

# **Comparison Between Marine Shales and Lacustrine Shales in China\***

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## **Abstract**

The thorough study of Pre-Cambrian to Quaternary shales in China indicates marine shales have tremendous shale gas potential and lacustrine shales in China have huge both shale oil and shale gas potential. Thick prospective marine shales were widely deposited during sea level rise period in the shelf to basinal settings in the Yangtze platform region including Sichuan Basin and Tarim Basin from Pre-Cambrian Sinian to Silurian. Potential lacustrine shales were mainly developed in pro-delta setting of many basins scattered in China during basin rifting or post-rift high lake level period since late Permian. Both these marine and lacustrine shales are proven source rocks with high TOC (usually >2%). In terms of mineralogy, the quartz rich marine shales in China are remarkably alike Barnett shale, the lacustrine shales have higher clay mineral content and many contain swelling smectite and I/S mix layers when comparing with marine shales. As for the porosity and permeability, micro-pores and intra-organic nano-pores were observed from both marine and lacustrine shales, it seems the marine shale reservoir is tighter even marine shales have more intra-organic pores than lacustrine ones. All the organic rich marine shales e.g. Cambrian to Silurian shales in Sichuan Basin in China are in dry gas window and are emerging thermogenic shale gas plays. The Mesozoic lacustrine shales with high TOC and medium Ro (wet gas window) can be thermogenic shale gas plays based on recent drilling for Triassic Yanchang shale in Ordos Basin and Jurassic Daanzhai shale in Sichuan Basin. Most Meso-Cenozoic shales (e.g. Triassic Yanchang shale in Ordos basin, Paleogene Shahejie shale in Bohai Bay Basin) are in oil window and have shale oil potential. Since both marine and lacustrine basins in China experienced complex tectonic/structural activities, which could cause the leak of ancient shale gas and shale oil reservoirs, exploration should be focused in relative tectonic stable regions.

## **Selected References**

Selley, R.C., L.R.M. Cocks, and I.R. Plimer, eds., 2004, Encyclopedia of Geology: Elsevier Academic, Amsterdam, The Netherlands, 5 volumes.

Chalmers, G.R.L. and R.M. Bustin, 2008, Lower Cretaceous gas shales in northeastern British Columbia, Part I: geological controls on methane sorption capacity: *Bulletin of Canadian Petroleum Geology*, v. 56/1, p. 1-21.



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# Comparison Between Marine Shales and Lacustrine Shales in China

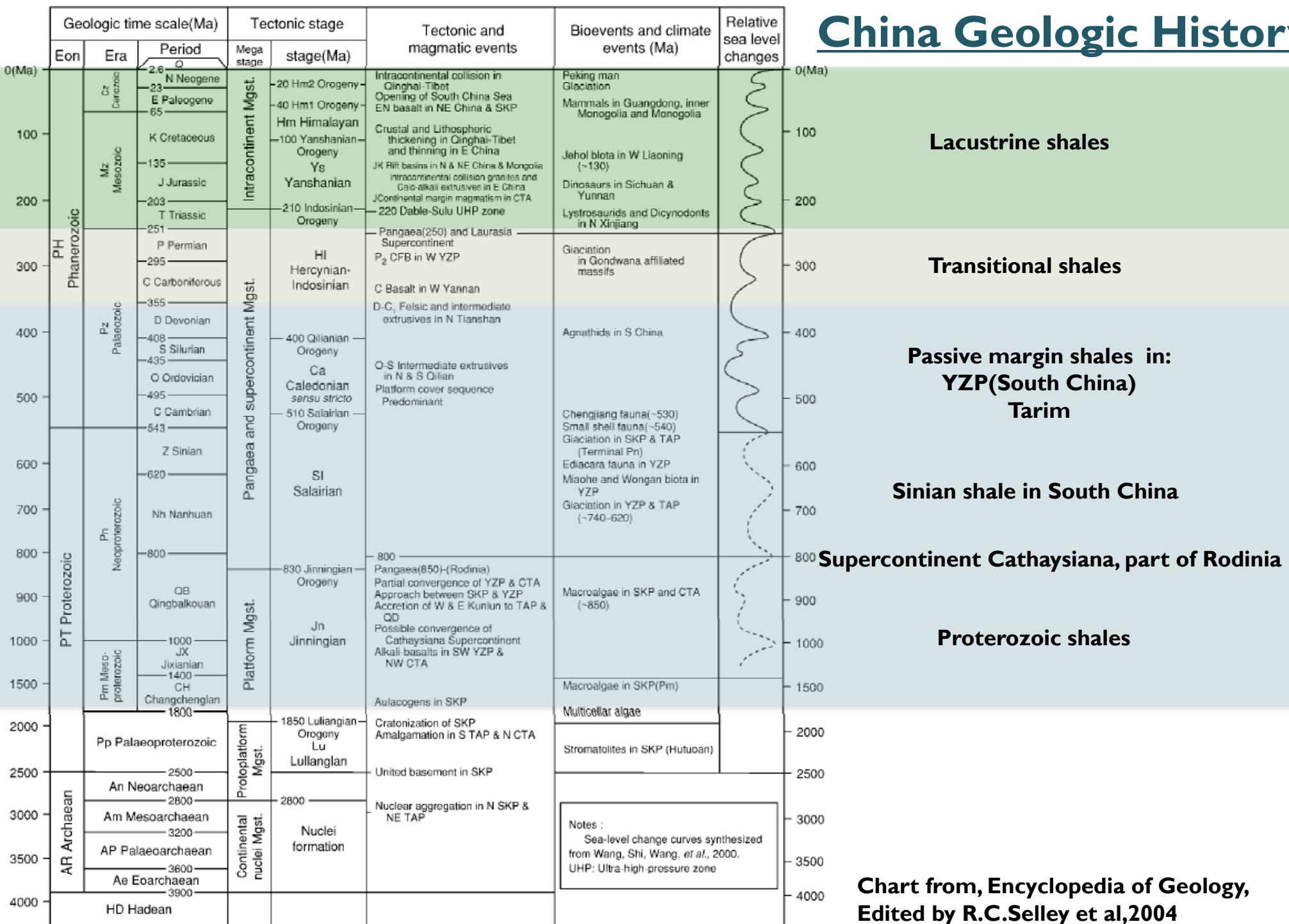
Shu Jiang, Nick Dahdah, Peter Pahnke (EGI–Univ of Utah),  
Jinchuan Zhang (China Univ. of Geosciences at Beijing)

Shu Jiang | May 22, 2013

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# China Geologic History



Lacustrine shales

Transitional shales

Passive margin shales in:  
YZP(South China)  
Tarim

Sinian shale in South China

Supercontinent Cathaysia, part of Rodinia

Proterozoic shales

Chart from, Encyclopedia of Geology,  
Edited by R.C.Selley et al,2004

# China Shale Plays Types & Distribution

Depositional setting		Age and Formation	Distribution area
Lacustrine	Cenozoic	Neogene	Qaidam
		Paleogene	Bohai Bay Basin
		Cretaceous	Songliao Basin Turpan-Hami, Junggar,Tarim, Sichuan,
	Mesozoic	Jurassic	Qaidam Basin
		Triassic	Ordos, Sichuan
	Paleozoic	Late Permian	Junggar,Turpan-Hami
		Late Permian (Longtan Fm)	Yangtze
Transitional (coastal setting with coal)		Early Permian (Taiyuan, Shanxi Fm)	North China
		Late Carboniferous (Benxi Fm)	North China
Marine	Silurian	Early Silurian (Longmaxi Fm)	Yangtze
	Ordovician	Late Ordovician (e.g.Wufeng Fm)	Yangtze,Tarim
	Cambrian	Early Cambrian (e.g. Qingzhusi Fm)	Yangtze,Tarim
	Pre-Cambrian	Sinian	Upper and Middle Yangtze

