

# Source-Rock Properties and Hydrocarbon-Generating Kinetics of Lacustrine Shales in Ordos Basin, China\*

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## Abstract

Upper Triassic Yanchang shale in Southeast Ordos Basin (SOB) is a main potential source rock for conventional petroleum fields and has been recently recognized as an important unconventional reservoir. The hydrocarbon potential of lacustrine Yanchang shales stemmed from SOB was investigated using bulk and quantitative pyrolysis techniques. The rock samples were taken from Chang7 and Chang9 intervals of upper Triassic aged cores. The analytical program included total organic carbon (TOC), Rock-Eval, pyrolysis gas chromatogram (Py-GC), source rock analyser (SRA) and micro-scale sealed vessel (MSSV) pyrolysis. The results were used to determine petroleum type, hydrocarbon composition, bulk kinetics and phase behavior of fluid generated from Yanchang shales. The investigated shale rocks proved to contain type II/III kerogen with quality organic abundance. The heterogeneity was identified and total sulphur content is lower than 1.5%. These black shales generate paraffinic-naphthenic-aromatic (P-N-A) low wax oils, whereas samples with increasing maturity show a potential for gas condensate generation. Bulk kinetic parameters reveal a relatively broad distribution of activation energies and indicate that Chang9 kerogen is more stable. Hydrocarbon generation could be characterized by a frequency factor A (1/S) = 2.20E+12 and a main active energy at 50 kcal/mole. Computed onset (transformation ratio=10%) and peak generation temperatures were 121°C and 132°C respectively using a 3°C/million years constant heating rate. Compositional kinetic modelling predicts that 75% of the hydrocarbons were generated as oil and 25% as gas. The liquid is predominated by boiling ranges C<sub>7-15</sub> and C<sub>16-25</sub>, while n-C<sub>1</sub>, n-C<sub>2</sub> and n-C<sub>3</sub> contribute to the gas composition. The saturation pressure (Psat) and formation volume factor (Bo) display a linear correlation as a function of transformation ratio. And the property of the generated hydrocarbons is in agreement with

naturally occurring petroleum fluids. The pressure-temperature (P-T) envelope is defined for hydrocarbons generated from Yanchang shale. It is possible to determine if a single or two-phase fluid could occur at different TRs. This research provides the first compositional kinetic description of lacustrine Yanchang shale in the studied area and demonstrates excellent shale gas and oil potential.

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Tang, X., J. Zhang, X. Wang, B. Yu, W. Ding, J. Xiong, Y. Yang, L. Wang, and C. Yang, 2014, Shale characteristics in the southeastern Ordos basin, China; Implications for hydrocarbon accumulation conditions and the potential of continental shales: International Journal of Coal Geology, v. 128-129, p. 32-46.

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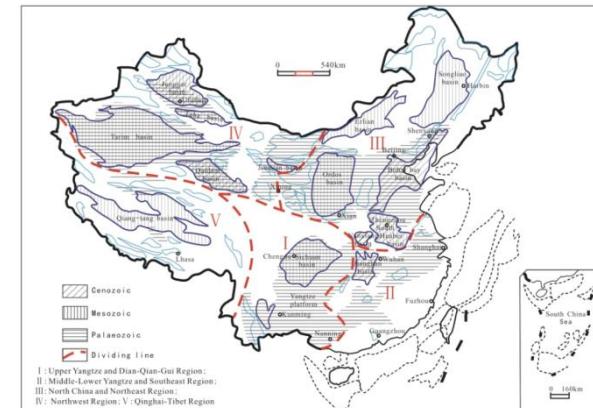
# Outline

## ➤ Introduction

## ➤ Shale Properties

## ➤ Kinetics Modelling

## ➤ Conclusion



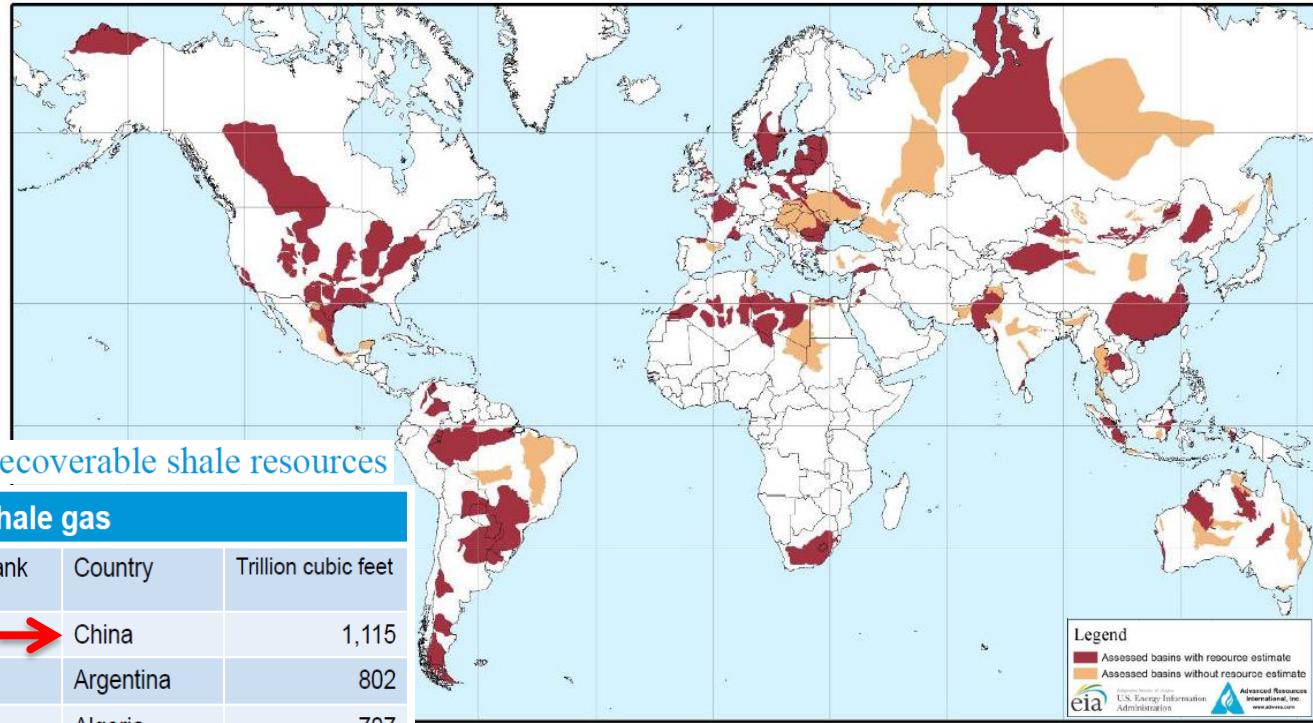


# World shale-gas and shale-oil resource assessment (EIA)

Top ten countries with technically recoverable shale resources

Shale oil		
Rank	Country	Billion barrels
1	Russia	75
2	United States	58
3 →	China	32
4	Argentina	27
5	Libya	26
6	Venezuela	13
7	Mexico	13
8	Pakistan	9
9	Canada	9
10	Indonesia	8
World total		345

