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A new tool for prospect evaluation in shale gas reservoirs

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ABSTRACT

In recent years, unconventional gas (particularly shale gas – *SG*) has played an increasing role in satisfying gas demand both in North America and beyond. Despite extensive development, minimal work has been done to develop tools and methodologies for *SG* prospect analysis. Due to the complexity and variability among *SG* prospects, it is crucial to not only investigate all possible prospects, but also to investigate all areas within the selected prospect to pick pilot locations which offer the best potential for commercial success. In addition, due to the complexity of *SG* reservoirs, many authors have suggested that stochastic techniques should be used to assist in quantifying the risk and uncertainty of the analysis.

This paper discusses a new tool that was developed specifically for *SG* exploration and development. This tool combines the latest production data analysis and rate forecasting techniques with a simple, yet rigorous stochastic method for analyzing pilot well locations. The paper discusses the rate forecasting techniques used in the tool, as well as the tool development and application. Both simulated and field cases are provided to demonstrate the new methodology. This paper is an extension of the work presented by Williams-Kovacs and Clarkson (2011).

1. Introduction

In recent years, there has been a significant focus on unconventional gas, particularly in North America, due to the large extent of the resource and declining production from conventional gas reserves. Several estimates suggest that there are over 30,000 Tcf of unconventional gas resources worldwide (excluding hydrates), with approximately 50% of the resource coming from *SG* (Perry and Lee, 2007; Aguilera, 2009). Fred Julander, CEO of Julander Energy, described *SG* as "the most important energy development since the discovery of oil" (Kuuskra and Stevens, 2009).

Improvements in horizontal drilling, hydraulic fracturing, relatively high natural gas prices (prior to 2009) and recent commercial success in the Barnett Shale and several other *SG* plays have made *SG* desirable in the United States and exploration and development has begun to spread into Canada and several other regions around the world (Ground Water Protection Council and ALL Consulting, 2009).

Due to the complexity and large extent of *SG* prospects, it is crucial to develop tools and methodologies specifically designed for *SG* applications, which do not attempt to adapt techniques which have been commonly used in conventional gas and *CBM* applications. Several authors including Gray et a1. (2007) and Harding (2008) have suggested that decision making based on deterministic solutions is unsuitable for *SG* as they do not incorporate the risk and uncertainty associated with complex plays and often lead to overly optimistic results.

To date, minimal work has been completed on *SG* prospect analysis despite active exploration in North America and Europe and recently declining commodity prices. Declining commodity prices make it crucial to only develop the highest quality prospects which are most suitable for the company of interest and give the best potential to compete with low-cost conventional foreign gas deposits (i.e. Qatar and Saudi Arabia associated gas). Williams-Kovacs and Clarkson (2011) provided a review of current work relating to unconventional prospect analysis and provided a comprehensive six-stage prospect analysis and development evaluation methodology (*PADEM*), which was designed specifically for *SG* applications. In the paper, the authors also demonstrated a tool which was developed specifically for screening *SG* prospects and selecting the prospect(s) which are most suitable for a more detailed analysis. This paper builds upon the work presented by

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Williams-Kovacs and Clarkson (2011), focusing on prospect evaluation and selection of pilot locations within a prospect which has been selected for a more in-depth analysis.

The objective of the current work is to: 1) develop a methodology and accompanying analytical tool to assist in the exploration phase of *SG* development; and 2) demonstrate the application of the developed techniques to a tight siltstone/shale prospect in Western Canada. The primary contribution of this work is the development and demonstration of a rigorous analytical method for analyzing *SG* prospects, which can be used to generate a distribution of forecasts for pilot wells based on uncertainty in input variables while accounting for co-dependence. All previous work (i.e. Gray et a1., 2007 and Harding, 2008) has focused on generating full-field development scenarios, which cannot be generated quickly with the minimal data commonly available in early stages of prospecting and development.

2. Tool development

In this work, a tool was developed for analyzing *SG* prospects which have been selected using a pre-screening methodology, such as that presented by Williams-Kovacs and Clarkson (2011). This paper will focus on the development and application of the tool to analyze different areas of a prospect to determine whether they are suitable for a pilot project and represents the *Exploration* phase of the *PADEM* workflow presented in Fig. 1. The purpose of the exploration phase is to investigate prospects selected from screening in greater detail, in order to improve understanding of reservoir flow characteristics and the ability to produce consequential hydrocarbon. In this work we use probabilistic scoping economics on individual pod type wells as the exploration criteria to determine whether the prospect is suitable for a pilot project. The overall prospecting and development methodology is discussed in detail by Williams-Kovacs and Clarkson (2011), while a summary is provided in Table 1 for completeness.

