Improvements in the Geological Understanding and Exploration Technology on Lithological Traps in China*

By
Wenzhi Z. Zhao[1], Chengzao Z. Jia[2], and Caineng N. Zou[1]

Search and Discovery Article #10154 (2008)
Posted October 7, 2008

*Adapted from oral presentation AAPG Convention, San Antonio, TX, April 20-23, 2008

[1]PetroChina Research Institute of Petroleum Exploration and Development, Beijing, China. (zwz@petrochina.com.cn)
[2]PetroChina Company Limited, Beijing, China.

Abstract

The recent petroleum exploration strategy in China is characterized by a paradigm shift from structural traps to stratigraphic traps. Favorable geological conditions for forming large-scale stratigraphic traps exist in many Chinese sedimentary basins. Significant variations in lithology appear to be the norm in nonmarine basins and so are gentle structures in small marine cratonic basins. As almost 60% of the remaining petroleum resources in China occur in stratigraphic traps, they have become the focus of current and future exploration activities.

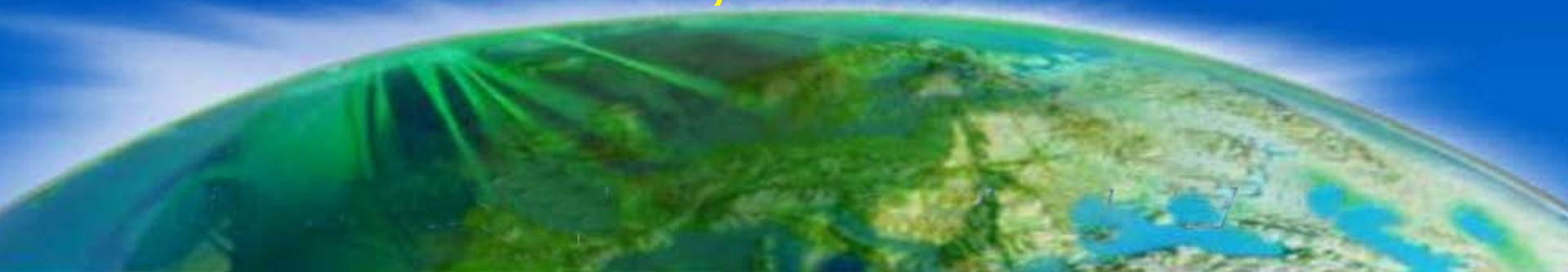
Basic geological controls for the development of stratigraphic traps include six lines (pinch out, onlap, erosion, change in lithology, variation in fluid properties and structural contours) and four surfaces (fault planes, unconformity, flooding surface and over-/underlying beds). Large variation in the distribution of stratigraphic traps has been found in four different types of basins (rift, depression, foreland and craton), leading to 14 different stratigraphic play types. Detailed study of the trap elements, structure-sequence combinations and reservoir filling mechanisms is vital to the future petroleum exploration in China. This presentation reviews the recent advances in the geological theory and exploration practices related to stratigraphic traps in China.

中国石油

Improvements in the Geological Understanding & Exploration Technology on Lithological Traps in China

W.Z. ZHAO, C.Z. JIA and C.N. ZOU

RIPED, PetroChina

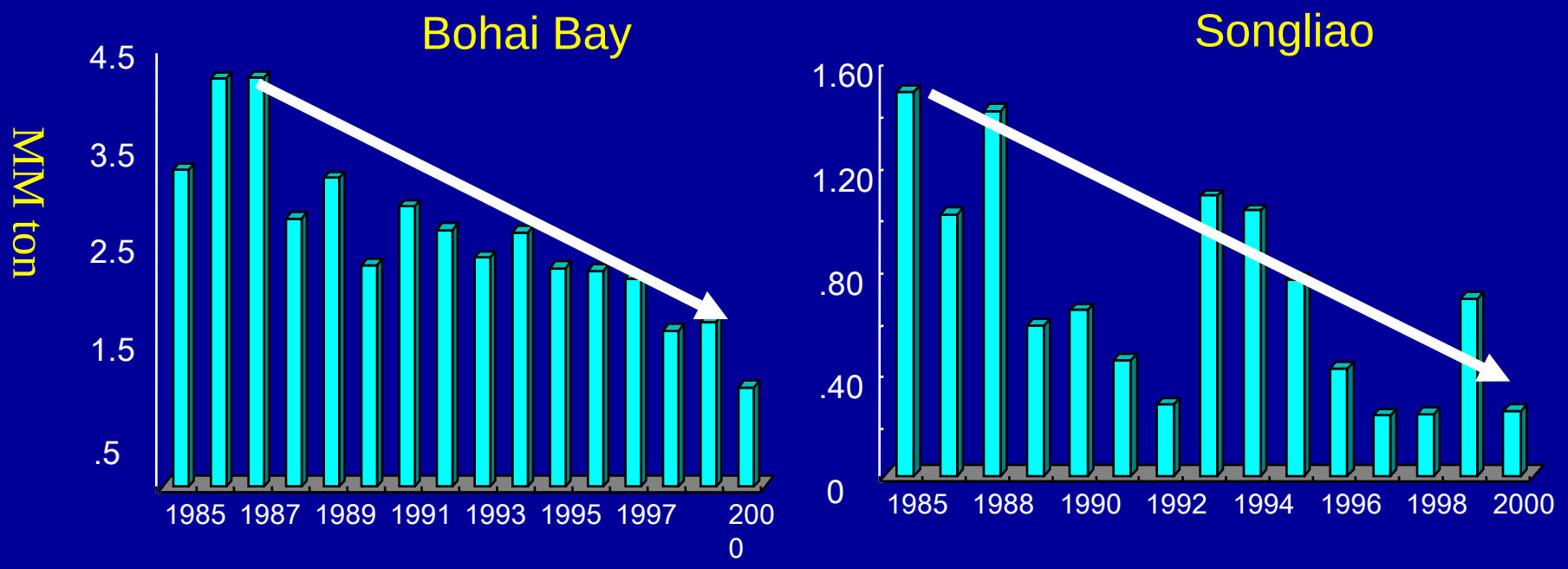


Outline

- Background
- Improvements in the Geological Understanding & Expl Technology
- Conclusions