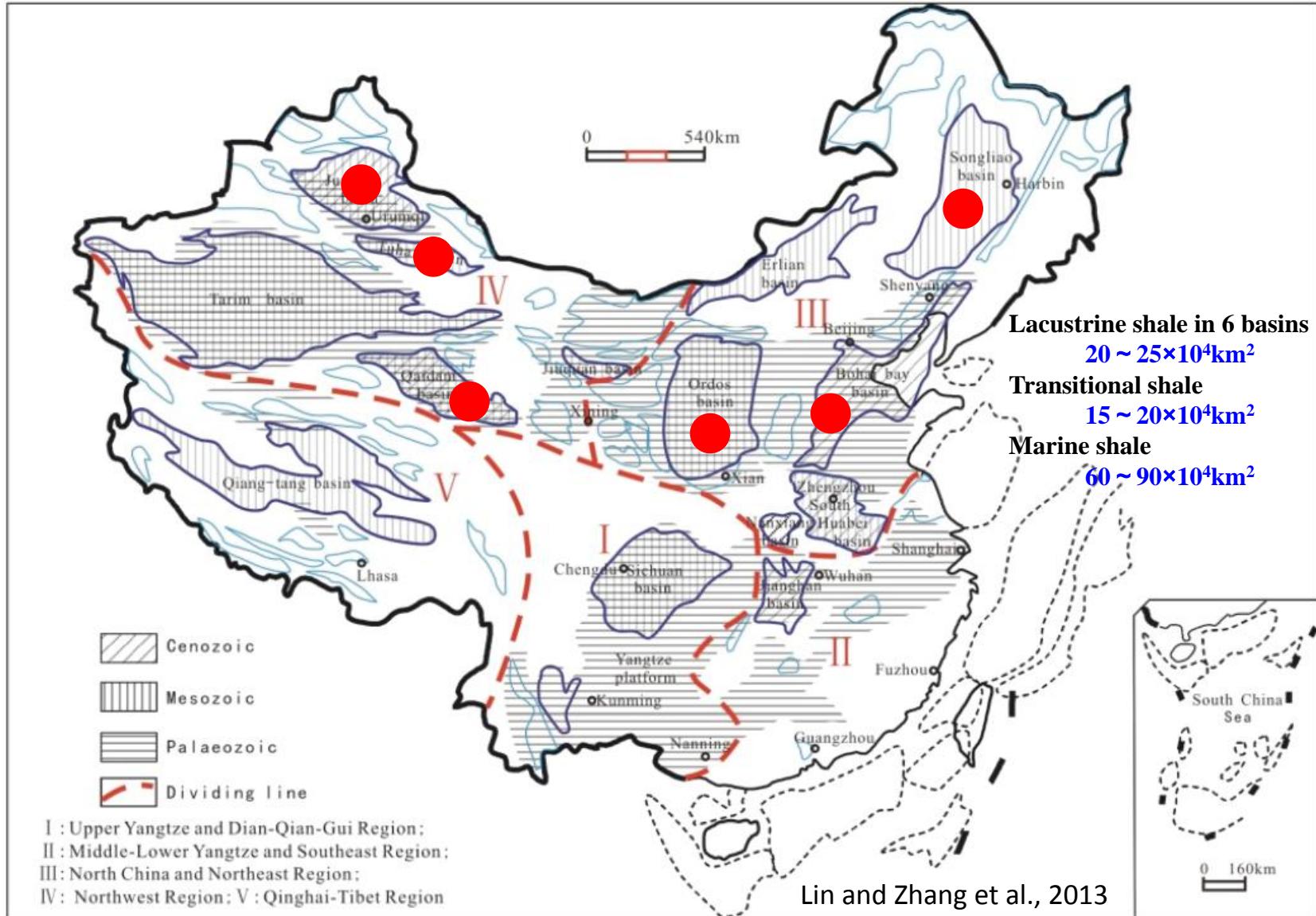
Shale gas		
Rank	Country	Trillion cubic feet
1 →	China	1,115
2	Argentina	802
3	Algeria	707
4	United States	665
5	Canada	573
6	Mexico	545
7	Australia	437
8	South Africa	390
9	Russia	285
10	Brazil	245
World total		7,299





# Shale Distribution in China

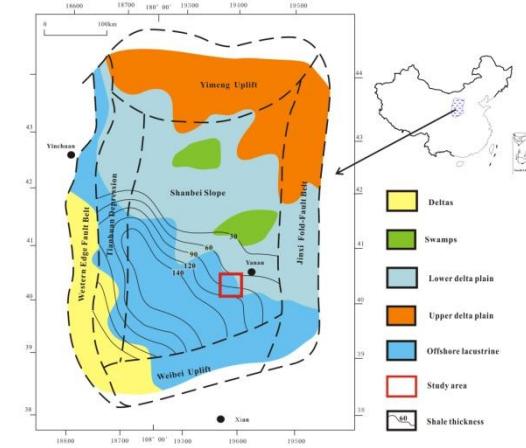
A various types of multi-age, organic-rich shale have been developed





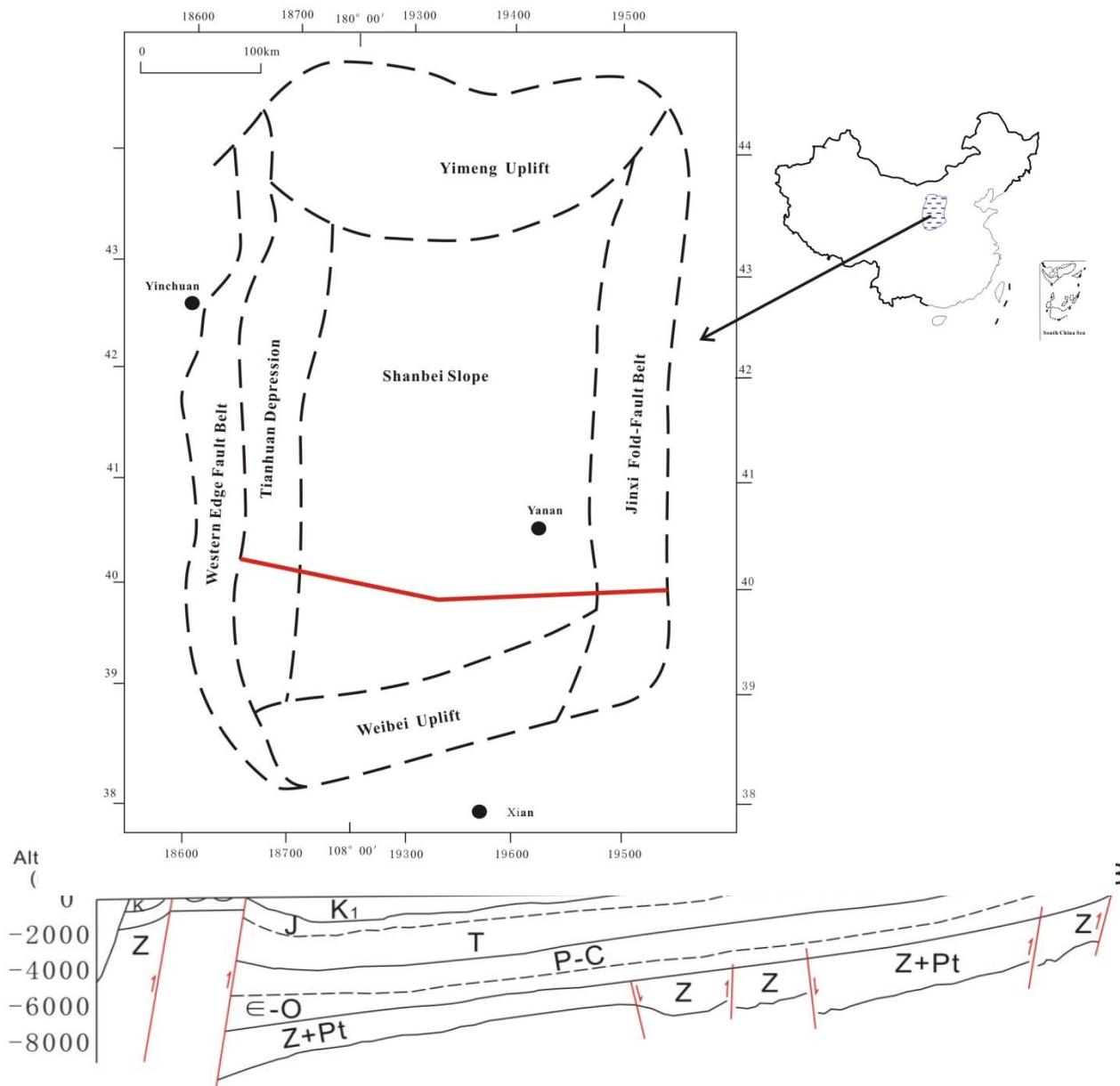
# Outline

- **Introduction**
- **Shale Properties**
- **Kinetics Modelling**
- **Conclusion**





