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Hydro-mechanical modelling of a coalbed methane production well *via* a dual-porosity approach

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Most coal seams hold important quantities of methane which is recognized as a valuable energy resource [1]. Coal reservoir is not conventional because methane is held adsorbed on the coal surface [2]. Coal is a naturally fractured reservoir made of matrix blocks and cleats (*i.e* fractures) [3]. In general, cleats are water saturated with the hydrostatic pressure maintaining the gas adsorbed in the coal matrix. Production of coalbed methane (CBM) first requires a decrease of the hydrostatic pressure. It is followed by desorption of methane from the matrix during which gas molecules diffuse through the matrix and then migrate through the cleat system (Figure 1) [4].

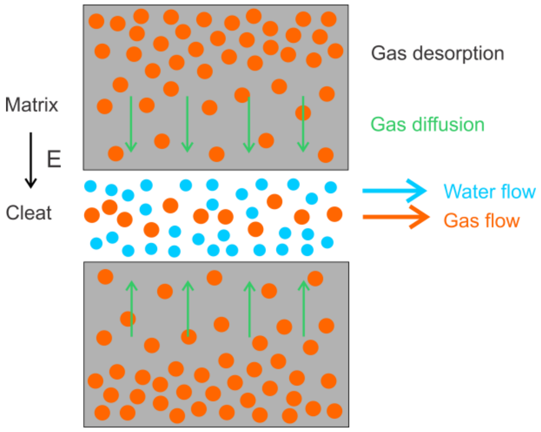

Figure 1: Migration processes in coal.

Changes of coal properties during methane production are a critical issue in coalbed methane recovery. Any change of the cleat network will likely translate into modifications of the reservoir permeability. In particular, two distinct phenomena are known to result from reservoir pressure depletion [5]. First, the reservoir compaction due to the increase in the effective stress (Terzaghi's principle) tends to decrease the permeability. The second effect is the matrix shrinkage following gas desorption, which, in contrast, tends to increase the permeability.

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This work consists in the formulation of a hydro-mechanical model of the reservoir at the macroscale. Due to the particular structure of coal, the model is based on a dual-continuum approach to enrich the macroscale with microscale considerations.

Regarding the mechanics, the matrix is treated as a linear elastic material [6] and the cleats are described as interfaces having a normal stiffness function of the cleat aperture. Elastic moduli of this dual system are then deduced for an equivalent continuum medium, by analogy with a series of two springs. Finally, the balance of momentum is used to express the mechanical equilibrium of the material.

Concerning the hydraulic aspects of the model, mass balance equations are established following a compositional approach [7] which consists of balancing the species rather than phases. Balance equations involve different variables such as densities, degrees of saturation or fluid fluxes. These dependent variables are linked to water pressure and gas pressure through some constitutive equations. For example, water flow is related to pressure gradients as per Darcy's equation. When applying Darcy's equation to the cleat network, the cubic law is used to compute the permeability from the fracture aperture. In the context of coalbed methane production, the Langmuir's isotherm gives the maximum quantity of adsorbed gas as a function of reservoir pressure. Finally, shape factors are employed to take into account the geometry of the matrix blocks in the formulation of the mass exchange term between the two systems, matrix and fractures [8].

The hydro-mechanical model here proposed is fully coupled. For example, it captures the sorption-induced volumetric strain or the dependence of permeability on fracture aperture, which evolves with the stress state. The model has been implemented with a finite element method in the Lagamine code and is used to model methane production at the scale of the production well. To date, attention has focused on a series of parametric analyses that can highlight the influence of the key parameters related to the reservoir (e.g. Langmuir's parameters and dimensions of the fractures and matrix blocks) and the well (pressure/pumping rate).

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