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Effectiveness of self-sealing after gas transport in Boom Clay

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The study of gas transport in low permeable materials is becoming a significant focus in energy-related geotechnics, particularly for managing deep geological disposal of long-lived and heat-emitting radioactive waste. Argillaceous rocks, studied to host the disposal, may present induced fractures caused by the excavation activities that increase the permeability to liquid and gas. The generation of gases can also lead to an excessive pressure build-up in these saturated media resulting in the development or reactivation of fractures/fissures creating preferential pathways for the gas flow [1]. Nevertheless, these rocks present the advantage of self-seal (via swelling of clay minerals due to re-saturation, consolidation or creep), reducing fissure permeability and potentially restoring the barrier function [2].

This study focuses on Boom Clay, a Cenozoic clay candidate for hosting the repository in the Belgian programme, aiming at characterising the effectiveness of its self-sealing process after gas injection/dissipation tests due to the swelling of clay minerals during re-saturation. This poorly indurated rock presents sedimentary bedding planes that can act as preferential pathways during the gas invasion. In a previous experimental campaign, samples at two bedding orientations (parallel and orthogonal to the flow) were tested under oedometer conditions [3, 4]. The results indicate that gas transport induced slight expansion of the samples in both orientations, increasing their intrinsic permeability, which suggested the opening of preferential paths. Furthermore, the analyses of the pore network using mercury intrusion porosimetry (MIP) and micro-focus X-ray computed tomography (µ-CT) confirmed the development of gas pathways following the bedding direction or interconnecting bedding planes [4, 5].

To assess the self-sealing capacity, oedometer tests were carried out at two bedding directions using an oedometer cell with lateral stress measurement to comprehensively understand the stress state and ensure that gas flow occurred through the sample rather than between the sample-ring interface. Prior to the gas injection stage, water permeability was measured. Subsequently, a gas injection/dissipation stage was performed at constant vertical stress. Immediately after, the sample was placed in contact with synthetic water to allow re-saturation. Finally, the water permeability was measured again. The self-sealing capacity of the clay was assessed by comparing the water permeability at both stages. If the obtained values are similar, the barrier function has been restored. Some tests also included a second gas injection to evaluate the potential pathway reopening. MIP and µ-CT data allowed for evaluating microstructural changes due to these processes.

The experimental results demonstrate that gas can flow at pressures lower than the minor lateral stress, and the computed effective gas permeability is always higher than the initial intrinsic water permeability, pointing to the opening of preferential pathways (Figure 1a). Water permeability after re-saturation showed values comparable to the initial intrinsic permeability, recovering the hydraulic barrier function thanks to the clay minerals' swelling (Figure 1a). This indicates the good self-sealing capacity of the Boom Clay. The gas permeability calculated during a second injection/dissipation stage is slightly higher than the initial one, suggesting some memory of the previously opened path (Figure 1a). The self-sealing effect was also observed in the CT images performed under unstressed conditions after water-undrained unloading of the tested samples. The fissures detected after the gas injection (Figure 1b left) are no longer visible after re-saturation within the technique resolution (fissures > 40µm) (Figure 1b middle).

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However, a small proportion of large and disconnected pores were identified in CT images, likely due to some gas exsolution. Regarding the subsequent gas injection, it again led to the development of fissures following the bedding direction detected with microstructural techniques (Figure 1b right).

