

Recent Significant Discoveries in Mature Basins – Take Offshore Bohai Bay Basin as an Example*

Zhu Weilin¹, Xia Qinglong², and Zhou Xinhui²

Search and Discovery Article #10342 (2011)

Posted July 31, 2011

*Adapted from oral presentation at AAPG Annual Convention and Exhibition, Houston, Texas, USA, April 10-13, 2011.

¹China National Offshore Oil Corp., Beijing China. (shf606@163.com)

²Tianjin Branch of China National Offshore Oil Company Ltd., Tianjing, China.

Abstract

The Bohai sea area is the offshore part of the Bohai Bay Basin. The drilling of the first new field wildcat dated back to 1966 and the discovery peak occurred during 1995-2000 when a number of major heavy oil fields with an initial oil in place of over 100 million tons had been found. They include PL19-3, QHD32-6, CFD11-1, BZ25-1S fields. By the end of 2004, about 2.7 billion cubic meters of oil in place had been found in the offshore Bohai Bay Basin. With increasing exploration maturity, however, it has become more and more difficult to make new significant discoveries. Maintaining a highly efficient and sustainable petroleum exploration venture have met serious challenges.

Since 2005, systematic studies of effective source kitchens, high-quality reservoirs distribution and oil/gas migration patterns indicated that the Tan-Lu strike-slip fault zone and the slopes surrounding the Bozhong depression were the prospective areas for petroleum enrichment. The exploration in the offshore Bohai Bay basin entered a new exploration phase which was characterized by exploration for oil and gas in multiple stratigraphic intervals and targeting multiple types of traps. The exploration focused on traps rich in oil and gas and meanwhile the prospectivity of the areas surrounding these traps were quickly and thoroughly assessed.

The JZ25-1, JX1-1, BZ28-34, KL10-1 trends and the eastern plunging end of the Shi-Jiu-Tuo arch were selected for drilling. The exploration results proved that all the five trends are petroleum enrichment belts. The fields newly found in the trends led to the second peak of petroleum discovery in the offshore Bohai Bay basin. About 1.6 billion cubic meters of oil in place had been discovered in five years. Recent discoveries have been made in new plays and new domains which include the Neogene lithologic traps, steep slope zones of depressions, and fault transfer zones. The occurrence of second discovery peak indicates that new exploration ideas and technological innovations have played an important role in petroleum exploration in mature

basins. Exploration in China's offshore areas and similar basins may take lessons and guidance from the successful exploration practice in the offshore Bohai Bay Basin.



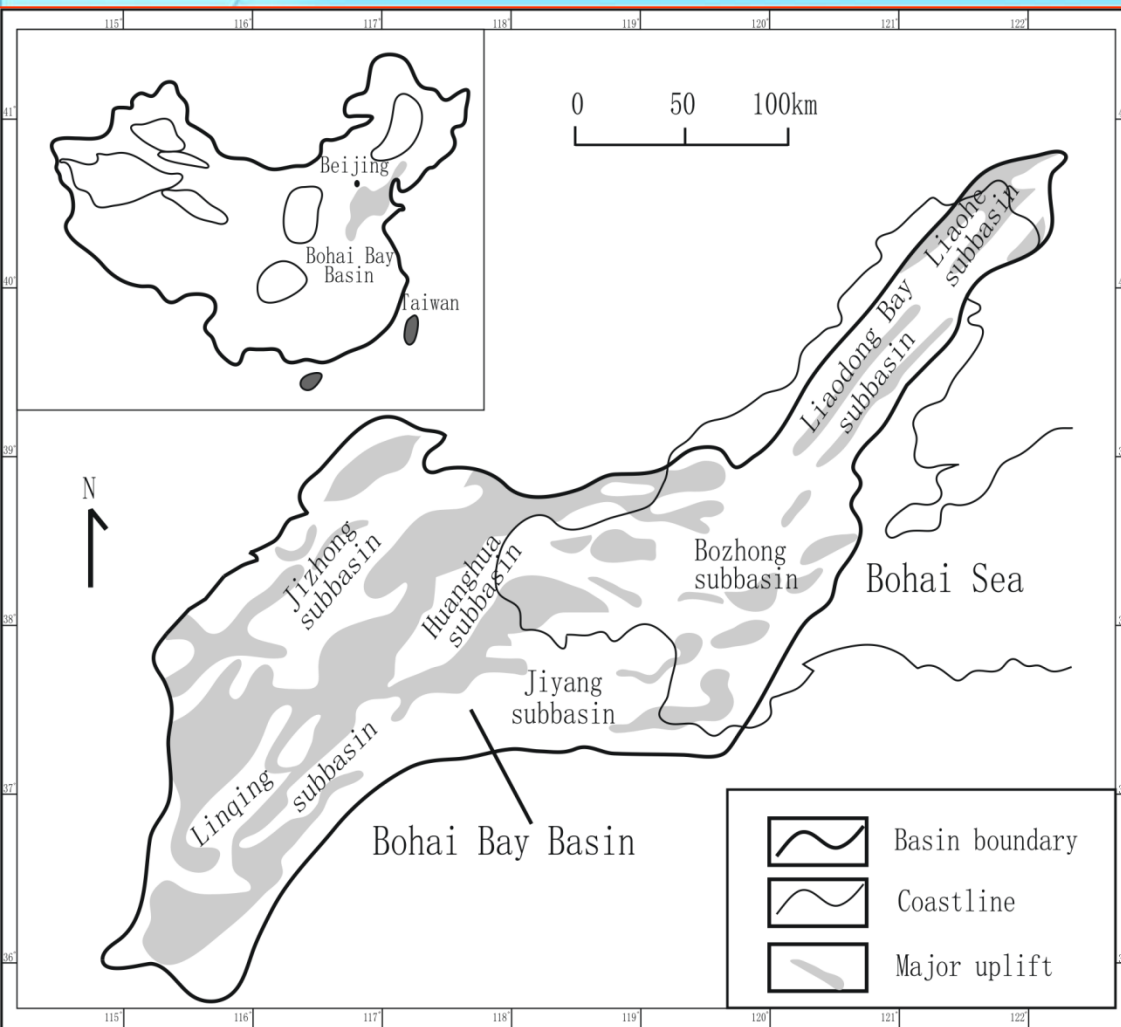
Recent Significant Discoveries in Mature Basin –Take Offshore Bohai Bay Basin As An Example

Zhu Weilin, Xia Qinglong, Zhou Xinhuai

4-12-2011



Introduction to Bohai Offshore



Bohai bay basin:

1. Coverage **200,000 km²**.
2. Estimated Oil and gas resources:
30 Billion tons and 2.6 Trillion m³;
3. Discovered oil and gas:
10 Billion tons and 0.3 Trillion m³

Bohai Offshore

Exploration Area: 44,000 km²

15 sags and 13 Uplifts

650 Exploration and appraisal wells

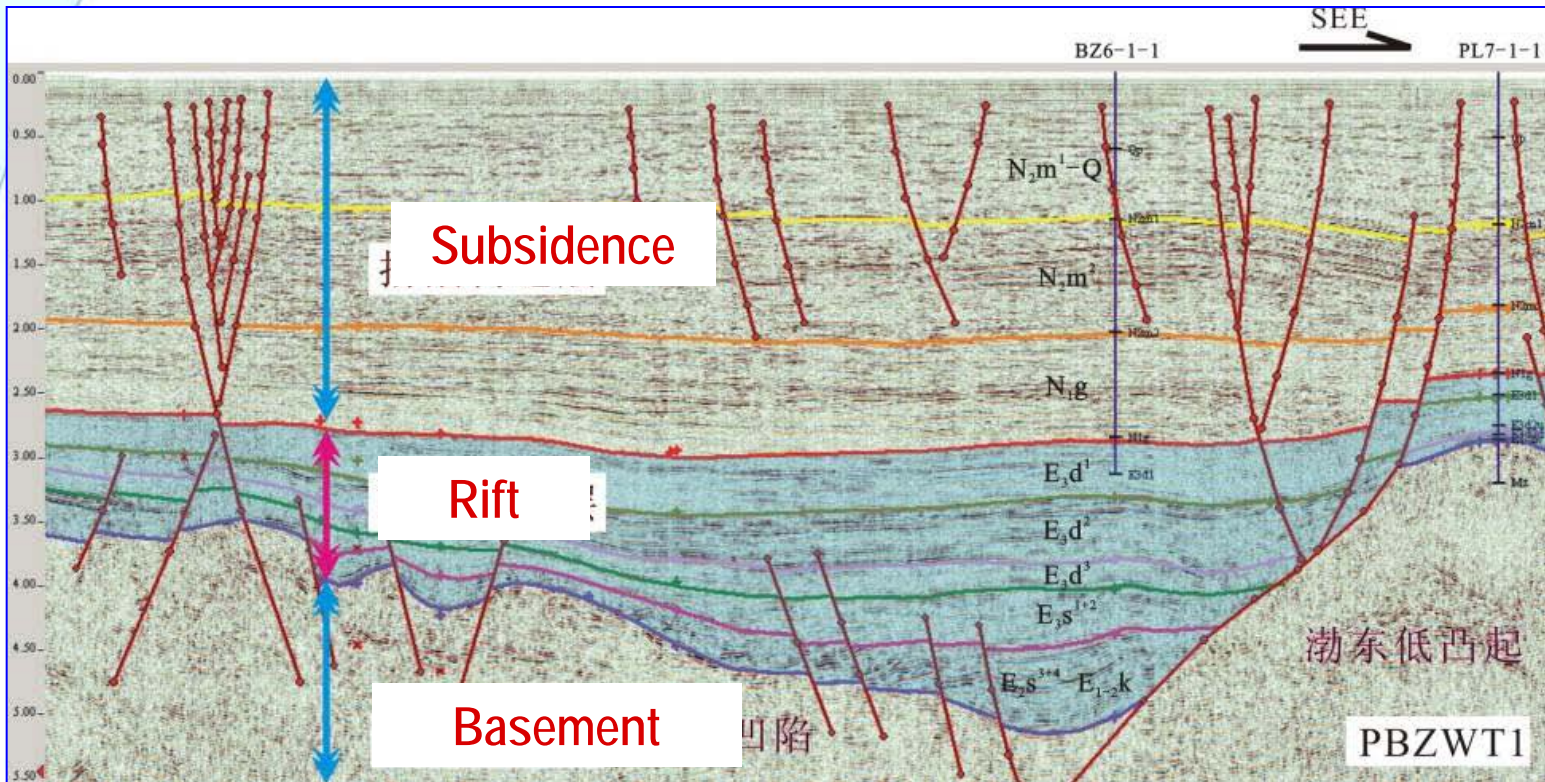
4.9 Billion m³ oil equivalent found

Mainly in Liaodongwan and Bozhong area;

Estimated resource 13~14 Billion m³



Basin Structure



Cenozoic basin. deposits include: 1. the pre-Tertiary Basin basement; 2. Tertiary rifting deposits and, 3. Depression deposits composed of Neogene and Quaternary



Petroleum Systems

1. Source rocks

Paleogene 3rd members of Dongying and Shahejie Fms;

2. Reservoirs:

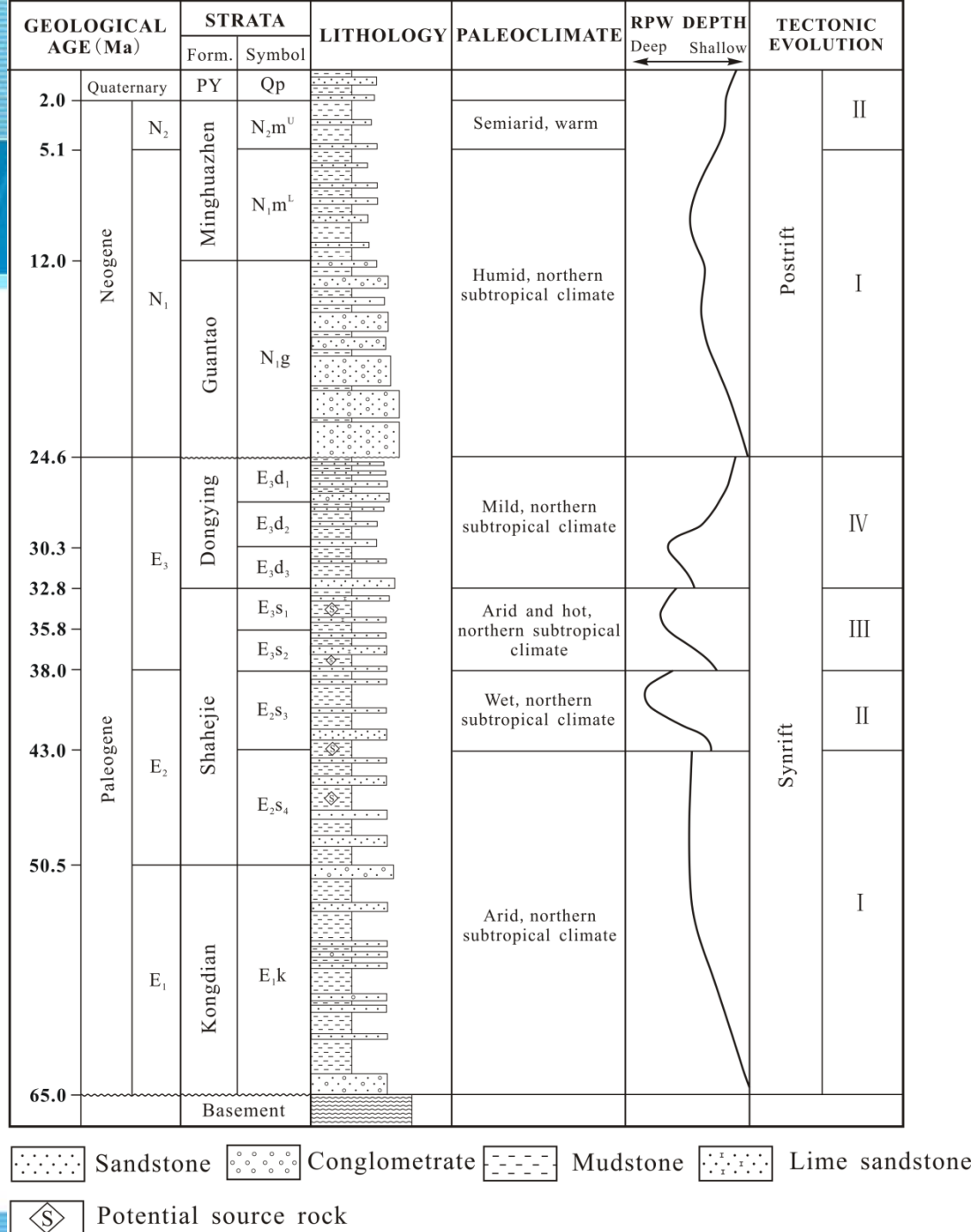
Fluvial, deltaic sandstones in all stages; burial hills;

