Diagenesis and Reservoir Quality of Lengdong Area, Qaidam Basin, China*

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Abstract

Based on thin section observation and homogenization temperature of the fluid inclusions analysis, combining with reservoir modeling, the reservoir characteristics of Jurassic coal measure strata and neighboring sandstone and the evolution of pores in Lenghu Tectonic Zone of the North Margin of the Qaidam Basin has been studied. The analysis results indicated dissolution by organic acid fluid, together with sequence boundary and favorable sedimentary facies, is one of the main controlling factors on reservoir quality.

In the early diagenesis stage, the decaying plant decomposed quickly and then produced humic acid, resulting in an acid medium of pore water in the process of sedimentation. Therefore, in early diagenesis most reservoir of coal measure strata lacks calcite, gypsum and zeolite cement filling, etc. And the compaction decreased primary porosity, reducing throat thinning and thus permeability. The coal measure strata in this stage are commonly low porosity and permeability reservoir quality. In the middle diagenesis stage, a large amount of organic acid fluid formed and intensively dissolved the unstable components such as feldspar, debris, etc. As the rock in this stage has almost been consolidated and the compaction rate decreased, the secondary dissolution porosity was likely preserved and thus relatively high quality reservoir formed.

In addition, the acid fluid from coal bearing strata went into the neighboring reservoir along the fault in Lenghu Tectonic Zone. By reservoir modeling, the effects of acid fluid on porosity of reservoir were simulated. As the acid fluid migration distance increased, the quality of reservoir got better and then deteriorated before ameliorating. The diagenesis of acid fluid in different conditions can be modeled by changing the related parameters. Owing to the acid fluid in Jurassic coal measure strata, the Jurassic reservoir, neighboring Lulehe and Lower Ganchaigou Group is of high quality, despite the upper Lulehe Group. The experimental results fit well with testing data, so the simulation is a practical method in coal measure strata diagenesis. This study can provide references for prediction and exploration of petroleum in reservoir studies.

China University of Geosciences

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Sep 2016

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- Introduction
- Geological Settings
- Methods
- Reservoir lithologies
- Diagenetic minerals
- Reservoir properties
- Discussion
- Conclusions

Introduction

- **Qaidam Basin**
  - large inland lake sedimentary basin
  - abundant resources

- **Lengdong Area**
  - located in northwestern of North Qaidam
  - produced good industrial oil flows in shallow layer
  - has good gas show in deep Jurassic and basement rock

- **Reservoir Quality**
  - high quality reservoir
  - reservoir evaluation

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Geological Settings

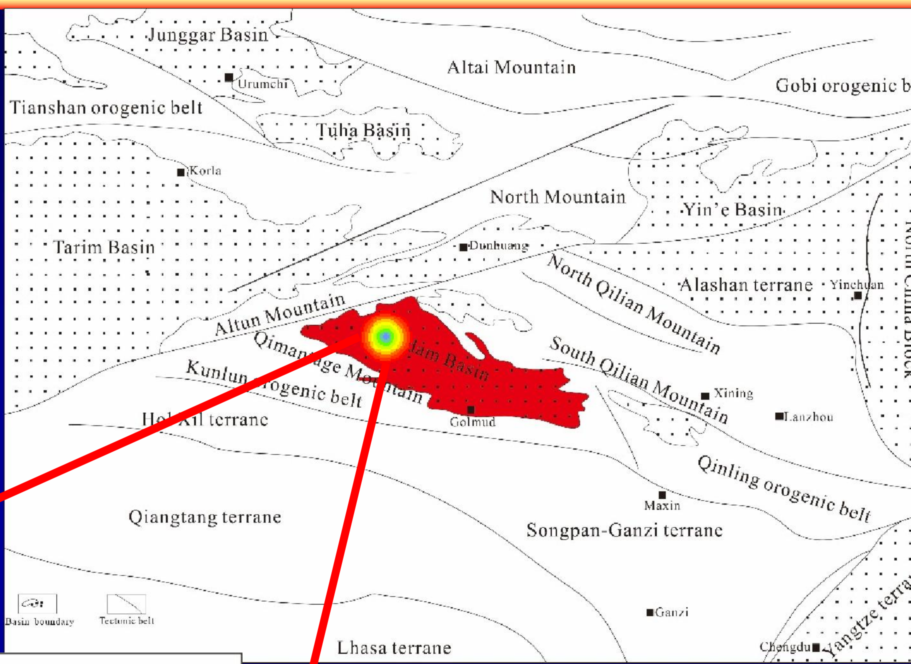

Fig.1 The tectonic map of Qaidam Basin

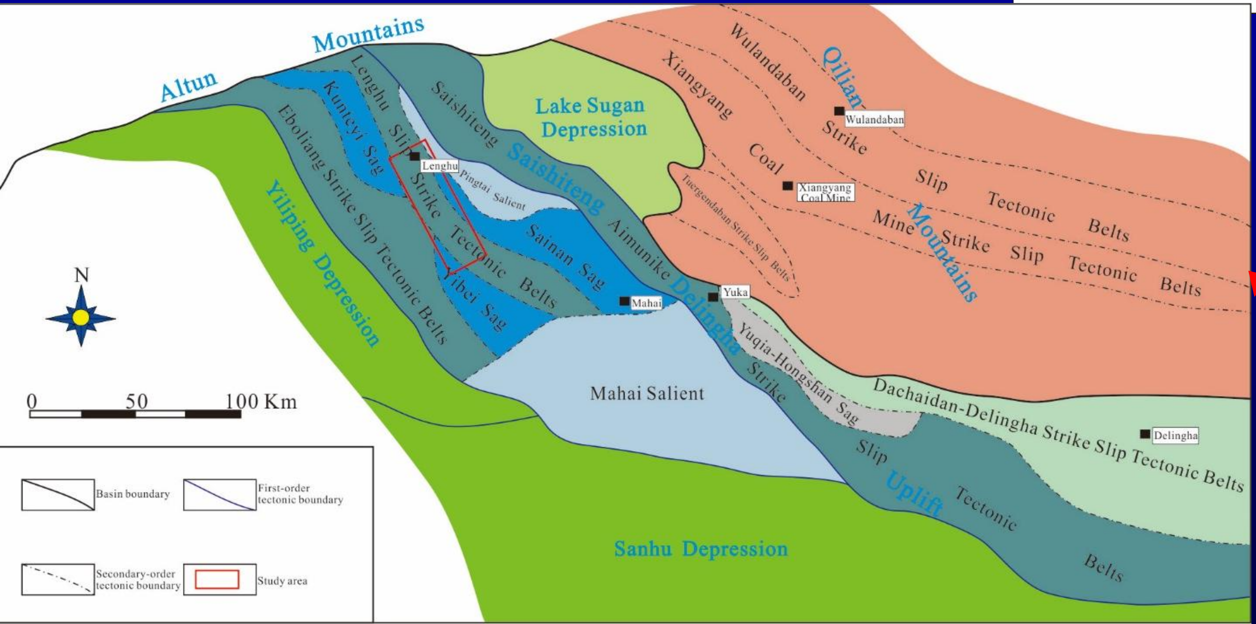

Fig.2 The tectonic map of Lengdong area

Geological Settings

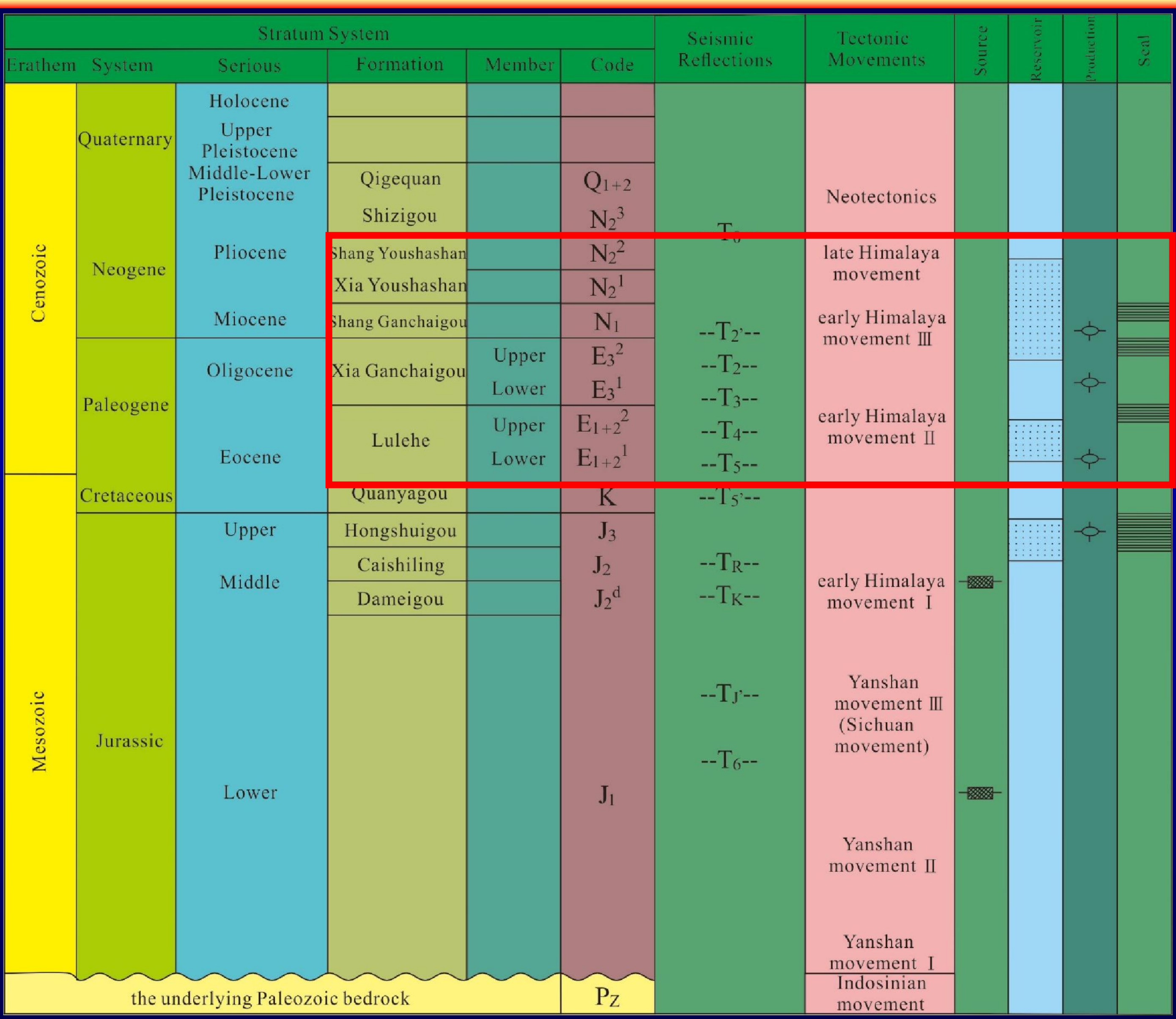

Figure 3 Synthetical Stratum Histogram

Contents

Methods

- **Optical microscopy**
  - Processed: vacuum, blue resin, mixed Alizarin Red-S and Potassium Ferri Cyanide.
- **SEM (scanning electron microscopy)**
  - JSM-5500LV and energy dispersive X-ray spectroscopy (EDS),Petroleum geology analysis and test center, Research Institute of Exploration and Production of Sinopec Zhongyuan Oilfield Company, China.
- **XRD (X-ray diffraction)**
  - The sample treatment method refers to Moore and Reynolds (1997) and Hillier (2003).
- **CL (cathode luminescence)**
  - CITL Cold Cathode Luminescence 8200mk3, excitation energy 20 kV and 400mA, Cameca SX100 electron microprobe, 15 kV, 10 nA, 5mm.

