CNRS Post-doctoral position at GeoRessources laboratory (Nancy, France)

Investigation of hydromechanical couplings during gas migration in saturated clayey rock at mesoscopic scales

Background and Objectives: Deep geological disposal is widely agreed to be one of the best solution for final disposal of the most radioactive wastes produced. In such a context, corrosion of ferrous materials under anoxic conditions, associated with radioactive decay of waste and water radiolysis, will lead to the formation of hydrogen. A full understanding of the migration behavior of this gas is of fundamental importance for the reliability of scenarios predicting the long-term evolution of geological repositories. If the rate of gas production exceeds the rate of gas diffusion into the pores of the host rock, a distinct gas phase will form. Capillary forces opposing the movement of the gas will cause the pressure to increase to a critical value beyond which it can penetrate into the surrounding material and move through advective processes. However, different mechanisms specific to clayey rocks and their nanoporous nature could influence these viscous capillary flows.

Due to the high pressures generated, the percolation of gas generates an expansion of the percolating paths, which can lead to a localized displacement of water away from these paths [1]. These hydro-mechanically coupled processes can potentially damage the host rock and modify its hydrogeological properties.

The objective of this post-doctorate is to propose mesoscopic models capable of taking into account HM couplings when simulating flow and transport in large representative elemental volumes (REVs) typically out of reach of molecular methods. These models will allow quantitative analyses of the simultaneous effects of real clay morphology and HM couplings on transport properties.

Scientific content: Numerical simulations of drainage will be carried out on high-resolution 3D images (MET and FIB-SEM images) of the COx argillite. The lattice Boltzmann method (LBM), will be used for this purpose. The models will be validated on the basis of experimental tests from the literature or carried out in the laboratory.

We will consider hydro-geomechanical couplings to reproduce some characteristics of long-term gas behavior, and more particularly the development of expansion paths with gas migration through localized fractures. Several numerical strategies with different levels of complexity will be considered to describe these poromechanical effects in the LBM models. The different results will be compared and regime diagrams will be established in order to evaluate the most relevant approach with respect to the hydrodynamic constraints (*e.g.*, maximum gas pressure) and the degree of accuracy required.

Firstly, immersed boundary conditions or interpolated boundary conditions [2] will be implemented in the LBM model in order to make the pore scale geometry evolve under the effect of increasing pore pressure. Secondly, a more complex approach will consist in coupling the LBM model with a discrete element method (DEM) in order to accurately describe the mechanical behavior of the solid skeleton and the creation of new percolating paths. The DEM will model the solid phase as an assembly of interacting particles while the LBM will solve Navier Stokes' incompressible equations within the interparticle poral space. The interaction at the fluid/solid interface will be described by an immersed boundary condition scheme. All new developments will be implemented in an existing in-house LBM code developed at GeoRessources laboratory [3].

Prerequisite: The candidate must be a highly motivated and autonomous person with a PhD in mechanics, reservoir engineering, applied mathematics, civil engineering or other relevant field with a strong background in programming. He or she must demonstrate a fundamental knowledge of the principles of fluid and solid mechanics governing the behavior of porous media. Experience in the development of LBM and/or DEM methods would be a strong asset. The candidate should be fluent in English.

Funding: The proposed thesis is funded by a CNRS post-doctoral contract and is part of a larger EU project (EURAD) that aims to mobilize academic research on major nuclear-related issues.

This post-doctoral project is funded for 1 year, ideally starting January 2021. This post-doctorate work will be carried out within the GeoRessources laboratory (in the research team "Multiscale HydroGeoMechanics", University of Lorraine/CNRS) in Nancy. The gross salary, will be around 2968€/month (net salary: 2385 €) including social benefits and health care.

Contacts: Candidates are invited to send their CV and cover letter by email to

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References :

[1] Cuss R., Harrington J., Giot R., Auvray C. (2014), Experimental observations of mechanical dilation at the onset of gas flow in Callovo-Oxfordian claystone, Geological Society, London, Special Publications, vol. 400, no. 1, pp. 507–519.
[2] Benioug M., Golfier F., Tinet AJ., Buès M.A., Oltéan C. (2015) Numerical efficiency assessment of IB-LB method for 3D pore-scale modeling of flow and transport, Transport in Porous Media 109(1): 1-23.
[3] Pazdniakou, A.; Tinet, A.-J.; Golfier, F.; Kalo, K.;Gaboreau, S.; Gaire, P. Numerical Efficiency Assessment of the Lattice Boltzmann Model for Digital Nano-Porous Rock Applications. Advances in Water Resources 2018, 121, 44–56. https://doi.org/10.1016/j.advwatres.2018.08.001.