

Petrology of Siltstone Laminae in Zhangjiatan Shale of the 7th Member of Yanchang Formation and Their Significance for Shale Gas, Ordos Basin, China*

**Yuhong Lei¹, Xiangzeng Wang, Xiaorong Luo, Lixia Zhang, Likuan Zhang,
Chengfu Jiang, Ming Chen, and Yuxi Yu**

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Abstract

Zhangjiatan Shale in the 7th Member of Yanchang Formation, Ordos Basin, China, is a potential reservoir of continental shale gas. It appears that laminated siltstone laminae affect gas accumulation in and production from the shale. The role of siltstone laminae in shale gas accumulation is assessed on the basis of their petrologic features and spatial distribution using outcrop, core, well-log, and microscopic and SEM data. The siltstone laminae occur mainly in the upper and lower parts of Zhangjiatan Shale and are 0.2-2 mm thick and 5-30 laminae/m in distribution (i.e. density). Siltstone/shale ratio ranges from 5 to 25%. Framework grains are quartz and feldspars. Clay minerals are mainly illite and parallel to bedding plane. Minor fossil and organic debris and pyrite are present. Pore types include primary inter-granular among framework grains, dissolutional in feldspar, crystalline in cements, inter-granular around clay minerals, intraparticle in organic matter, and fractures. Low-angle cracks occur in shale where siltstone laminae are present. Some cracks are open, while others are cemented by calcite. The number of cracks apparently increases with the density of siltstone laminae. Some cracks grew along bedding plane. Such phenomenon results in anisotropic hydraulic property: the horizontal permeability of the shale is 2-5 times larger than the vertical permeability. Results of water emersion test of shale cores indicate release of natural gas generally along siltstone lamination surfaces. Collected gas volume correlates positively with the density of siltstone laminae. Hence, siltstone laminae not only provide pore space for gas accumulation, but also serve as carriers for shale gas flow into boreholes. Understanding the depositional environments and diagenetic processes of siltstone laminae is important to predict sweet spots and assess shale gas resources.



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2013.5.22



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(Group) CO., LTD., China*)



CAS(*Chinese Academy of Sciences*)



Outline



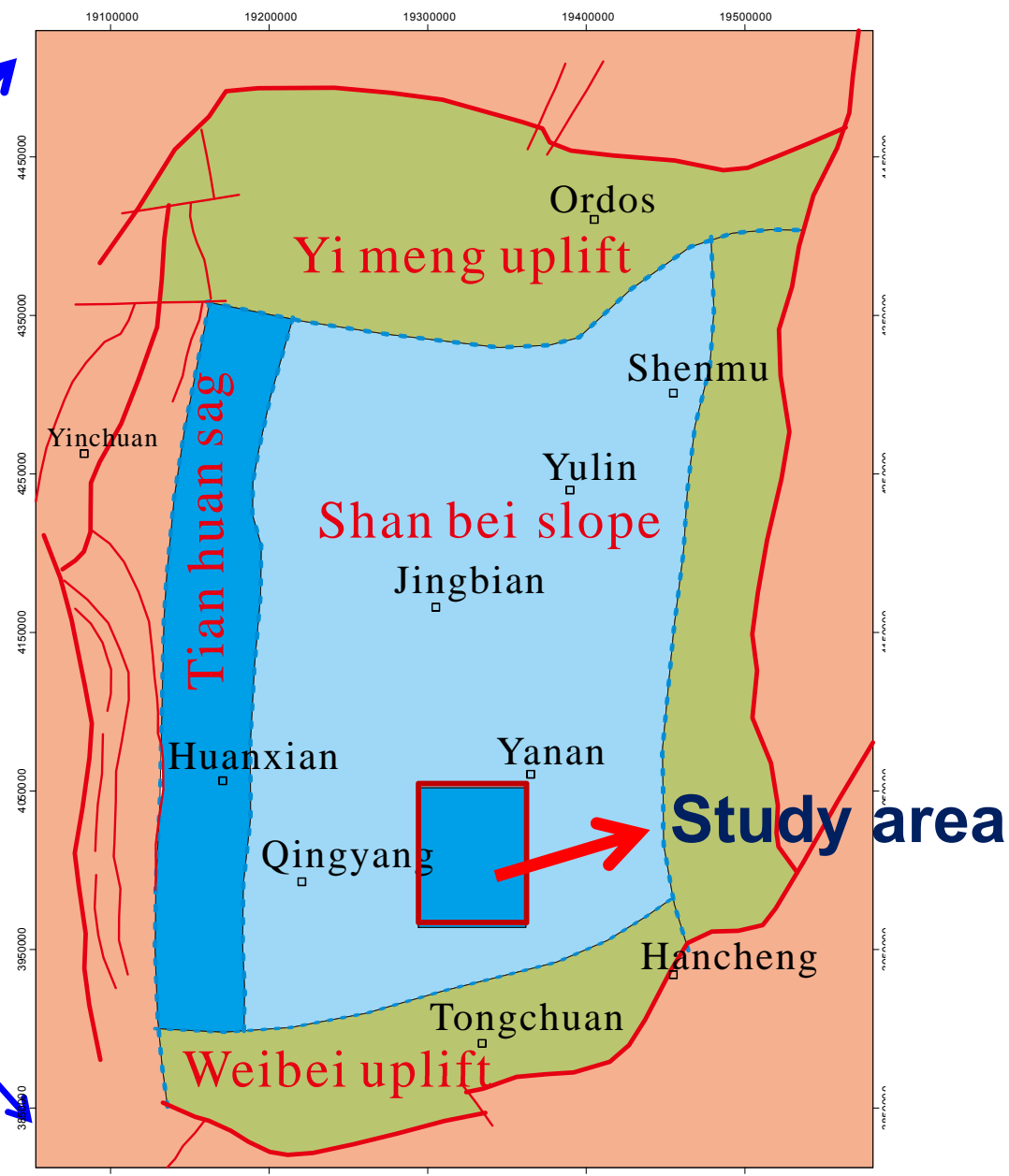
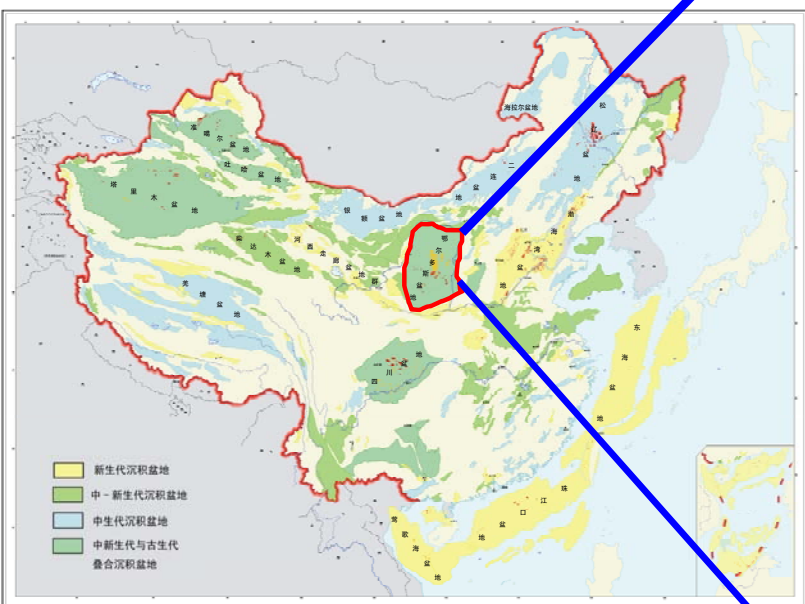
1、 Introduction

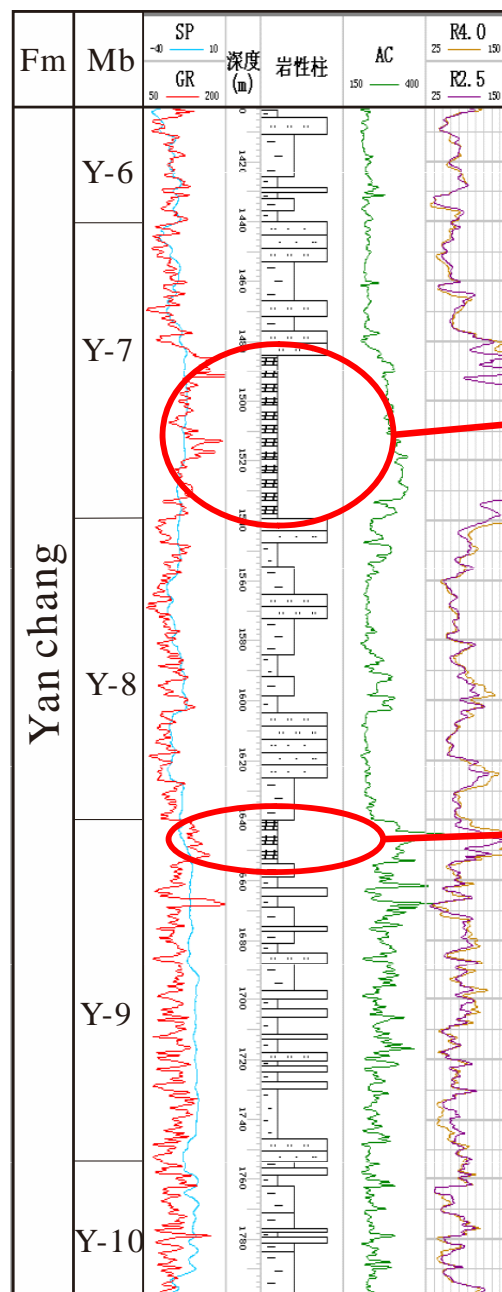
2、 Petrology characteristics of silt laminae

3、 Significance of silt laminae for Shale Gas

4、 Conclusions

Introduction



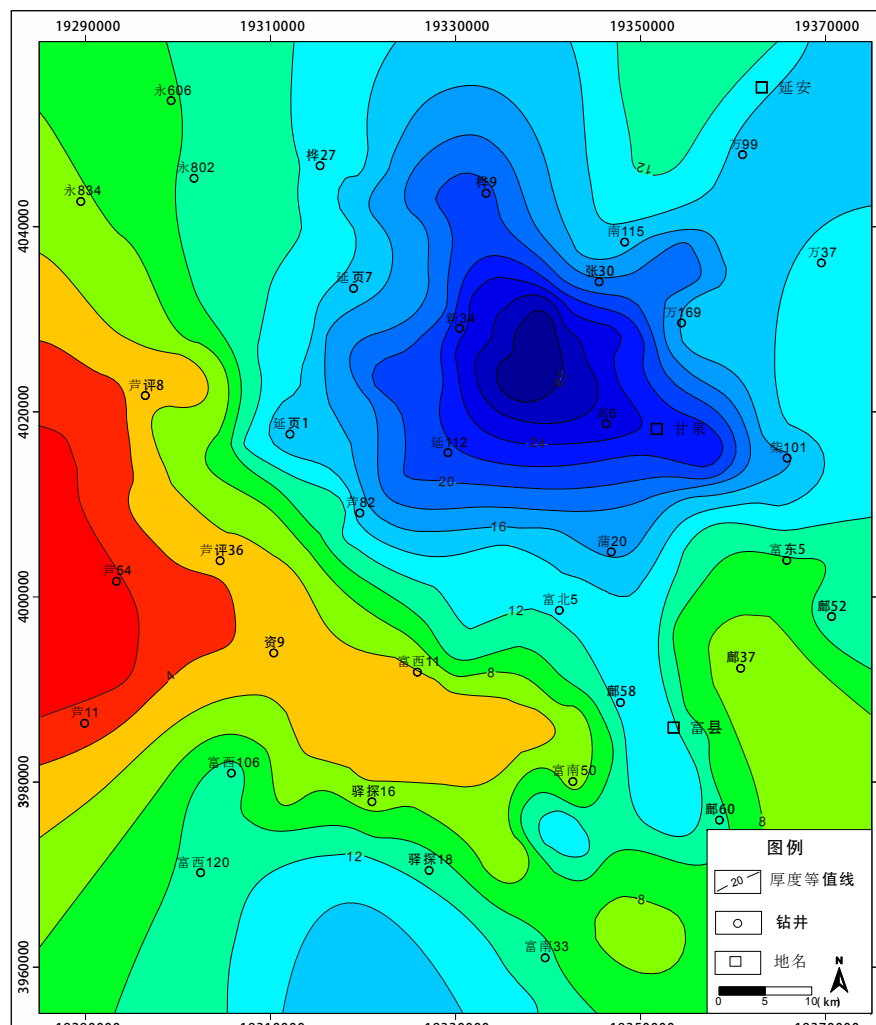


Zhangjiatan
shale

Lijiapan
shale

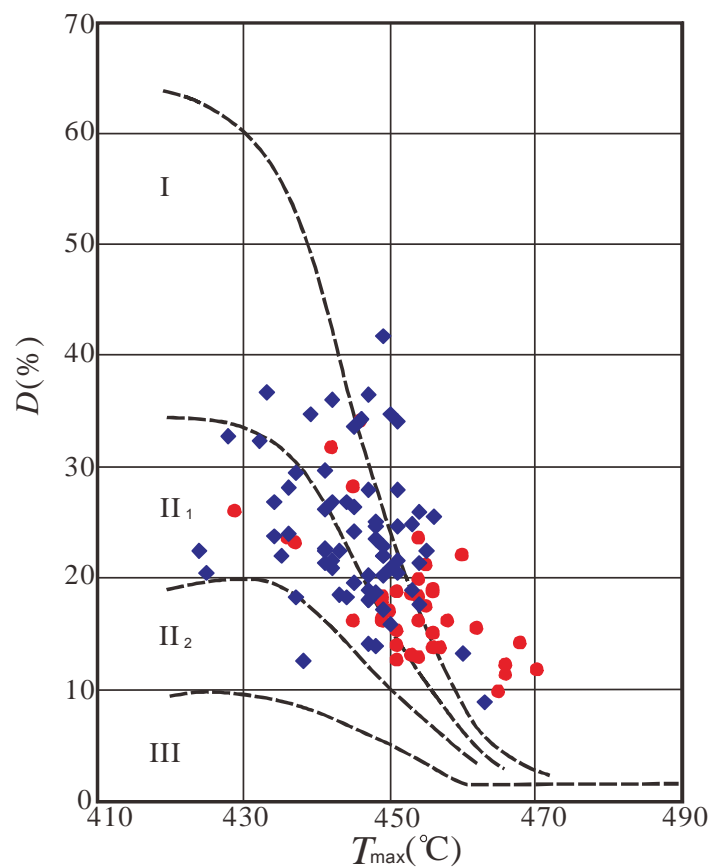
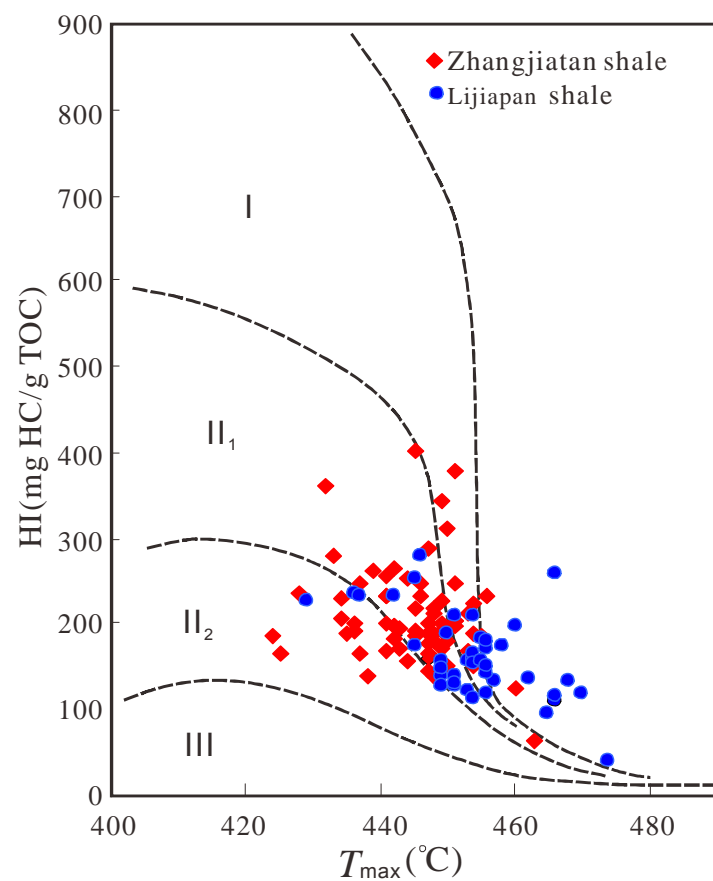
Yanchang formation deposited in the late Triassic period, two sets of shales developed at the bottom of member 7 and at the top of member 9, respectively.