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Reservoir lithologies

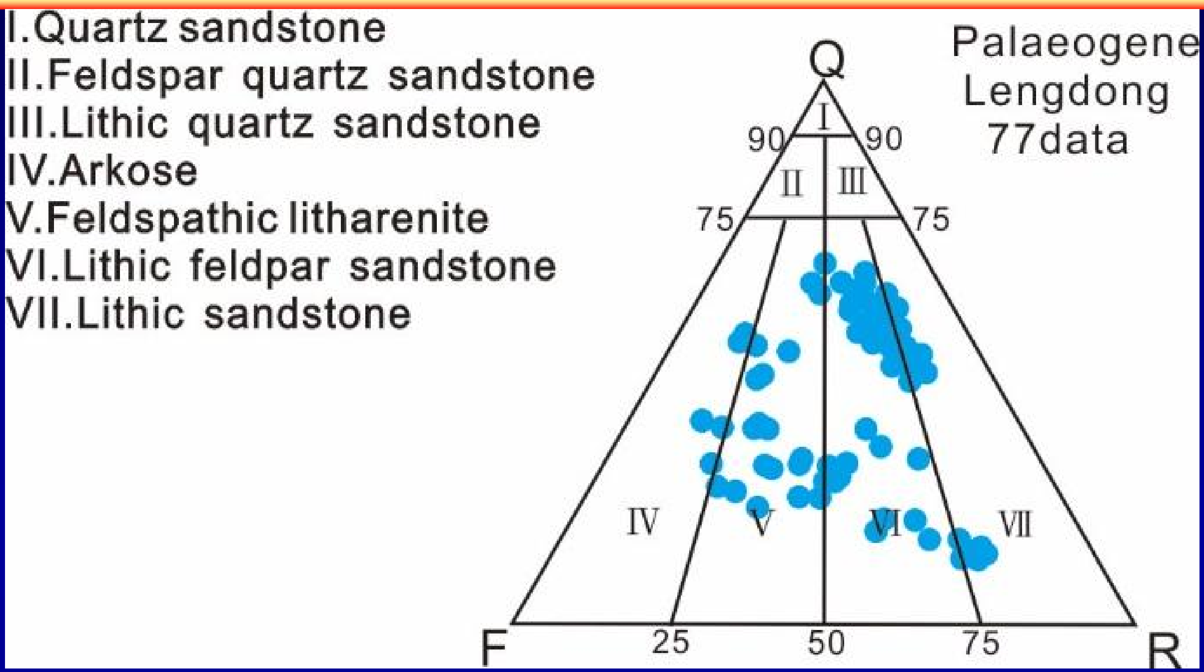

Figure 4 Lithologic Classification

Particle characteristic: subangular to subrounded, medium to fine grain, medium to well-sorted, line, point-line and line-point contacts.

Component: 35.21% quartz, 27.16% lithic fragment, 19.32% feldspar.

Heavy minaral :magnetite, garnet, epidote and zircon ,ZTR 20.51%.

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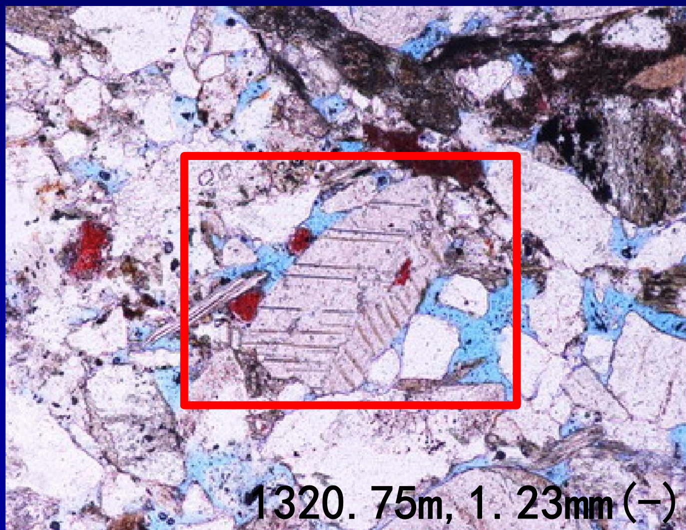
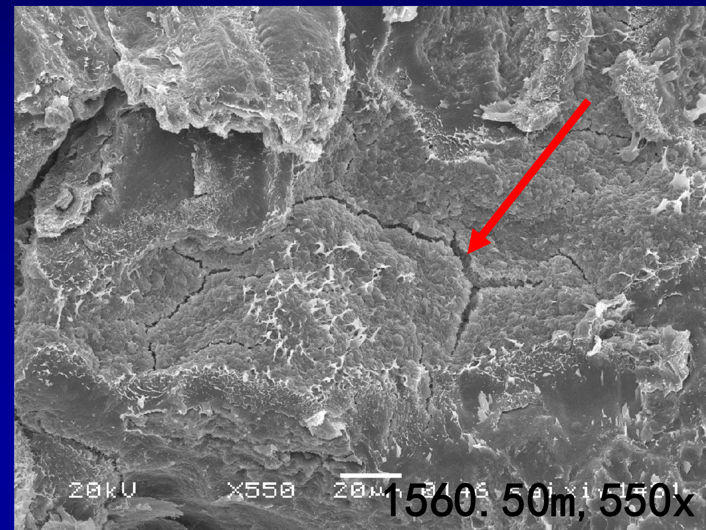
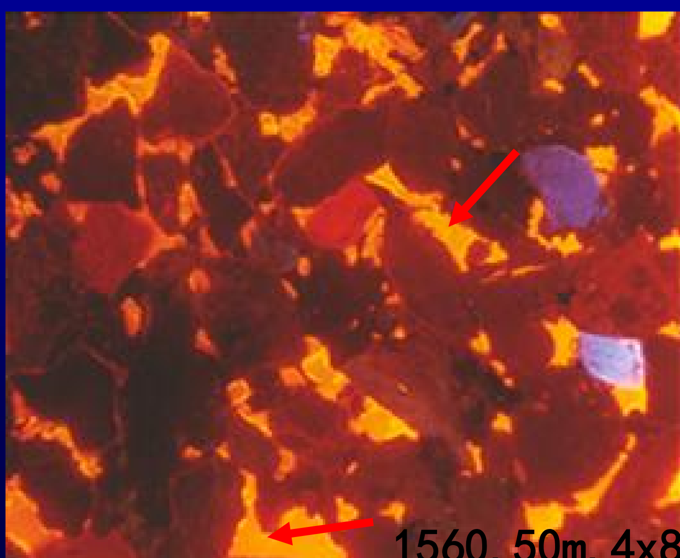
Diagenetic minerals

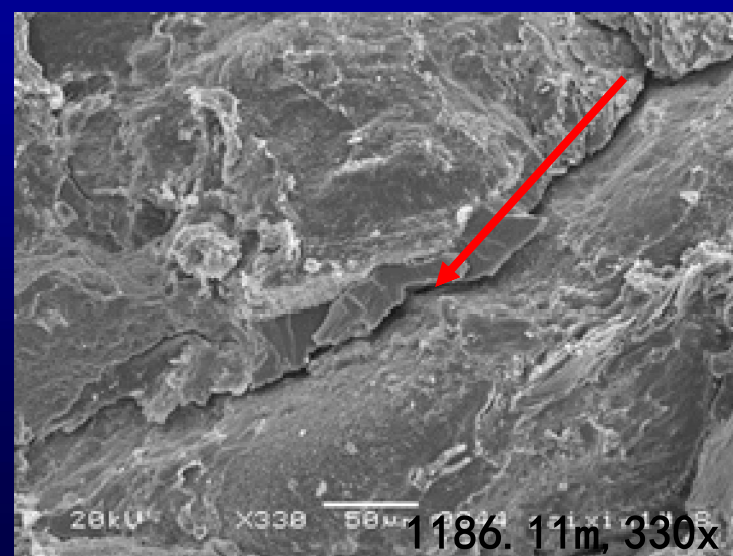
Well Saixin 1

Ⅰ. Calcite









Diagenetic minerals

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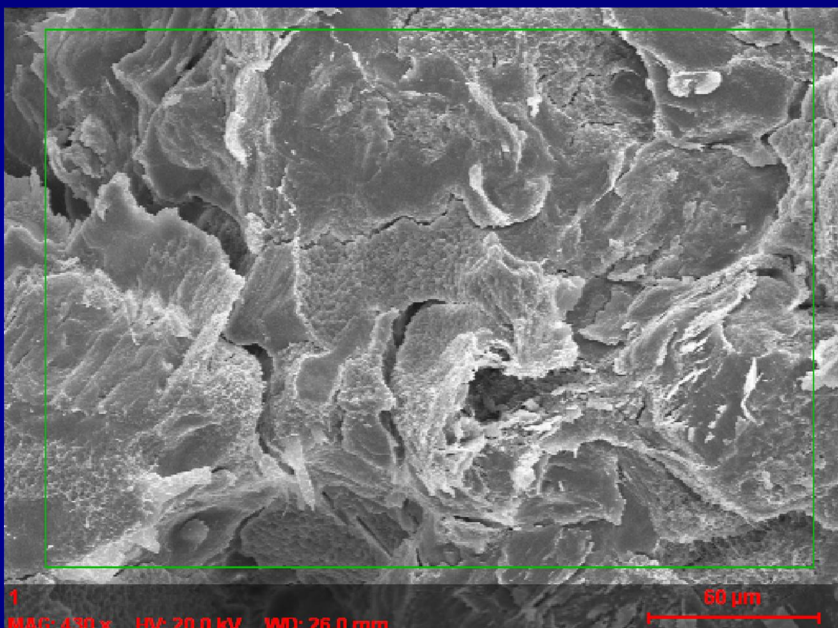

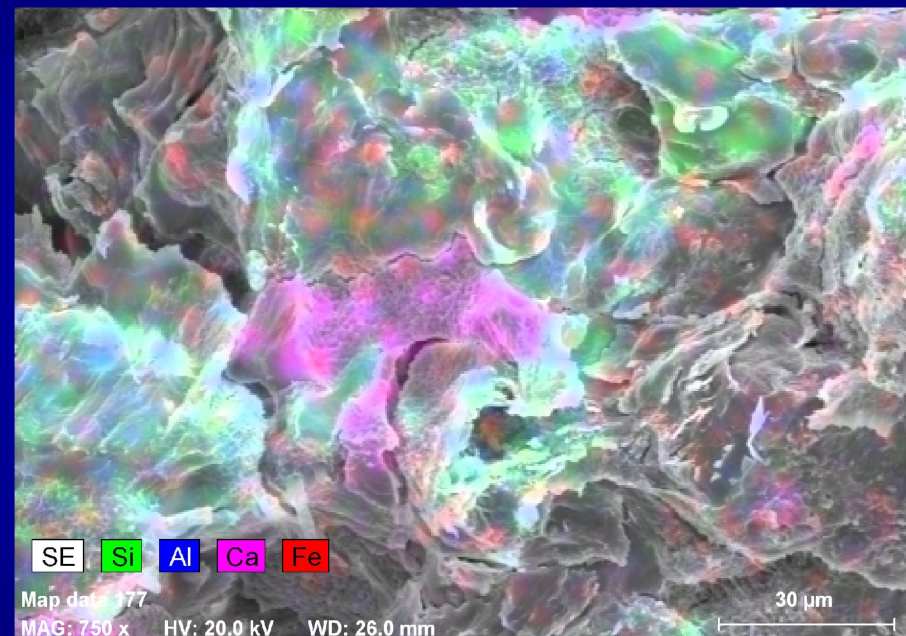

Figure 5 Energy Spectrum Analysis of Well Saixin 1, 1174.30m,430×

Diagenetic minerals

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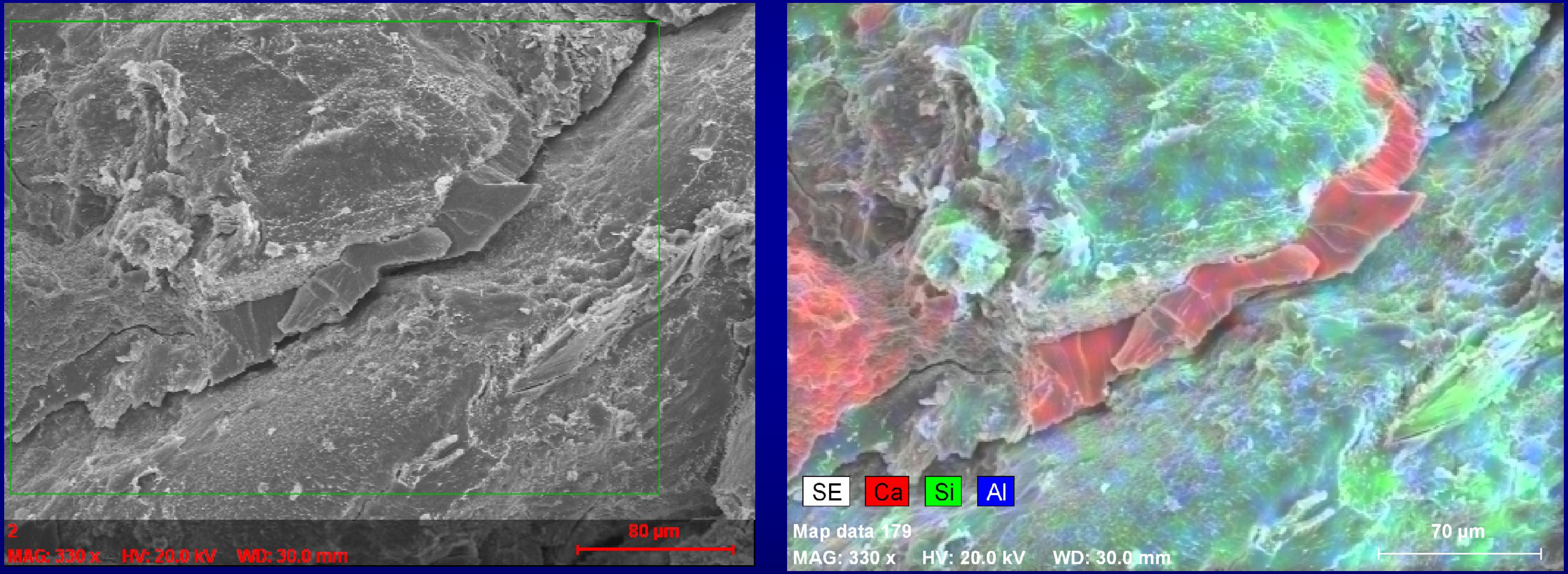