1. Project Rationale

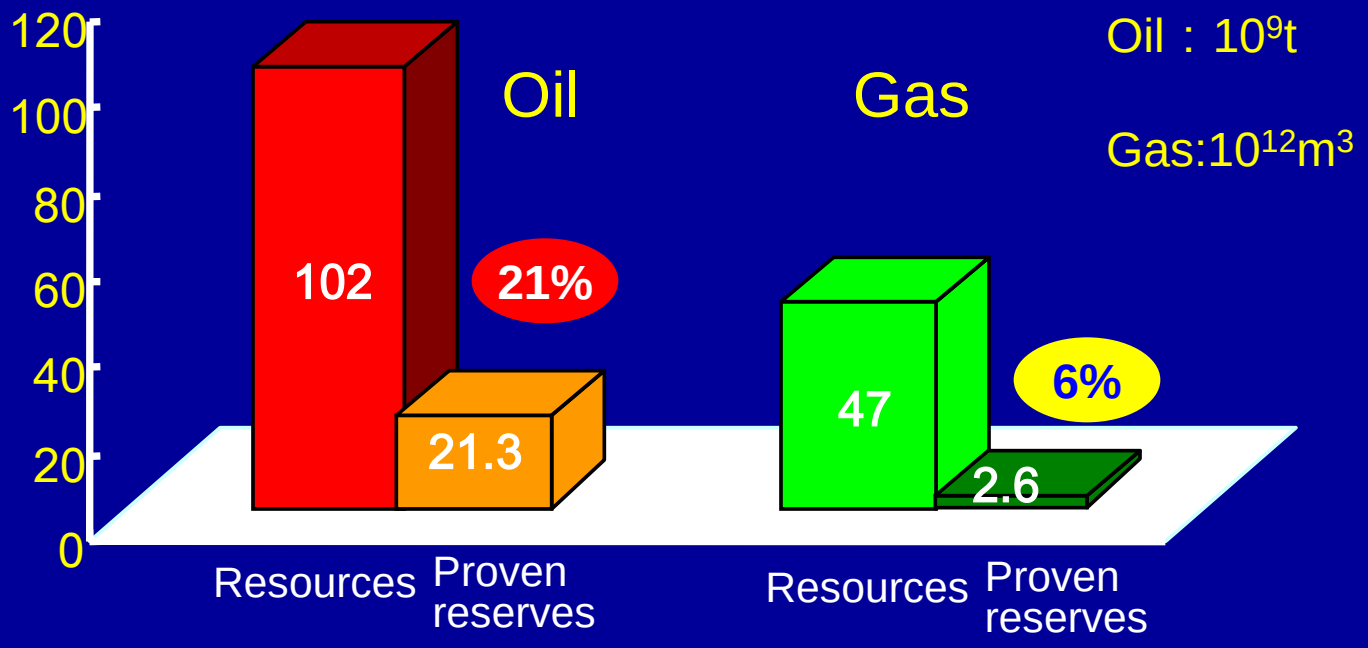
(1) Increasing difficulties of exploration in structure-type reservoirs



Trap-scale trend for single reservoirs in eastern region of China

1. Project Rationale

(2) Low rate of resources to reserves, new frontiers needed

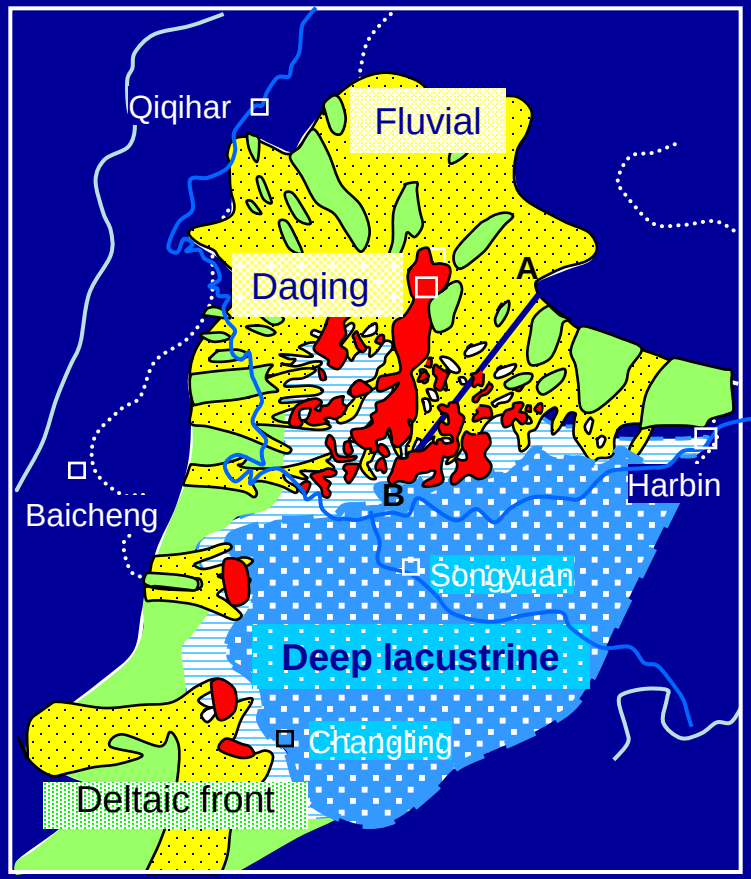


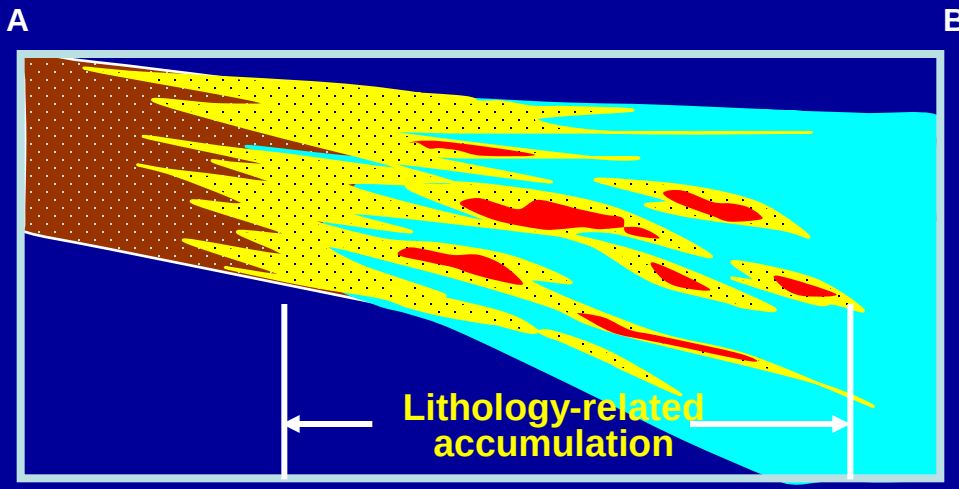
Oil/gas resources and reserves in China by the end of 2000

1. Project Rationale

- **Nonmarine Case**

(3) Favorable geological conditions for lithological traps





Lithological trap play

Facies map in the Songliao basin

1. Project Rationale

(4) Remaining Resources Potential

Plays	Recoverable oil (10^9 t)				Recoverable gas (TCM)			
	Total	Proved	Remains	Proportion (%)	Total	Proved	Remains	Proportion (%)
Litho-stratigraphic	7.56	1.68	5.87	41	3.62	0.94	2.68	14
Mature basin	6.3	3.4	2.89	20	1.29	0.28	1.01	5
Foreland	3.36	1.06	2.3	16	8.19	0.65	7.55	40
Deep seated & superimposed	2.71	0.31	2.39	17	6.89	0.62	6.28	33
Others	1.29	0.44	0.84	6	2.04	0.64	1.40	7
Total	21.2	6.9	14.3	100	22.03	3.11	18.92	100

Distribution of Undiscovered Resources in China

Outline

- Background
- Improvements in the Geological Understanding & Expl Technology
- Conclusions

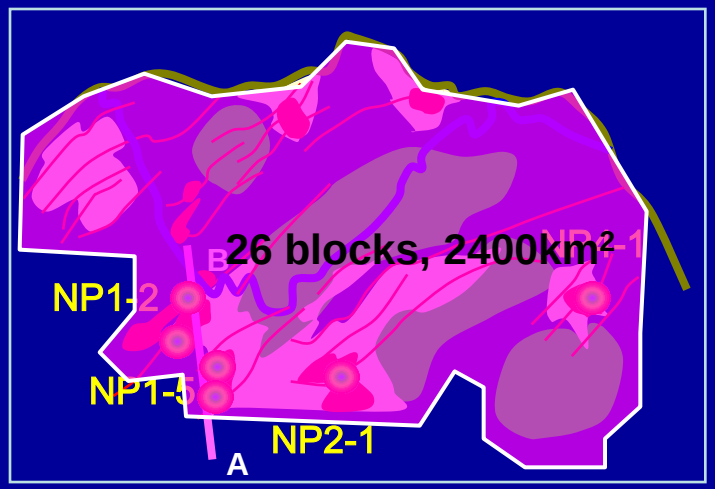
2. What Have We Done?

