The Relationship Between Diagenesis, Porosity Evolution and Hydrocarbon Charging of Deeply Buried Sandstone Reservoirs in Dongpu Sag, Bohai Bay Basin, East China*+

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Abstract

In the process of study of deeply-buried sandstone reservoirs in Dongpu Sag, which is deeper than 3,500 m, we found that there are several features: (1) the sandstone is tight, its grains of the reservoir are very fine, and porosity is low; (2) the abnormally high porosity belts were developed locally, but its formation mechanism and distribution laws are unclear; and (3) the reservoirs containing high oil saturation usually have high porosity. For example, the siltstone at 4,153m in well W203-59 contains oil, and its porosity is 19%. Has the early hydrocarbon charging prevented the process of cementation filling, and left high porosity? Or has the oil just filled the spaces where the early cementation missed? In other words, whether hydrocarbon charging can control the diagenesis and porosity evolution of deeply-buried sandstone reservoirs in Dongpu Sag? And how it controlled? Using the data of thin-sections analysis, cathodoluminescence, SEM and fluid inclusions, we studied the characteristics of diagenesis, porosity type and evolution of reservoirs in different depth, and the relationships between hydrocarbon charging and development of effective reservoir and make the following conclusions. (1) Early carbonate cementation had impeded diagenesis, and it had eliminated the further packing of detrital grains during compaction, and is good for the reservation of pore spaces. (2) Latter carbonates mainly include ferroan calcite and ankerite. By the organic acid, early carbonates, feldspar and clay minerals provided material bases for latter carbonates, and the dissolved matters will move to some places by acidic fluid and deposit again, and it usually decreased the porosity of the reservoir. (3) In the reservoirs undertaken hydrocarbon charging, corrosion of feldspars and calcites were strong, and it produced large amount of secondary porosities, which made of the major pore spaces of the deeply-buried sandstone reservoirs. (4) The hydrocarbon charging controlled the diagenetic evolution of the reservoir. It had impeded the quartz overgrowth and latter carbonate cementation filling. (5) The hydrocarbon charging influenced the formation and conversion of clay minerals in the reservoirs. For example, only in the reservoirs in which the hydrocarbon saturation is low, the secondary illites were largely developed.

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1. Introduction

The Dongpu Sag is a secondary unit of Linqing Depression in Bohai Bay Basin, East China, extending in NNE direction. The area is about 5,300 square kilometers (Fig. 1).