Figure 6 Energy Spectrum Analysis of Well Saixin 1, 1186.11m,330×

Diagenetic minerals

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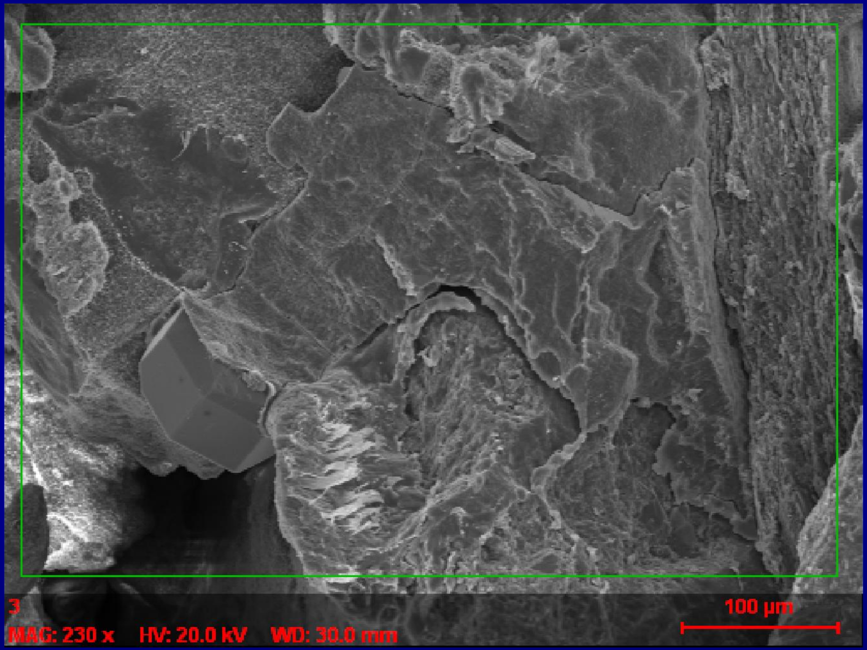

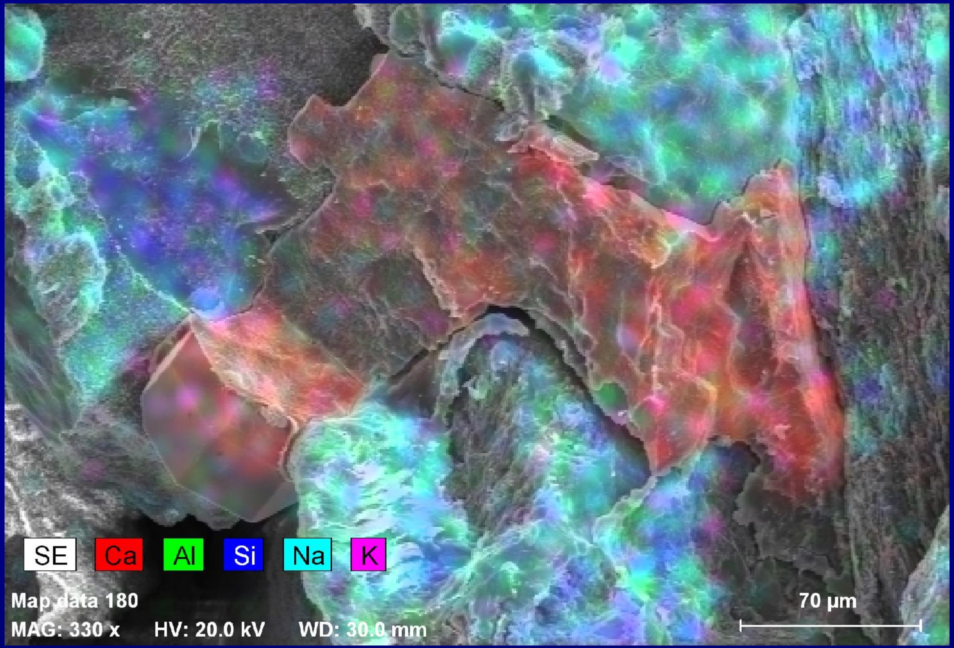

Figure 7 Energy Spectrum Analysis of Well Saixin 1, 1310.50m,330×

Diagenetic minerals

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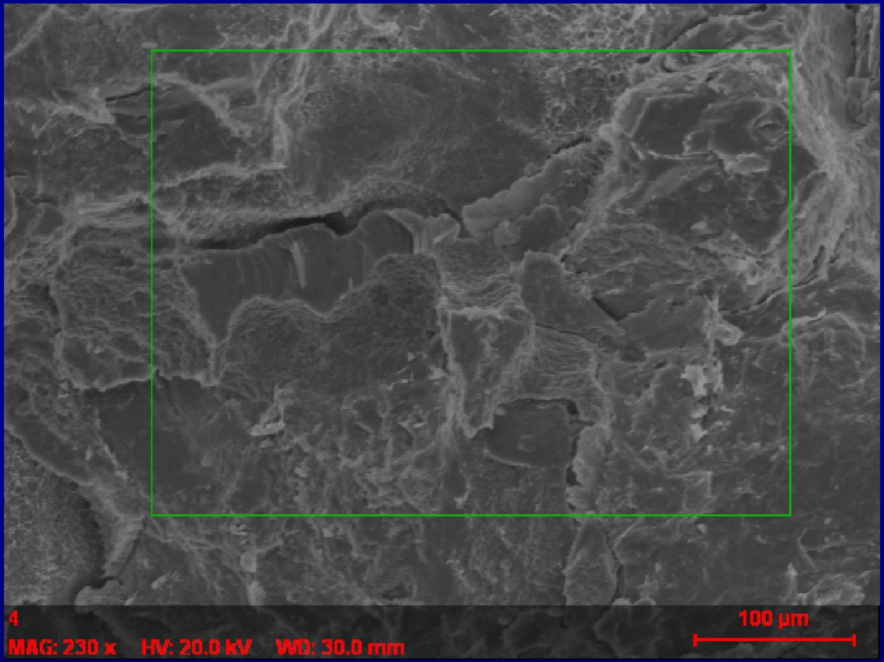


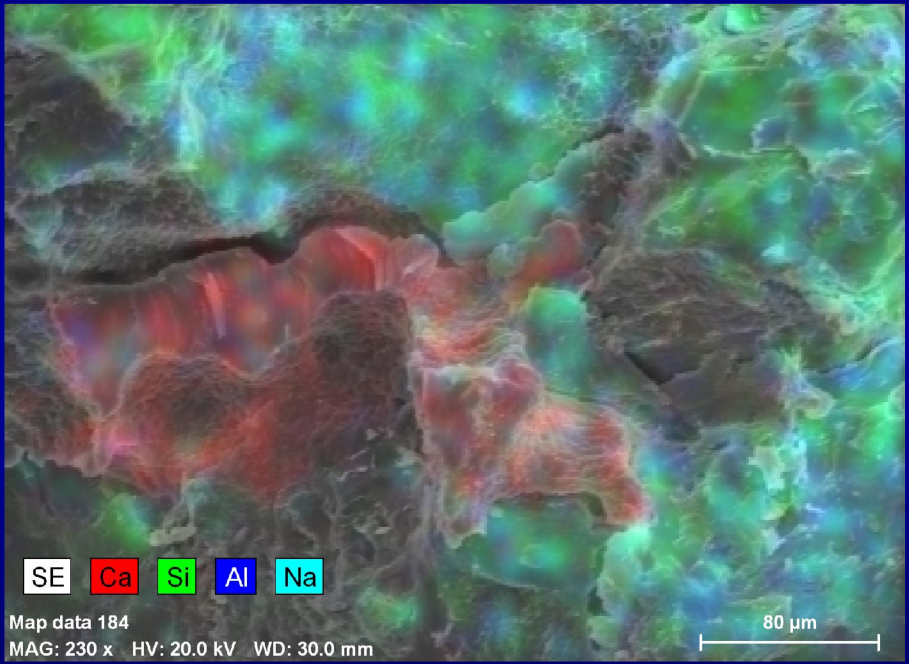
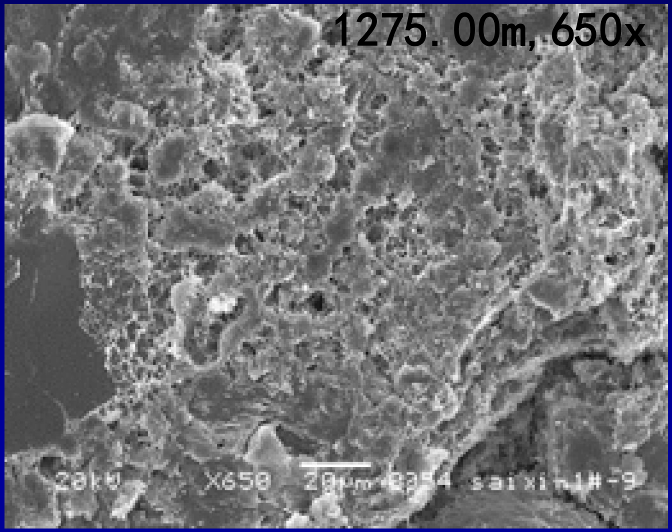


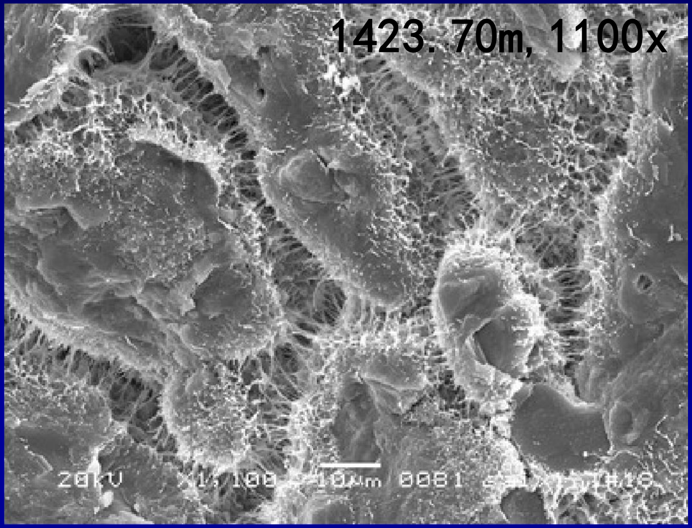
Figure 8 Energy Spectrum Analysis of Well Saixin 1, 1466.50m,230×

