Shale Gas Characteristics in the Southeastern Part of the Ordos Basin, China: Implications for the Accumulation Condition and Potential of Continental Shale Gas*

Xuan Tang[1], Jinchuan Zhang[1], Bingsong Yu[1], and Wenlong Ding[1]

Search and Discovery Article #10481 (2013)**
Posted January 31, 2013

*Adapted from oral presentation at AAPG International Conference and Exhibition, Singapore, 16-19 September, 2012

[1]China University of Geosciences, Beijing, China (tangxuan@cugb.edu.cn)
[2]Petroleum Exploration and Research institute, CNOOC Shenzhen branch, GuangZhou, China.

Abstract

Marine shale gas has recently gained significant success in USA, and has triggered a world-wide fever on shale gas resources. In contrast there has been little work on and less attention to continental shale gas. Continental shales are widespread in northern China. They are characterized by low thermal maturity and high clay content, significantly different from that of marine shale documented in USA and elsewhere. There is an urgent need to characterize continental shales and evaluate their gas potential as a viable resource.

Triassic strata of the Chang-7 Member of the Yanchang Formation in the southeastern part of the Ordos Basin contain typical continental shale. Recently some vertical wells were drilled and produced up to 3000 m^3 per day after fracturing. Shale samples collected from the base of the Chang-7 Member show that Chang-7 shale and mudstone were developed in shallow to deep lacustrine environments. Clays account for 40% to 60% of the mineral composition. The percentage of the brittle minerals is lower than that reported in the marine shales. The shales are characterized by relativelylow thermal maturity with vitrinite reflectance 0.7% to 1.5%, predominantly Type I-II kerogen, and a rather good organic content (TOC range of 1.5% to 4%). The shale gas is primarily thermogenic gas associated with oil generation, as it is presently still in the oil to wet gas windows. The gas shale in the Chang-7 Member is interbedded with oil shale layers, which differ from shale gas accumulations presently successfully developed around the world. Desorption gas measured from fresh core yields 1.25-5.75 m^3/t, more than that reported in the Barnett Shale, suggesting such a low maturity shale (Ro: 0.7% to 1.5%), as in the Chang-7 Member succession in the Ordos Basin, could possess significant gas potential.

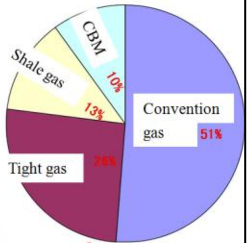
Shale Gas Characteristics in the Southeastern Part of the Ordos Basin, China

Xuan TANG, Jinchuan ZHANG
Bingsong Yu, Wenlong DING

China University of Geoscience, Beijing

18/09/2012

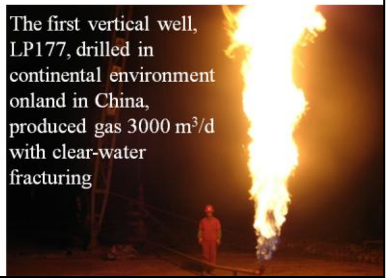
Question



Marine shale gas has recently gained significant success in USA and has triggered a world-wide fever on shale gas resources.

In contrast there is little work done and less attention on the continental shale gas. Continental shales are widespread in northern China.

There is an urgent need to characterize continental shales and evaluate their gas potential as a viable resource.



Presenter's notes: Marine shale gas recently has gained significant success in USA (shale gas composes 13 percent of total gas production). This success has triggered a worldwide fever on shale gas resources. In contrast there is little work/attention on continental shale gas. Continental shales are widespread in northern China, and are the most significant source rock for huge oil fields in the north and east of China. The first vertical well, LP177, drilled in continental environment strata in onland China, produce gas 3000 m^3/d with clear water-fracturing; horizontal drilling is undergoing so we can see if they have significant resource potential. There is an urgent need to characterize this kind of shale and evaluate its gas potential as a viable resource.

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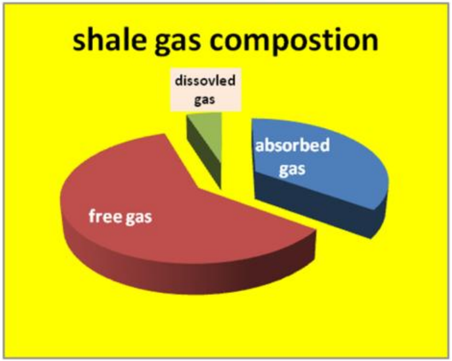


Focus : The characteristics of continental shales & main controlling factors for shale gas accumulation of different shale gas types