Thickness contour map of shales

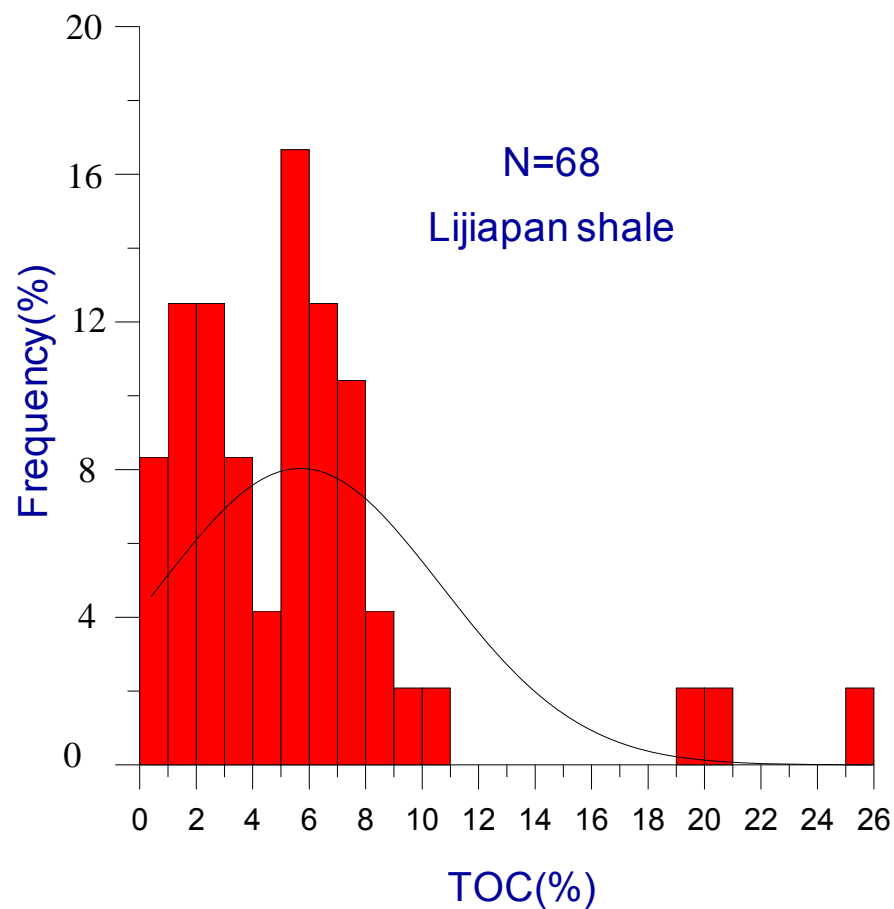
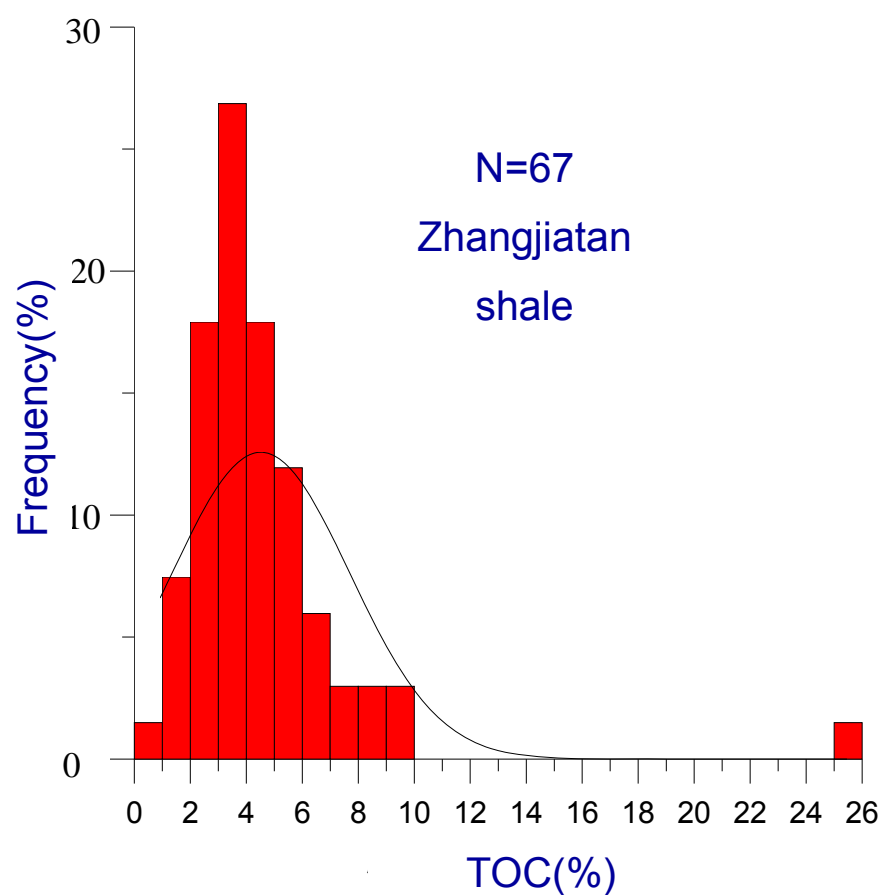


Zhangjatan shale :10 ~ 80m; Lijiapan shale: 10 ~ 30m。

Kerogen type

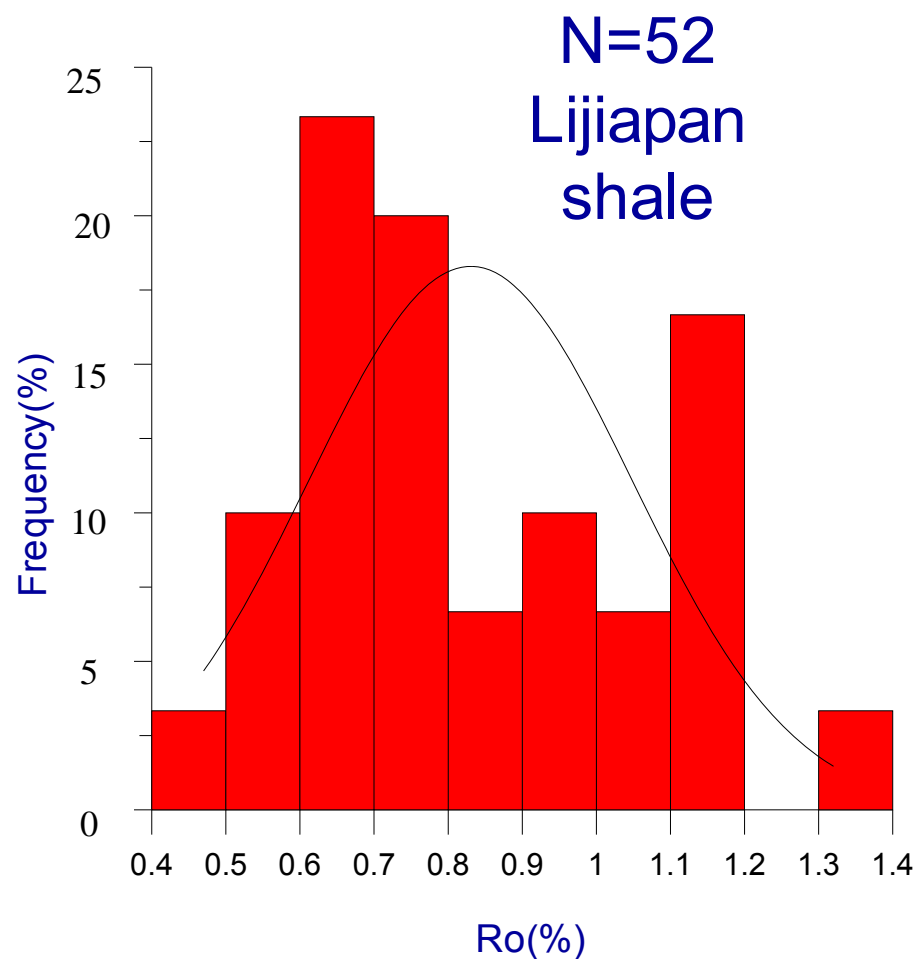
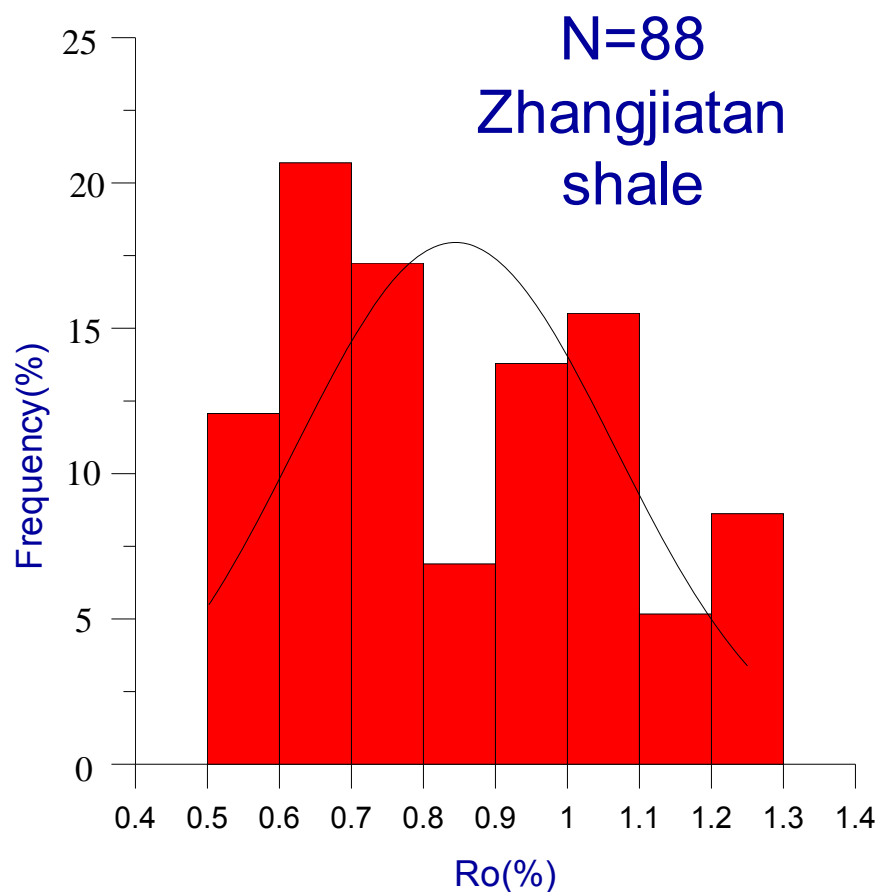


TOC



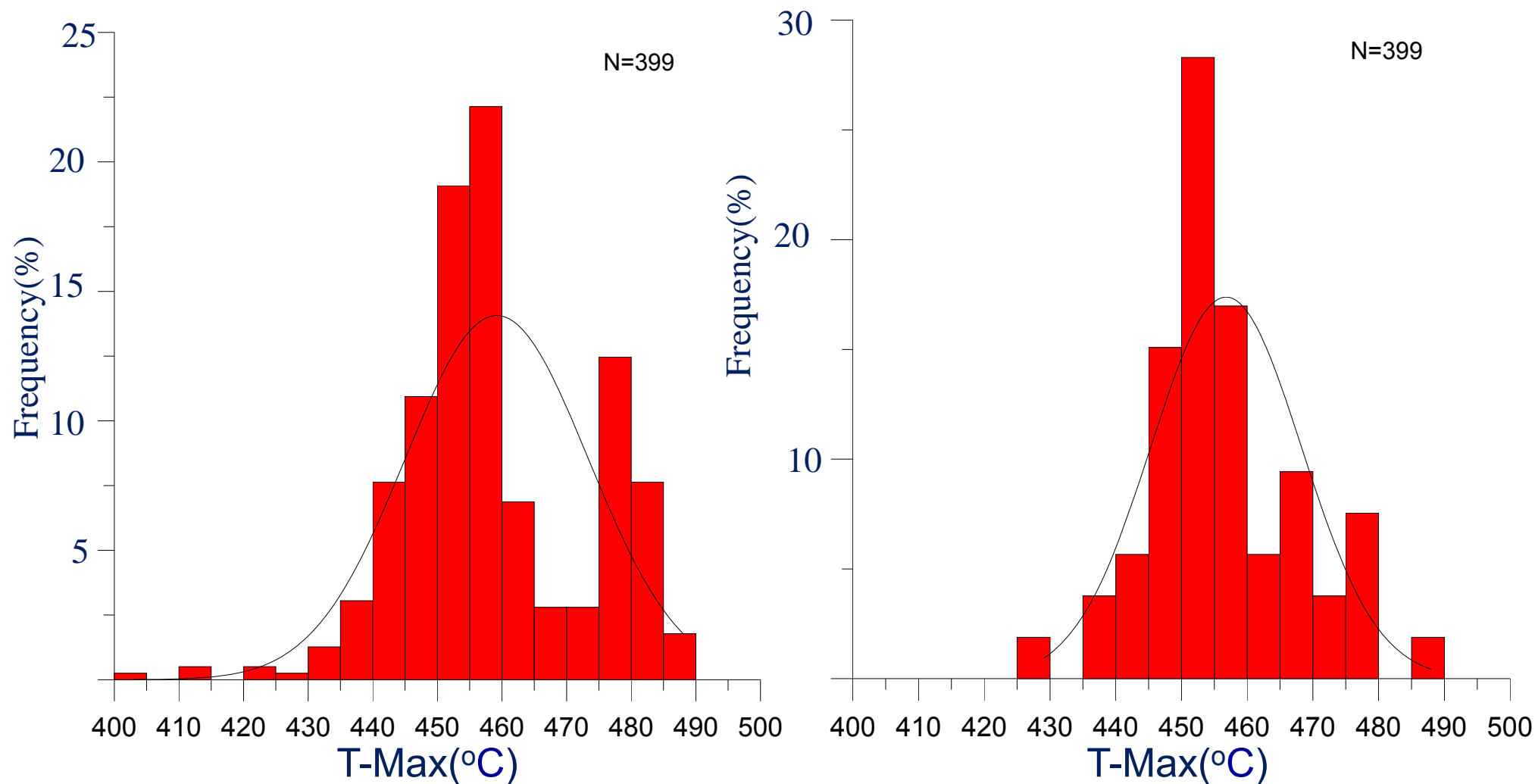
zhangjiatan shale :1-10%; Lijiapan shale: 1-11%.