# Overview of Ordos Basin





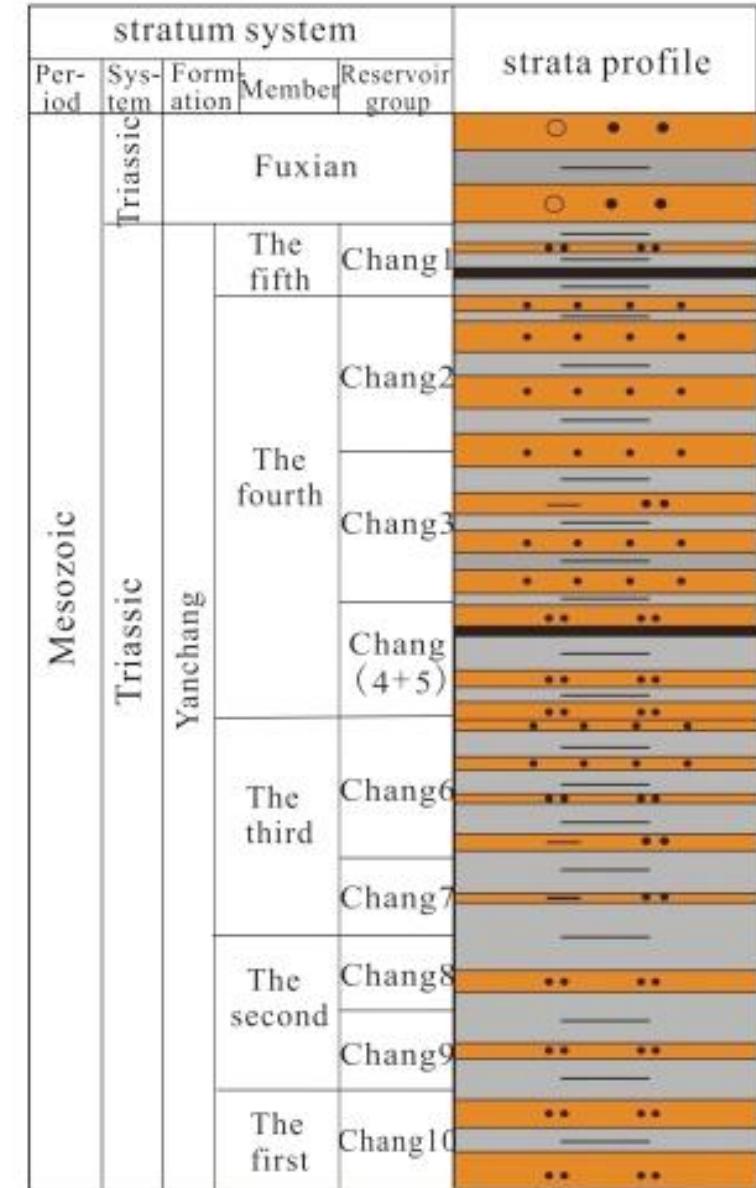
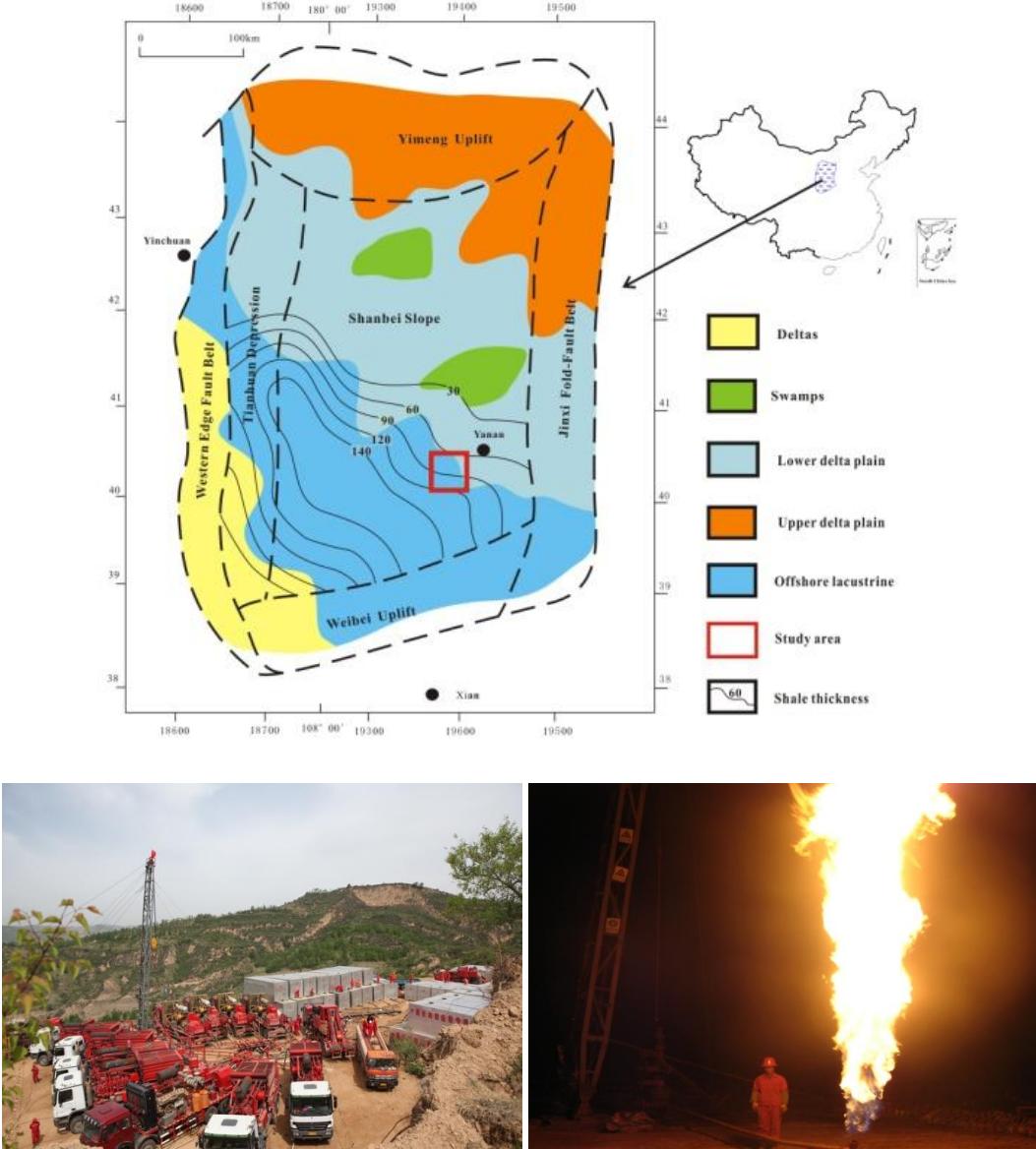
# WHY??

- ❖ Large gas fields have been discovered.  
Coalbed methane is also involved
- ❖ Several potential source rocks are identified
- ❖ Upper Triassic shale is reported as oil source rock
- ❖ **Work on shale gas and shale oil is scarce!!**
- ❖ **Kinetics of petroleum generation??**

Epoch	Group/ Formation	Thickness (m)	Deposystems	Potential Source Rocks
Cretaceous	Zhidan	100–1200	Eolian	
Jurassic	Fenfanghe	100–1200	Alluvial	
	Anding	150	Lacustrine	●
	Zhiluo	200–600	Fluvial	
	Yanan	250–300	Fluvial–lacustrine	●
	Fuxian	0–156	Fluvial	
Triassic	Yanchang	200–1400	Fluvial–lacustrine	●
	Zhifang	1100	Fluvial–lacustrine	
	U.Shihezi	200	Lacustrine	
Permian	L.Shihezi	100–200	Fluvial	●
	Shanxi	37–125	Fluvial	
	Taiyuan	22–276	Nearshore fluvial, deltaic, shallow marine	●
Pennsylvanian	Benxi	0–40	Nearshore fluvial, deltaic, shallow marine	
	Majaigou	100–900	Shallow marine platform	●



