Intelligent Data Acquisition Techniques Enhance Completions in Unconventional Formation

Petrophysical review improves understanding of key production drivers critical to Bakken formation production success

**CHALLENGE**
Predict well performance based on reservoir quality and stress state in an unconventional oil reservoir while addressing infill completions, the impact of depletion patterns, and completion optimization.

**SOLUTION**
Build and interpret petrophysical and geomechanical models using integrated high-tier data to capture completions and production observations, predict completion results, and improve well performance.

**RESULTS**
Modified completions and development program based on accrued petrophysical knowledge and improved reservoir understanding; reduced costs and increased production after implementation of engineered designs.

**Optimize completions in horizontal Bakken wells**
One of the largest North American deposits discovered in the last few decades, the Bakken formation rivals the size of some of the world’s largest proven reserves. As the use of long horizontal wells and multistage fracturing technology has significantly increased productivity and activity in the basin, the challenges associated with infill completions, depletion, and controlled fracture growth must be addressed to ensure that efficient and effective practices are deployed, encouraging long-term planning without hindering investment.

Statistical sample-size calculations showed that, to determine with 90% confidence if a design change would be successful across a group of wells, the sample size required is in the range of 45–74 wells. This demonstrates that the statistical approach to determining the optimal completion strategy is both expensive and vague if a coupled modeling approach is not used. To circumvent these operations while maintaining accurate, reliable results, an operator in the area sought to incorporate petrophysics, geomechanics, completion evaluation, and single-well production modeling to optimize its completion and development plan.

**Include comprehensive, high-tier data and modeling in strategy**
The operator chose to work with Schlumberger in the project, which included the study of two separate areas to better understand production drivers and development challenges in the Middle Bakken. Pilot well log data were analyzed, and the resulting petrophysical input was used to construct both a mechanical earth model (MEM) and single-well models used for completions and production modeling. The single-well models were built early in the program to serve as a fast loop for calibrating petrophysics with the MEM, which estimated direct inputs for hydraulic fracture modeling and evaluation, including elastic properties, pore pressure and earth stresses. Building and analyzing the MEM enabled better understanding of the rock mechanical properties and in situ stress state for input and optimization of the completion designs.

To provide petrophysical properties for the study, wireline logs were obtained using a high-tier logging suite that comprised
- ECS* elemental capture spectroscopy sonde for quantitative mineralogy and lithology
- Sonic Scanner* acoustic scanning platform for full 3D acoustic characterization from axial, azimuthal, and radial sonic measurements
- Rt Scanner* triaxial induction service for vertical and horizontal resistivity measurement
- CMR combinable magnetic resonance tool for enhanced nuclear magnetic resonance measurements of permeability, pore-size distribution, and hydrocarbon pore volume.

All wells were logged for resistivity, caliper, and gamma ray, and three wells also had core data. A history match on both the hydraulic fracture pressure history and production history served as the basis for reducing uncertainty around fracture geometry in these models. The production history match used inputs from rate-transient analysis, core, and fracture modeling to determine what the possible solutions are. Repeatability of the history matching allows for confidence in the models. This study summarized results from analysis across five high-tier data sets, and modeling included the data well and offset wells if water cuts, gas-oil ratios and fracture gradients were within tolerance: ±3% on water cuts and ±300 psi on fracture gradient estimates.
CASE STUDY: Petrophysical review improves understanding of key production drivers in Bakken formation

Enhance completions decisions and increase production
Comparison of fracture geometries obtained in both areas demonstrated that the optimization opportunities that exist in Area 1 would be significantly different from that in Area 2. Analysis from Area 1 indicated that little growth occurred from the Middle Bakken into the Three Forks, net pressures were high, and containment was good relative to Bakken propagation. Thus, it was recommended to increase the job size rather than increase stage count. The propagation of multiple fractures from a single stage in this area also indicated that little benefit would be seen from a stage count increase.

A pilot was conducted to initially test the hypothesis; no cost change was observed in this design change, and the production results were positive. In the second pilot, aggressive design changes were implemented that were associated with cost reduction. In both pilot tests, no change in flowing pressures, water cuts, or GORs were observed.

The result of the integration of petrophysical, geomechanical, and completion observations into a reservoir simulation model highlighted the importance of considering key parameters in asset development, including how hydraulic fracture geometry changes with depletion and local stresses. Modeling showed that asymmetry and limited vertical connectivity would occur if an offset well produced more than 200,000 bbl, which highlights the importance of considering completion timing in the field-development program. Acquiring and integrating high-resolution logs and core data also helped in understanding upscaling effects and assigning appropriate facies and flow unit characterization.

Impact of fracture asymmetry on development program.

Difference in stress profile and fracture propagation of Areas 1 and 2.