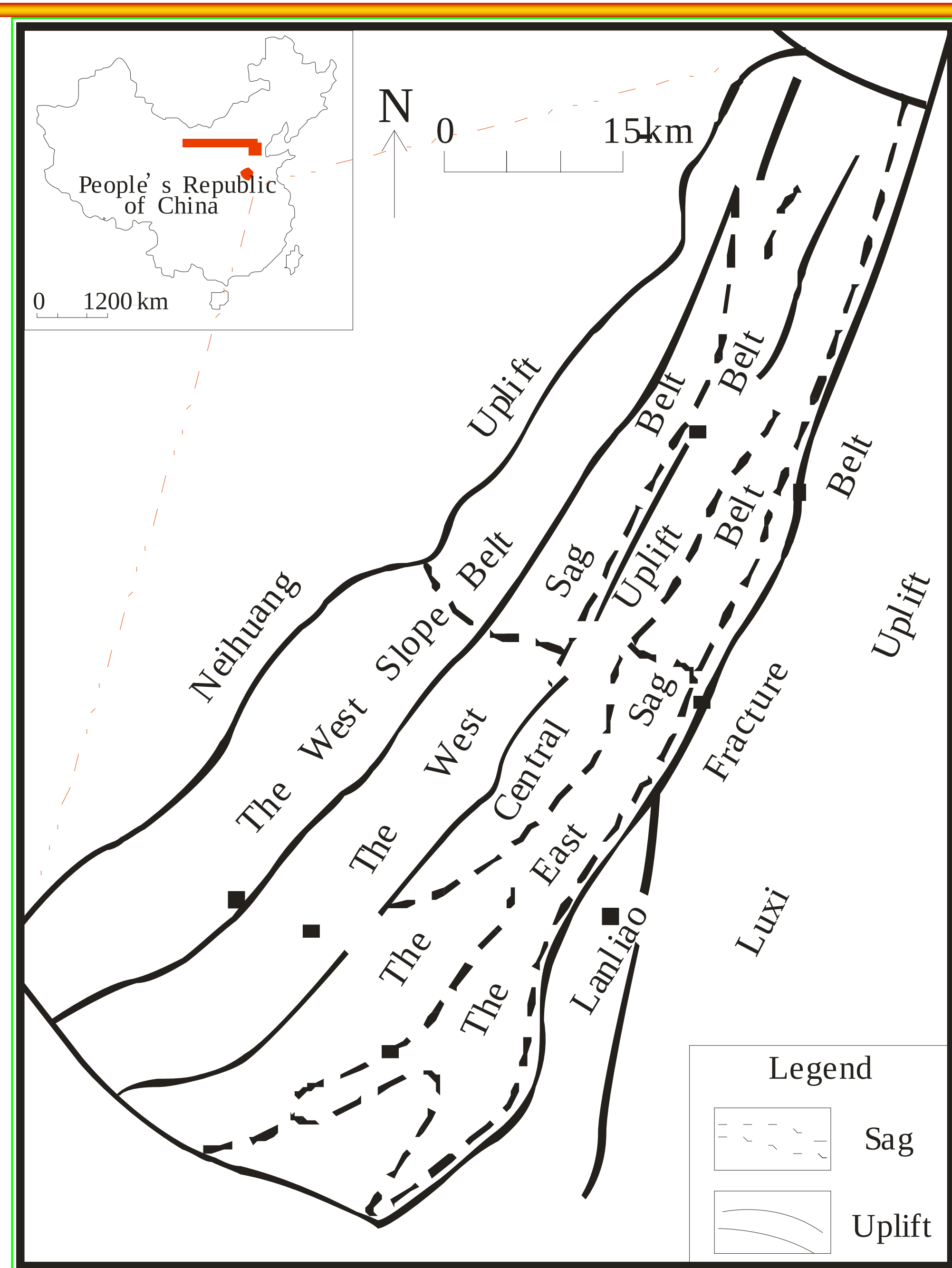

Fig. 1 The geologic map of the Dongpu Sag, Bohai Bay, East China

1. Introduction

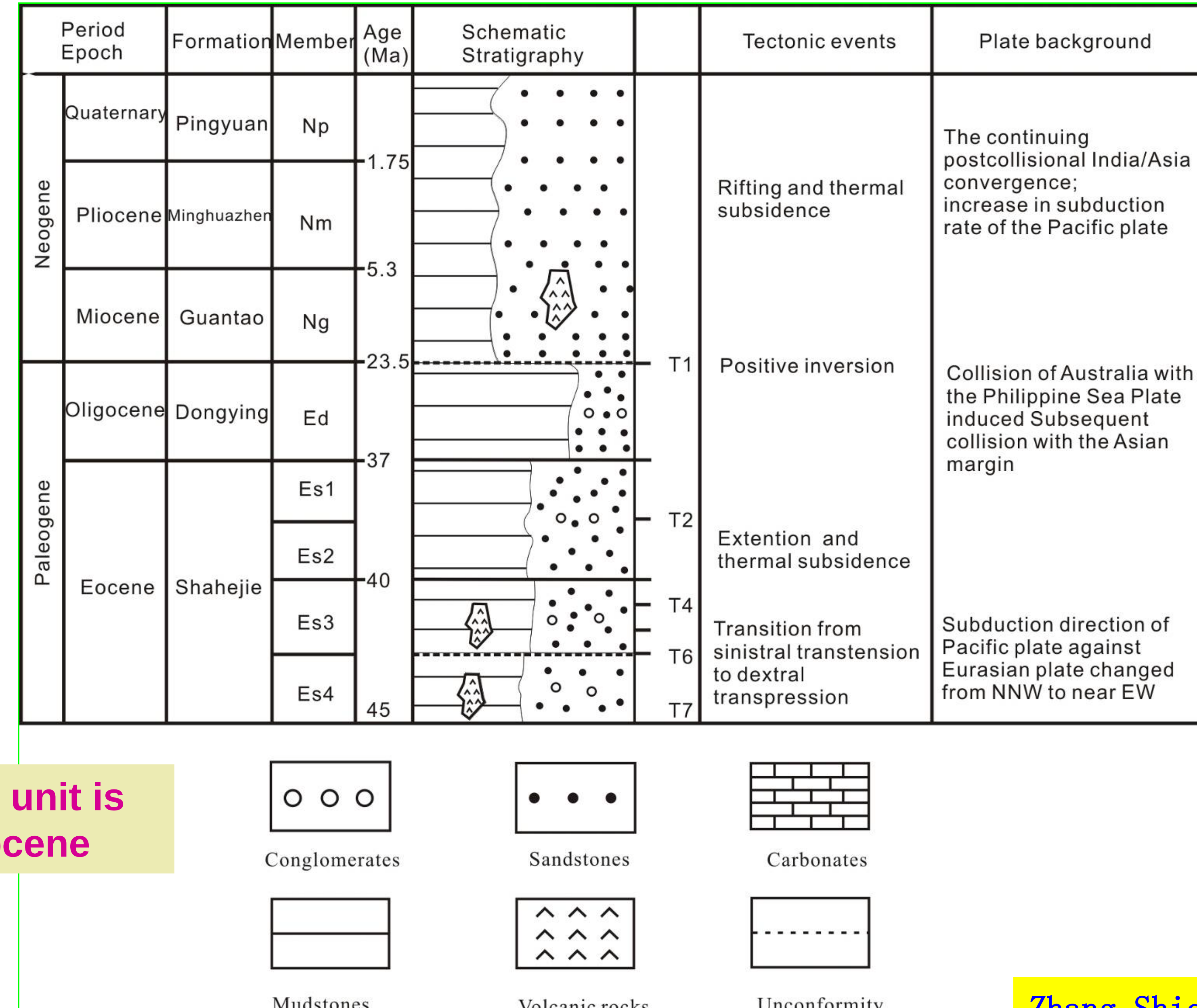

Fig. 2 study unit is in lower Pliocene

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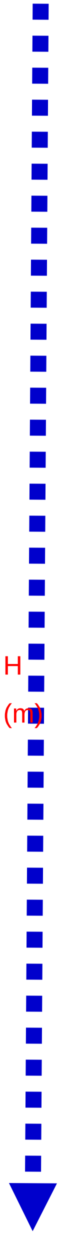
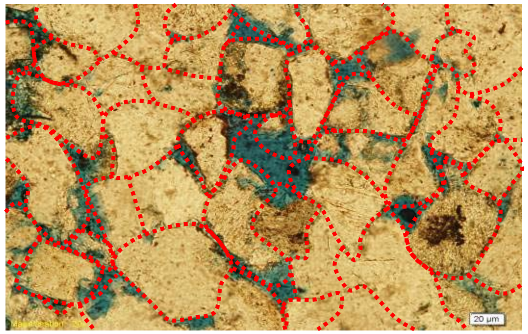
2.Pores Types and Characteristics of Porosity Evolution

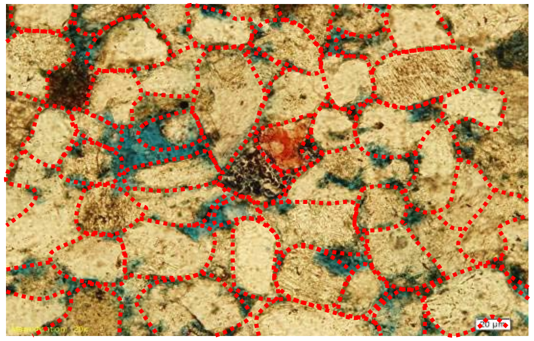
2.1 Pores types

And the content of primary porosity decreased with the increasing of reservoir depth (Fig. 3).