Vitrinite reflectance(R_o)



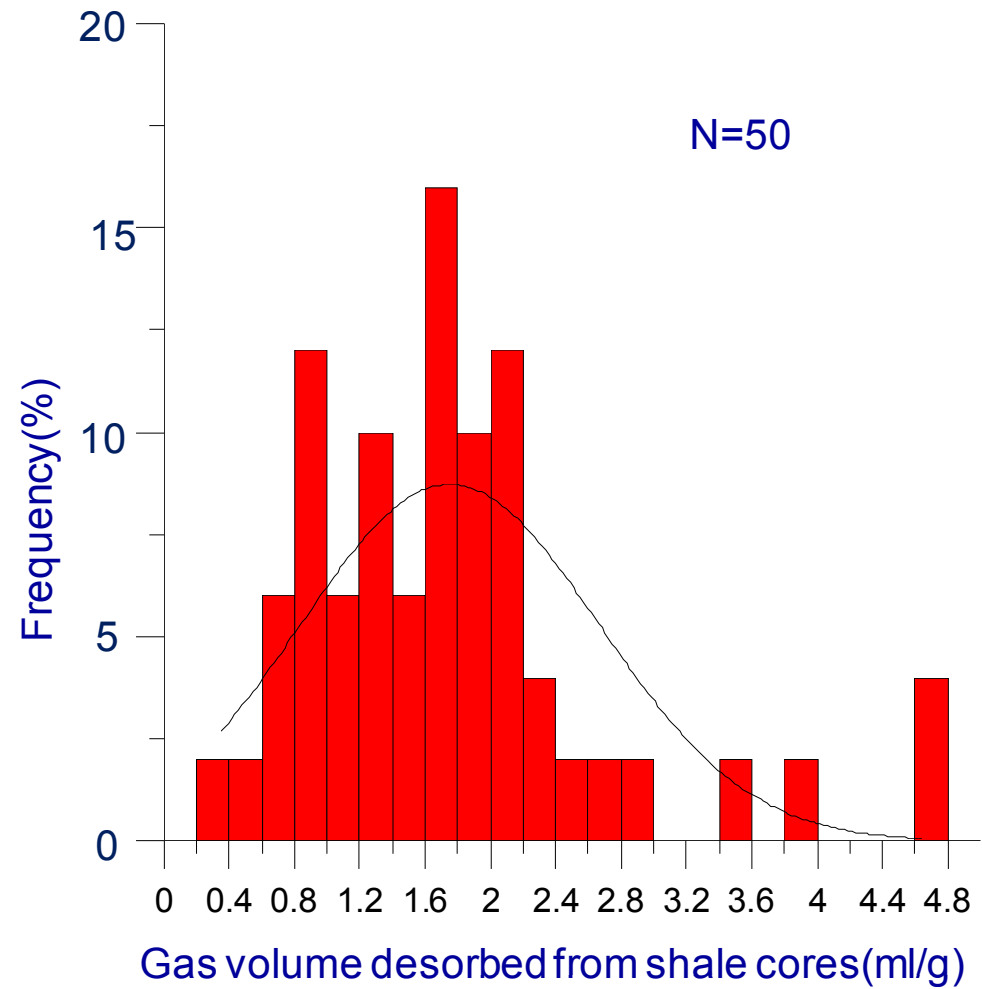
Zhangjiatan shale :0.5-1.3%; Lijiapan shale: 0.5-1.4%.

T-Max



Zhangjiatan shale: 430-490°C; Lijiapan shale: 430-490°C.

Gas volume



Gas volume desorbed from shale cores:0.6-4.7ml/g

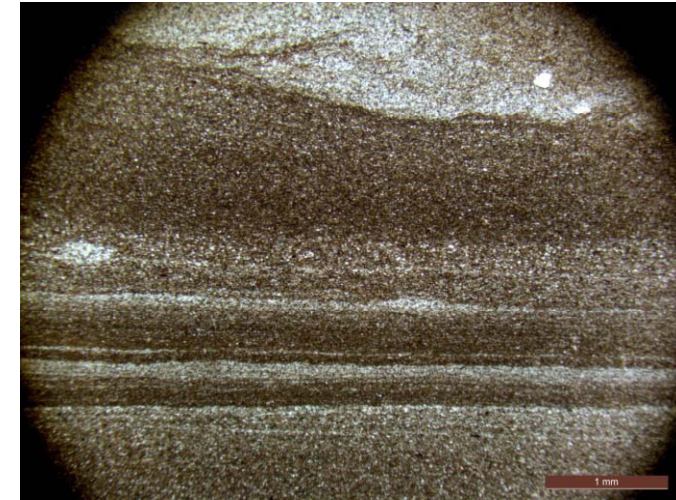
The Zhangjiatan shale is a potential reservoir for shale oil and gas



Outcrop



Shale core



Thin section of shale

Silt laminae develop widely in the shale, which may affect the shale gas accumulation and production.



Outline

1、 Introduction

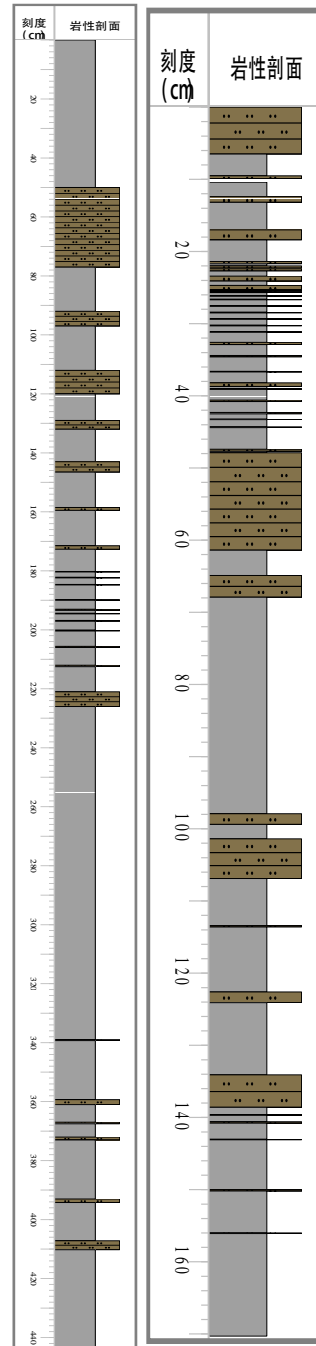
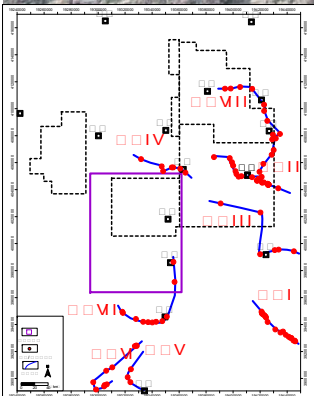
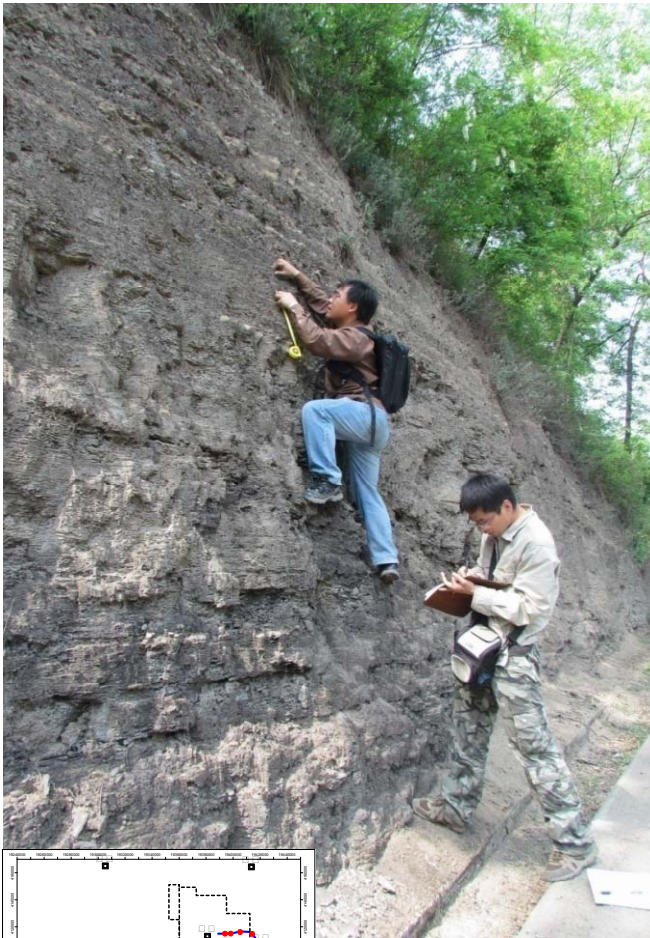


2、 Petrology characteristics of silt laminae

3、 Significance of silt laminae for Shale Gas

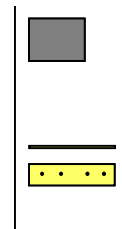
4、 Conclusions

Characteristics of silt laminae



Outcrop observation

The silt laminae in Zhangjiatan shale are **0.2-20 mm** thick and **5-24 laminae/m** in distribution (i.e. density). Siltstone/Total thickness ratio ranges from **5 to 24%**.



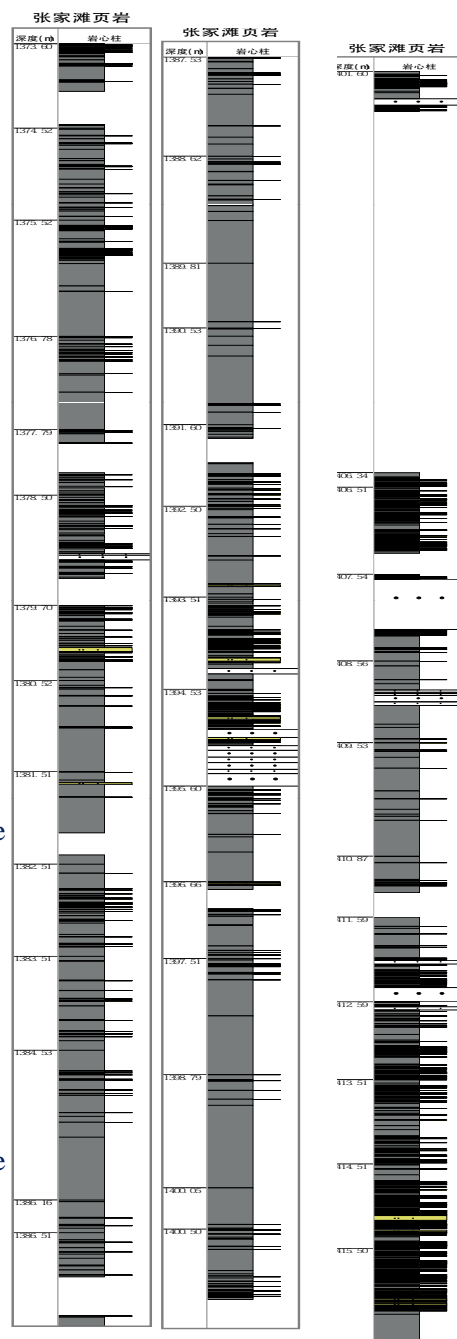
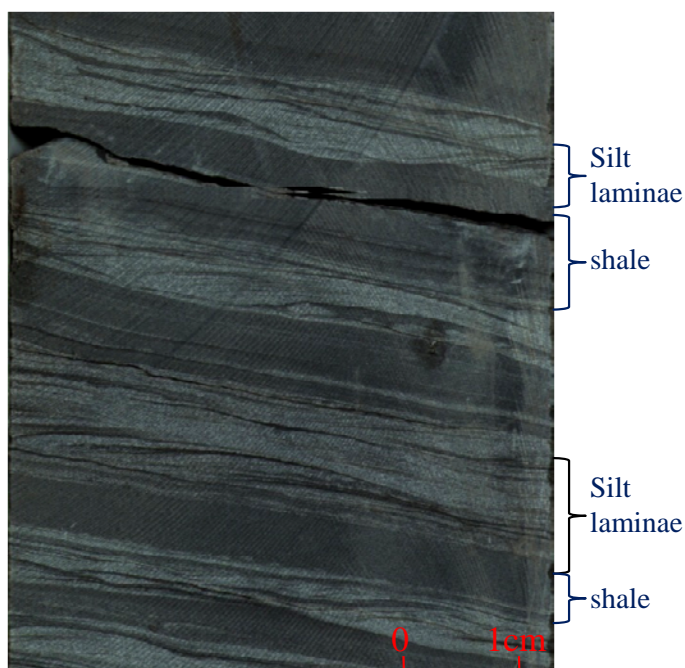
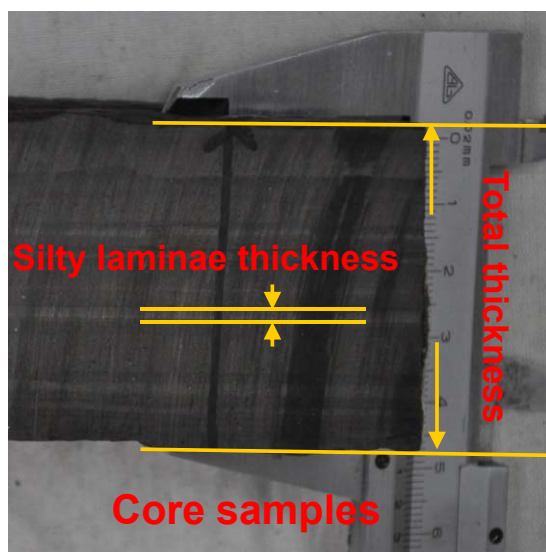
shale

Silt laminae

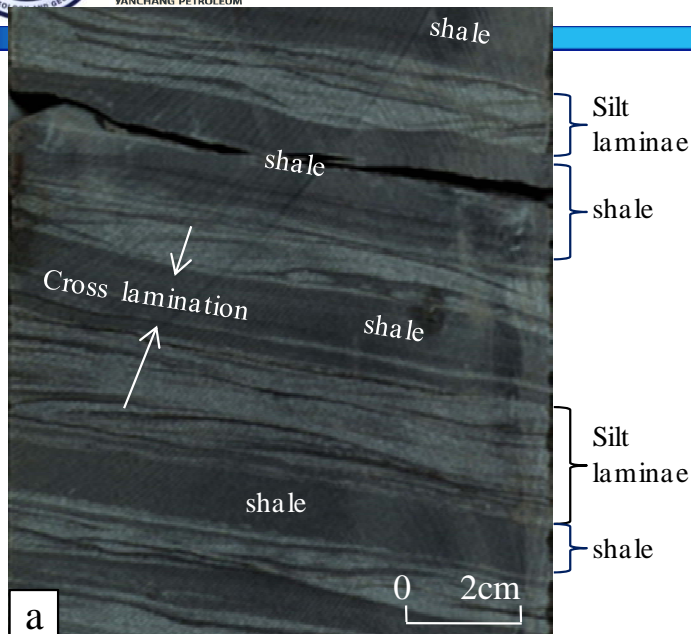
Characteristics of silt laminae

Core samples description

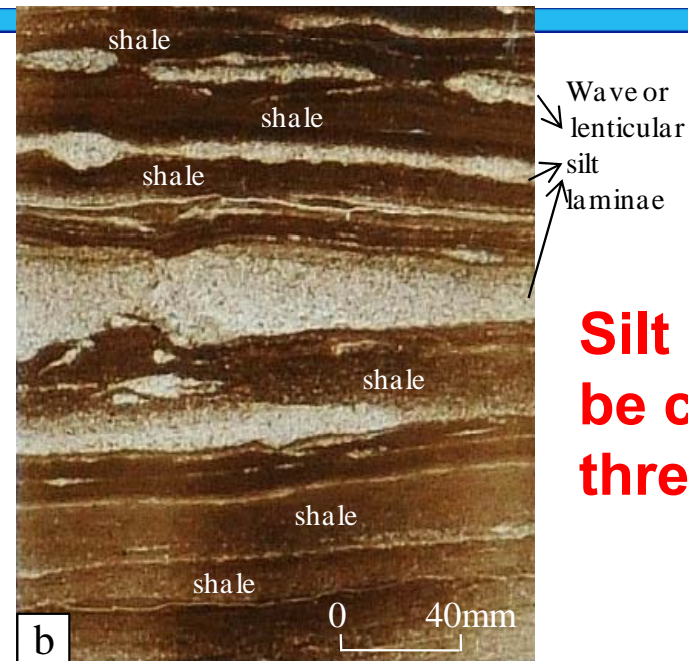
The silt laminae are **0.2-5 mm** thick and **8-40 laminae/m** in distribution (i.e. density). Siltstone/total thickness ratio ranges from **7 to 16%**.



Characteristics of silt laminae

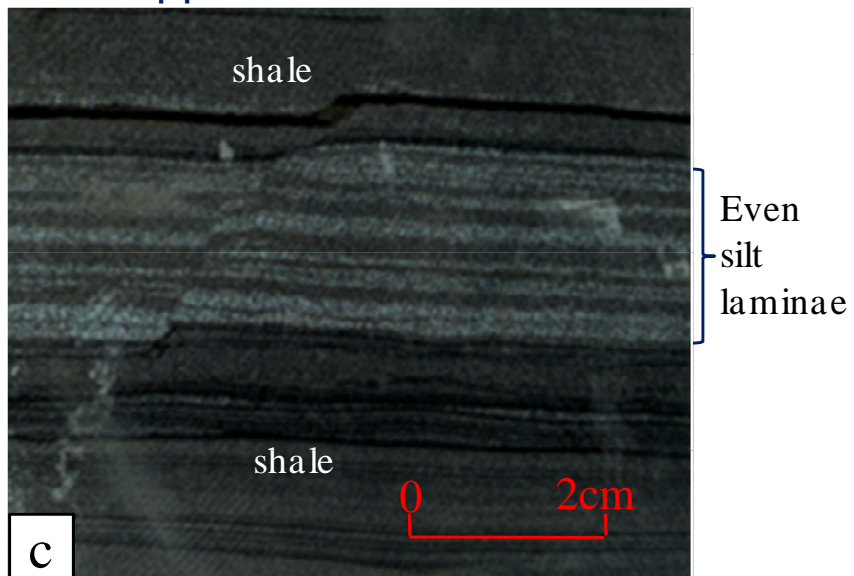


silt/shale couplets, silt laminae interbedded with shales; silt laminae composed of several cross or ripple laminae.