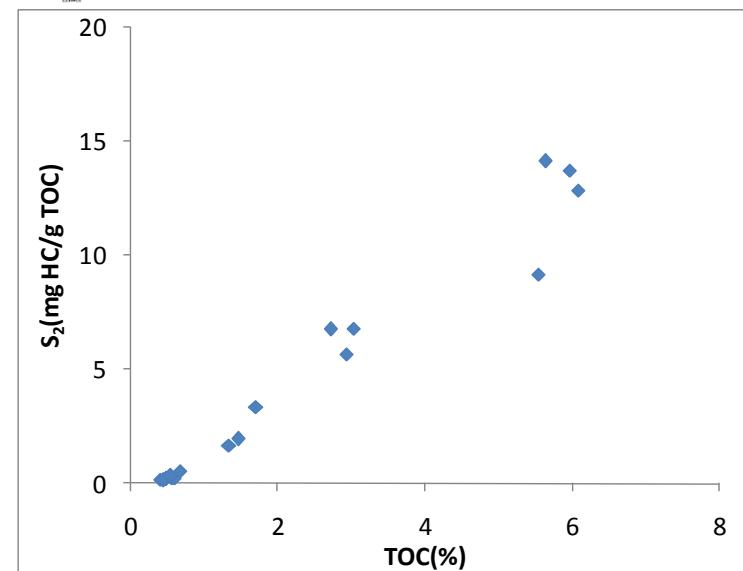
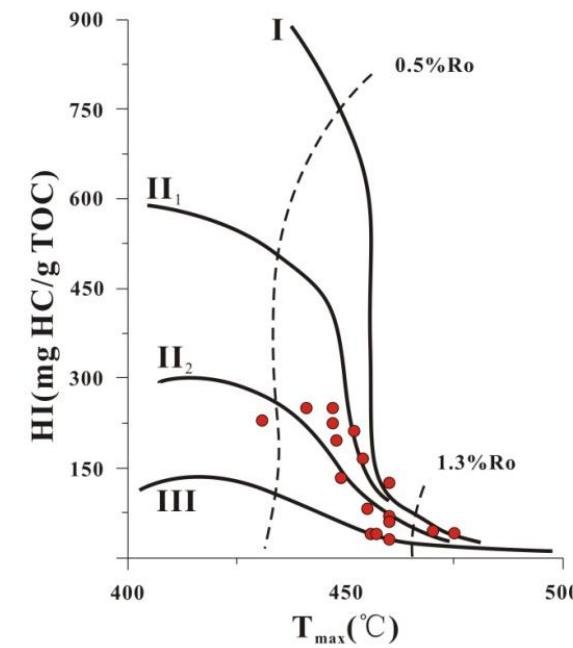
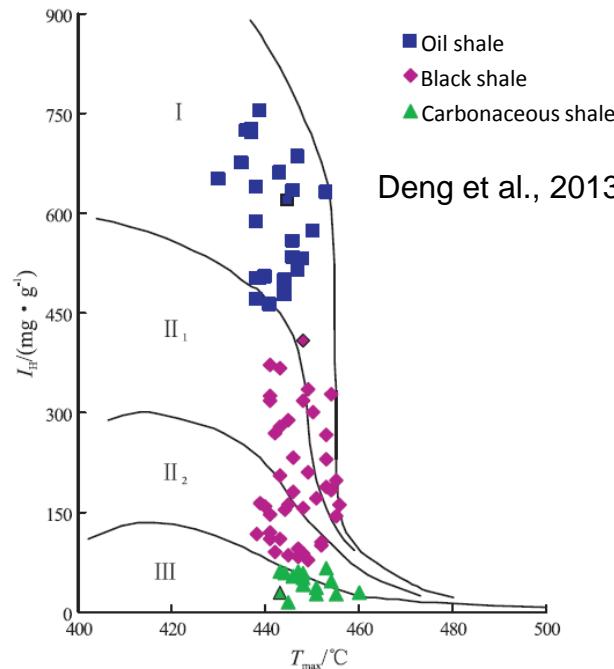
# Geological Setting of Southeast Ordos Basin (SOB)



Lin and Zhang et al., 2013

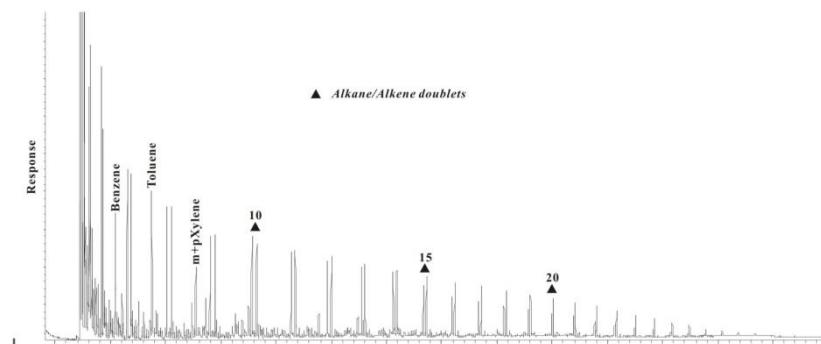
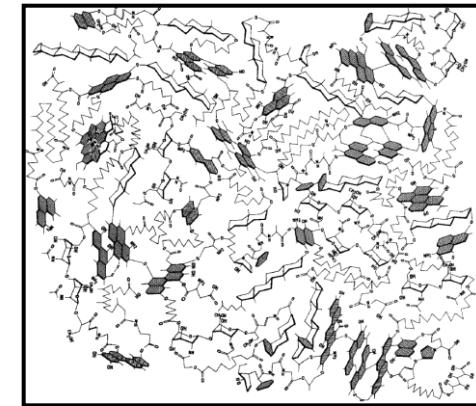
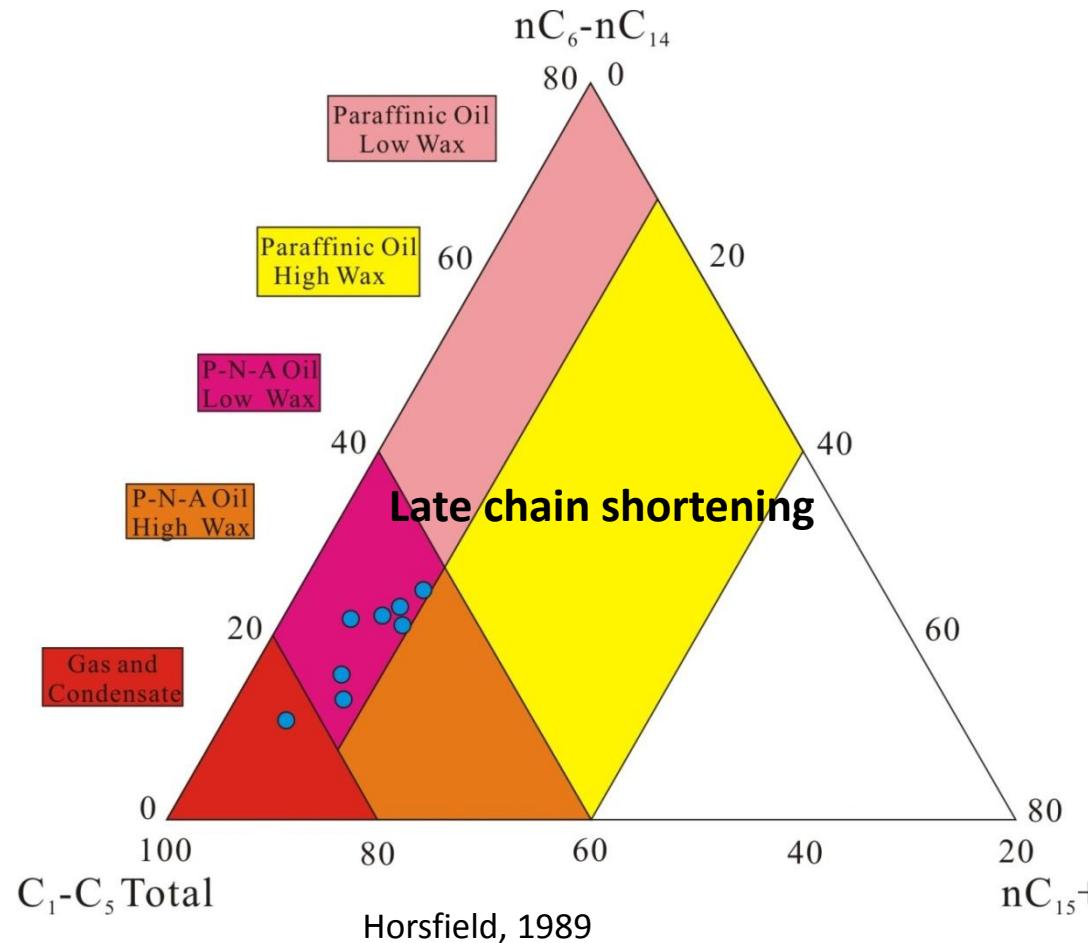


