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Research paper

Full field reservoir modeling of shale assets using advanced data-driven analytics

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ABSTRACT

Hydrocarbon production from shale has attracted much attention in the recent years. When applied to this prolific and hydrocarbon rich resource plays, our understanding of the complexities of the flow mechanism (sorption process and flow behavior in complex fracture systems - induced or natural) leaves much to be desired. In this paper, we present and discuss a novel approach to modeling, history matching of hydrocarbon production from a Marcellus shale asset in southwestern Pennsylvania using advanced data mining, pattern recognition and machine learning technologies. In this new approach instead of imposing our understanding of the flow mechanism, the impact of multi-stage hydraulic fractures, and the production process on the reservoir model, we allow the production history, well log, completion and hydraulic fracturing data to guide our model and determine its behavior. The uniqueness of this technology is that it incorporates the so-called "hard data" directly into the reservoir model, so that the model can be used to optimize the hydraulic fracture process. The "hard data" refers to field measurements during the hydraulic fracturing process such as fluid and proppant type and amount, injection pressure and rate as well as proppant concentration. This novel approach contrasts with the current industry focus on the use of "soft data" (non-measured, interpretive data such as frac length, width, height and conductivity) in the reservoir models. The study focuses on a Marcellus shale asset that includes 135 wells with multiple pads, different landing targets, well length and reservoir properties. The full field history matching process was successfully completed using this data driven approach thus capturing the production behavior with acceptable accuracy for individual wells and for the entire asset.

1. Introduction

Much of the success in turning the shale source rock into an economically viable and producible hydrocarbon reservoir is accredited to George Mitchell and his team of geologists and engineers at Mitchell Energy & Development[1]. The success in production of shale oil and shale gas dates back to 1981 when multiple combinations of processes and technologies where examined before ultimately succeeding in 1997 with the use of a "slick-water" frac that made production from Barnett Shale economical and changed the future of the US natural gas industry (NGW, 2011). Today horizontal wells that include multi-stage, multi-cluster hydraulic fractures and pad drilling are the norm in developing shale oil and shale gas assets in North America and expanding throughout the world.

Shale reservoirs are characterized by extremely low permeability rocks that have a number of unique attributes, including high organic content, high clay content, extremely fine grain size, plate-like micro-porosity, little to no macro-porosity, and coupled Darcy and Fickian flow through the rock matrix. Unlike conventional and even tight sandstone gas reservoirs where all the gas is in the free state in the pore space, the gas in shale is stored by compression (as free gas) and by adsorption on the surfaces of the solid material, either organic matter or minerals (Guo et al., 2012).

This combination of traits has led to the evolution of hydraulic fracture stimulation involving high rates, low-viscosities, and large volumes of proppant. The stimulation design for plays such as Marcellus Shale is drastically different than anything else that has

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[1] Mitchell Energy & Development. Mitchell sold his company to Devon Energy in 2002 in a deal worth $3.5 Billion.

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been performed in the past. It takes large amounts of space, materials, and equipment to treat the Marcellus Shale to its fullest potential (Houston et al., 2009). Currently, the Marcellus shale, covering a large area in the northeastern US, is one of the most sought-after shale-gas resource play in the United States. It has presumably the largest shale-gas deposit in the world, having a potentially prospective area of 44,000 square miles, containing about 500 TCF of recoverable gas (Engelder, 2009).

This geological formation was known for decades to contain significant amounts of natural gas but was never considered economical. Uneconomic resources, however, are often transformed into marketable assets by technological progress (Considine et al., 2009). Advances in horizontal drilling and multi-stage hydraulic fracturing have made the Marcellus shale reservoir a focal point for many operators. Nevertheless, our understanding of the complexities associated with the flow mechanism in the natural fracture and its coupling with the matrix and the induced fractures, impact of geomechanical properties and optimum design of hydraulic fractures is still a work in progress.