(1) Exploration procedure for lithological traps

- Optimal selection of oil/gas-rich sags
- Sag-wide 3-D seismic and integrated process & interpretation
- Construction of sedimentary facies maps within isochronal stratigraphic framework
- Reservoir description on play scale
- Lithological traps description & assessment
- 3-D Exploration within multi-formations and targets

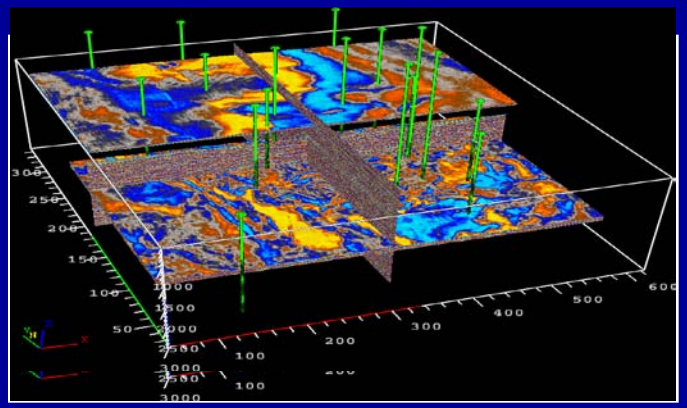
2. What Have We Done ?

● **Case :** Jidong Oil Field



① Optimal selection of oil/gas rich sags

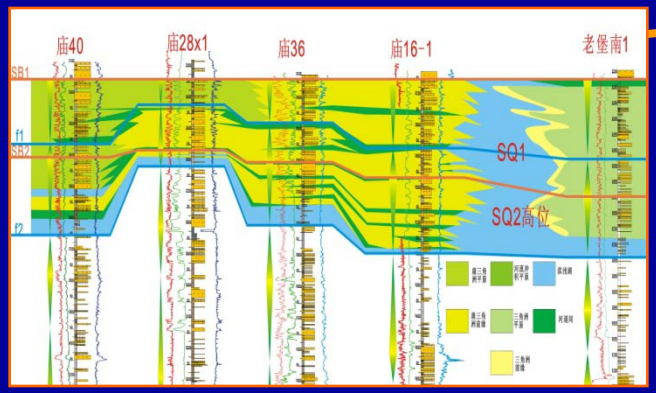
② Sag-wide 3D seismic and integrated interpretation



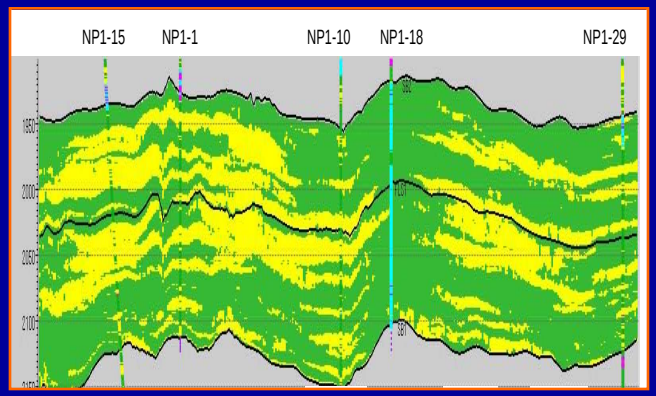
2. What Have We Done ?

● **Case :** Jidong Oil Field

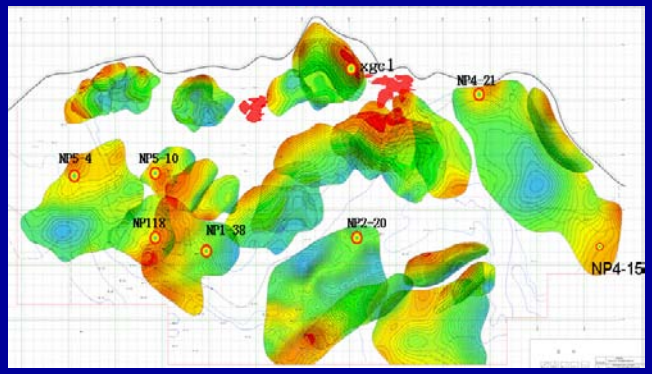
③ Depositional environment reconstruction



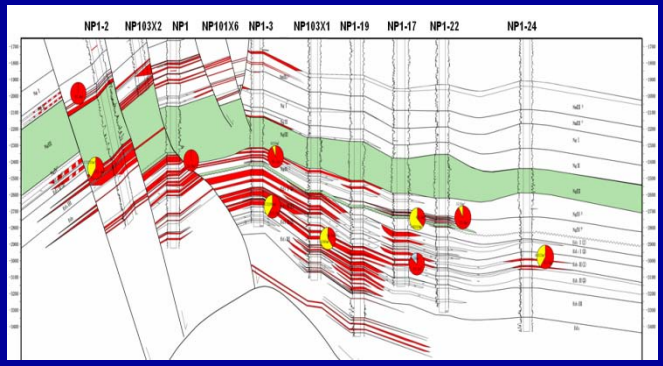
④ Reservoir description



⑤Lithological trap assessment



⑥ 3D expl on Multi-fms and targets



2. What Have We Done ?

(2) Distribution patterns of lithological traps in four types of sedimentary basin

- Major systems tracts

Nonmarine rift	●Steep slope: LST-TST—alluvial fan—fan delta—turbidite fan ●Gentle slope: LST-TST—braided delta—tubidite fan
Nonmarine depression	●Brachyaxis: LST-TST-HST—braided delta (main facies) ●Macroaxis: LST-TST-HST—large-scale fluvial delta
Nonmarine foreland	●Thrust side: LST-TST—alluvial fan—fan delta ●Slope side: TST—braided delta
Marine craton	●Platform margin: TST—rimmed reef & bank complex ●Inner platform: TST—patchy or blocky reef & shoal & dolomite

