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*

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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

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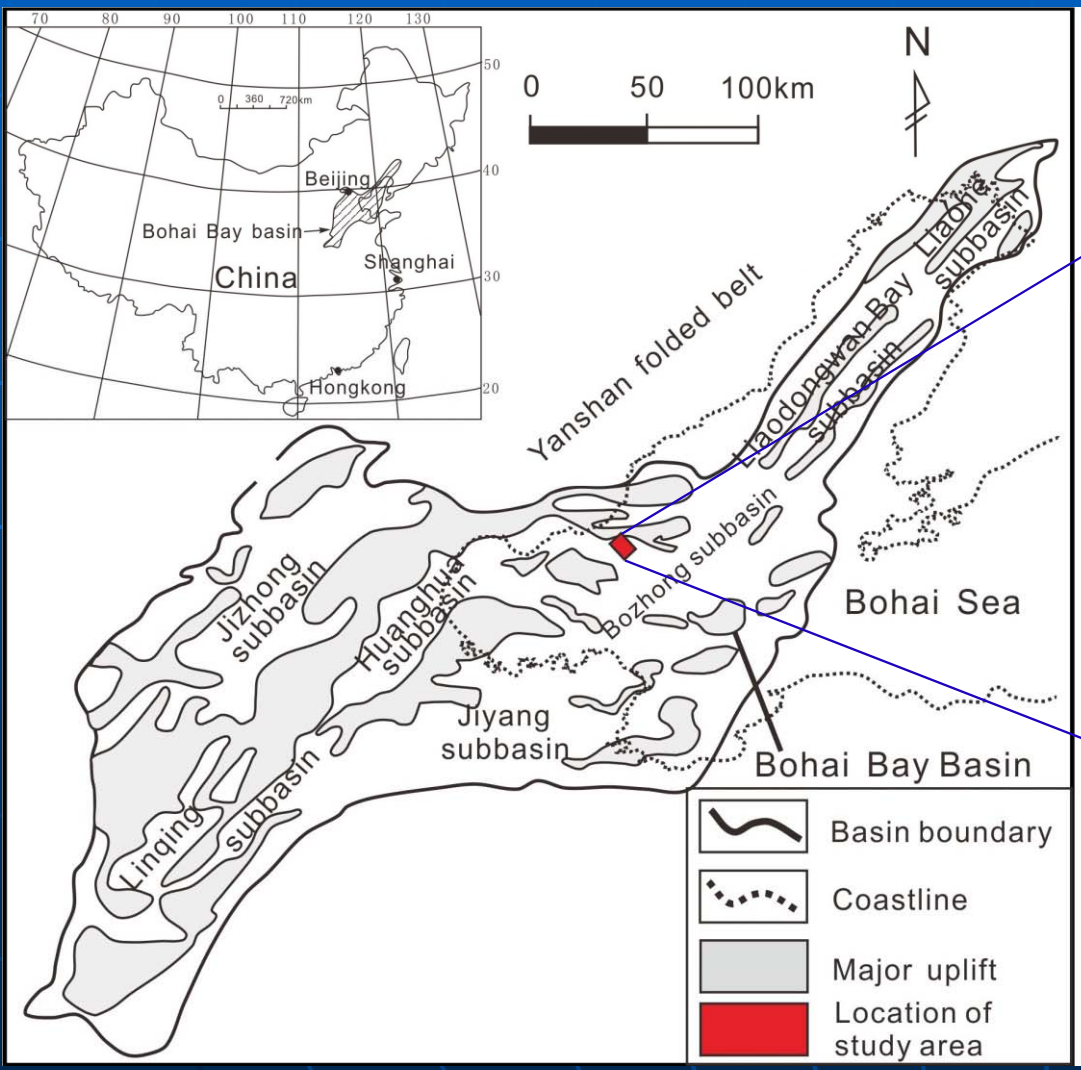
Presentation Outline

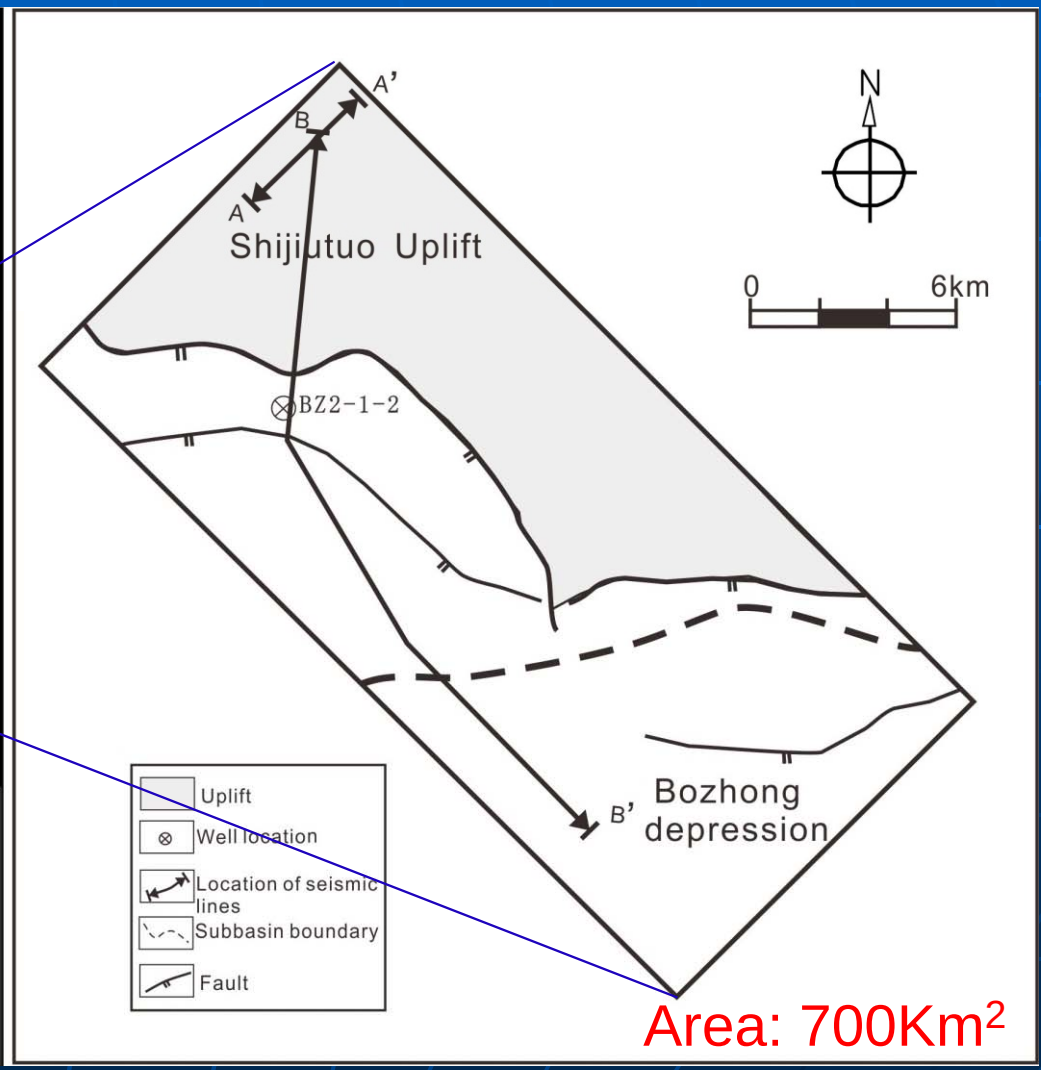
- Geologic setting
- Sequence stratigraphic framework
- Sediment transport pathway
- Depositional systems analysis
- Spatial and temporal evolution of sedimentary facies

Geologic setting

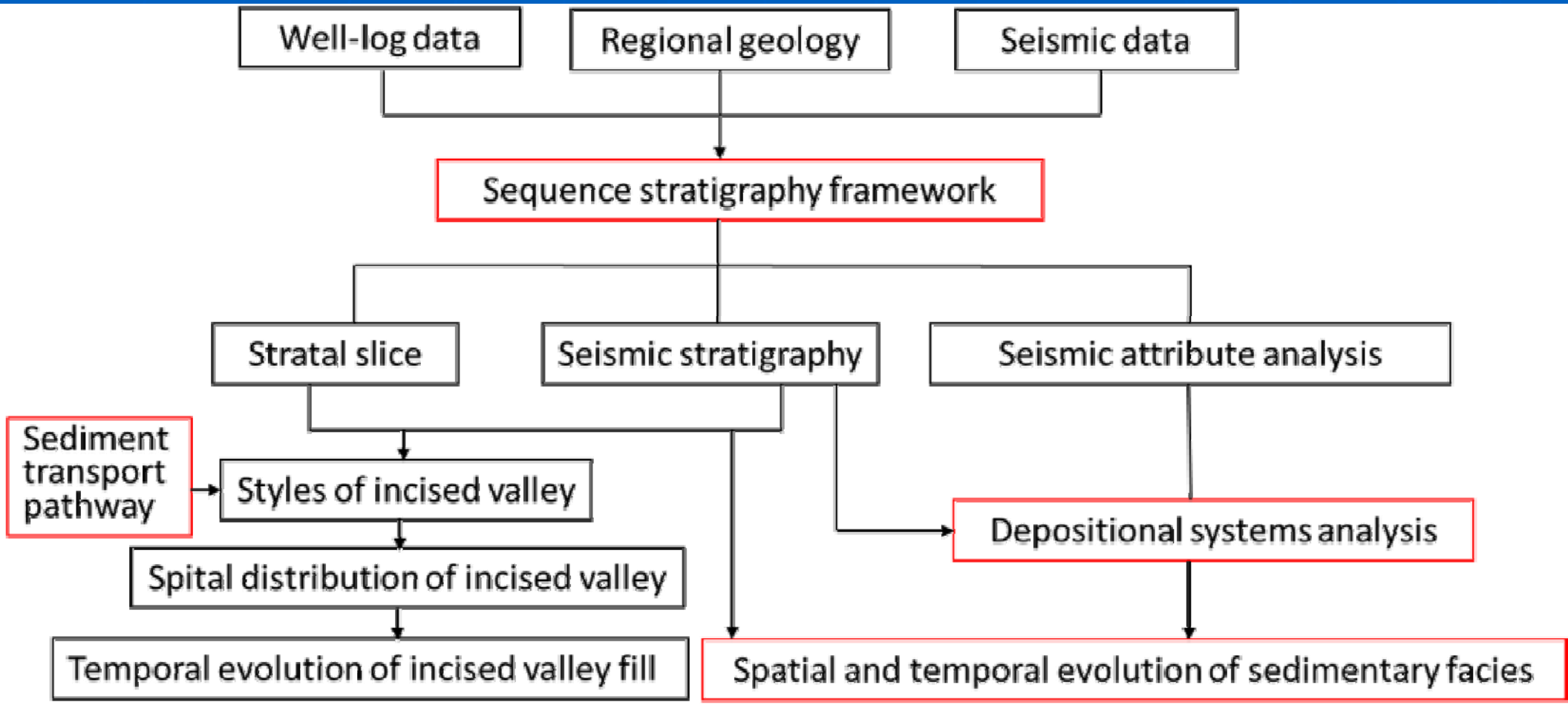
<u>Study area</u>: BZ3-1 Block, western slope of Bozhong Sag, Bohai Bay Basin, China