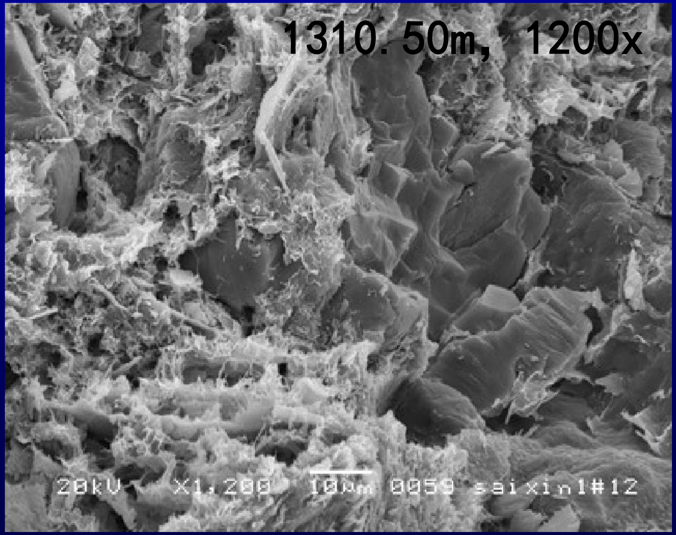
Diagenetic minerals

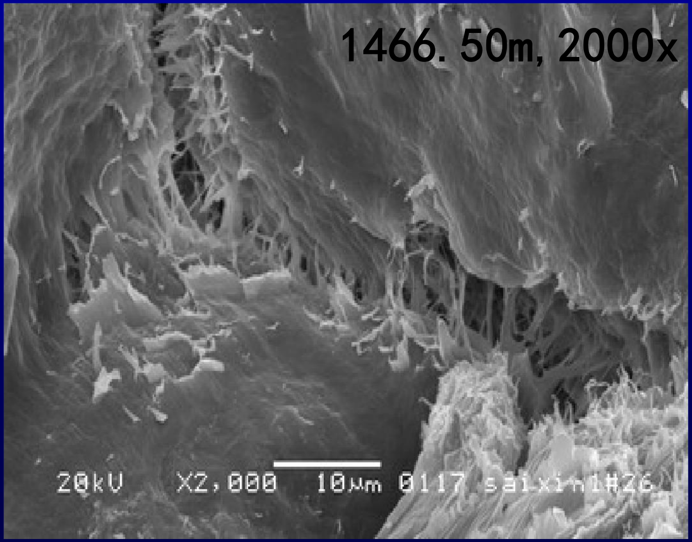
Well Saixin 1

Ⅱ.Illite and illite/smectite





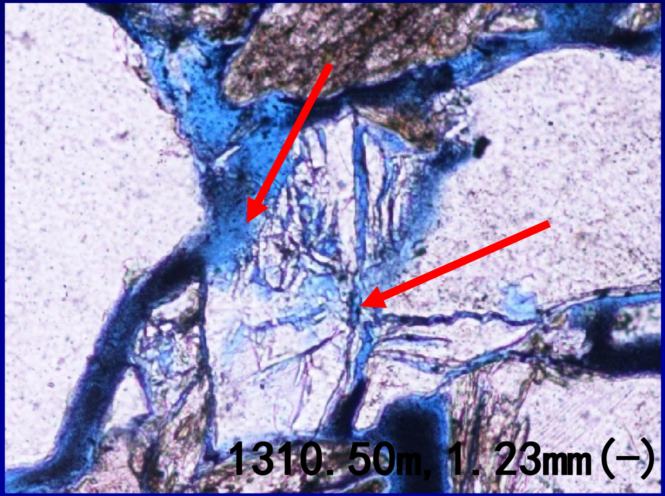


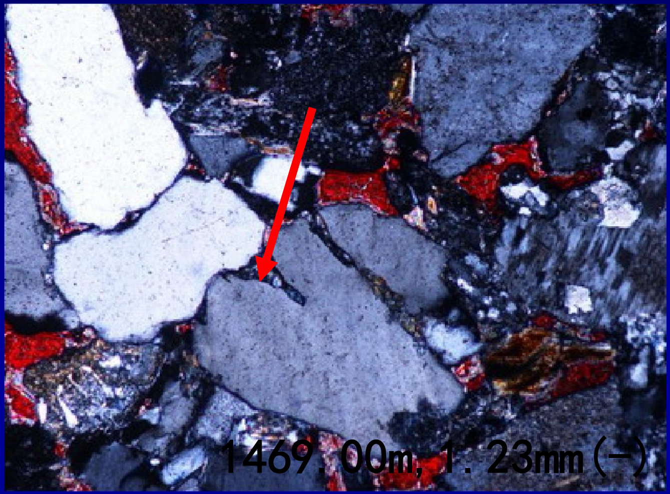


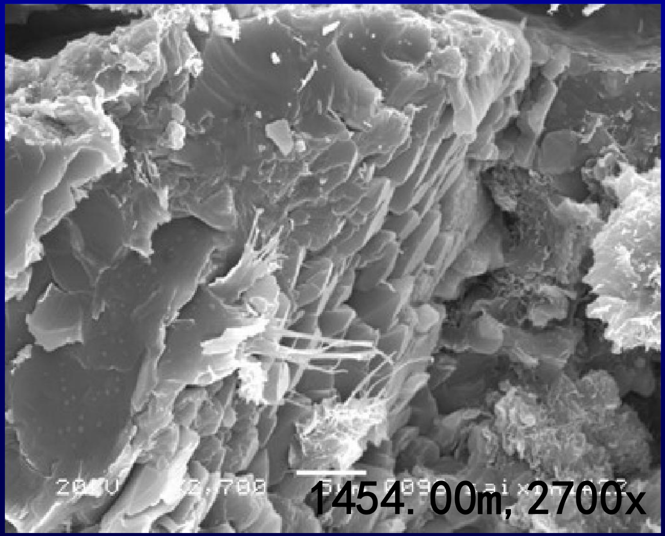
Diagenetic minerals

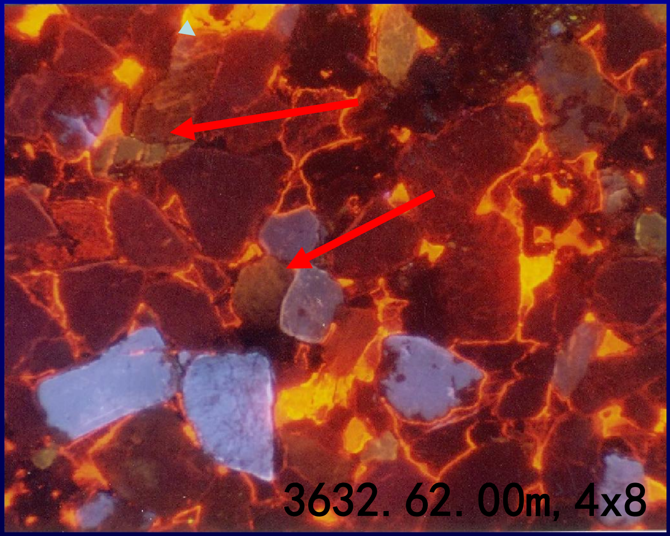
Well Saixin 1

Ⅲ.Quartz





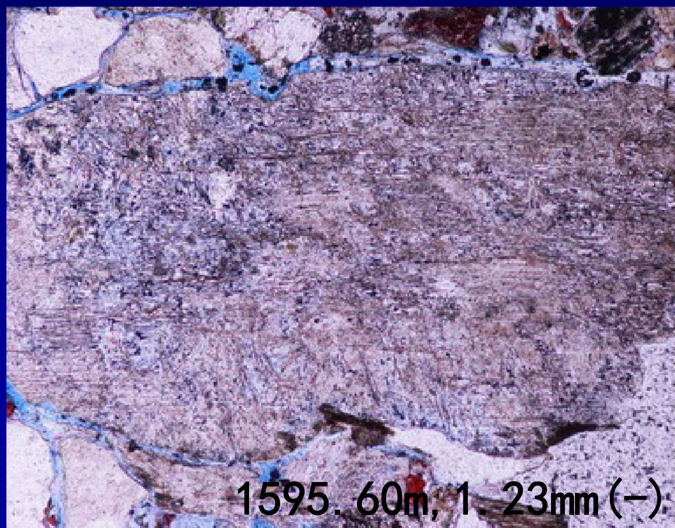




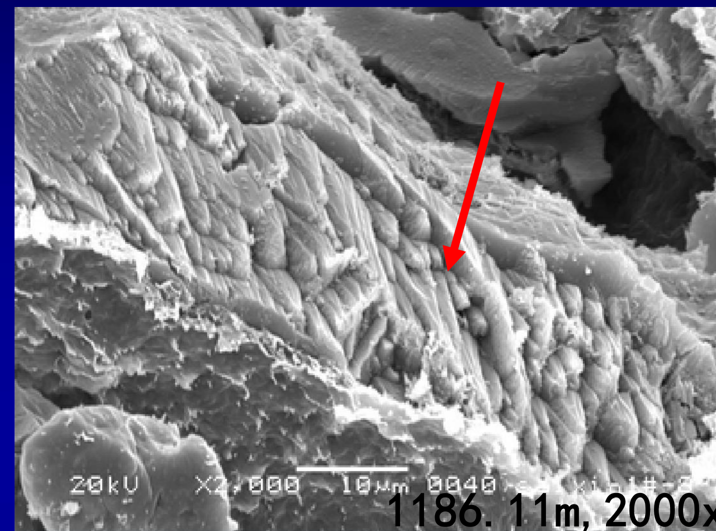
Diagenetic minerals

Well Saixin 1

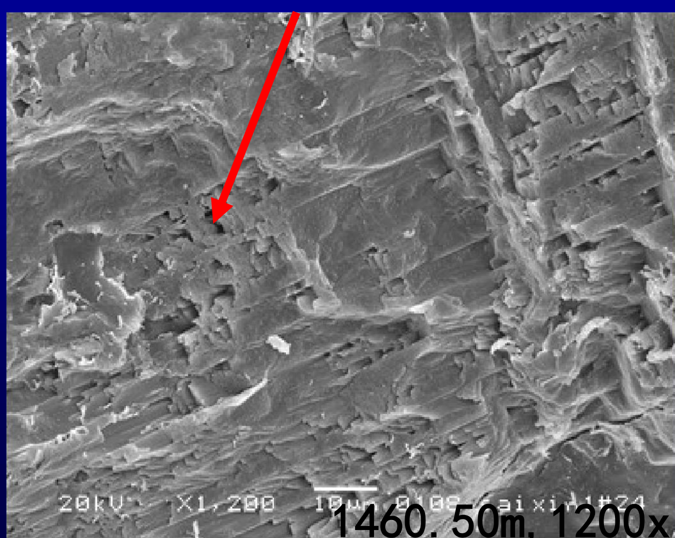
Ⅳ. Feldspar



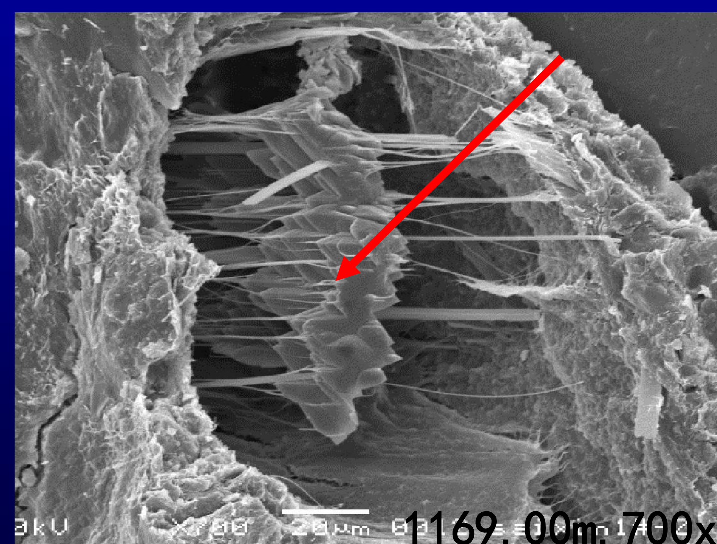
1595.60m, 1.23mm(-)