2. What Have We Done ?

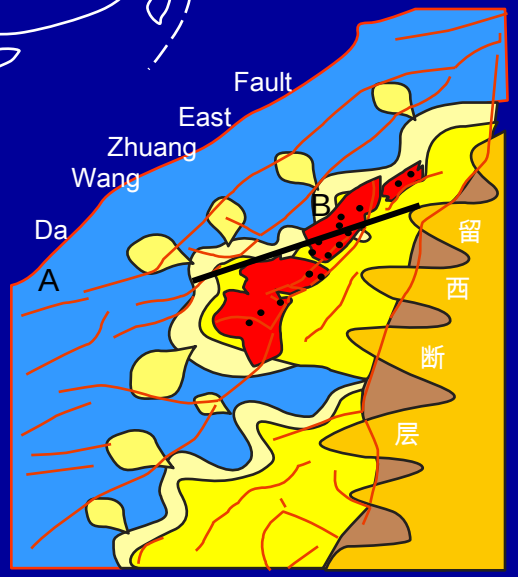
(2) Distribution patterns of lithological traps in four types of sedimentary basin

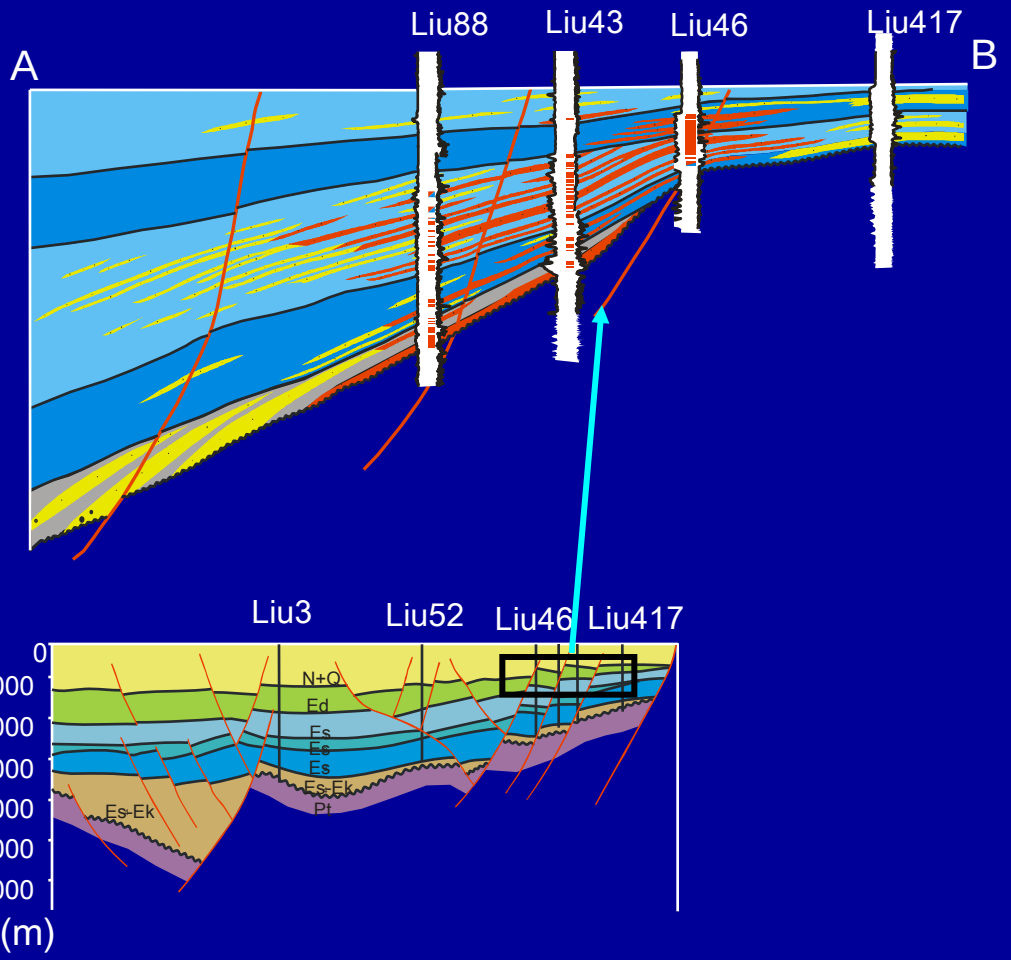
- 14 kinds of lithological HC plays

Nonmarine rift	1、Steep fault-step—TST-HST, fan delta-turbidite fan 2、Gentle fault-steps—TST, sand updip pinchout in fluvial delta 3、Deep fault sag—TST-HST, volcanic explosive & overflow 4、Central high flank—HST, sand updip pinchout in fluvial delta
Nonmarine depression	5、Brachyaxis gentle—HST, lentic sands in braided delta 6、Brachyaxis steep—HST, sand updip pinchout in braided delta 7、Macroaxis gentle—TST-LST, fluvial delta
Nonmarine foreland	8、 Brachyaxis steep—LST, sand updip pinchout in alluvial fan-fan delta 9、 Brachyaxis gentle—TST, sand updip pinchout in braided delta
Marine craton	10、Platform margin—TST, carbonate reef and shoal complex 11、Inner platform—TST, carbonate grainy shaols 12、Inner platform—TST, coastal sandbody 13、Inner platform —HST, extensive fluvial delta in marine (diagenetic) 14、Regional unconformity of weathering crust

2. What Have We Done?

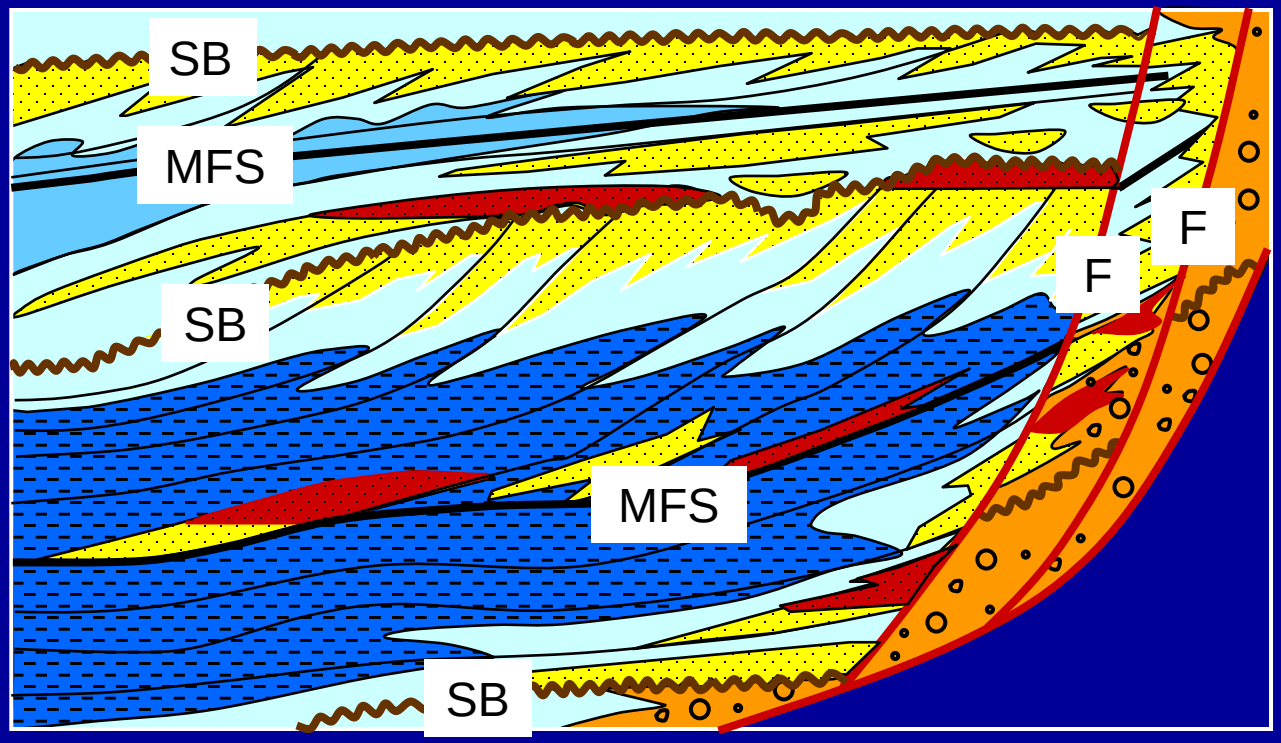
- Case from Raoyang depression: Steep slope—TST-HST braided delta