# Geochemical Characterization





# Detailed Kerogen Composition





# High clay content

Liu177, 1470m

Triassic

Ordos Basin

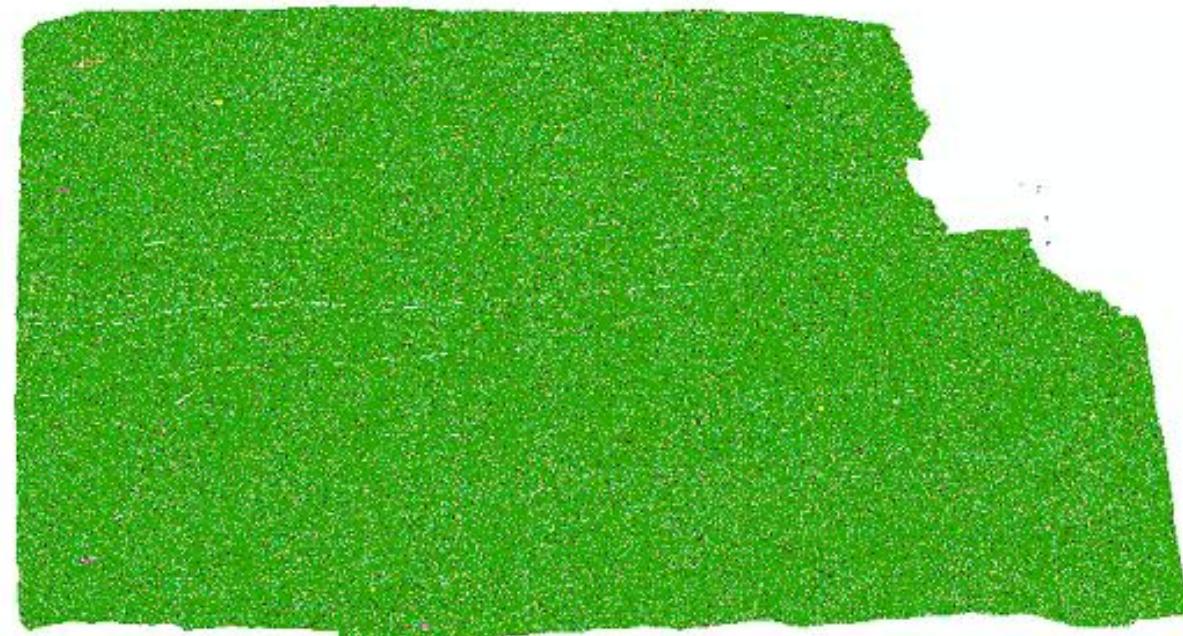
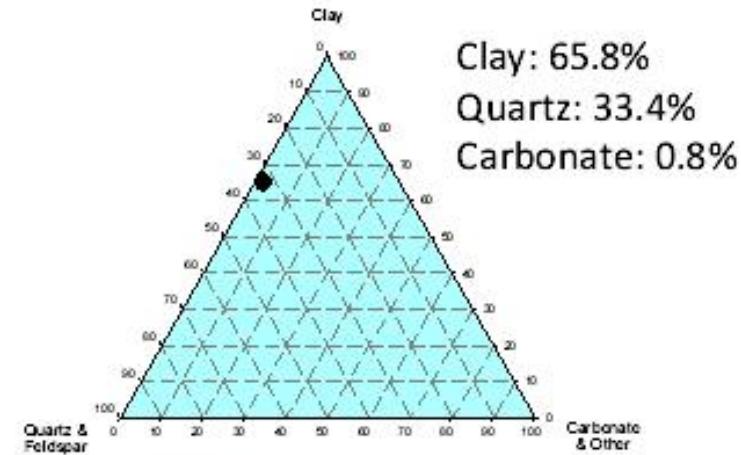
Lacustrine

TOC – 5.24

Ro% – 0.77

Mineral Name	Area %
Illite	80.41
Quartz	5.47
Plagioclase	4.50
Smectites	2.81
Chlorite	1.78
Other Silicates	1.36
Biotite	1.35
Background	0.78
Alkali Feldspar	0.48
Glauconite	0.35
Pyrite	0.34
Other	0.29
Particle Rims	0.27
Micrite	0.15
Apatite	0.14
Dolomite	0.10
Muscovite	0.07
Siderite	0.05
Calcite	0.03
Fe-oxides	0.01
Ankerite	0.01
Rutile	0.01
Kaolinite	0.00
Ilmenite	0.00
Zircon	0.00

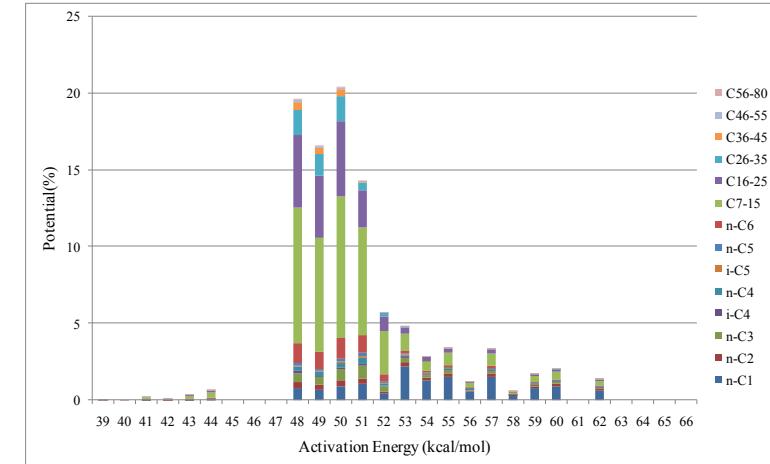
CS104R  
XRD Data





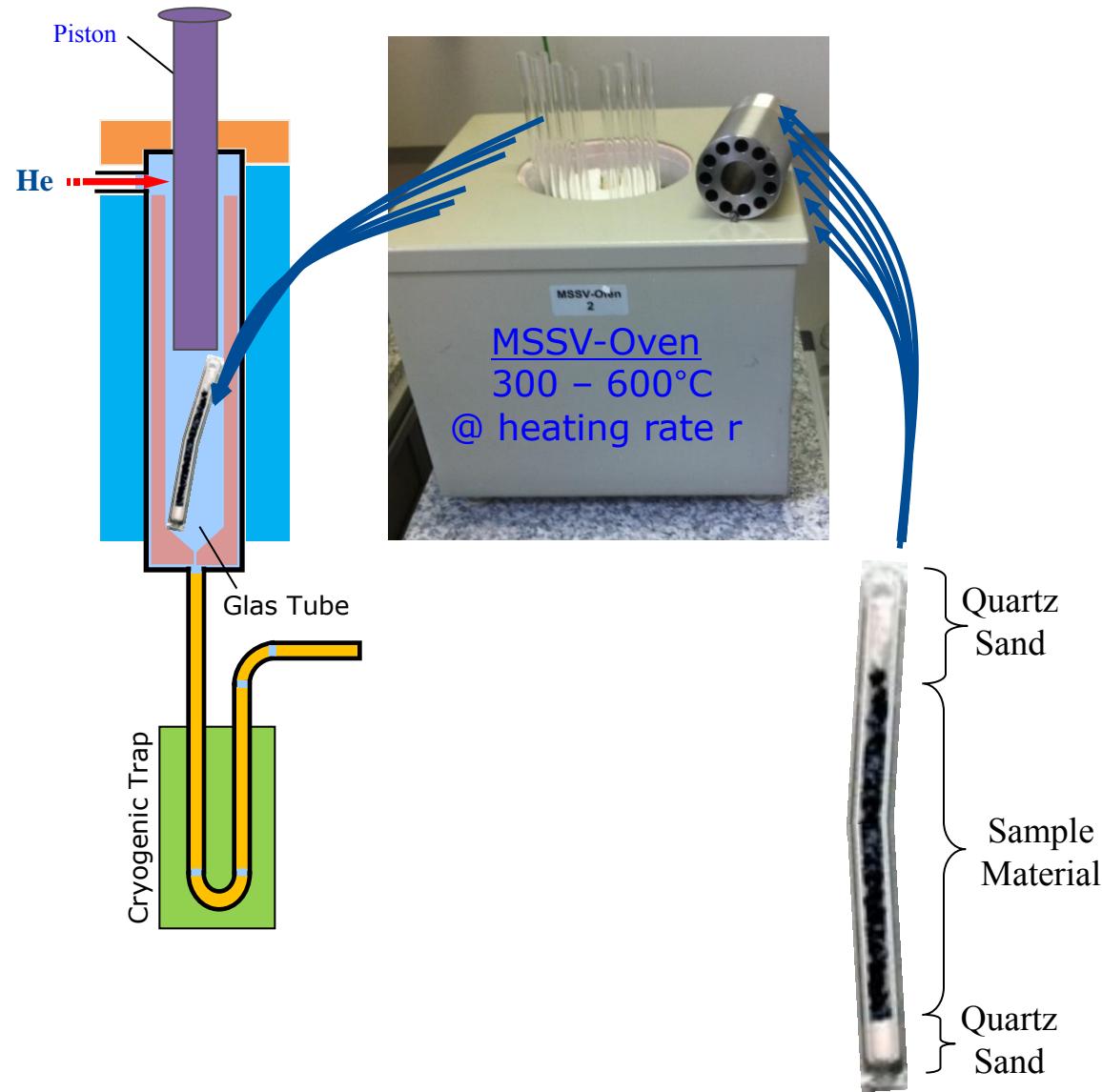
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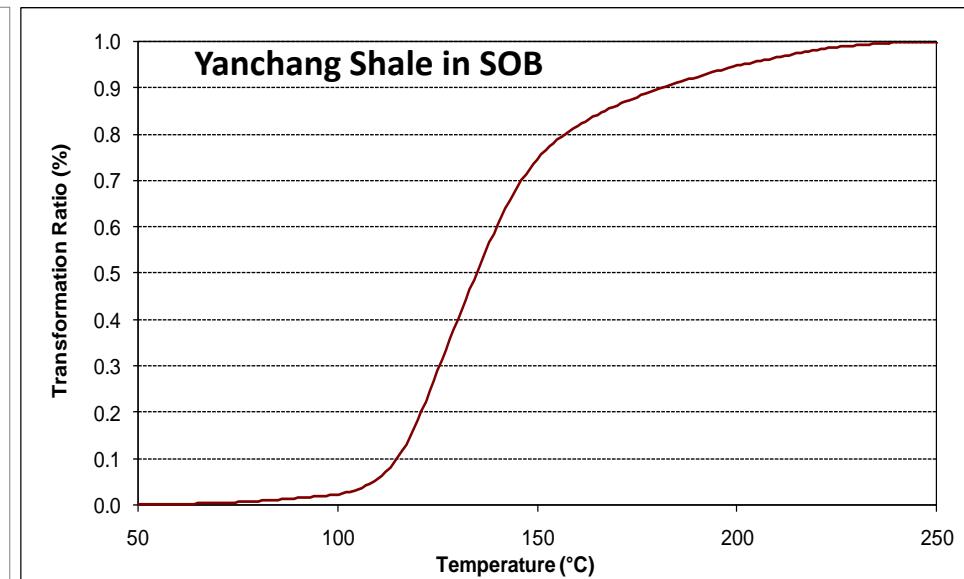
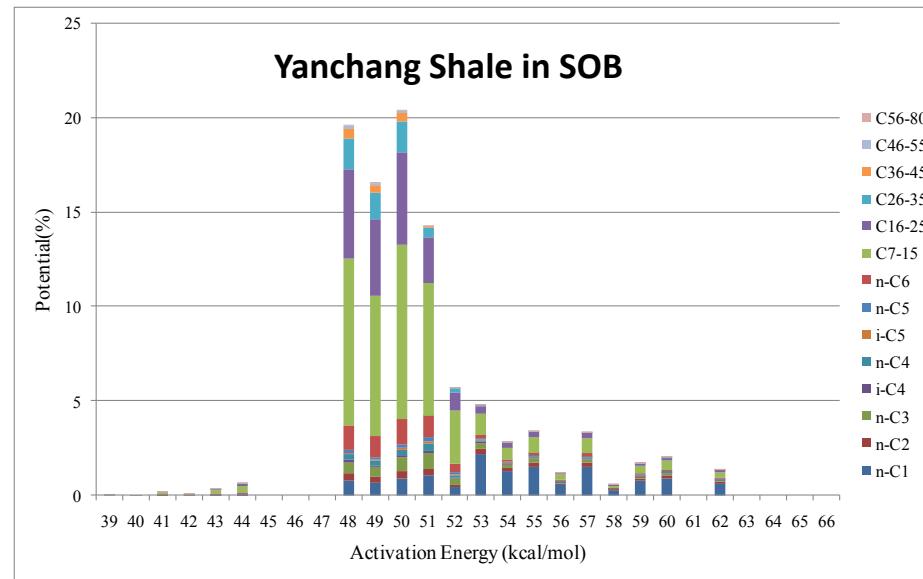