# Shale Play Types, Distribution and Exploration Activities

**81 wells for both marine and lacustrine shales (shallow & deep)**

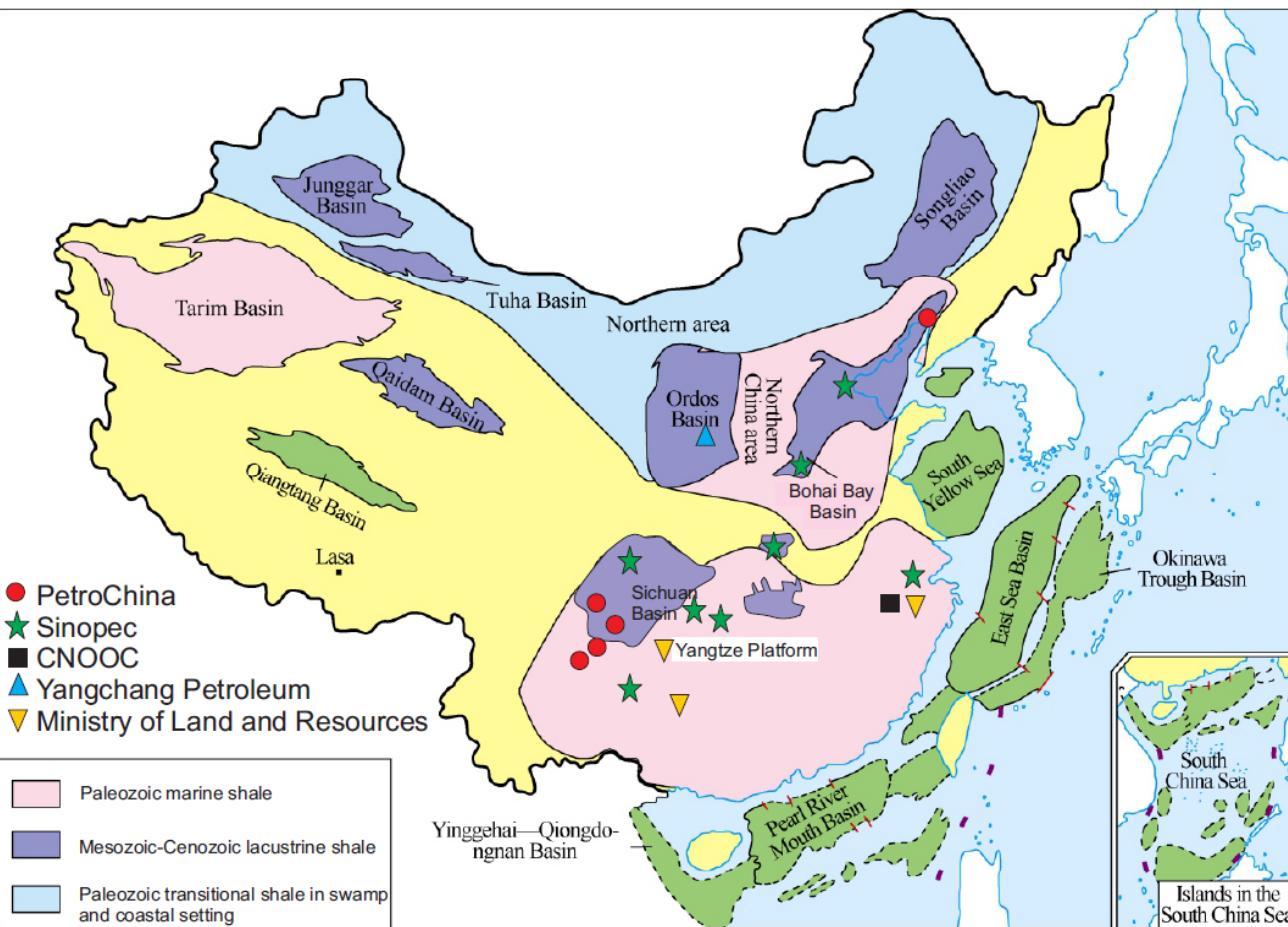
- 20 horizontal wells to date

## **Shale gas (marine and lacustrine)**

- gas flow/gas show from half of shale gas wells, e.g. 430,000 cubic meters/day (15 million cubic feet) from Yang201-H2 in SW Sichuan

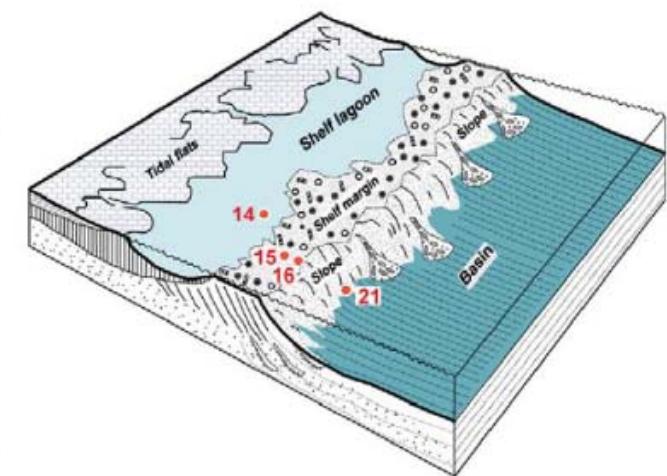
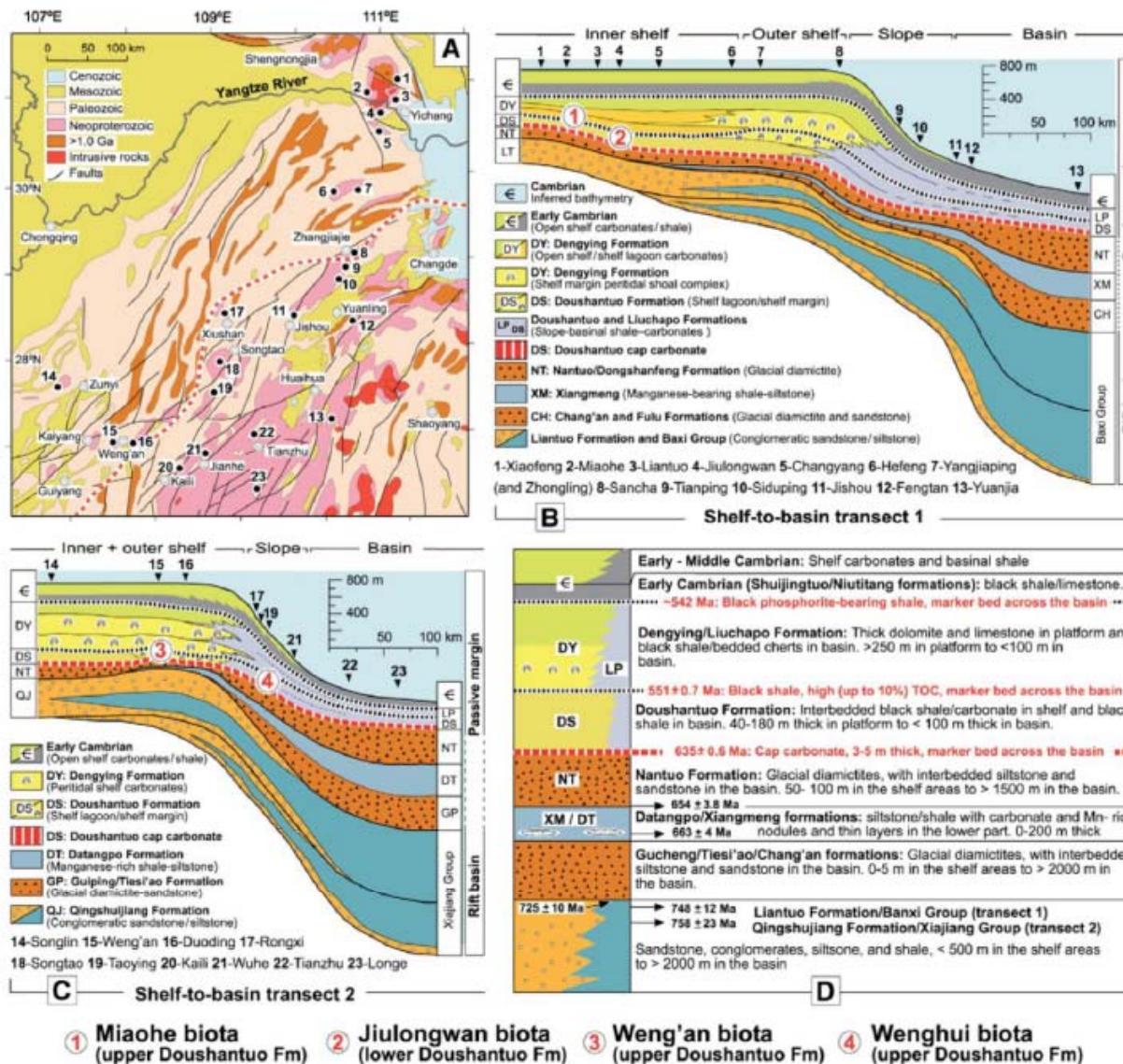
## **Shale Oil (lacustrine)**

- oil flow from nearly 7 wells e.g. 33.79 tons of condensate from Shiping 2-2H well in NE Sichuan