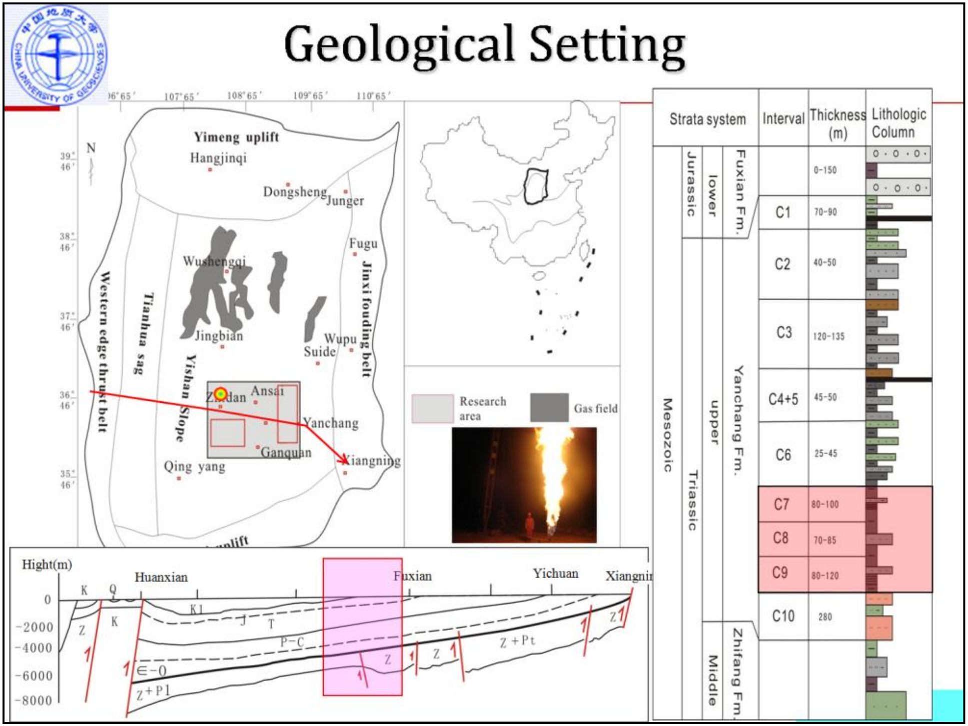
Outline

1 *Geological Setting*

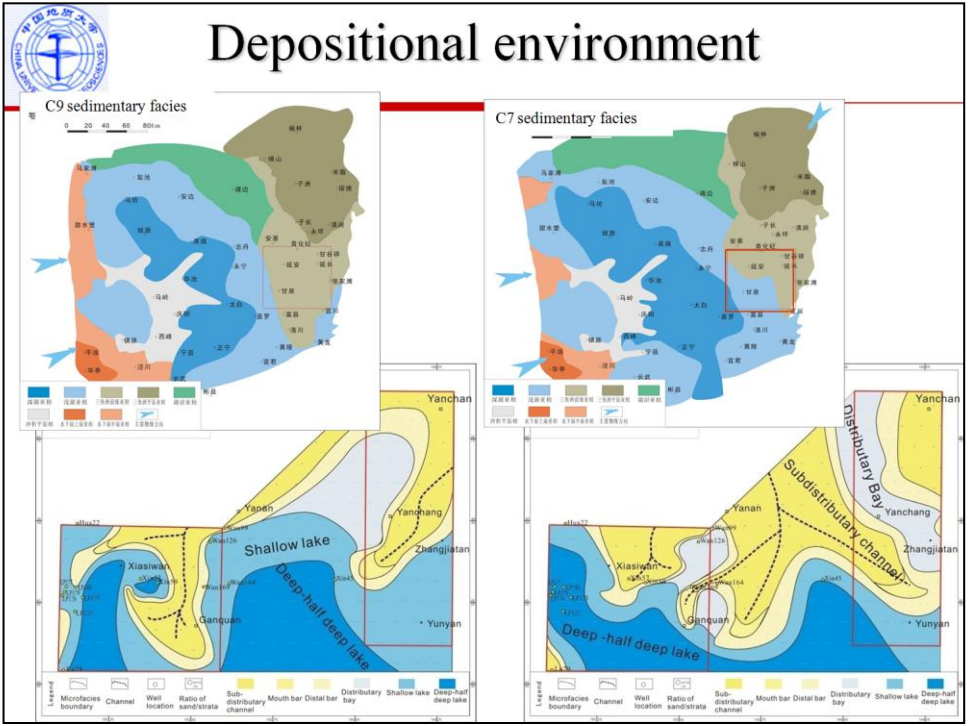
2 Continental Shale Characteristics

3 Main Controlling Factors for Continental Shale Gas Accumulation

4 Conclusions

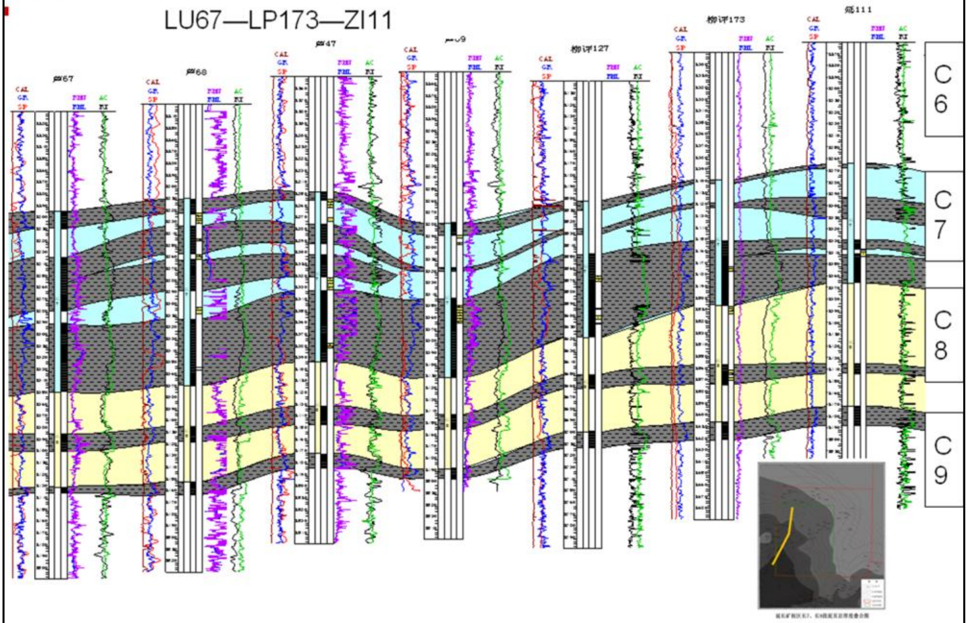


Presenter's notes: In Ordos basin, located in the middle part of northern China, there are large conventional oil and gas fields (the northern part of this basin. As a whole, the basin is a foreland basin, with a large-scale extended simple slope in the eastern part of the basin. Triassic Yanchang Formation was deposted in typical continental lacustrine environment; the formation can be divided into ten sections (from C1 to C10 intervals from top to bottom). The C7 to C9 interval is shale-rich. The southeastern part is my research area, where vertical well Lp 177 has produced 3000m^3/day.



Presenter's notes. Most of the southern part of the area shown here is deep to shallow lake.

Lacustrine Shale Spatial Distribution



Presenter's notes: On SSW-NNE cross section (in research area), lacustrine shale in C7 is distributed widely and rather uniformly thick; average thickness of 60m; interbedded are 2 to 3 tight sand beds. C9 shale is thinner, with thickness of 20-30m.

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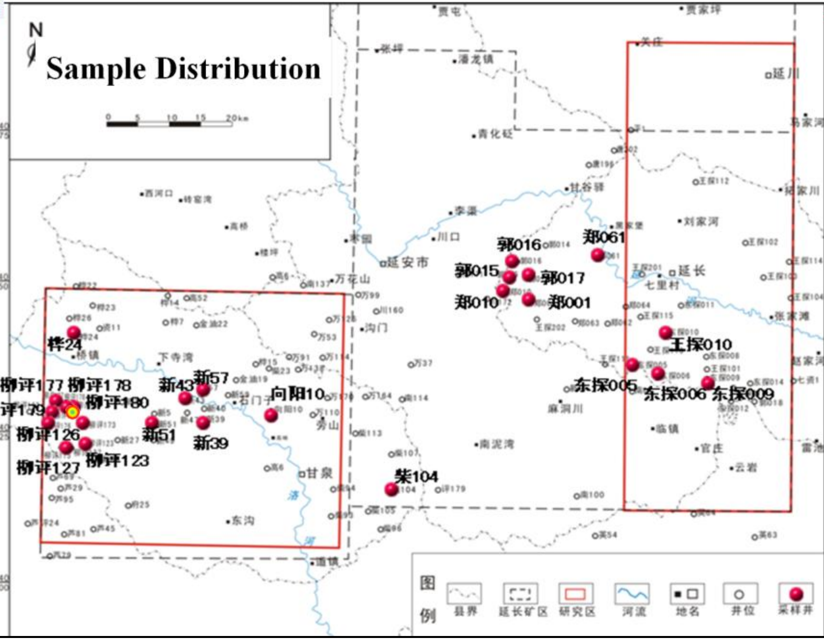
Presenter's notes: Follows are the characteristics of the continental shale in Triassic of Ordos basin and shale gas characteristics.