3. Peak hydrocarbon expulsion

At Neogene Guantao Fm

4. Hydrocarbon distribution

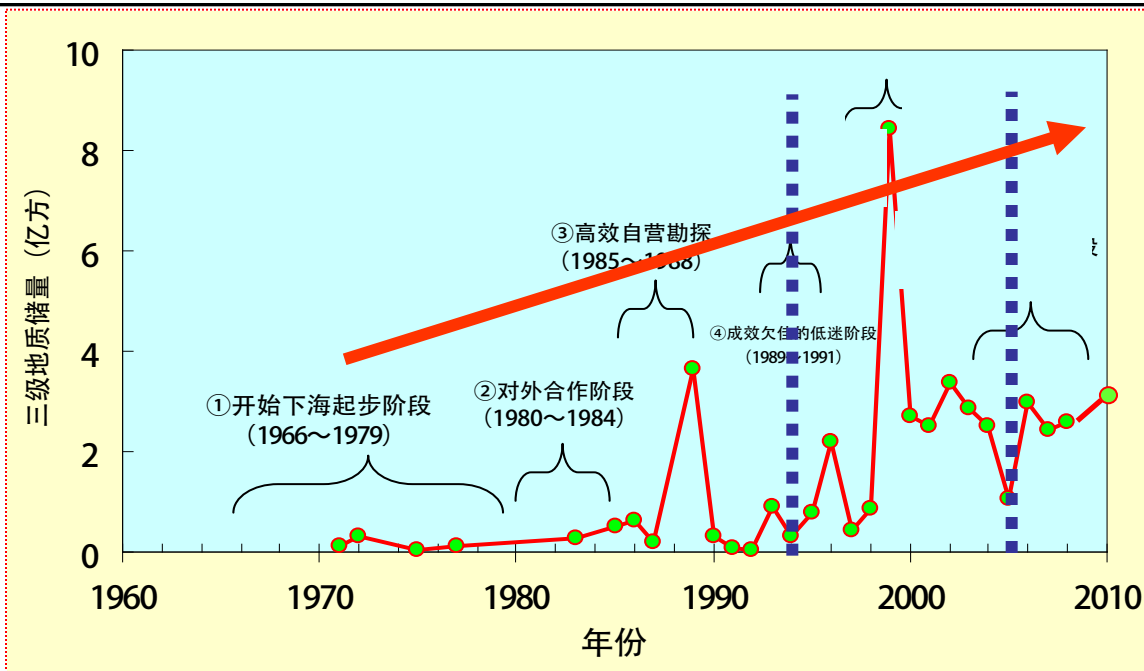
Mainly in Bozhong and Liaodongwan areas.





Forty Four Years Exploration : Concept Shift Lead to Success

1. 1966 ~ 1994: Targeting at burial hill and Paleogene, small size reserves found.
2. 1995 ~ 2005: Many Heavy Oil fields found under the concept of Sags delineation and uplifts exploration
3. 2005 ~ present: continuously discovered light oil and field with the concept of "all round exploration".





Improved Understanding and Discoveries
in the past five years

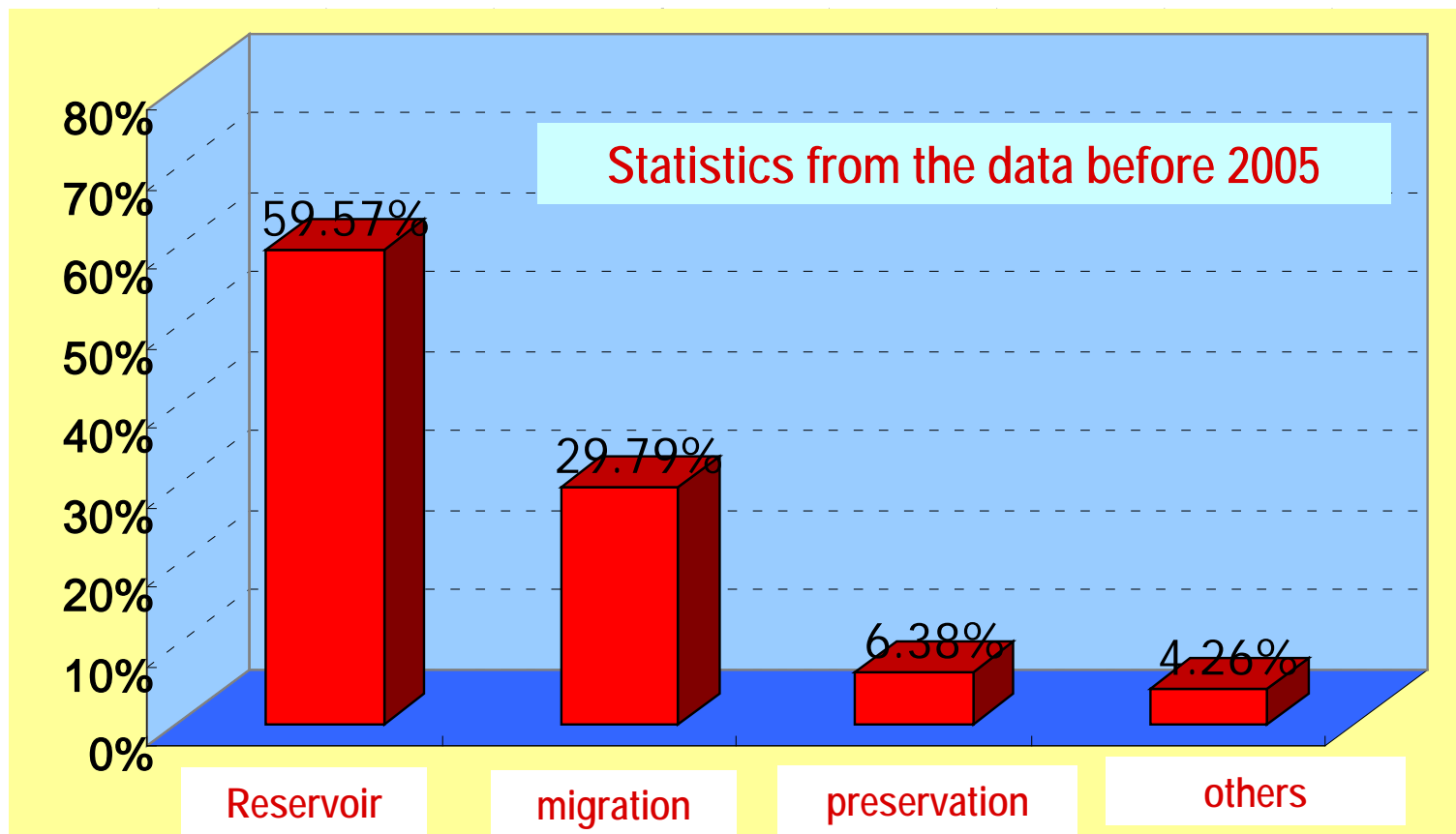


New Discoveries Attribute to Improved Geological Understandings

1. The relationship between the Hydrocarbon accumulation and Paleogene **effective reservoirs** development with the strike slip faults system.
2. **Middle - deep reservoirs** predication based on the Hydrocarbon accumulation mode in the steep slope area of prolific basin.
3. Hydrocarbon accumulation and entrapment modes in the **extremely shallow lacustrine and lacustrine deltaic deposition systems**



Reservoir is key to Deep Prospect Exploration



Most of the discoveries are the results of integrated studies of the above three aspects, of which reservoir analysis is the key.



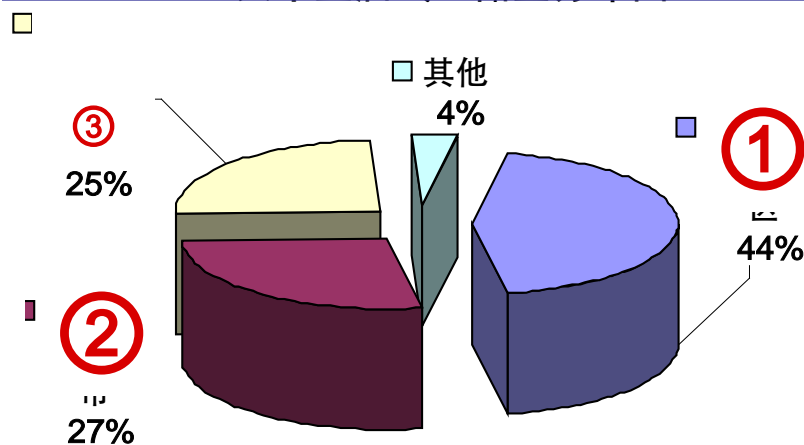
Five Over 100 MM Tons Light Oil Field Groups Found in the Past 5 Years

渤海海域
油气勘探形势图



1. Five light oil fields groups each over 100 million tons have been discovered in the past 5 years. Among them, 16 over 30 million m³ and 3 over 100 million tons: JX1-1, KL 10-1 and JZ 25-1
2. 85% of the newly discoveries are of light oil, contrast to before 2005, the 85% reserve is heavy oil.

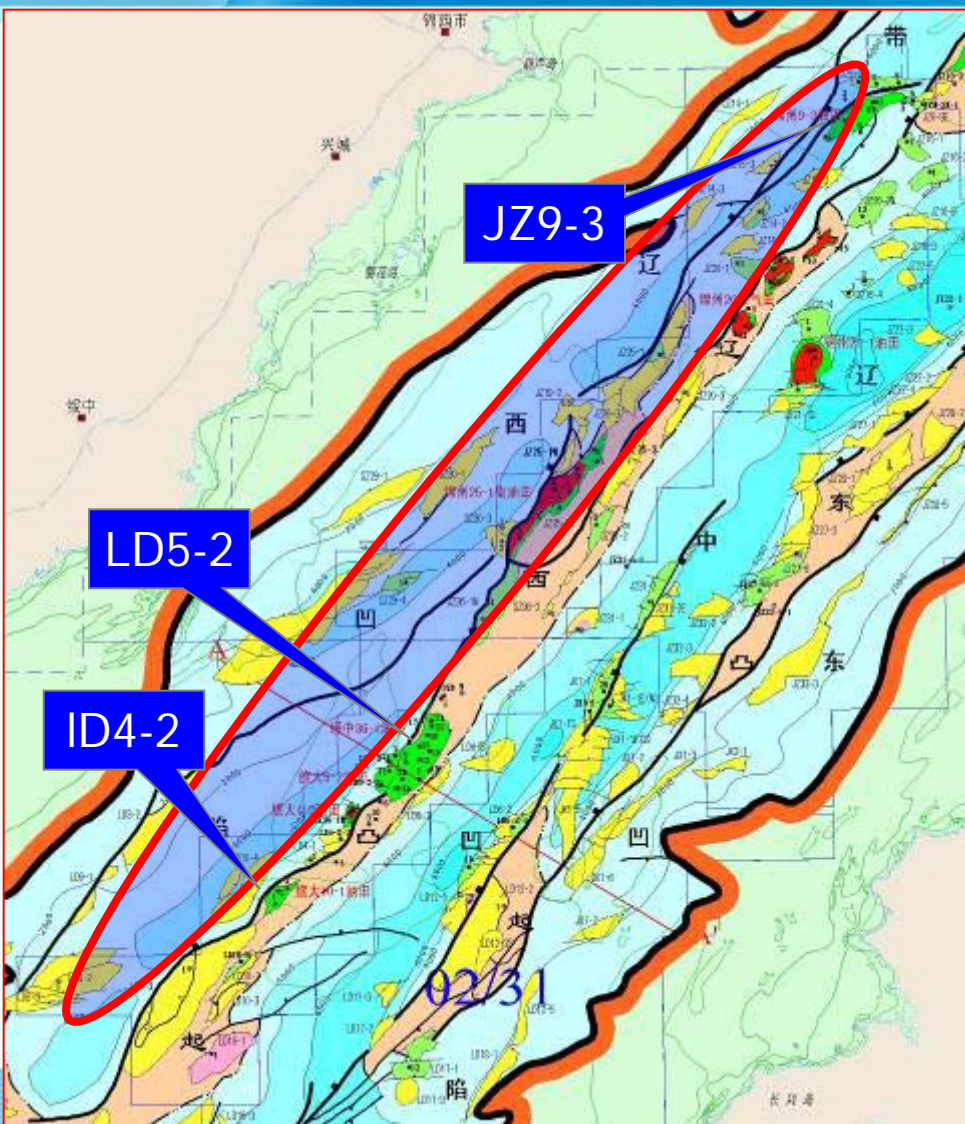
Reserves distribution of moderate-large fields discovered in the past 5 years