Modified base map courtesy of Caineng Zou, 2011

# Depositional Setting for Pre-Cambrian and Lower Paleozoic Marine Shales



**Intra-shelf, lagoon, slope to basinal settings**

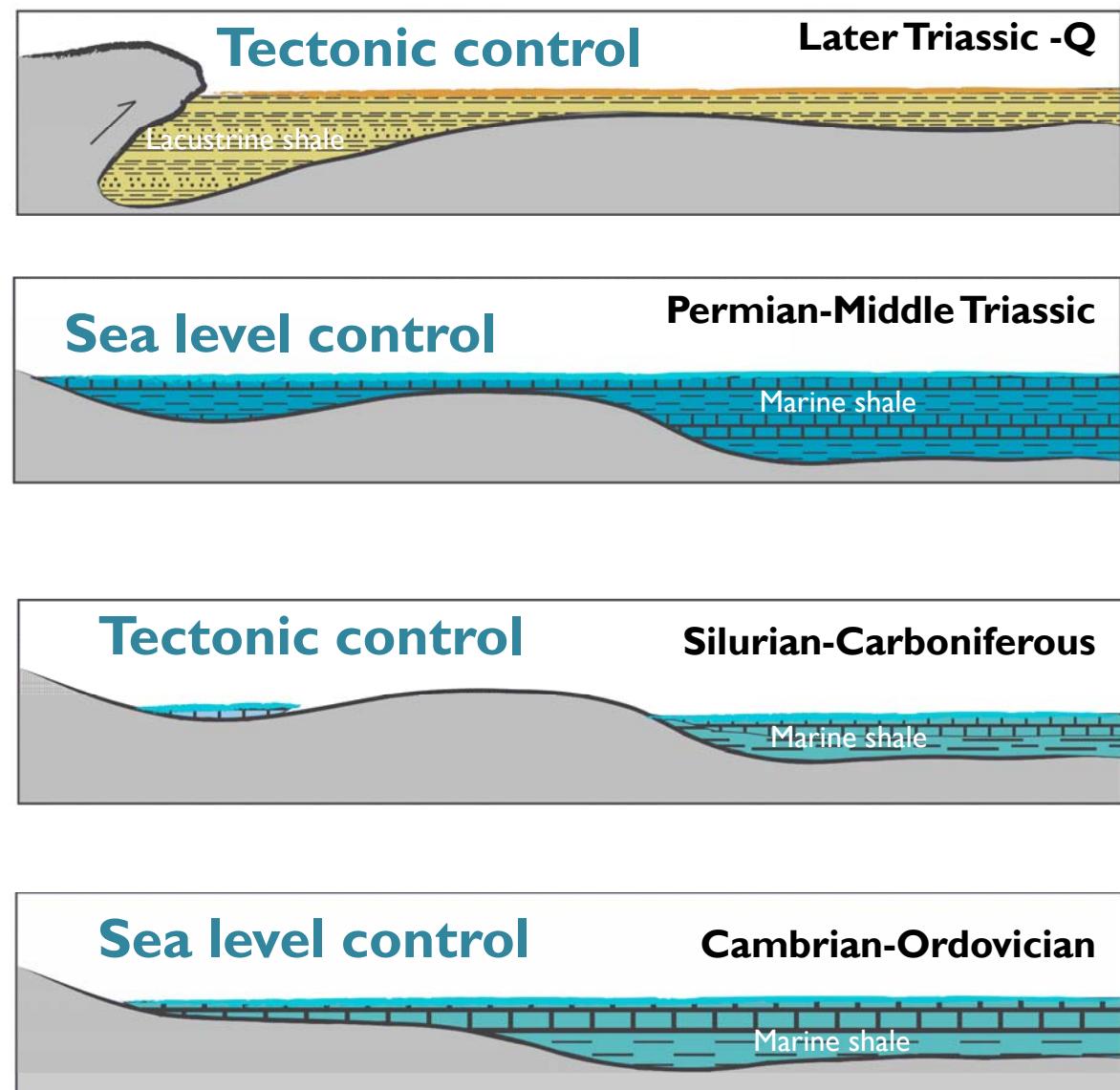
**Example from:  
Yangtze Platform**

Ganqing Jiang, Gondwana Research, 2011

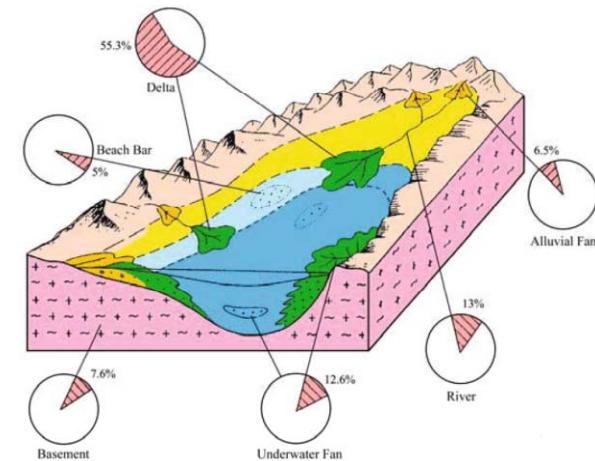
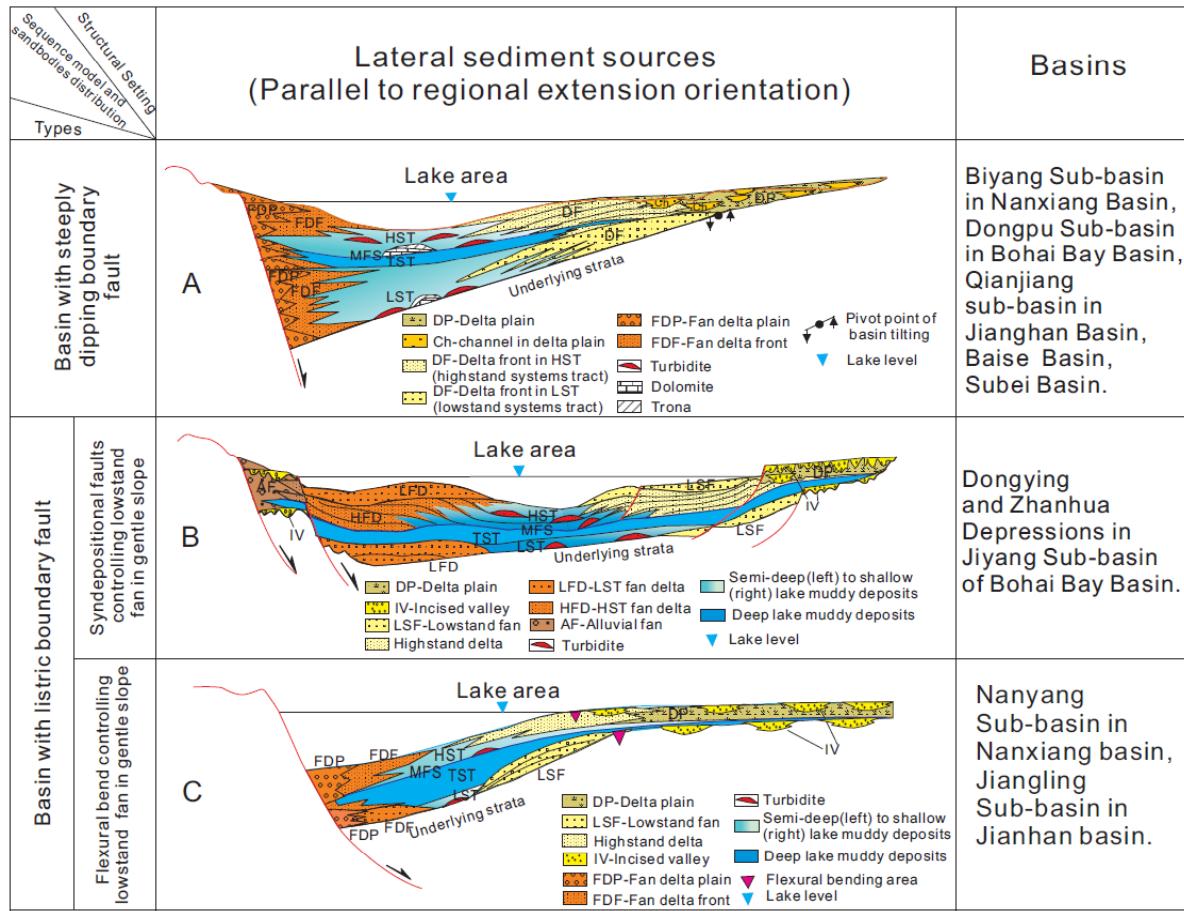
**Fig. 2.** (A) Simplified geological map showing exposures of Neoproterozoic strata in the central Yangtze platform of South China and position of the late Neoproterozoic platform margin (coarse dotted line). Numbers 1–23 indicate the location of stratigraphic sections used for paleogeographic reconstruction (for other sections, see Zhu et al., 2007). (B) Neoproterozoic shelf-to-basin transect from north to south in Hubei and Hunan provinces (transect 1). (C) Shelf-to-basin transect from west to east in Guizhou and Hunan provinces (transect 2). (D) Summary of stratigraphic units with major age constraints and marker beds (thick lines) for shelf-to-basin correlations.

# Tectonic and Depositional Settings for Shale Development – Example: Sichuan Basin

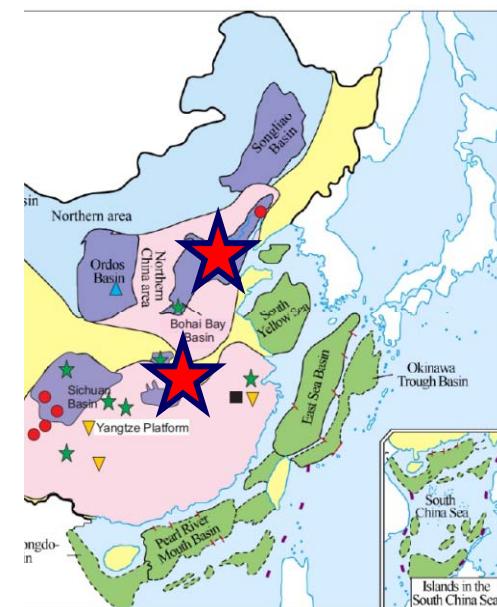
System	Tectonic cycle	Tectonic event	Basin development	
Mesozoic	Cenozoic	Himalayan	Late Himalayan Early Himalayan	
		Late Yanshan	Rejuvenated foreland basin	
		Yanshanian	Intracontinental Subsidence	
			Peripheral foreland basin	
			Passive margin	
	Triassic	Indosinian	Dongwu Yunnan	
			Emei basalt	
			Marginal extension	
			Foreland	
			Passive margin	
Paleozoic	Caledonian	Hercynian	Silurian Ordovician Cambrian	
			Tongwan	
			Early continental rift	
			Metamorphic Basement	
			Jining	
	Yangtze		Chengjiang	
			Pre-Sinian	
			Sinian	
			Chengjiang	
			Jining	