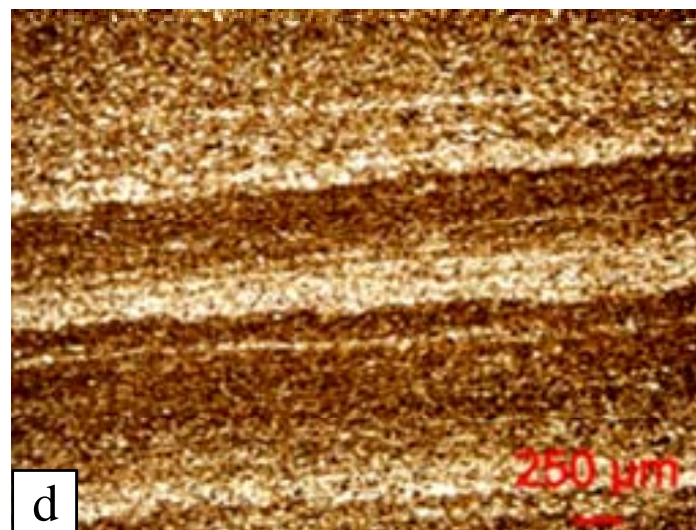


Wavy-lenticular silt laminae

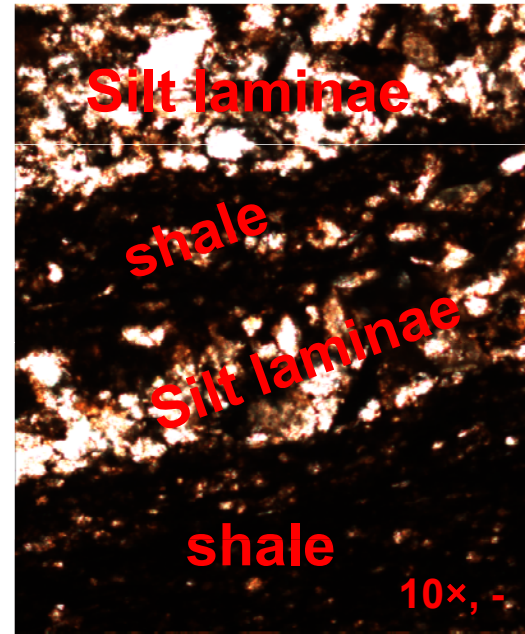
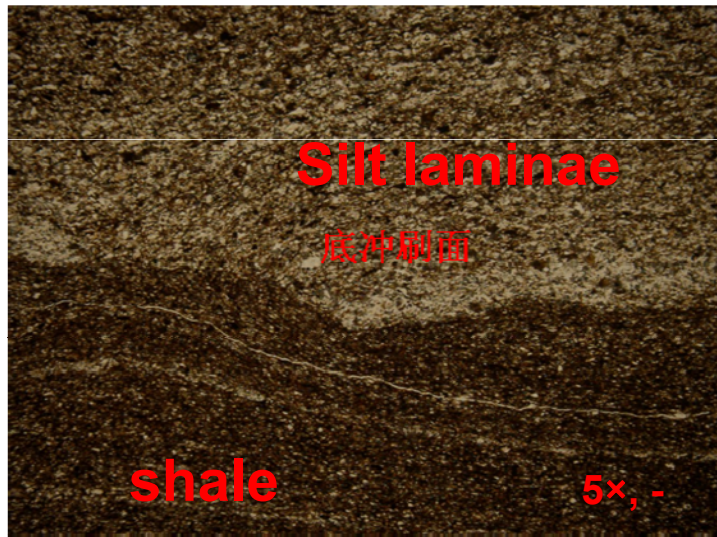
Silt laminae can be classified into three types



Even silt laminae: a bundles of closely spaced silt laminae occur in massive shale)



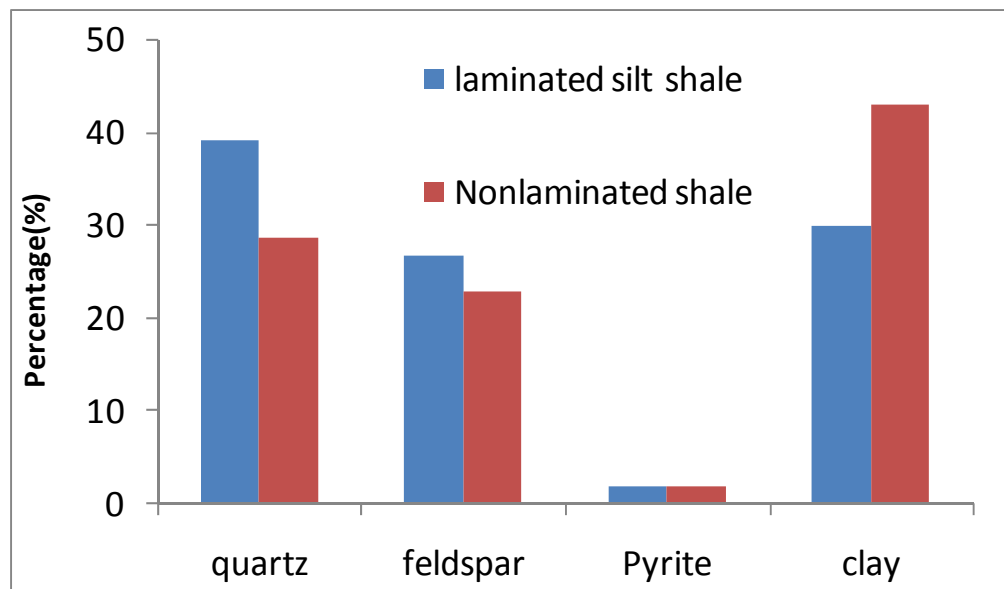
Characteristics of silt laminae



The silt laminae are different from shales in color, mineral composition, grain size, porosity, and so on.

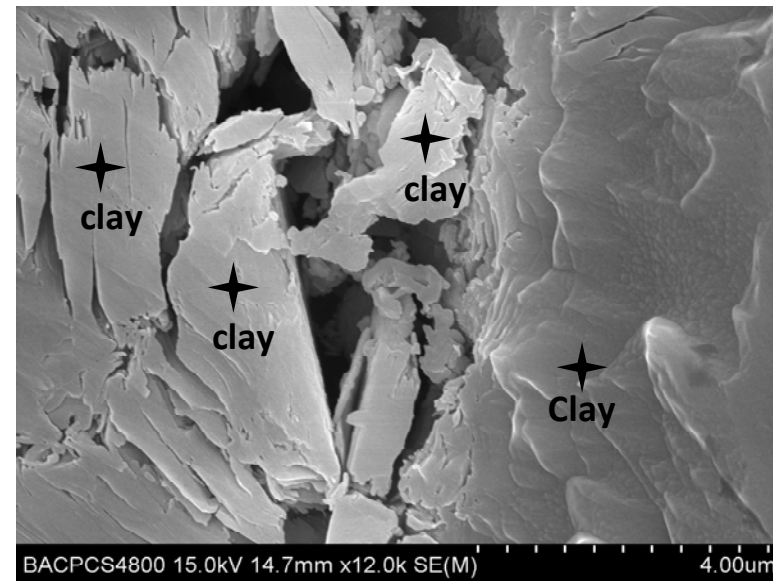
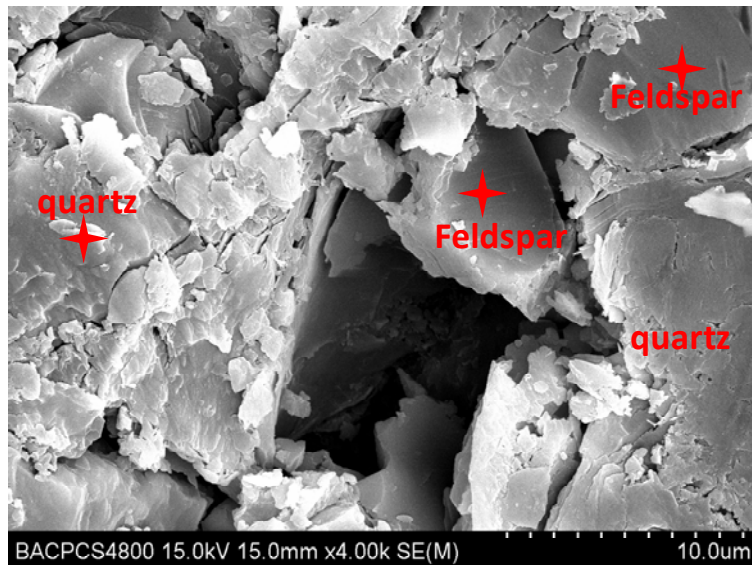
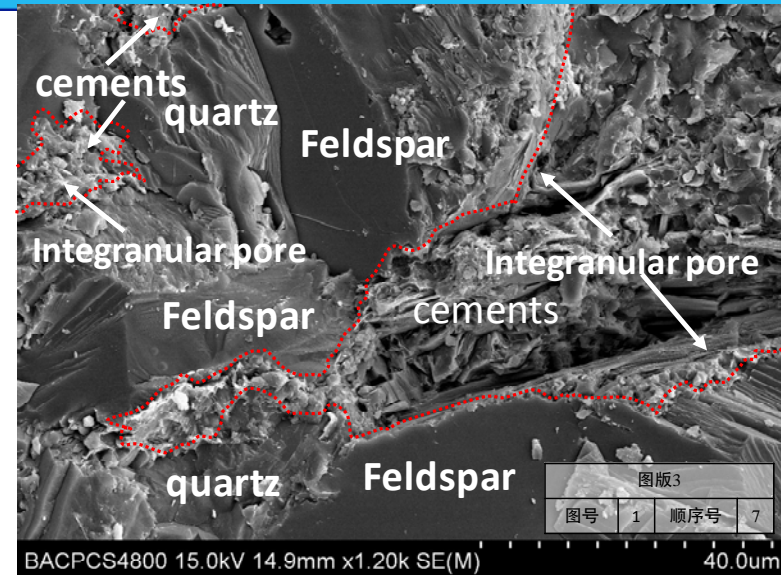
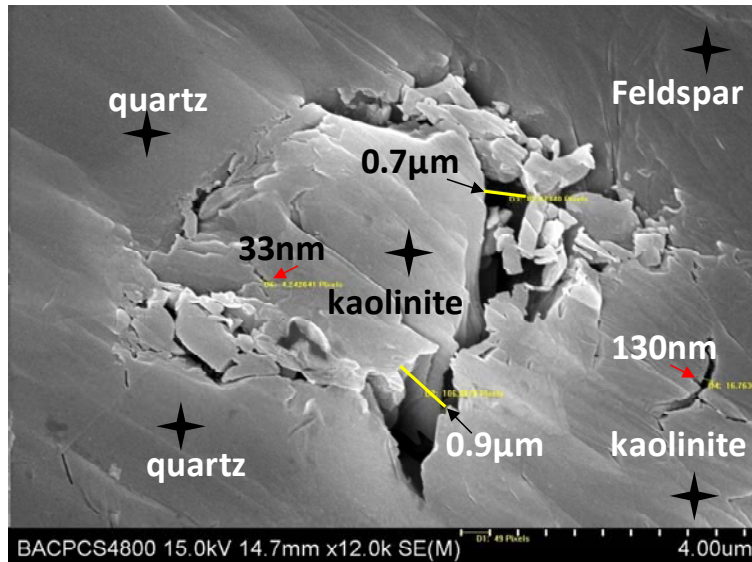
Relative mineral composition of shales (X-ray)

Sample		Depth	Quartz	Dolomite	Calcite	Feldspar	Pyrite	Siderite	I/S	It	Kao	C
laminated silt shale	L81	1226.8	47			27	3	2	16	2	1	2
	YT18	731.1	36	6		35			17	4		3
	H27	1506.0	39			36	1		20	1		3
	L171-1	1736.4	42	1	4	19	4	3	22	1		4
	Y7-1	1149.7	39			29	1	3	19	2	4	4
	L58	1032.4	33			34			29	1		3
	FN33	8454.6	38	3		25	1		26	2	2	3
	Y1	1315.1	37			22	4		33	2		2
	X39	1179.9	35	6		23	1		27	3		5
	Y7-3	1308.1	44			18	1		35	1		1
Nonlaminated shale	Y8-1	1522.9	30			20	2	10	33	2		3
	Y8-2	1519.9	27			27	2	2	27	4	5	6
	Y7-2	1140.0	26			26	1		40	3		4
	Y860	1846.6	28			13	4	3	42	4		6
	L36	1382.3	32			28	1		24	10		2



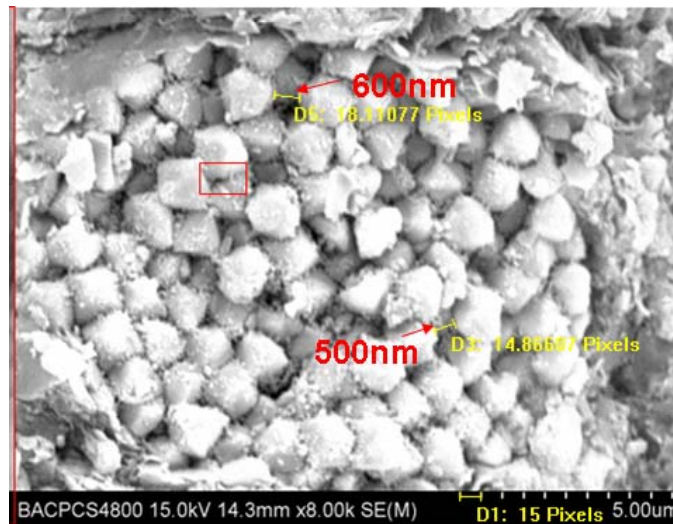
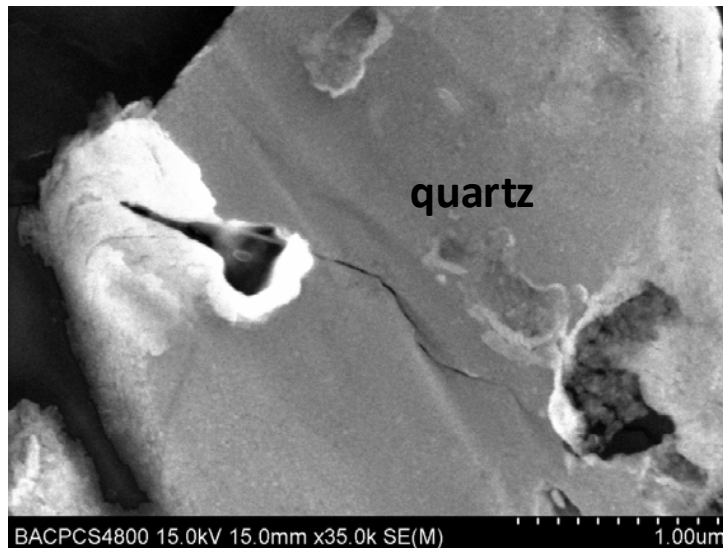
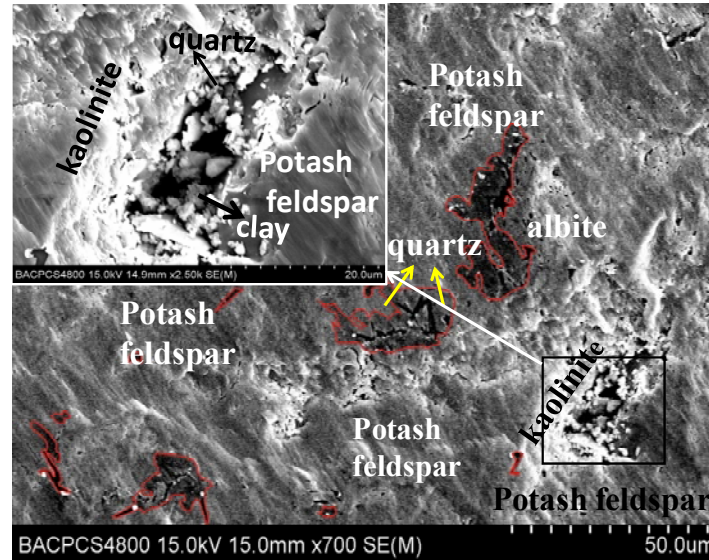
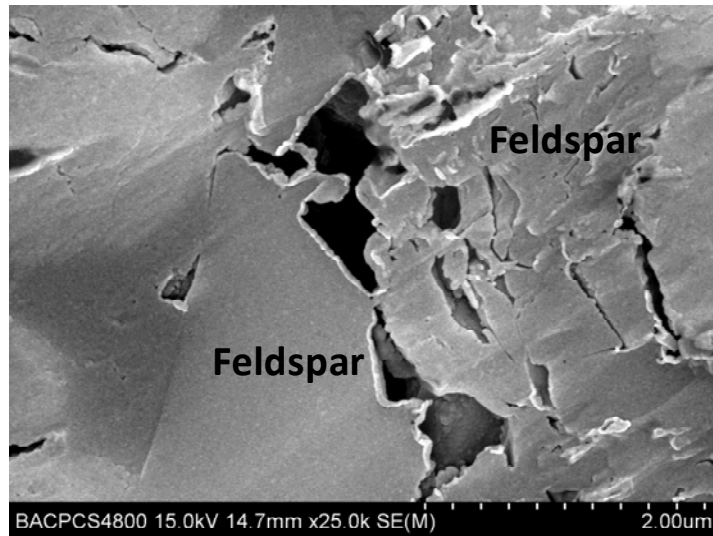
The contents of carbonate cement are very low