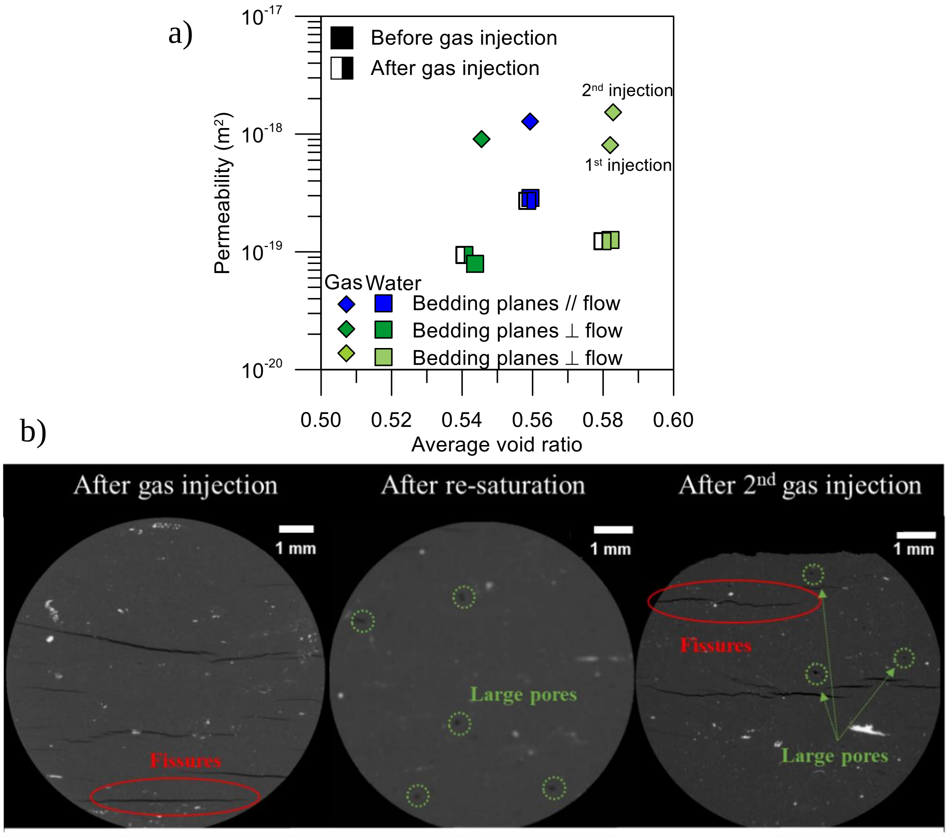

Figure 1: a) Intrinsic water and effective gas permeability at different stages in samples with bedding planes parallel and orthogonal to the flow. b) μ-CT images of the samples with bedding planes orthogonal to the flow after gas injection (left), after re-saturation (middle) and after a second gas injection (right).

Contributor statement

L. Gonzalez-Blanco: Conceptualization, Methodology, Formal analysis, Visualisation, Writing - Original Draft; E. Romero: Conceptualization, Methodology, Project administration, Resources, Writing - Review & Editing; S. Levasseur: Conceptualization, Resources, Writing – Review & Editing.

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References

[1] NEA (2010). Annual Report, Nuclear Energy Agency. ISBN : 978-92-64-99159-0

[2] Bastiaens, W., Bernier, F., & Li, X.L. (2007). SELFRAC: Experiments and conclusions on fracturing, self-healing and self-sealing processes in clays. *Physics and Chemistry of the Earth*, 32(8–14), 600–615. https://doi.org/10.1016/j.pce.2006.04.026

[3] Gonzalez-Blanco, L., Romero, E., Jommi, C., Li, X., and Sillen, X. (2016). Gas migration in a Cenozoic clay: Experimental results and numerical modelling. *Geomechanics for Energy and the Environment*, 6. 81–100. https://doi.org/10.1016/j.gete.2016.04.002

[4] Gonzalez-Blanco, L. and Romero, E. (2022) A multi-scale insight into gas migration in a deep Cenozoic clay. *Géotechnique* (Ahead of Print), pp.1–18. https://doi.org/10.1680/jgeot.21.00208.

[5] Gonzalez-Blanco, L., Romero, E., Jommi, C., Sillen, X., Li, X. (2017). Exploring fissure opening and their connectivity in a Cenozoic clay during gas injection. In*: Ferrari, A., Laloui, L. (eds) Advances in Laboratory Testing and Modelling of Soils and Shales (ATMSS). ATMSS 2017*. Springer Series in Geomechanics and Geoengineering. Springer, Cham. https://doi.org/10.1007/978-3-319-52773-4_33