# Tectonic and Depositional Settings for Meso-Cenozoic Lacustrine Shales



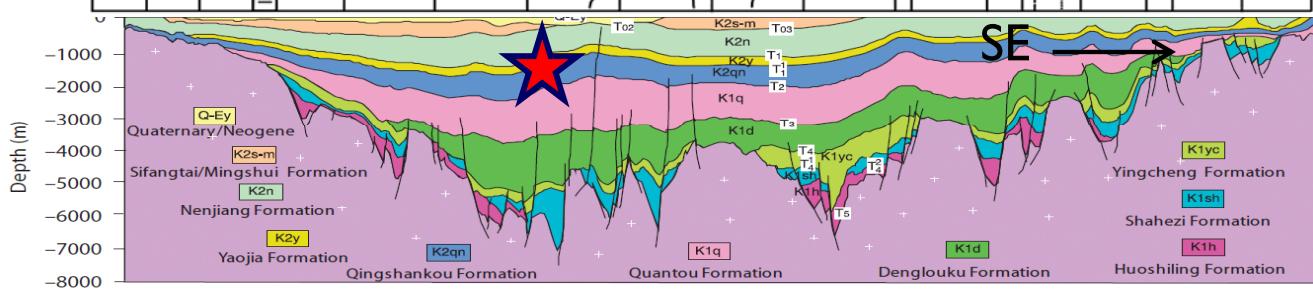
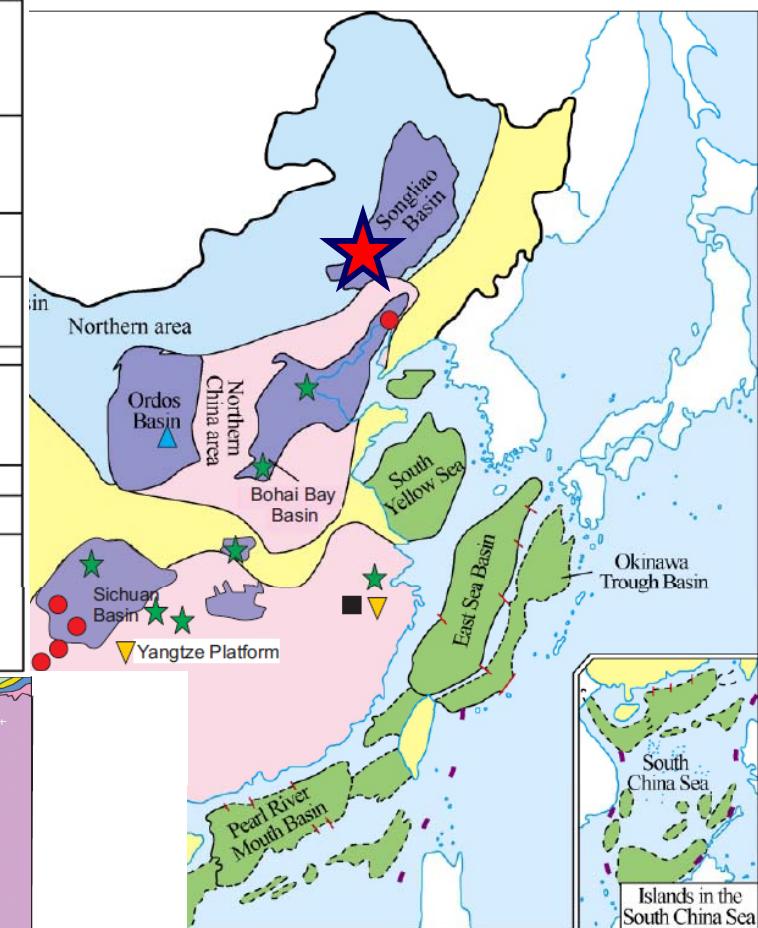
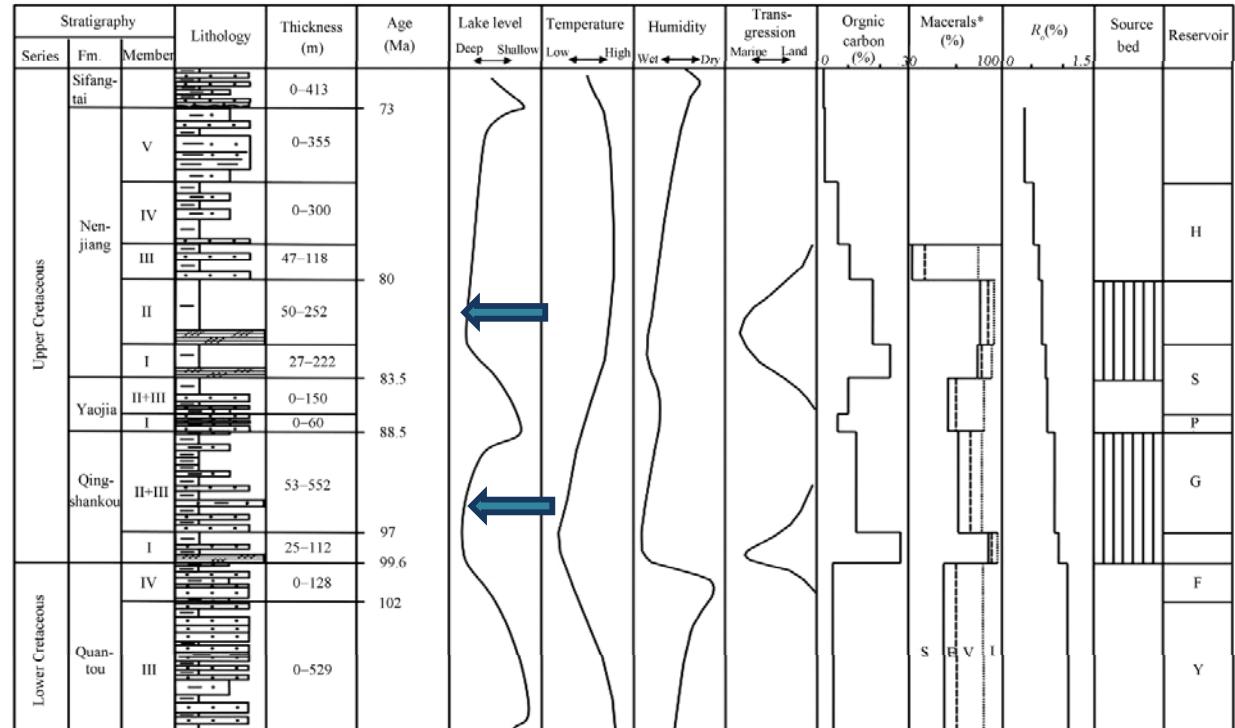
Z.Qiu et al., 1997,  
C.Jia et al., 2012



## Models for East China Cenozoic Lacustrine Basins

S.Jiang, et al., 2013

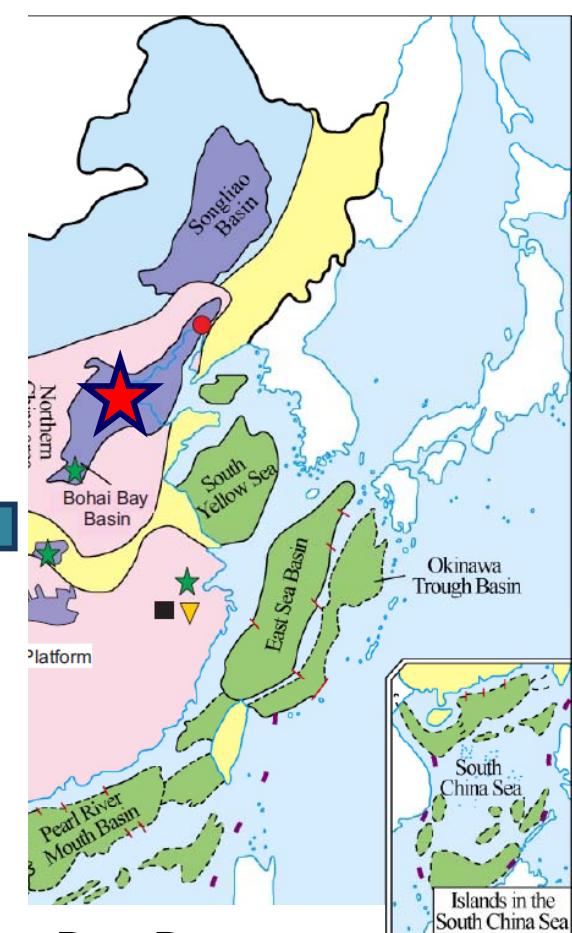
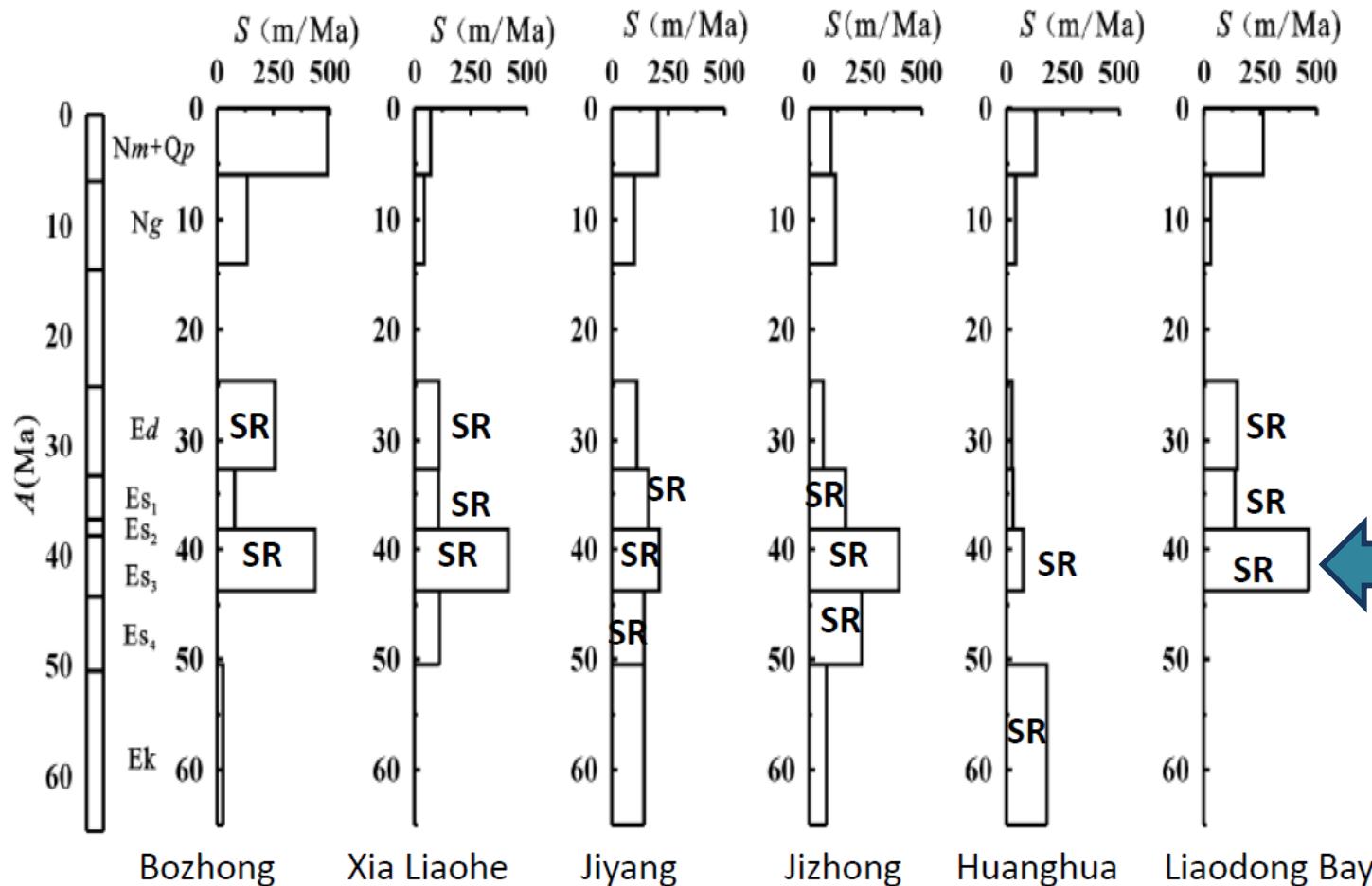
# Lake Level Controls on Lacustrine Shale Development – Example: Songliao Basin