Shale characteristics

Shale gas characteristics

Samples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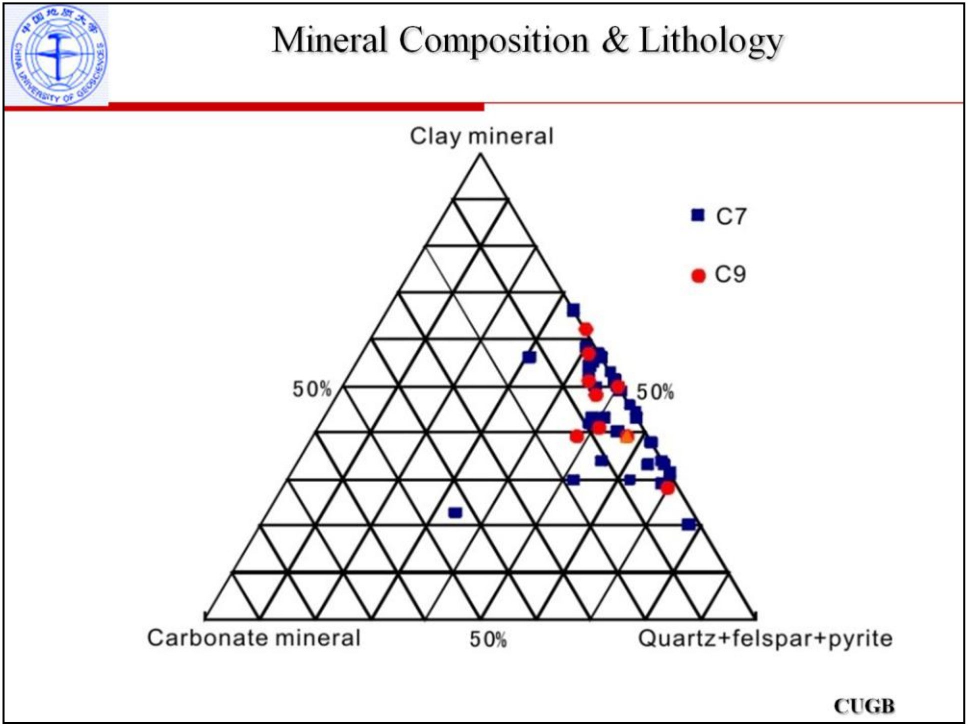
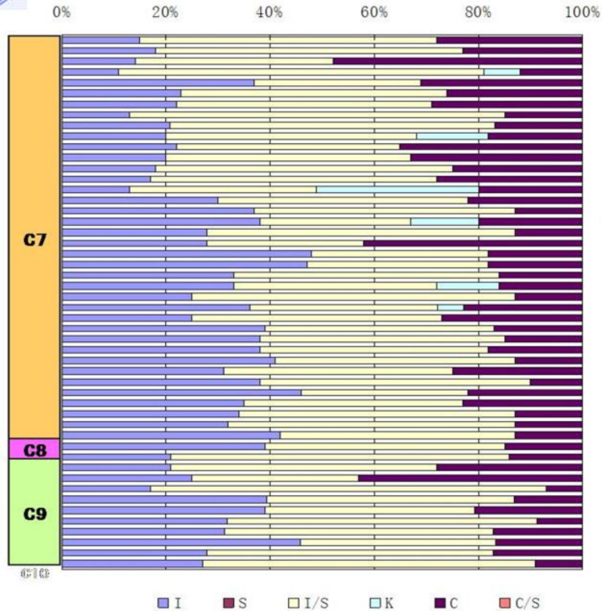
Sample Distribution
0 5 10 15 20km
郭016
郑061
郭015
郭017
郑010
郑001
王探010
东探005
东探006
东探009
柴104
向阳10
新57
新43
新51
新39
柳评177
柳评178
柳评180
柳评126
柳评123
柳评127
延安市
延长
甘泉
图例
县界
延长矿区
研究区
河流
地名
井位
采样井

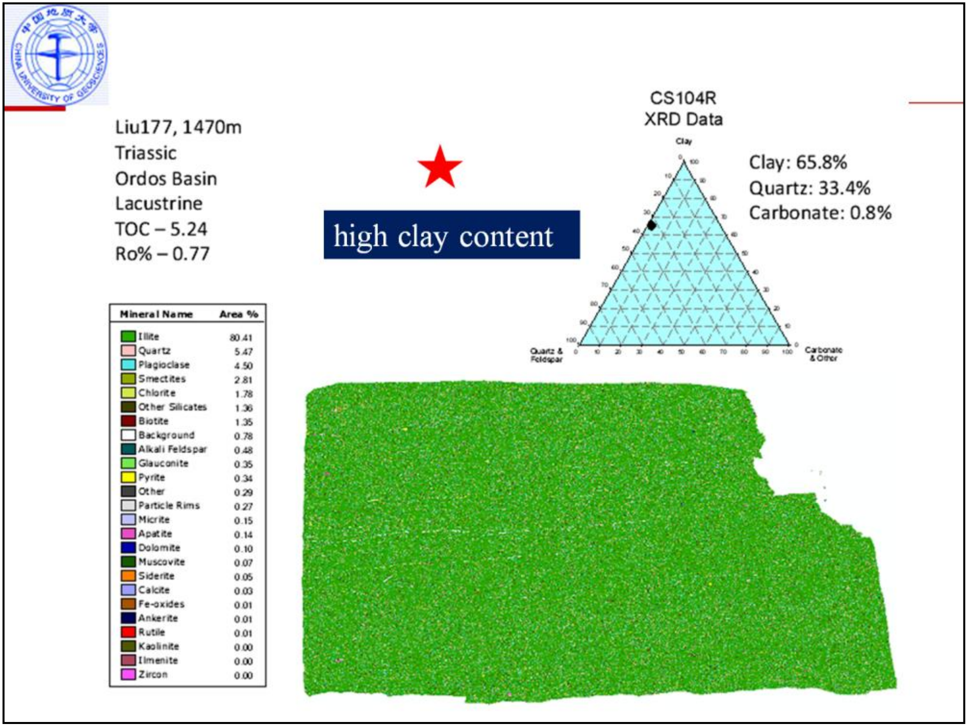


Presenter's notes: Analysis of shale samples shows that C7 and C9 shales are composed by brittle minerals and clay minerals (almost half and half).

Clay Mineral Composition

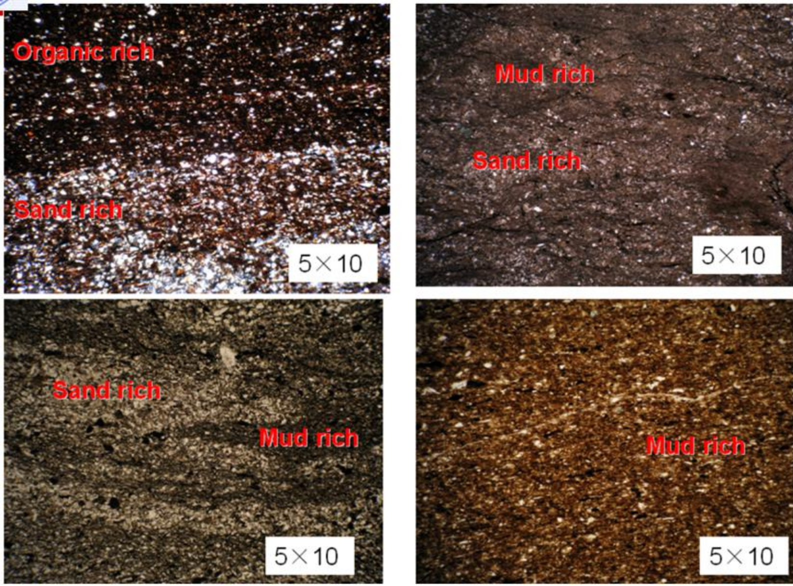


Among clay minerals, illite is predominant, also illite/smectite, chlorite, smectite



Presenter's notes: Quaemscan picture shows that some shale samples are homogeneous, basically of illite.

Shale Heterogeneity



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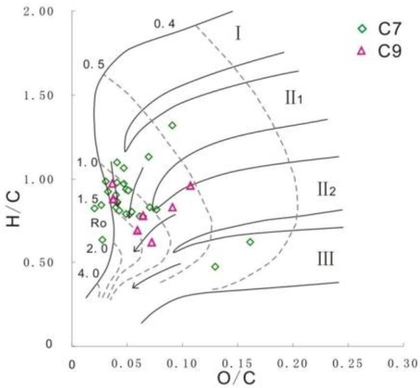
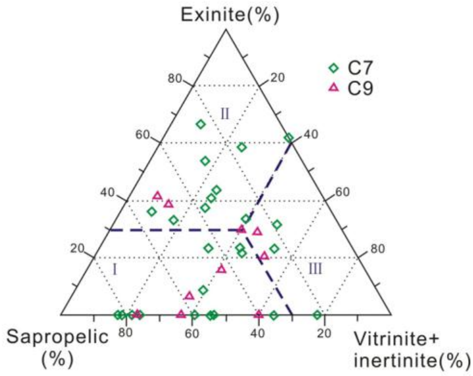
Presenter's notes: However, most shale samples are heterogeneous; for example, these photographas show that some layers are organic-rich; some layers are sand-rich; some are mixed; some are pure mud.