Analytical modeling is chosen over numerical modeling for this application since the set-up and initialization time is much shorter, incorporation of Monte Carlo simulation is simple and the level of detailed data required to generate an accurate numerical model is often not available early in the exploration process. Despite the improvements of numerical techniques, analytical methods continue to be used extensively, both in industry and in the literature (i.e. Bello and Wattenbarger, 2009, etc.). A summary of the key components of the developed tool is given below.

2.1. Mapped properties

Likely the most crucial component of the exploration tool is the development of accurate property maps for key reservoir, geomechanical, petrophysical and geochemical properties. These maps can be derived from a combination of geological models, rate-transient analysis (*RTA*), pressure-transient analysis (*PTA*), petrophysical investigation, etc. These property maps are used for visualization of the prospect, pod selection and analysis of the individual pods. Property maps of original gas-in-place (*OGIP*), k_m-h, fracture brittleness, etc. can be useful in selecting representative pods and for selecting areas with greater development potential, even in highly heterogeneous plays. Pods are used as a method of assessing production characteristics of different areas within the prospect, which are thought to behave similarly, based on geological and petrophysical observations. Using pods simplifies the analysis by not having to develop a type well for each grid block, while still accounting for variability and uncertainty through the application of Monte Carlo simulation. The pod methodology was also used by Clarkson and McGovern (2005) for assess *CBM* prospects. Reservoir property maps can be created in Excel® by importing the X–Y coordinates and the reservoir property (Z) from Petrel™. The pivot table application is then used to sort the data and the maps are created using the 2D charting application. Since early petrophysical models are commonly developed using limited data sets, uncertainty in model parameters can be accounted for when selecting uncertain inputs and parameter ranges for Monte Carlo simulation on an individual pod. This method of accounting for uncertainty will be demonstrated in the example presented in this paper.

2.2. Hydraulic fracture model

For this work, hydraulic fracture half-length is predicted using a simple bi-wing fracture model developed by Valko (2001) for conventional and tight gas applications. This model uses matrix permeability, Shear Modulus (function of Young's Modulus and Poisson's Ratio) and other reservoir parameters as inputs and must be recalculated at every Monte Carlo iteration if any of the input parameters are modeled with uncertainty. Fracture half-length can

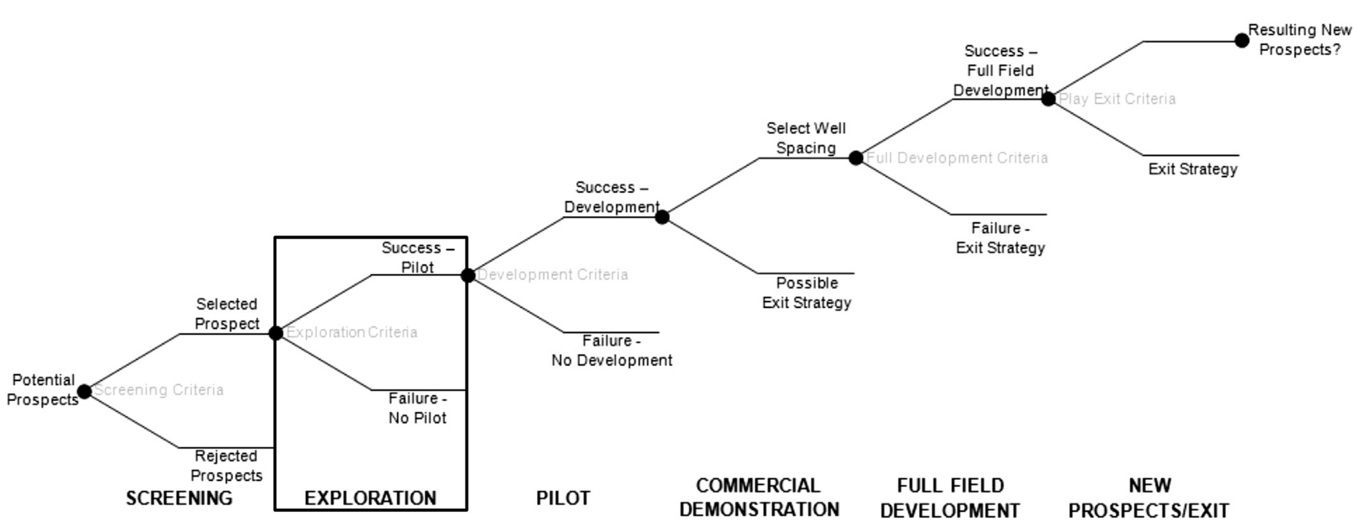

Fig. 1. Unconventional gas prospecting/development tool workflow with the exploration stage highlighted.