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Identification of potential locations for well placement in developed coalbed methane reservoirs

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ABSTRACT

This study investigates well placement in developed coalbed methane (CBM) reservoirs. A workflow is developed to find potential locations for well placement within the reservoir. It consists of a reservoir simulator and statistical analysis. The application of this workflow is to reduce the need to perform computationally expensive simulations in large reservoirs to obtain potential locations for drilling an additional well. The workflow is also used to study the role of dominant reservoir properties in finding potential locations for well placement. The effects of permeability anisotropy, gas and water relative permeabilities, sorption time, and water content in well placement are discussed.

Results demonstrate that permeability anisotropy results in the formation of elliptical drainage areas around the wells. When drainage patterns are orthogonal to the direction of placement of wells, the drainage area of the reservoir is large and penetrated into distant locations. This leads to a non-uniform drainage area and extends well placement options to distant locations. Comparison between well placement in two scenarios with different gas and water relative permeabilities shows that potential locations tend to be on a border region between existing wells and virgin area when water mobility is restricted by water relative permeabilities. This region has the advantage of having higher pressure and gas content compared to locations among existing wells. In this study, changing the sorption time does not affect the well placement within the reservoir. Except at very early times, gas production from presented reservoir models is mainly controlled by Darcy flow in cleat system (permeability-dominated) rather than diffusion process in coal matrix.

1. Introduction

Well placement is an important task to minimize the risk of unproductive drilling and also to maximize the production. Successful well placement requires investigation of reservoir description, production performance, and economic evaluation (Gould and Sarem, 1989). Positioning a CBM well in optimal locations can maximize gas production, minimize water production, and extend the life of the wellbore. Optimal well placement in CBM reservoirs is attained when gas production is maximized while water production is kept at a minimum level (Clarkson and McGovern, 2005).

The failure of CBM projects is mainly related to low coal permeability (low gas rates) combined with low gas price at the market resulting in uneconomical gas production from coalbeds (Clarkson and Bustin, 2011). In wet coals, high cleat porosity results in higher water production from coalbed and it may cut down the profitability of CBM projects. In Queensland, Australia, the average rate of water production from a coalbed well is almost 126 barrels per day per well and can vary between only a few barrels up to thousands of barrels per day per well (CSIRO, 2012). However the quality of CBM water is better than produced water from conventional gas wells (Rice and Nuccio, 2000), the cost of water treatment and disposal can be up to 2.5 $/STB (Ham and Kantzas, 2008). The hydrodynamics of a CBM reservoir can be a key to understanding reservoir performance and designing well placement. Pashin conducted a study on hydrodynamics of CBM reservoirs in Black Warrior Basin and discussed the importance of reservoir hydrodynamics on reservoir pressure and well performance (Pashin, 2007).

Reservoir simulation and economic evaluation are widely used to optimize well placement in heterogeneous reservoirs (Hazlett and Babu, 2005). Clarkson and McGovern (2005) developed an integrated approach to optimize CBM exploration and development strategies by integration of reservoir simulation and economic tools (Clarkson and McGovern, 2005). Karacan et al. used a dynamic three dimensional reservoir model to study the effects of different horizontal methane drainage borehole patterns, borehole lengths, and degasification times to investigate their effectiveness on methane emission reduction (Karacan et al., 2007). Feng et al. (2012) optimized well placement in CBM reservoir by integration of reservoir simulation and particle

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Table 1
Reservoir properties used in the simulation model.

Reservoir properties used in base case	
Coal thickness (ft)	47
Coal density (t/acre ft)	1726
Reservoir temperature (°C)	49
Initial reservoir pressure (psi)	1600
Sorption time (Days)	10
Langmuir pressure (psi)	565
Langmuir volume (scf/t)	433
Initial gas content (scf/t)	258
Skin factor (all wells)	0
Initial water saturation	1

swarm optimization algorithm and their objective function was to maximize net present value (NPV) in a synthetic reservoir (Feng et al., 2012). Salmachi et al. (2013) constructed an integrated framework to attain the best-obtained optimal location of infill wells in CBM reservoirs through integration of reservoir simulation, an economic model, and the genetic algorithm (Salmachi et al., 2013). Well placement using simulation and optimization algorithms can be computationally very expensive due to the size of the reservoir model, the number of possible scenarios, and limitations on computational resources (Özdoğan, 2004).

