cases} \frac{\lvert\tau_m\rvert}{\cos(\phi)\,\tau_f(\sigma_m)}, & \sigma_m \leq \sigma_m^{max} \\ \max(\frac{\lvert\tau_m\rvert}{\cos(\phi)\,\tau_f(\sigma_m)}, \frac{\sigma_m}{\sigma_m^{max}}), & \sigma_m > \sigma_m^{max} \end{cases}$

Two types of gas injection experiments, carried out by the Institute for Rock Mechanics (IfG GmbH, Popp et al. 2007), were used for simulation:

- The first experiment demonstrates an advective gas transport through the sample and an elastic deformation.
- The second experiment highlights the formation of a tensile fracture (plastic deformation) and preferred flow path.

Boundary Conditions

Figures 2 and 3 show the applied hydraulic (injection pressure) and mechanical (confining pressure) boundary conditions.

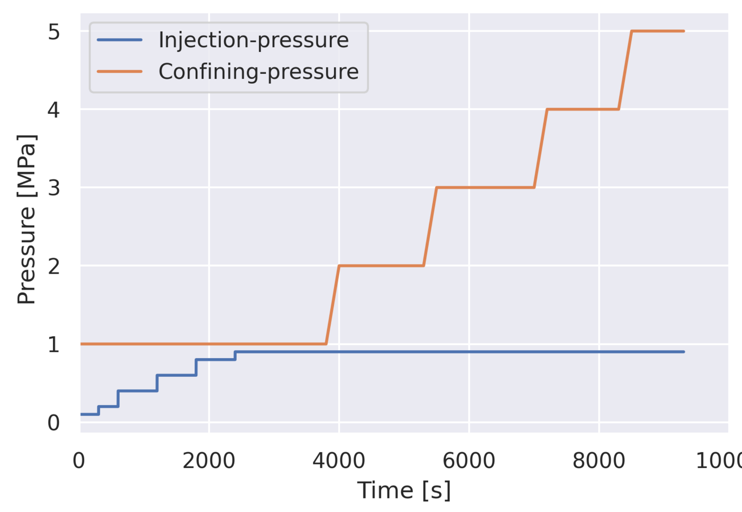

Figure 2. Experimental plan, first experiment

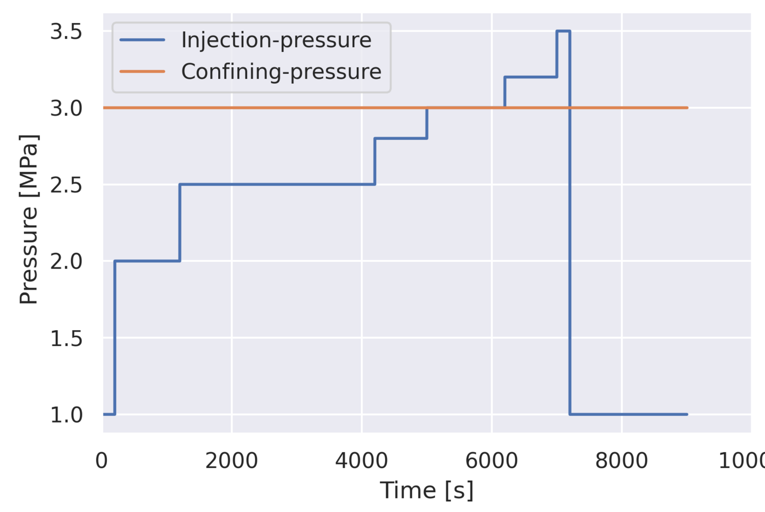

Figure 3. Experimental plan, second experiment

Results

Figures 4 and 5 show a comparison between numerical and experimental gas production. Figures 5 and 6 show average vertical permeability alterations.