Target: Dongying formation, Paleogene



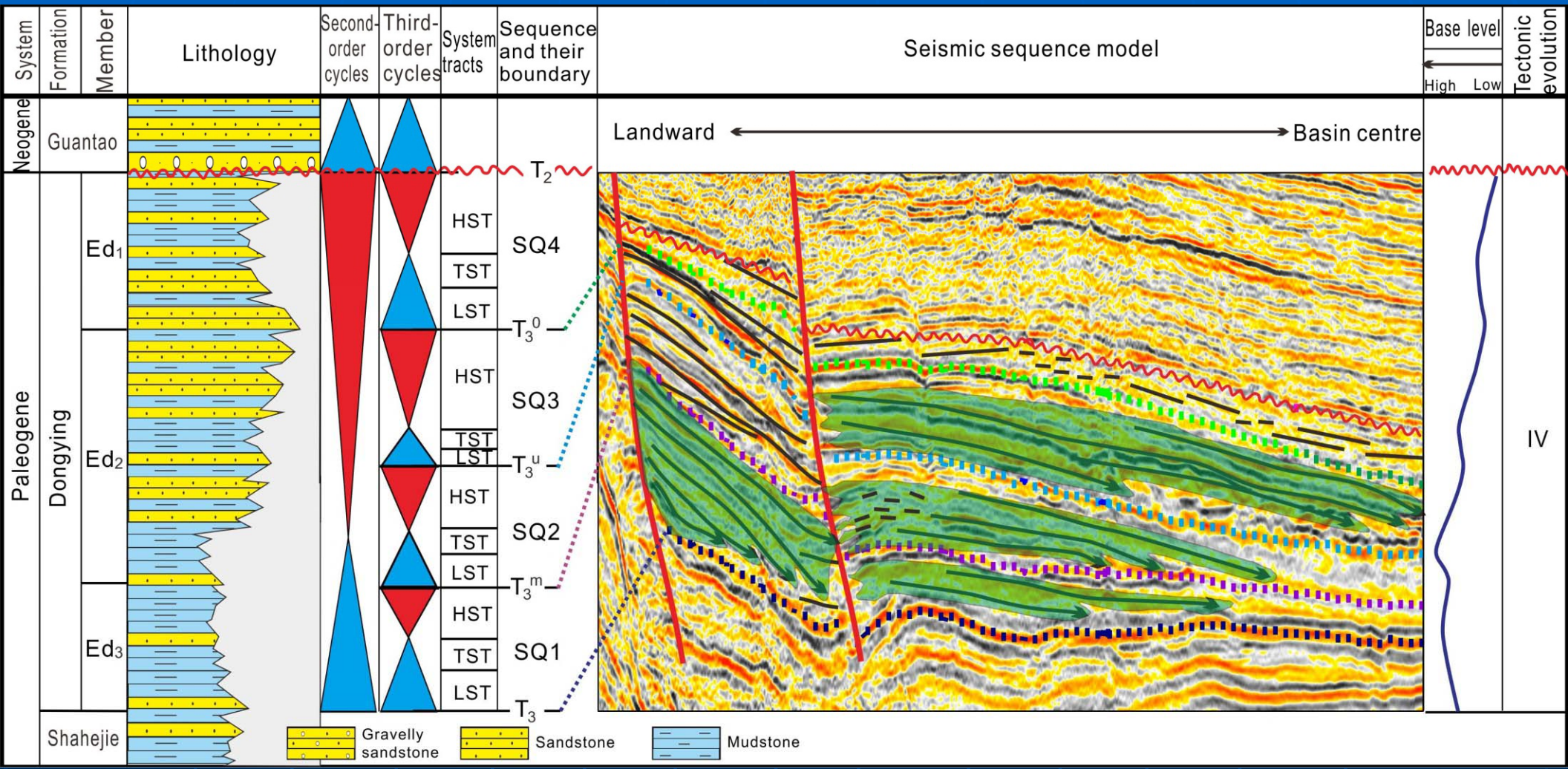


Methodology



Sequence stratigraphic framework

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.

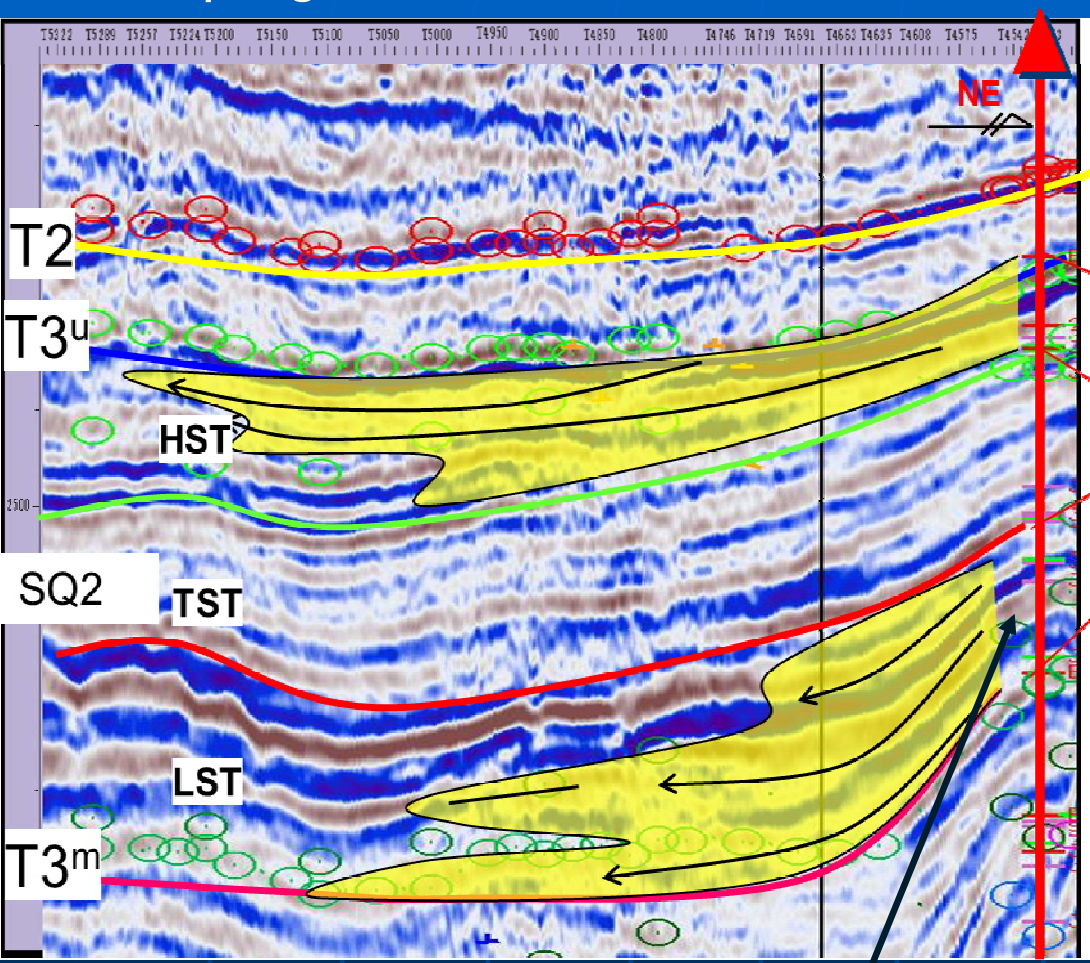


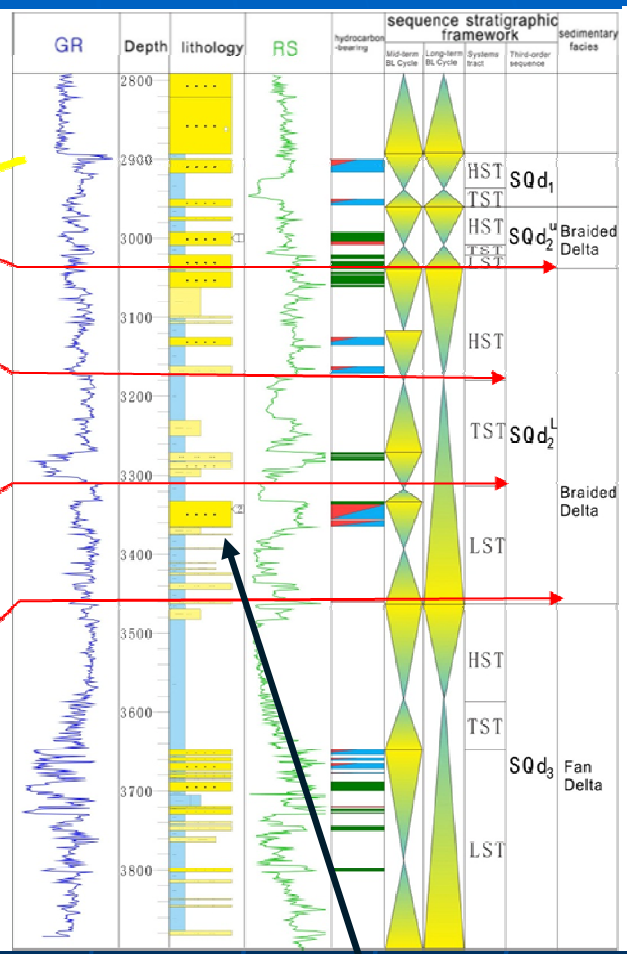
Generalised stratigraphic column and tectonic evolution in the Dongying formation in study area