Geochemical characteristics





Kerogen type: Ⅱ1-Ⅱ2

Vitrinite reflectance (Ro) ranging 0.5%-1.5%, mostly 0.8-1.5%

Kerogen type: Ⅰ1-Ⅱ2mostly

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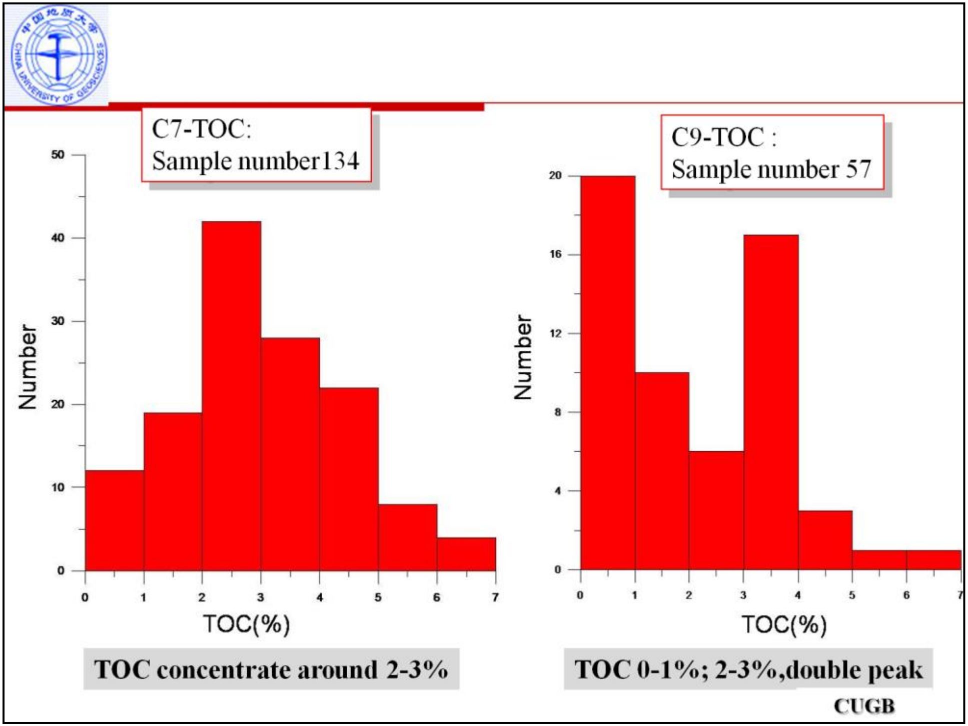
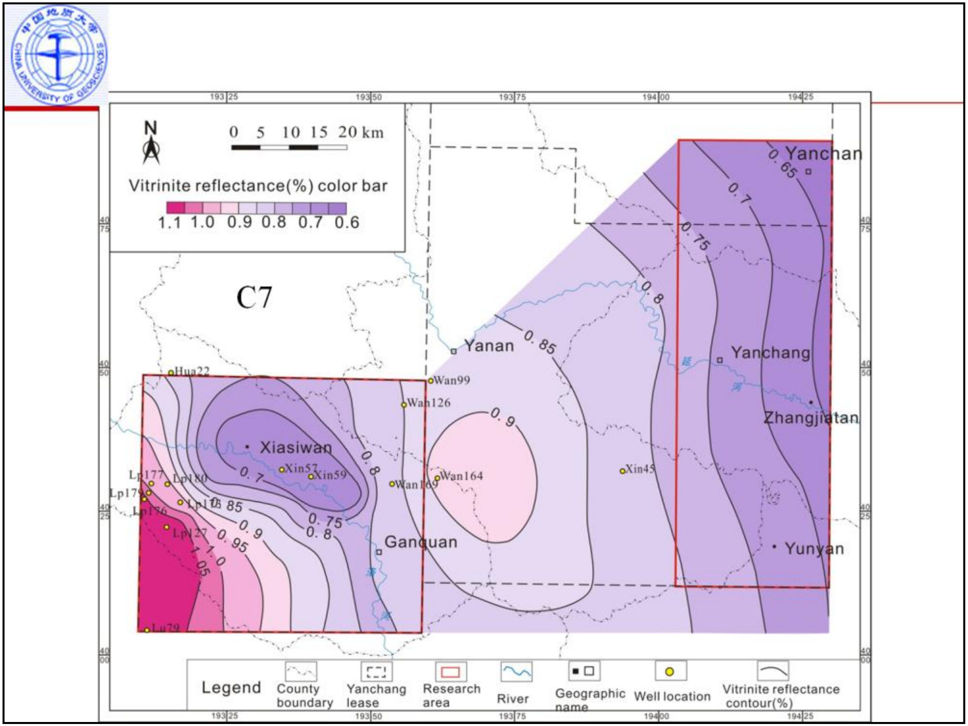
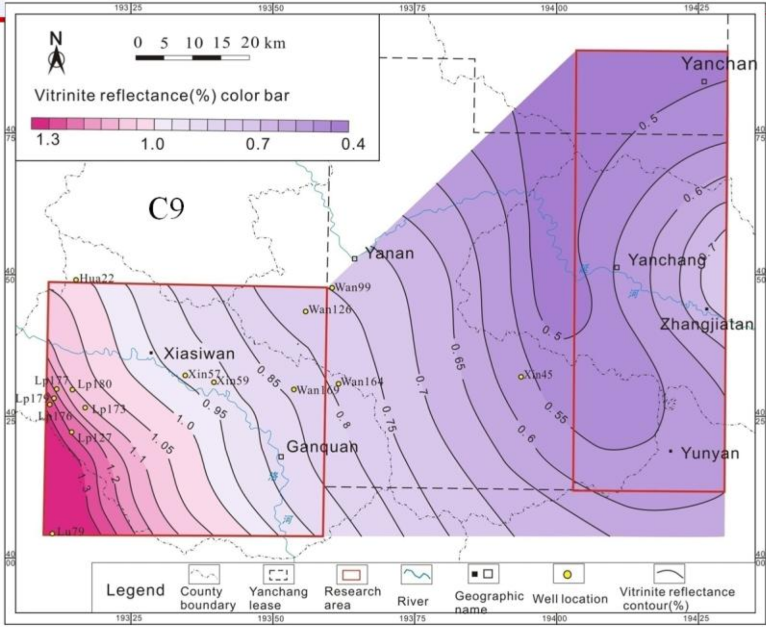
Presenter's notes: Kerogen type is mostly Type I-II; vitrinite reflectance ranges from 0.5 to 1.5%; most values are 0.8 to 1.5%; this means much of the organic matter in shale in this area are just entry in the the oil window thermal stage.



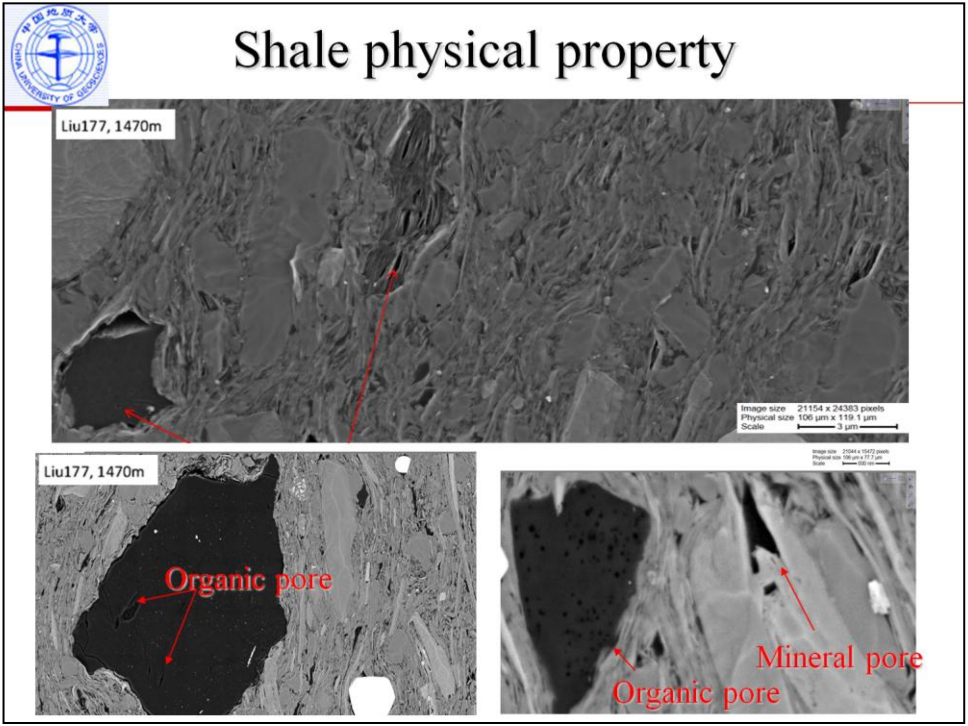
Presenter's notes: Total organic carbon content in 134 samples from C7 and C9 average 2-3%.



