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Petrel Platform Enables High-Resolution, Quantitative Modeling of Complex, Heterogeneous Reservoir

Anisotropic porosity and lithofacies distribution accurately defined in Bahariya and Kharita Formations, Western Desert, Egypt

CHALLENGE
Accurately define the structural and stratigraphic heterogeneity of a complex, stacked sandstone reservoir in the Western Desert of Egypt.

SOLUTION
Use the Petrel* E&P software platform together with structural, core, and log data to identify the depositional environment and develop a reliable, high-resolution 3D reservoir model.

RESULTS
Significantly improved understanding of porosity and lithofacies distribution in stacked sandstone units in a tidal-flat environment.

Complex, heterogeneous geology and lithofacies challenged interpretation

The Shahd SE oil field, located in the northern part of Egypt's Western Desert, has NW-SE trending Cretaceous faults that form a prominent horst structure. The crest of the horst is controlled by a southern bounding fault, where the Bahariya Formation gently dips to the northeast toward the northern bounding fault. The main bounding-fault trend follows the general structural trend of the Late Cretaceous fracture elements, which were initiated by the dextral shear tectonics that dominated the northern Western Desert during that time.

The complex geological structure of the Bahariya Formation exhibits a tidal channel geometry that varies vertically and laterally across the field. The operator requested assistance to develop a detailed model that would accurately depict the structural and stratigraphic heterogeneity of this complicated channel system.
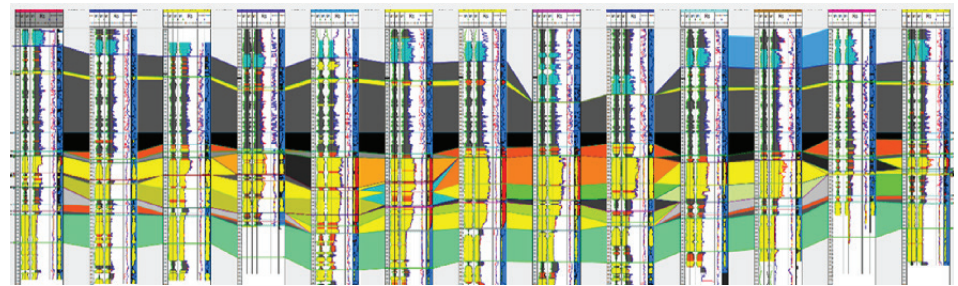

Upper and Lower Bahariya well-log correlation showing flattening of the top of the Lower Bahariya section.

3D reservoir model created using three-step process

For accurately describing the structural and stratigraphic heterogeneity of this complex, stacked sandstone reservoir, Schlumberger used the Petrel platform to construct a 3D reservoir model in three main stages:

- Conceptual stratigraphic and structural model was generated by correlating log data.
- Structural 3D model was built using the three main horizons (Upper Bahariya, Lower Bahariya, and Kharita Formations) identified by seismic interpretation.
- High-resolution 3D property model was generated showing the distribution of facies and porosity.