1186.11m, 2000x



1460.50m, 1200x

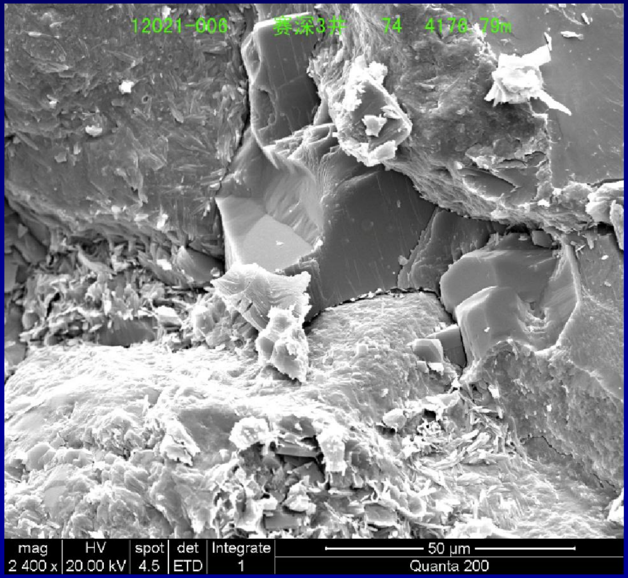


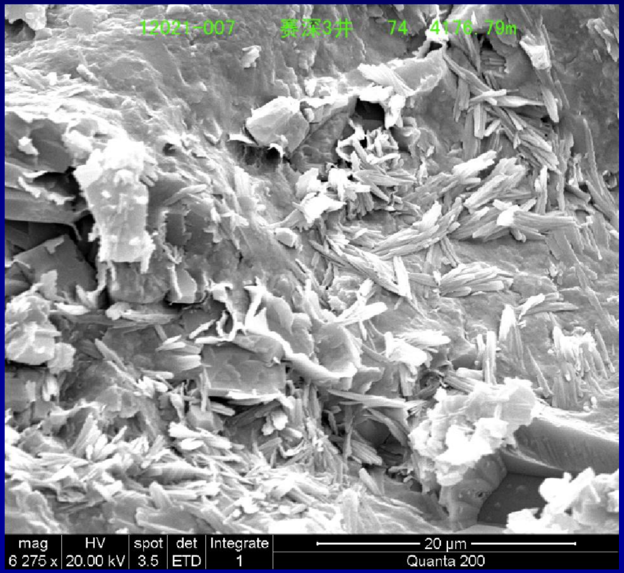
1169.00m, 700x

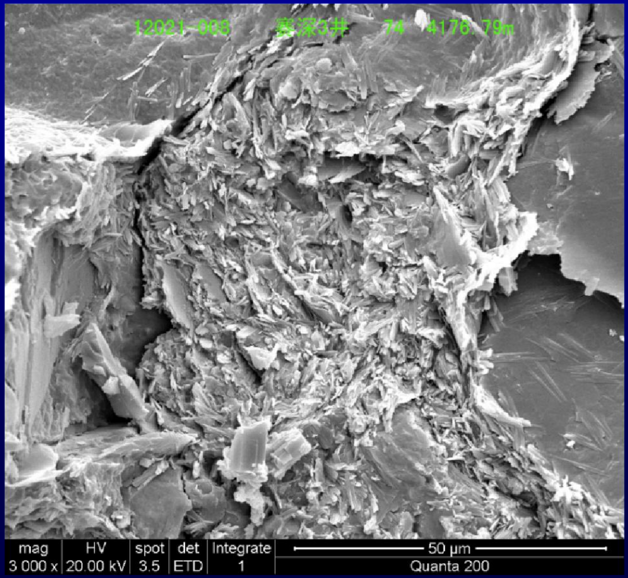
Diagenetic minerals

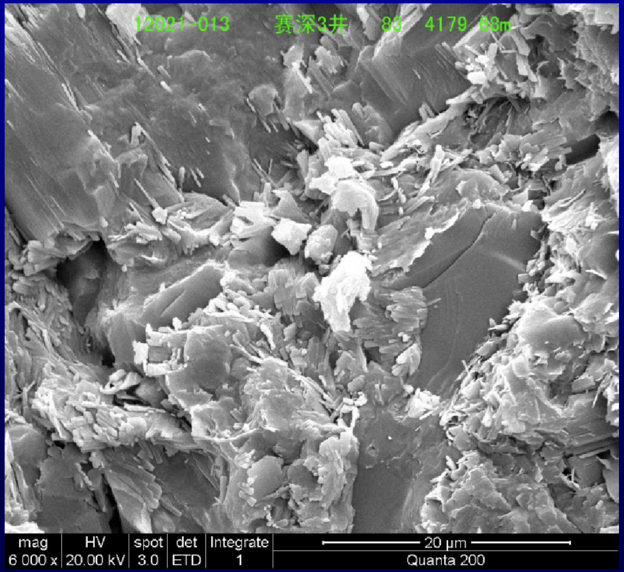
Well Saixin 1

Ⅴ.Laumontite









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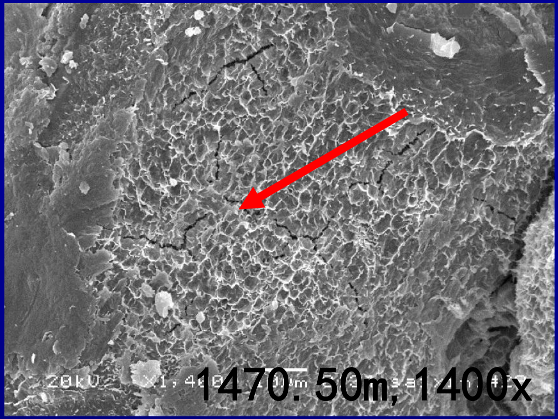
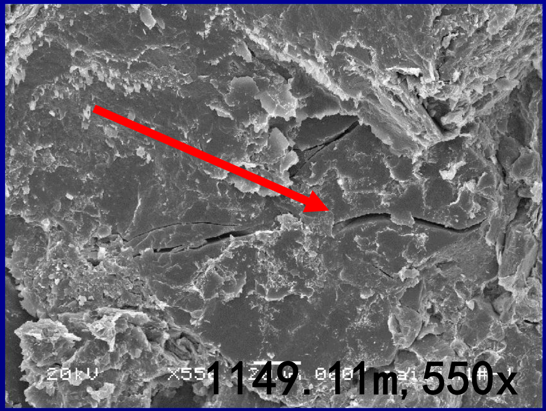
Reservoir properties

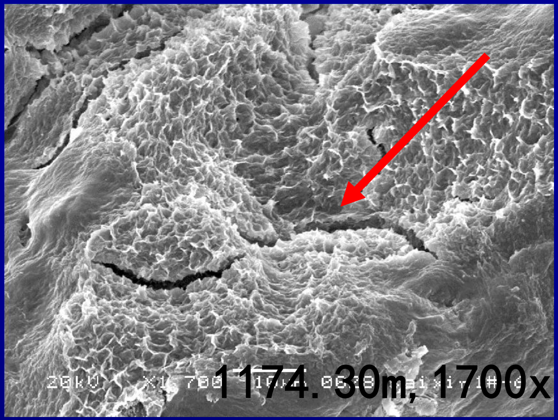
porosity

Lulehe and Shangganchaigou Formation. The average porosity is 10.24%，with 6.7% (E1+2), 10.52% (E3) and 17.48% (N1)

main pore types: primary pore(54.68%),secondary pore(42.47% secondary intergranular pore and a small amount of intragranular pore, moldic pore and matrix pore), micro fracture(2.84%).