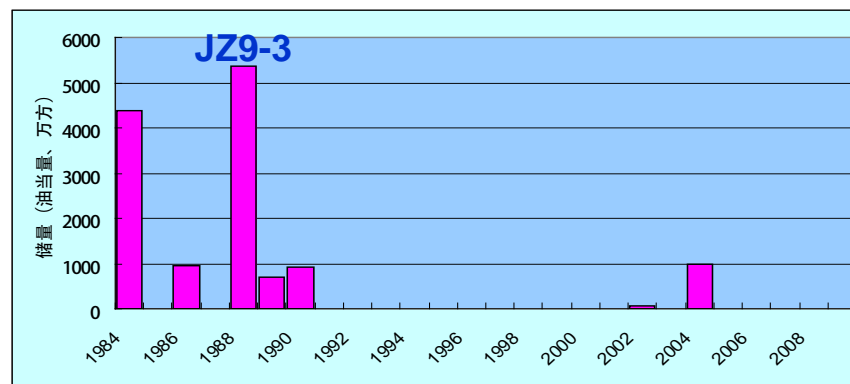
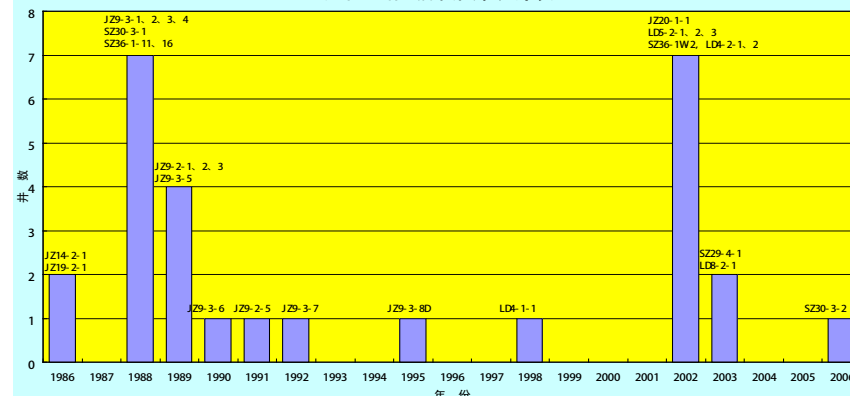


JZ 25-1 Oil field: Liaoxi Area Exploration

27 wells had been drilled in the past 20 years, and only 3 fields found. Does it still has potential? If yes, where?



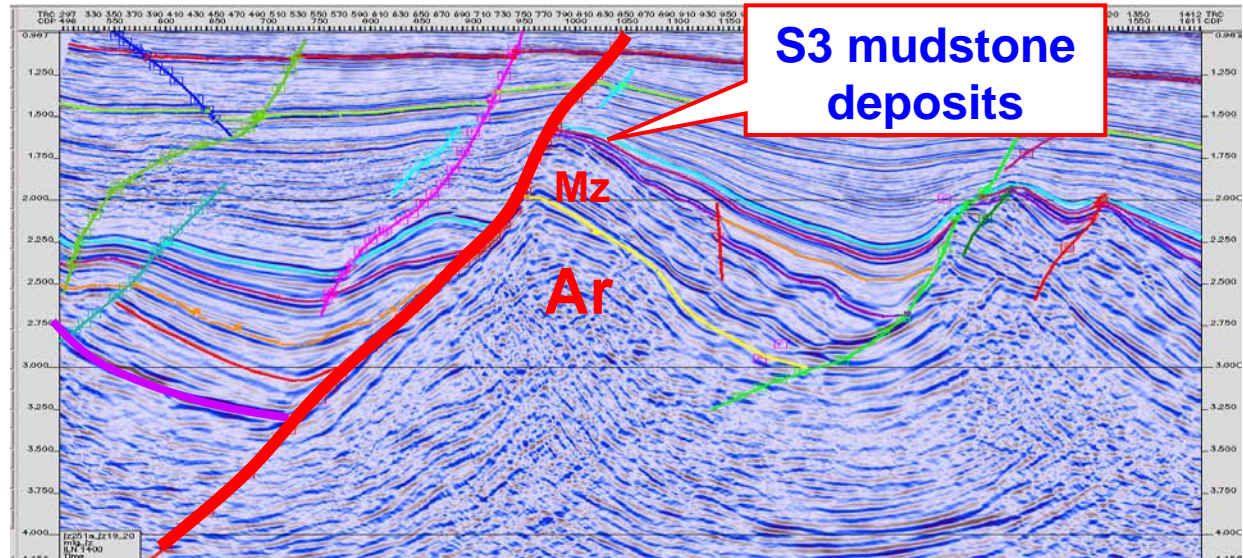
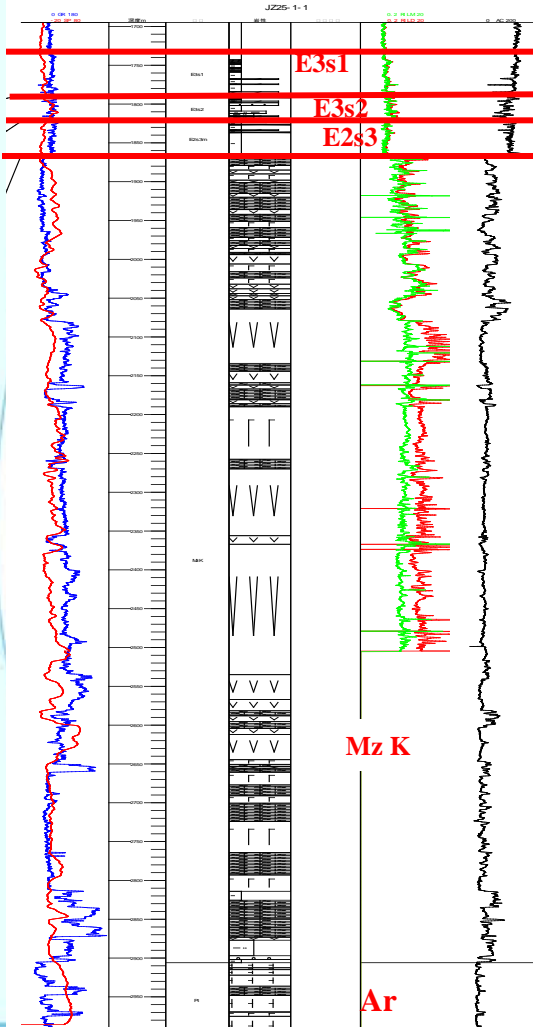
辽西凹陷勘探钻井统计表





JZ 25-1 Oil Field

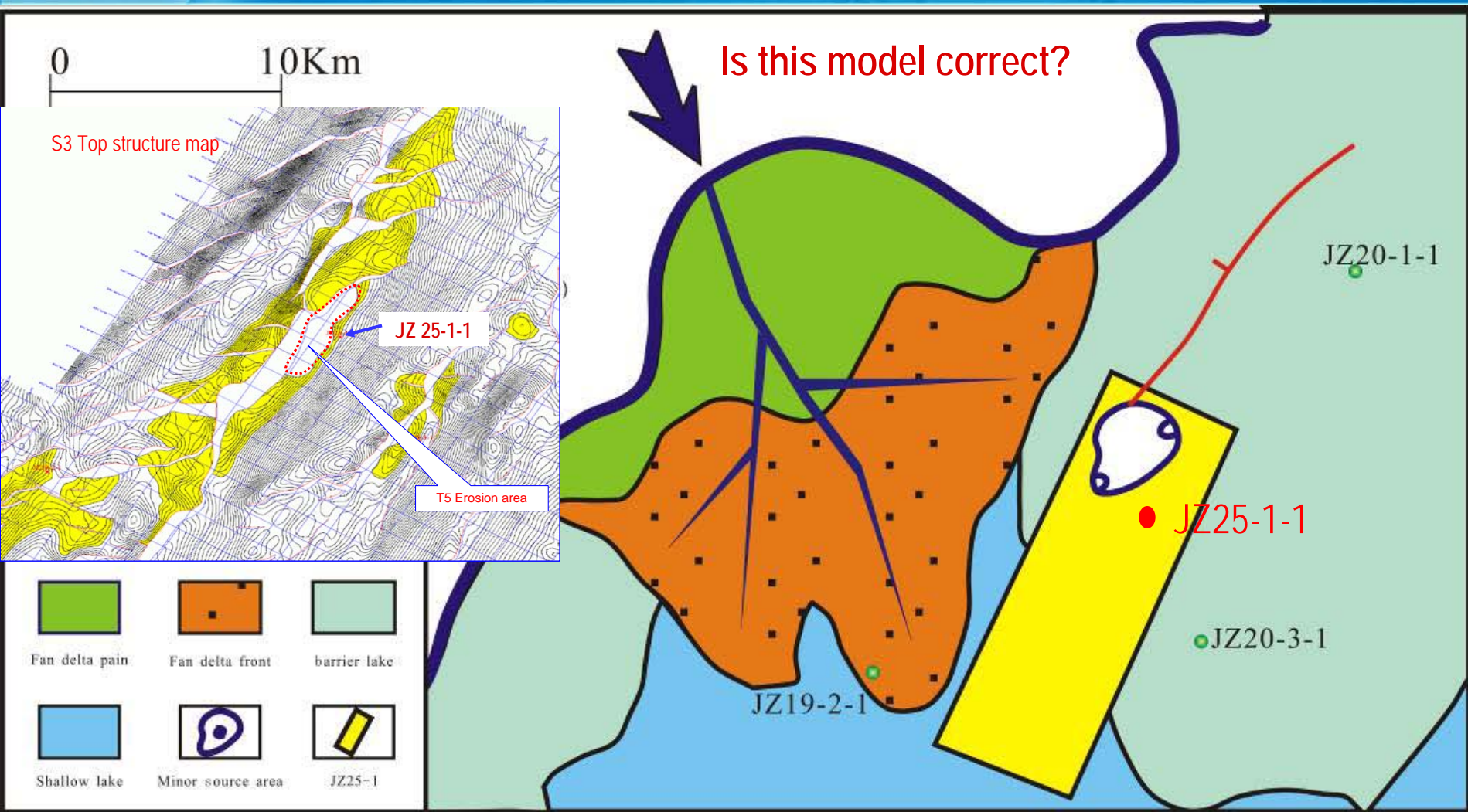
JZ25-1-1



The objective is the S3 sandstone, however, drilling indicates the mudstone overlaps on the Mesozoic strata, therefore, the post drilling analysis speculate no sediments deposits downslope and reservoir is key element for future exploration



JZ 25-1 Oil Field: Geological Model





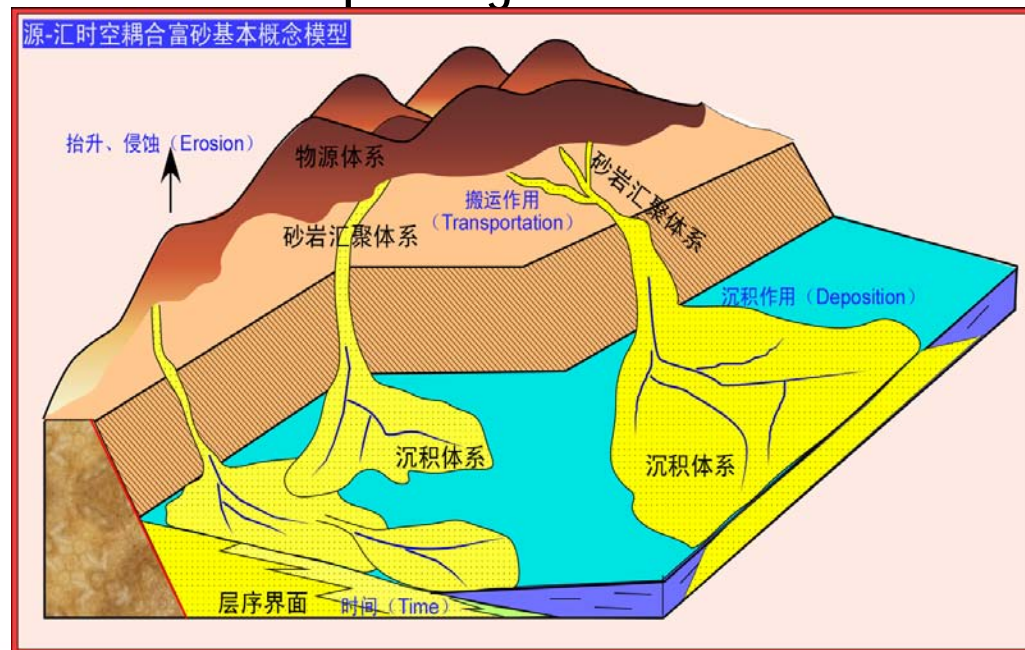
New Sand Deposition Model in Lacustrine Rift Basin

In lacustrine rift basin, sand deposition is controlled by four factors: from source to sink system.

1. Effective Material Source (Source system): Providing source
2. Long-time eroded gully (Transportation system): Providing the effective transportation pathway
3. Slope break (Sink system): Location of sediments depositing
4. Base level of deposition (Time system): Deposition time of the sediments

Source-Gully-Slope-Level control

Sand deposition is controlled by the joint working of the above four factors. If we can find the coexistence of effective source and sink place, we could find sand reservoir.





Effective sources include obvious (long time eroded and very easy to identify)and unobvious sediments source, and the latter is very important for identifying effective sand from a lean sand setting.