# Closed system pyrolysis (MSSV)

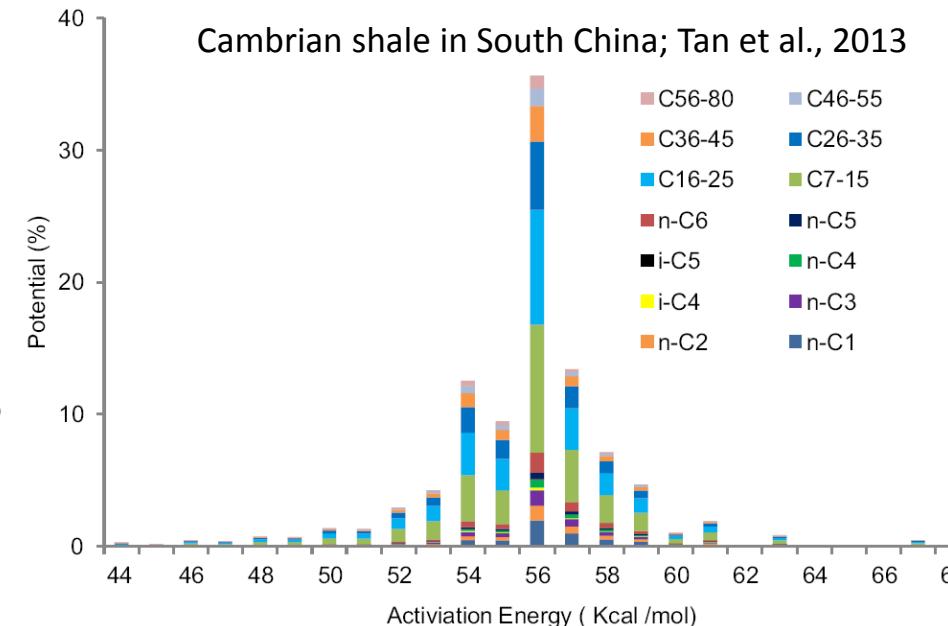




# Bulk and Compositional Kinetics

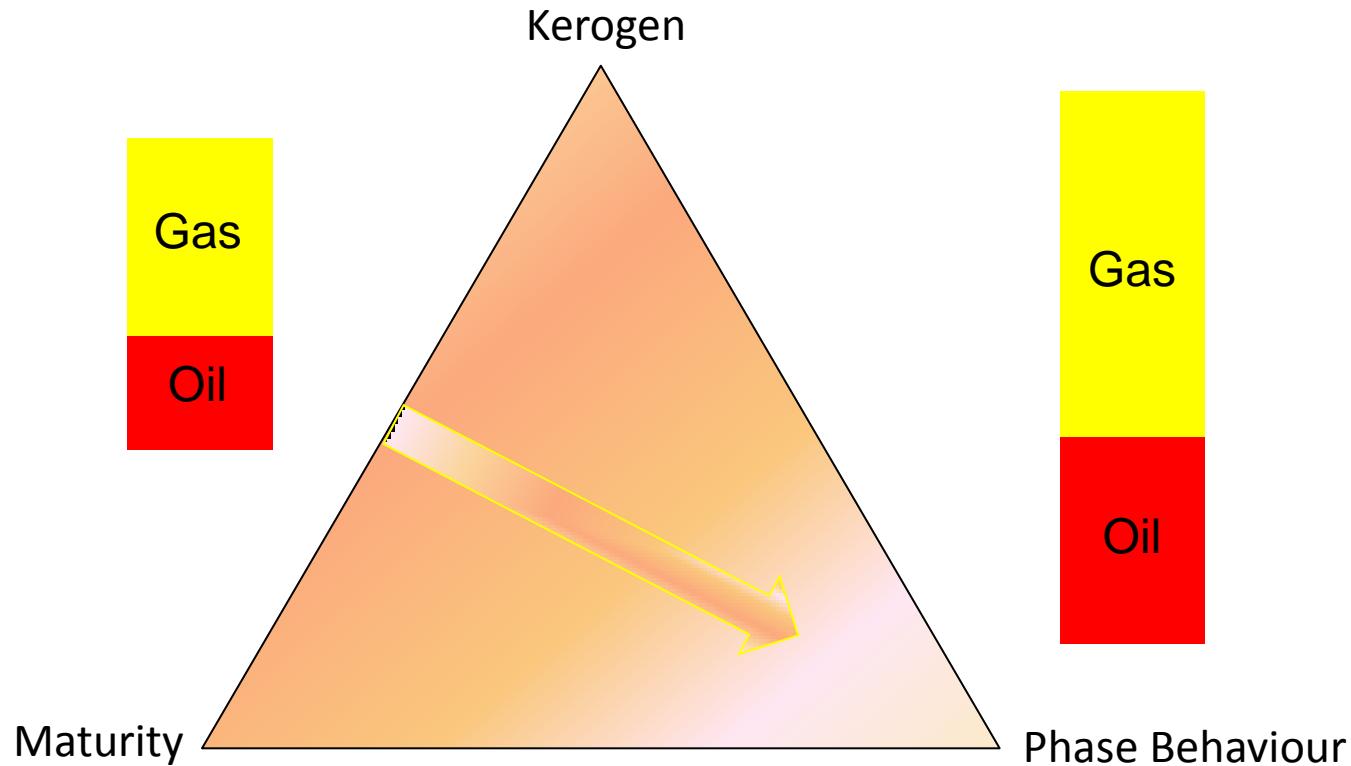


- ✓ Gases are dominated by  $n\text{-C}_1$ ,  $n\text{-C}_2$  and  $n\text{-C}_3$
- ✓ Liquids are dominated by lumped boiling ranges  $C_{7\text{-}15}$  and  $C_{16\text{-}25}$



