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High Resolution Near Wellbore 3D Structural Modeling with LWD Resistivity Image and Deep Azimuthal Resistivity

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SUMMARY

The Delaware basin of Western Texas and Southeastern New Mexico consists of multi-stacked reservoirs with most common drilling activity targeting the Bone Spring formation. For the purpose of optimized completions and production, sweet spot interval is defined based on rock quality and fracability. Available suite of logging while drilling (LWD) with azimuthal measurements aided in accurately placing horizontal wells within defined target stratigraphic zone. With LWD borehole image dip data and azimuthal deep resistivity measurements, integrated near wellbore reservoir-scale structural modeling was done using advanced 3D modeling technique. Workflows which includes dip interpretation, dip sequence analysis, extraction of local structural components, true stratigraphic computation, isopaching, structural axis delineation and definition of structural units and elements were applied. Resultant high resolution structural model is useful for taking decisions on sidetracking, well planning and well placement in reservoirs with sub-seismic structural elements and complex 3D structures.

Introduction

The Delaware basin of western Texas and southeastern New Mexico is a major hydrocarbon-bearing province of about 6.4 million acres. The basin consists of multistacked plays with most drilling activity targeting Bone Spring, where operators are active in multiple stratigraphic sections of 3,000 to 3,600 vertical feet. Recently, fieldwide production history has suggested that sweet spot characterization within the stacked sand and carbonate package is necessary for optimizing hydraulic fracturing, completions, and subsequent production. Within the Bone Spring section, defined sweet spots are typically 10 to 15 feet thick. Staying in zone within this preferred interval is often challenging because of structural complexity, rock property heterogeneity, and lack of azimuthal measurements in the bottomhole assembly (BHA).

The BHA for one horizontal well in the region includes a real-time high-resolution LWD resistivity imager and a real-time deep-azimuthal resistivity bed-boundary mapping service to enable optimized well placement and geosteering within 12 feet of the true stratigraphic thick (TST) target sand. Geosteering and acquired borehole image LWD data was used to demonstrate a workflow for 3D structural modeling.

Methodology

Based on the project objective and available data, which often depends on the field age, the industry uses different available inputs, such as seismic, well tops, bed-boundary dips from image data, to generate structural maps and 3D earth models. Based on data density, user knowledge, and software availability, generated models have their associated uncertainties. What is usually important is the level of error or uncertainty and whether it is within an acceptable limit. The user must understand the strength and limitations of any chosen methodology and data input. In the absence of seismic data, this study demonstrates the application of true bed boundary dip data and high-resolution structural cross-sectional interpretation from bed-boundary mapping for enhancing 3D structural model generation, constraining local structural architecture, and limiting structural uncertainty.

Bed-boundary dip interpretation from LWD image data was the primary input for advanced 3D near-wellbore structural modeling. Available software can utilize image data and interpreted bed-boundary true formation dips to perform dip sequence analysis (DSA), which is used to filter in-sequence and out-sequence dips (Etchecopar, et al.1992). After DSA, local structural components were extracted, and TST index at the borehole level was computed. These led to structural dip computation (SDC), structural axis delineation, and definition of structural units and elements depending on the conceptual model complexity and geological history of the area. These attributes were then combined with structural dip projection to create more accurate isopach models. Finally, an integrated 3D structural model was generated using key horizons and structural cross-sectional output from real-time deep-azimuthal resistivity distance to bed-boundary mapping output. The combination of LWD images and advanced 3D structural modeling enables resolving and more accurately representing local structural complexities and reservoir architecture. As more wells are drilled in the area, the geomodeling and dip-analysis software can integrate multiwell data to construct a full-field structural model, optimize well planning, and characterize reservoir properties using the structural model output whenever needed.

Figure 1 final output using integrated solutions from LWD measurements for high-resolution 3D structural modeling in the absence of seismic data. Picture (A) shows the structural cross-section model output from a geosteering software. The lower section confirms match of the bed-boundary mapping service distance to resistivity measurement with interpreted formation dips from borehole resistivity image data shown as dip sticks. Picture (B) is the 3D structural model; structural architecture of the area is modeled as a half-anticlinal model with local southeast structural dip. Picture (C) shows the horizontal well trajectory with dip data and image wrapped around the borehole. Healed resistive fractures are also seen on the borehole image. The drilling polarity log (drilling up/down/parallel) to bed boundary is also represented.

Conclusions

As shown in this study, for one or more wells with borehole image data, the fieldwide structural architecture can be modeled for better understanding structural geology, characterizing reservoir properties, and optimizing well planning. In the absence of good-quality seismic data and limited well control, the integrated workflow using data from LWD image and other deep directional imaging measurements yields an acceptable 3D near-wellbore structural model with limited structural uncertainty. This workflow can also be applied in projects that require structural-model update when new wells are drilled with borehole image acquisition tools. In addition to this study example, the high-resolution LWD resistivity images also identified mineralized fractures along the well path, optimizing completion.

References

Etchecopar, A. and Dubas, M.O. "Methods for geological interpretation of dips," *SPWLA 33rd Annual Logging Symposium* (June 14–17, 1992) 1-8.