Unobviousness means:

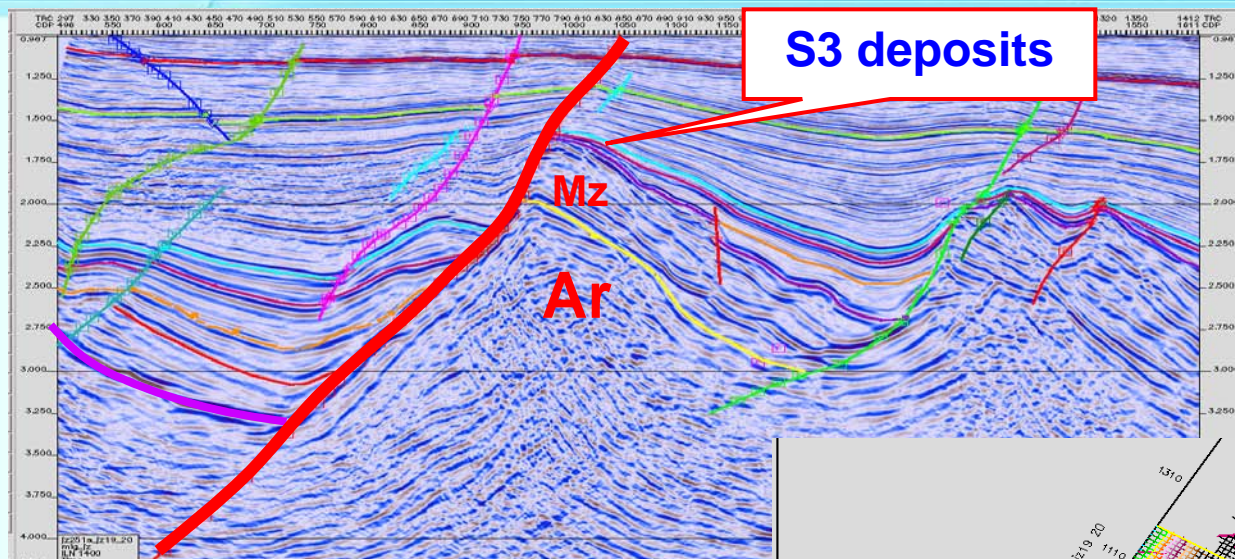
Unobvious Time: In a third order sequence, the source location occurred a early erosion (providing source) and later deposition (can't providing source).

Unobvious space: Source location move with the strike slip movement

Identification method : Paleotopography reconstruction



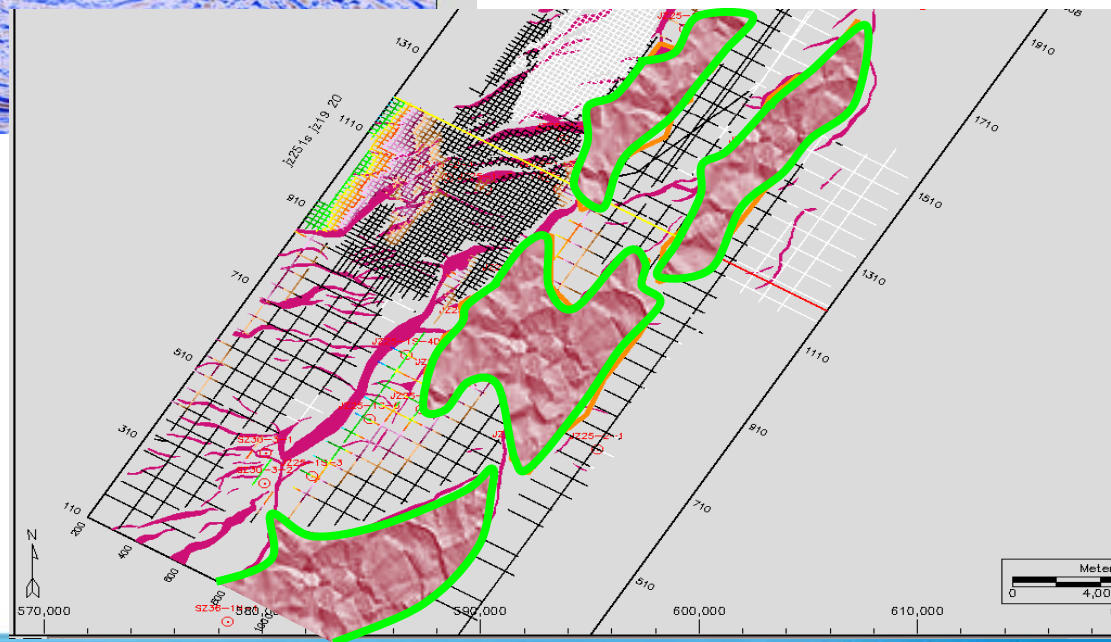
Unobvious Source Identification On The Uplthrown Block in JZ 25-1



Previously:
The S3 mudstone deposits overlap on Mesozoic strata. No reservoir occurred down-slope due to no sediments (sand) source.

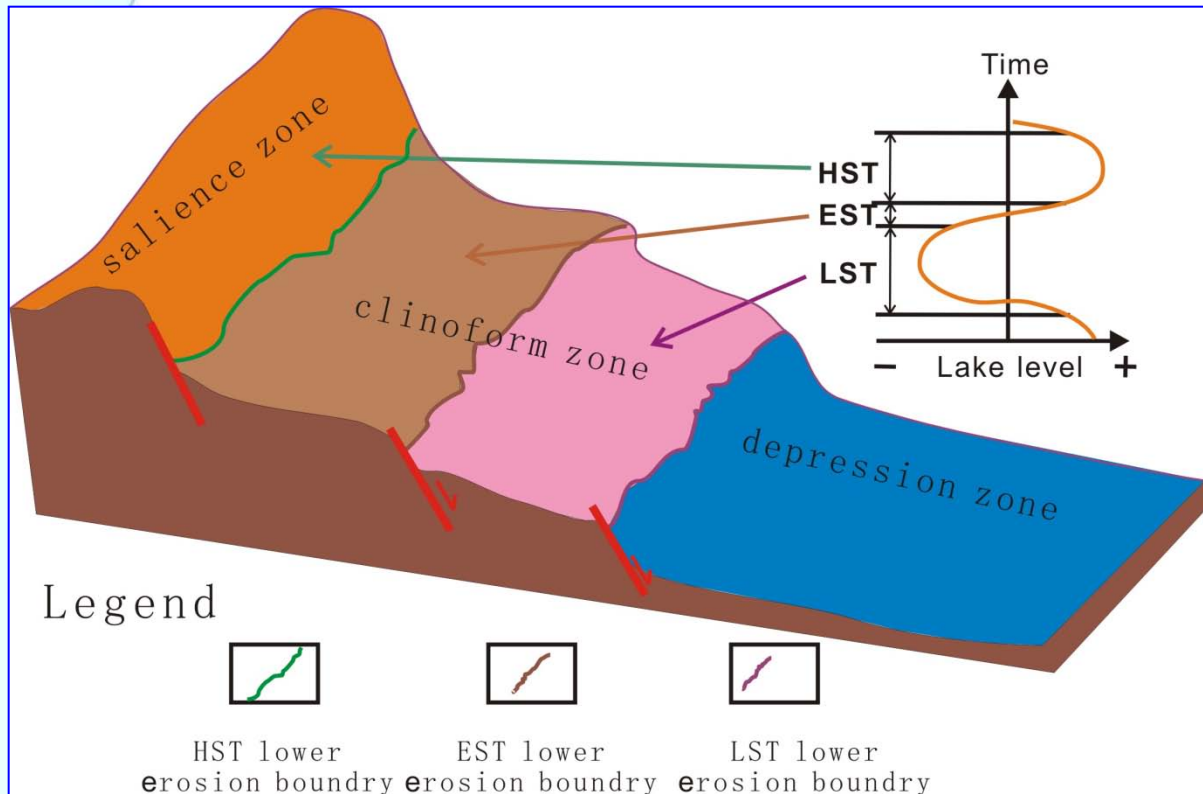
Present

There are sediments sources distributed on Liaoxi low uplift through paleotopography reconstruction based on the thoroughly analysis of high resolution sequence stratigraphy.





Effective Source System in JZ 19 -25 Area



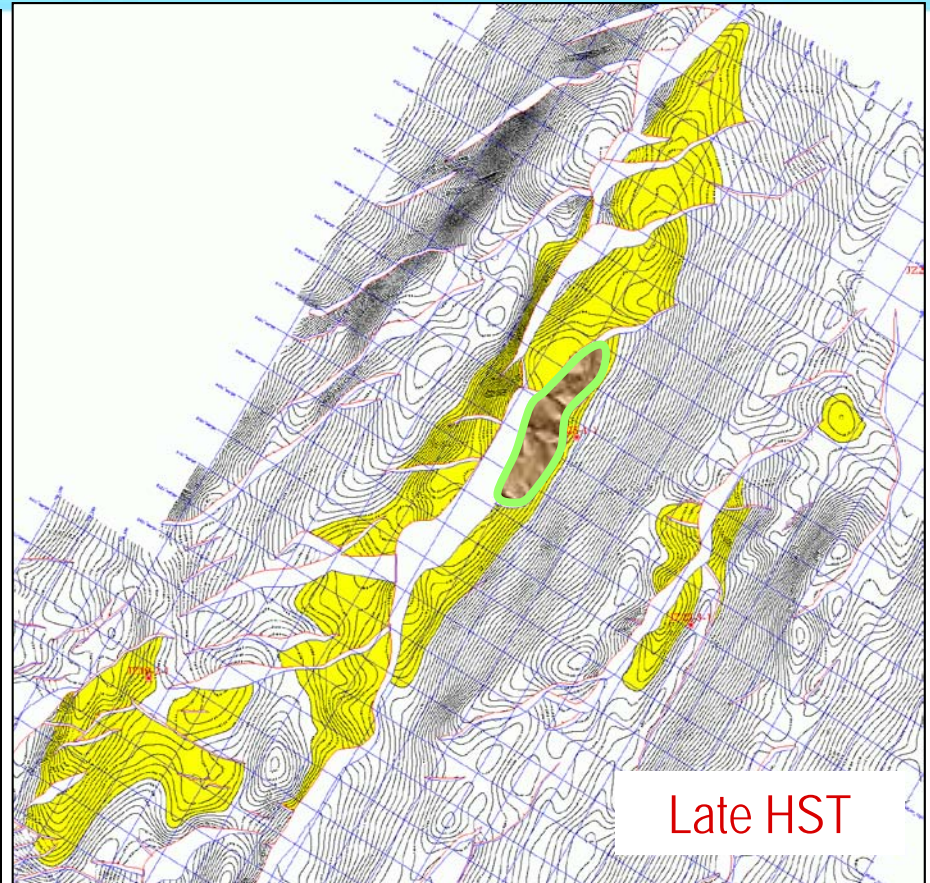
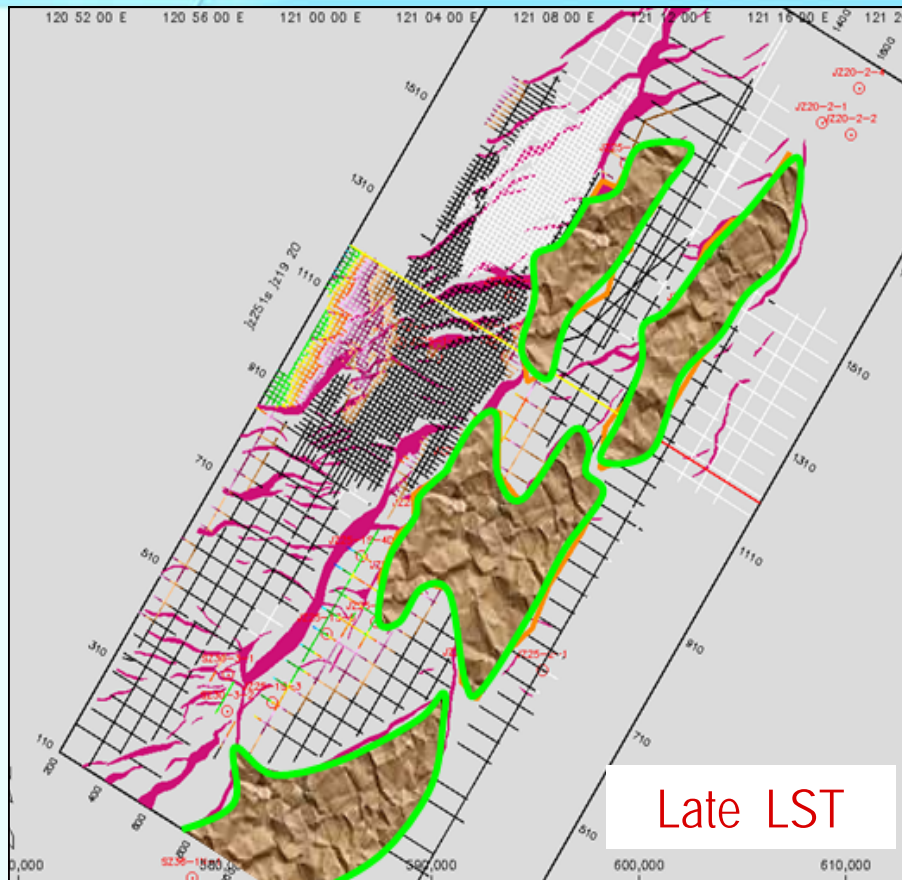
Dynamic source:

Source area changes in different deposition stages in a sequence. In the low standing period, erosion (source) area increases as the lake surface down, and in the high standing period, the erosion area reduces or disappears with the surface rise.