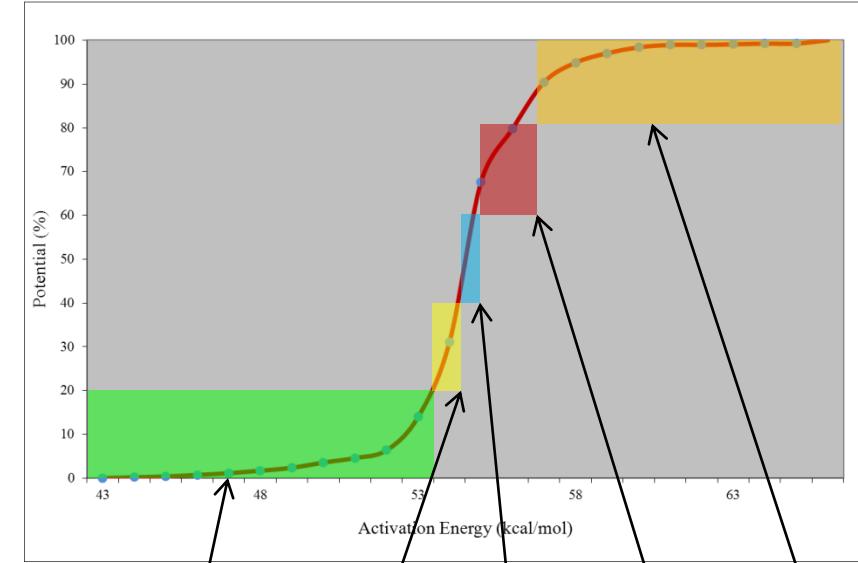
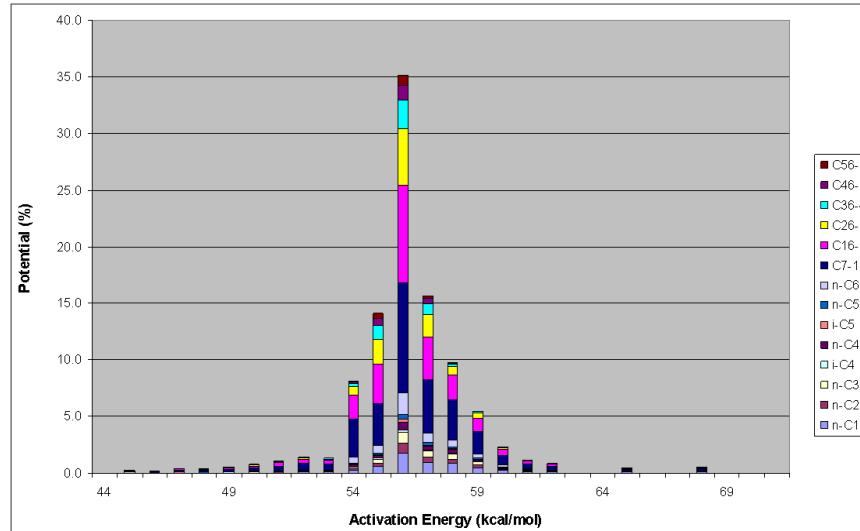
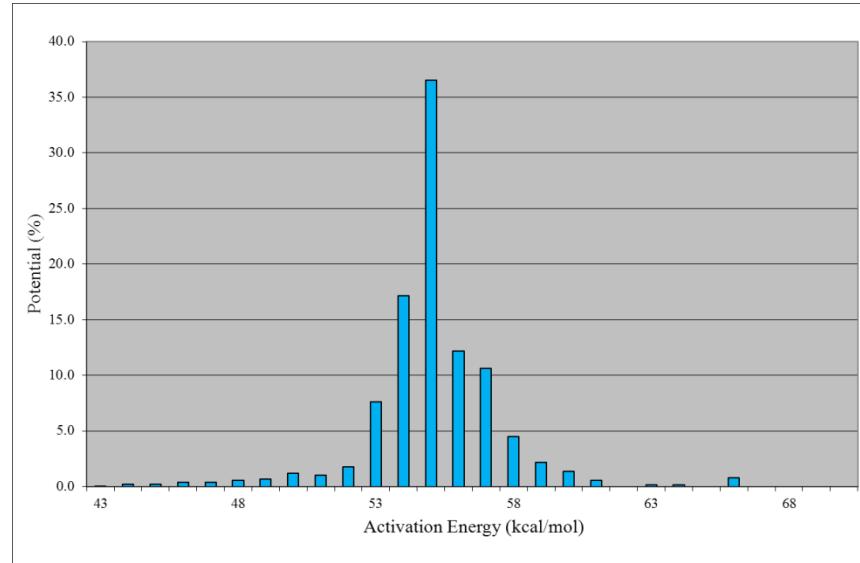