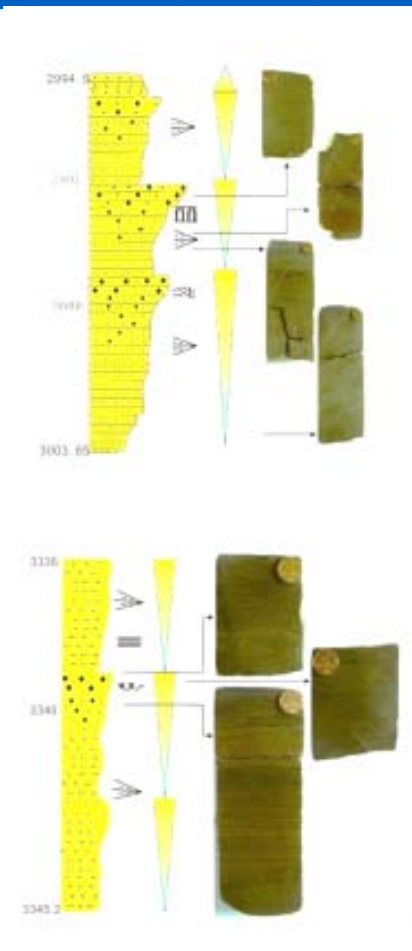
Seismic-well log-core of SQ2

Visible progradational seismic reflection

Upward-coarsening cycles (fan/delta)





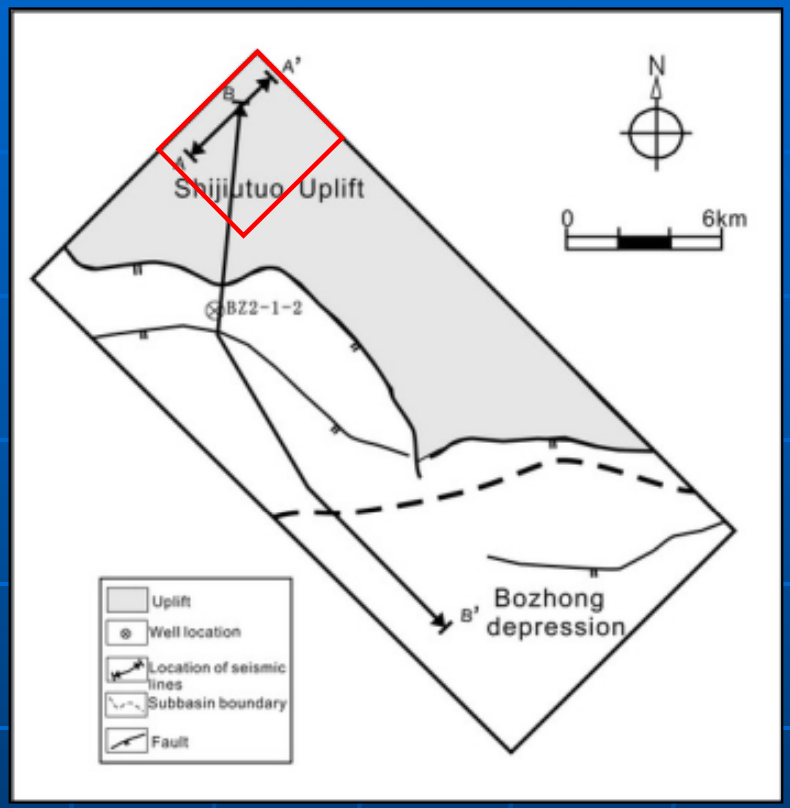


Strong positive amplitude anomaly = Sand-prone facies

Sediment transport pathway

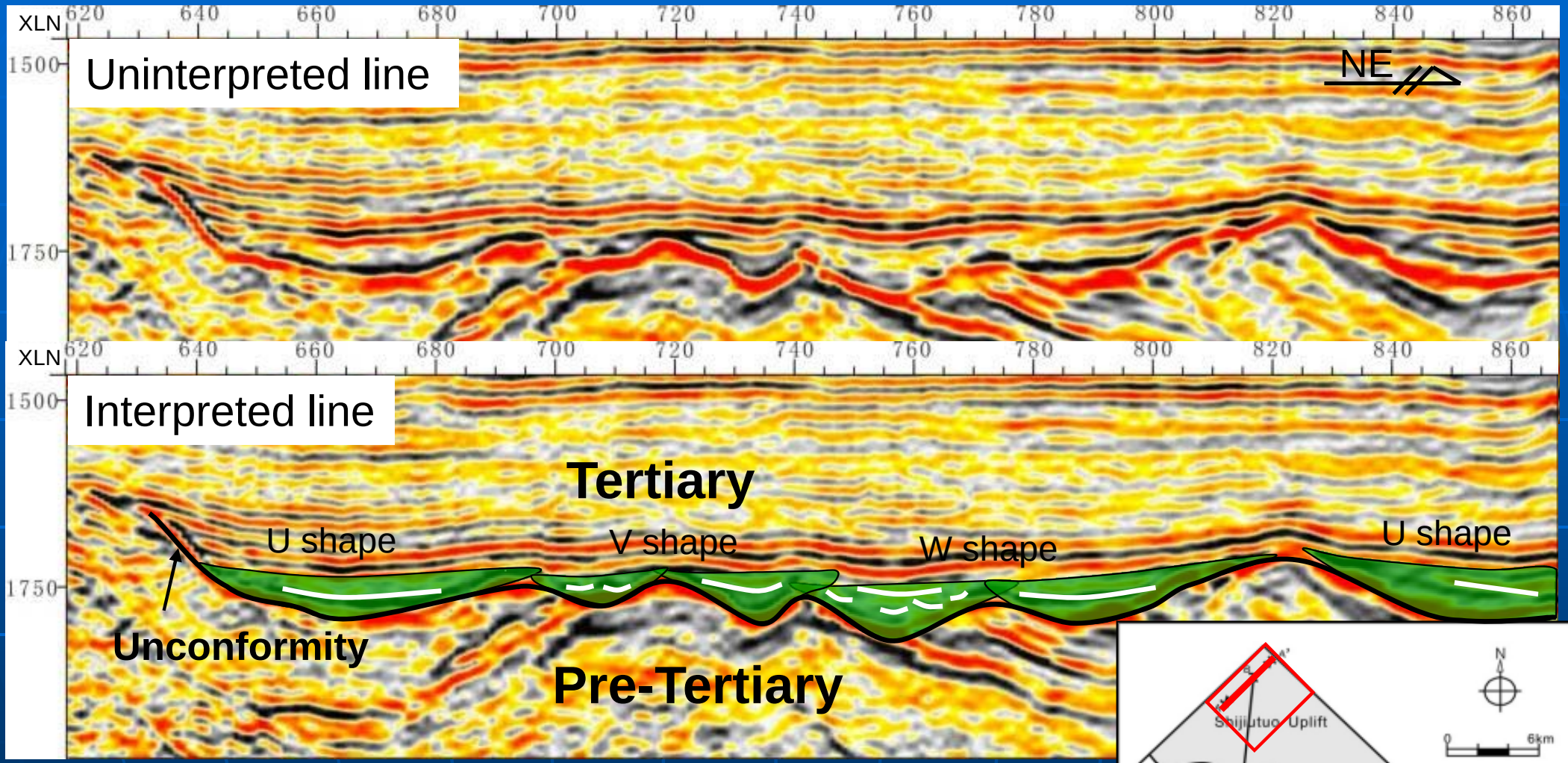
Styles of incised valley

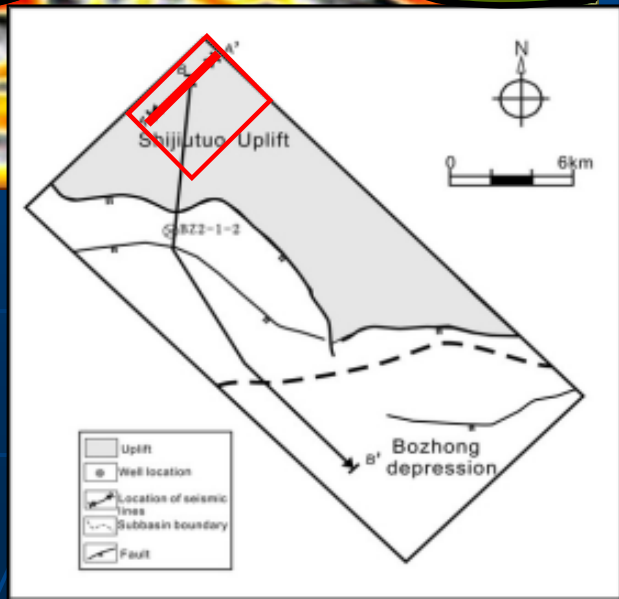
Incised valley	infilling style	seismic reflection
V shape		
U shape	vertical stack	
	lateral stack	
W shape		
Combined shape		