Pores in silt laminae



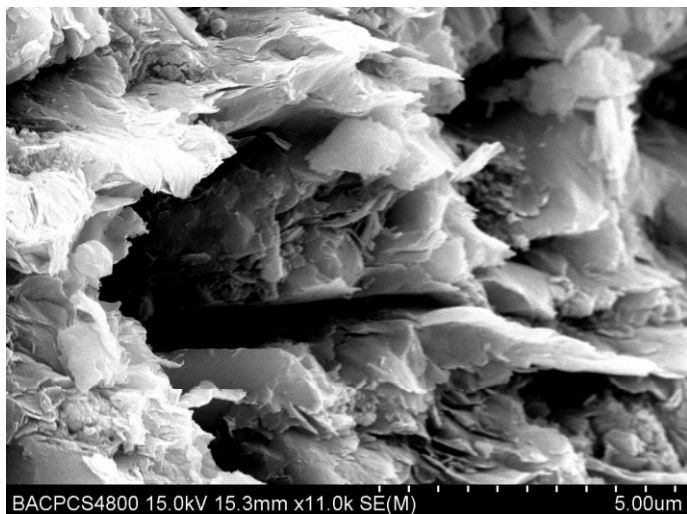
Intergranular pores around quartz, feldspar grains, clay marcopores and mesopores

Pores in silt laminae

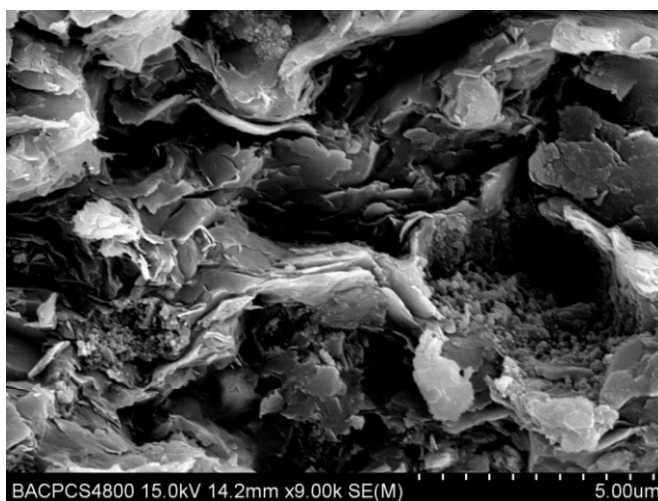


Dissolved pores are usually created from the dissolution of feldspar matrix and cements: macropores and mesopores

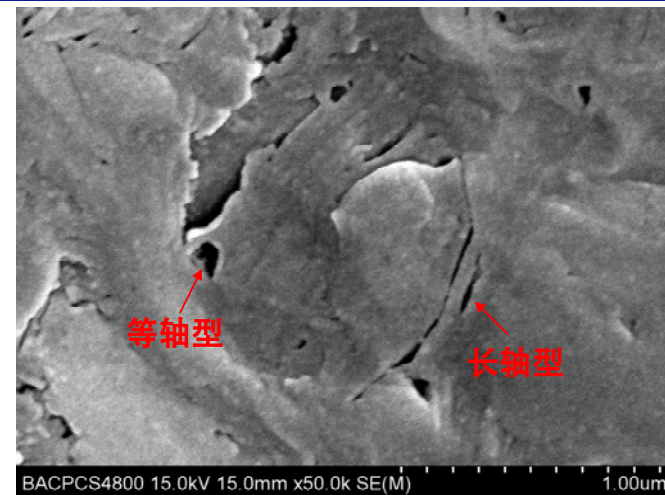
Pores in shales



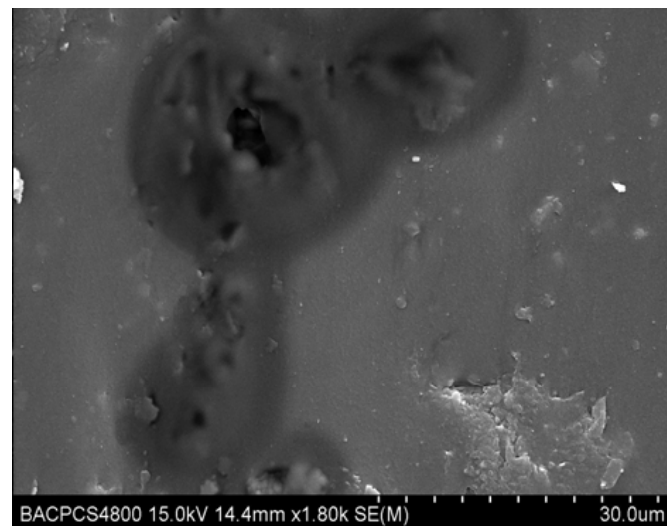
Floccule pores



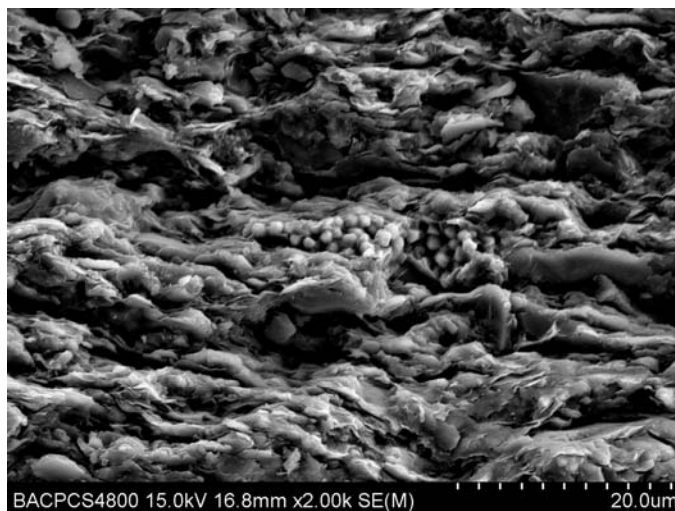
Floccule pores



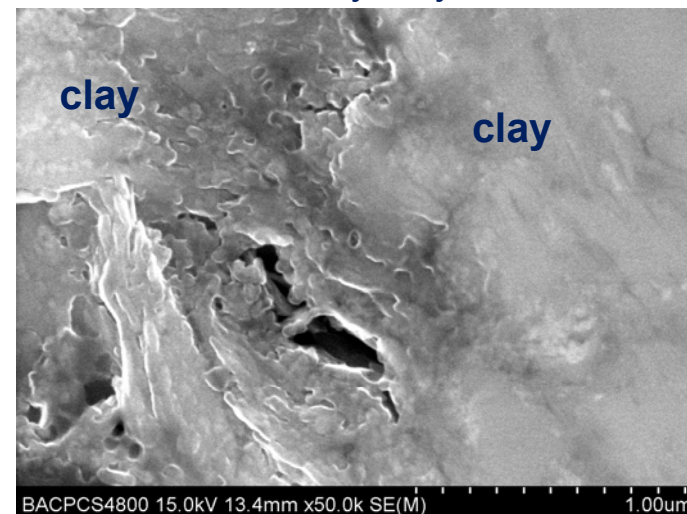
Intergranular pores and intercrystalline pores in clay matrix and secondary clay minerals



Pores in organic matters

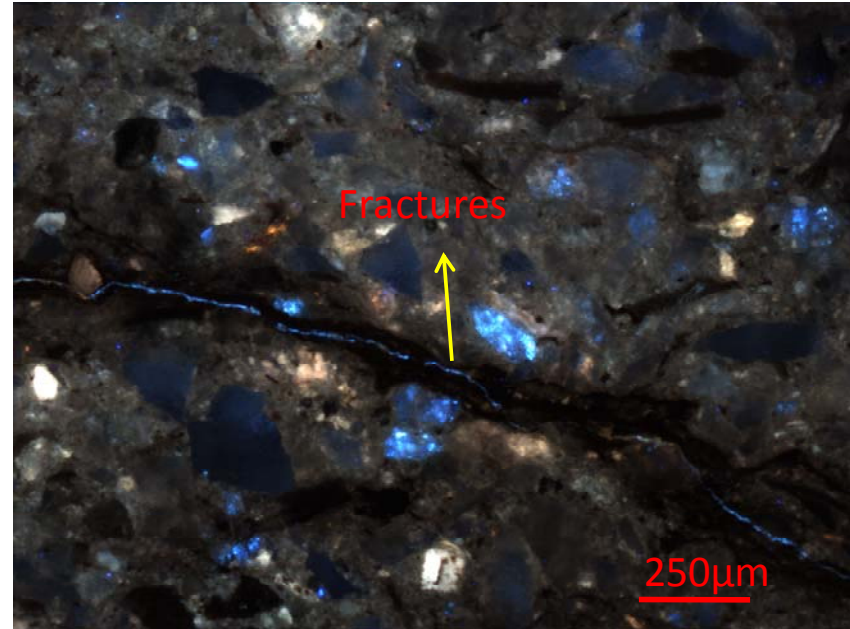
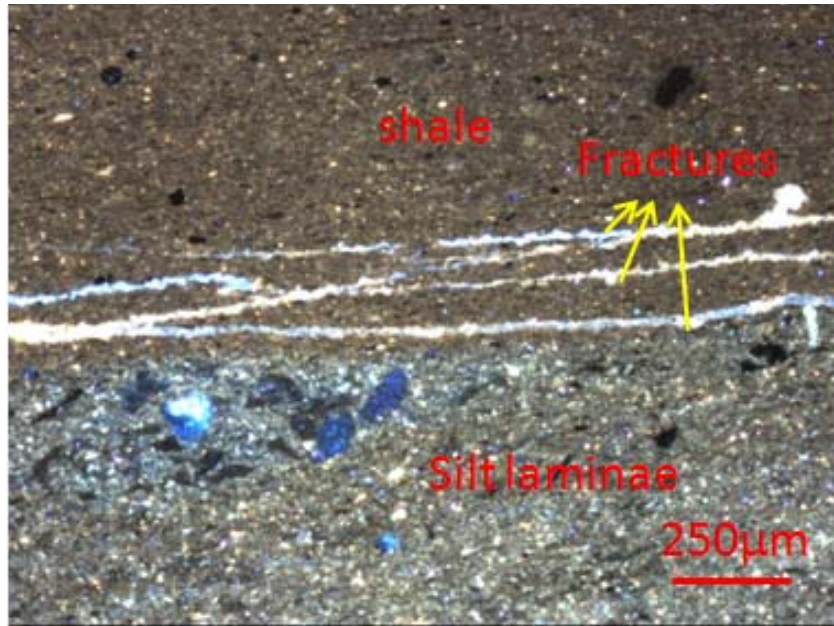


Pores within pyrites



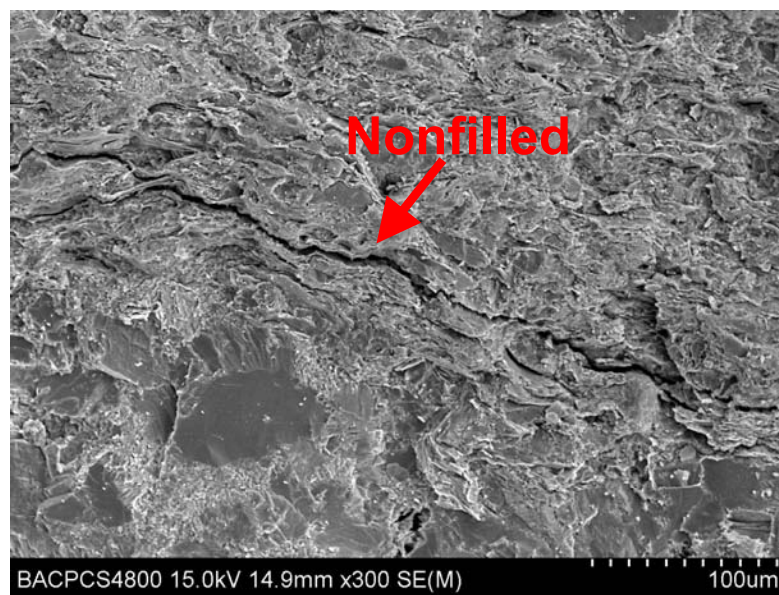
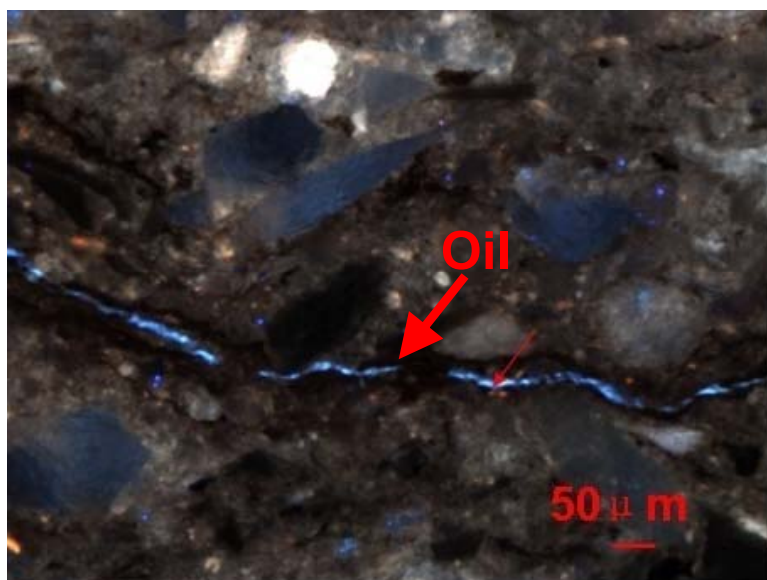
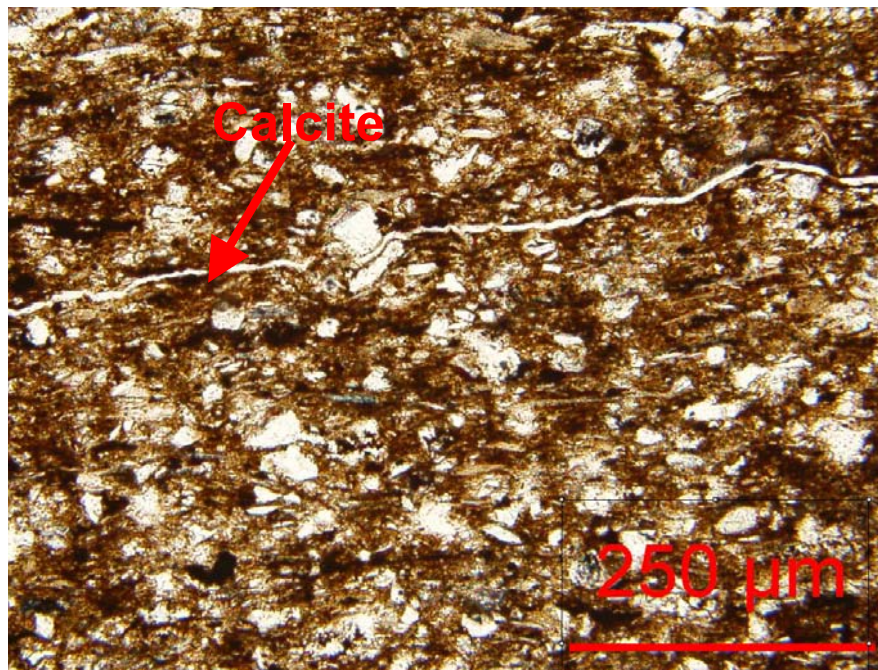
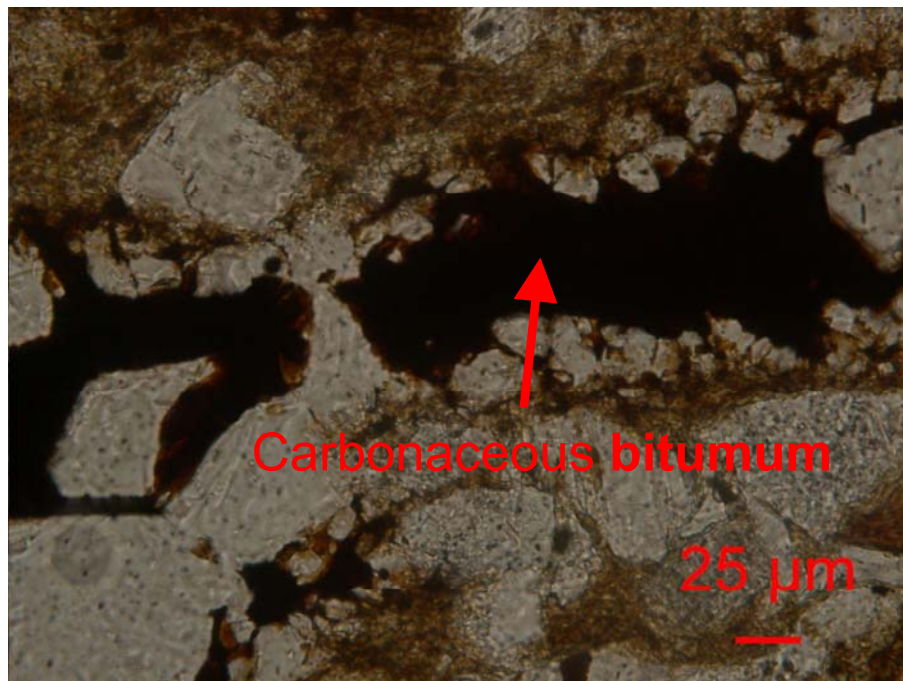
Dissolved pores in/among clay minerals

