Journal of Petroleum Science and Engineering 149 (2017) 553–563

Contents lists available at ScienceDirect

Journal of Petroleum Science and Engineering

journal homepage: www.elsevier.com/locate/petrol

Hot spot hunting: Optimising the staged development of shale plays

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ARTICLE INFO

Keywords:
Appraisal and development
Unconventional plays
Geostatistics
Bayes's rule
Barnett Shale

ABSTRACT

The development of unconventional plays tends to unfold in many stages, each of which involves incremental investment and a reduction in the geological uncertainty of the reservoir. These two characteristics yield a large decision space where future decisions are optimised based on the near-continuous arrival of new information. This managerial flexibility can be exploited by operators during the development of unconventional plays.

We introduce a methodology that demonstrates how value can be created by a staged and partial development of a shale play that would have been unprofitable if fully developed. Compared to existing methods the novel methodology is more consistent with the characteristics of how plays are currently developed as existing methods assume that upon a successful appraisal stage a play is developed in its entirety in a single development phase.

As more data become available after each development phase of the play, the potential of the remaining undrilled locations is updated using Bayes's rule. The method is couched in geostatistical principles, combined with an algorithm that allows for a continuous optimisation of drilling targets.

An example of a shale gas project has been investigated that consists of 225 possible drilling targets each containing 10 well locations. A maximum of 200 wells can be produced by drilling 20 of the 225 targets. The mean performance of the well population is uncertain. The scenario with the highest mean well performance yields a value of −160 MM USD and the expected project value across all scenarios of mean well performance equals −920 MM USD, given that all 200 wells are drilled at randomly chosen drilling targets. In the model presented in this study the resource can be developed in up to 19 stages upon completion of an appraisal programme. After each development stage an assessment is made where, and if, the next batch of 10 wells should be drilled. This strategy of stage-wise development yields an expected value of 49.2 MM USD. The spatial dependency of well performance enables the algorithm to restrict the development of the play to the most prolific areas.

The appraisal programme provides a view on the variability of well performance across the play. A trade off exists between the size, and the consequential accuracy, of the appraisal programme and the cost of appraising. The example illustrates that the expected project value increases from 33.3 MM USD for an appraisal programme in which two locations were appraised, to a maximum of 49.2 MM USD after the appraisal of four locations, and subsequently decreases to 29.0 MM USD after having appraised eight locations.

The assumptions around the variability of Estimated Ultimate Recovery (EUR) used in our example are informed by data from 10,000 horizontal wells located in the Mississippian Barnett Shale in the Fort Worth basin in Texas.

1. Introduction

Performance of wells in shale plays is found to be very variable even if wells were drilled in sites with apparently similar geology and production characteristics (Wright, 2008; Sutton et al., 2010; LaFolette and Holcomb, 2011; Strickland et al., 2011). The identification of “hotspot” in areas of similar geology typically requires the drilling of many wells and the review of associated production data (McGlade et al., 2013; Coll and Elliott, 2013; Addis et al., 2015). Williigers et al. (2014) demonstrated that accurately locating the hotspot areas in the core of the Barnett play entailed acquiring production data from several hundred wells.

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http://dx.doi.org/10.1016/j.petrol.2016.10.052
Received 23 June 2016; Received in revised form 3 October 2016; Accepted 27 October 2016
Available online 07 November 2016
0920-4105/

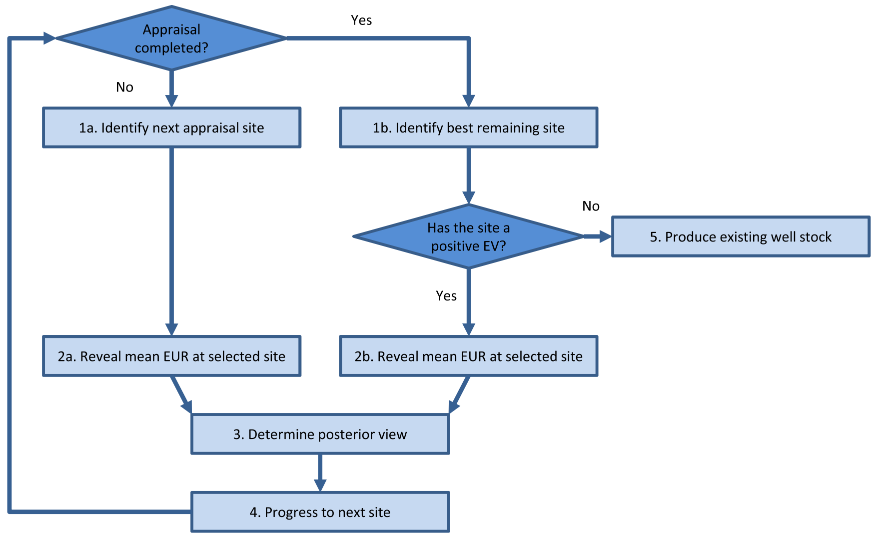

Fig. 1. Flow chart for the determination of a drilling sequence in a shale play for a given play realisation.