Presenter's notes: The vitrinite reflectance of C7 shows that only in just southwestern part of the research area is in the oil window; in most of the research area C7 is less mature.

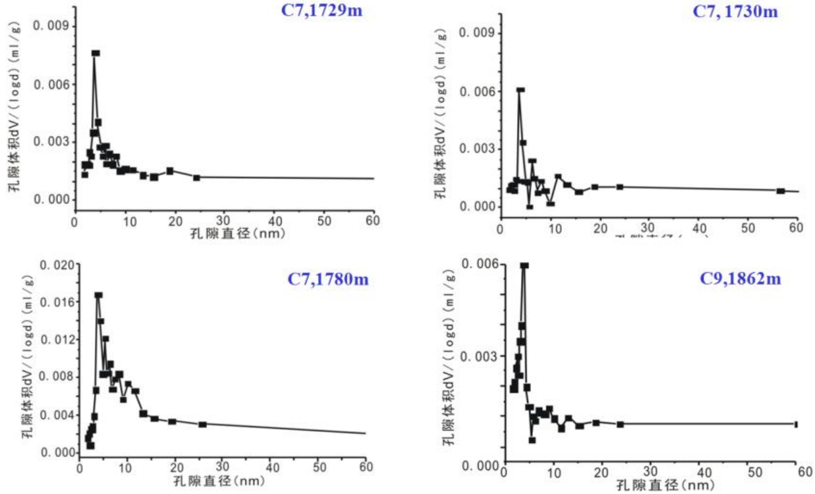


Presenter's notes: The vitrinite reflectance of C9 has similar but relatively higher maturity values; in the western part C9 is more mature.



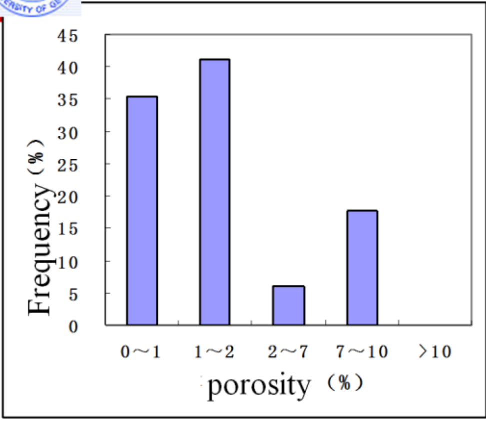
Presenter's notes: Ion-smoothed SEM photographs show shale pores; there are three types—organic, mineral, fracture. Organic pores are well developed, and mineral pores also could make significant contribution to the porosity of shales.

Pore diameter distribution of shale samples from LP171



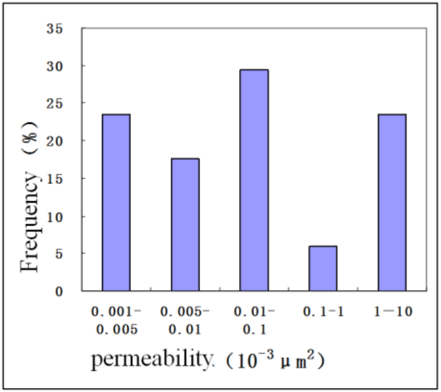
Pore diameter ranging from 1-2nm to >20nm, based on BET surface area analysis.

Presenter’s notes: BET surface area analysis shows that the pore diameter of shale samples ranges from 1-2 to greater than 20 nanometers something. Most are 5 to 10 namometers in diameter.



Major of effective porosity: 0-2%.

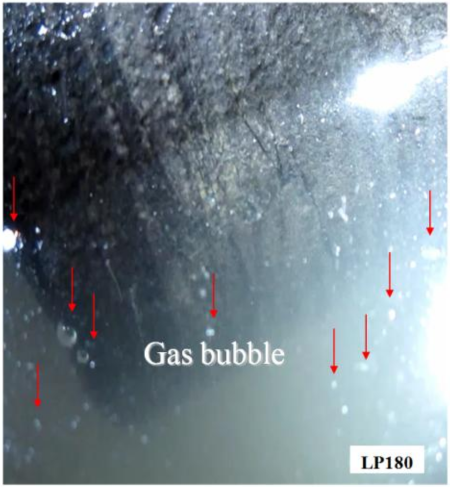
Permeability of matrix is generally less than 0.1 md.

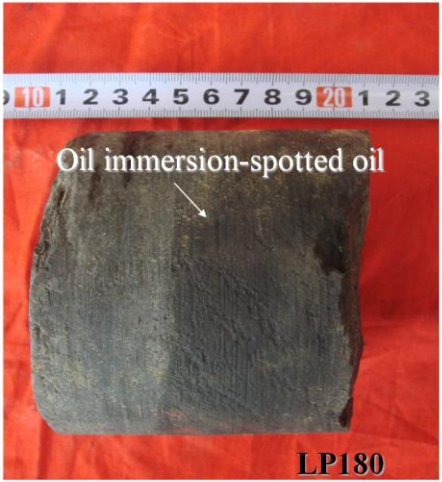


Shale characteristics

Shale gas-bearing and characteristics

Unique Characteristics-- Gas & Oil Paragenesis



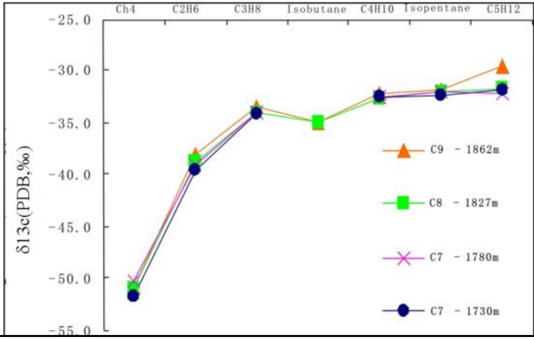


Gas Genesis

Stable carbon isotope of desorption gas from well LP171

Strata	Depth (m)	δ13C (PDB, ‰)						
		CH_4	C_2H_6	C_3H_8	isobutane	C_4H_{10}	isopentane	C_5H_{12}
C7	1730	-51.8	-39.6	-34.2	0.0	-32.6	-32.4	-31.9
C7	1780	-50.3	-39.1	-34.0	0.0	-32.5	-32.1	-32.2
C8	1827	-50.9	-38.8	-34.1	-35.1	-32.7	-32.1	-31.8
C9	1862	-50.9	-38.1	-33.6	-35.0	-32.3	-32.0	-29.7

Shale gas from C7 and C9 have same stable isotope characteristics.



Shale gas δ13C1 ranging from -55‰ - -35‰ shows its genesis (oil-associated).