- **Internal reflection configuration**
- **External form**

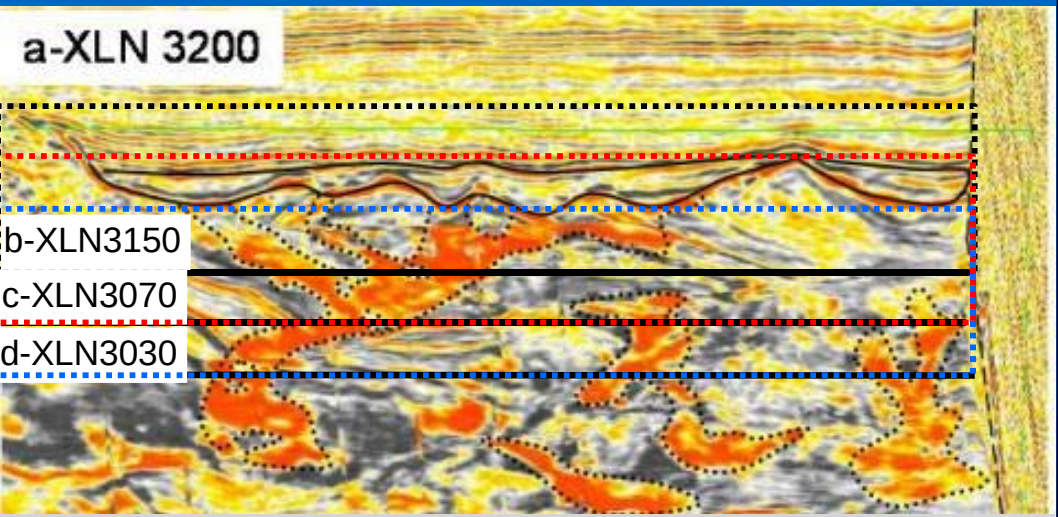
One example of incised valley



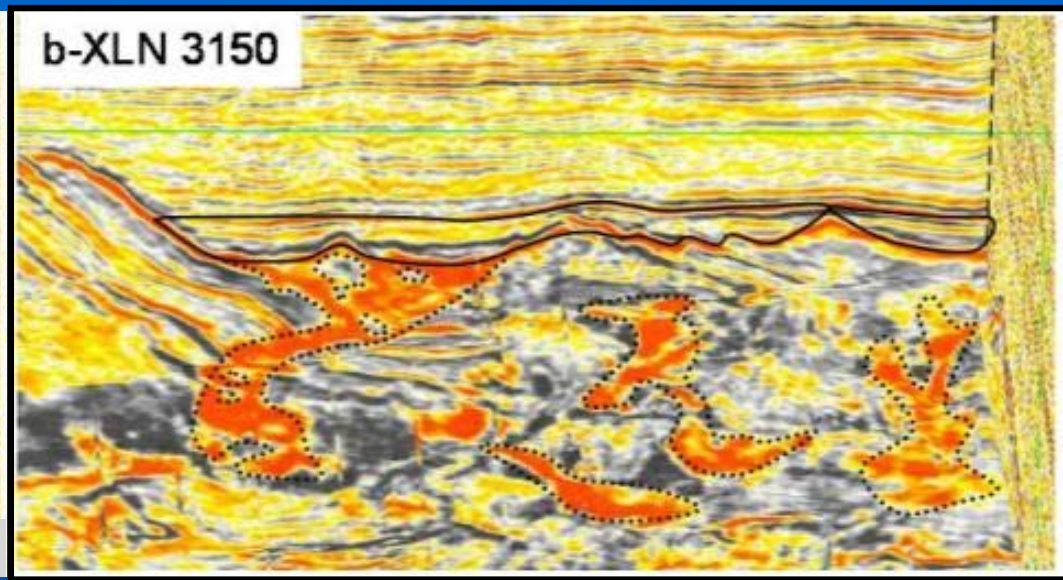


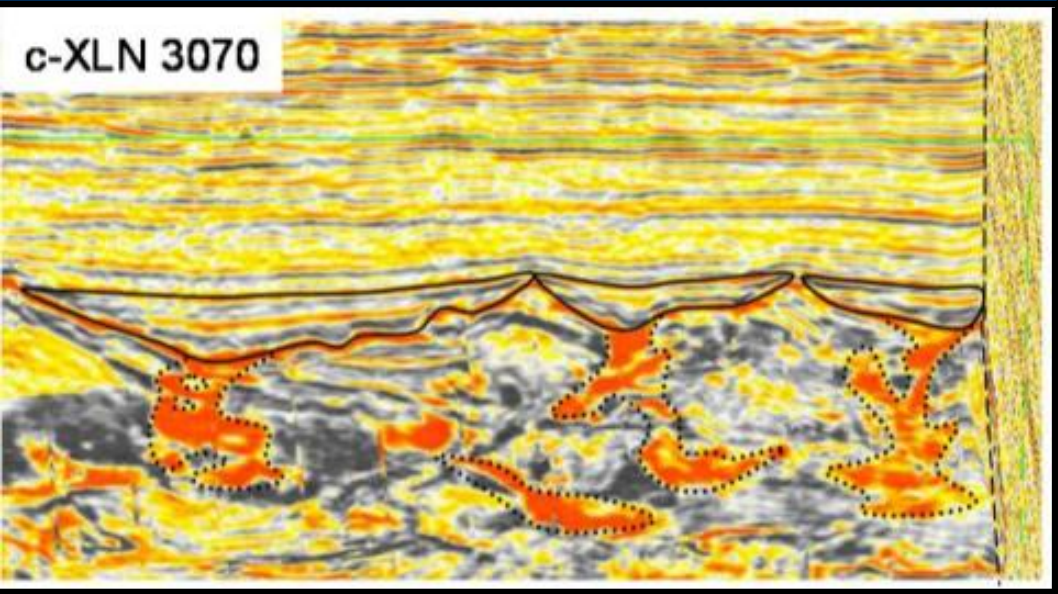
- **Six canyons**
- **Three styles**
- **Bi-directional onlap**

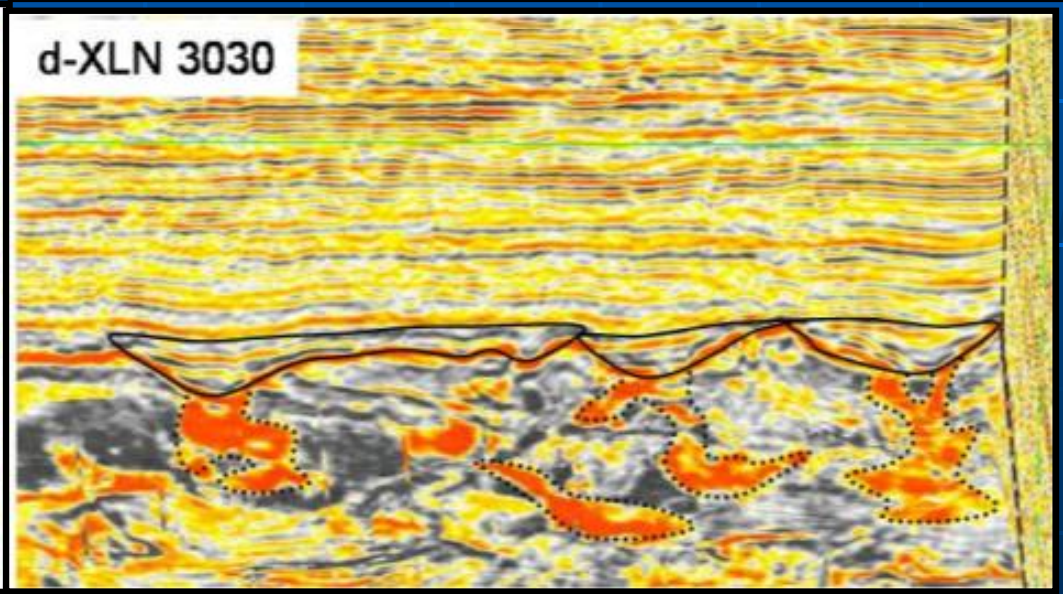
Spatial distribution of incised valley



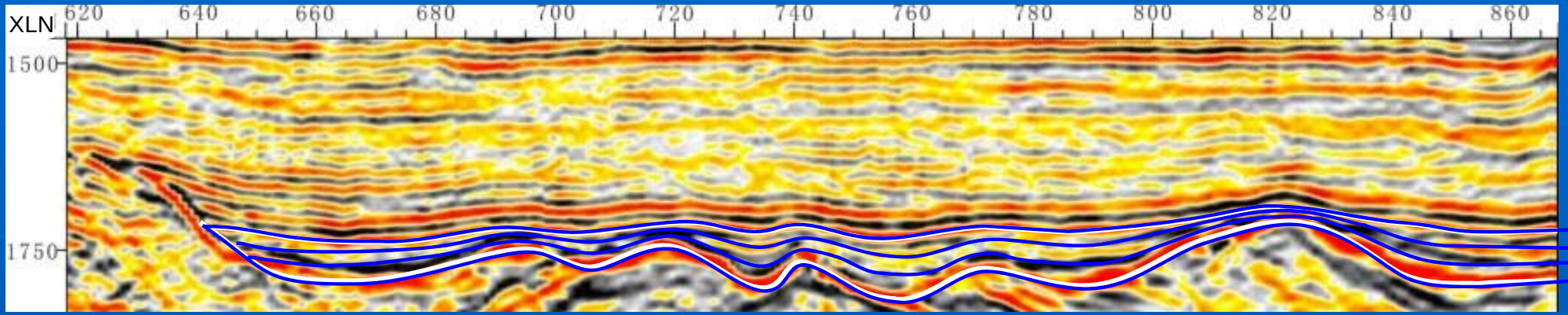
Strong converging and branching amplitude anomalies

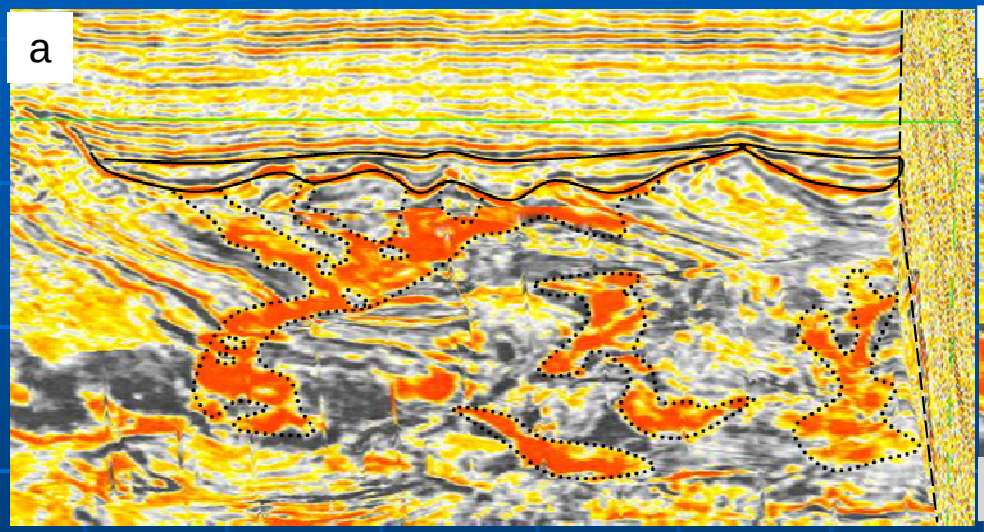


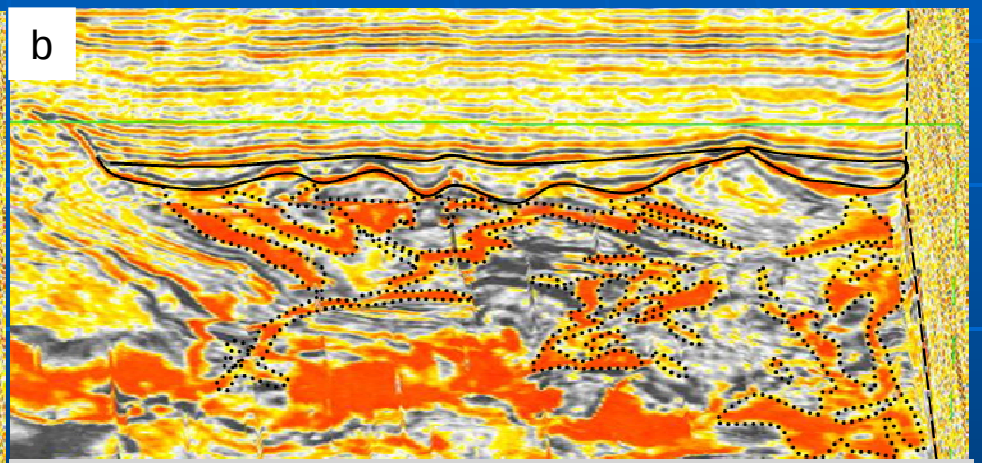




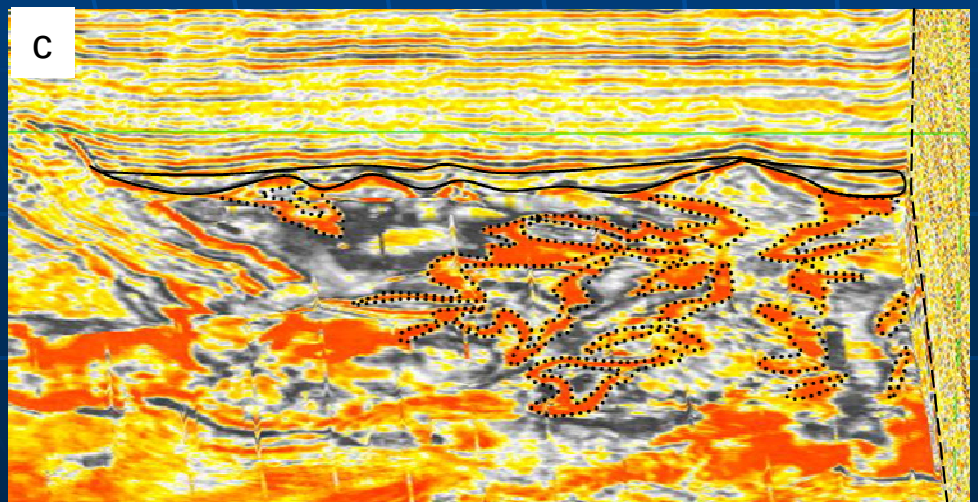
Temporal evolution of incised valley fill