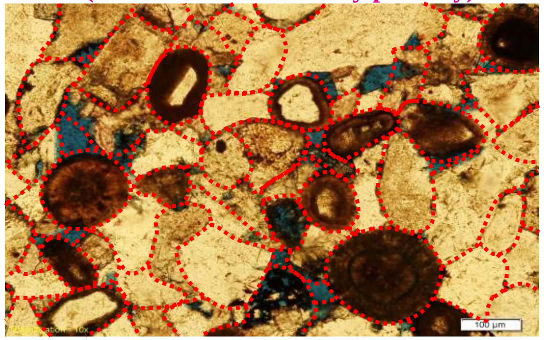




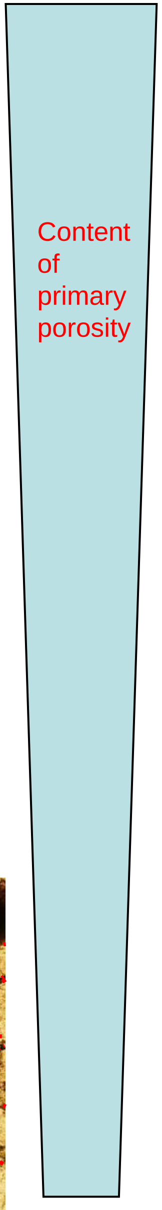
Wen 203-59, 3594.1m, Porosity 10.6%
(about 30% are Primary porosity)



Wen 203-59, 4163.15m, Porosity 10.9%
(about 25% are Primary porosity)



Qiao 203-59, 4427.56m, Porosity 9%
(about 20% are Primary porosity)



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2.2 Characteristics of Porosity Evolution

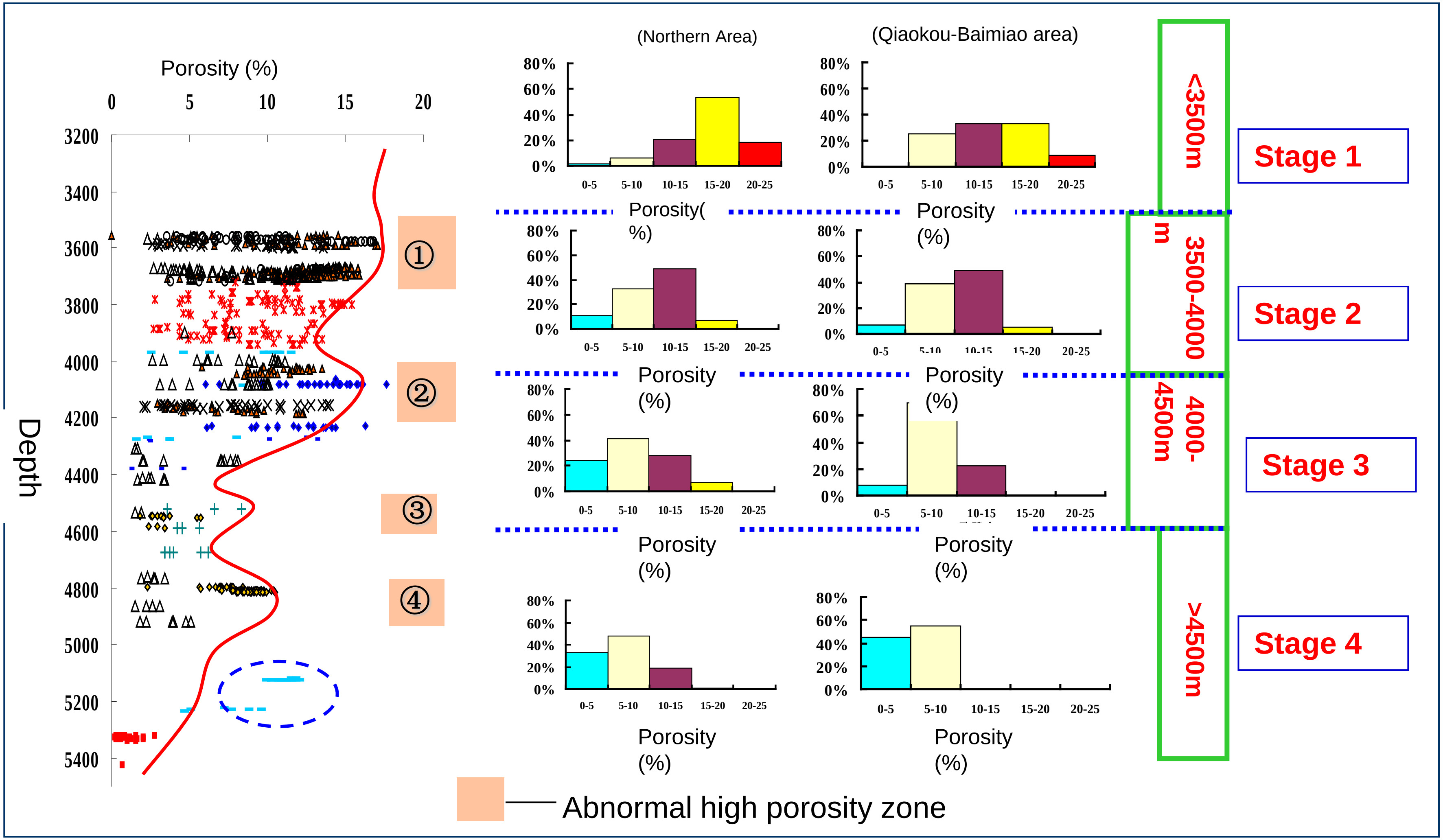

Fig. 4 The relationship between the porosity frequency and depth, and the vertical distributions of the abnormal high porosity zones