Gas Production

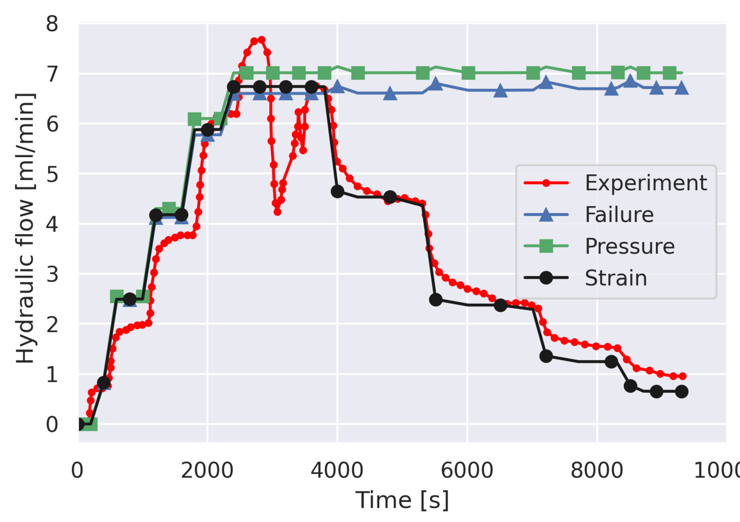

Figure 4. Gas production. Advective gas transport, first experiment

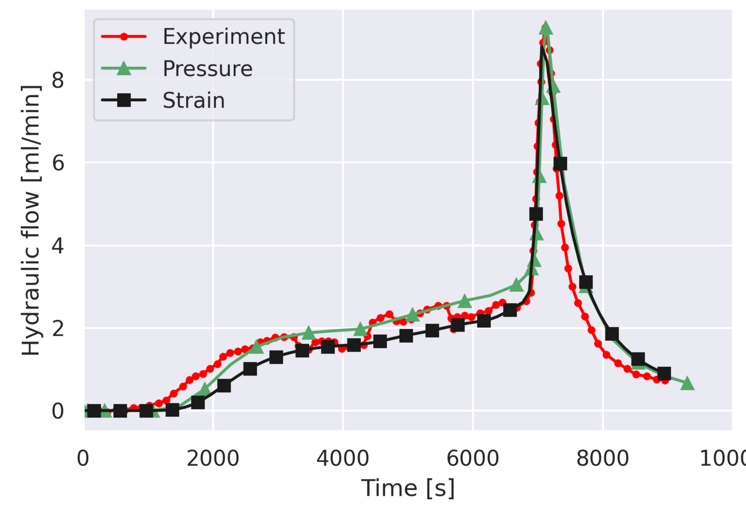

Figure 5. Gas production through fracture, second experiment

Permeability Alterations

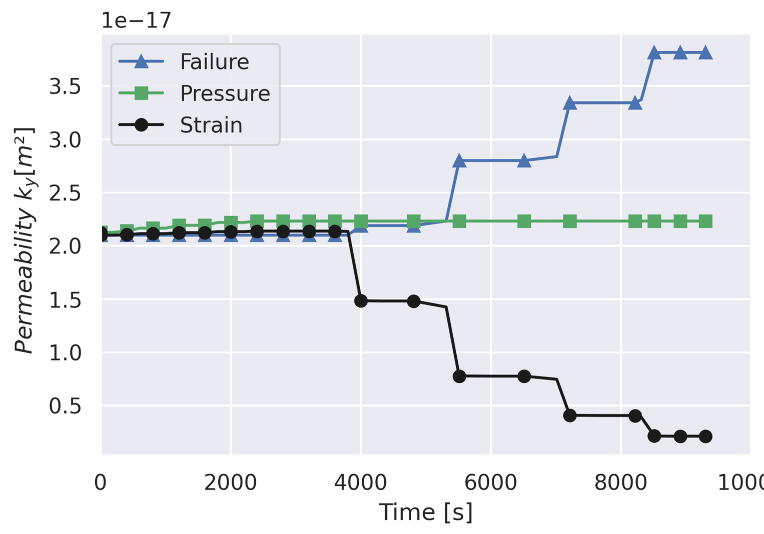

Figure 6. Average vertical permeability changes, first experiment

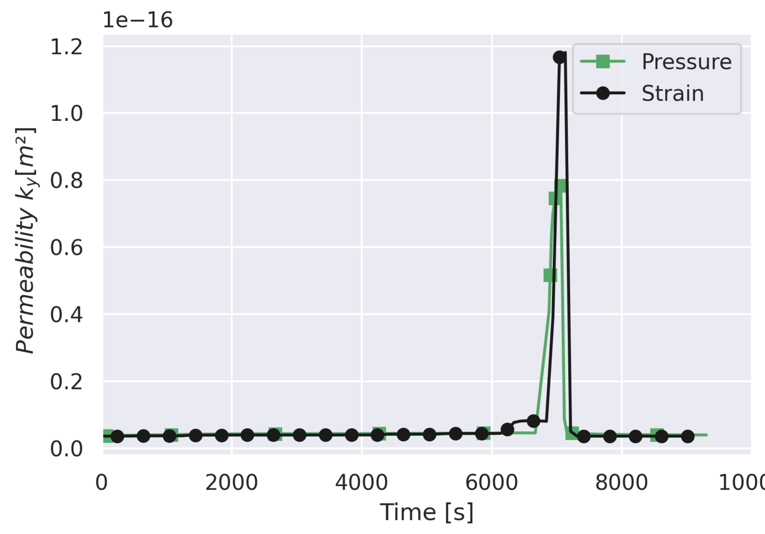

Figure 7. Average vertical permeability changes, second experiment

Conclusion and Outlook

This numerical study examined different permeability models and compared the results with experimental data. The best results were obtained using the strain-dependent permeability model, where the gas production behaviour is sensitive to both changes in pore pressure and in confining pressure. The gas pressure-dependent permeability model predicts the production behaviour associated with pore pressure changes appropriately but is not sensitive to changes in confining pressure. In future studies, experiments carried out by other partners, where similar processes are applied, will be investigated.

References and Acknowledgements

Xu, w. et al. (2013). Coupled multiphase flow and elasto-plastic modelling of in-situ gas injection experiments in saturated claystone (Mont Terri Rock Laboratory. Engineering Geology, 55--68.

Popp, T. et al. W. (2007). Untersuchungen zur Barriereintegrität im Hinblick auf das Ein-Endlager-Konzept. Leipzig, Germany.: Institut für Gebirgsmechanik GmbH

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