Horizontal microfractures

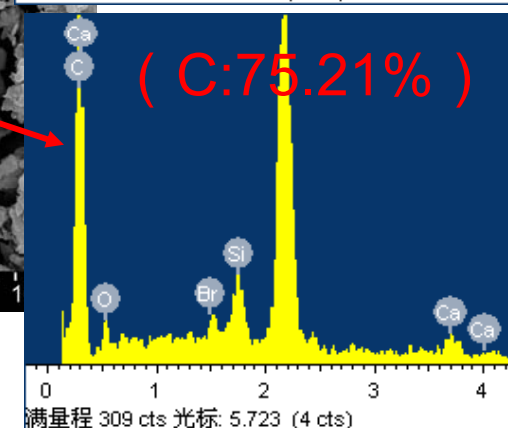
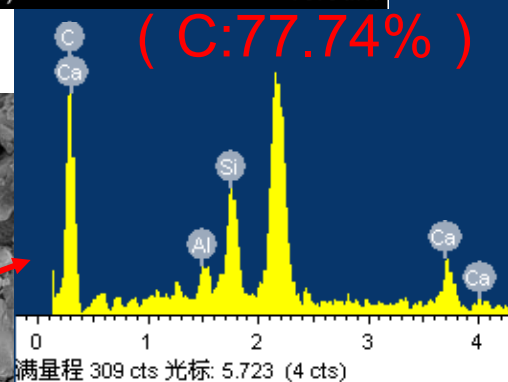
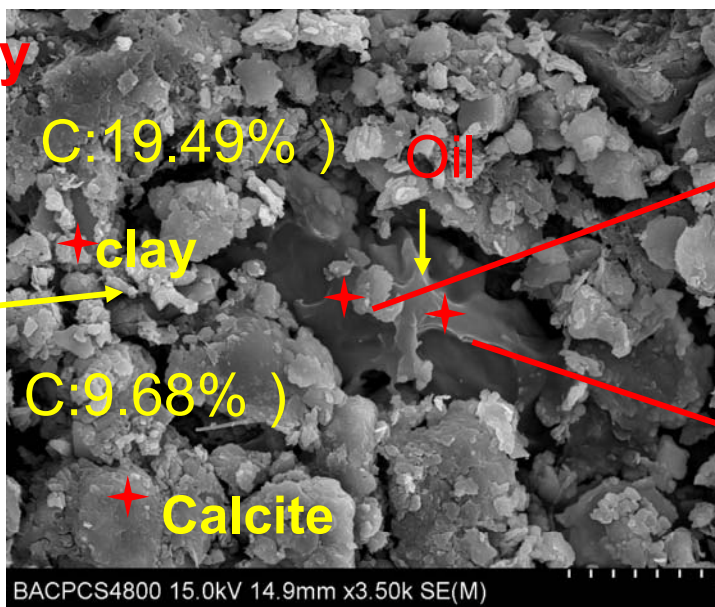
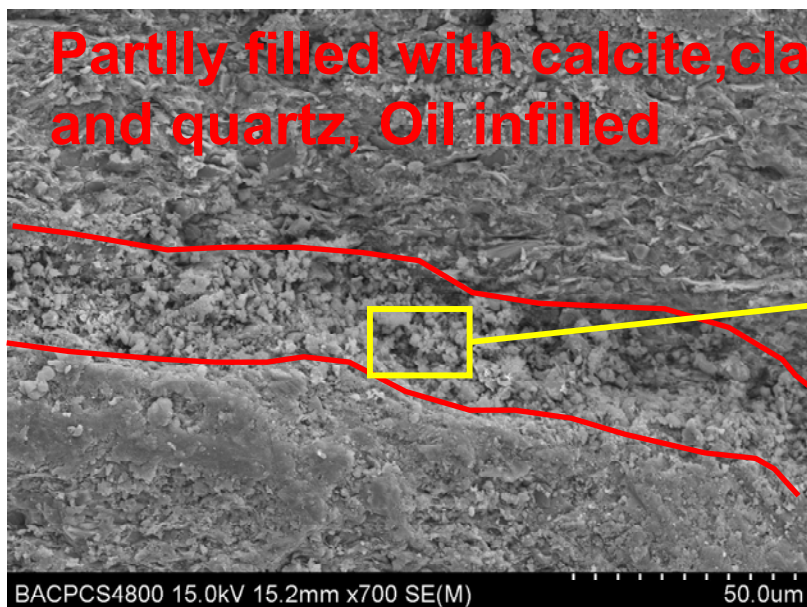
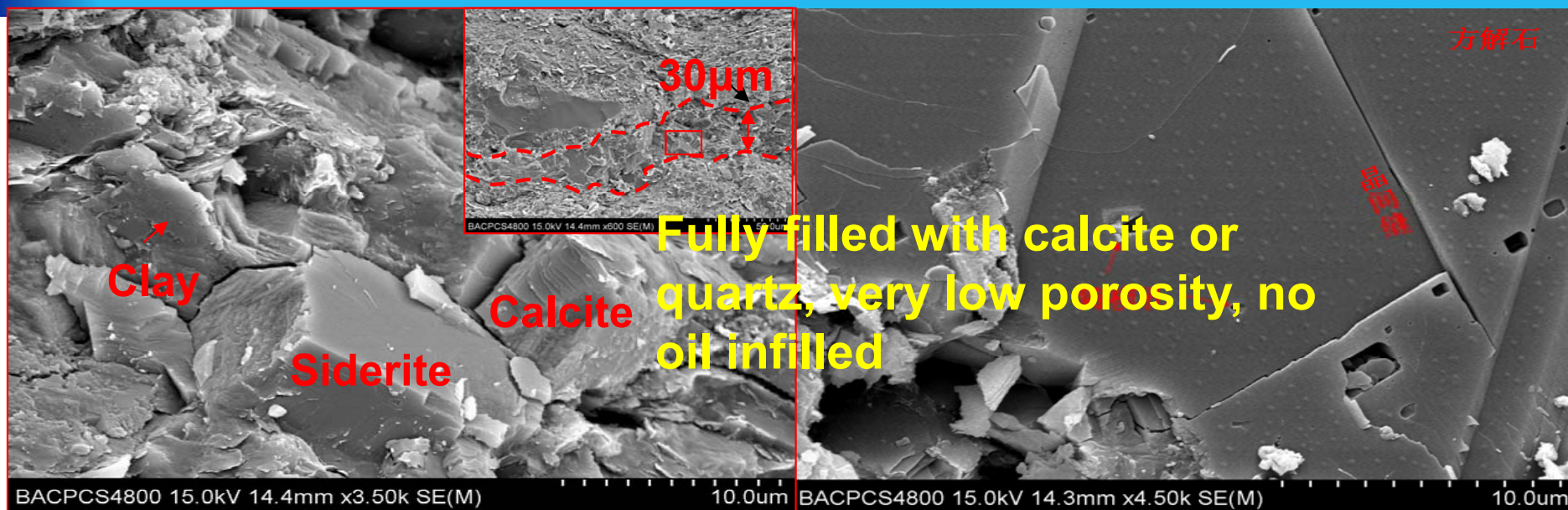


Horizontal microfractures are common in laminated shales, which usually developed in shale adjacent to the silt laminae.

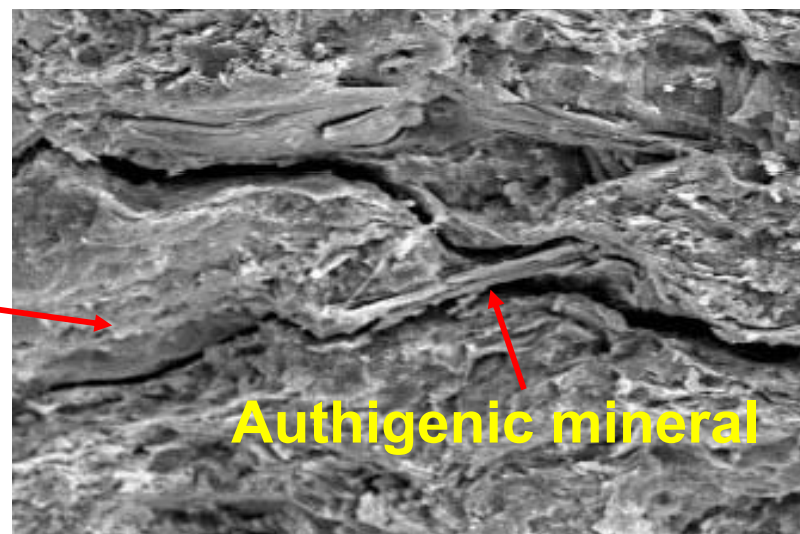
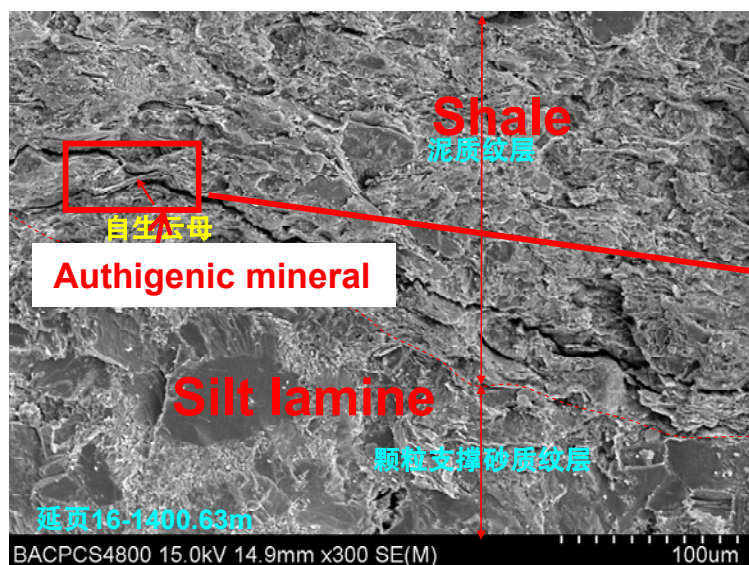
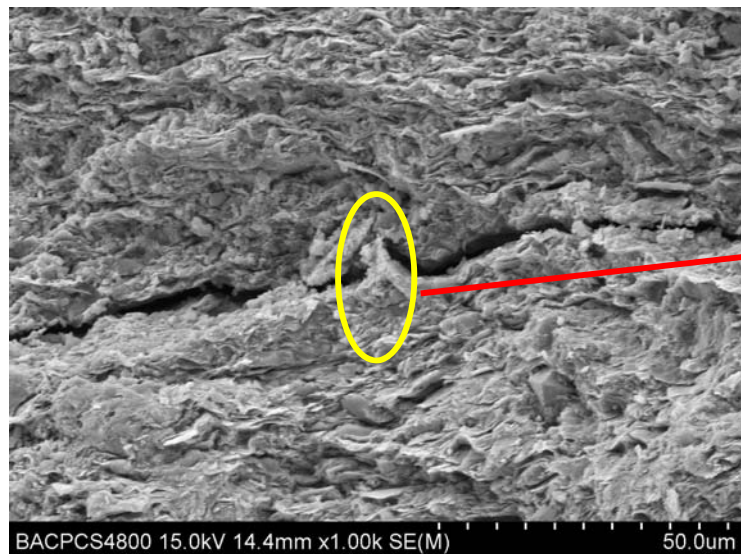
Horizontal microfractures