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2.2 Characteristics of Porosity Evolution

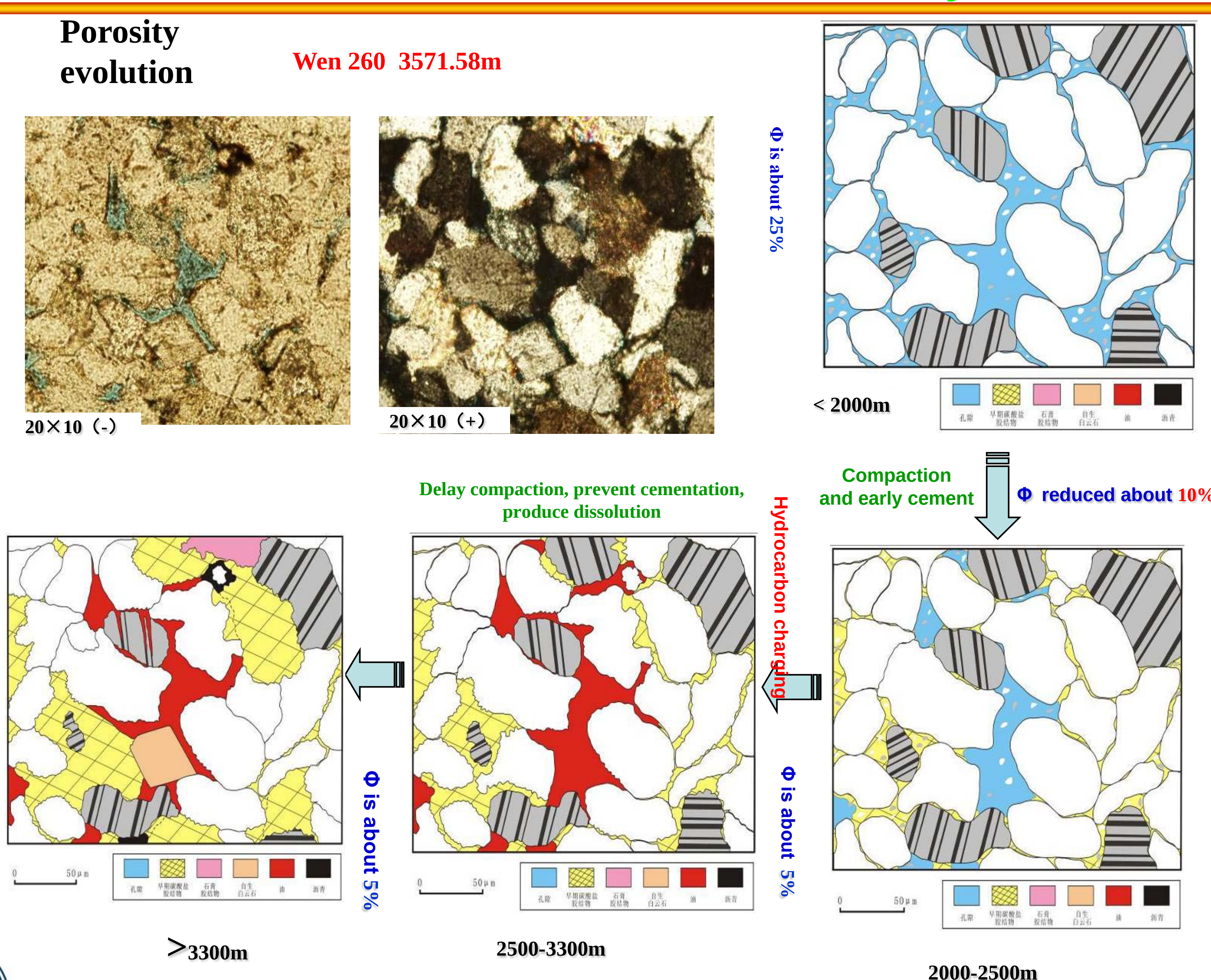

Fig. 5 Models of porosity evolution influenced by different diagenetic activities

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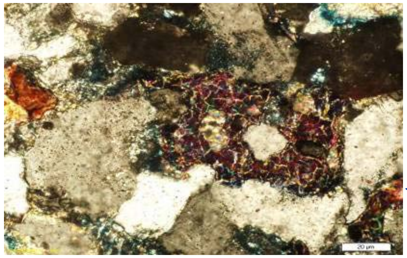
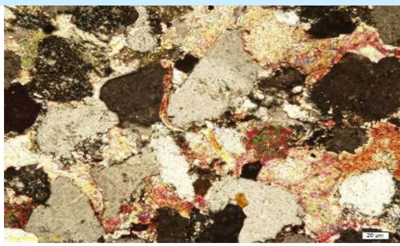
3. Controlling factors of effective reservoir forming of Dongpu Sag

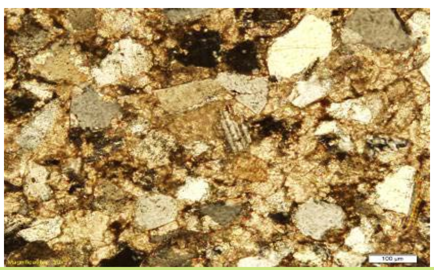
3.1 Influence of Hydrocarbon charging to effective reservoir



3903.73 m, water formation, the content of carbonate cement is 13% , and early cement / late cement = 21% / 79%。

