MATURE FIELDS

CASE STUDY

Operator Uses Three-Dimensional Electromagnetic Inversion to Understand Complex Fluid Boundaries

EARTHSTAR® SERVICE 3D ANISOTROPIC INVERSION HELPS DEFINE LITHOLOGY OF APPARENT OIL-WATER CONTACT

NORWEGIAN CONTINENTAL SHELF

CHALLENGE

- Understand undulating OWC in a trilateral well
- Avoid penetrating OWC
- Interpret fluid boundary with advanced logging-while-drilling (LWD) solution

SOLUTION

EarthStar® ultra-deep resistivity service with 3D inversion:

- Innovative LWD technology providing anisotropic inversion and lithology identification

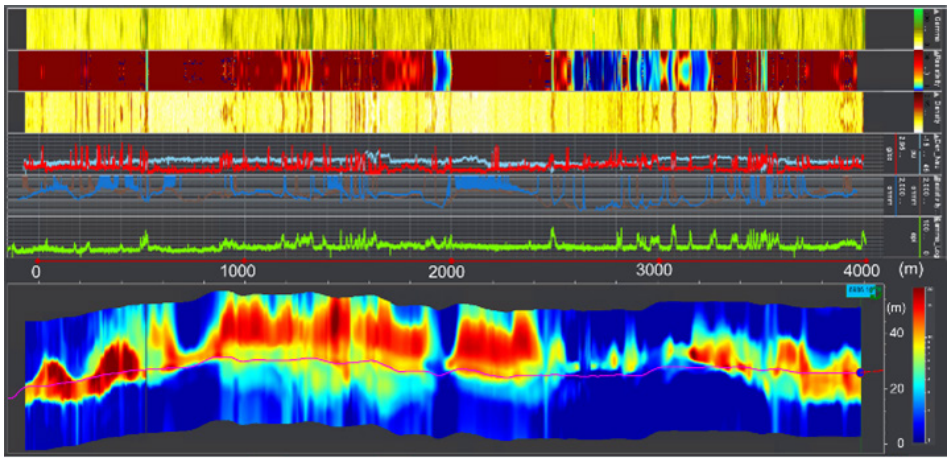
RESULTS

- Identified a thin anisotropic layer below the target reservoir as a shale separating the oil-filled and water-filled sands
- Proved that the thin shale was limiting lateral water movement in the reservoir

OVERVIEW

A complex, undulating oil-water contact (OWC) in a trilateral well, identified by seismic data before drilling and confirmed with the EarthStar® ultra-deep resistivity service from Halliburton, proved to the operator that reservoir complexity is not easily understood if investigated via conventional tools and inversion for resistivity alone. Advances in the EarthStar service three-dimensional (3D) electromagnetic (EM) inversion technology allow mapping of both resistivity and anisotropy (the vertical to horizontal resistivity ratio) data.

Anisotropy is used to differentiate between low resistivity, water-filled sand units marked by low anisotropy ratios, and low resistivity shale units that exhibit high anisotropy. Gaining insight into anisotropy helped the operator understand the undulating fluid contact issue for maximizing the value of this asset.



Shows undulating water contact below the well, with shale above.

CHALLENGE

The OWC morphology was identified before drilling commenced using seismic and offset log data. As expected, it clearly showed considerable total vertical depth (TVD) variation along the wellbore. However, this is difficult to explain in a permeable sand environment. In some places, the depth shift created a very steep, near-vertical, angle with the OWC. The operator required a better explanation for why the water did not move laterally in these zones, smoothing out the fluid contact.

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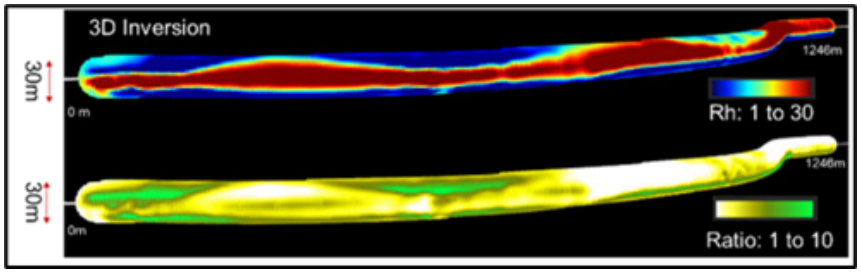
SOLUTION

The EarthStar ultra-deep resistivity service with 3D inversion was recommended to measure both resistivity and anisotropy. Water-flooded sands and low resistivity shales can show similar resistivity values. Since water-flooded sands are isotropic while shales are anisotropic due to their laminated nature, the anisotropic inversion from the EarthStar service provides a way to differentiate water-flooded sands from shales, and to reveal the lithology of low resistivity zones.

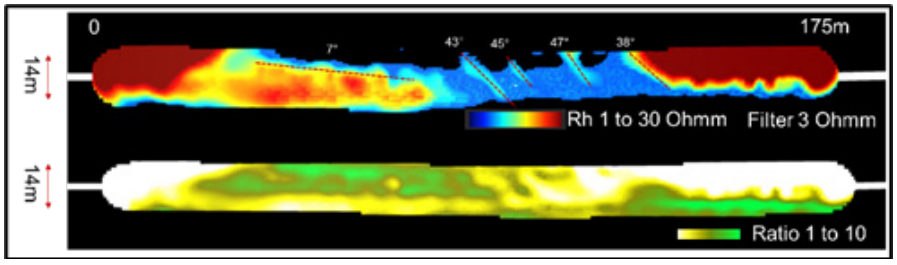
RESULTS

The EarthStar service 3D inversion for anisotropy showed a thin anisotropic zone directly underlying the hydrocarbon-filled sand. This unit can be directly correlated to thin shale zones seen in the offset log data.



EarthStar 3D inversion for anisotropy identifies shale bounding the oil-water contact.

Successful, real-time geosteering operations avoided penetrating the underlying zone until the latter portions of the well. Here, the oil-filled reservoir pinched out, and a sharp elevation of the OWC resulted in the well entering water-filled sand. Small shale beds penetrated by the well within the sands also showed high anisotropy, and the water-filled sand exhibited low anisotropy. This confirmed that the thin anisotropic zone below the well is a shale separating the oil-filled and water-filled sands.



Water intrusions into the overlying reservoir are controlled by anisotropic shale units.

The EarthStar service 3D anisotropic inversion process highlighted a previously unidentified barrier to fluid flow, which protected hydrocarbon zones and limited water movement. Mapping these insights onto future wells will help the operator optimize completion and production strategies.

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