A vibrant and fast-growing literature that covers operational and technological challenges of production from shale oil and shale gas is currently thriving. The research includes all aspects of drilling, completion, and production as well as difficulties in formation evaluation/characterization, in modeling macro- and micro-scales of fluid transport, and in developing reliable reservoir simulators. Understanding reservoir properties like lithology, porosity, organic carbon, water saturation and mechanical properties of the rock, which includes stresses, and planning completions based on that

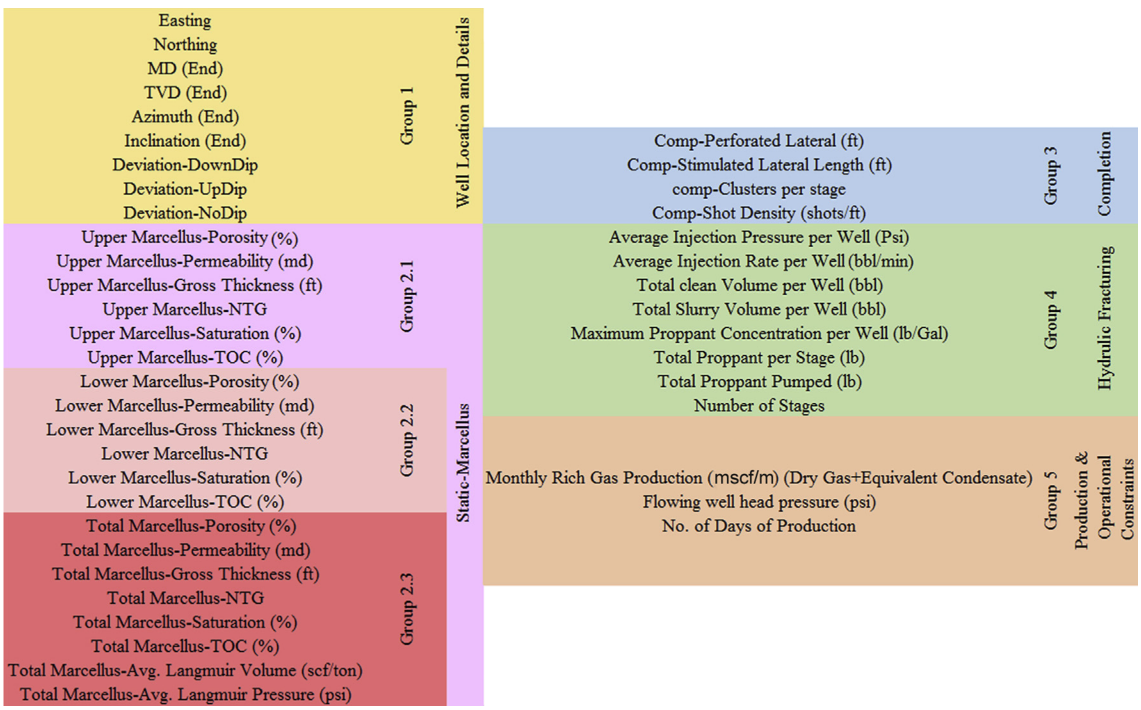

Figure 1. Data available in the dataset that include location and trajectory, reservoir characteristics, completion, hydraulic fracturing and production details.

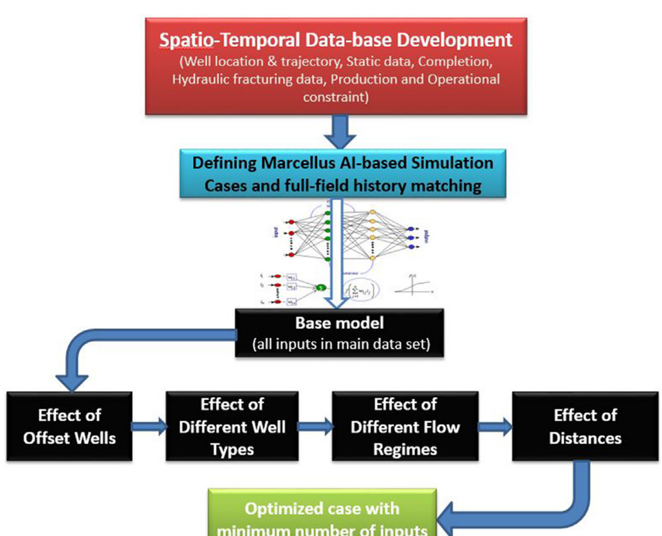

Figure 2. Marcellus shale AI-based Full-field history matching process.