Ph.D. position at the University of Lorraine (France)

GeoRessources Laboratory

Title: Multi-scale hydro-mechanical modeling of coalbed methane recovery

Context: Nowadays, the increasing demand of energy, as well as the growing concerns about global warming, has resulted in a search for alternative but clean energy sources. While considered a non-renewable energy resource, coalbed gas or coalbed methane (CBM) may contribute to this diversification and takes part to the future environmentally-friendly energy mix (cleanest burning hydrocarbon, aid in CO_2 sequestration). Currently, CBM is a valuable source of energy in the USA, China and Australia. The significant estimated gas reserves in Lorraine, in the northeast of France ($3.71 \cdot 10^{11}\, m^3$ against $2. \cdot 10^{13}\, m^3$ for the total USA CBM resources) represent an attractive and promising target for CBM exploitation. Based on the reuse of abandoned flooded coal mines, methane production is driven by the release of pore pressure in the coal seam during water pumping. The recovery of coalbed methane can be also enhanced by injecting CO_2 into the seam. In the so-called enhanced coalbed methane recovery (ECBM), methane is produced and replaced by the adsorbed CO_2 which is then permanently stored through an in situ preferential adsorption/desorption process. An alternative advantage of this technique under investigation, in addition to the expected increase of methane recovery, is the storage of large amount of CO_2 to mitigate greenhouse gas emissions.

Objectives and work summary: The objective of this PhD thesis will be to develop a conceptual and hydro-mechanically coupled numerical model giving a detailed description of methane desorption and gas recovery through the coal fracture network. Part of the difficulty is related with the highly complex multiscale nature of coal. This dual-porosity system is characterized by a network of orthogonal fractures, so-called cleats, through which water and gas can percolate, as well as by a porous matrix where methane is mainly trapped as an adsorbed layer and where diffusion prevails. When CO2 is injected, matrix tends to swell, adding therefore complexity to the already complex hydro-mechanical processes at stake in such environment. Indeed, the efficiency of methane recovery is driven by the coupling between two-phase flow dynamics with sorption/desorption mechanisms and compaction/deformation processes driven by effective stress changes. With the recent advances achieved in digital rock imaging, precious insight has been gained in the complex hierarchical pore space structure of coals and it should thus benefit to an improved mechanistic understanding of CBM recovery.

In this PhD thesis, a hydro-mechanical 3D pore-scale model will be developed to investigate these coupled processes. A discrete fracture network (DFN) flow model will be used to describe two-phase flow and mass transport within cleats. A discrete element method (DEM) where the solid material is seen as a collection of bonded particles will be used to simulate the deformations induced by fluid depressurization that will, in turn, directly impact the fracture hydraulic properties. The DEM code Yade Open DEM will be used (V. Smilauer, 2015). YADE has already been successfully applied to simulate the mechanical behavior of coal (Scholtès et al., 2011) and recent advances have led to make it suitable to describe hydromechanical coupling in fractured rocks (Papachristos et al., 2017). 3D representative geometries of cleat networks obtained from X-ray CT images of coal samples will be considered for the simulations. The diffusion flux of the adsorbed methane species from the coal matrix will be obtained from experimental correlations or using a rigorous mathematical upscaling from the lower scale. First, we will study CBM recovery only by water pumping. In a second step, CO_2 injection will be considered and coal matrix deformation will be introduced. Time and space changes of the fracture network geometry due to stress-state variations and the related impact on local permeability and porosity will be particularly investigated. Numerical predictions will be compared to laboratory experiments conducted in a parallel PhD thesis.

Student profile: The candidate must be a highly-motivated and self-directed person with a recent university master's degree (or equivalent) in computational mechanics, reservoir engineering, applied mathematics, civil engineering, or other relevant fields. He or she should demonstrate fundamental knowledge of solid and fluid mechanics principles governing the behaviour of porous and fractured media and show motivation for working at the interface between disciplines. An experience in developing numerical methods, particularly DFN/DEM would be an asset. The candidate will need to be fluent in English. Fluency in French or willingness to learn French will be an advantage).

Funding: The proposed PhD is funded as part of a larger Coalbed Methane Recovery Project, called REGALOR, supported by the regional Council of Lorraine and European regional developments funds. This project, done in collaboration with Française de l'Energie, the French CBM company, has the objective of supporting CBM exploitation in the former mining regions of France with low environmental impacts. The project is expected to demonstrate the commercial viability of full-scale recovery exploitation using modern equipment and techniques.
This PhD project is funded for 3 years, starting on October 1st 2019 (Net salary, including social security: ~ 1 650 €/month).

Applicants should send via email a Curriculum Vitae, copy of the master thesis and the names and email addresses of two references to:

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