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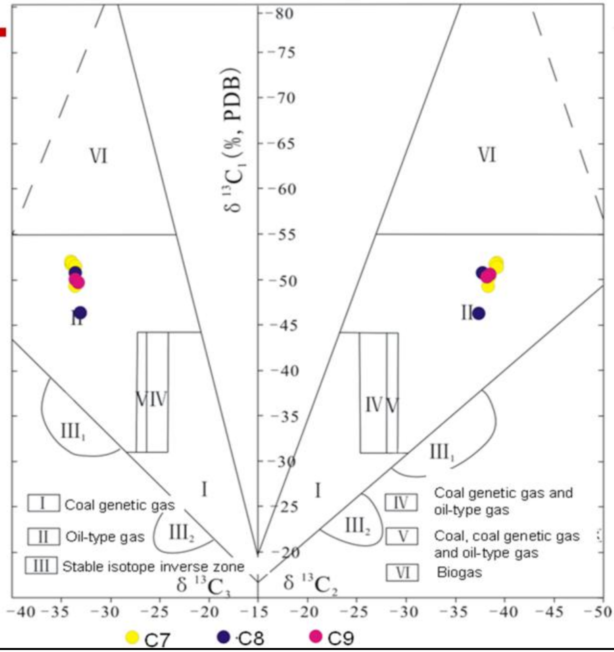
Gas Genesis: Oil-Type Gas



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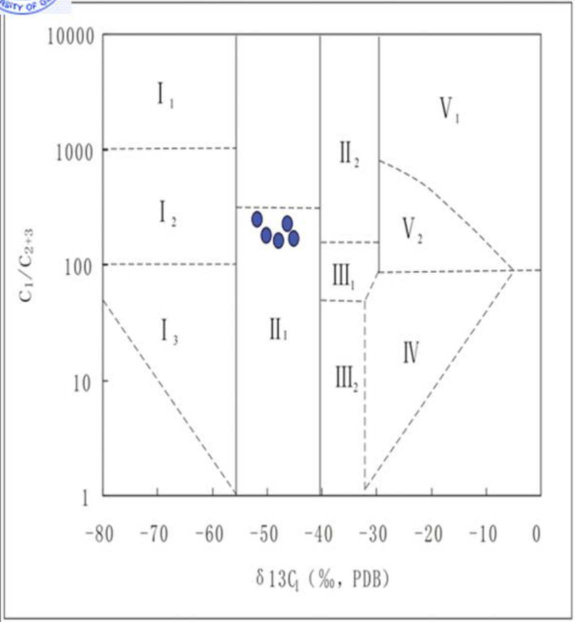
Presenter's notes: Isotope chart also shows the same result--the shale gas is oil-type gas.

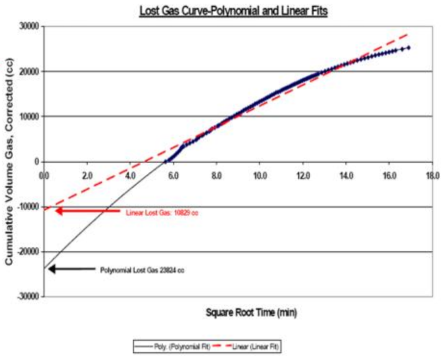
Gas Genesis: Oil-Associated Gas



Legend

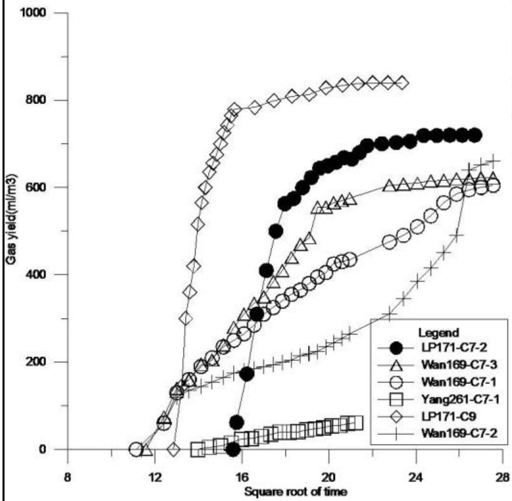
- I1—Biogas
- I2—Biogas and sub-biogas
- I3—Oil-associated gas
- II1—Oil-associated gas
- II2—Oil-type cracked gas
- III1—Oil-type cracked gas and coal-type gas
- III2—Condens oil-associated Gas and coal gas
- IV—Coal genetic gas
- V1—Inorganic gas
- V2—Inorganic gas and coal genetic gas

Gas-bearing: Amount



Well Wan 169 desorption gas calculations

	depth (m)	Linear gas desorption (m3/t)	Polynomial gas desorption (m3/t)
C7	973	1.548	2.143
C7	974.4	3.4832	3.876
C7	976.7	4.646	7.714
C9	1129.67	2.28	4.978
C9	1131.38	3.9514	8.986
C9	1133.7	4.614	5.098

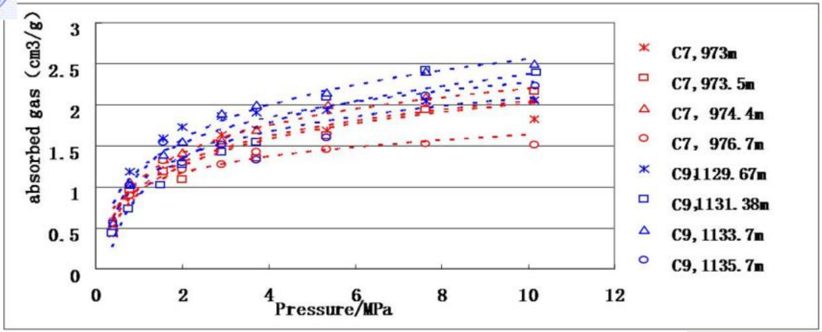


Gas desorption curve in site

Presenter's notes: As shown before, gas-occurring in shale can be free, absorbed, and dissolved; the first two are more common. Gas adsorption from shale core may include both absorbed gas and free gas. Howver, it is not known how much gas is lost when core samples during ascent to the surface. Here linear and polynomial fits can give different values of lost gas. We use them as the upper and lower estimate of lost gas.

Isothermal Adsorption

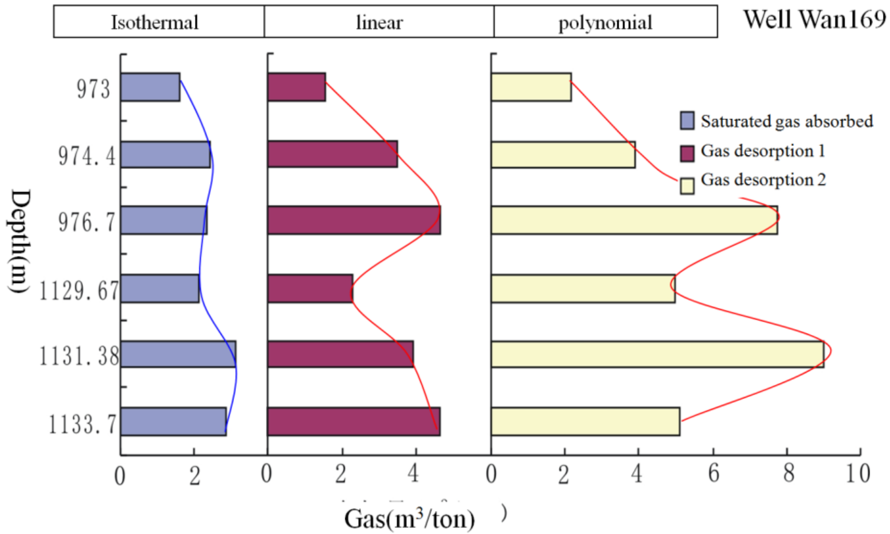
Wan169 C7



Sample	Detph (m)	0.42MPa	0.81MPa	1.56MPa	2MPa	2.93MPa	3.73MPa	5.36MPa	7.63MPa	10.16MPa
W169-L-1	973	0.42	0.88	1.21	1.34	1.63	1.7	1.68	1.98	1.83
W169-L-2	973.5	0.47	0.97	1.18	1.09	1.52	1.35	1.62	1.93	2.16
W169-L-3	974.4	0.51	1.05	1.34	1.41	1.57	1.7	2	2.1	2.06
W169-L-7-1	976.7	0.58	0.89	1.31	1.21	1.27	1.42	1.46	1.52	1.51
W169-L-9-1	1129.67	0.45	1.18	1.59	1.77	1.86	1.76	1.74	1.9	1.99
W169-L-9-4	1131.38	0.43	0.73	1.02	1.27	1.42	1.54	2.09	2.42	2.39
W169-L-9-3	1133.7	0.56	1.02	1.39	1.55	1.89	2	2.15	2.4	2.5
W169-L-9-2	1135.7	0.55	1.02	1.54	1.29	1.51	1.33	1.6	2.11	2.23

Presenter's notes: Isothermal adsorption experiments can show the shale gas adsorption capacity, changing with increasing pressure. Here as pressure reaches about 8 to 10 mpa, the absorbed gas does not change much; this absorbed gas may represent saturated gas adsorption capacity.