The knowledge of gas and water mobility (controlled by relative permeabilities) and the preferential extension of reservoir drainage area in a particular direction (controlled by permeability anisotropy) assist in positioning new wells in the reservoir. The significance of relative permeabilities, permeability anisotropy, and sorption time in production from coalbeds is discussed in details in various studies (Clarkson et al., 2011; Karacan, 2008, 2013). Karacan et al. (2014) used coalbed reservoir simulation and geostatistical property realization for production history matching for a case study in Illinois Basin, Indiana, USA. They discussed that gas-in-place and effective permeability maps can assist in finding potential locations for future well placement (Karacan et al., 2014). The importance of reservoir properties when discussed in the context of well placement can help to investigate how potential locations change in respond to change in reservoir properties.

It is the intent of this work to introduce a workflow to facilitate finding potential locations for well placement using reservoir simulation. This workflow employs a series of evaluation parameters which are proxies for fluid flow and fluid depletion within the coalbed. The use of these evaluation parameters and the statistical analysis help to reduce the need to perform excessive and computationally expensive simulations to obtain potential locations for well placement. Moreover, this paper aims to study the effects of relative permeabilities, permeability anisotropy, sorption time, and water content in well placement. For this purpose, we have constructed a base reservoir model and several other cases with different reservoir properties. A single realization is assumed for reservoir properties in this work. The results from each case are compared with the results from the base reservoir model for analysis and will be discussed in the paper.

2. Development of the workflow

The quality of a location for well placement is assessed based on the amount of gas and water that is produced when a well is placed in that location (higher gas and lower water productions are desired). The higher well performance (higher profit) of potential locations is the result of combination of reservoir characteristics such that higher production is obtained. The higher gas and lower water productions result in higher net present value for a well location.

A simulation-based statistical workflow is developed to find potential locations for drilling an additional well in a CBM reservoir. We only address the placement of vertical wells within the reservoir. This workflow is also used to investigate the role of dominant reservoir characteristics in well placement. The presented workflow employs a series of evaluation parameters which are proxies for fluid flow and fluid depletions within the reservoir. A reservoir simulator (Eclipse E100) is used to create the production data and also to obtain the reservoir property values required to calculate the evaluation parameters. A section of the reservoir representing the heterogeneity of the reservoir is selected. Potential locations for well placement and their corresponding evaluation parameters are obtained within the selected region using the reservoir simulator. Then, a statistical analysis (decision tree) is performed to find the optimum range for each evaluation parameter corresponding to highest productions. Finally, evaluation parameter values and optimum ranges are used to predict potential locations for well placement outside of the selected region. In the rest of this section, the evaluation parameters and the statistical analysis (decision tree) used in this study are described in details.

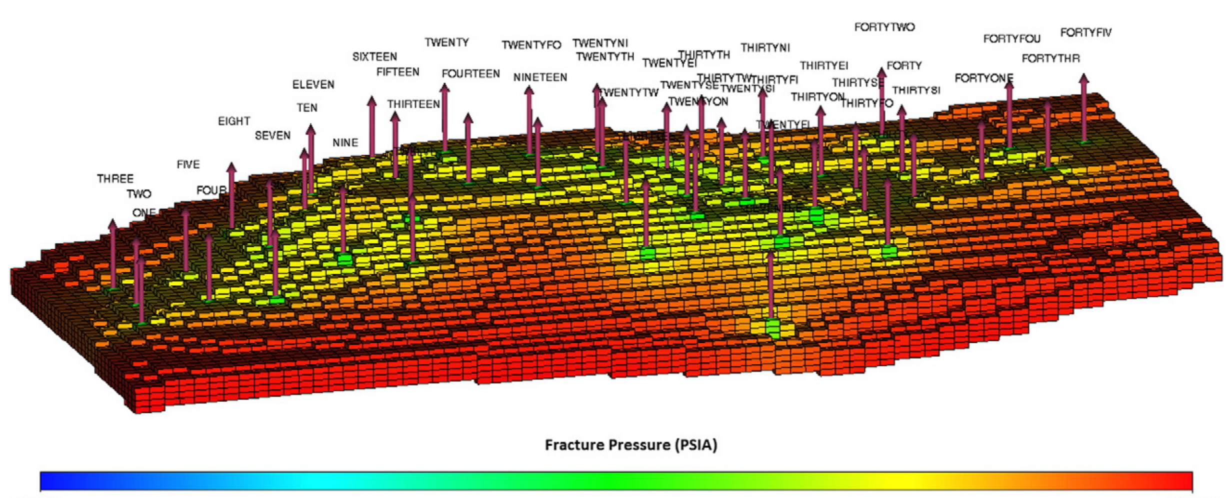

Fig. 1. The 3D view of the simulation model shown with reservoir pressure values.