Horizontal microfractures

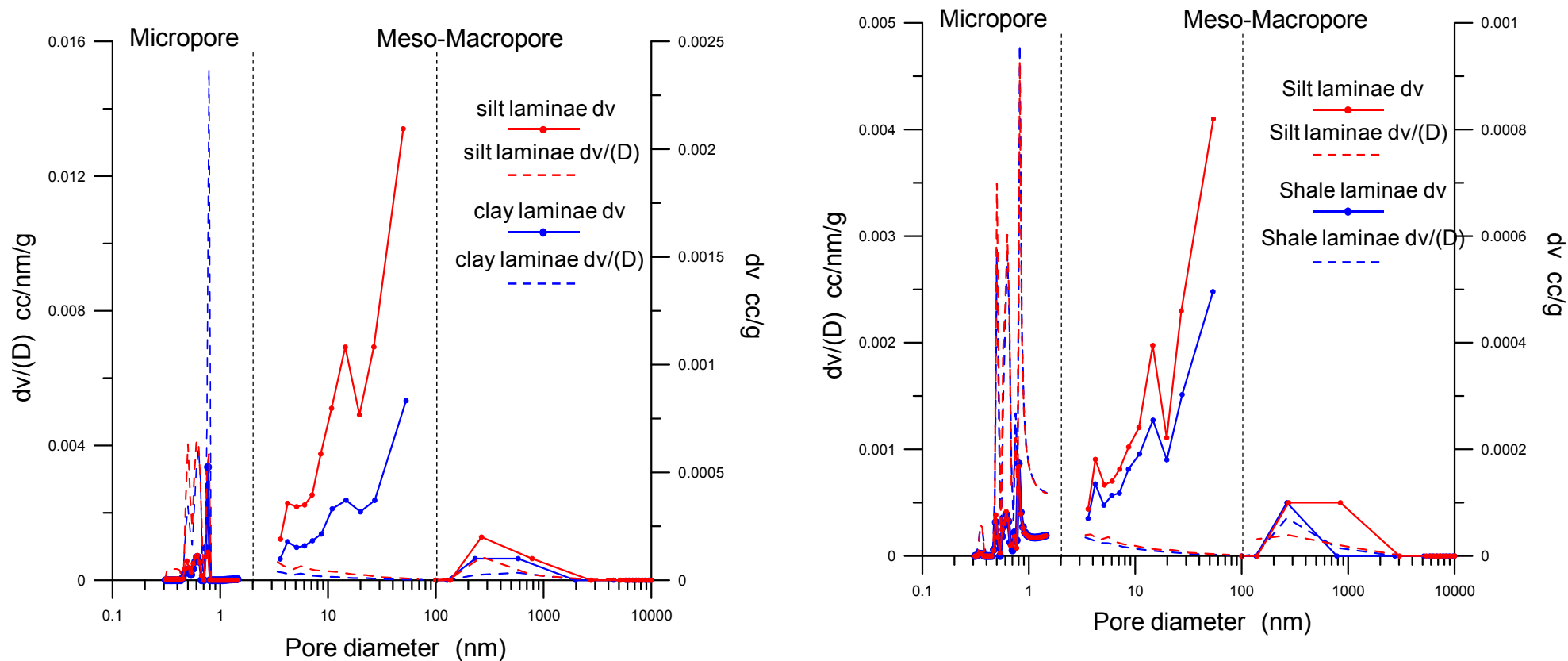


Non filled fractures



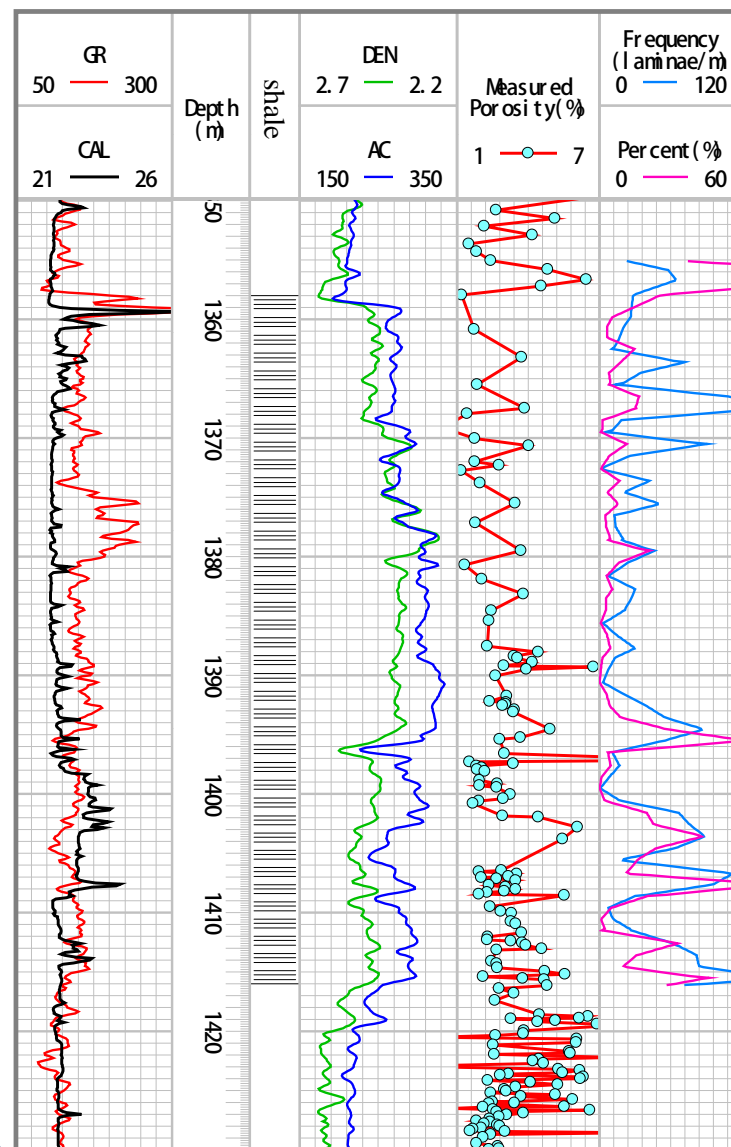
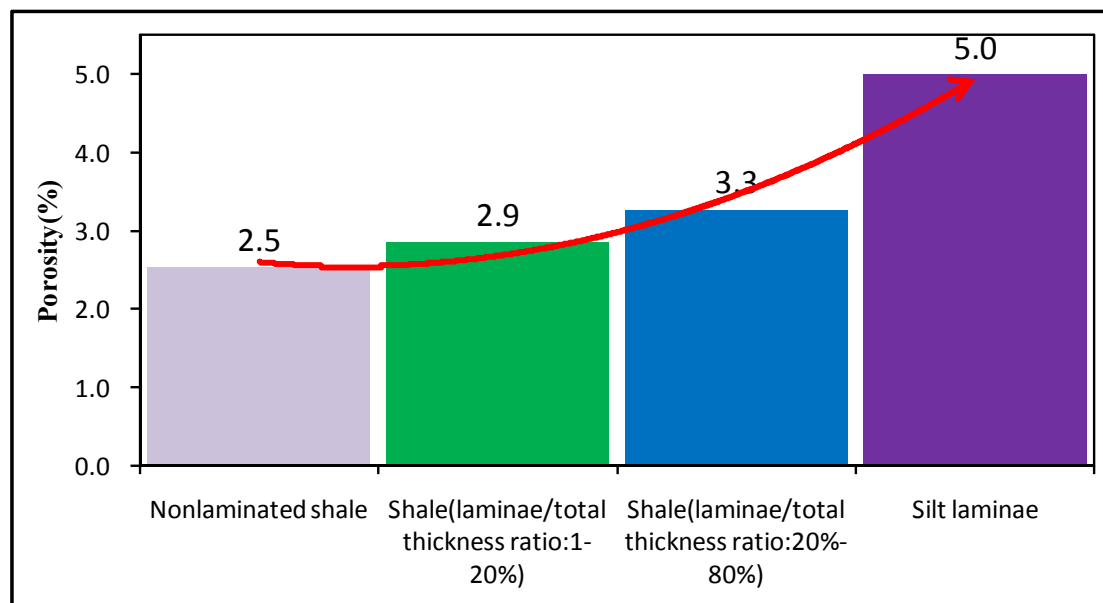
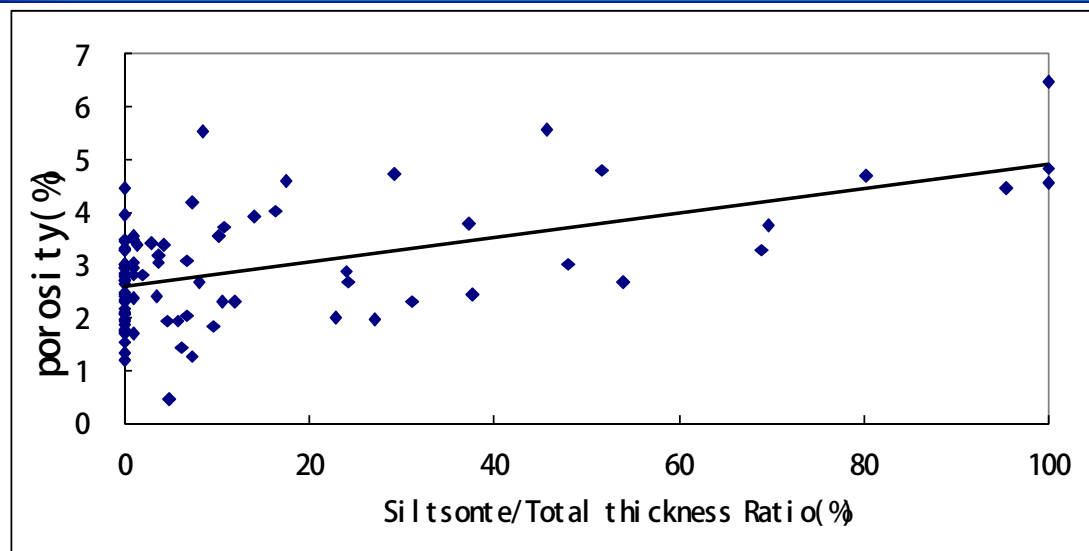
Authigenic minerals ensure that are natural fractures, non induced fractures

Pore structures



Surface areas and total pore volumes of silt laminae are larger than that of nonlaminated shales.

Porosity



Total porosity correlates positively with the density of siltstone laminae.



Outline

1、 Introduction

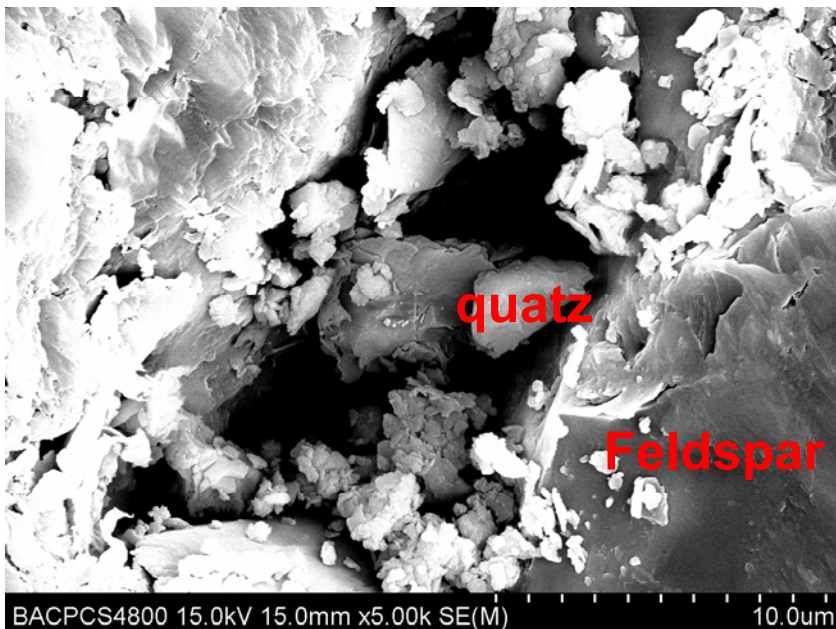
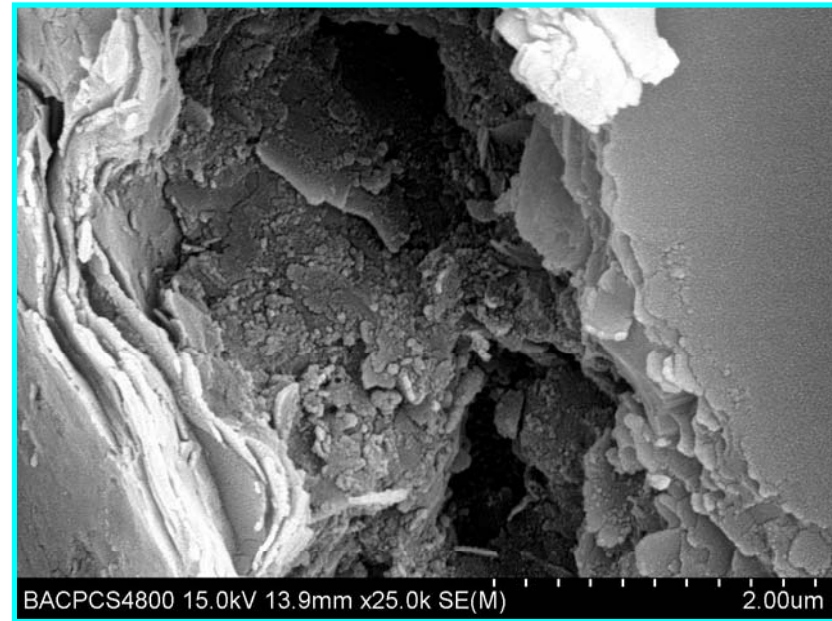
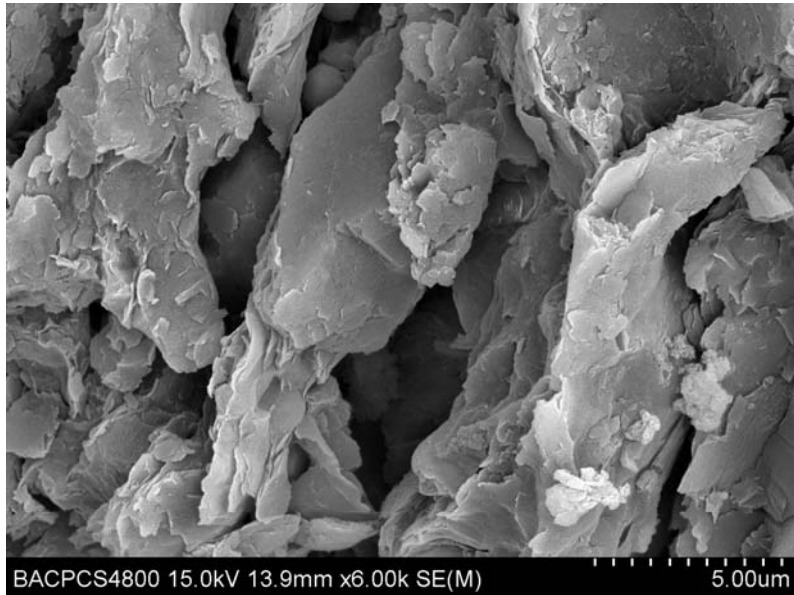
2、 Petrology characteristics of silty laminae



3、 Significance of silt laminae for shale gas

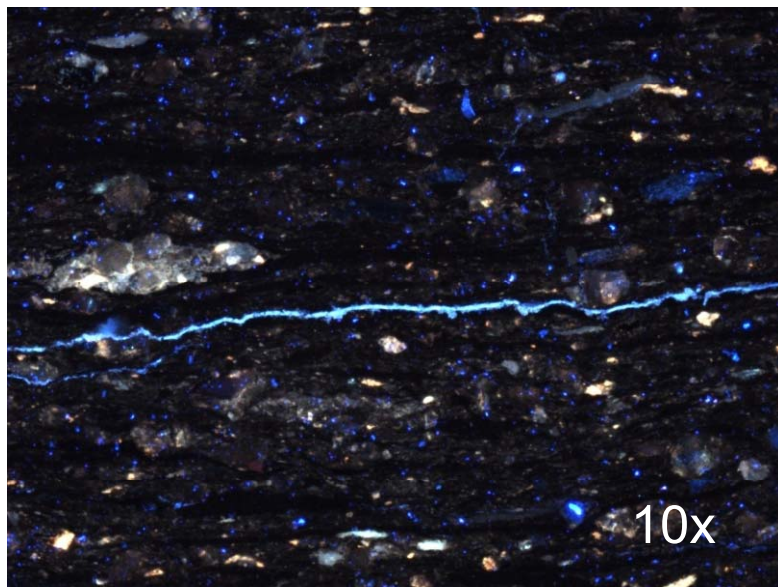
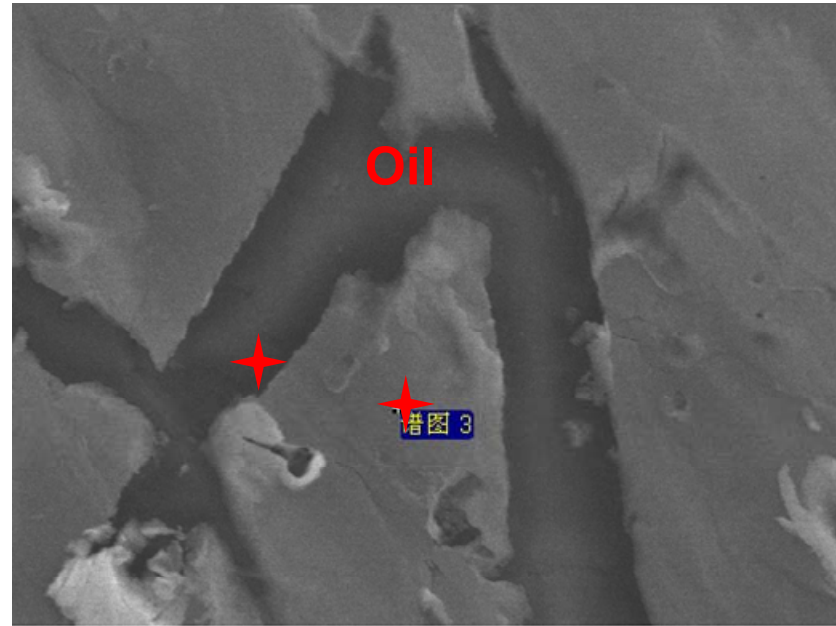
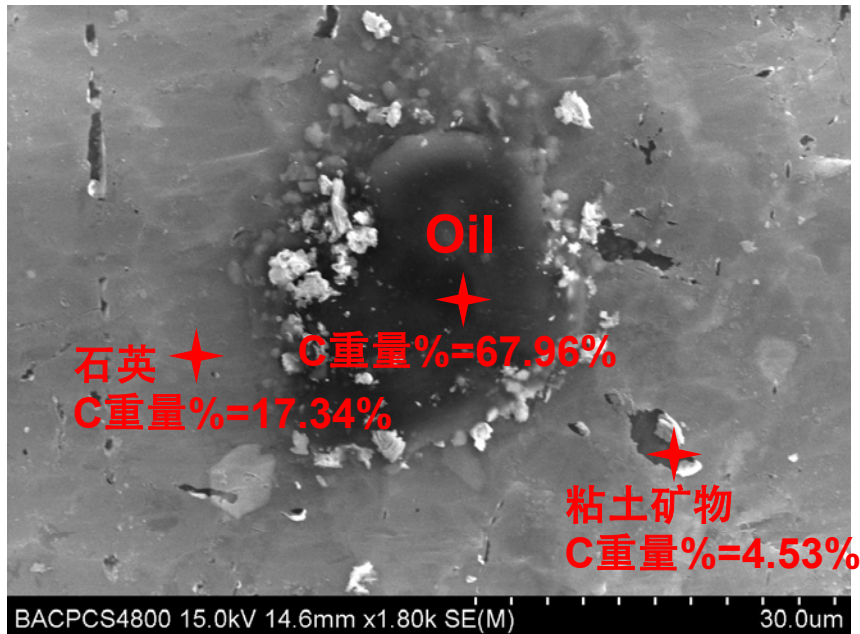
4、 Conclusions

