The Geomodeling of Fan-delta Reservoir with Clastics and Carbonate in Bohai Bay

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CNOOC
Paleogene is the next direction of petroleum exploration and development in China offshore

- The limited evaluation wells in offshore oil field
- Low quality seismic data
- Serious internal heterogeneity
Vertical complex lithology distribution because of the clastic and carbonate mixed deposition.
● Thickness of the reservoir is large but with quick lateral changes
● Low porosity and super-low permeability
Key technologies combination

1. Build stratigraphic framework combined lithology with seismic

2. Identify fan-delta sedimentary structure guided by seismic attribute

3. Constraint reservoir property distribution by lithology classification

Build Digital Reservoir of Paleogene Fan Delta
Build stratigraphic framework combined lithology with seismic

Build Digital Reservoir of Paleogene Fan Delta
Identify complex reservoir lithology

- Judge lithology-mineral assemblage by ECS (element capture spectroscopy) macroscopically
- Identify rock type combined with cores and thin sections microscopically

ECS logging response characteristics (Q-5)

- Identify complex reservoir lithology
  - Judge lithology-mineral assemblage by ECS (element capture spectroscopy) macroscopically
  - Identify rock type combined with cores and thin sections microscopically

A

B

Calcareous sandstone
Dolomitic sandstone
Oolitic dolomite
Dense layer
Tuffaceous glutenite
Glutenite
Bioclastic dolomite
Oolitic litharenite

CNOOC Research Institute
Build stratigraphic framework

Lithological distribution
Seismic sequence
Oil-water relation

Cycle correlation

Build the seismic-scale stratigraphic framework
Build stratigraphic framework

Seismic attribute slice analysis

Subdivide formation by seismic attribute slice analysis to build the fine stratigraphic framework
Build structural model
2

Identify fan-delta sedimentary structure guided by seismic attribute

Build Digital Reservoir of Paleogene Fan Delta
Predict fan-delta distribution

Seismic multi-attribute analysis

Sensibility analysis of seismic attributes
Predict fan-delta distribution

Seismic attributes slice (III)

Seismic attributes slice (II)

Seismic attributes slice (I-1)
Build Facies model

Structural model

Deterministic modeling method

Facies model

Fan-delta distribution range
Build Facies model

Facies model section (along the source direction)

Seismic section (along the source direction)
Constraint reservoir property distribution by lithology classification

Build Digital Reservoir of Paleogene Fan Delta
In exploration evaluation phase, the relation of porosity-permeability not built by different lithology leads to low interpretation precision.
Reconstruct the relation of porosity-permeability of basic principles:

- Similar lithology
- Similar property
- Build in different interval
Optimize different lithological permeability interpretation

NMR (Nuclear Magnetic Resonance) logging response characteristics of Q-5

Relation of porosity-permeability (in phase division of early study)

- Oolitic dolomite: $y = 0.0085e^{0.277x}$
- Oolitic litharenite: $y = 3E-05e^{0.5696x}$
- Calcareous sandstone: $y = 0.059e^{0.159x}$
- Bioclastic dolomite: $y = 8E-06e^{1.3586x}$
- Tuffaceous glutenite: $y = 0.0232e^{0.2165x}$
- Dolomitic sandstone: $y = 0.0024e^{0.4258x}$
### Lithofacies division evidence

<table>
<thead>
<tr>
<th>Rock type</th>
<th>The main lithology</th>
<th>Por</th>
<th>Perm</th>
<th>Displacement pressure</th>
<th>Pc50</th>
<th>Pore throat radius median</th>
</tr>
</thead>
<tbody>
<tr>
<td>I (Fine)</td>
<td>Oolitic dolomite</td>
<td>20~25</td>
<td>≥10</td>
<td>0.041~0.71</td>
<td>0.8~4.2</td>
<td>0.17~0.92</td>
</tr>
<tr>
<td></td>
<td>Bioclastic dolomite</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>II (Medium)</td>
<td>Dolomitic sandstone</td>
<td>15~20</td>
<td>1~10</td>
<td>0.32~2.4</td>
<td>8.2~24.1</td>
<td>0.03~0.09</td>
</tr>
<tr>
<td></td>
<td>Oolitic litharenite</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Tuffaceous glutenite</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>III (Poor)</td>
<td>Calcareous litharenite</td>
<td>9~15</td>
<td>≤1</td>
<td>8.5~13</td>
<td>27~42.5</td>
<td>0.02~0.03</td>
</tr>
</tbody>
</table>

*POR: porosity, Perm: permeability, Pc50: capillary pressure at 50% saturated*
Build model with multilevel constraint method

1. Facies model
2. Lithofacies model
3. Porosity model
4. Permeability model

Deterministic modeling method

Sequential Indicator Simulation

Sequential Gaussian Simulation
Techflow

- Identify Reservoir Lithology
- Predict Fans Distribution Range
- Optimize Different Lithological Interpretation
- Geological Knowledge Database
- Multilevel Constraint Facies Modeling
- Facies Controlled Modeling
- Property Model
Application Effect

The Geomodeling of Fan-delta Reservoir with Clastics and Carbonate in Bohai Bay
Characterize the high quality reservoir distribution

<table>
<thead>
<tr>
<th>Lithofacies</th>
<th>POR (%)</th>
<th>PERM (mD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I-1</td>
<td>10.8</td>
<td>14.75</td>
</tr>
<tr>
<td>I-2</td>
<td>17.2</td>
<td>4.08</td>
</tr>
<tr>
<td>I-3</td>
<td>13.7</td>
<td>5.86</td>
</tr>
</tbody>
</table>

**Perm model section**

**Lithofacies model section**

High quality reservoir
Characterize the high quality reservoir distribution

Geologic reserve distribution in different layers

- I-2: 37.1% with 7.5% in layer I-3, 0% in layer 0, 53% in layer 1
- I-1: 23.1% with 25% in layer 1
- II: 23.1% with 7% in layer 1
- III: 9.2% with 24% in layer 1
Optimize well pattern and well location

- Evaluate the OWC location and the reservoir boundary and gas cap
- Evaluate the reservoir boundary
- Evaluate the gas cap and fault location
- Development well location

The oil-bearing area of layer II
Summary

- Identify the complex lithology by ECS logging and optimize different lithological permeability interpretation by NMR logging to divide the reservoir lithofacies.

- Combine seismic attribute slice analysis with lithology distribution of wells to identify different sedimentary phase of fan deltas and build fine stratigraphic framework.

- Use seismic multi-attribute analysis technology to predict sandbody distribution, then use deterministic modeling and stochastic simulation with multilevel constraints method to build lithofacies model.

- Use the lithofacies model as constraint to establish property model with stochastic simulation method.

- The model does not only subdivide the reservoir but also make the high quality reservoir distribution clearly.