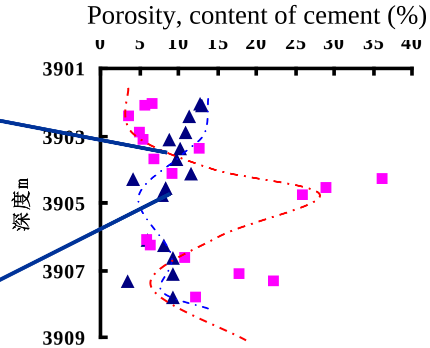


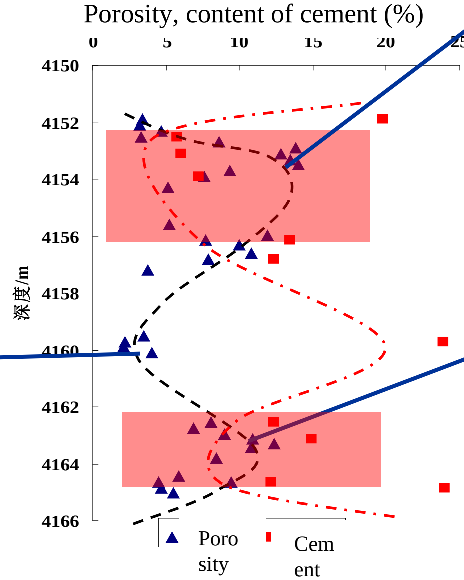
3904.93m, water formation, the content of carbonate cement is 25% , and early cement / late cement = 16% / 84%。



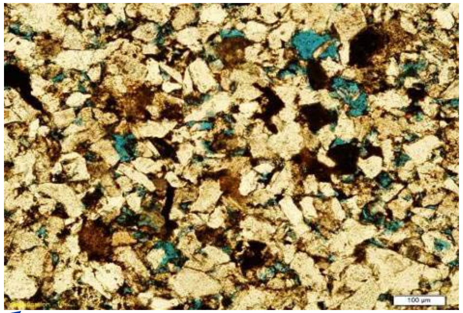
4159.71m, Dry formation, the content of carbonate cement is 24% , and early cement / late cement = 30% / 70%。

Qiao 20 The cores from Run 5
Water formation

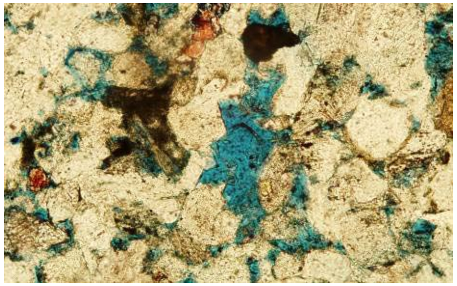




Wen 203-59 The cores from Run 4次
Oil formation, Dry formation



4153.11m, Oil formation , the content of carbonate cement is 6% , and early cement / late cement =72% / 28%



4163.15m, Oil formation , the content of carbonate cement is 5% , and early cement / late cement =61% / 39%。

Fig. 6 The content changes of early and late carbonate cement in different kinds formation

