Modern Reservoir Modeling and Simulation of Wells in Shale Resource Plays

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Shale recourse plays are the current rage in the E&P industry and have opened a new era for oil and gas production. Organically rich shales, once ignored by drillers seeking easier plays and faster returns on their investments, are now boosting the fortunes of midsized producers across the United States. Numerous operators including super majors, midsized producers and small independents continue to identify new plays and add incremental production in existing shale resources. Globally, shale-gas resources are estimated to exceed 16,000 Tcf thus it is clear that tremendous potential exists for future growth. Across the United States, from the West Coast to the Northeast, around 21 geographic basins are recognized sources of shales which continue to be one of the hottest plays in the United States.

Drilling is expanding rapidly in shale resource plays, especially in the south-central United States, the Appalachian basin, and numerous Rocky Mountain basins. On the operation side, shale wells are not hard to drill, but they are difficult to complete. The challenge is to release hydrocarbons from rocks as impermeable as concrete. Horizontal drilling and stimulation treatments are the key enabling technologies that make development and recovery of unconventional shale formations economically viable. Long a dream for the E&P industry, horizontal drilling came into widespread use during 1990s.

Horizontal drilling has been an efficient way of removing hydrocarbons from conventional reservoirs and is currently being used by drilling companies to enhance recovery rates in the ultralow permeabilities they encounter in shale resource plays. The rock around the laterals must be hydraulically fractured before the wells can produce any significant amounts. Various well placement and hydraulic fracturing treatment schemes are designed, tested and performed. Longer horizontal wells are drilled and more massive multistage, multicluster hydraulic fracturing treatments are executed. The more fractures in the shale around the wellbore, the faster the production.

In every shale resource play, fractures are the key to good production. Because of shale's extremely low permeability, the best fracture treatments are those that expose as much of the shale as possible to the pressure drop that allows the gas to flow. Multistage and multicluster hydraulic-fracturing treatments create complex fracture networks that can be represented by large stimulated reservoir volumes (SRV) that have been effectively contacted and contribute to higher production profiles.

Understanding the performance of very tight, low perm, low porosity unconventional resource plays, such as shales introduces new challenges to the E&P industry. This is due to the effect of multistage hydraulic-fracturing treatments in creating stimulated reservoir volumes with a very complex and unpredictable growth patterns. Reservoir characterization, modeling and simulation offer the best techniques to help understand the shale resource plays; evaluate the performance of wells; and estimate the field ultimate recovery. Reservoir modeling and simulation technologies have been proven to be the most cost-effective way of understanding the shale reservoirs behavior under different drive mechanisms, changing fluid behaviors, and completion configurations whose effectiveness and performance may change with time. These technologies provide the information operators need to make quicker and better reservoir development decisions.

Reservoir simulation results play an important role in understanding the stimulated volumes in shale resource plays. History matching or replicating the past well behavior is the primary step in reservoir

simulation and is very difficult; however, as complex as it is, history matching for simulation-model calibration is required to generate convincing forecasts. This research intends to first model the shale resource plays, and consequently simulate and forecast the performance of wells.

The main challenges in reservoir modeling and then simulating past/future production profiles of shale resource plays include properly describing the stimulated volumes, the geometry of the fractures and their location; fractures intensities and characterizing the matrix/fracture attributes. The location and geometry of the SRV created by hydraulic fracturing is complex but microseismic has played an important role in understanding an initial estimation of the SRV and the fracture intensities and thus can provide means to guide the reservoir modeling and simulation efforts. Reservoir simulation results indicate that due to the extremely low permeability of shales, the flow behavior is dominated by the extent and configuration of the hydraulic fractures. In addition, reservoir modeling and simulation results offer valuable insight for designing the best perforation strategy, completion practices and re-stimulation plans to maximize the effective stimulated reservoir volumes throughout the life-cycle of the shale resource play.

Modern techniques to characterize and model shale resource plays and simulation of wells by focusing on the mentioned matrix and fracture challenges to sensitize the complex growth and attributes of hydraulic fractures are presented. A systematic methodology is utilized to integrate the variety of information and obtain accurate reservoir characterizations and consequently perform reliable simulations to expand our understanding of the flow behavior in shale resource plays.

This work presents an integrated workflow that demonstrates an effective methodology for capturing the essential characteristics of shale resource plays and aims to offer quantitative procedures for optimizing the field production. The developed techniques played an important role in understanding the stimulated shale volumes. Key conclusions of achievements include the capability to generate more reliable forecasts and predictions that are highly critical if it is aimed to understand well performance and optimize its productivity. This research has led to a game-changing methodology for the global E&P industry that enables operators to develop an early understanding of the performance of shale wells where such detailed knowledge is vital to optimizing exploitation economics and estimation of reserves and resource potential.

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