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Accurate Structural Model in Near-well Space from Borehole Images

P. Marza* (Schlumberger), L.I. Trøan (Lundin Norway AS), B.A. Bakke (Lundin Norway AS), F. Perna (Schlumberger), V. de Leeuw (Schlumberger), A. Khan (Schlumberger), M. Bower (Schlumberger) & H. Charef-Khodja (Schlumberger)

SUMMARY

The 3D structural information provided by borehole image dips is critical to the accuracy of a reservoir structural model at the wellbore. We explore how to better use borehole dips away from the well. We describe a workflow for extending the borehole dip information away from the well. We base the robustness of the borehole image interpretation on the integration of multiple measurements with various depths of investigation. The results are provided in a 3D near-wellbore structural model. We present an example of a single horizontal well interpretation. The example is a horizontal well drilled in 14-m-thick shoreface sands (Ula formation) of Upper Jurassic age. The structural setting is controlled by halokinesis of underlying Zechstein salt. The 3D near-well structural model is built from the interpretation and structural modelling based on a density image and a deep-reading EM tool.

Introduction

The 3D structural information provided by borehole image dips is critical to the accuracy of a reservoir structural model at the wellbore. For that purpose, borehole dips can be used in multiple ways. We explore how to better use borehole dips away from the well as well as how to avoid some small-scale uncertainties.

We describe a workflow for extending the borehole dip information away from the well. We base the robustness of the borehole image interpretation on the integration of multiple measurements with various depths of investigation. The results are provided in a 3D near-wellbore structural model. We present an example of a single horizontal well interpretation that provides an appropriate measurement integration scenario with a borehole image and a deep-reading electromagnetic tool.

Workflow

Dip picking. After the manual dip picking of tectonic (minor and major faults) and sedimentary surfaces (erosion, bedding, etc.), true stratigraphic thickness (TST) index and a stratigraphic drilling polarity log are computed.

Structural analysis. Bedding dips are upscaled through a structural dip computation process. Upscaled dips are used for near-well structural modelling. Main faults are characterized based on dip-vector plot interpretation. Major tectonic structures (monocline, fold, unconformity, etc.) are characterized based on a combination of arrow plot, dip vector plots, and stereonet plots.

TST correlations and fault throw characterization. For a single horizontal well, formation-top correlations are performed between different sections (drilled up or drilled down) of the well, in a TST-indexed display. TST index allows an image and log display respecting the true thickness of the formation, where the drilled up stratigraphic intervals are flipped upside down. When major faults are identified from the structural analysis, TST correlations allow estimating the amount of missing or repeat sections introduced by the fault throw.

Interpretation of formation surfaces from deep-reading electromagnetic (EM) inversion. When a borehole image is used in combination with a deep-reading EM tool, the interpreter can pick formation boundaries at the borehole and at distances from the borehole.

3D near-well structural modelling. 3D modelling is based on a structural delineation technique. The geometric properties of each tectonic structure crossed by the well(s) are characterized and subdivided in structural units and structural elements. All the geometric properties are combined with the formation thickness to project the structural dips and the horizons interpreted from the deep-reading tools in the near-well space. The dip projection results provide the material for the 3D surface modelling in the near-well space. Modelled horizons honour the structures and findings of the various depths of investigations provided by the tool combination.

Example

The example is a horizontal well in the Brynhild field (Norwegian North Sea). The well is drilled in the Ula formation of Upper Jurassic age, deposited as a transgressive sheet of shoreface sand above Triassic alluvial and fluvial sediments. The 3D near-well structural model is built from the interpretation and structural modelling based on a density image and a deep-reading EM tool. It extends 800 m horizontally along the logging interval and 90 m laterally away from the well. The structure appears as a local collapse and folding (mostly by the mean of tilted monoclines next to a fault zone) of a wider (mostly out of the study interval) southeast-dipping monocline. This structural setting controlled by halokinesis of underlying Zechstein salt, results in a local depression of the 14-m-thick Ula reservoir.

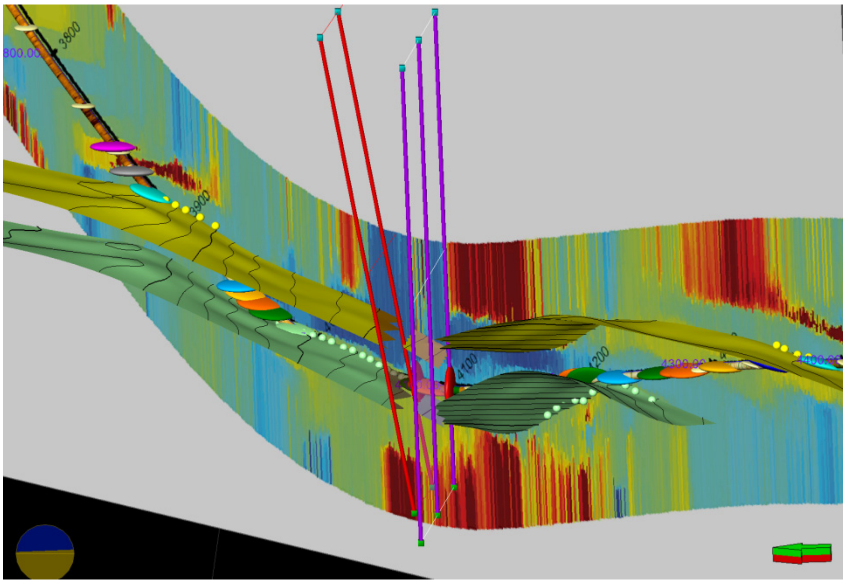

Figure 1 *3D view from west of the top and bottom surfaces of the Ula reservoir formation. These surfaces are modelled from dips picked on a density image and from stratigraphic horizons interpreted on the results of the inversion of deep-reading EM (background picture).*

Conclusions

Using the borehole dips away from the well and keeping a good control of small-scale uncertainties can be achieved by integrating the borehole image with a deep-reading EM measurement. In the near well space, it is decisive for production or injection decision making, because the resolution of the reservoir structure is beyond the reach of models based on surface seismic only.

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