Concept of Dynamic source



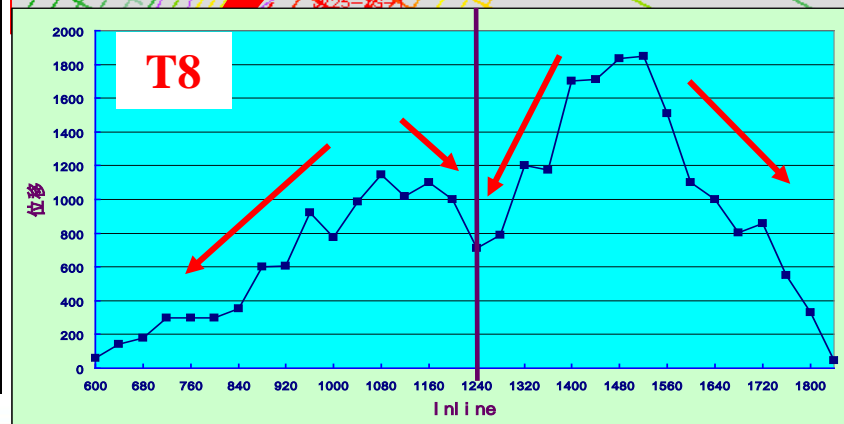
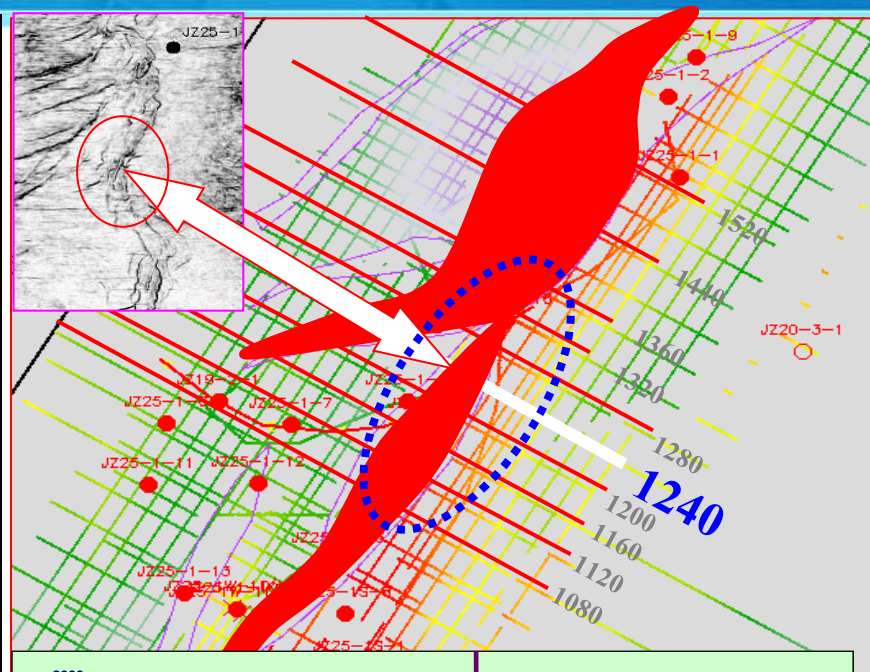
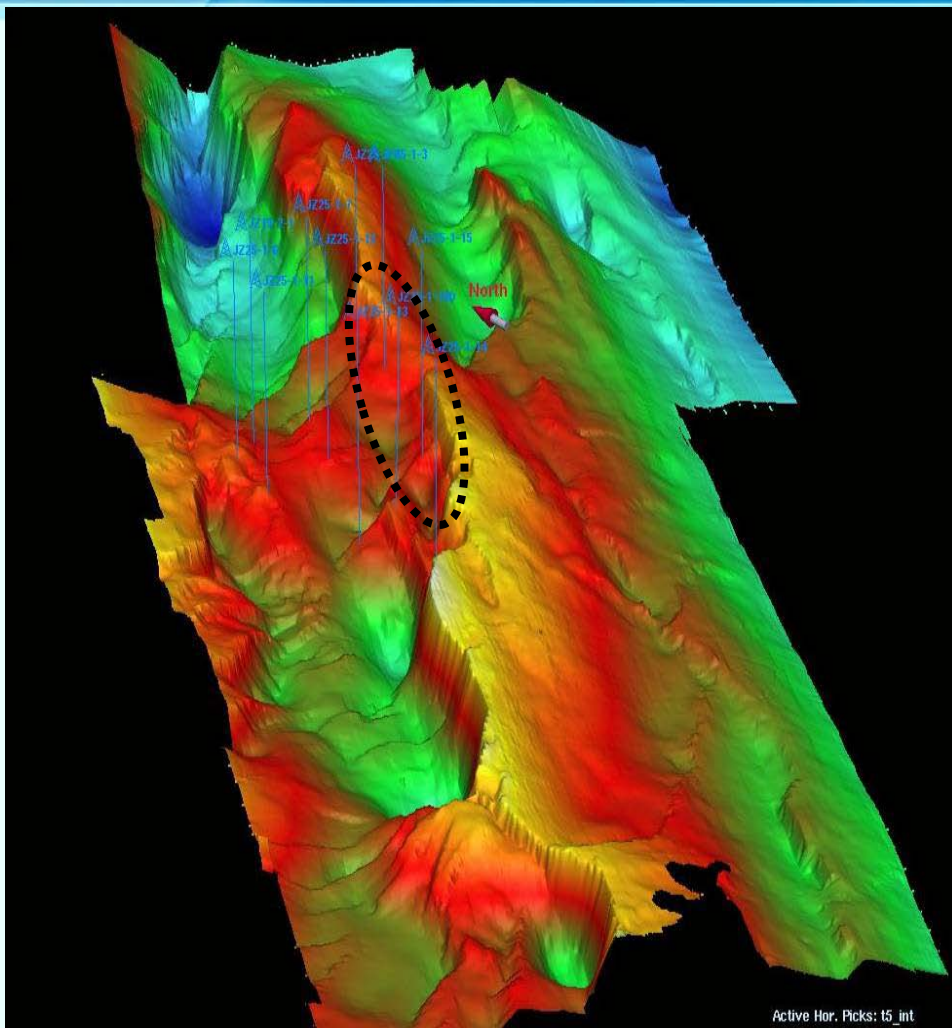
Unobvious source : Source Area Changes With Deposition Sequences



The erosion areas of JZ 25-1 in LST and HST during the third member of Shahejie Fm



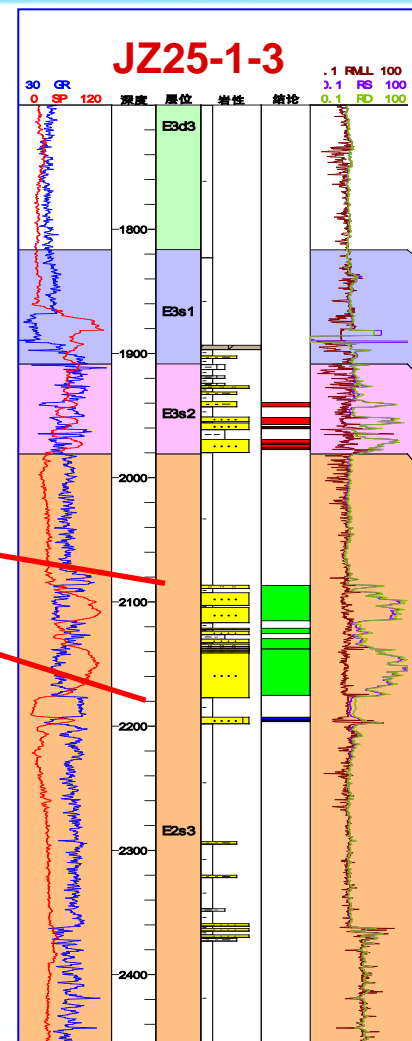
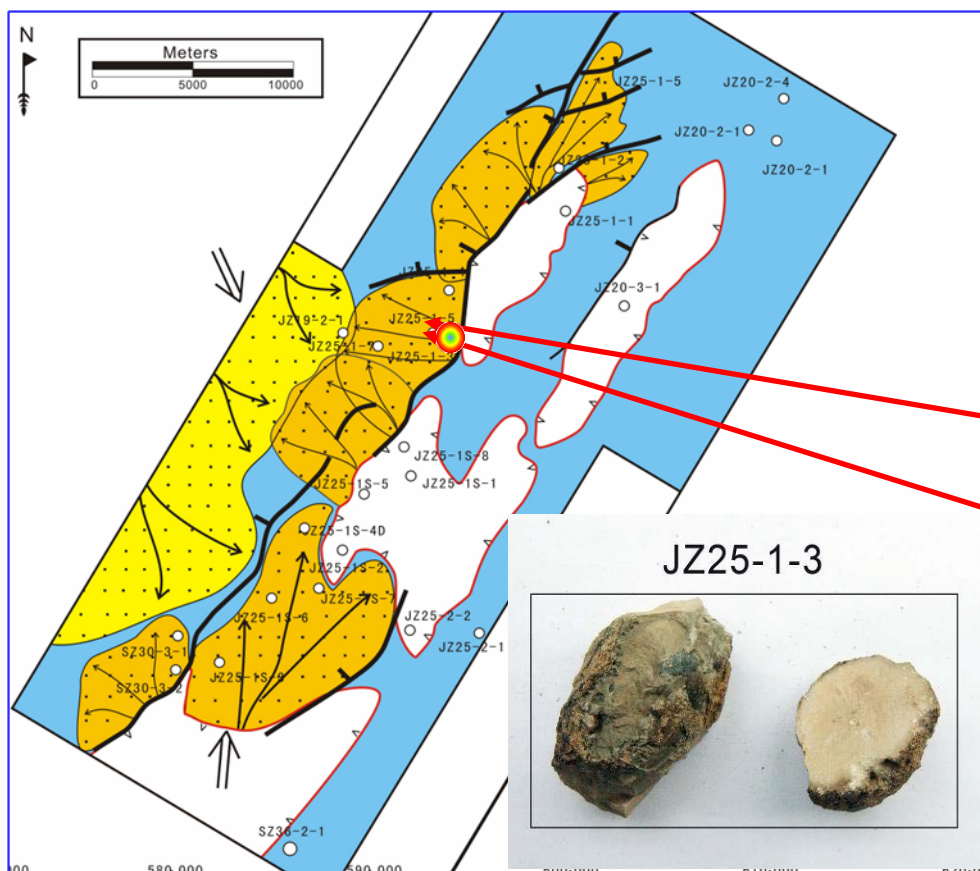
Sink System: Sediments Deposits Along the Basin Margin Faults





Source-Sink System in JZ 19 and JZ25 Areas

Lake transgressive deposition sequence distribution of JZ 19-25 area in the middle sections of the third member of Shahejie Formation