Gas Phase & Composition



Desorption gas is much more than saturated absorbed gas; this means free gas takes up significant percentage

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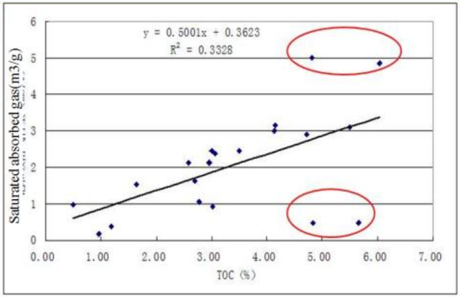
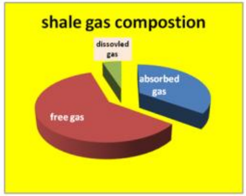
2 Continental Shale Characteristics

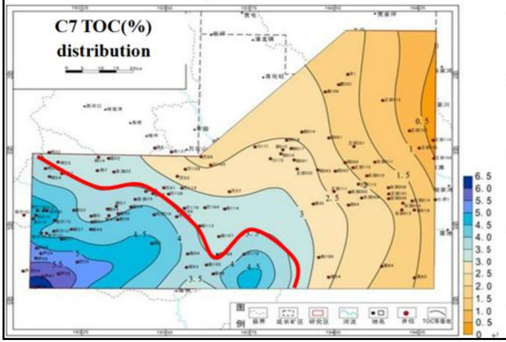
3 *Main Controlling Factors for Continental Shale Gas Accumulation*

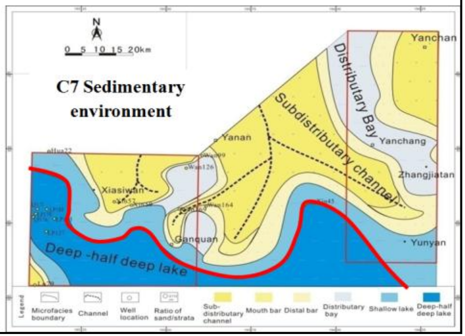
4 Conclusions

Absorbed Gas Controlling Factors

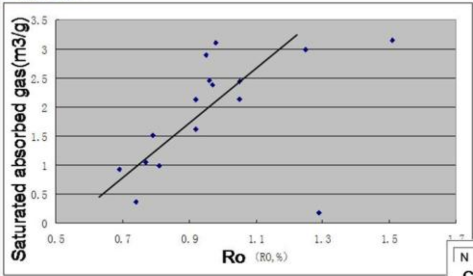




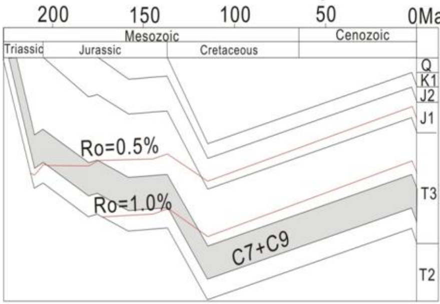


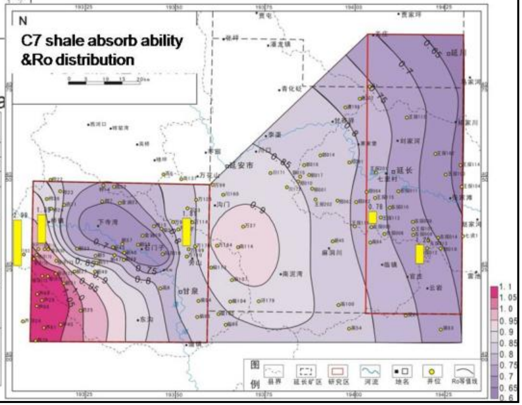


Absorbed gas also controlled by thermal maturity

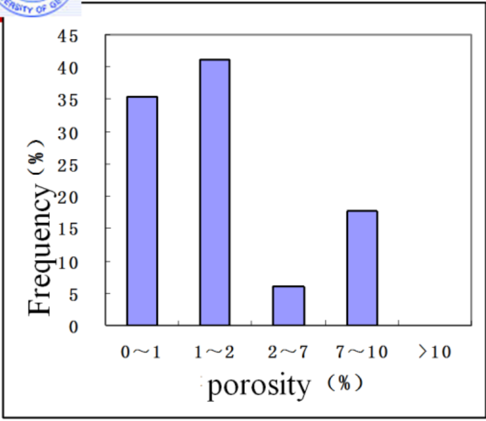


LP177 burial and thermal history

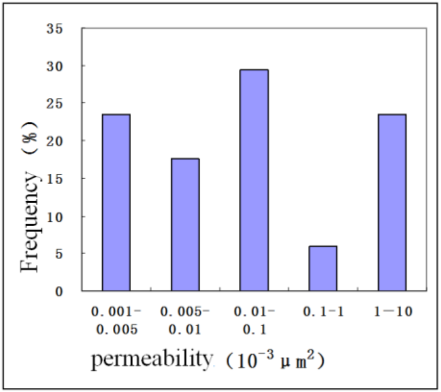




Free Gas Controlling Factors



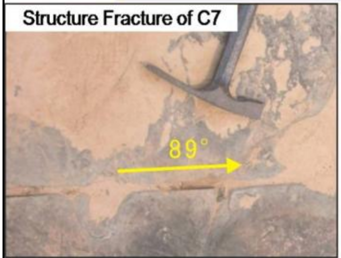
Permeability of matrix is generally less than 0.1 md; some high values, mostly caused by fractures.