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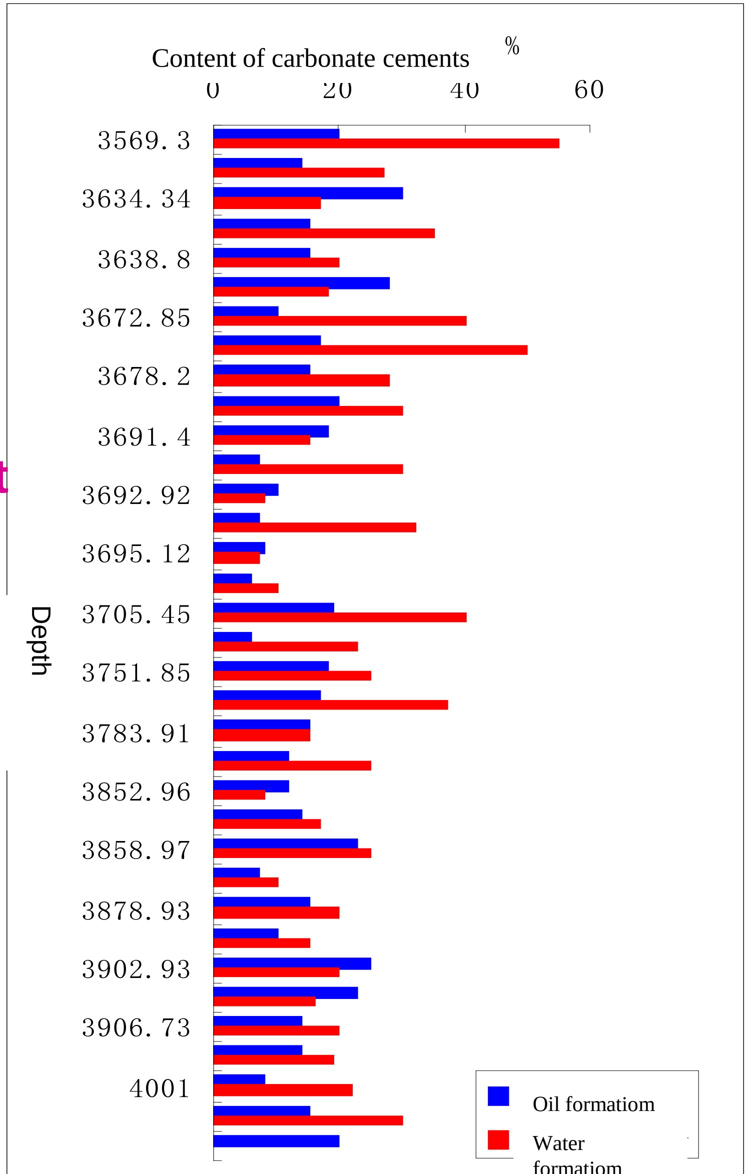
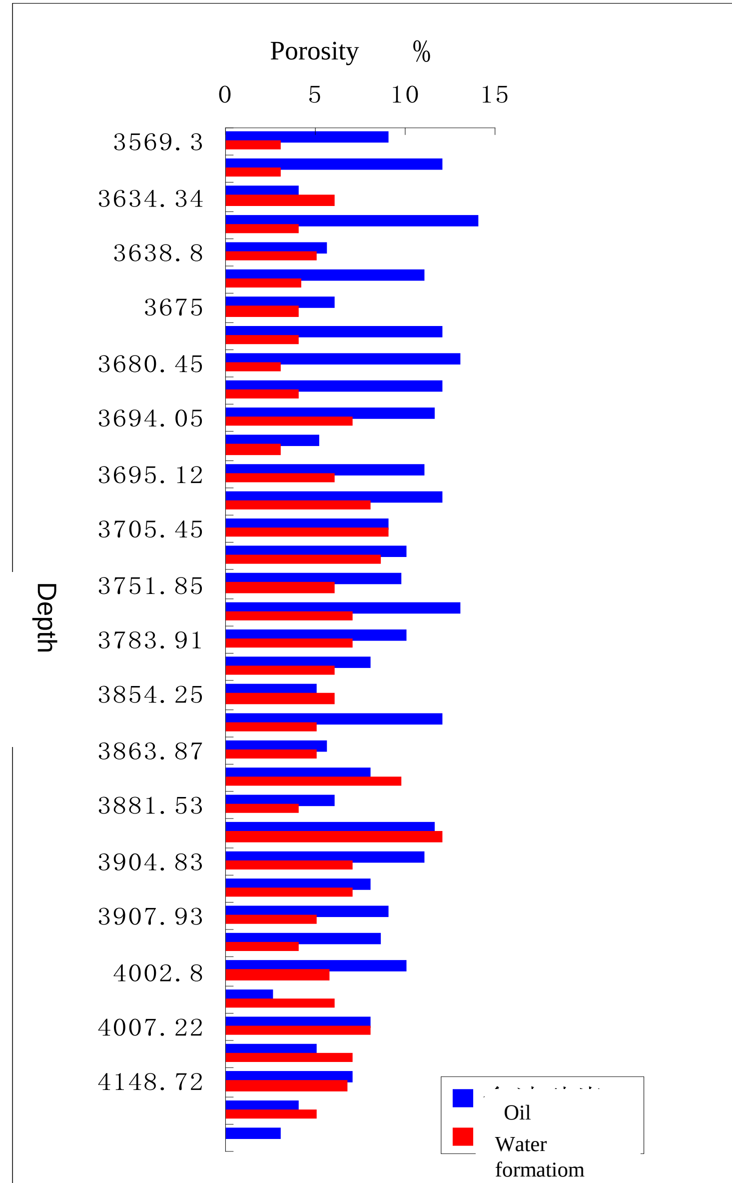
3.1 Influence of Hydrocarbon charging to effective reservoir

Fig. 7 Contrast maps of carbonate cement content and porosity between oil formations and water





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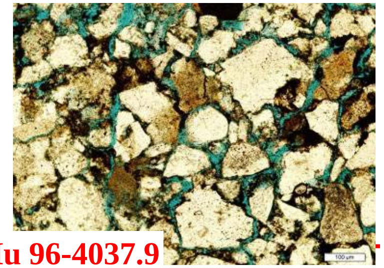
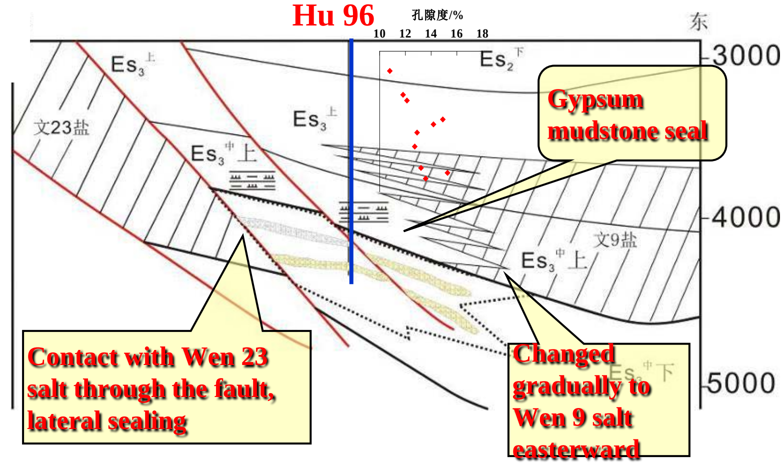
3.2 Influence of abnormal high pressure to effective reservoir

(a) Abnormal high pressure caused by closed environment (Hu 96 well area)

