An integrated approach for complex faulted reservoir characterization using Petrel: a case study from deepwater Nigeria

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• **Area location:** Niger Delta Basin, deep water area of Nigeria
• **Trap:** 4-way closure structure complicated by dense normal faults
• **Reservoir:** Mesozoic deep-water turbidite sandstone
• **Positive:** Two wells were drilled (2003, 2005) and discovered hydrocarbon
• **Negative:** too many fault blocks, revealed OWC, not reach the economic threshold
• **After more than 10 years, in 2017, re-evaluate the reservoir**
Research challenges

- Complex fault fine interpretation
  - Densely developed, intersect in different directions
  - Channels crosscut faults, increasing the difficulty
  - Conventional fault attributes are not clear

Fault density: 6-8 strips/km

Variance Attribute

Layer C
Research challenges

- Hydrocarbon detection - distinguish between oil and water reservoir
  - Strong amplitude caused by lithology often affects the hydrocarbon identification. So it is difficult to discriminate whether the strong amplitude area that below the depth of drilled OWC is oil or water layer

- Sealing fault identification and reservoir unit determine
  - Faulted structure
  - Laterally changing reservoir
Integrated approach - key technologies

1. Complex fault recognition
2. Sealing Fault identification
3. Hydrocarbon detection
Complex fault recognition

- With the help of fault attribute sliding along depth or horizon, the 3D fault interpretation can be carried out efficiently
- Multi-attribute optimization and CMY fusion are used to improve the capability of fault recognition

CMY fusion: Variance & Dip RMS & Ant tracking

- Three attributes are fused in CMY mode
- Faults are delineated much more clearly

To overcome sediment interference, we use the Directional Light Source tool to enhance the fault display.
Fault attributes from frequency-dependent seismic data are also used to enhance faults of different scales.
CMY fusion of attributes from low, medium and high frequency data shows fault much clearer than directly using the original data.

Ant tracking of Variance attribute from different data:

- The attribute from low-frequency data is helpful to describe large scale faults, while the attribute from high-frequency data is helpful to describe small faults and fault details.
Complex fault recognition

- Through the complex fault recognition technology, the faults are fine interpreted and the fault distribution of each target layer is mapped efficiently. It provides a basis for the reservoir characterization.
Sealing fault identification

- **Role:** Sealing fault is a basic element of reservoir unit division and directly affects the reserves calculation and well design

- **Affecting factors:**
  - Fault throw
  - Sedimentary thickness
  - Whether the seal part completely cut the sediment

**First step:** prepare the fault throw and sediment thickness distributions

- fault throw is firstly calculated automatically with fault model, and then is checked manually

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**Manually verified fault throw**

**Sediment thickness**
Sealing fault identification

- **Second step:** identify sealing segment where fault throw is larger than sediment thickness
- **Last step:** define the sealing segment that can completely disconnect the sediment as the unit boundary of reserve calculation

The total number of faults developed in the trap: **58**
Faults whose fault throw is larger than the sediment thickness: **36**
Faults can completely disconnect sedimentary: **16**
Hydrocarbon detection – AVO fluid factor

- Analysis works on drilled wells: AVO modeling, Rock physics analysis, Fluid substitution, Porosity substitution
- Generally, oil reservoir appears to be class II or class III AVO, and the water reservoir is mainly class I AVO
- AVO anomaly is a necessary condition for the existence of high quality oil reservoirs in this area

The AVO fluid factor matches with the drilled wells and predict the target area to be oil-bearing reservoir.
Hydrocarbon detection – Flat point and contour

- Flat point DHI plays an important role in hydrocarbon determining and fluid interface prediction, however, it is usually not easy to distinguish.
- The flat point is shown more clearly after optical stacking.
- The flat points are enhanced and easily discriminated by using the variance attribute along the layer.
- Both the AVO anomaly and flat point DHI are consistent with the contour, which increased confidence that it’s an oil bearing reservoir in the target area.
With the integrated approach, an undrilled fault block is found in the south wing of the structure with predicted high-quality reservoir and good superposition in layers.

The P-3 well is drilled successfully and high-quality reserves are verified below the previous drilled OWC.

Proved reserves have been greatly increased and reach the threshold of commercial development.
After the successful prediction and assessment of the main reservoir. The AVO anomaly and double flat points are newly found on the flank, and they are consistent with the depth contour.

It is predicted that the upper of layer is gas, the middle is oil, and the lower is water.

It can be jointly developed with the main reservoir, further enhancing the development potential.
• Explorations in the deep-water area become more and more complex and difficult. More careful and efficient work is required to identify and assess the resource potential.

• The integrated approach based on PETREL includes three main technologies: complex fault recognition, sealing fault identification and hydrocarbon detection.

• The approach has made a significant contribution to the re-assessment of the reservoir and to the promotion of new drilling. Consequently, the structure is upgraded from an uneconomical oil-bearing structure to a commercial oilfield.

THANKS

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