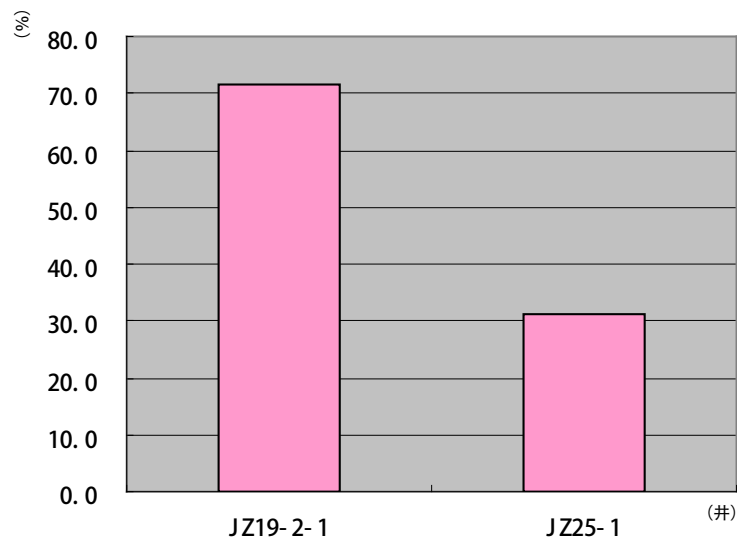




Evidence 1 : Distribution of ZTR Index

Resistant mineral content increases with transporting distance increase

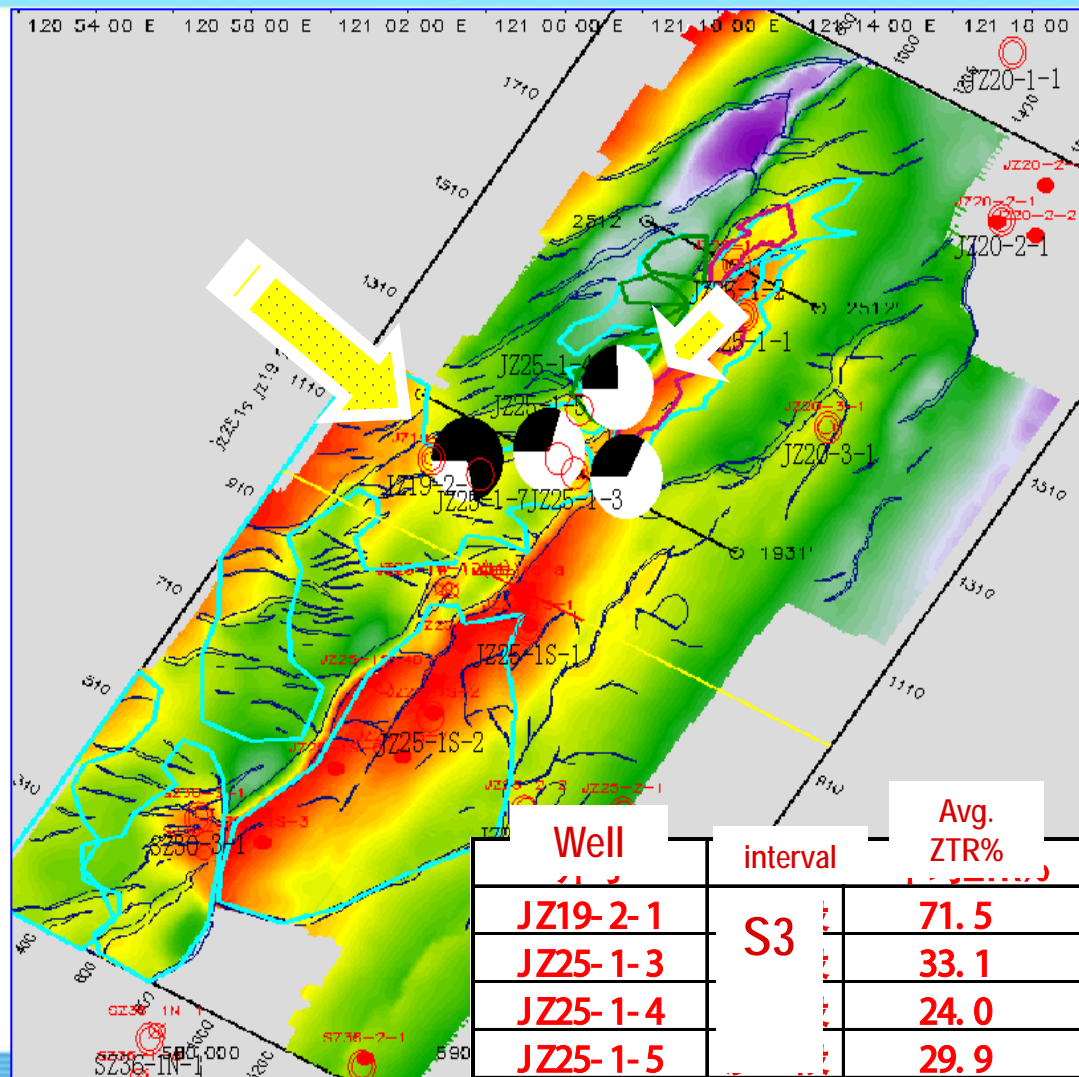
沙三段ZTR指数分布图



Avg. 71.5%

Avg. 31.1%

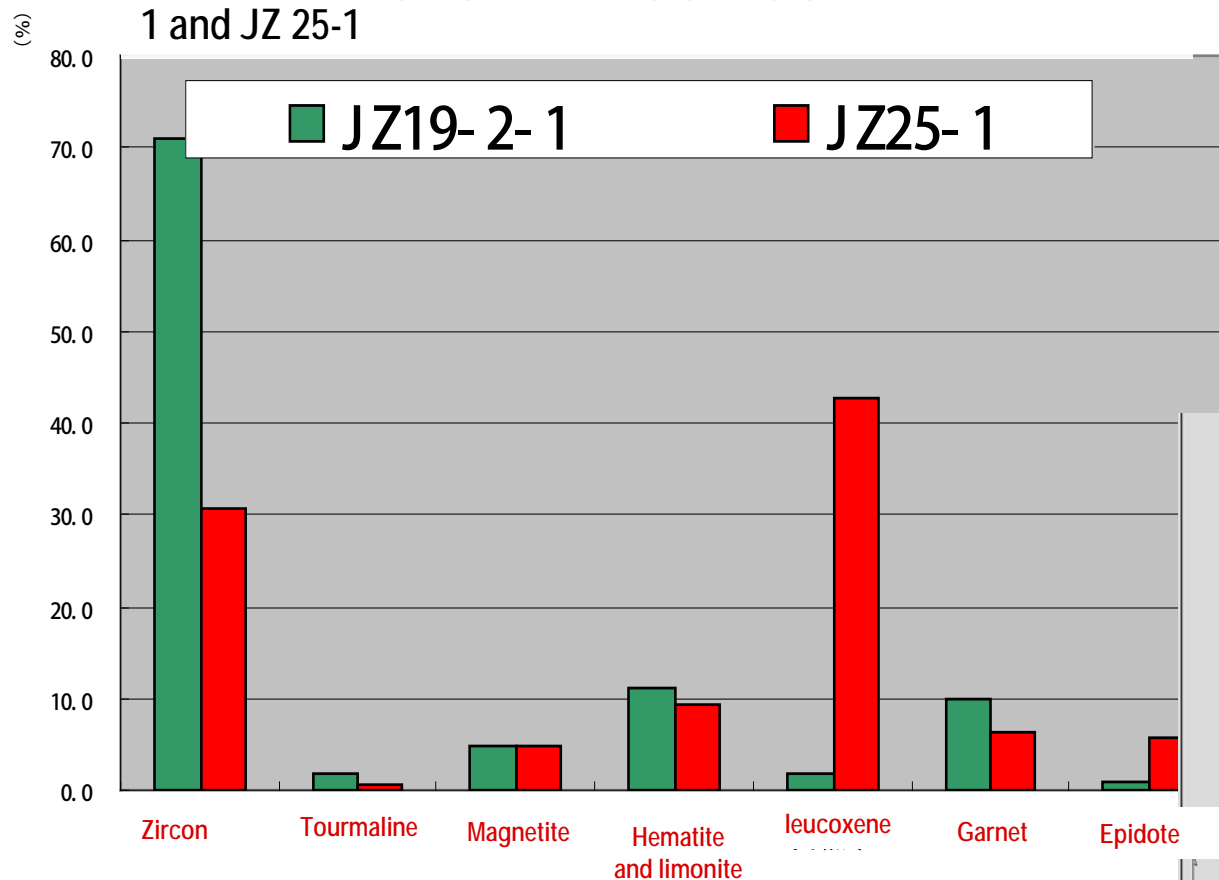
Z—zircon, T—tourmaline, R—rotite



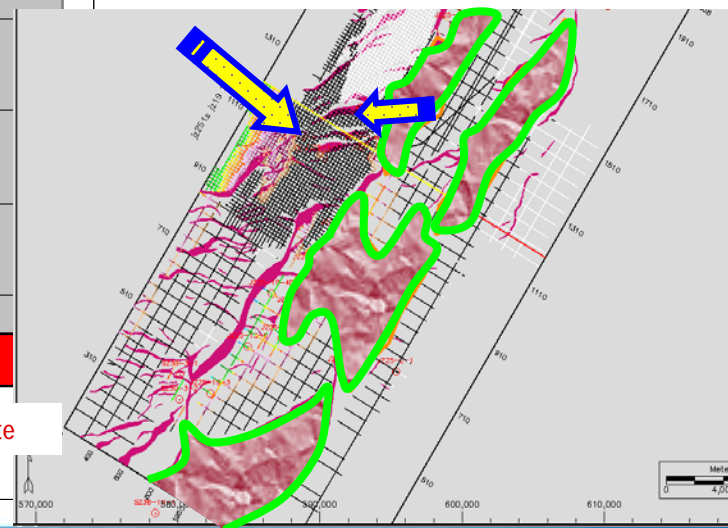


Evidence 2: Heavy Mineral Difference Indicates Multiple Source Suppliers

Comparison of Heavy minerals contents between well JZ 19-2-1 and JZ 25-1

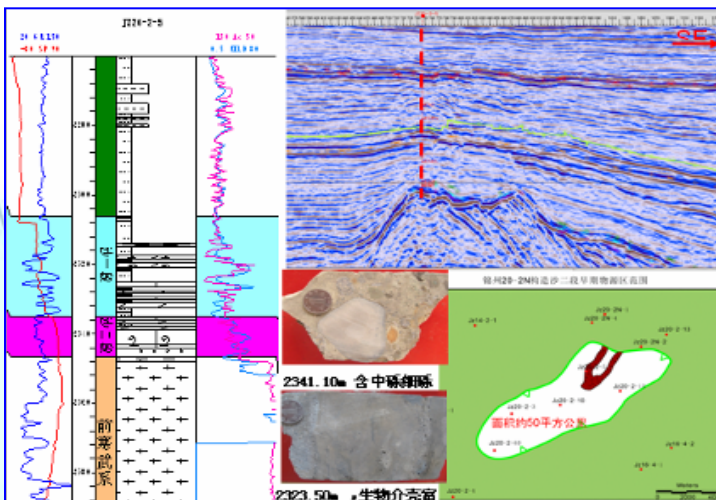
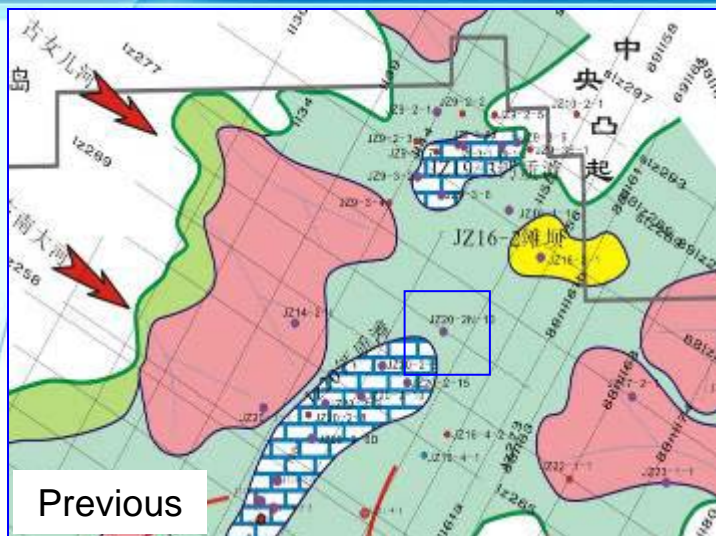


The third member of Shahejie Fm in JZ 19 and JZ 25 areas have Significant difference in heavy mineral contents, indicates the sediments sourced from different regions.

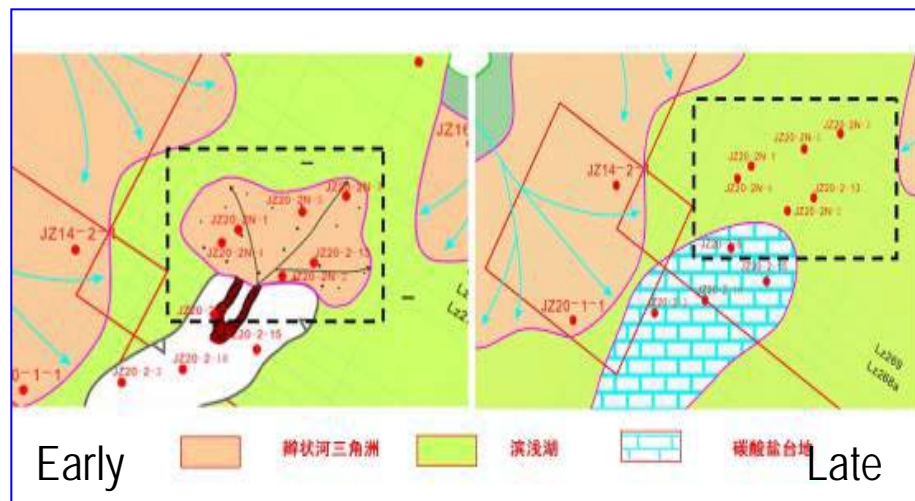




Dynamic Source Concept Continuously Proved By Drilling



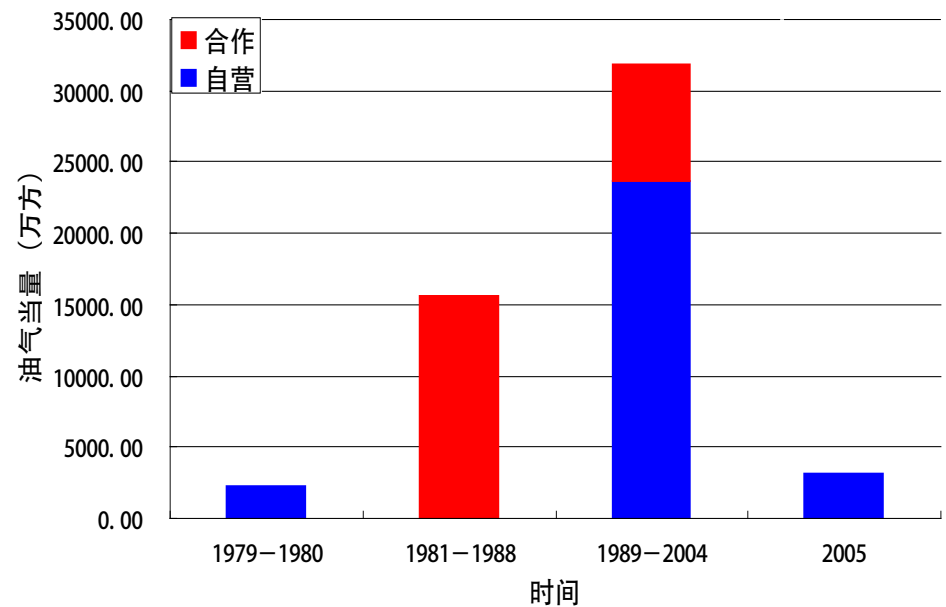
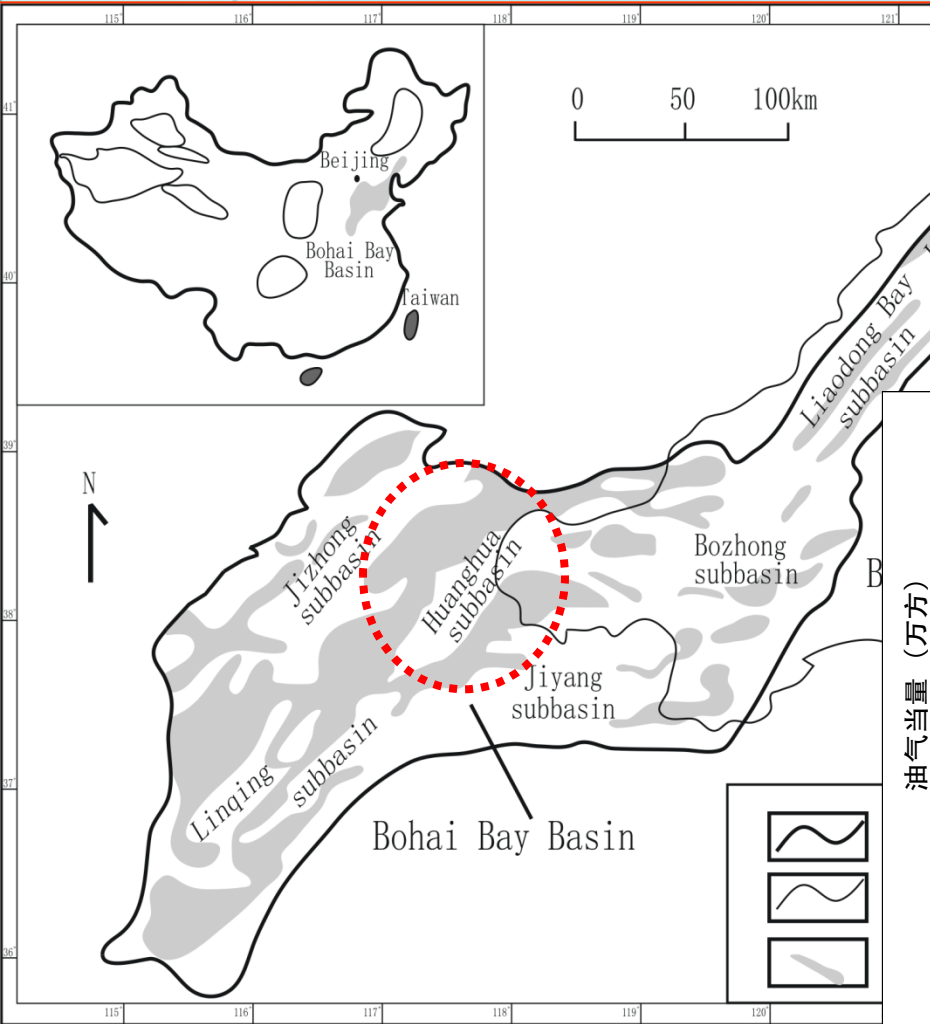
The LST reservoir prediction of the third member of Shahejie Fm in JZ 20-2N were proved true by drilling.