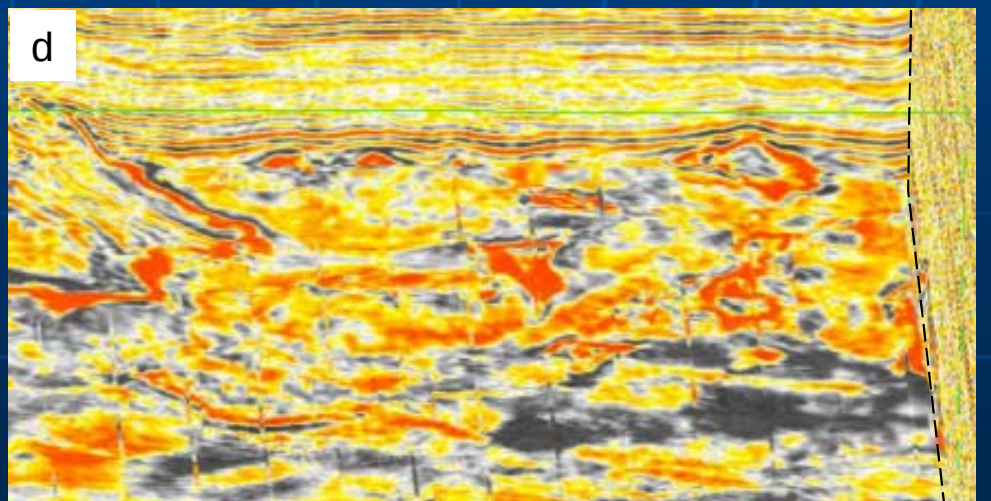




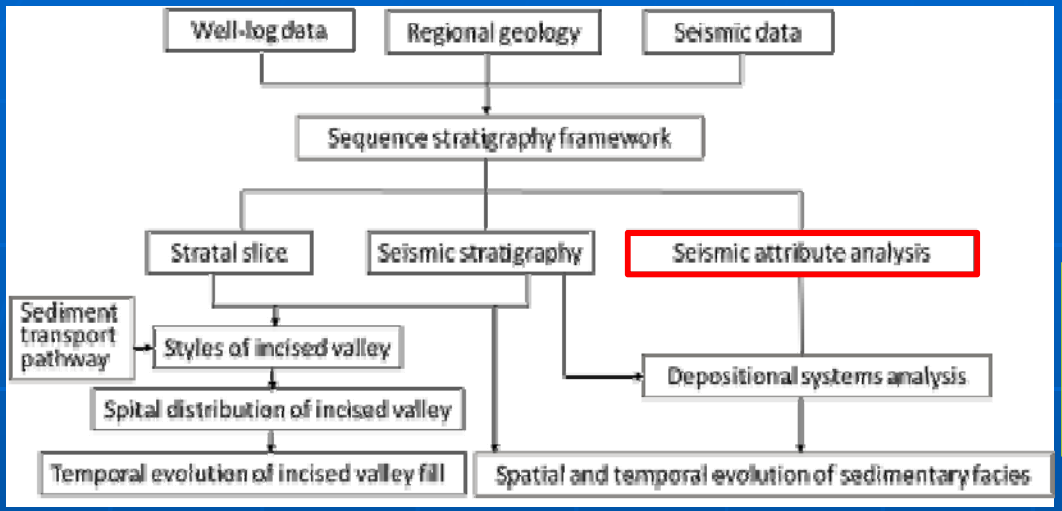


the number of anomalies increase while the width decrease



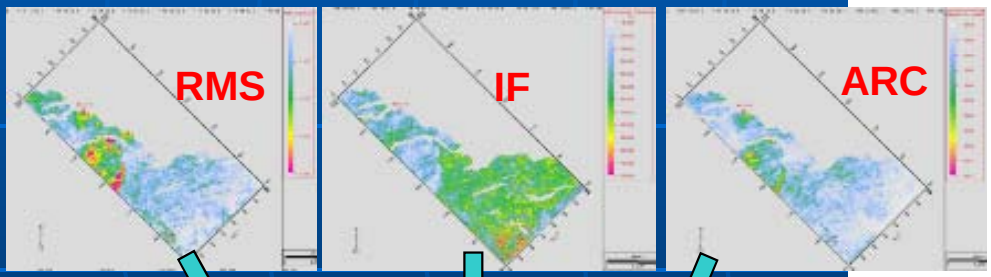


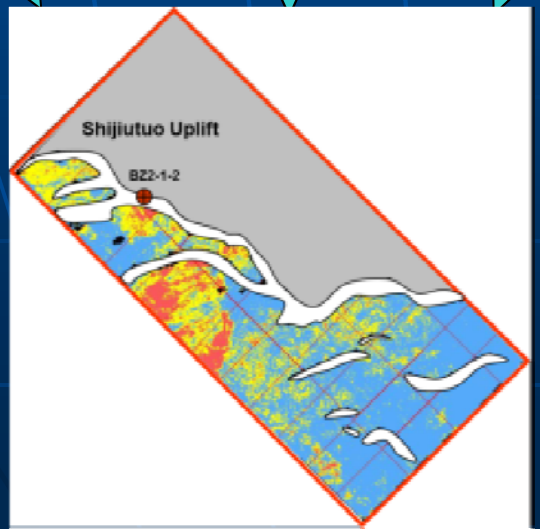
Depositional systems analysis



Methodology

Seismic facies classification with multiple seismic attributes





Seismic single-attribute extraction

Seismic single-attribute analysis

Unsupervised clustering

Training data selection

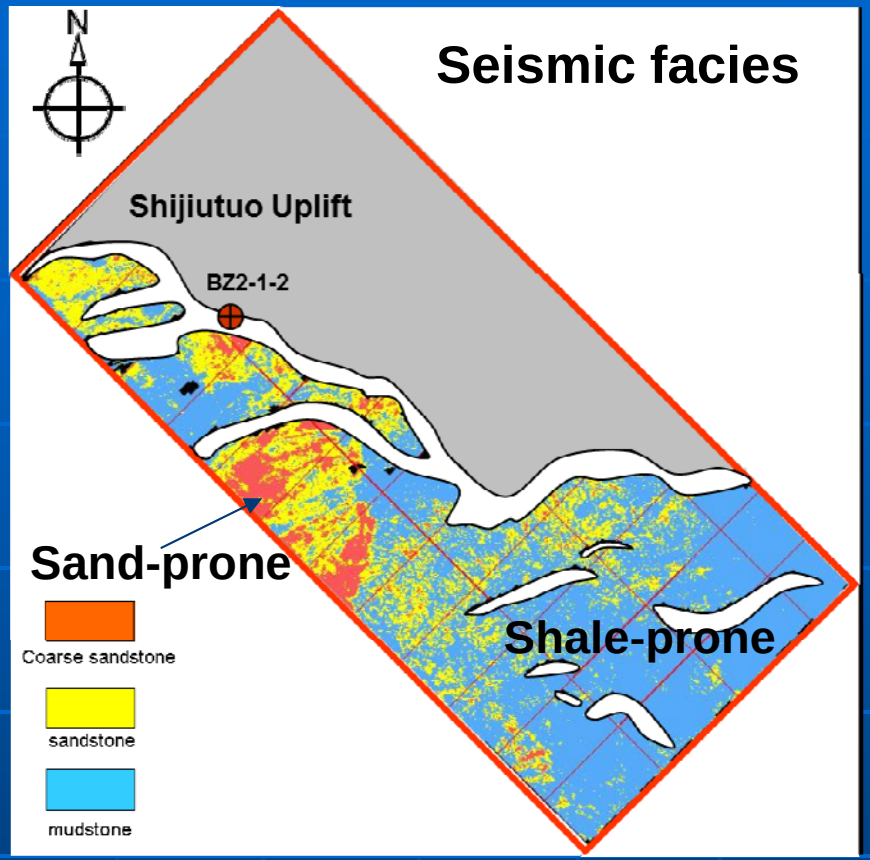
Classification algorithm: Back Propagation