Several studies used Bayes's rule to update the view of the economic potential of a population of undrilled wells in a play in light of production data (Haskett and Brown, 2005; Bickel, 2014; Willigers et al., 2016a, 2016b). The premise of these studies is to define the most cost effective appraisal programme that can provide confidence that the population of undrilled wells will yield a positive economic return. These studies assume that the entire population of possible wells will be drilled upon a successful completion of the appraisal programme. In reality many operators aim to find and develop the hotspot areas and leave the non-hotspot areas undeveloped. Although the partial development of a reservoir was addressed in Stabell et al. (2007) and Williams-Kovacs and Clarkson (2011), these studies did not rigorously model how data gathered during the development of a play affects the view on the unexplored part of the play.

Development of unconventional plays tends to take place in a series of development phases (Burkholder et al., 2012; Addis et al., 2015). Once the economic potential of shale resources has been demonstrated in one locality the development of a shale play is extended to neighbouring areas. Choice of what part(s) of a play to develop next or when to stop the further development of a play need to take account of already drilled locations, possible drilling locations, spatial dependencies between performances at those different well locations, and uncertainty as to whether a well or a batch of wells will be economic. Although Haskett and Brown (2005) and Allan (2013) considered exit-points during the development of an unconventional play, the decision space associated with real-life unconventional projects is vastly more complex than has been suggested by those studies.

Haskett and Brown (2005), Bickel (2014) and Willigers et al. (2016b) did not consider the spatial dependencies between well locations. Willigers et al. (2014) showed how Bayes's rule can be combined with standard geostatistical methods to update a view on the location and size of the hotspot areas upon the arrival of new well data. However, Willigers et al. (2014) made no attempt to determine the value of the unconventional projects. Willigers et al. (2016a) demonstrated how the Value of Information of an appraisal programme can be maximised by the number and placement of appraisal wells but this study did not consider the possibility of value creation using a strategy aimed to limit the development of a play to the hotspot areas (i.e. to develop only the most prolific portion of the population of undrilled well locations) using a staged development programme.

This study illustrates how geostatistical techniques, combined with an appraisal-development algorithm and the Value of Information (VoI) methodology, can be used to value shale oil & gas projects. The main contributions of this paper are (1) the creation of a simple, but realistic, algorithm for how operators should develop a shale play by continuously optimising drilling targets, and (2) to demonstrate how value can be maximised by carefully selecting which parts of a play to develop and when to stop further development of the play.

The remainder of this paper consists of four sections. The first section describes the methodology developed in this study. The second section develops a numerical example using the developed method. The third section discusses the implications of the developed method on the valuation of a shale project. The fourth section provides concluding remarks.

2. Method

2.1. Summary of proposed method

First, the area involved in a shale play is subdivided to form a grid. The grid cell represents the smallest unit that can be selected for drilling. If a cell is selected, a predetermined number of wells will be drilled within it. A cell contains appraisal wells or development wells, but not both. Appraisal cells are cells that contain appraisal wells. Development cells are cells that contain development wells. The only difference between appraisal and development cells is that a commitment on the number and location of appraisal cells is made before drilling starts, whereas the number and location of development cells is dependent on the data acquired during the appraisal and development of the play. The gradual appraisal and development of a shale play is simulated by repeatedly adding undrilled cells to the set of already drilled cells (Fig. 1). After the addition of a cell, the data acquired about the cell are used to update the view of the play. The process starts by drilling all appraisal cells. This phase is referred to as the appraisal phase. In the subsequent phase, the development phase, the undrilled development cell with the highest expected value is selected as the next drilling target, provided that its expected value is positive; otherwise, no further cells are added.

2.2. Uncertainty versus variability when modelling unconventional hydrocarbons plays

A distinction can be made between variability and uncertainty. Uncertainty, which is quantified by probability, relates to a quantity whose value is unknown. Variability, which is quantified by statistics (eg frequencies), relates to a quantity that has different values (known or unknown) at different locations (Begg et al., 2014). For example, the ultimate recovery (UR) of an undrilled well location is an uncertainty