Huanghekou Area: Extremely Shallow Water Delta

Area is 3000k², and 530 million m³ oil equivalent discovered by over 90 wells through 2005, Main Problem is the discovered fields reservoir is very thin and discontinuous. Does it still have huge potential? Where the potential is?





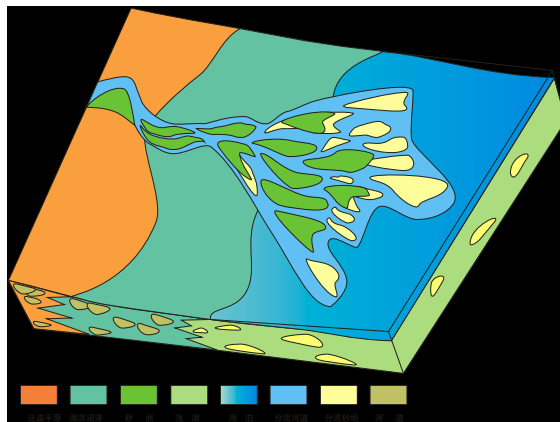
Extremely Shallow Water Delta: High Quality Reservoir Predication

Depositing features of lake shrinking:

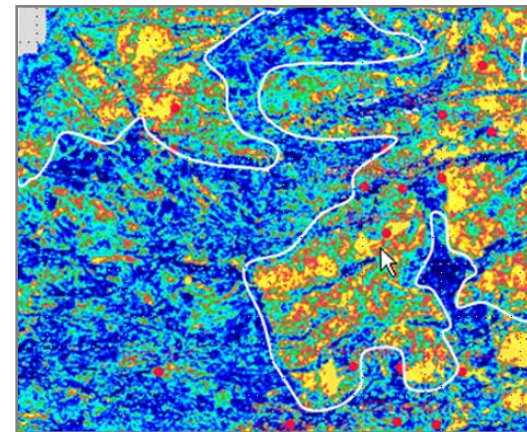
1. Big lake coverage but average water depth less than 9m,
2. Relative stable tectonic setting and a flat fluvial topography (no slope break).
3. High frequent interactions of fluvial and lake.



Modern analogue



Deposition mode



Sand deposition



Poyang Lake: Analogue of Extremely Shallow Delta



Expanding stage



Shrinking stage

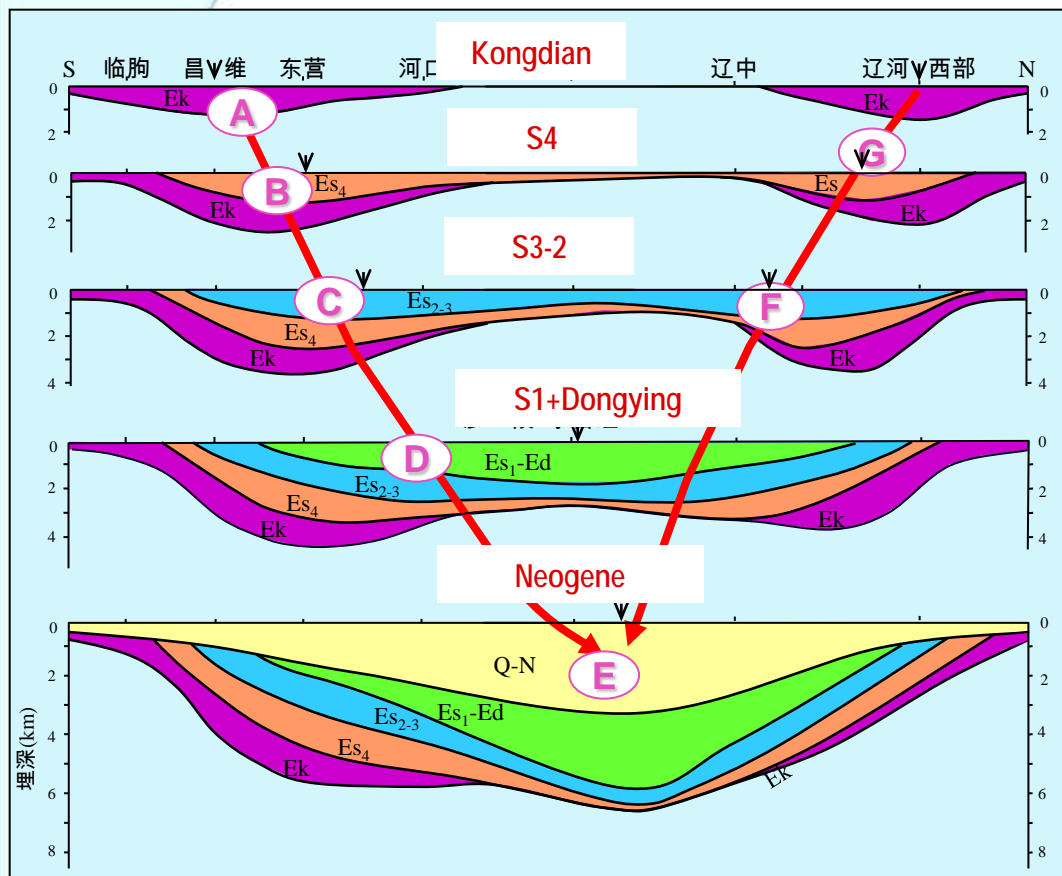
Expanding stage: the delta develop as lobes and clusters, with a wide front, interdistributary deposits occurred between the lobes

Shrinking stage: the delta develop as dendritic, vascular, the levee act as deposition frame, which is 3~4 times wider than the channels.



1. Long Time Lake Environment

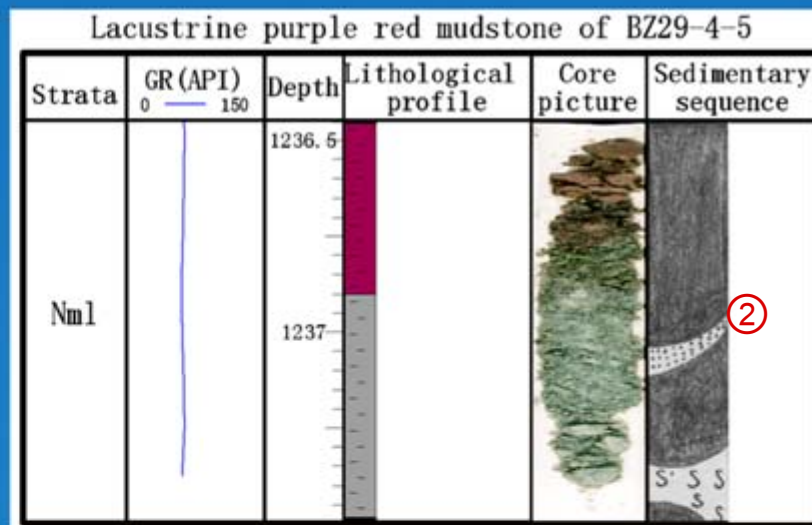
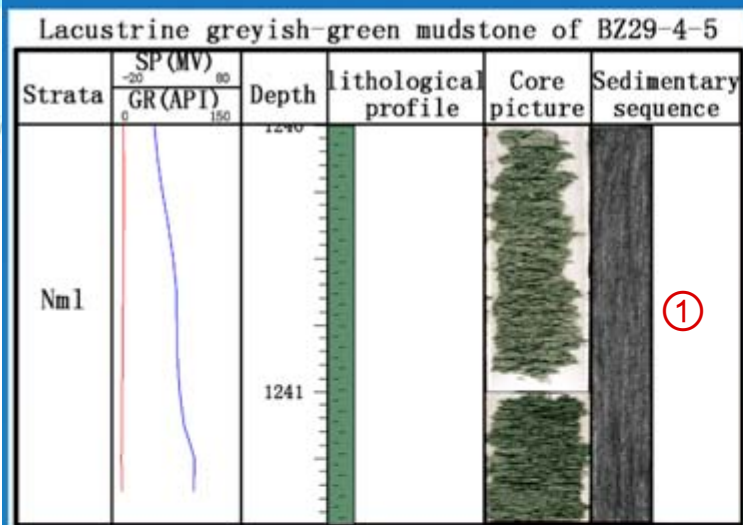
Later Oligocene to Quaternary Bozhong Depression gradually Became Depositing Center



Jiyang▶ Bozhong ◀..... Xialiaohe



2 : Mudstone Color: Lacustrine Environment



①—Light green, greyish green mudstone

②—gray green, purple mudstone

③—Brown mudstone and varicolored soiled mudstone (fluvial)



3. Deposition Structure: Lacustrine Deposition



River Mouth Bar

Rolling bedding

Horizontal bedding

Shallow lacustrine mud



Channel lag-boulder clay

Submerged distributary channel

4. Shallow Water Fossils



BZ29-4-5井, N₂m^L
(1726.8~1727.0m)

(鉴定单位: 南京地质古生物所)

Abundant Shallow water fossils like Bivalve, Gastropod are found in the core.



5. Paleo-water Depth

Modern analogues:
Shallow water
+ large coverage

<div> <div>参 数</div> <div>Lake</div> </div>	Avg. Water depth (m)	Max Water depth (m)	Area (km ²)
Dongting	6.39	23.5	2625
Poyang	8.4	25.1	3283
Huanghekou	6~9	>16	2570
Bozhong			8660