Classification method: Neural Network

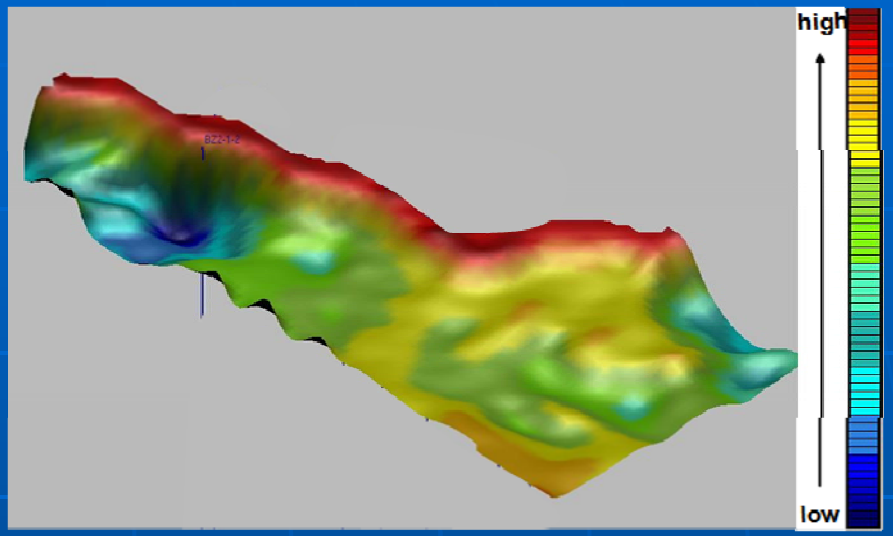
Supervised clustering

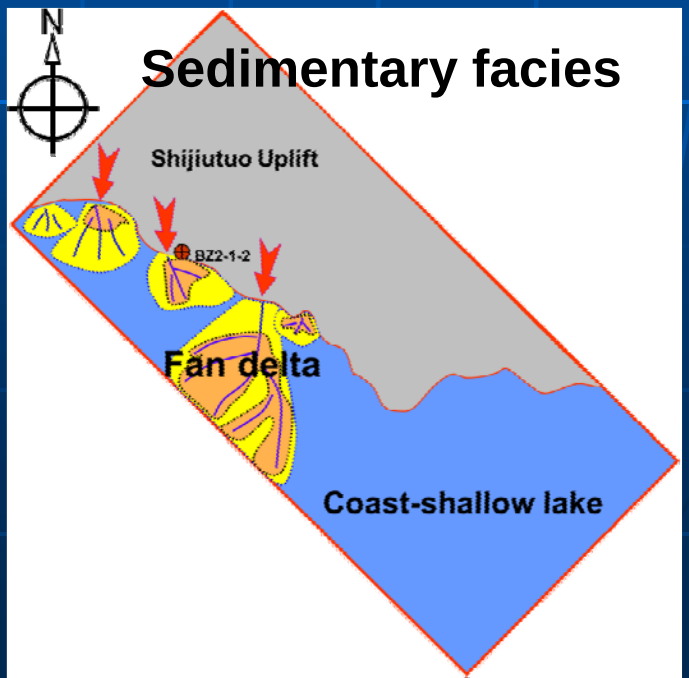
Seismic facies classification maps

From seismic facies to sedimentary facies (SQ1)



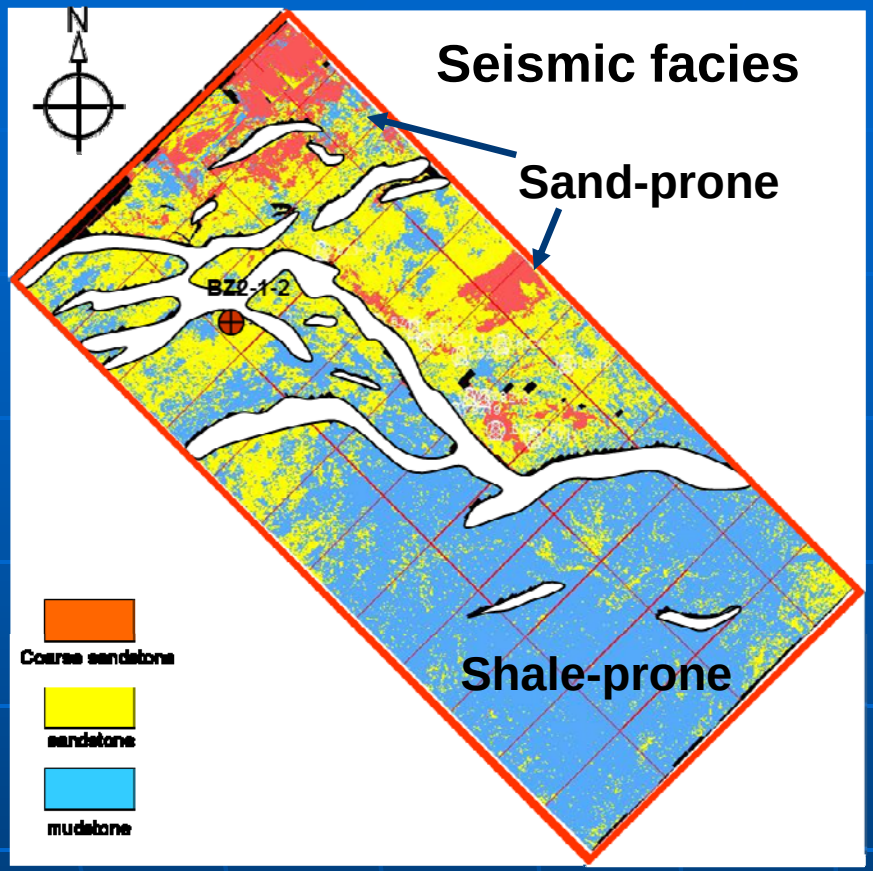
Paleogeomorphology (paleo-structure)





Fan-shaped multiple seismic attribute anomalies, located at the foot of hanging wall of bounding normal fault.

From seismic facies to sedimentary facies (SQ2)



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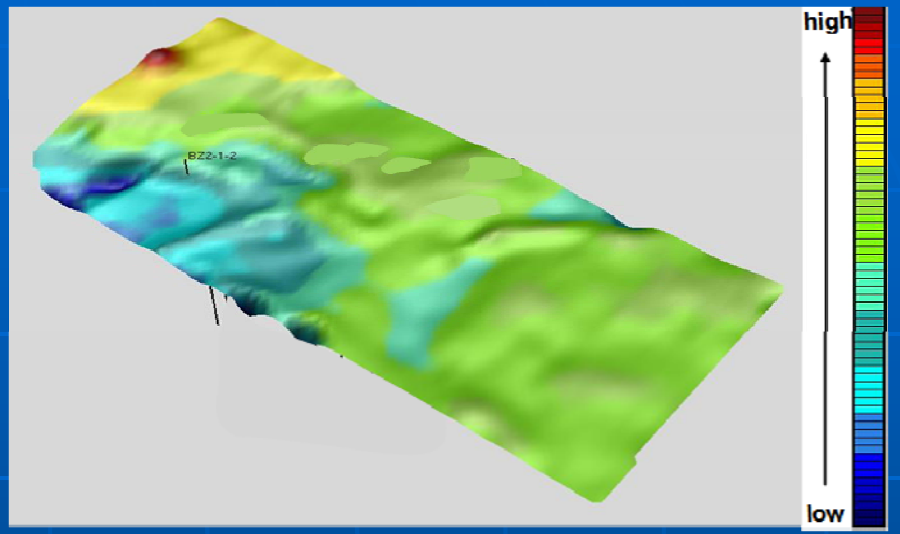
Paleogeomorphology (paleo-structure)



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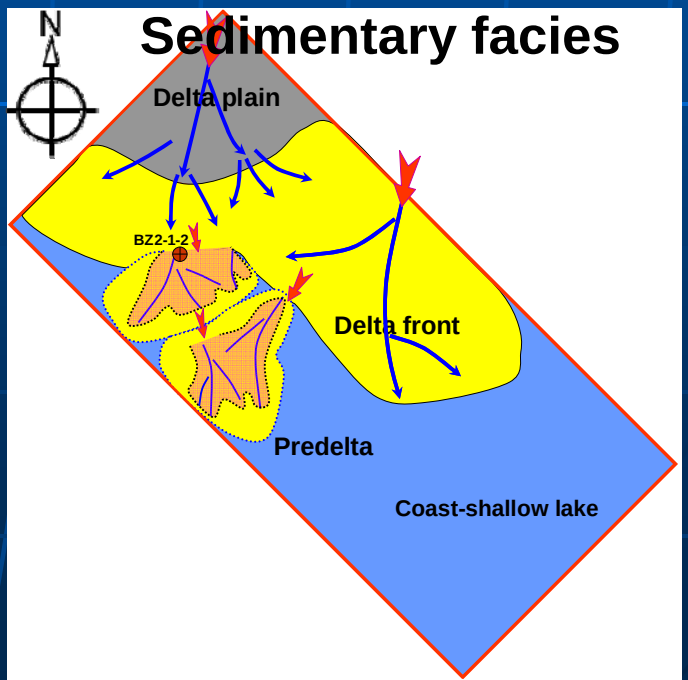
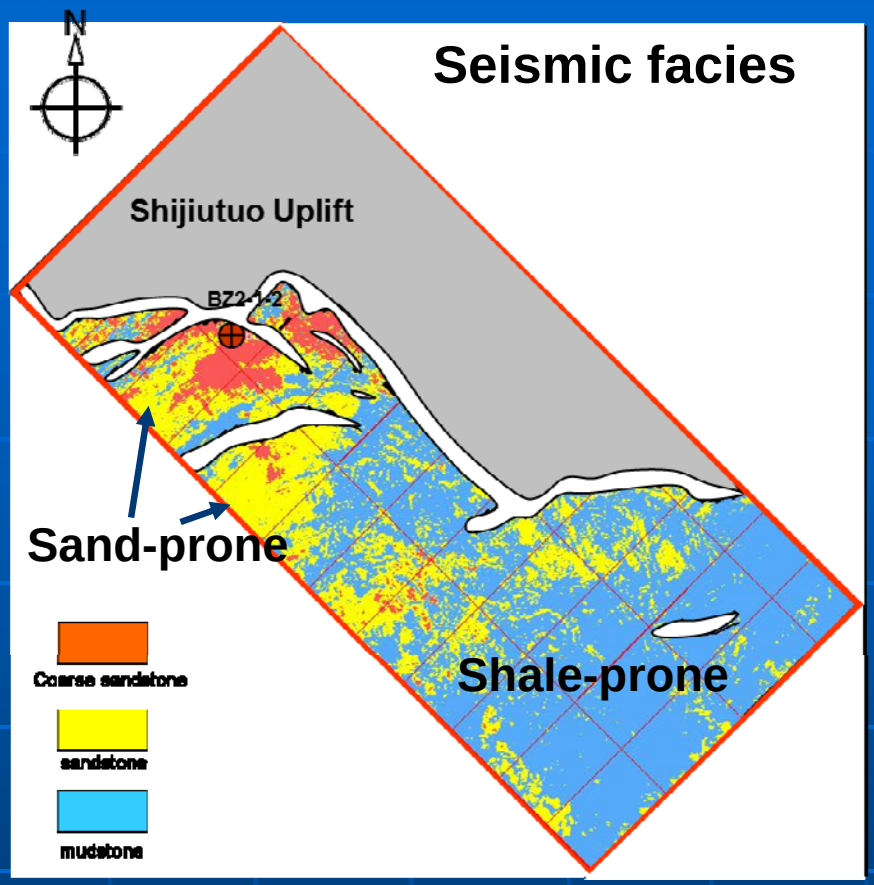
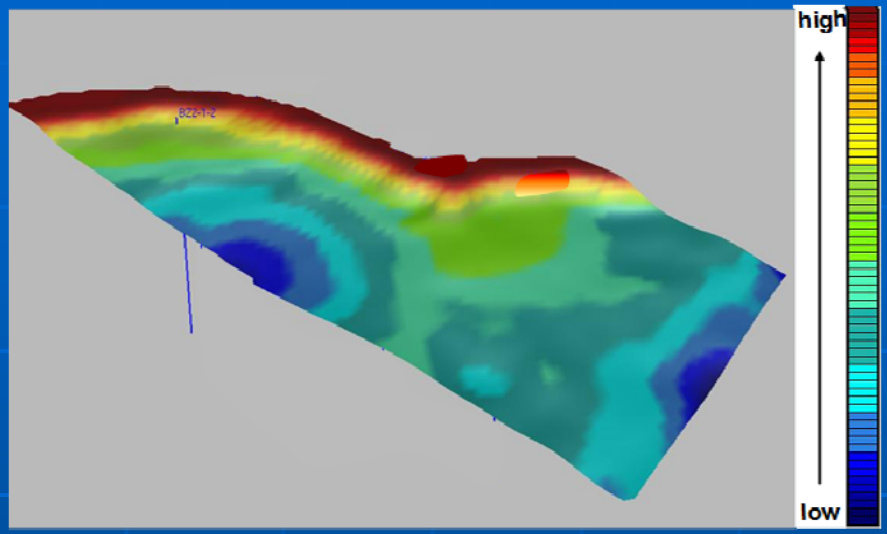