2. What Have We Done ?

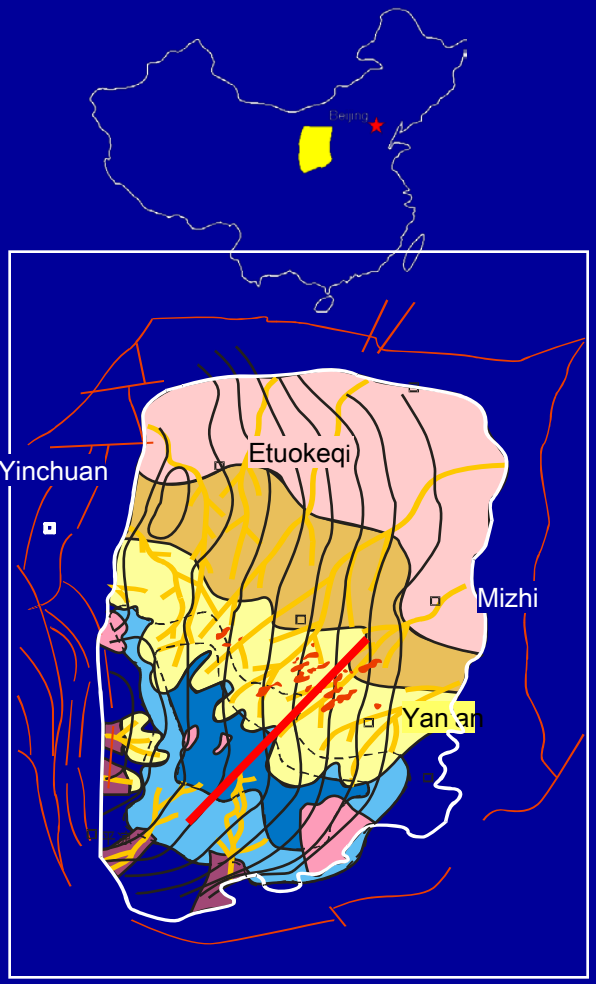
(3) **Geological** controls on formation of lithological traps

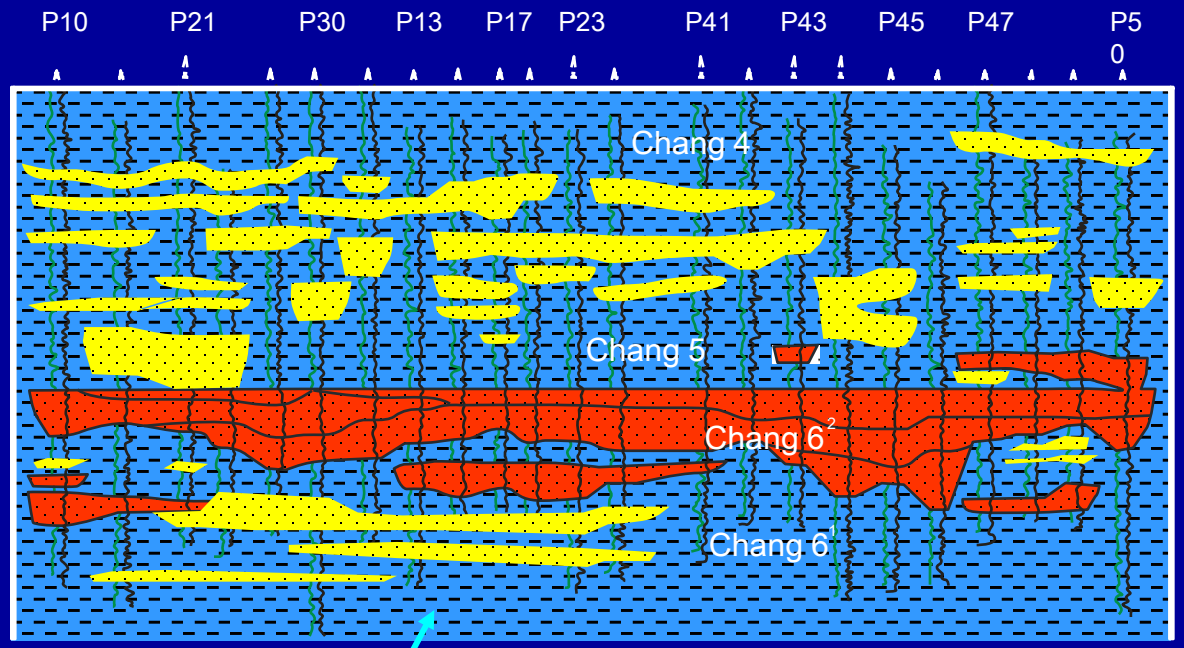


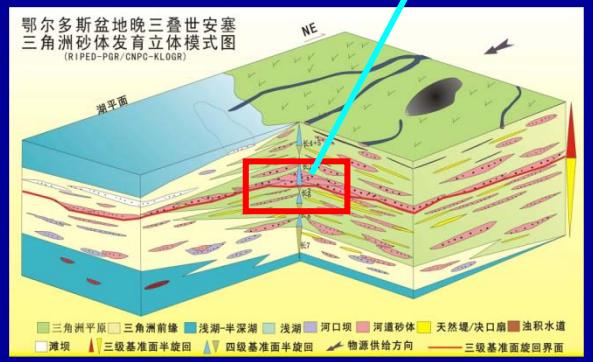
Three interfaces control the distribution of major lithological traps