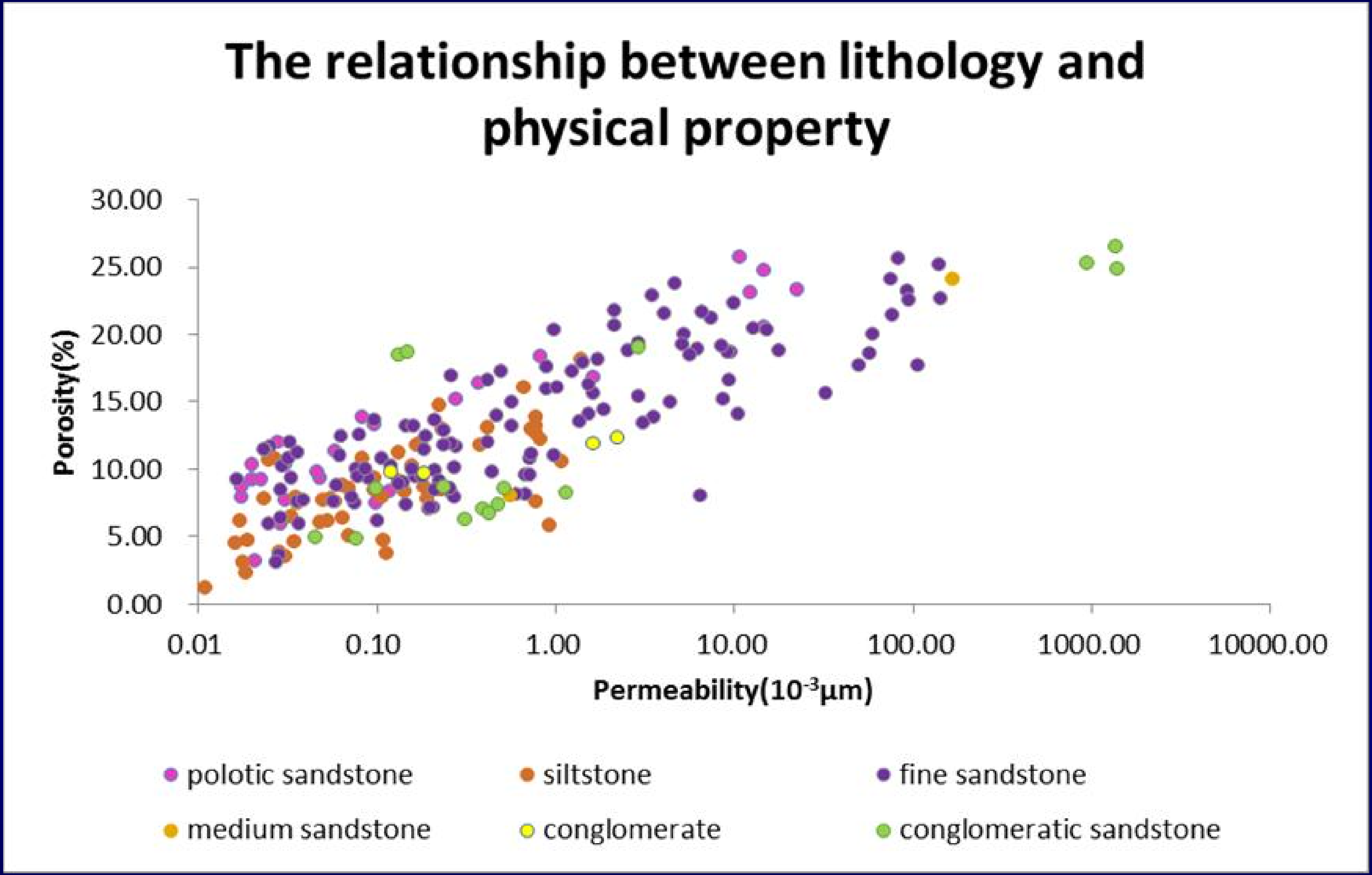






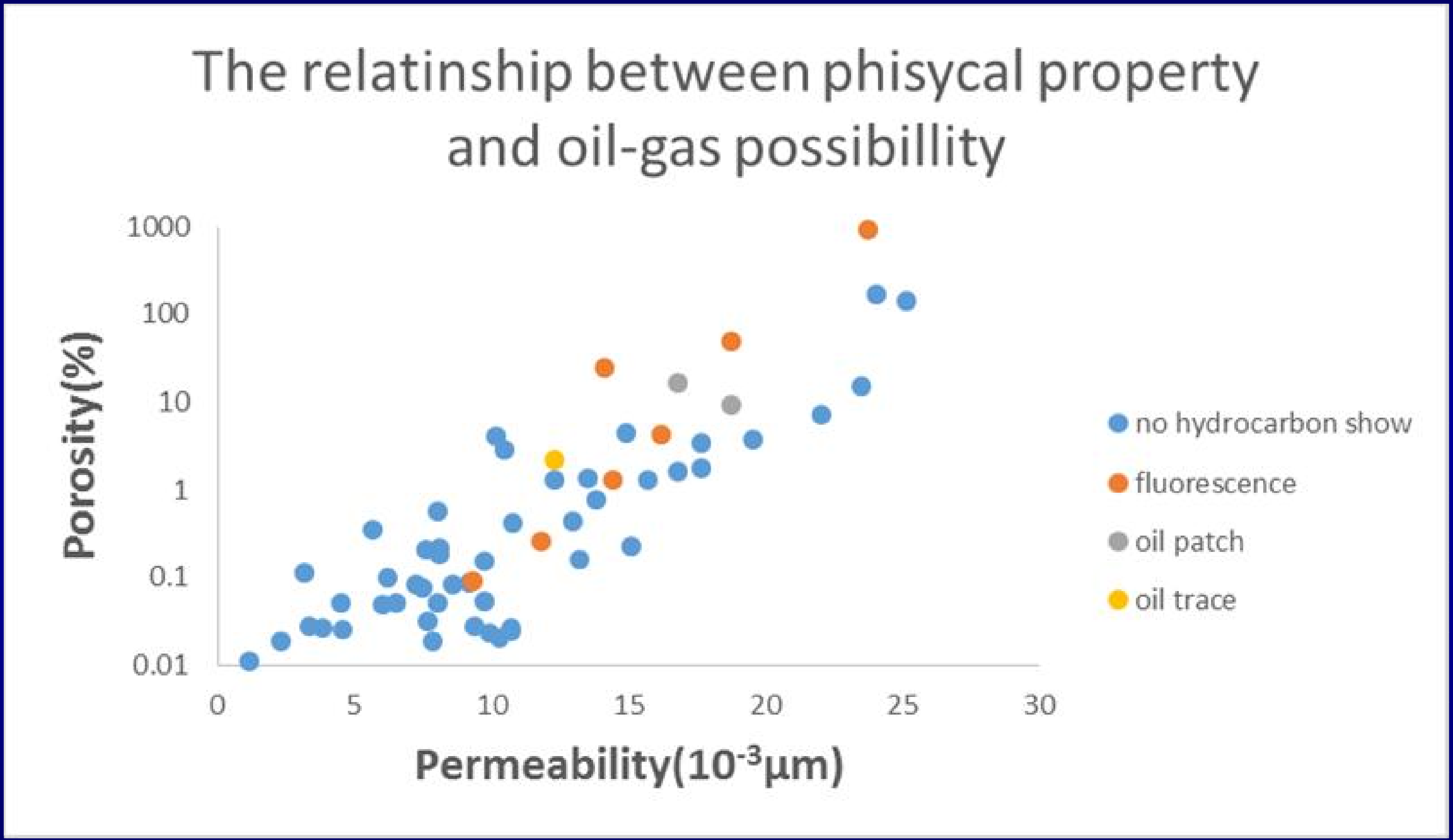
Reservoir properties

porosity



Reservoir properties

porosity



Reservoir properties

porosity

Table 1 Statistical table of relationship between physical parameters and microfacies

Microfacies types	Physical para	
	Porosity（%）	Permeability（$10^{-3}\mu m^2$）
Underwater distributary channel		
Distributary channel		
Mouth bar		
Channel bar		
Flood fan		
Underwater distributary interchannel		
Distributary interchannel		
Sand flat		
Mud flat		

Reservoir properties

porosity

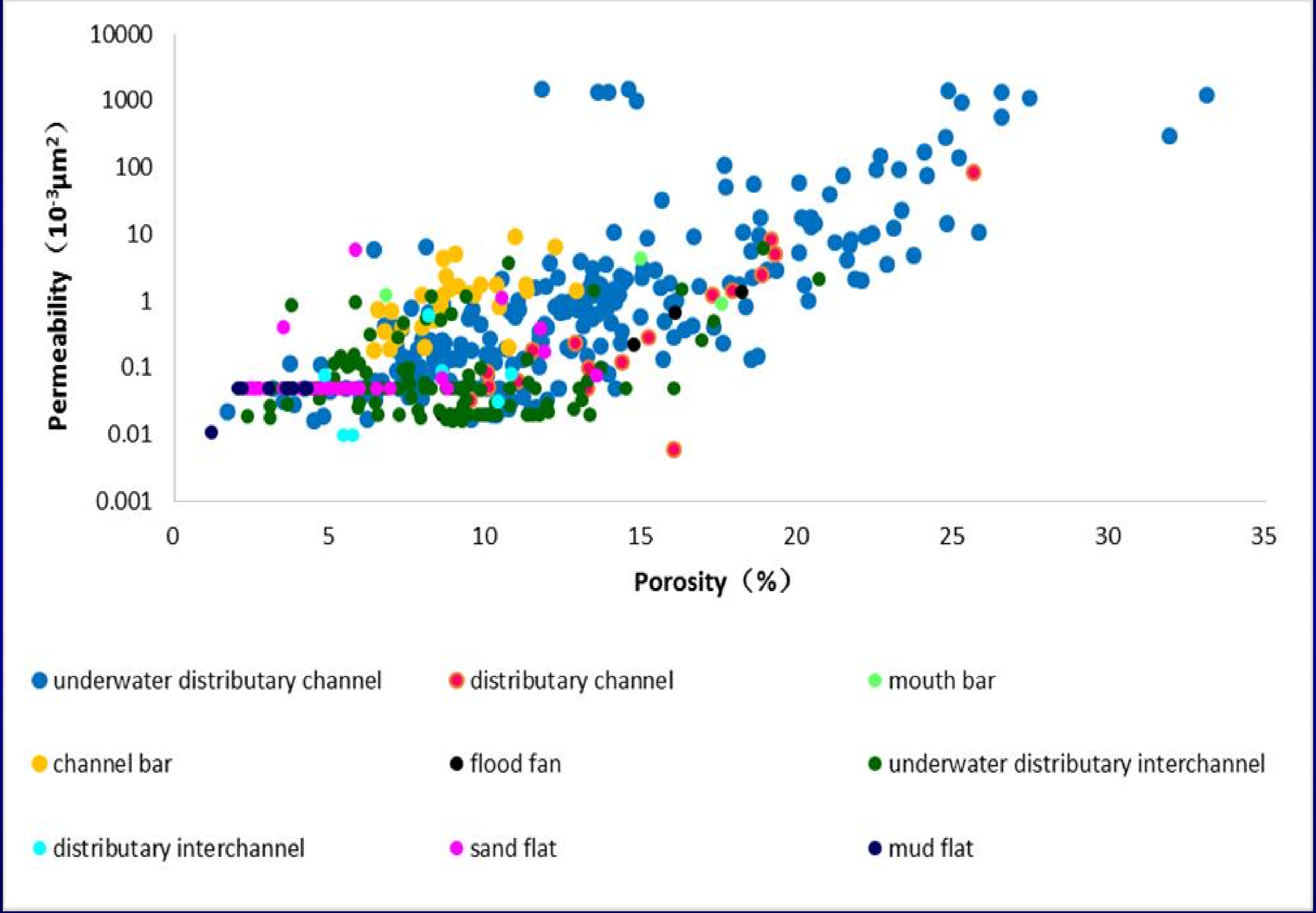


Figure 9 The relationship between physical parameters and microfacies

Reservoir properties

permeability

From 0.03 to 82 mD with an average of 30.54 mD. The average permeability of Lulehe (E_{1+2}), Xiaganchaigou (E_3) and Shangganchaigou (N_1) Formation is 0.82, 40.31 and 21.57 mD respectively.