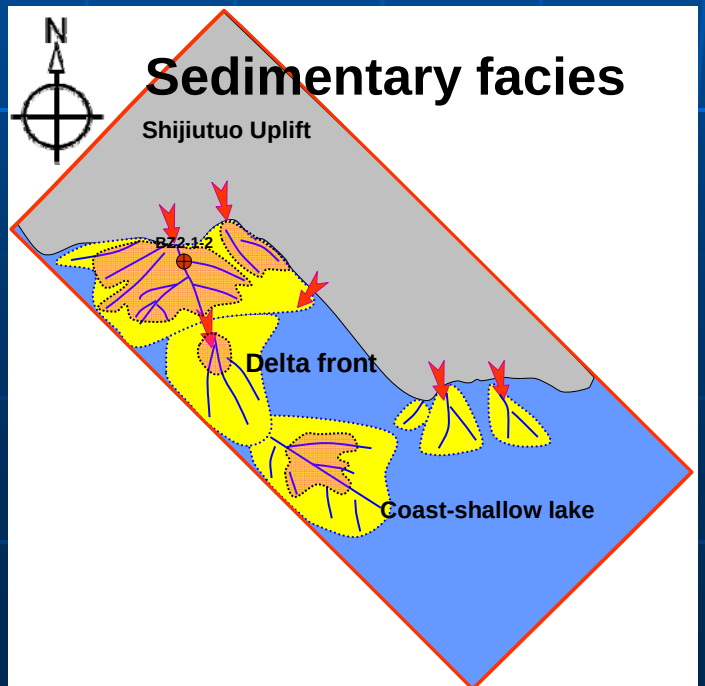
As lake level rise, all deposits shifted landward.

From seismic facies to sedimentary facies (SQ3)



Paleogeomorphology (paleo-structure)

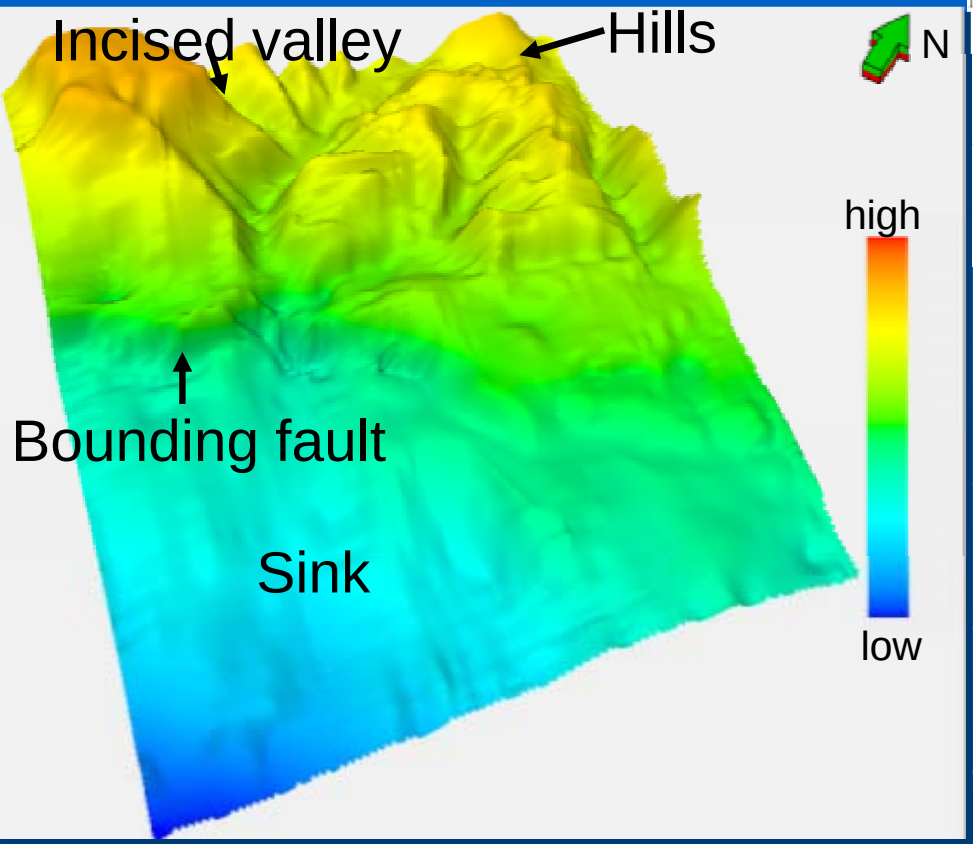


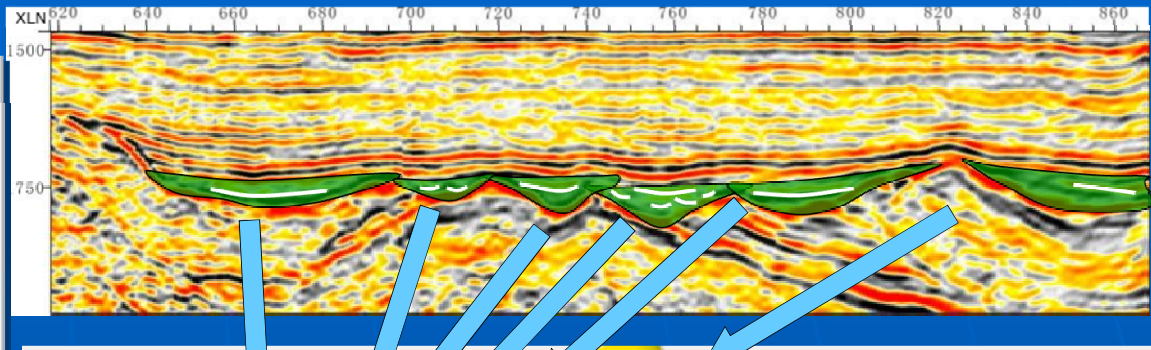


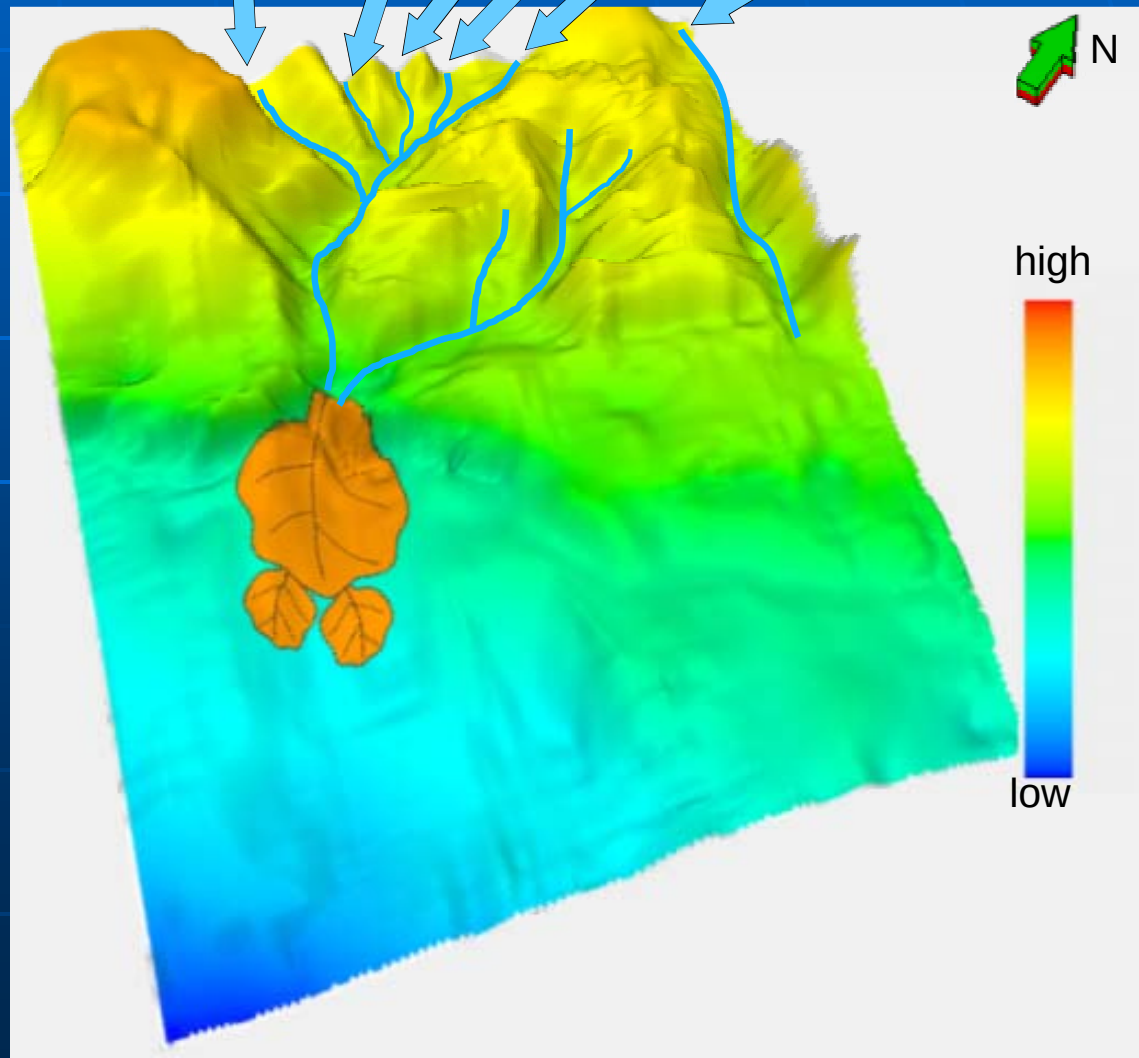
As lake level fell, all deposits shifted basinward.