2. What Have We Done ?

- Case from Ordos basin: Unconformity control





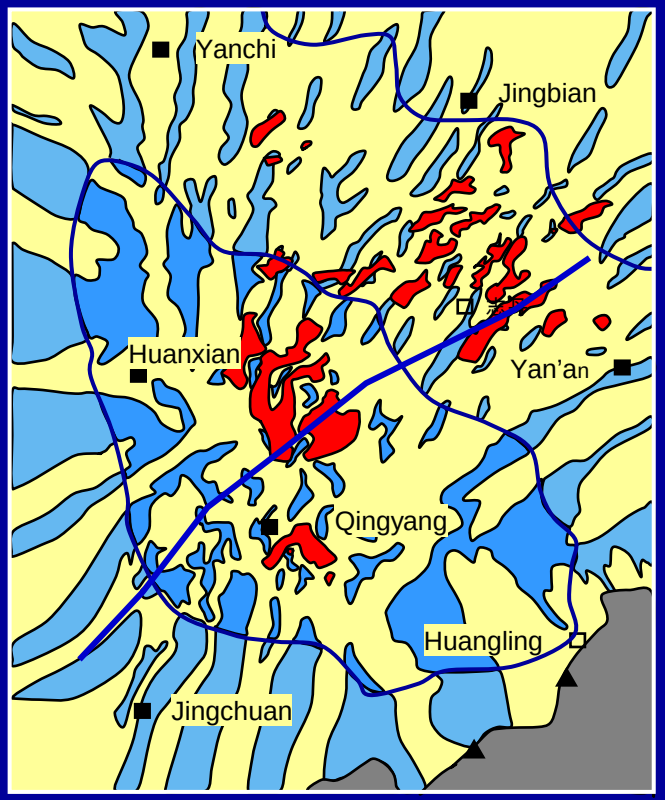


Chang 6: Proven reserve 0.76 Bt, about 45% of the basin's total

2. What Have We Done ?

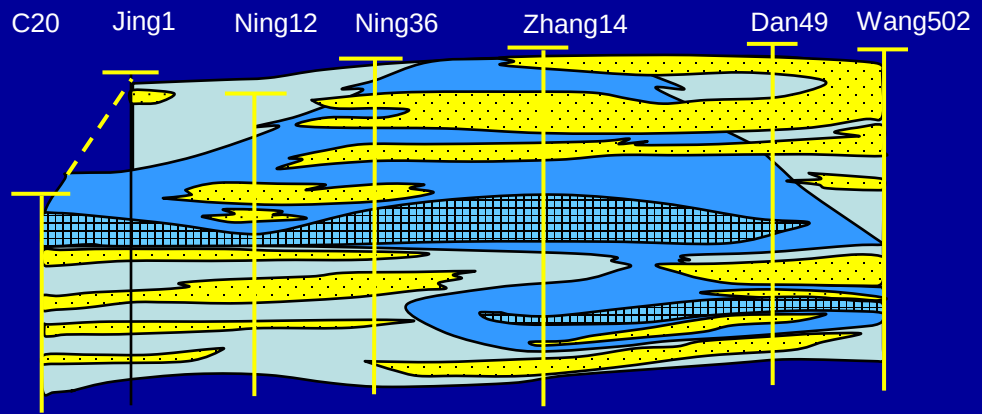
(4) Mechanism for the formation of low-medium abundance gas accumulation with large area