Z. Feng Zhi-qiang, et al., 2010

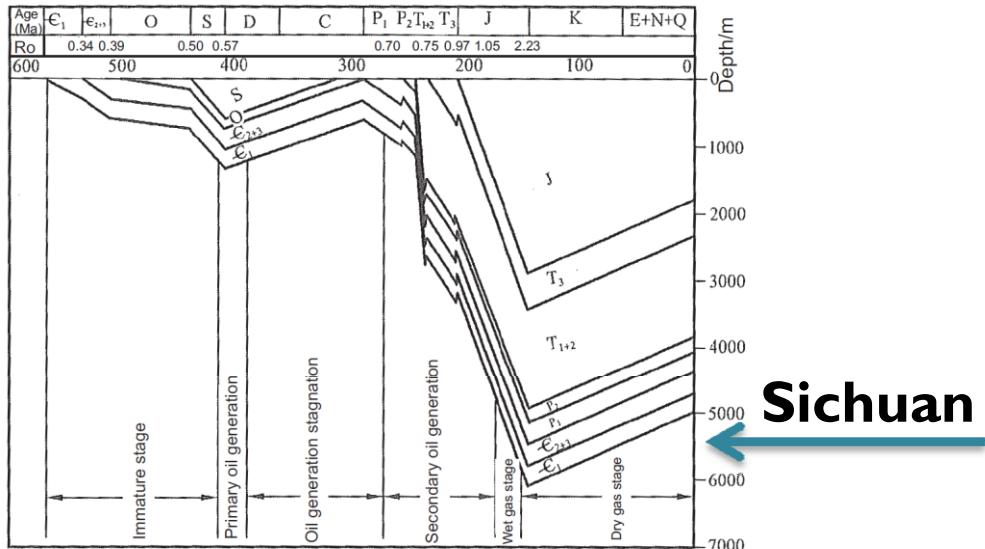
# Tectonic Control on Lacustrine Shale Development

## Example: Cenozoic Bohai Bay Basin

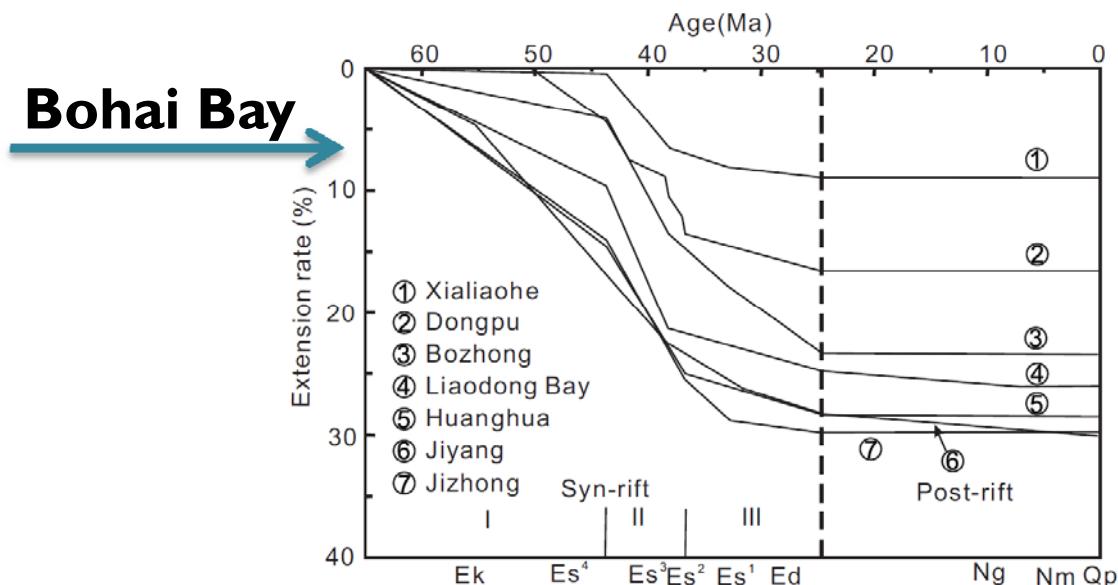
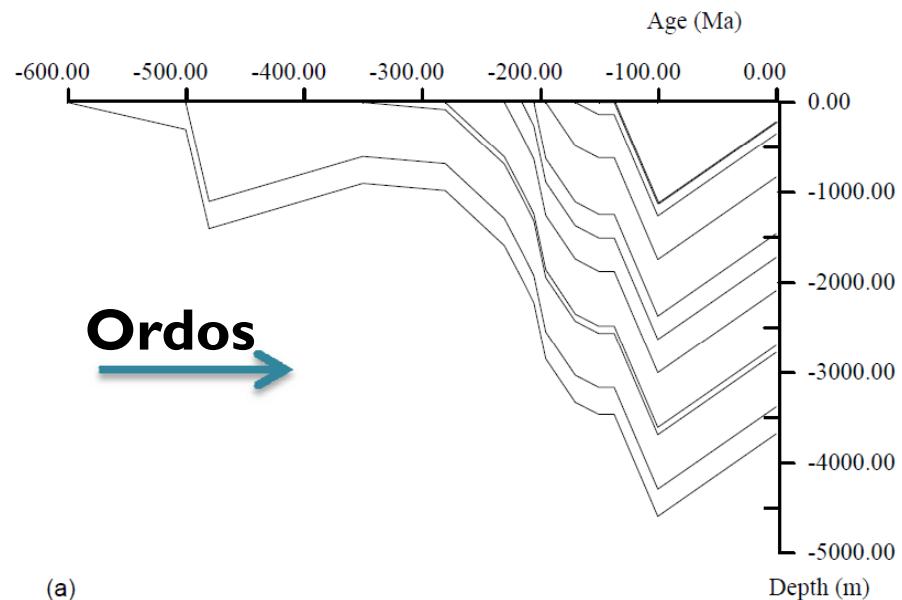
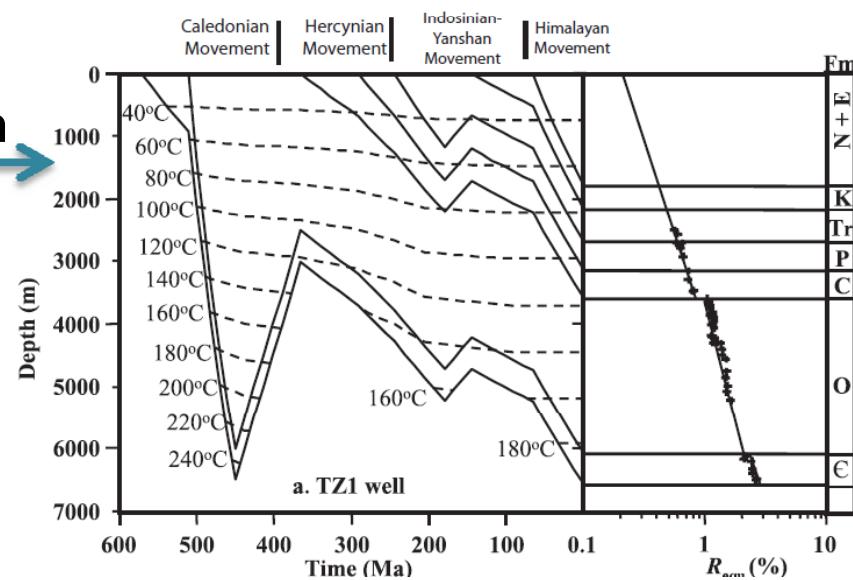


Basement subsidence rates between sub-basins within Bohai Bay Basin.  
(A – Age; S – Subsidence rate; **SR** – Lacustrine shale source rock)

# Complex Burial History of China Shales

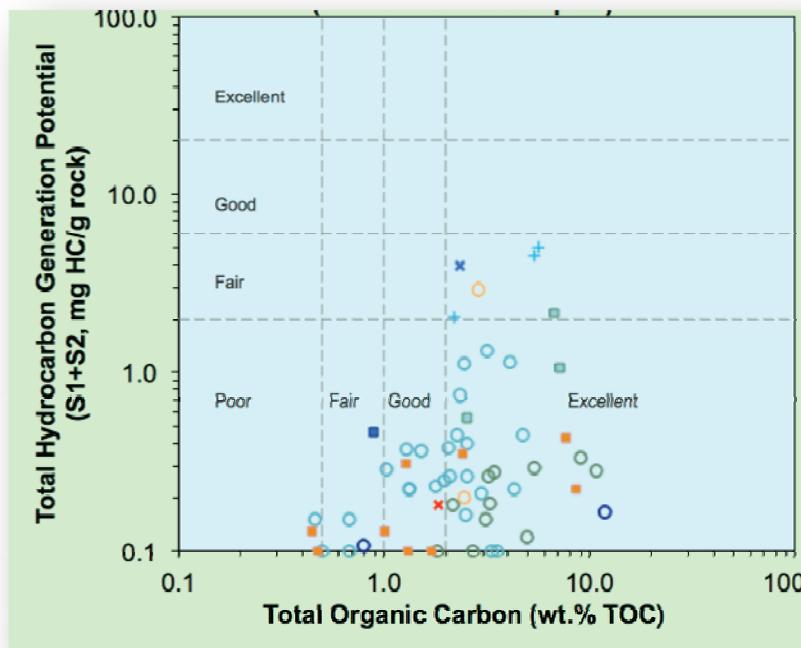


The burial history of Gaoke1 well and Ro evolution of lower Cambrian organic matter  
 (modified from Jiajing Yang, 2001)