Dispersal pattern of depositional systems

Paleogeomorphology

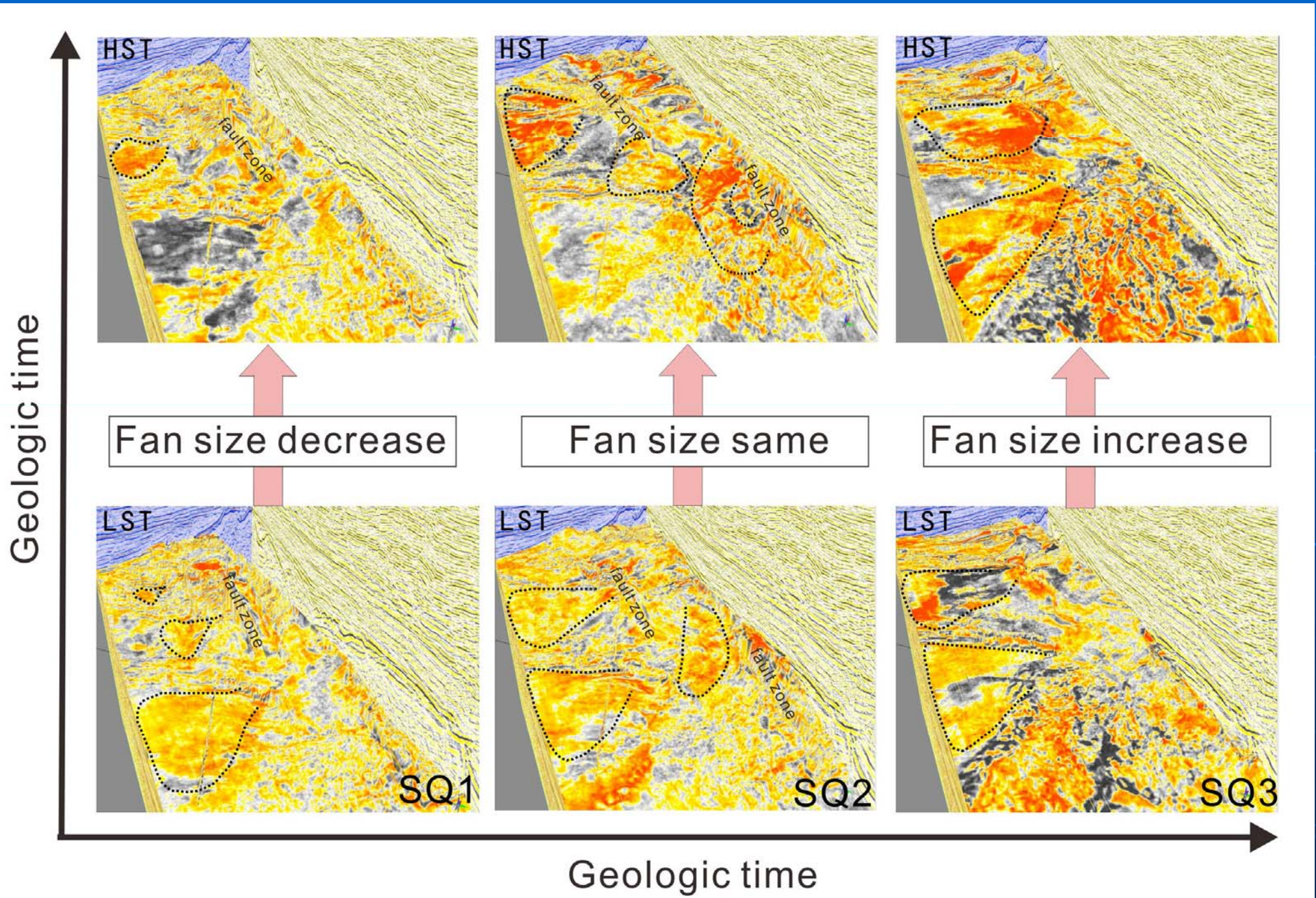




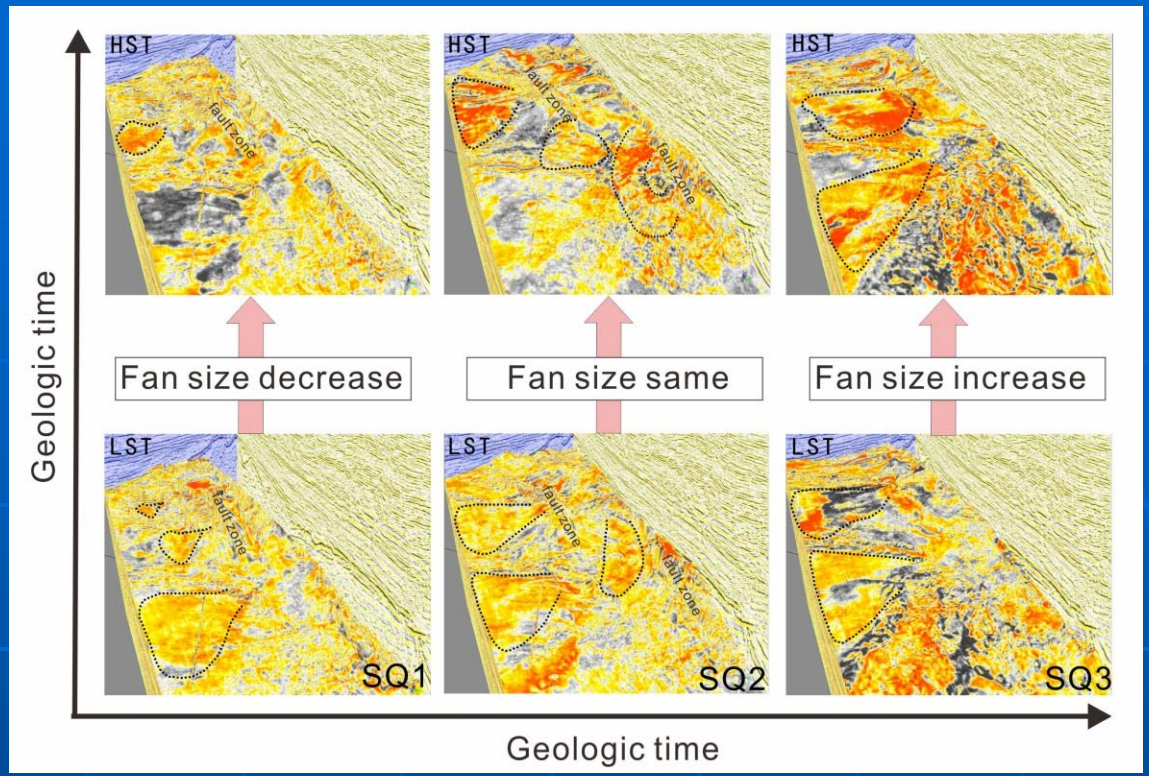


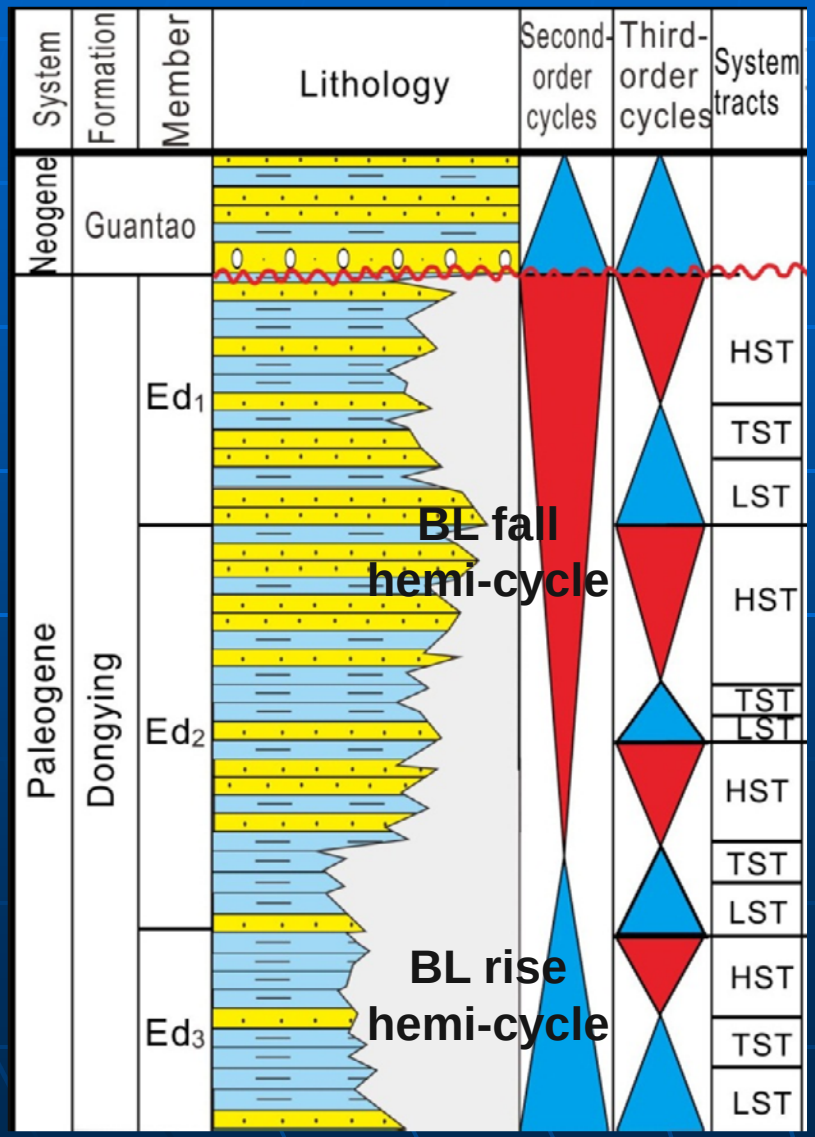
The incised valleys converged gradually from source to sink.

Spatial and temporal evolution of sedimentary facies



Spatial and temporal evolution of sedimentary facies





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;
- Palaogeomorphology 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.
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