- "Sandwich" architecture: sandstone & source rock



Chang-6 Sandstone distribution,

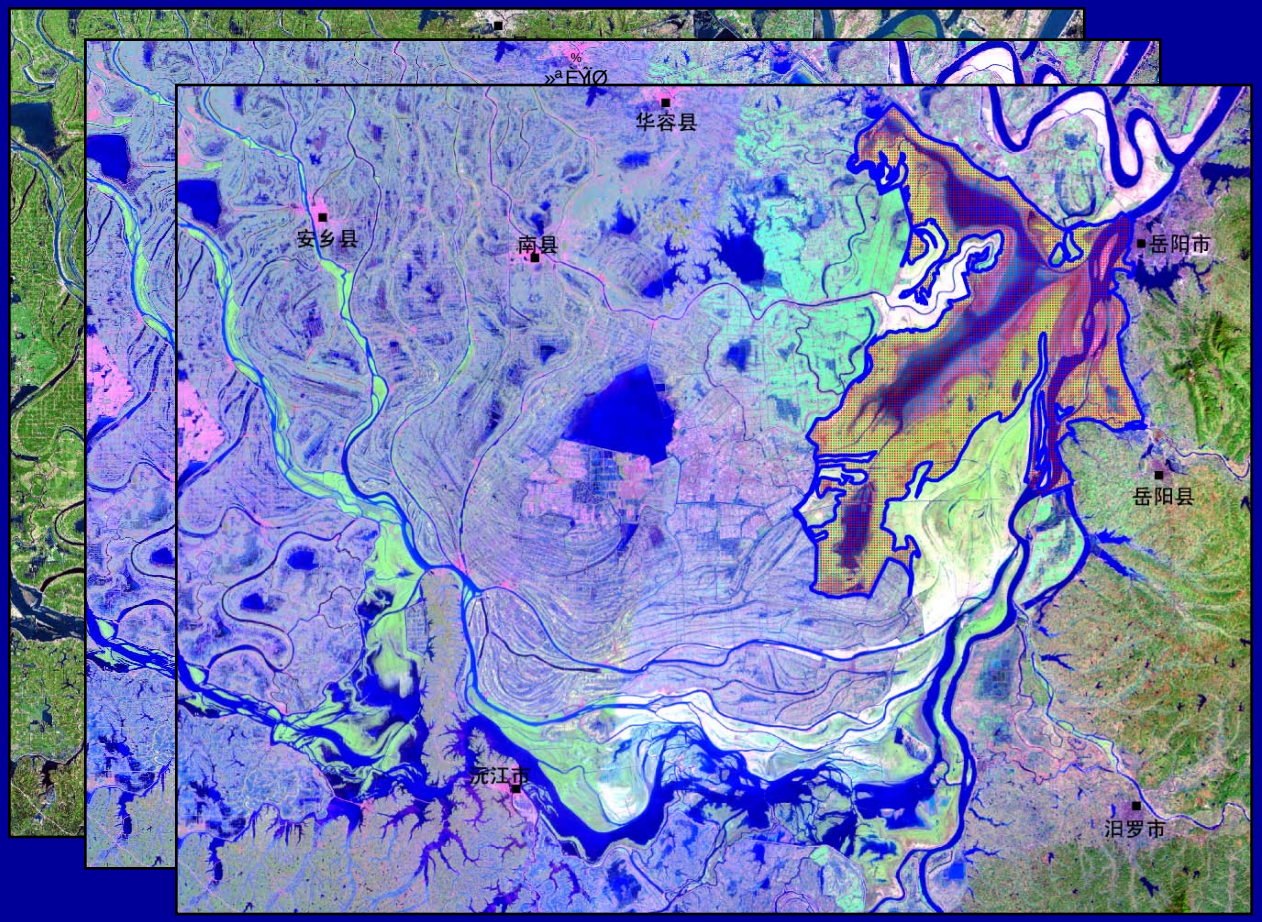
T3y, Ordos basin



Facies section, Well C20 - Wang502-C6 - C9

2. What Have We Done ?

- Case: Observation on present-day deposition



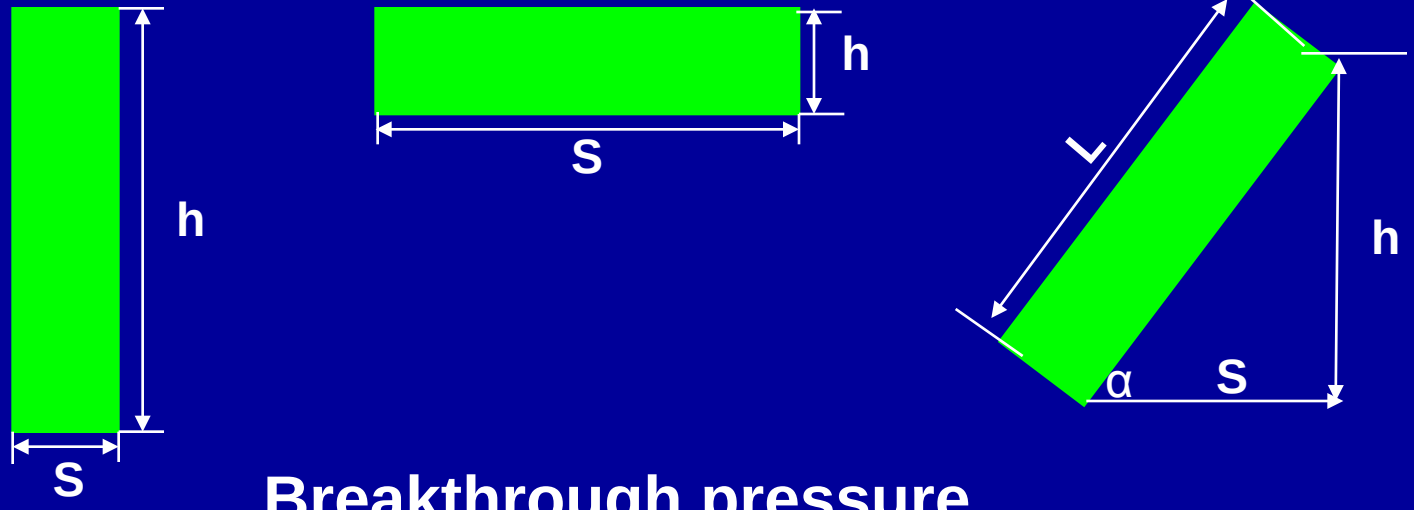
Lake water-area variation of flooding and dry seasons in the Lake Dongting

2. What Have We Done ?

(4) Mechanism for the formation of low-medium abundance gas accumulation with large area

- Low oil/gas column and formation pressure decrease threshold for reservoir formation