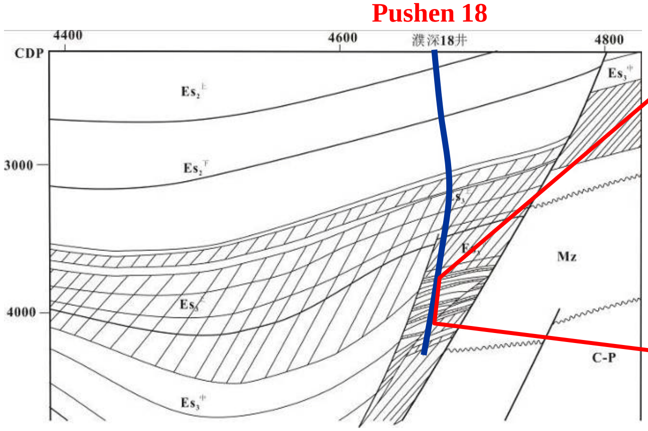


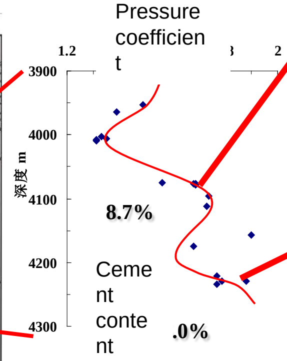
Hu 96-4037.9

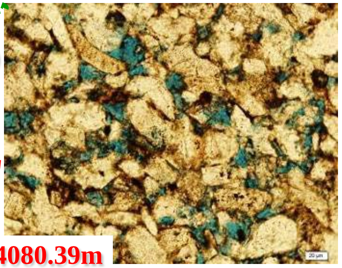
4037.85-4039.77m， pressure coefficient is 1.53
The average φ=13.15%，
$K>1.48\times10^{-3}\mu m^2$



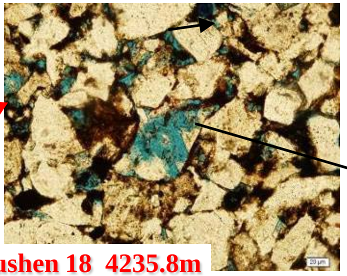
(b) Abnormal high pressure under salt bed (Pushen 18 well area)





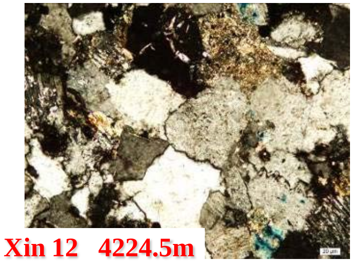


4080.39m



Pushen 18 4235.8m

Average pressure coefficient is 1.78，point-line contact between grains



Xin 12 4224.5m

Pressure coefficient is 1.3, stylolite contact

High pressure delay compaction, barrier pressure dissolution and cementation, is good for pores reconstruction.

Fig. 8 Relationship of effective reservoir and abnormal high pressures caused by different mechanics

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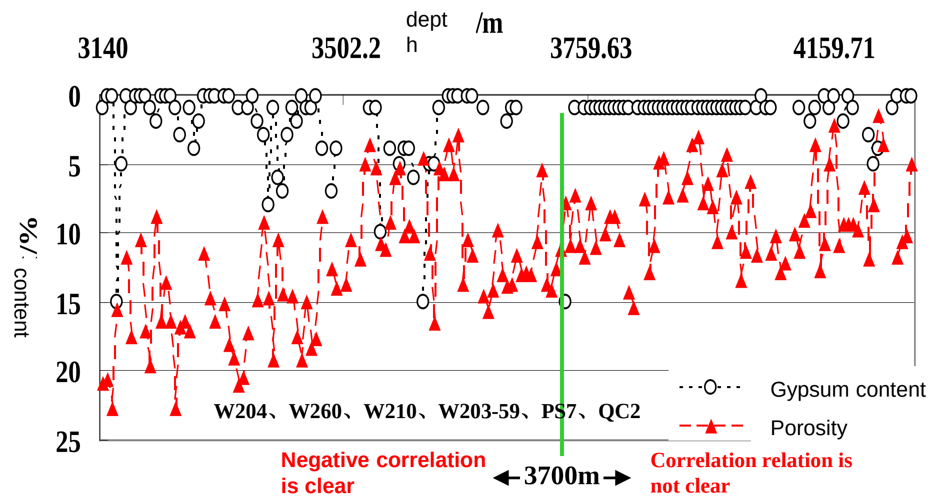
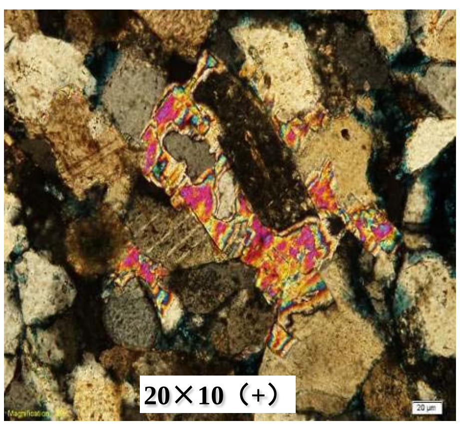
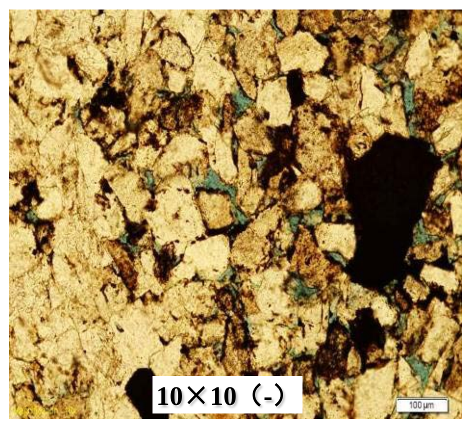
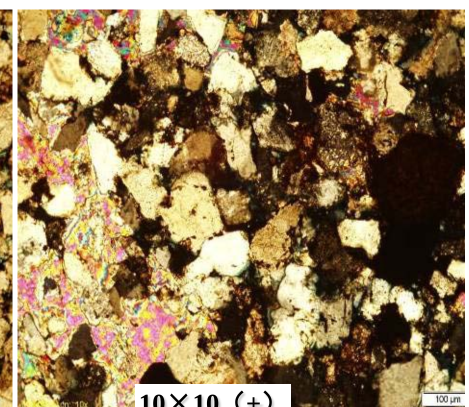
3.3 Influence of Gypsolyte and salt beds to effective reservoir

Gypsum and NaCl are common in Deep reservoir, the content is limited. Mainly developed in Wendong, Qiaokou and Liutun areas, cemented and replaced the grains.