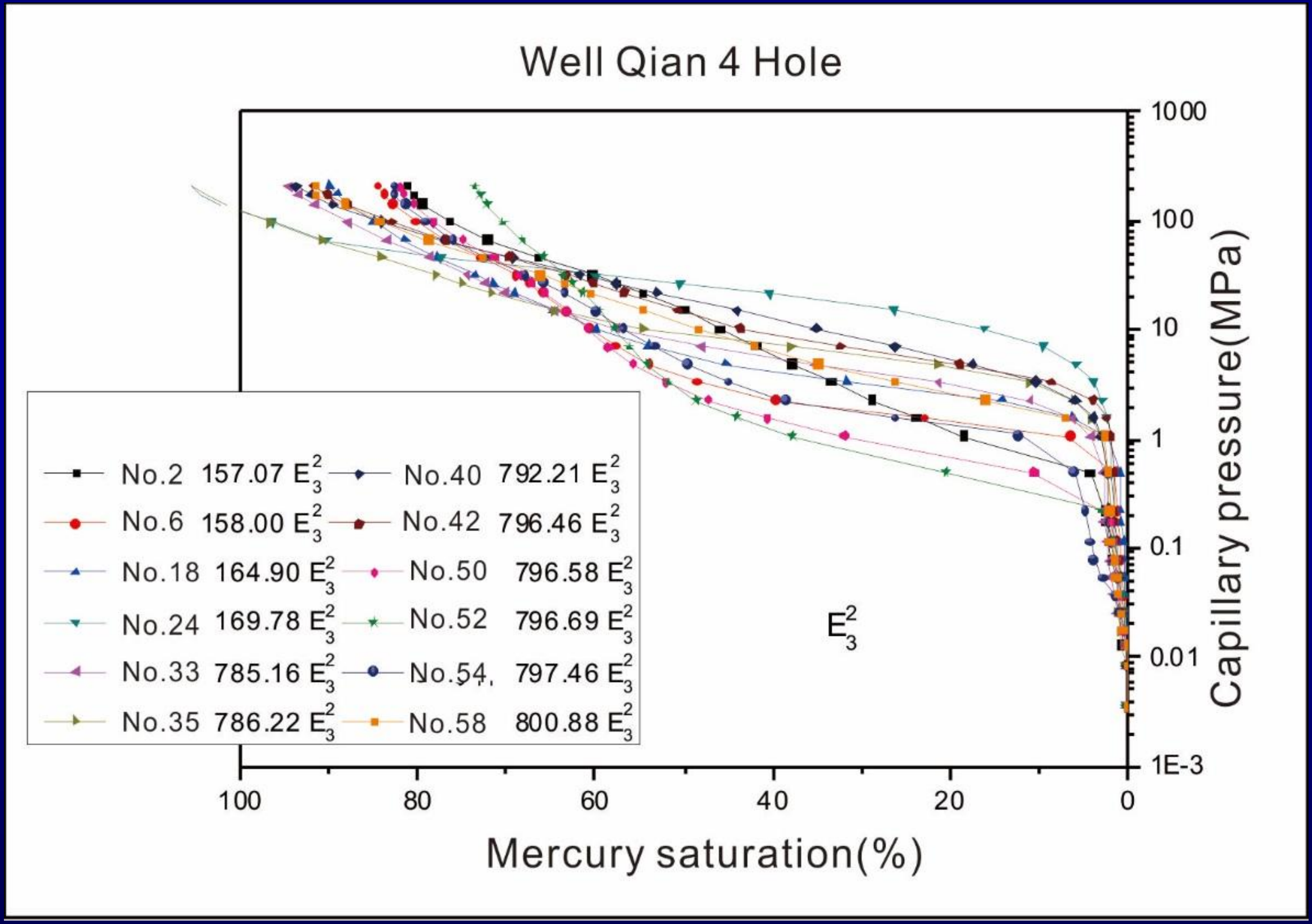


Figure 10 The capillary pressure curve graph of Well Qian 4 Hole

Reservoir properties

permeability

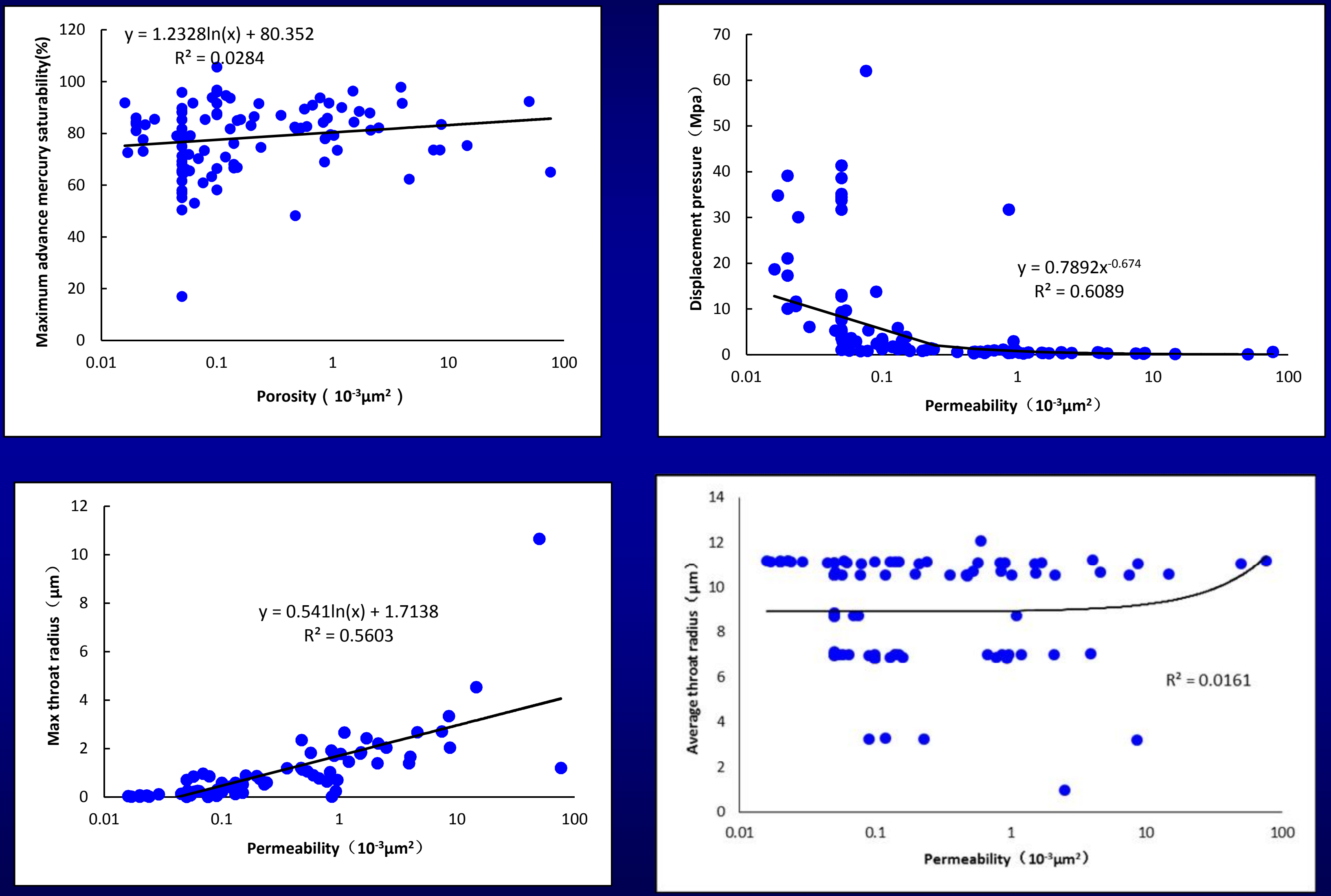


Figure 11 The relationship between permeability and pore structure parameter in Lengdong area

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Discussion

Diagenetic evolution

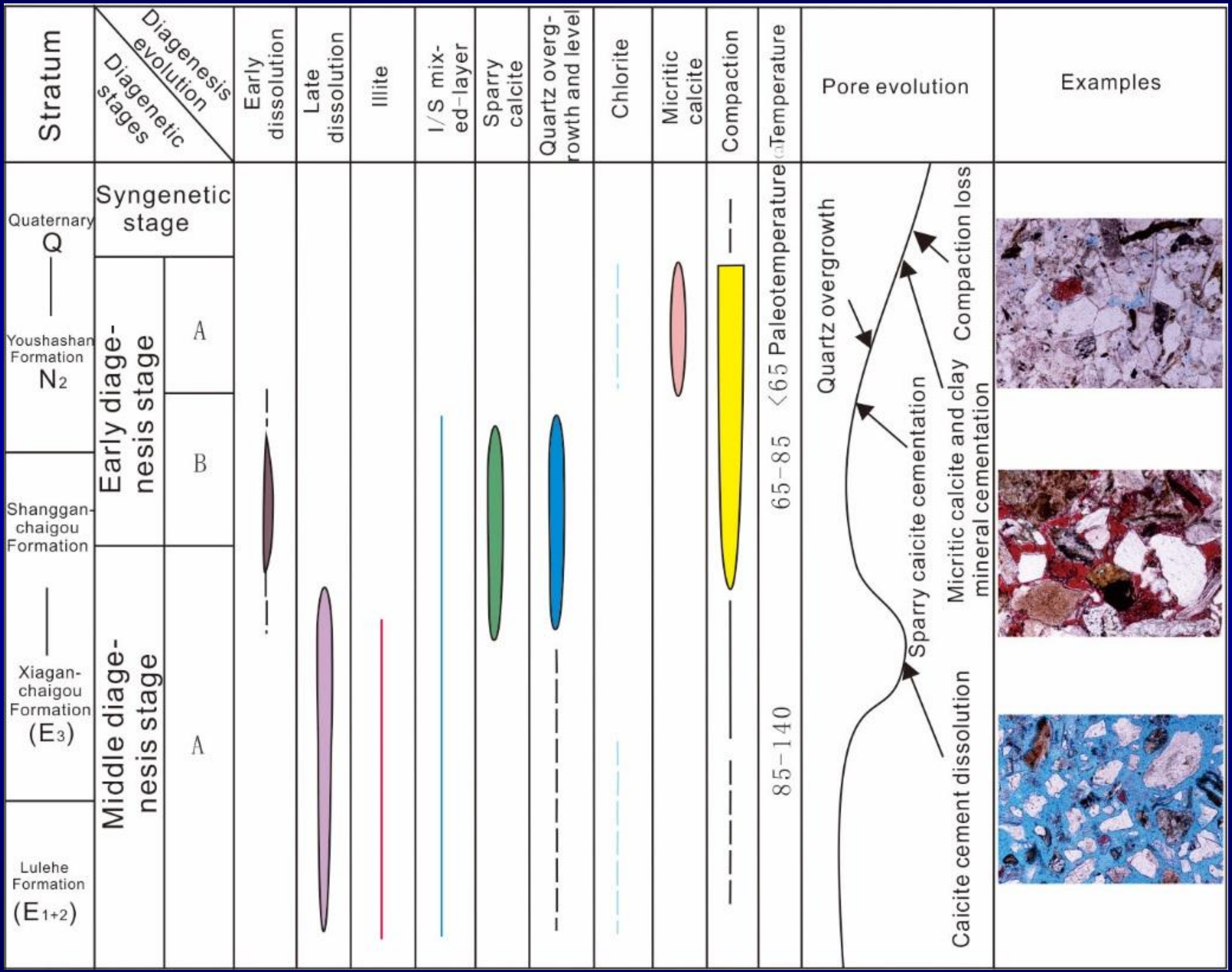


Figure 12 The diagenesis stage of Lengdong Area

Discussions

Compaction:

Table 2 The porosity loss by compaction

	average porosity of original pore	Numbers of samples	average porosity of extant pore	Numbers of samples	average loss
Shangganchaigou formation (N1)	27.40%	35	14.23%	532	13.17%
Xiagganchaigou formation (E32)	30.40%	30	12.18%	483	18.22%.
Xiagganchaigou formation (E31)	31.09%	160	9.58%	168	22.51%
Lulehe formation (E1+2)	27.89%	60	7.07%	291	20.82%

Discussions

Cementation

➢**Calcite cements**

Two-side effect on reservoir:decrease pore space, porosity and permeability—— weakenthe effects of compaction and provide with the material foundation for late dissolution.

➢ **Authigenic clay minerals like illite and illite- smectite mixed-layer**

Two-side effect on reservoir: prevent overgrowth of mineral—— severely reduced throat connectivity and permeability.

➢ **Siliceous cement**

Quartz and feldspar overgrowth.

Discussions

Dissolution

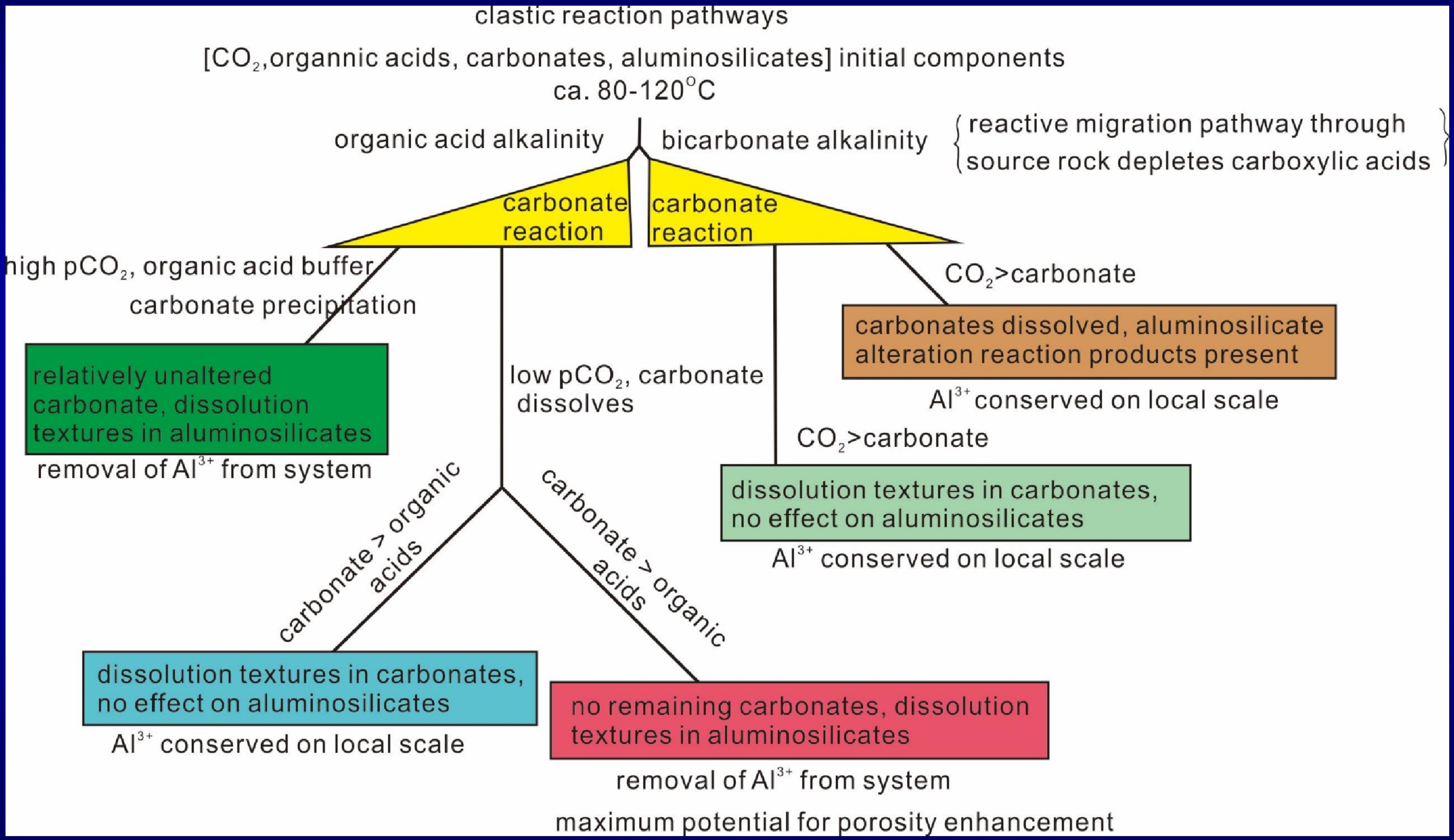


Figure 13 Flow diagram combining aspects of organic and inorganic diagenesis(modified from Surdam et al. 1984)