Mechanism Model

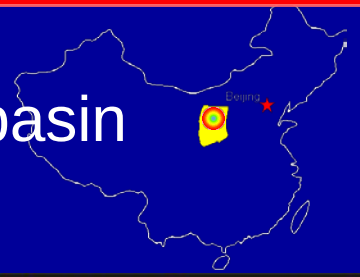


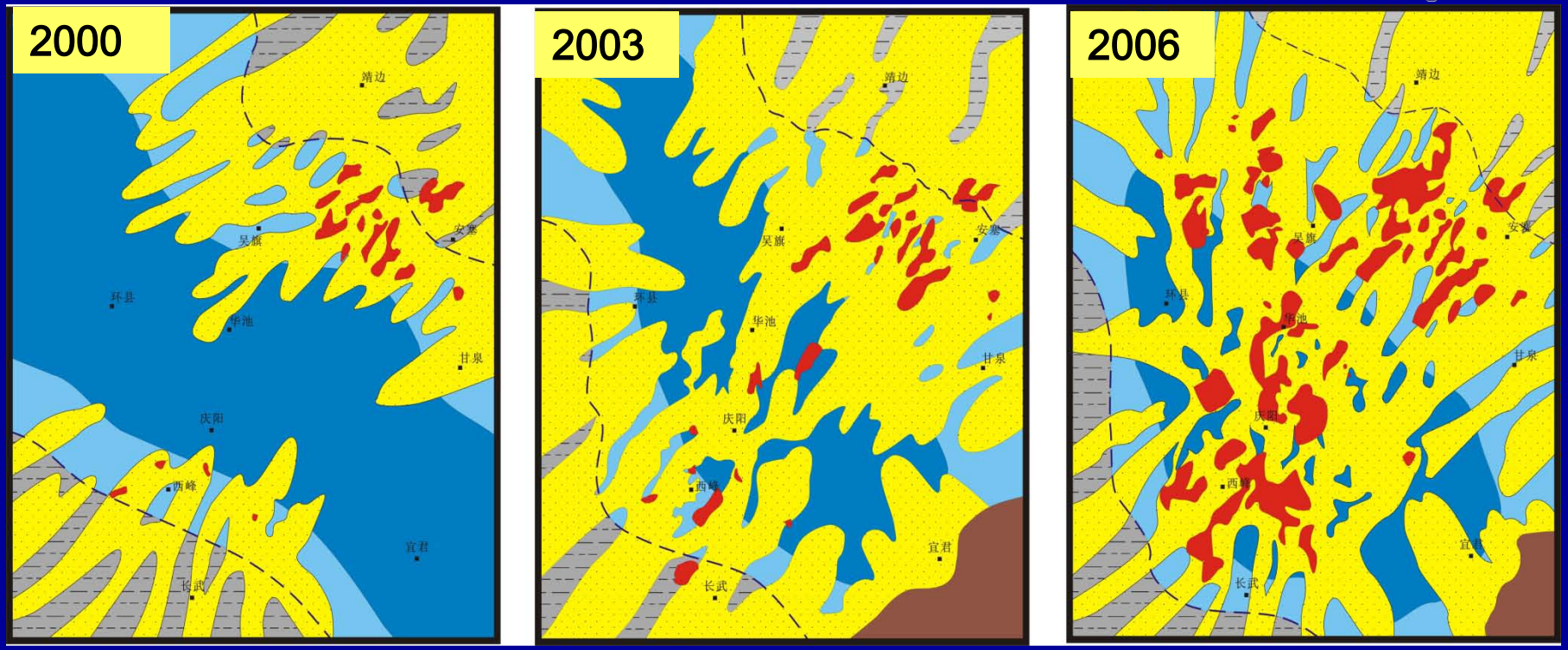
Breakthrough pressure

$$P=L(\rho_w-\rho_{o/g}).g.\sin\alpha$$

2. What Have We Done ?

- Case: discoveries in the synclinal region, Ordos basin





New reserves increased by 460 million tons in 2003-2006

2. What Have We Done ?

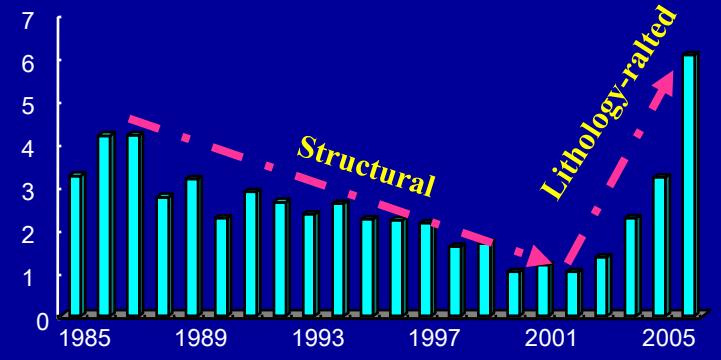
- Exploration Results

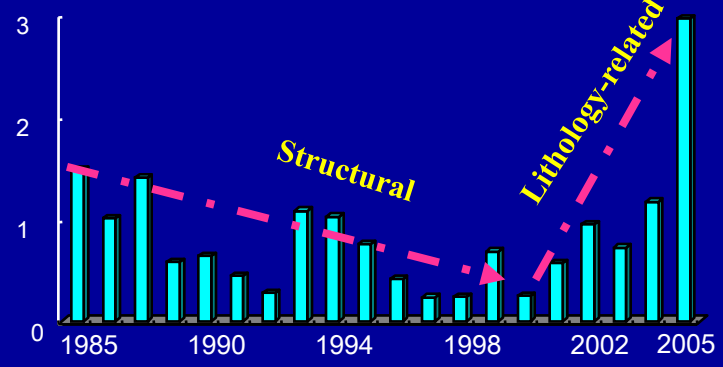
Bohai Bay

Songliao

Rewerve size per unit

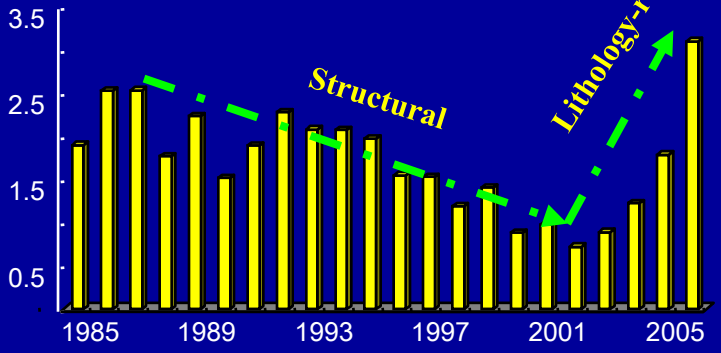
Million ton

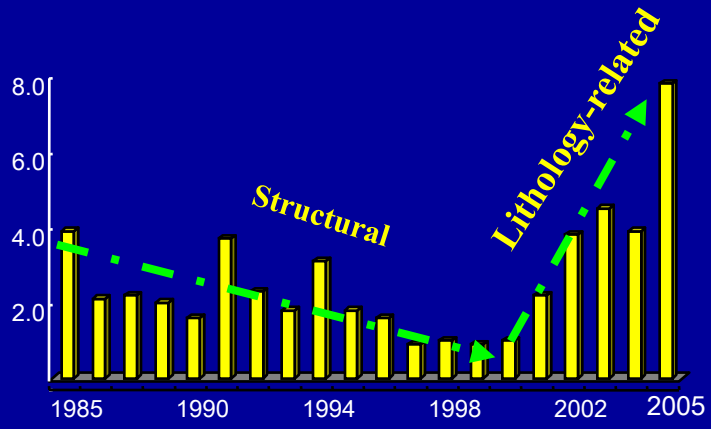




Trap Size

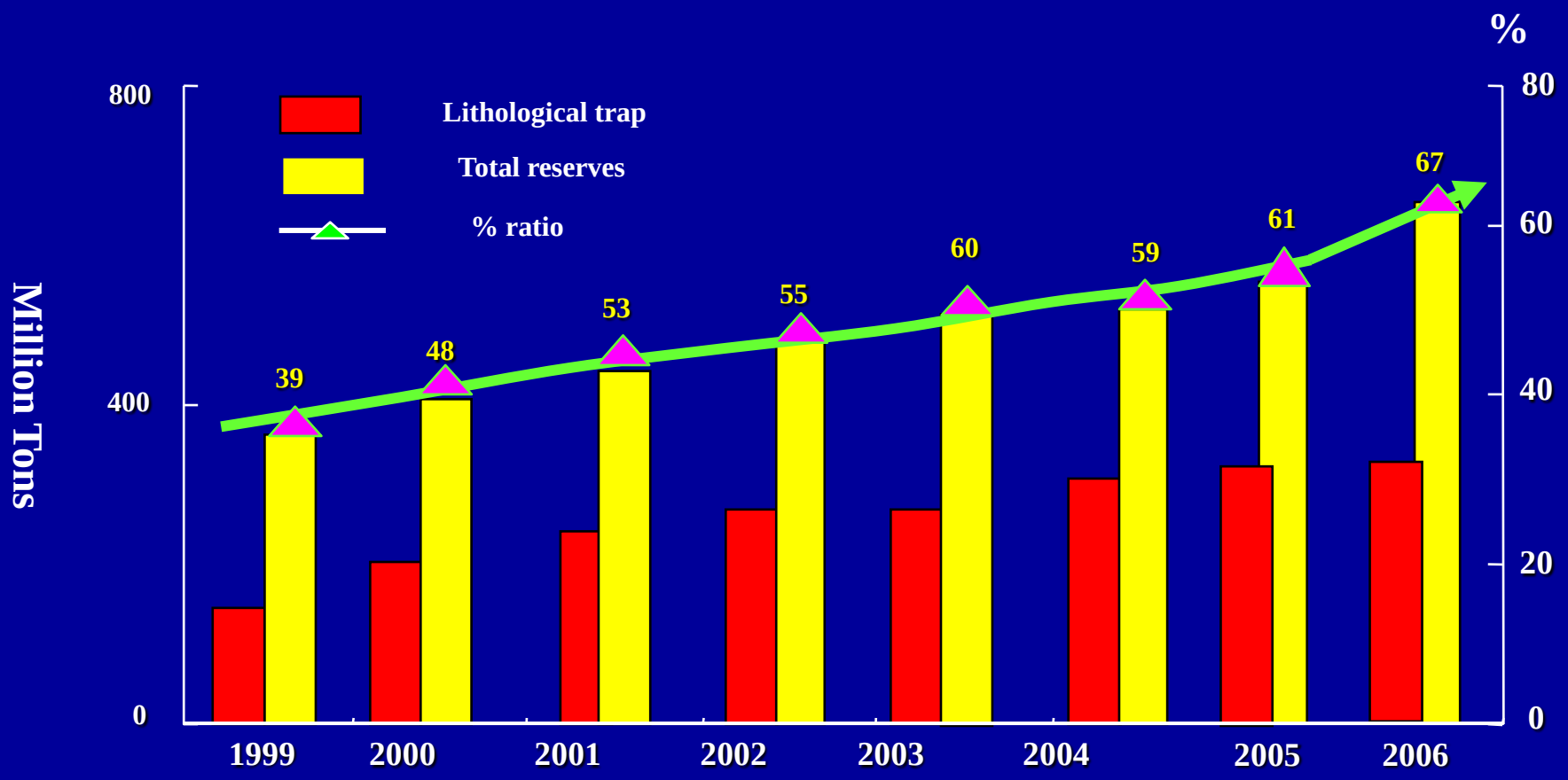
km^2





2. What Have We Done?

- Exploration Results



Proven reserves in lithological traps, PetroChina

Outline

- Background
- Improvements in the Geological Understanding & Expl Technology
- Conclusions

Conclusions

- Recent exploration success in lithological traps helped China maintain a high rate of reserve growth. With abundant remaining resource, lithological traps have highest potential in reserve growth, and the growth can be maintained at least 10 years

Conclusions

- Advances in new concept-driven expl procedure and technology played a key role in commercial exploration and discoveries in large scale lithological traps, which were made by chance a decade ago. Today, the lithological traps contribute to about 2/3 of China's total proved reserves.

Conclusion

- The currently targeted lithological traps in China have self contained source and reservoir combinations. A large number of secondary lithological and stratigaphic traps are dominant in central-western China. Once technology breakthrough is made in future, great discoveries are inevitable.

For further information, please contact:

Dr. Zhao Wenzhi, PetroChina

E-mail: zwz@petrochina.com.cn

Thank you !