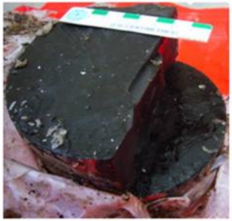


Two types of fractures

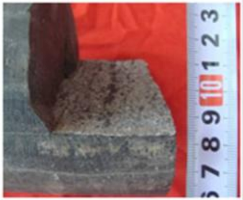
Structural fracture

Structure Fracture of C7





Yanye 8 well,1524.92m



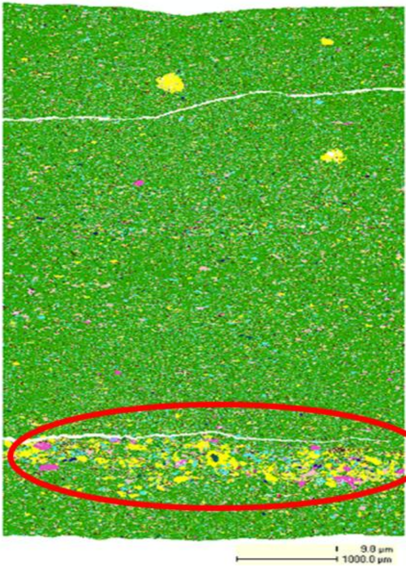
Wan 169 well,1111.4m

Inter-layer fracture

Inter-layer Fracture of C9

Liuping 179 well,1592.2-1582.5m

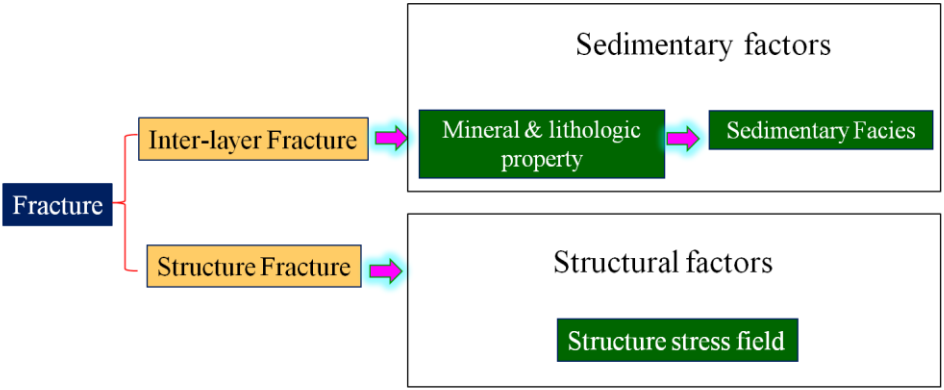
LP177,1470m QUEMSACEN



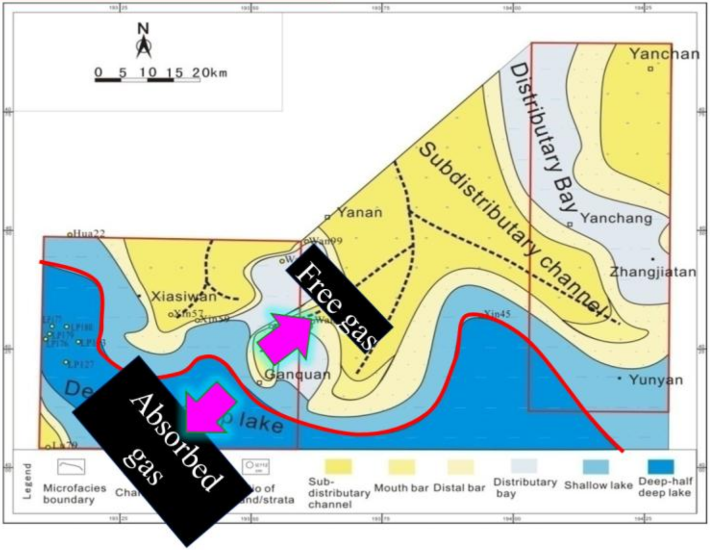
Mineral Name	Area %
Illite	65.16
Plagioclase	7.85
Quartz	6.78
Other Silicates	3.60
Chlorite	3.39
Pyrite	2.79
Smectites	2.69
Biotite	2.11
Background	1.76
Particle Rims	1.46
Glauconite	1.30
Alkali Feldspar	0.93
Apatite	0.63
Other	0.52
Micrite	0.22
Dolomite	0.19
Siderite	0.10
Muscovite	0.09
Fe-oxides	0.08
Calcite	0.06
Rutile	0.02
Ankerite	0.02
Kaolinite	0.01
Ilmenite	0.00
Zircon	0.00

LP177,1471.4m

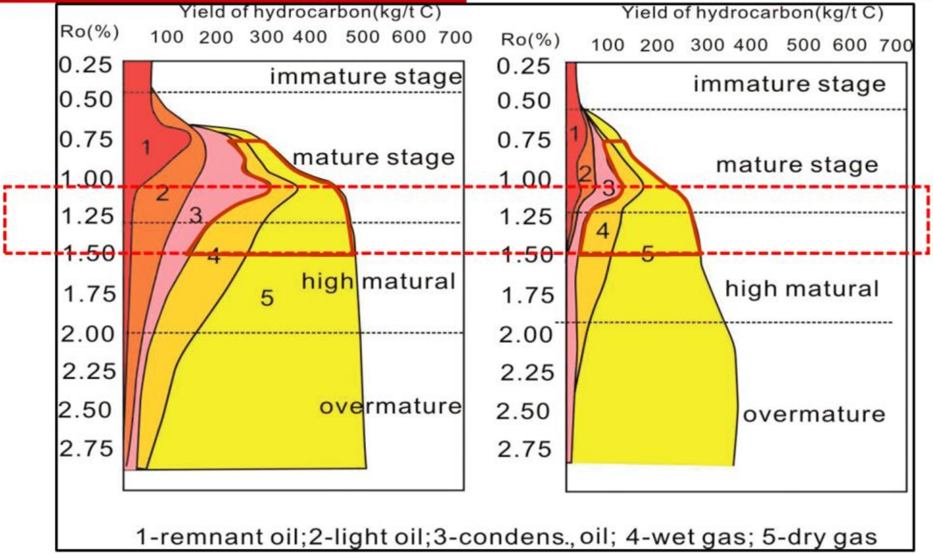
Free Gas Controlling Factors--Fracture



Controlling Factors--Sedimentary Facies

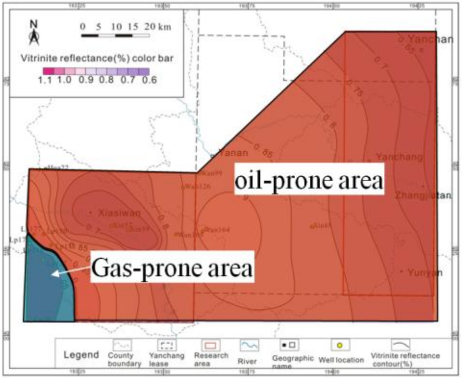


Kerogen type: II-1 Kerogen type: II-2

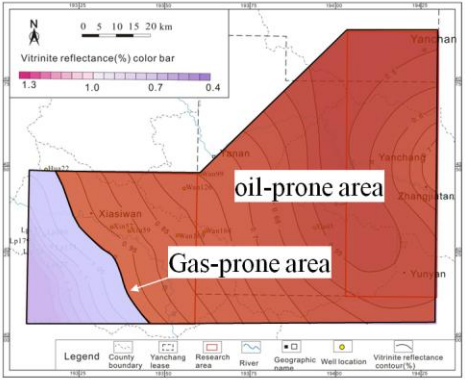


Kerogen produces oil and gas, oil peak occurs at vitrinite reflectance (Ro) of ~1.1% ; with more maturation, gas increases and composes ½ to 2/3 of all hydrocarbon generated at Ro 1.5%.

Shale gas potential of C7 member



Shale gas potential of C9 member



Outline

1. Geological Setting
2. Continental Shale Characteristics
3. Main Controlling Factors for Continental Shale Gas Accumulation
4. *Conclusions*

Conclusions

★ In Ordos basin, shale and mudstone were developed in shallow to deep lacustrine environments. Percentage of clays mineral is high, and the brittle minerals is lower than that reported in the marine shales. Heterogenity also is significant.

★ The shales are characterized by rather low thermal maturity with vitrinite reflectance 0.7% to 1.5%, predominantly Type II-III kerogen, and an organic richness (TOC range) of 1.5% to 4%.

★ Shale pore type includes organic and mineral pores, micro-pore predominant. Low porosity and permeability; locally permeability high for fracture.

★ The shale gas is primarily thermogenic gas associated with oil generation, as it is presently still in the oil to wet gas window. Oil and gas coexist.

★ Absorbed gas is controlled by sedimentary facies. Free gas is controlled by structural evolution and stress field.

Acknowledgement

Thanks to Yanchang oilfield company for permission to present this work and the organizers of this conference for providing the opportunity for us to present our work.

Thanks for financial support from the National Natural Science Foundation of China.

Thanks For Your Attention!

E-Mail:tangxuan@cugb.edu.cn