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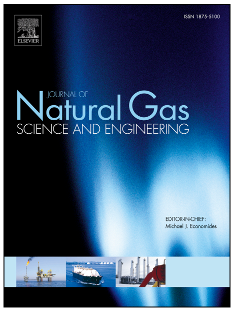

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A fully coupled hydro-mechanical model for the modeling of coalbed methane recovery

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Abstract

Most coal seams hold important quantities of methane which is recognized as a valuable energy resource. Coal reservoir is considered not conventional because methane is held adsorbed on the coal surface. Coal is naturally fractured, it is a dual-porosity system made of matrix blocks and cleats (i.e fractures). In general, cleats are initially water saturated with the hydrostatic pressure maintaining the gas adsorbed in the coal matrix. Production of coalbed methane (CBM) first requires the mobilization of water in the cleats to reduce the reservoir pressure. Changes of coal properties during methane production are a critical issue in coalbed methane recovery. Indeed, any change of the cleat network will likely translate into modifications of the reservoir permeability.

This work consists in the formulation of a consistent hydro-mechanical model for the CBM production modeling. Due to the particular structure of coal, the model is based on a dual-continuum approach to enrich the macroscale with microscale considerations. Shape factors are employed to take into account the geometry of the matrix blocks in the mass exchange between matrix and fractures. The hydro-mechanical model 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 is implemented in the finite element code Lagamine and is used for the modeling of one production well. A synthetic reservoir and then a real production case are considered. To date, attention has focused on a series of parametric analyses that can highlight the influence of the production scenario or key parameters related to the reservoir.

Keywords: Coalbed methane, Dual-porosity, Shape factor, Couplings, Reservoir modeling

1. Introduction

Coal seams typically contain large amounts of methane which can be recovered in the form of natural gas, the so-called coalbed methane (CBM) [1]. This methane is mainly located in Russia, Canada, China, Australia, and the USA. The first recorded well was drilled in 1931 in the USA in West Virginia but the commercial exploitation really began in the 1980s. The three major basins are the Black Warrior Basin (Alabama), the San Juan Basin (New Mexico, Utah, Colorado) and the Powder River basin (Wyoming and Montana) [2]. Thanks to these basins, the USA is currently the largest CBM producer in the world. About 90,000 CBM wells have been drilled in the USA, producing annually between 1 and 2 trillion cubic feet in the recent years (Figure 1). It represents almost 10% of the American natural gas production [3]. CBM production decreased in the past years but it is likely correlated to the oil price because American basins are expected to produce significant amounts of methane for at least one or two decades [4].

In order to determine the best production scenario, numerical models are interesting tools for oil and gas companies. However, models developed for conventional reservoirs are not suitable for the modeling of the CBM production. In conventional

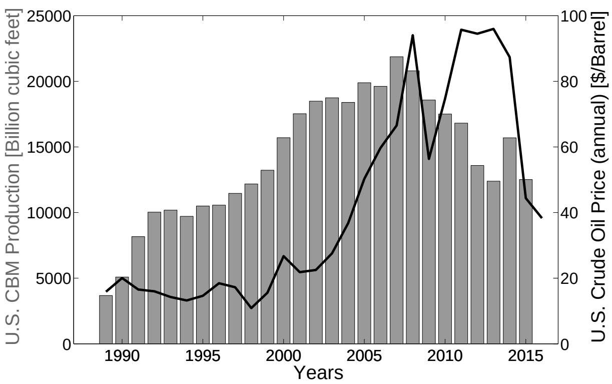

Figure 1: CBM estimated production in the USA compared with oil price. *Data from the U.S. Energy Information Administration.*

models, hydrocarbons are stored in porous and permeable host rocks with free gas compressed into the pore space (Figure 2a). In this case, gas flow rate is almost at the highest level from the beginning and it gradually declines accompanied by the increase of the water production (Figure 3a). In coal reservoirs, there are actually two key parts constituting the porosity system, fractures and much smaller pores in the matrix [4]. Methane is mainly stored by adsorption in the coal matrix while fractures,

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