**Dongting
Lake**



**Dongting
Lake**



**Poyang
Lake**

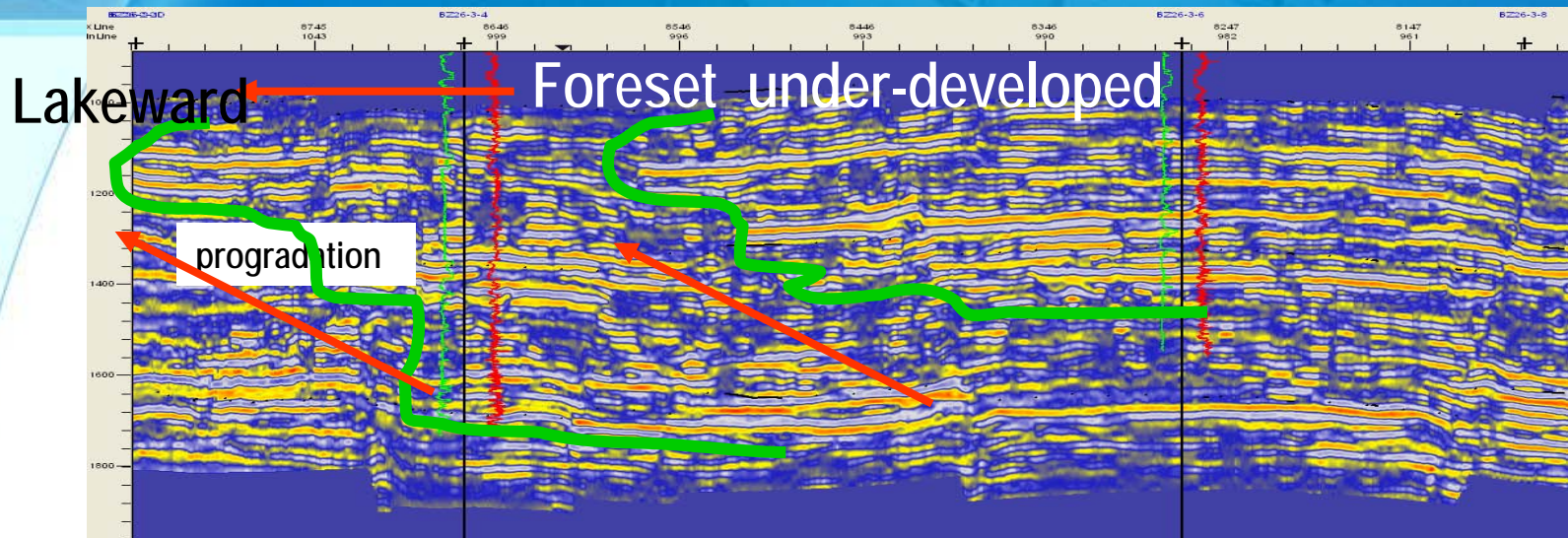


**Poyang
Lake**

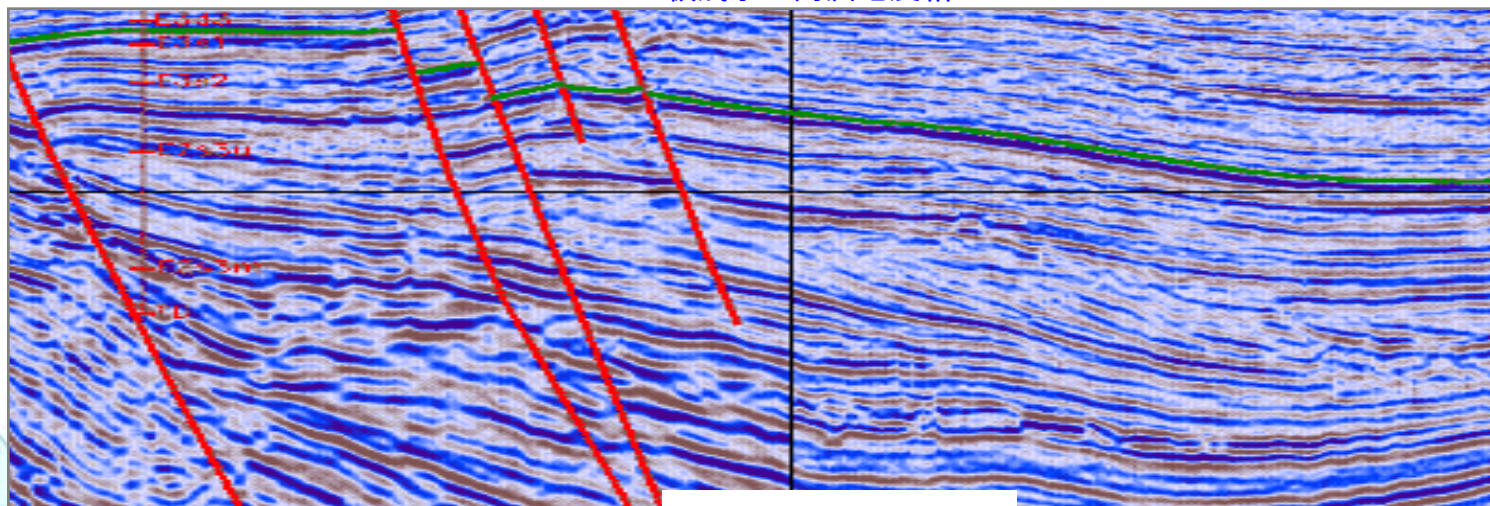




Identification Feature 1: Vertical Sequence



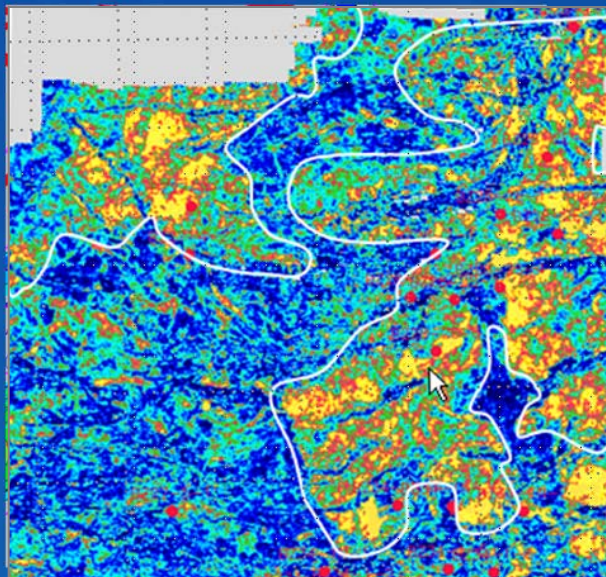
极浅水三角洲地震相



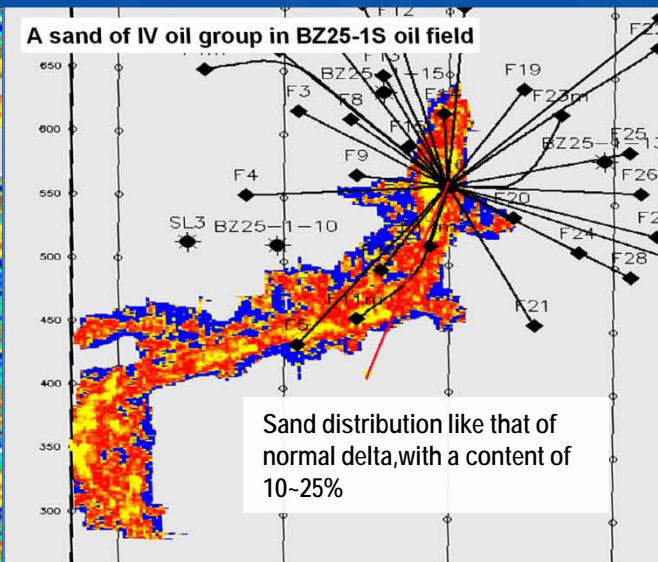
Normal delta



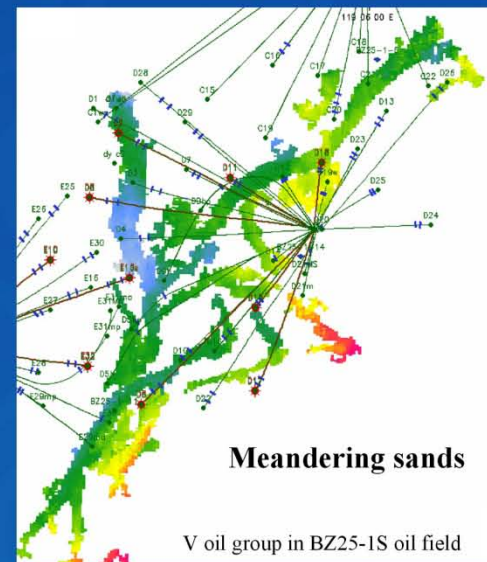
Identification Feature 2: Horizontal Features



Thickness map of the main oil group in BZ25-1S oil field



Some channel like sand configuration



Meandering sand bodies

Shallow water delta front sand
Wave dominated

Shallow water delta front sand
Fluvial dominated

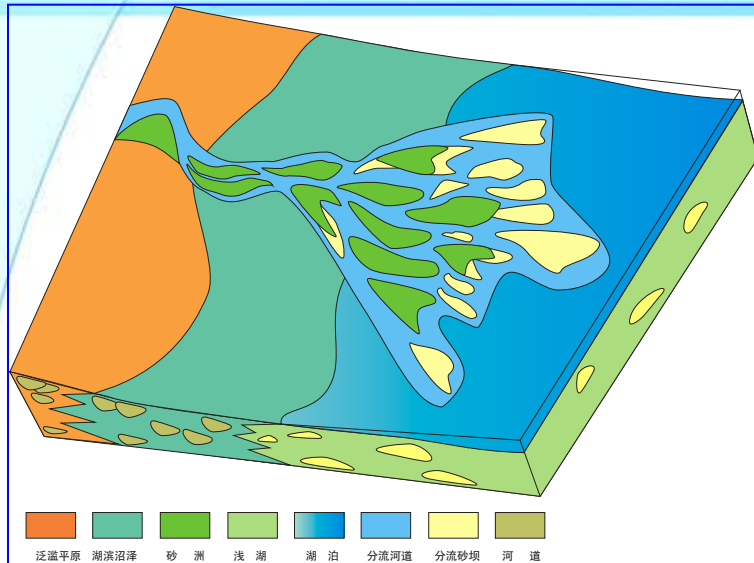
Meandering sands
Fluvial dominated

A/S (accommodation/supply) decreases with fluvial strengthen

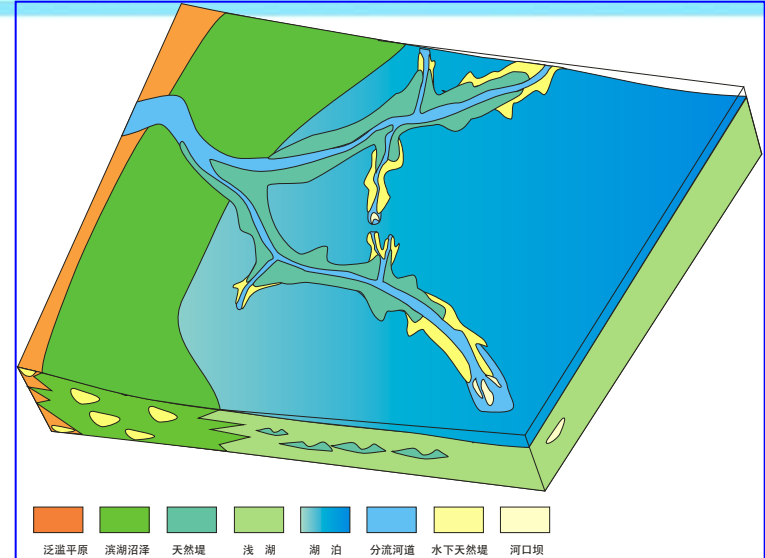




Two Extremely Shallow Delta Models in Bohai Offshore



Mode 1—Sand bar type

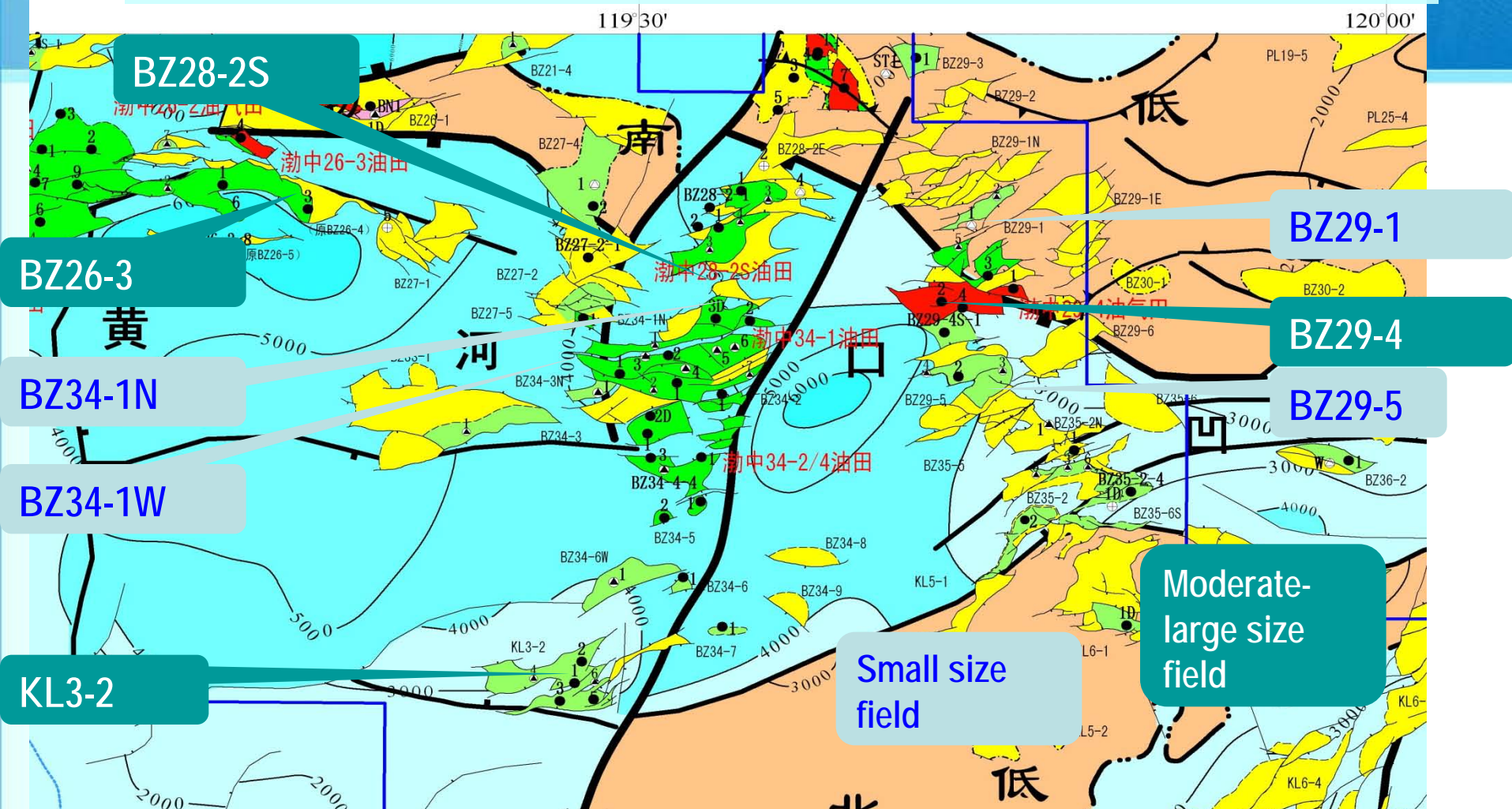


Mode 2—Channel type

- A/S increase with the lake surface rise
- Depositional frame is sand bar, later might be sand spit, with a wide swamp front
- The sand deposited in the distributary channels is very little but has a good connection

- A/S decrease with the lake surface rise
- Depositional frame is natural levee, the thickness of the sand deposited in the distributary channels is thinner than that of the levee
- Submerged distributary channels long and narrow developed.

Discoveries of the Past 5 years Using Shallow Delta Model in Huanghekou Area



Four moderate-large fields and many small fields, about 290 million m³ oil equivalent, have been discovered in the past 5 year under the instruction of geological model



Conclusions

- ✧ Instructed under Improved geological understandings, 5 light oil fields groups, each over 100 million tons, have been discovered in the past 5 years. 85% of the newly reserves is light oil, similar to the heavy oil proportion before 2005.
- ✧ Sand deposition is controlled by the joint working of four factors: the Source-Gully-Slope-Level. Effective sources include obvious and unobvious sediments source, and the latter is very important for identifying effective sand from a lean sand setting.
- ✧ Extremely shallow water delta deposits during lake shrinking. Two type of models are identified. For the sand bar type, sand deposited in the distributary channels is very little in content but has a good connection. Four moderate-large fields and a number of small fields, about 290 million m³ oil equivalent, have been discovered in the past 5 year with the instruction of shallow water delta model.