Qiao 35, 4235.77m, Gypsum Content is 12%, Φ=9.2%

Wen 260, 3701.43m, gypsum content is 15%, Φ=7.8%

Fig. 9 The relationship between gypsum content and porosity

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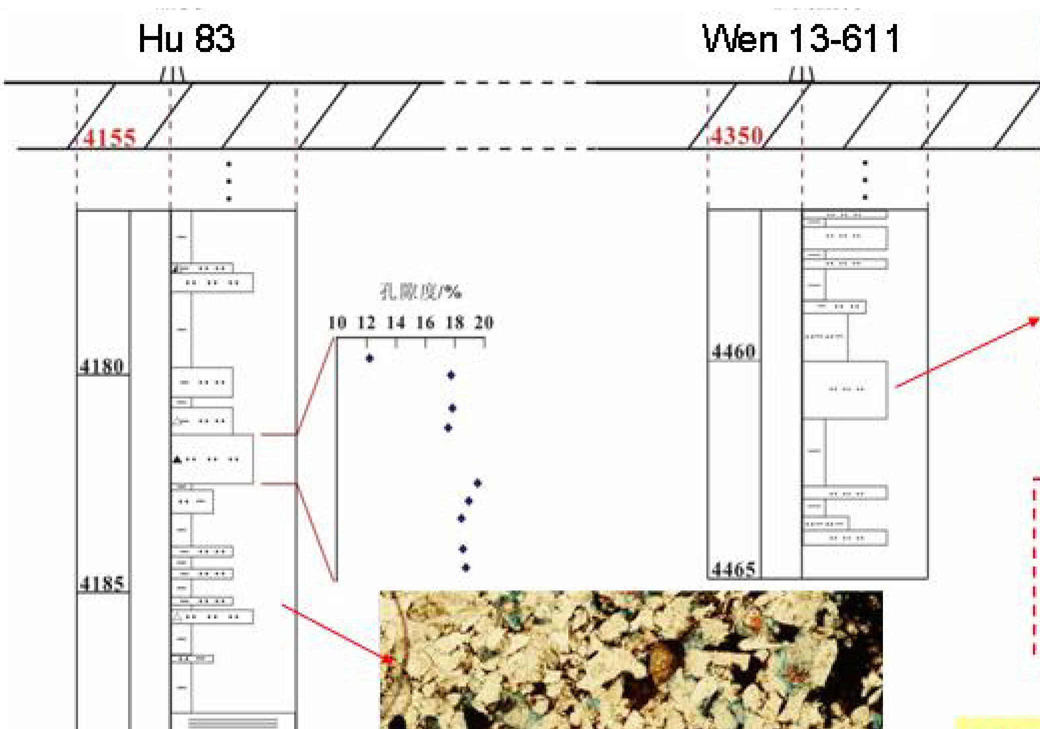
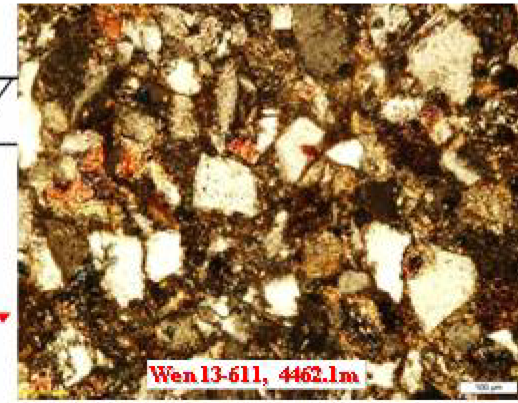
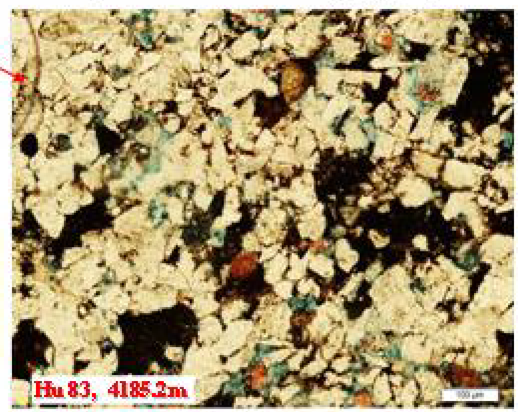
3.3 Influence of Gypsolyte and salt beds to effective reservoir





4460.5-4462.1m, Es4
Middle sorting
Fragment and mica: 8%
Debris: 12% , Φ<8%

4181.1-4182.14m Es_3^4
Pressure coefficient:1.76-1.79
Φ =12.2%-19.5%



Point-line contact, filled by bitumen

The difference of original materials influenced the controlling degree of gypsum-salt to the reservoir property.

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3.4 Influence of fracture distributions to effective reservoir

Fig. 11 The fracture characteristics of deep reservoirs

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4 Conclusions

(1)Early carbonate cementation had impeded diagenesis, and it had eliminated the further packing of detrital grains during compaction, and is good for the reservation of pore spaces.

(2) Latter carbonates mainly include ferroan calcite and ankerite. By the organic acid, early carbonates, feldspar and clay minerals provided material bases for latter carbonates, and the dissolved matters will move to some places by acidic fluid and deposit again, and it usually decreased the porosity of the reservoir.

(3) In the reservoirs undertaken hydrocarbon charging, corrosion of feldspars and calcites were strong, and it produced large amount of secondary porosities, which made of the major pore spaces of the deeply-buried sandstone reservoirs.

(4) The hydrocarbon charging controlled the diagenetic evolution of the reservoir. It had impeded the quartz overgrowth and latter carbonate cementation filling.

(5) The hydrocarbon charging influenced the formation and conversion of clay minerals in the reservoirs . For example, only in the reservoirs in which the hydrocarbon saturation is low, the secondary Illites were largely developed.

Acknowledgements

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