# Phase Behaviour of Generated Hydrocarbons





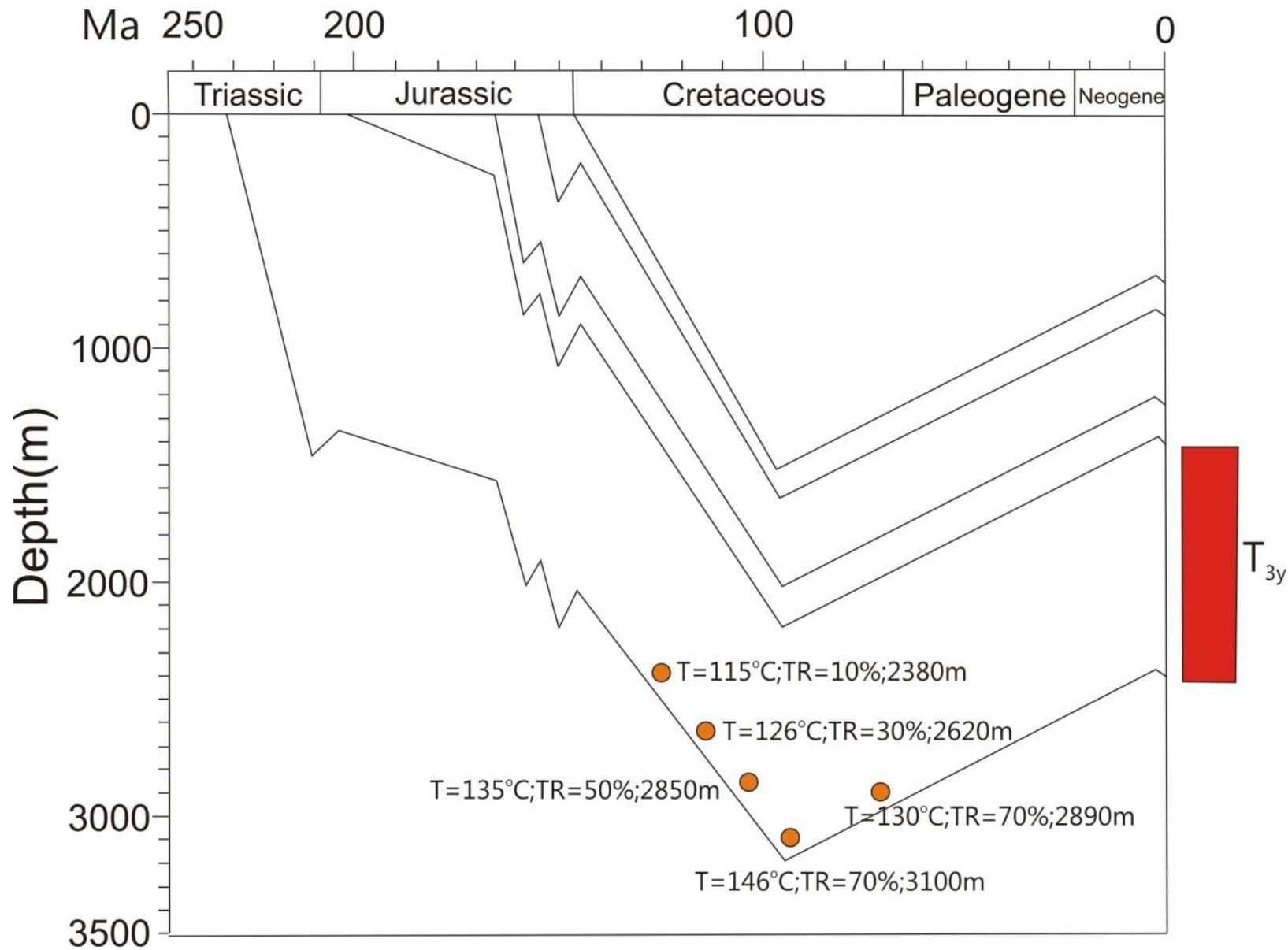
# PhaseKinetics Approach



TR	10	30	50	70	90
<b>n-C1</b>	23.05	25.04	25.53	26.82	34.48
<b>n-C2</b>	11.21	11.42	11.66	11.81	10.39
<b>n-C3</b>	10.46	11.43	11.61	11.59	10.16
<b>i-C4</b>	0.84	0.70	0.70	0.65	0.66
<b>n-C4</b>	5.24	4.74	4.40	4.30	3.67
<b>i-C5</b>	2.34	1.54	1.25	1.17	0.90
<b>n-C5</b>	3.09	3.07	3.08	2.91	2.42
<b>n-C6</b>	9.89	11.69	11.58	11.42	11.20
<b>C7-15</b>	17.00	15.82	16.07	16.22	15.37
<b>C16-25</b>	9.13	8.15	8.07	7.76	6.75
<b>C26-35</b>	4.23	3.61	3.48	3.18	2.52
<b>C36-45</b>	1.96	1.60	1.50	1.30	0.94
<b>C46-55</b>	0.91	0.71	0.65	0.53	0.35
<b>C56-80</b>	0.67	0.49	0.43	0.33	0.19

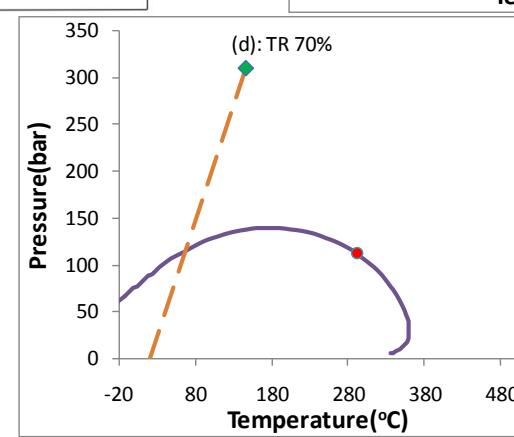
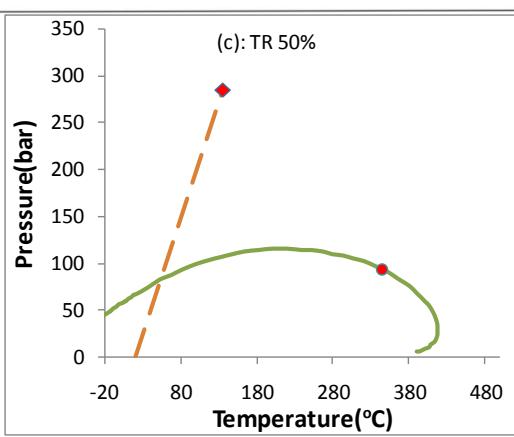
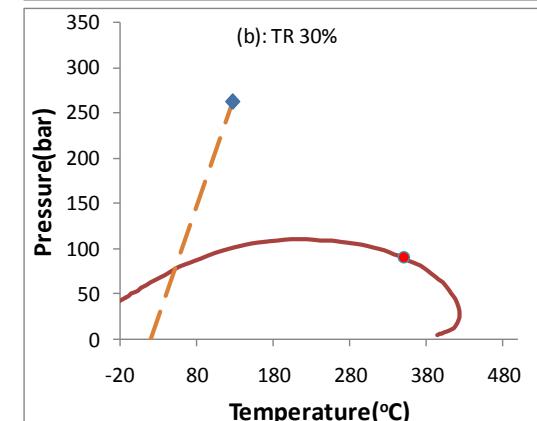
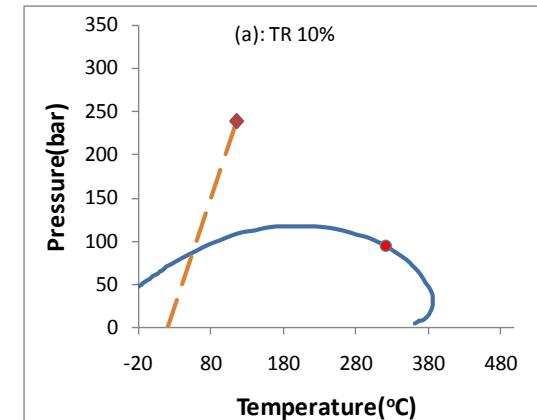
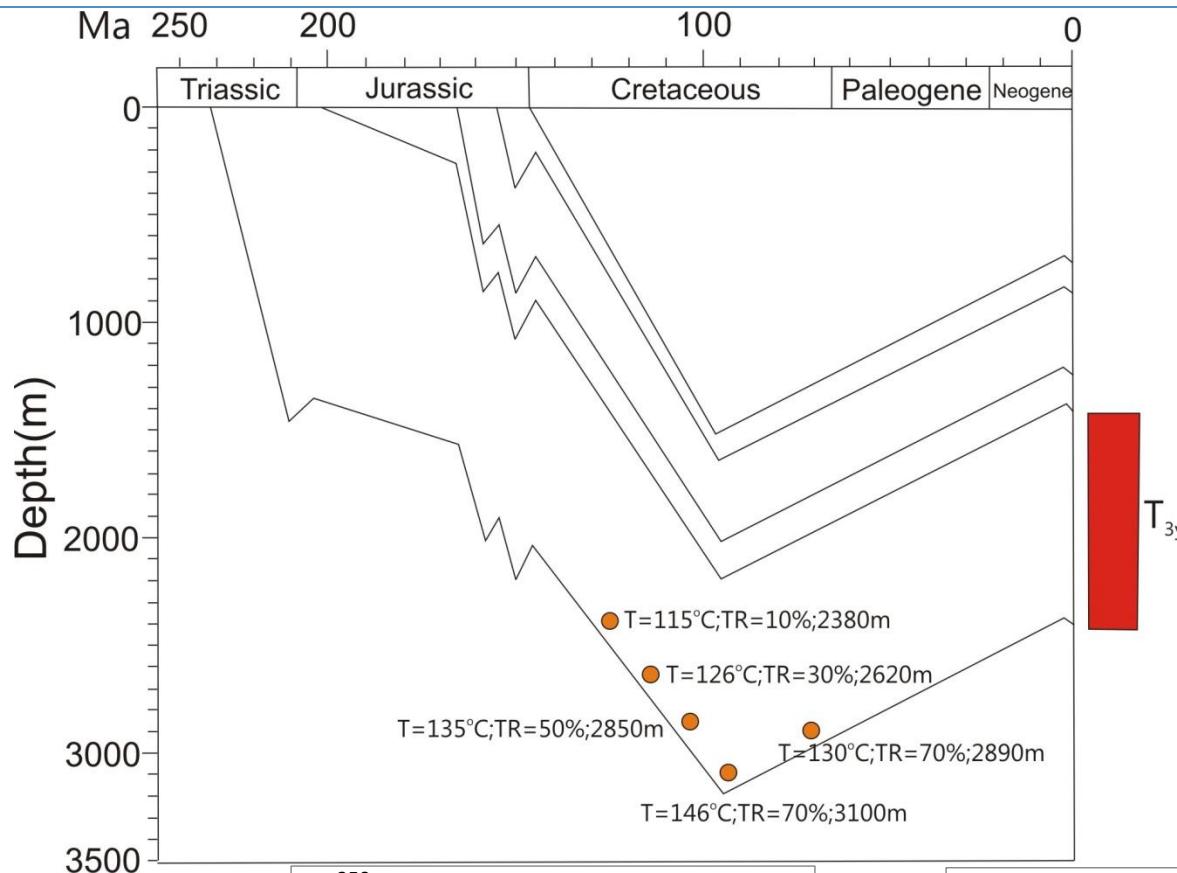


# Phase Behaviour of Generated Hydrocarbons





# Phase Behaviour of Generated Hydrocarbons





# Conclusion

- The organic matter comprises terrigenously influenced type II<sub>2</sub> kerogen which is in the oil to wet gas maturity stage. The detailed kerogen composition shows an organofacies generating PNA low wax oil, with some potential for gas condensate.
- A broad activation energy distribution can be observed and a very broad generation temperature range can be identified extrapolating to the regional context heating rate. Light hydrocarbons (C<sub>1</sub>, C<sub>2</sub>, C<sub>3</sub>, C<sub>7-15</sub> and C<sub>16-25</sub>) dominate the generated products.
- Only a single phase fluid occurred. However, the generated black oils would have evolved into a two-phase fluid if petroleum expulsion and migration occurred.

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**Thanks For Your Attention!**