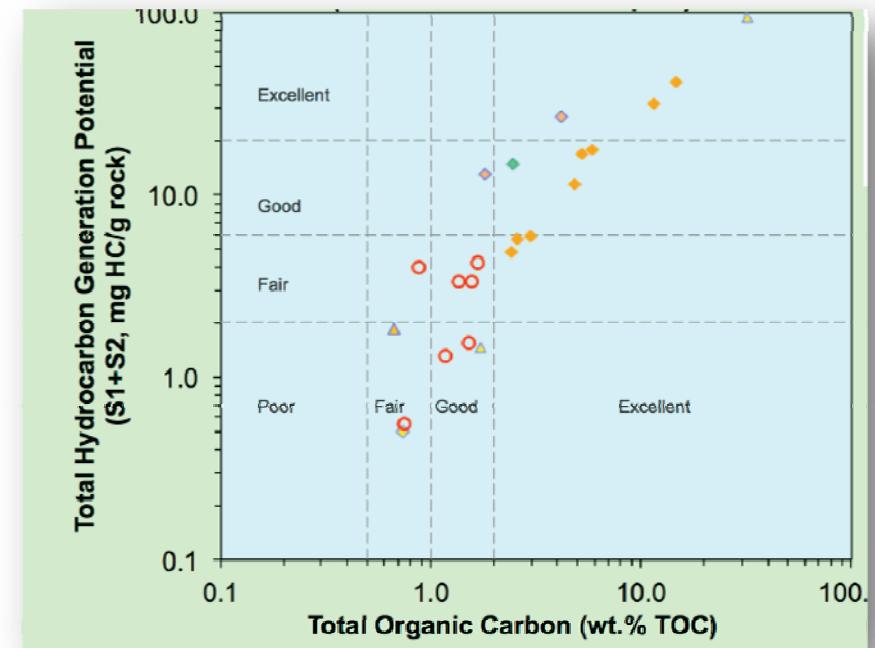


# Source Rock Quality Comparison of Marine and Lacustrine Shale Samples

Marine shale



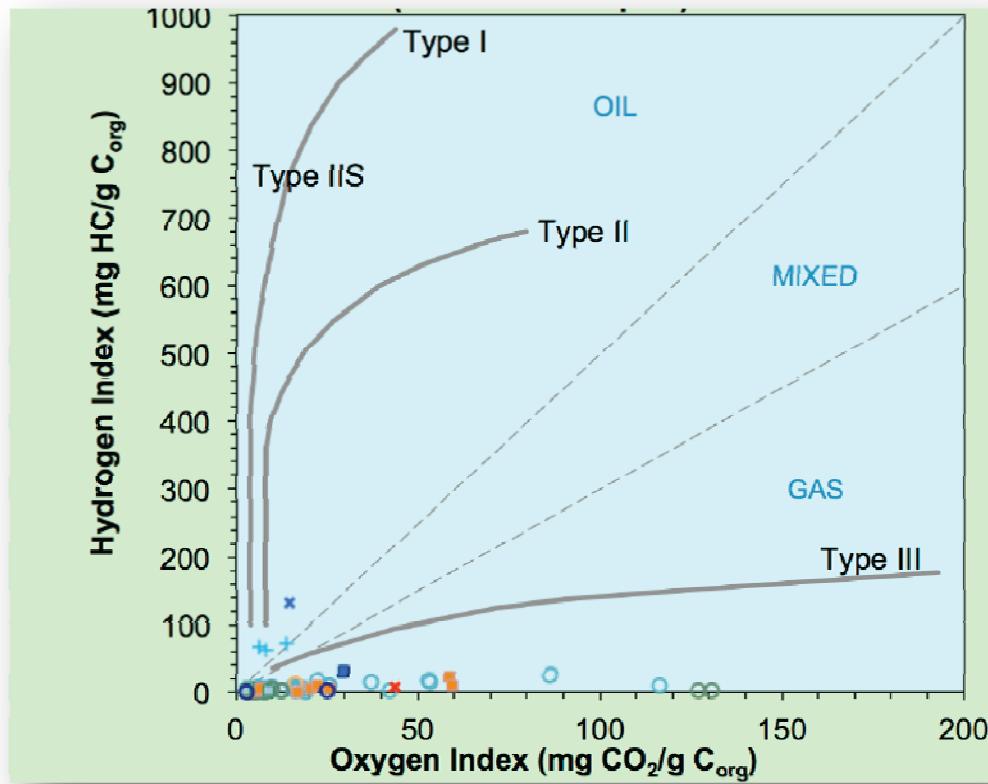
Lacustrine shale



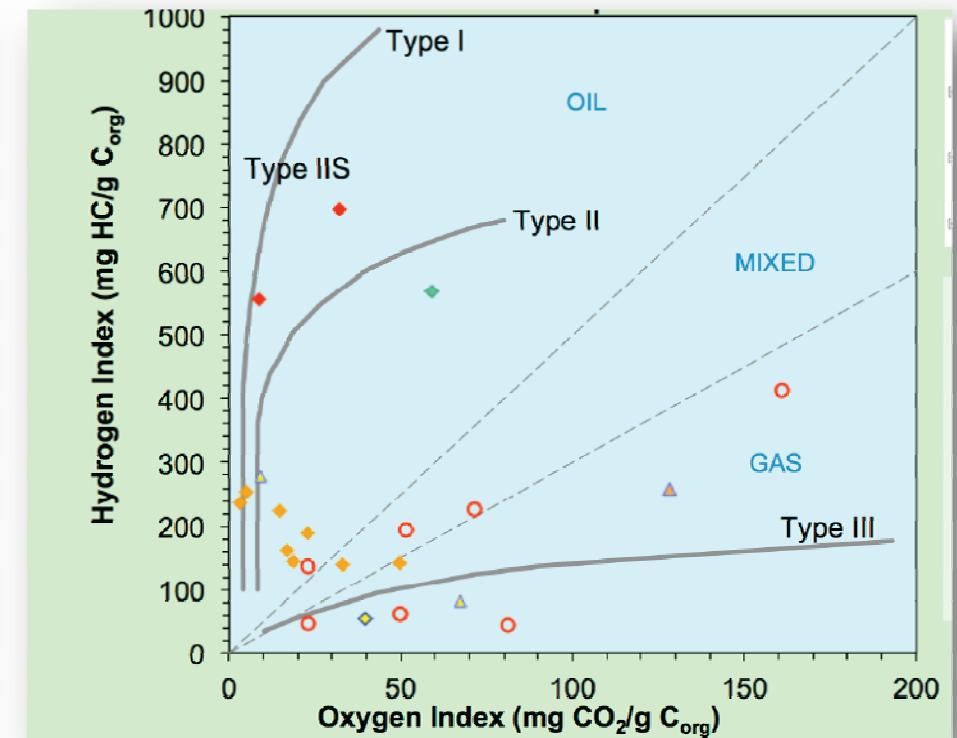
**China marine shales have lower hydrocarbon generation potential than lacustrine shales.**

# Pseudo Van Krevelen Plot from Marine and Lacustrine Shale Samples

Marine shale



Lacustrine shale

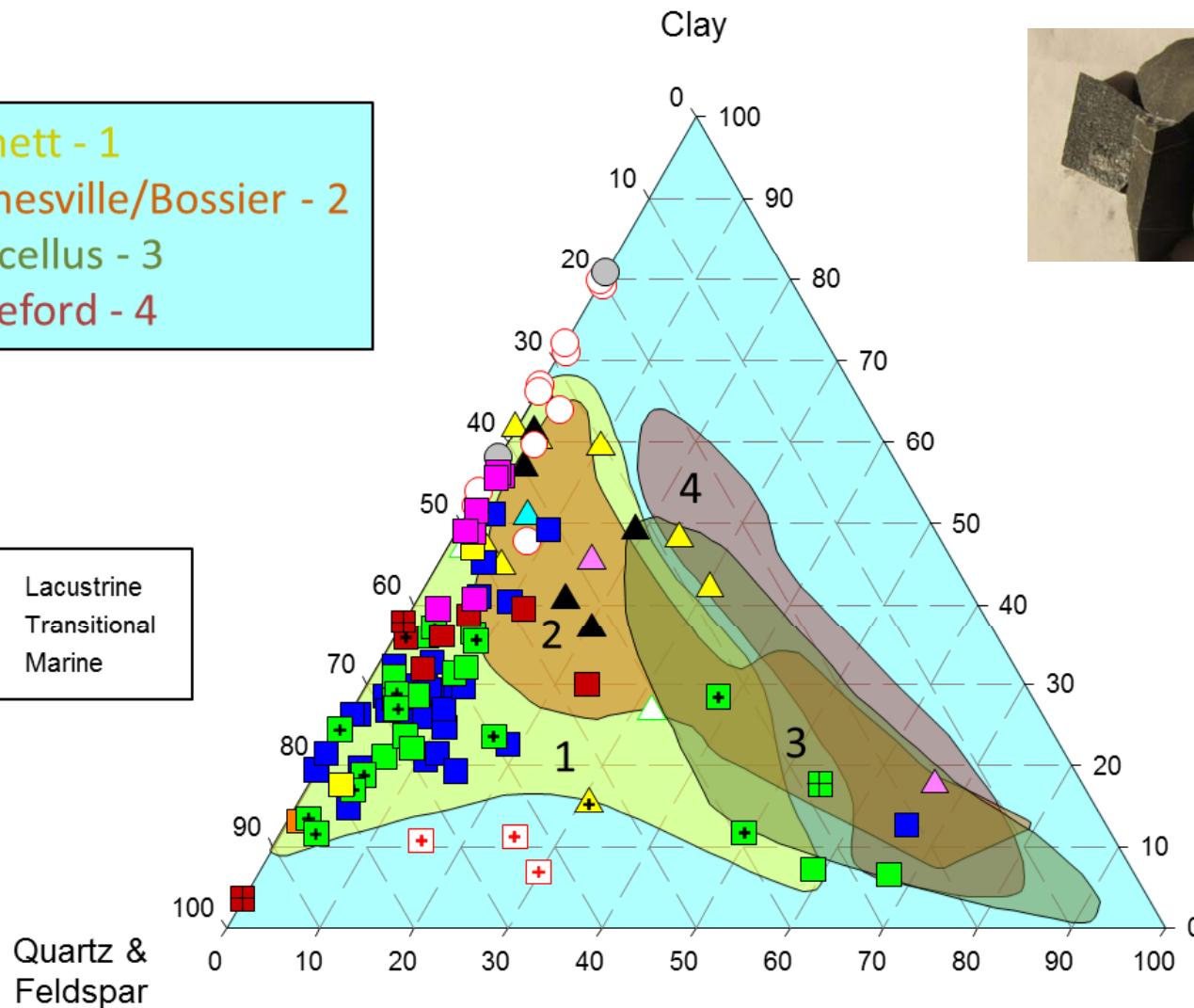


- China marine shales currently display type III kerogen (original type II).
- China lacustrine shales display type I to III kerogen (originally, main type I, Type III by terrestrial influence).