Discussions

Modeling

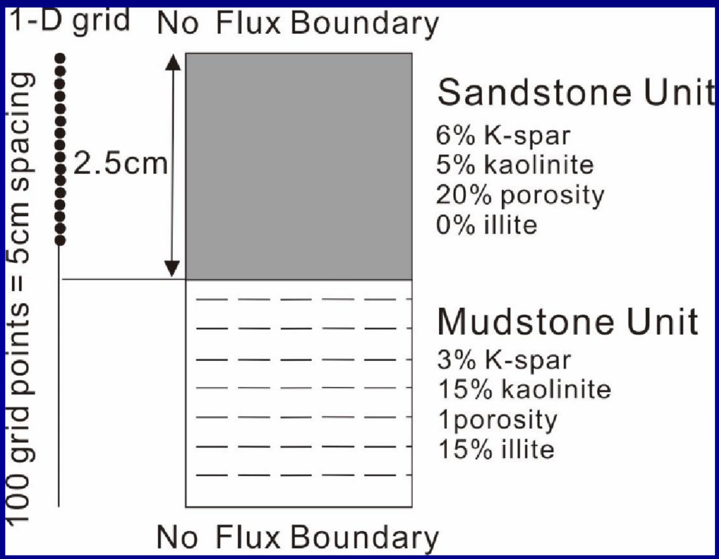


Figure 14 Schematic representation of system modeled with starting compositions along right side and model grid on left. Note scale, total length of the system is 5m and grid spacing in 5cm

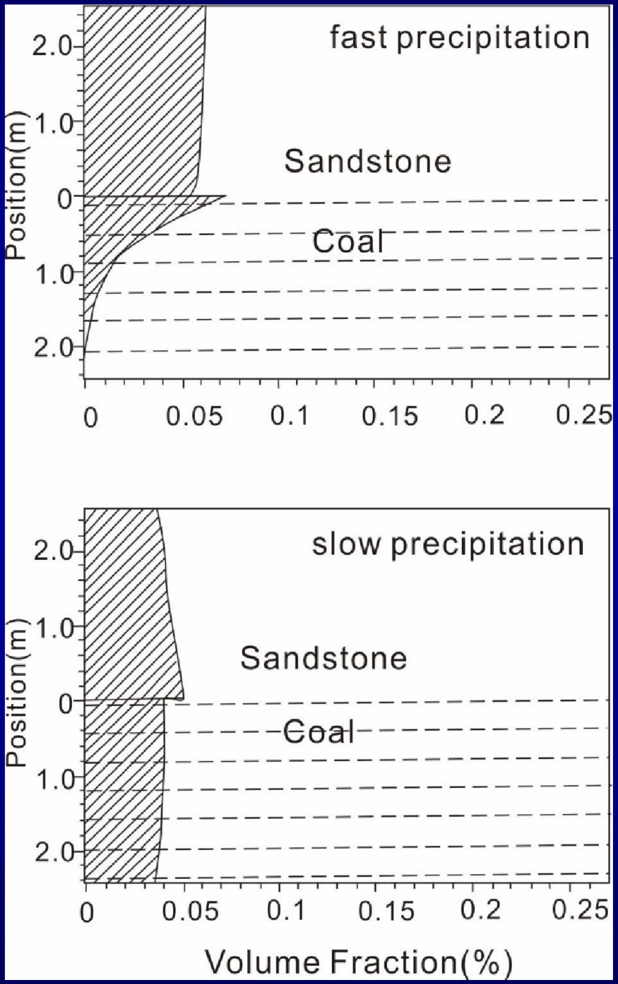
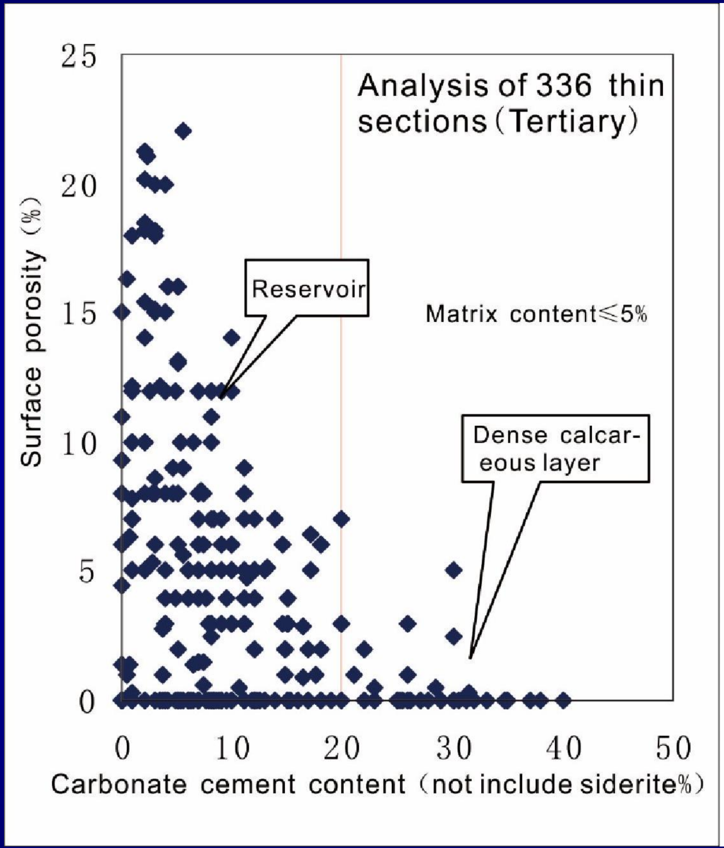


Figure 15 The final distribution of illite for fast and slow precipitation

Discussions

Overpressure



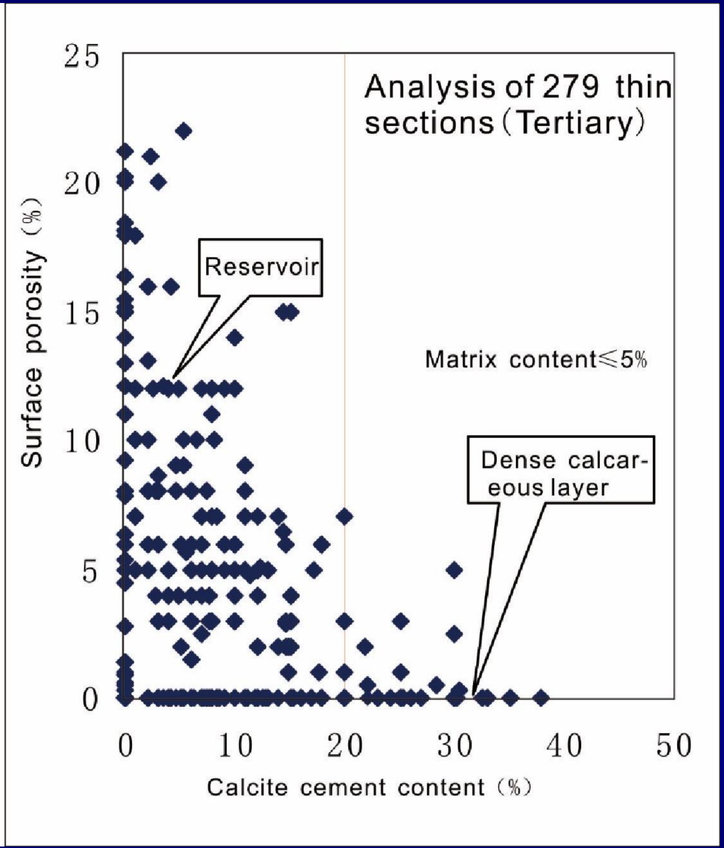


Figure 16 The relationship between surface porosity and carbonate cement content

Figure 17 The relationship between surface porosity and calcite cement content

Discussions

Influential factors on reservoir quality

Overpressure

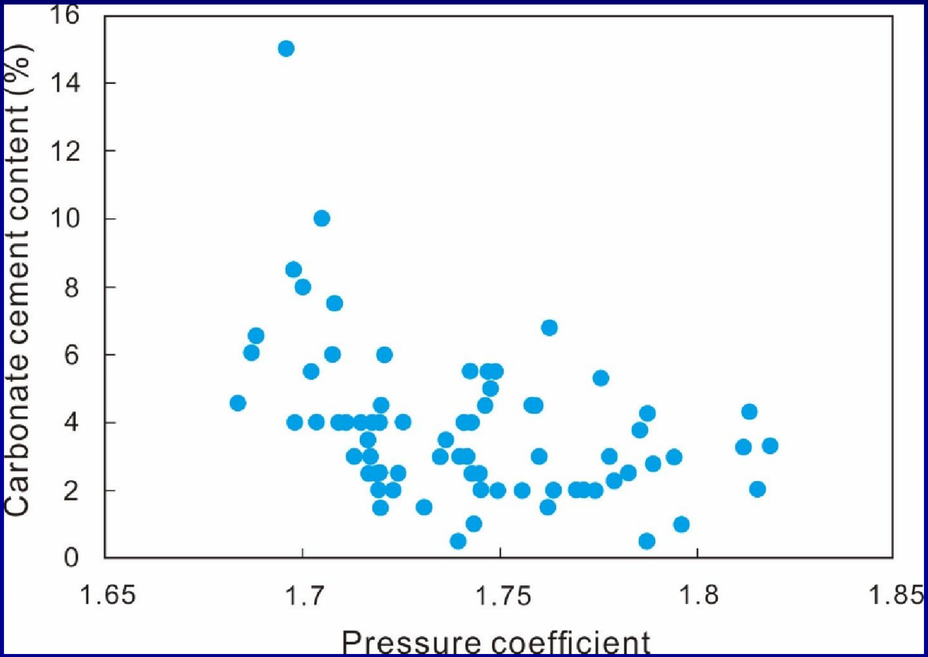


Figure 18 The relationship between carbonate cement content and pressure coefficient

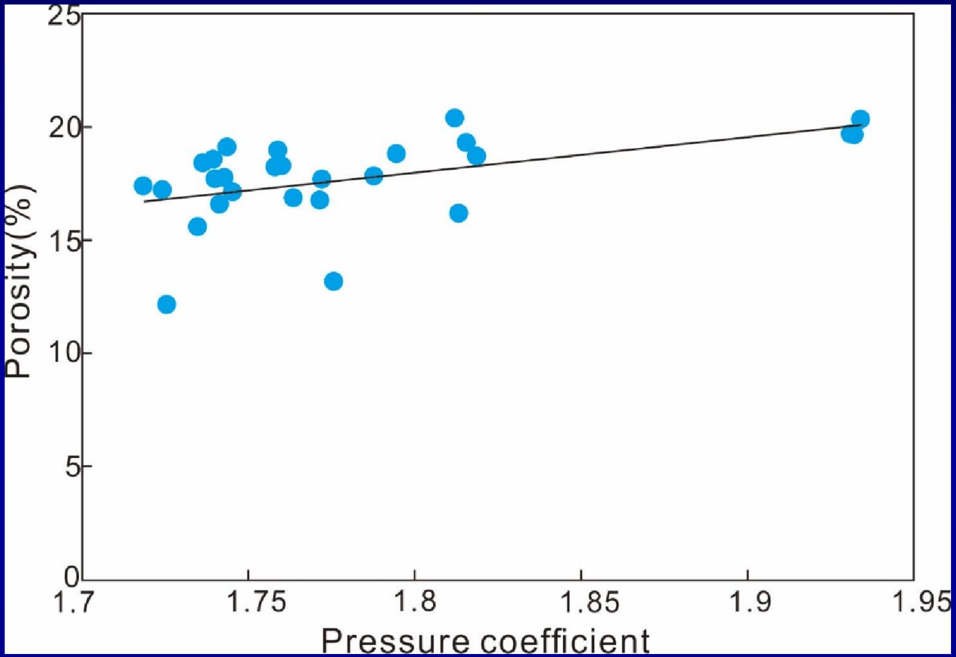


Figure 19 The relationship between porosity and pressure coefficient

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Conclusions

1) The Lengdong sandstones are mainly feldspathic lithic sandstone with lithic feldspar sandstone and lithic sandstones.

2) Diagenetic minerals of study area are dominated by calcite, illite and illite/semctite, quartz, feldspar, laumontite. They have different effects on the reservoir quality.

3) The diagenesis stage from Paleogene to Neogene in Lengdong area is from A sub-period of eogenetic to A sub-period of mesogenetic stage. The eogenetic stage can be divided into stage A and B and sediments are poorly consolidated. In Lengdong area, only A sub- period of mesogenetic stage is developed.

Conclusions

4) The mostly developed diagenesis in Lengdong area is compaction, cementation and dissolution. The acid fluid formed in coalification transferred in adjacent sandstones and changed the minerals distribution near the boundary.

5) Overpressure have an good impact on reservoir quality in some degree.

6) The best reservoir in Lengdong area is Xiaganchaigou (E3), with a porosity of 10.52% and permeability of 40.31 mD.