High Resolution, Three-Dimensional Facies Architecture Analysis Using Sequence Stratigraphy and Seismic Sedimentology: Example from Dongying Formation in BZ3-1 Block, Bozhong Sag, Bohai Bay Basin, China*

Hongtao Zhu1,2, Xianghua Yang1, Xinhua Zhou3, and Jianping Li3

Search and Discovery Article #50678 (2012)**
Posted August 13, 2012

*Adapted from oral presentation at AAPG Annual Convention and Exhibition, Long Beach, California, April 22-25, 2012
**AAPG©2012 Serial rights given by author. For all other rights contact author directly.

1China University of Geosciences, Wuhan, China (zhuht_oscar@yahoo.com.cn)
2The University of Texas at Austin
3China National Offshore Oil Corporation Limited-Tianjin, Tanggu, Tianjin

Abstract

Bohai Bay basin is a classic non-marine rift-basin. The Paleogene Dongying Formation is the main hydrocarbon-bearing stratigraphic unit in the basin. Using the recent 3D seismic data and sparse well control in the BZ3-1 Block in western slope of Bozhong Sag, we analyzed high-resolution, three-dimensional facies architecture of the Dongying Formation. Based on principles of sequence stratigraphy, the second-order sequence of the Dongying Formation was subdivided into three third-order sequences (from base to top: SQd3, SQd2L and SQd2u); analysis of high-resolution three-dimensional facies architecture was further developed using seismic sedimentology.

Sediment provenance is believed to have been derived from the northern Shijiutuo Uplift. The major sediment transport pathway was probably the paleo-channels found within Dongying Formation, which can be subdivided as four types, including type V, U, W and Compound. These facies are characterized by unique seismic facies and geometries. A seismic stratal slice movie delineates in detail the branching and converging characteristics of these channels from up-stream to down-stream and their evolution history. Based on an integrated analysis of seismic facies and multiple seismic attributes, two sedimentary facies have been recognized. The sand-rich facies is the fan-delta facies located in the footwall of growth faults with fan-shaped distribution of seismic anomaly, and the shale-rich facies is the coast-shallow lake facies characterized by various seismic attributes.
Finally, seismic stratal-slice analysis and 3D visualization revealed high-resolution, three-dimensional evolution of the fan-delta depositional systems. The number and scale of fan-delta systems have a close relationship with the system tracts in sequences of different order. The fan-deltas in third-order sequence SQd3 was mainly developed in lowstand periods, and fan-deltas in third-order sequence SQd2u occurred in highstand period. Channel-filled and fan-delta sand-bodies are excellent hydrocarbon reservoirs and potentially good exploration targets.
High resolution, three-dimensional facies architecture analysis using sequence stratigraphy and seismic sedimentology: example from Dongying Formation in BZ3-1 Block, Bozhong Sag, Bohai Bay Basin, China

Hongtao Zhu\textsuperscript{1,2}, Xianghua Yang\textsuperscript{1}, Xinhua Zhou\textsuperscript{3} and Jianping Li\textsuperscript{3}

1. Key Laboratory of Tectonics and Petroleum Resources of the Ministry of Education, China University of Geosciences, Wuhan, 430074, China
2. Bureau of Economic Geology, Jackson School of Geosciences, The University of Texas at Austin
3. China National Offshore Oil Corporation Limited-Tianjin, Tanggu 300452, Tianjin
Presentation Outline

- Geologic setting
- Sequence stratigraphic framework
- Sediment transport pathway
- Depositional systems analysis
- Spatial and temporal evolution of sedimentary facies
Geologic setting

**Study area:** BZ3-1 Block, western slope of Bozhong Sag, Bohai Bay Basin, China

**Target:** Dongying formation, Paleogene

Area: 700Km²
Methodology

1. Well-log data
2. Regional geology
3. Seismic data

Sequence stratigraphy framework

- Stratal slice
- Seismic stratigraphy
- Seismic attribute analysis

Sediment transport pathway

- Styles of incised valley
  - Spatial distribution of incised valley
    - Temporal evolution of incised valley fill