# Mineralogy Comparisons of Marine and Lacustrine Shale Samples from China and U.S.

Barnett - 1  
Haynesville/Bossier - 2  
Marcellus - 3  
Eagleford - 4

- △ Lacustrine
- Transitional
- Marine



Natural fractures  
in marine shale

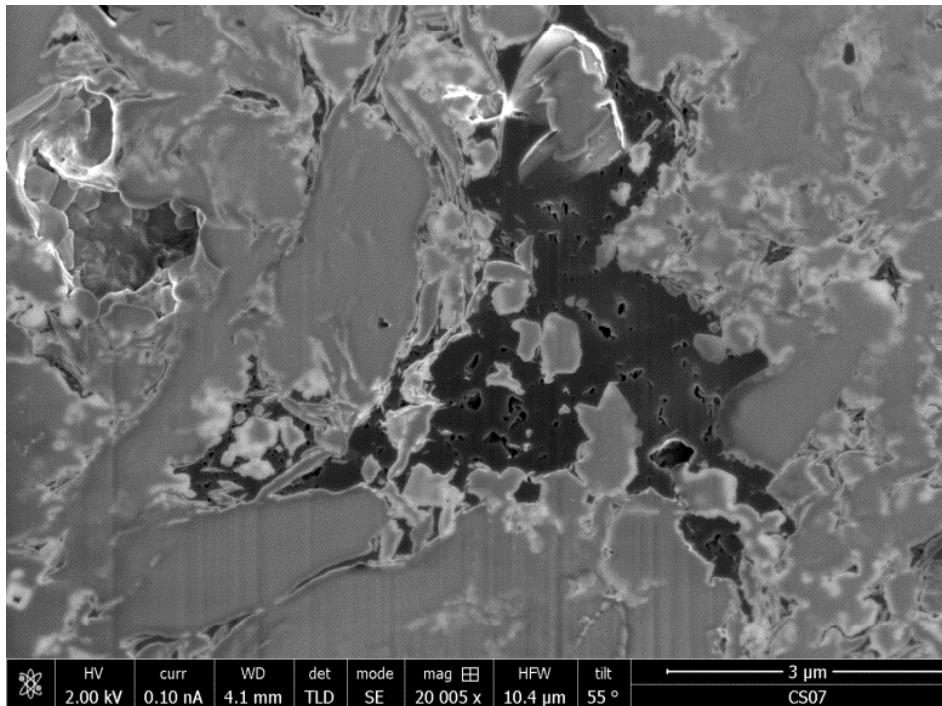


A lacustrine  
shale core sample

Carbonate  
& Other

# Pores – Marine and Lacustrine Shales (China)

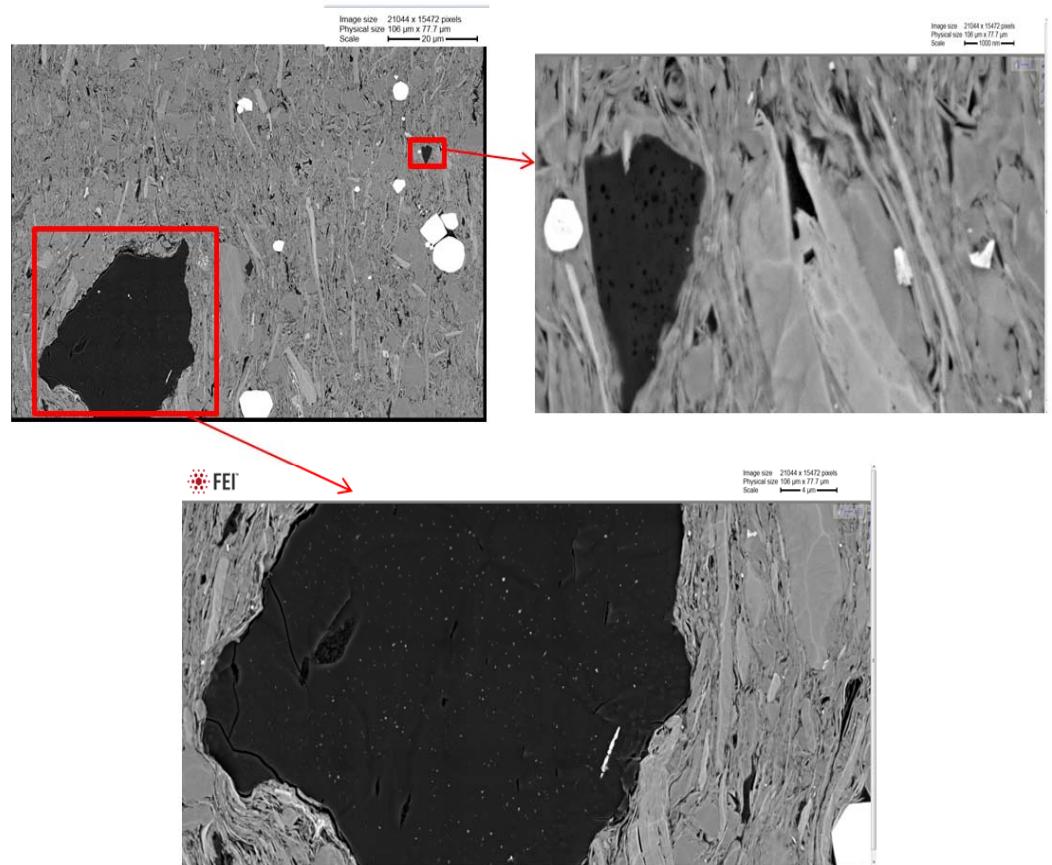
Marine



$TOC = 2.49\%$ ,  $R_o = 1.47\%$ ,  
and quartz content is 53%.

**Nano-pores developed in both high maturity  
marine shales and low maturity lacustrine shales**

Lacustrine



$TOC = 5.24\%$ ,  $R_o = 0.77\%$ ,  
and quartz content is 19%.

# Comparison of Shale Fabrics

**marine shale**

CS112R  
Marine  
L. Yangtze - Silurian  
20µm Resolution

Mineral Name	Area %
Quartz	56.88
Illite	36.92
Plagioclase	3.37
Smectites	1.51
Particle Rim	1.48
Other Silicates	1.39
Pyrite	1.14
Unclassified	0.98
Background	0.81
Other Feldspar	0.67
Other	0.66
Other Silicates	0.60
Glaucophane	0.36
Muscovite	0.28
Dolomite	0.23
Apatite	0.11
Muscovite	0.10
Other	0.04
Siderite	0.03
Chlorite	0.03
Biotite	0.03
Other	0.03
Fe-oxides	0.01
Biotite	0.01
Zircon	0.00
Calcite	0.00



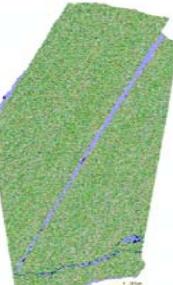
CS041R

Mineral Name	Area %
Quartz	78.55
Illite	11.43
Plagioclase	6.92
Alkali Feldspar	0.78
Chlorite	0.69
Smectites	0.39
Pyrite	0.21
Other Silicates	0.13



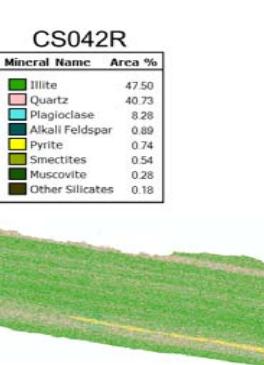
CS004R

Mineral Name	Area %
Quartz	36.70
Illite	31.72
Plagioclase	11.80
Alkali Feldspar	5.41
Calcite	3.08
Chlorite	2.05
Biotite	1.49
Other Silicates	1.45



CS042R

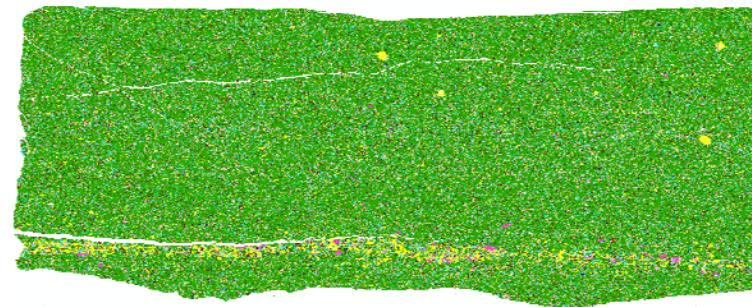
Mineral Name	Area %
Illite	47.50
Quartz	40.73
Plagioclase	8.28
Alkali Feldspar	0.89
Pyrite	0.74
Smectites	0.54
Muscovite	0.28
Other Silicates	0.18



**lacustrine shale**

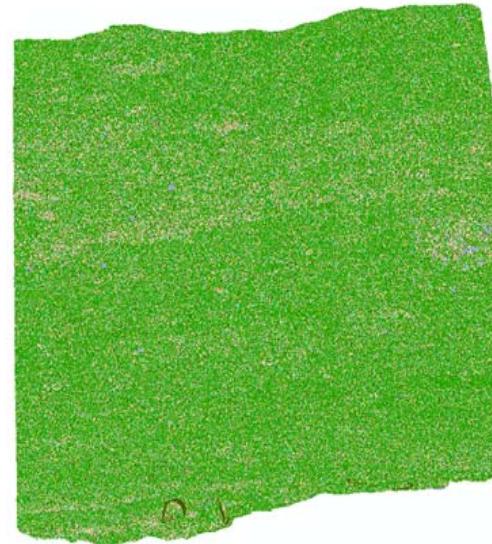
CS102R

Mineral Name	Area %
Illite	65.16
Plagioclase	7.85
Quartz	6.78
Other Silicates	3.60
Chlorite	3.39
Pyrite	2.79
Smectites	2.69
Biotite	2.11



CS059R

Mineral Name	Area %
Illite	65.41
Quartz	18.91
Plagioclase	4.77
Chlorite	3.17
Smectites	3.16
Other Silicates	1.53
Muscovite	1.11
Biotite	0.45



Laminated and massive structures for both marine and lacustrine shales.