Log interpretation used a deterministic approach to generate facies logs for 13 wells. A detailed petrophysical correlation was performed using gamma ray, neutron, density, and resistivity logs to delineate sand cycles and distinguish between reservoir and nonreservoir rocks. The volume of shale was determined from clay volume, porosity, and water saturation provided by gamma ray, microresistivity from the MicroSFL* spherically focused resistivity tool, neutron, and density logs. Neutron and density logs provided total porosity, which was corrected for the shale fraction to calculate effective porosity.
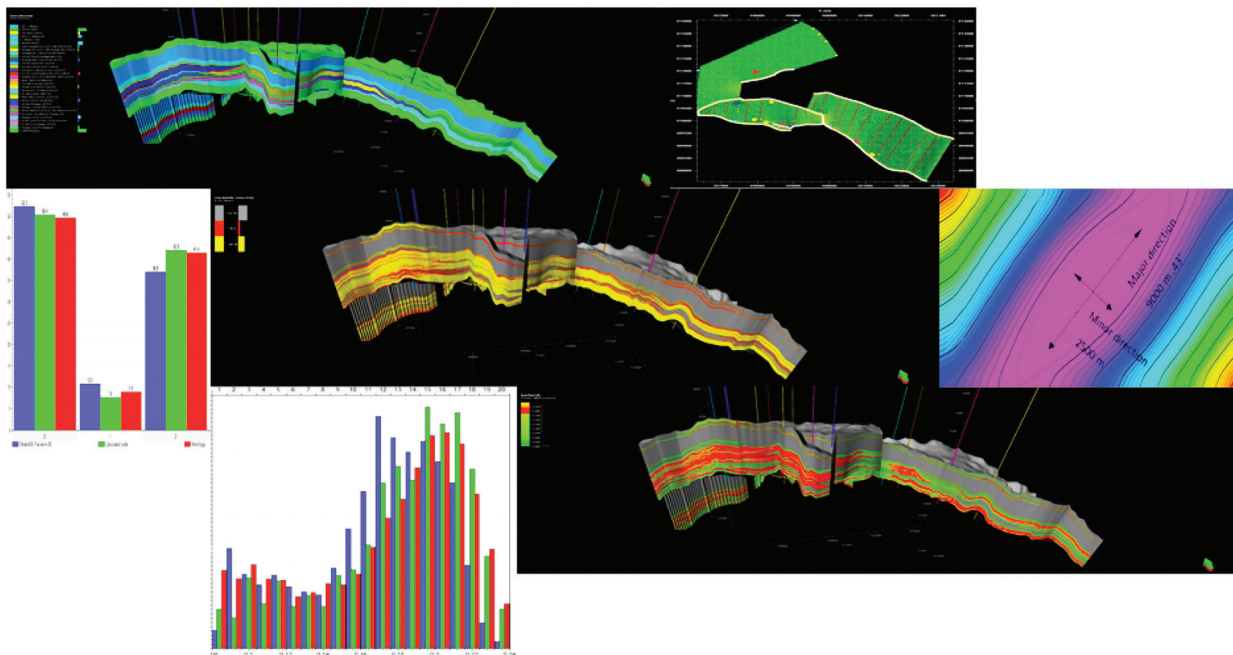
A 3D static geological model is provided through probability and variogram maps, using log, biostratigraphy, core, and petrophysical data.

The main inputs for the structural model were the structure maps of Upper Bahariya, Lower Bahariya, and Kharita Formations. These maps were used to manually generate fault sticks by drawing single polylines for upthrown and downthrown sides to represent the structural geometry. Fault pillars were generated to establish 3D grids and build models for the main horizons, which were divided into 34 zones to define a high-resolution stratigraphic framework.

Both the sediments deposited in the tidal-flat environment and the stacked sandstone units represent tidal deposits, indicating moderate to good reservoir quality. Percentage maps were generated for each zone taking the facies code into account and a variogram was created for each zone to determine the major direction, minor direction, and heading angle. A detailed understanding of the depositional environment's anisotropy was the main input for the sequential high-resolution simulation of facies distributions.

In addition, a static geological model is provided by probability maps— showing a percentage for each facies code—and variogram maps, using FMI* fullbore formation microimager and other log data, biostratigraphy data, core data, and petrophysical information.

Petrophysical model accurately identified porosity distribution

Using the Petrel platform and the Geostatistical Software Library (GSLIB), a stochastic petrophysical model was generated through sequential Gaussian simulation biased by facies distribution, which honors well data, petrophysical data transformation (porosity), variogram, and trends. Porosity is one of the most important petrophysical variables in hydrocarbon resource characterization because it describes the subsurface pore space

available for fluid storage. Using GSLIB, the lithofacies model is often used to constrain the spatial distribution of porosity because in the hierarchy of subsurface heterogeneities, depositional facies govern the spatial and frequency characteristics of porosity to a large extent. Even though porosity can be quite variable within each facies, porosity statistics by facies generally exhibit less variation.

The porosity analysis can help the transition from qualitative description to quantitative analysis, bridge the gap between descriptive geology and quantitative modeling, and provide useful constraints to condition the facies model to be geologically realistic. Variogram analysis can help characterize the continuity of rock properties, including geological object size and anisotropy.

A broad hierarchical modeling workflow is an efficient way of modeling multiscale subsurface heterogeneities, including large-scale structural and stratigraphic heterogeneities, intermediate-scale facies heterogeneities, and smaller-scale petrophysical properties. The innovative workflow successfully captured the structural and stratigraphic heterogeneity of a very complicated channel system and provided a simulation grid validated for the dynamic phase of modeling.

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