1、 Provide pore space for oil and free gas accumulation



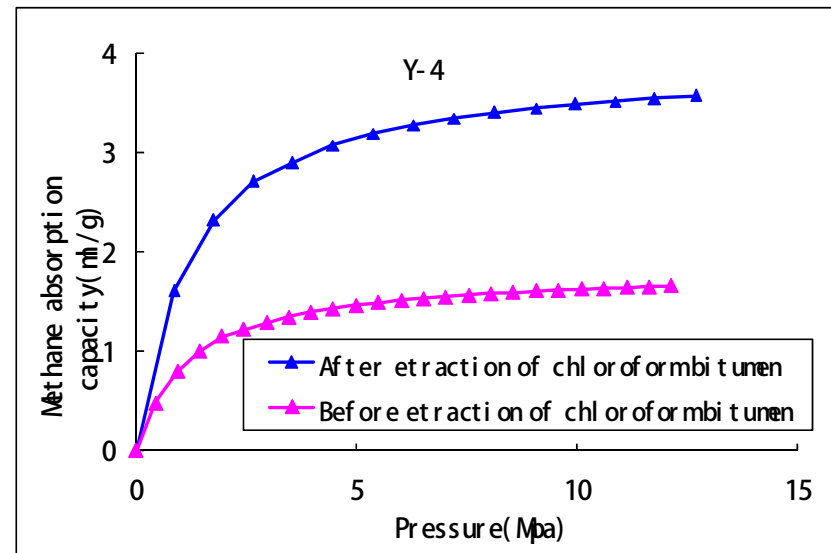
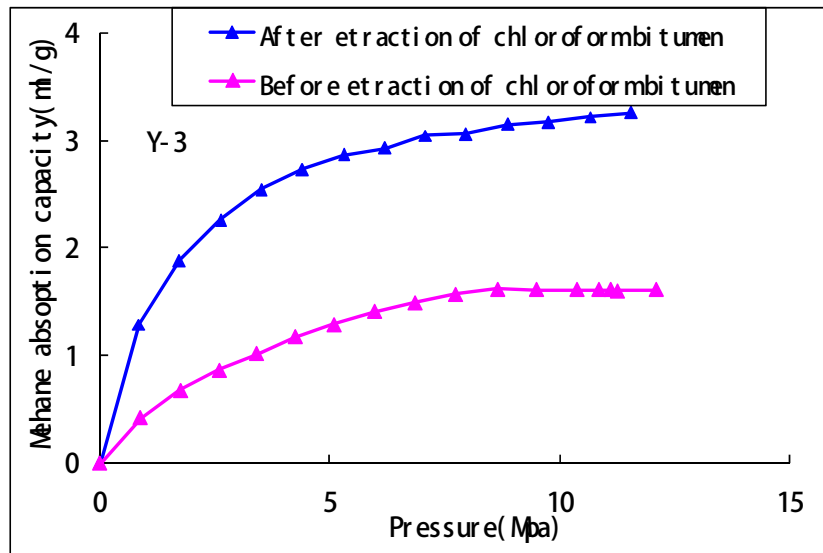
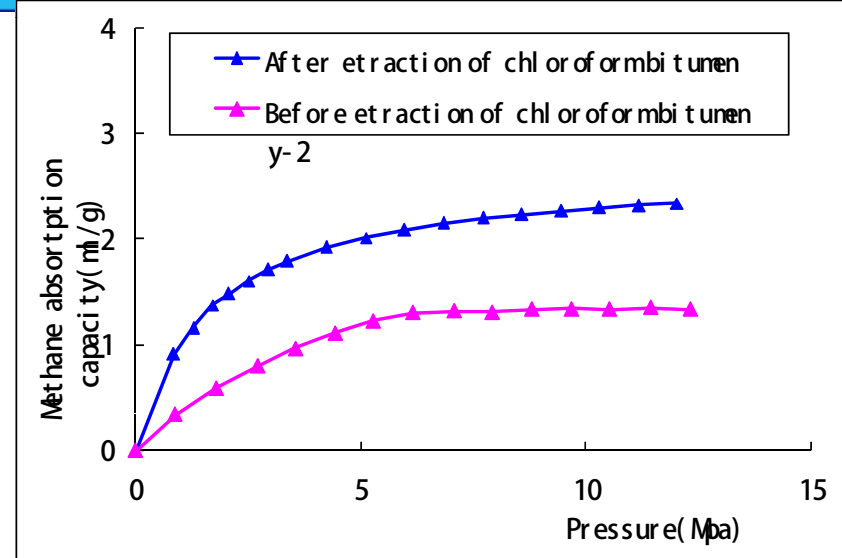
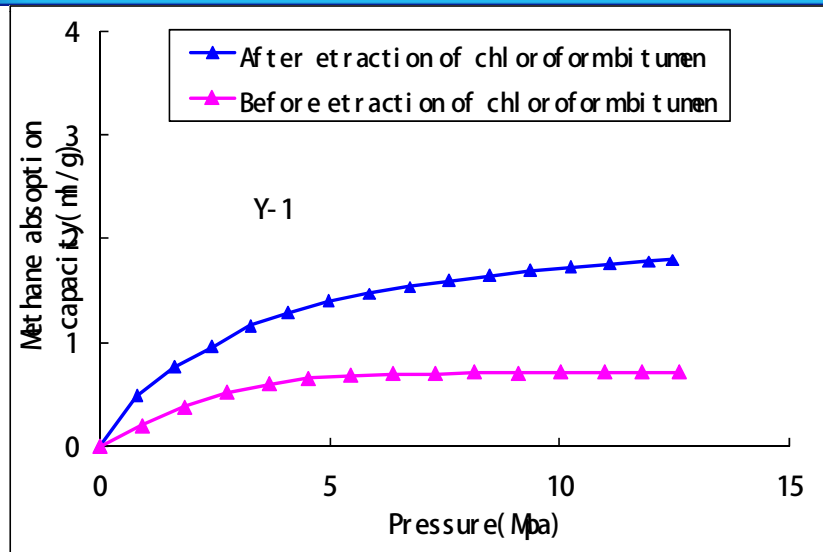
Macropores and mesopores in the silt laminae can provide storage spaces for free shale oil and gas.

2、Affect occurrence and abundance of shale gas



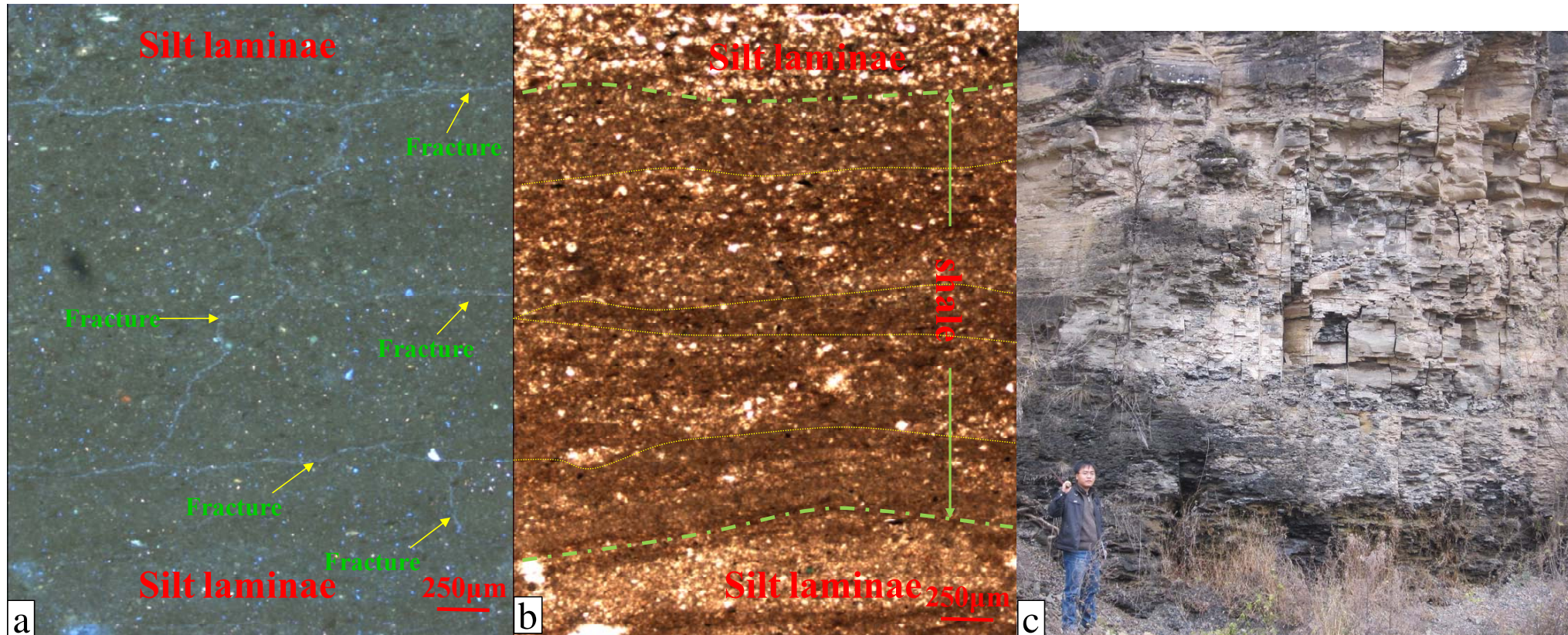
The free gas will be less, but the dissolved shale gas can not be neglected: 0.4 ~ 1.3ml/g , 12%-24% of the total shale gas. ●

2、Affect occurrence and abundance of shale gas



The oils filled in pores will reduce the quantity of absorbed shale gas.

3、Serve as carriers for shale gas flow



Besides the horizontal fractures, vertical joints and fractures are also developed, when interconnected, they serve as carriers for shale gas flow

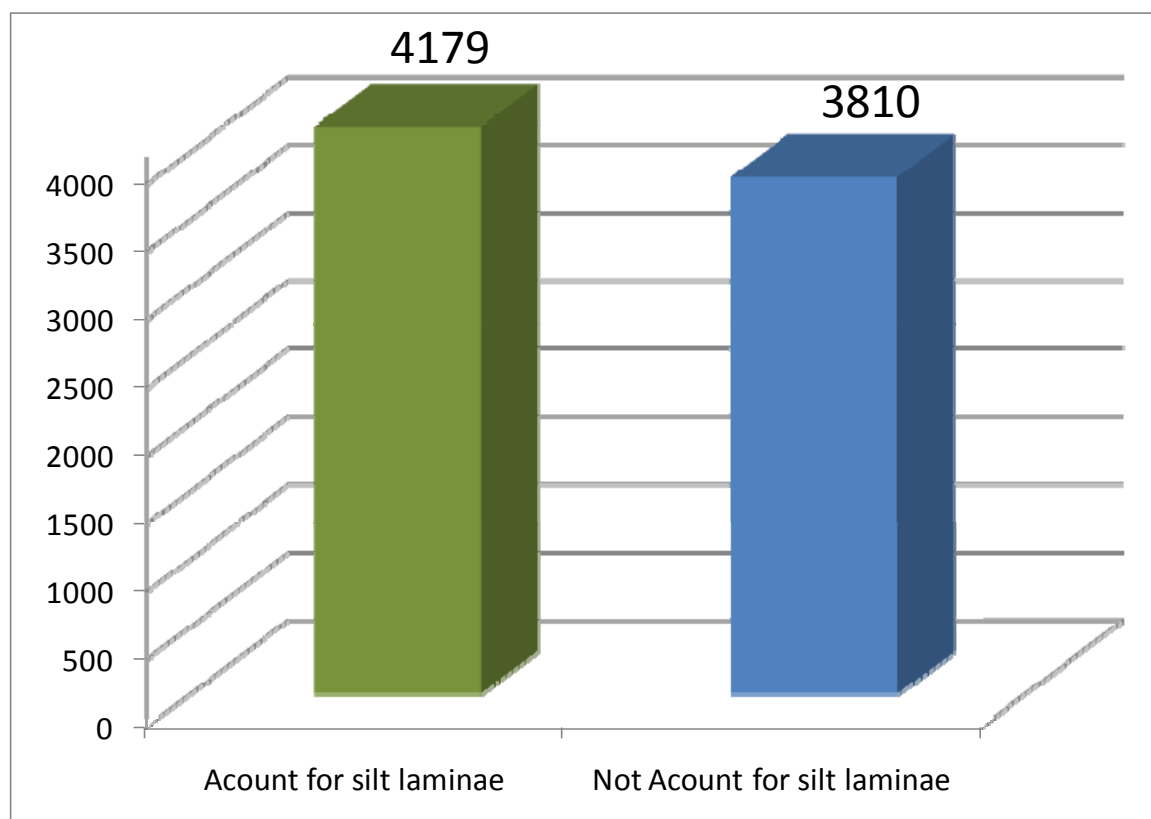
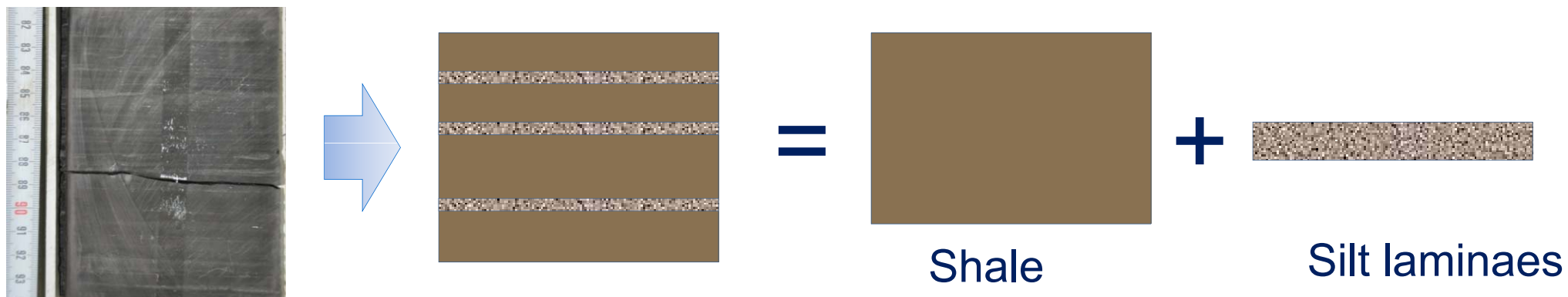
3、 Serve as carriers for shale gas flow



Results of water emersion test of shale cores indicate release of shale gas generally along siltstone lamination surfaces, horizontal fractures and foliations.



4、Evaluation of shale gas resource



If account for silt laminae, the gas resource will increase 10%.



Outline

1、 Introduction

2、 Petrology characteristics of silty laminae

3、 Significance of silt laminae for Shale Gas



4、 Conclusions



- 1. Silt laminae are common, average siltstone/total thickness ratio is about 12%.**
- 2. Lamilated shales have higher quantity of quartz and feldspar, lower clay minerals, larger surface areas and pore volumes.**
- 3. Horizontal microfractures are associated with silt laminae, which usually occur in shale adjacent to the silt laminae and serve as conduits for oil and gas flow.**
- 4. Silt laminae may be important to the occurrence and abundance of shale gas, need to further study.**