# Comparison of Isotherms

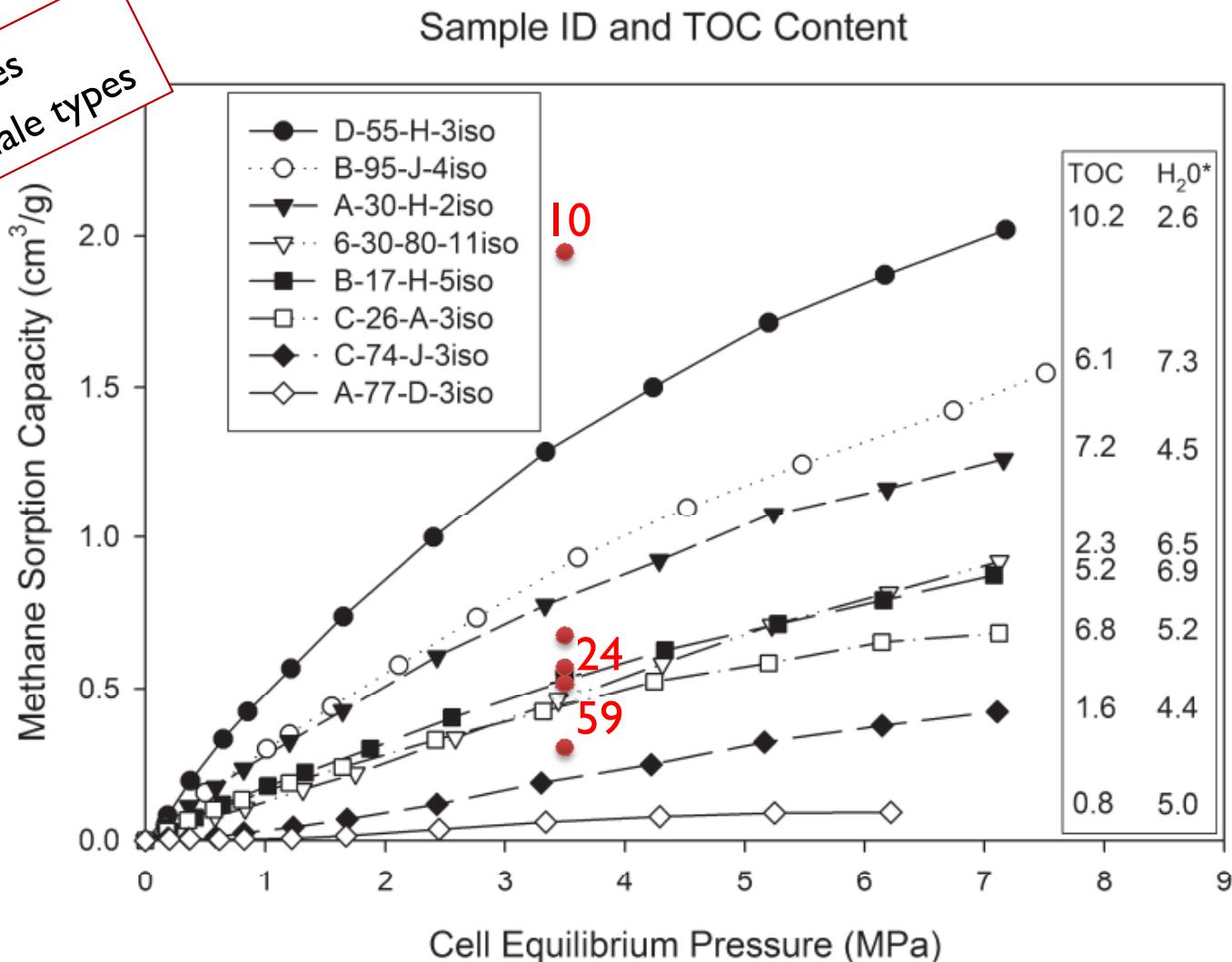
Measured values are typical for shales  
Mainly determined by TOC, not shale types

- Red dots – China shales
- Black dots – Chalmers and Bustin (2008)

10- Marine, TOC=8.6%

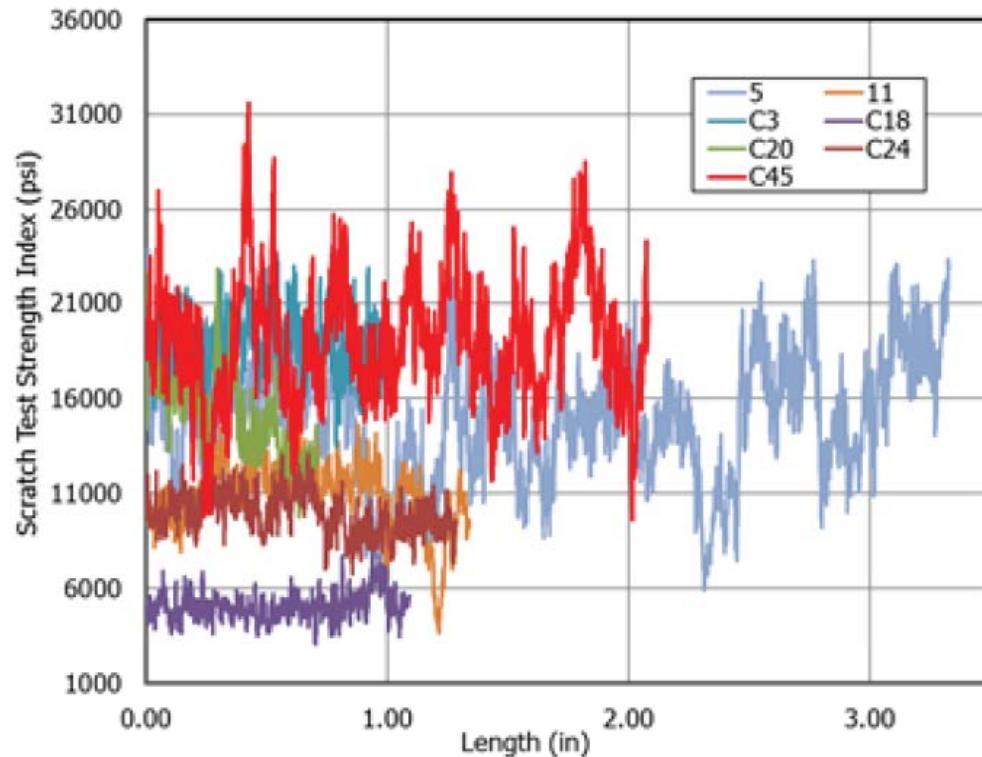
24-Lacustrine, TOC=1.71%

59-Lacustrine, TOC=1.16%



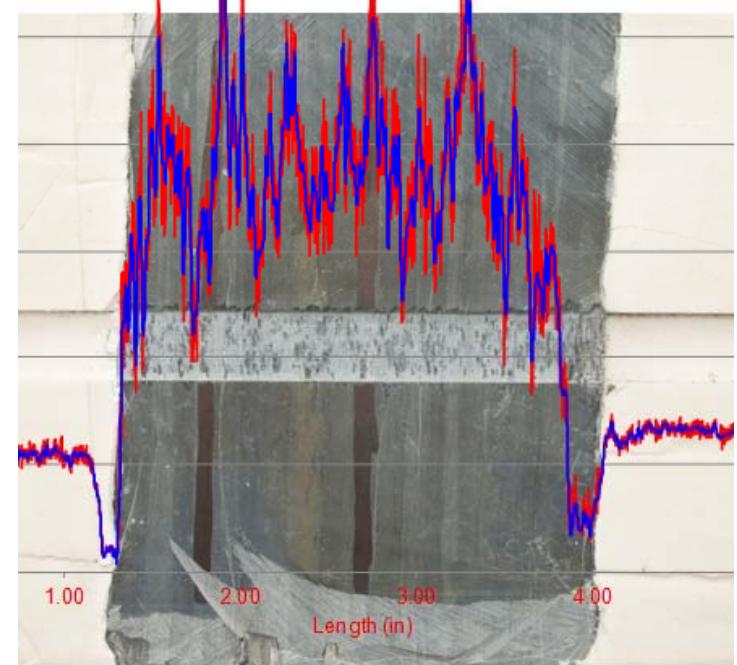
Chalmers, G. R. L. and R. M. Bustin (2008). "Lower Cretaceous gas shales in northeastern British Columbia, Part I: geological controls on methane sorption capacity." *Bulletin of Canadian Petroleum Geology* 56(1): 1-21.

# Geomechanics Comparisons



45, 5,3-Marine  
24, 20-Lacustrine  
18-Transitional

unconfined scratch strength



Rough trend is that marine shale has relatively higher strength

# Conclusions

- **Marine and lacustrine shales in China were generally formed during high sea, or lake level, or rapid basin subsidence periods. They are both in structurally active regions and have complex tectonic histories. Both have high TOC and intra-organic pores and both are heterogeneous in terms of mineralogy, fabrics, geomechanics, petrophysics, storage, and geochemistry, etc.**
- **Marine**
  - Mainly Precambrian to Silurian
  - Extensively distributed in the Yangtze Platform in Southern China and Tarim Basin in NW China
  - Intra-shelf lows, slope, basinal facies in passive margin and foreland settings
  - Good TOC and high maturity – shale gas potential
  - Siliceous, brittle, and similar to U.S. Barnett
- **Lacustrine**
  - Mesozoic-Cenozoic (besides late Permian shale in NW China)
  - Sporadically and widely distributed
  - Pro-delta and lake margin swamp settings
  - Good TOC and low maturity – mainly shale oil potential
  - More clay rich compared to marine shales, some are brittle



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A large, semi-transparent black rectangular box covers the top half of the slide, containing the EGI logo and text. Below it, a background image shows a satellite view of Earth's surface with a superimposed grid of energy-related data, such as oil well locations or seismic activity patterns.

# Thank you for your attention.

**Send questions, requests & feedback to:**

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