Depositional systems analysis

Spatial and temporal evolution of sedimentary facies
The second-order sequence of the Dongying Formation can be further subdivided into four third-order sequences, namely SQ1, SQ2, SQ3, and SQ4 from bottom to top.
Seismic-well log-core of SQ2

Visible progradational seismic reflection

Upward-coarsening cycles (fan/delta)

Strong positive amplitude anomaly

Sand-prone facies
### Sediment transport pathway

#### Styles of incised valley

<table>
<thead>
<tr>
<th>Incised valley</th>
<th>Infilling style</th>
<th>Seismic reflection</th>
</tr>
</thead>
<tbody>
<tr>
<td>V shape</td>
<td></td>
<td><img src="image" alt="V shape seismic" /></td>
</tr>
<tr>
<td>U shape</td>
<td>Vertical stack</td>
<td><img src="image" alt="U shape seismic" /></td>
</tr>
<tr>
<td></td>
<td>Lateral stack</td>
<td><img src="image" alt="Lateral stack seismic" /></td>
</tr>
<tr>
<td>W shape</td>
<td></td>
<td><img src="image" alt="W shape seismic" /></td>
</tr>
<tr>
<td>Combined shape</td>
<td></td>
<td><img src="image" alt="Combined shape seismic" /></td>
</tr>
</tbody>
</table>

- **Internal reflection configuration**
- **External form**
One example of incised valley

- Six canyons
- Three styles
- Bi-directional onlap
Spatial distribution of incised valley

Strong converging and branching amplitude anomalies
Temporal evolution of incised valley fill

The number of anomalies increase while the width decrease
Depositional systems analysis

Methodology

Seismic facies classification with multiple seismic attributes

Seismic single-attribute extraction

Seismic single-attribute analysis

Unsupervised clustering

Training data selection

Classification algorithm: Back Propagation

Supervised clustering

Classification method: Neural Network

Seismic facies classification maps
Fan-shaped multiple seismic attribute anomalies, located at the foot of hanging wall of bounding normal fault.
From seismic facies to sedimentary facies (SQ2)

Seismic facies
- Sand-prone

Paleogeomorphology (paleo-structure)
- Delta front
- Delta plain
- Predelta
- Coast-shallow lake

Sedimentary facies
- Shale-prone

As lake level rise, all deposits shifted landward.
As lake level fell, all deposits shifted basinward.
Dispersal pattern of depositional systems

Paleogeomorphology

The incised valleys converged gradually from source to sink.
Spatial and temporal evolution of sedimentary facies
Spatial and temporal evolution of sedimentary facies

<table>
<thead>
<tr>
<th>System Formation</th>
<th>Member</th>
<th>Lithology</th>
<th>3rd-order cycles</th>
<th>System tracts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neogene</td>
<td>Guantao</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ed1</td>
<td></td>
<td>BL fall hemi-cycle</td>
<td>HST</td>
<td></td>
</tr>
<tr>
<td>Ed2</td>
<td></td>
<td>BL rise hemi-cycle</td>
<td>TST</td>
<td></td>
</tr>
<tr>
<td>Ed3</td>
<td></td>
<td></td>
<td>LST</td>
<td></td>
</tr>
</tbody>
</table>

The number and size of fan-deltas have a close relationship with the system tracts in sequences of different order.
Conclusions

◆ The second-order sequence of the Dongying Formation was subdivided into three third-order sequences;

◆ The styles of incised valleys were subdivided into shape V, U, W and combined shape;

◆ With sparse well control, the sand-rich facies and shale-rich facies have been recognized on the basis of multiple seismic attributes analysis. The sand-rich facies is the fan-delta facies, located in the hanging wall of bounding faults with fan-shaped distribution of seismic anomaly;

◆ Palaeogeomorphology is an effective method to understand and predict the sedimentary facies.
Acknowledgements

◆ China National Offshore Oil Corporation Limited-Tianjin, CNOOC for providing geologic data.

◆ Bureau of Economic Geology (BEG), Jackson School of Geosciences, The University of Texas at Austin for the technical support.

◆ Dr. Hongliu Zeng for providing opportunity for my visiting research, and providing funding for my trip.