Preliminary Research on Reservoir Potential of Terrestrial Shale in China*

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Abstract

In this paper, shale oil is defined to be the mature oil that is stored in organic-rich shale stratum with nano-sized pore-throats, and it is a very promising exploration field in future. Based on the data of thin sections, Field Emission-SEM, Nano-CT, EDS, Mercury injection, N2 adsorption and production data, we carried out the preliminary research on the potential of shale oil in the Ordos Basin. This study is trying to determine whether terrestrial shales can be reservoirs and whether the commercial oil production is available in such shales.

The samples are black shale and dark grey mudstones developed in the semi-deep to deep lacustrine facies, with I-type and III-type kerogen. The thickness of shale with TOC higher than 2% and Ro higher than 0.7% is 21-36m, and the exploration area can reach 20,000 km^2. EDS data indicate that total percentage of brittle minerals is 45~59%, with quartz>20%, feldspar=10%~15%, calcite minerals=5~18%, pyrite+hematite=5~18%, which is similar to the mineral composition of gas shale in North America. With such high content of brittle minerals, Upper Triassic shale is prone to generate artificial fractures after hydro-fracturing. FE-SEM data indicate that intra-feldspar pores, inter-chlorite pores, inter-pyrites pores and parallel bedding fractures dominate the storage space. Organic matter (OM) pores are limited, and most of them are located between organic matters and surrounding matrix. Nano-CT data indicate that connected pores account for around 60% of whole space. The porosity of the samples is 0.6%~3.5%, and permeability is 0.00072~0.0023mD. The pore-throats in Upper Triassic shale are continuously distributed, ranging from less than 10nm to 15μm. The percentage of pore-throats with radius less than 1000 nm is 96.5%, among which pore-throats with radius less than 100 nm is more than 60%. Thus, nanometer-scale pore-throats dominate the reservoir spaces of Upper Triassic shale, which may be the fundamental reason for the special characteristics of unconventional tight reservoirs. The oil testing indicates that oil production can reach 20.4 tons per day for a well with three perforated intervals. Moreover, the API of crude oil is 35-58°, and the viscosity is 0.7-5 lcP.

This study may be helpful in knowing more about the potential of terrestrial shale/mudstone oil, and providing references for the unconventional petroleum exploration in the Ordos Basin.

Reference Cited

Wang, L., C. Wang, Y. Li, L. Zhu, and Y. Wei, 2011, Sedimentary and organic geochemical investigation of tertiary lacustrine oil shale in the central Tibetan plateau; Palaeolimnological and palaeoclimatic significances: International Journal of Coal Geology, v. 86/2-3, p. 254-265.

Website

Navigant Consulting, 2008, North American Natural Gas Supply Assessment, prepared for American Clean Skies Foundation, July 4, 2008.

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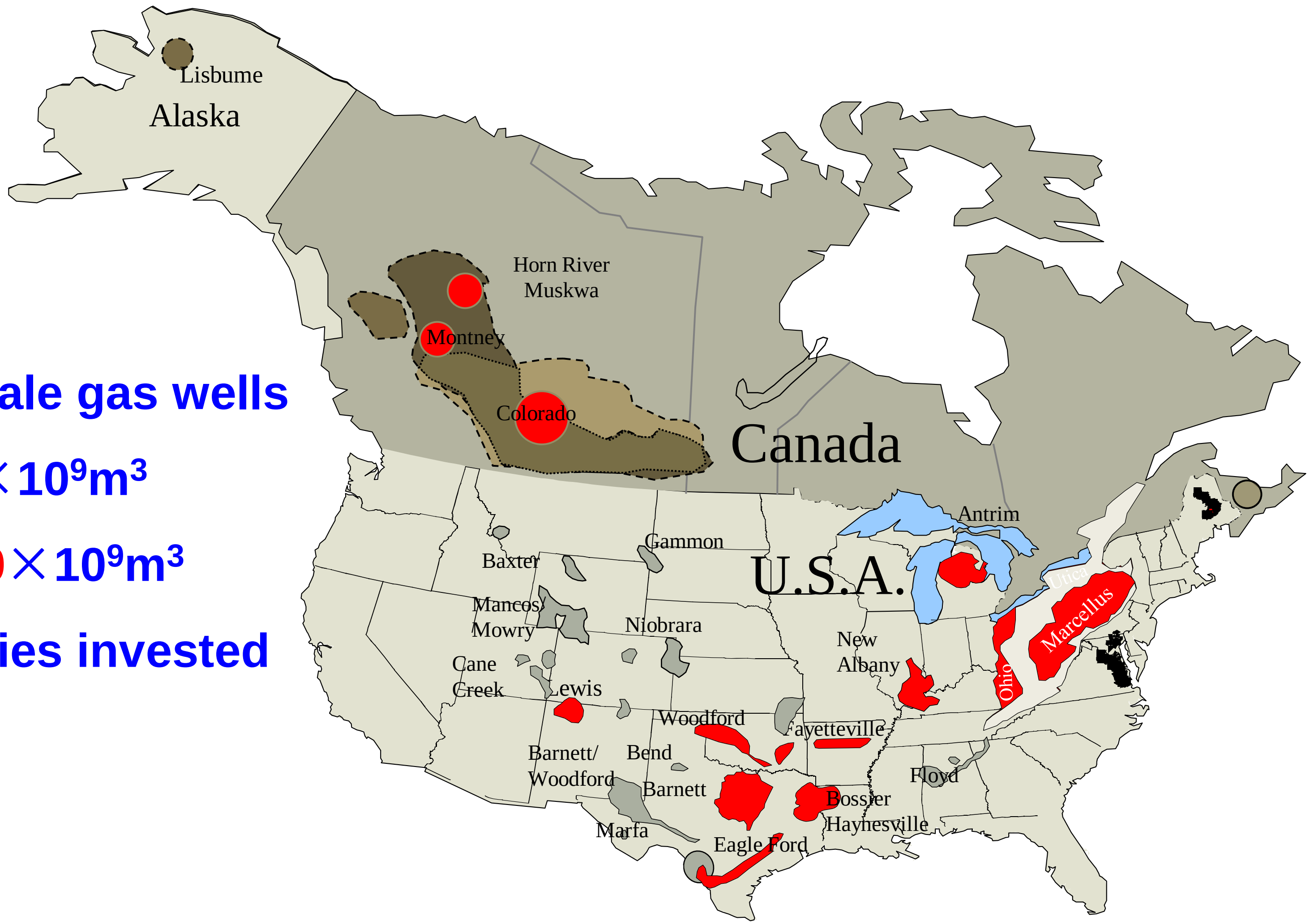
RIPED, PetroChina

May 22th, 2013

Shale gas: Big success in North America

- **>22 basins**
- **>40,000 shale gas wells**
- **2009: 878×10^9m^3**
- **2011: 1,700×10^9m^3**
- **>22 countries invested**



From Navigant Consulting, Inc. 2008

What does shale gas tell us?

source + seal < shale = source + seal +reservoir

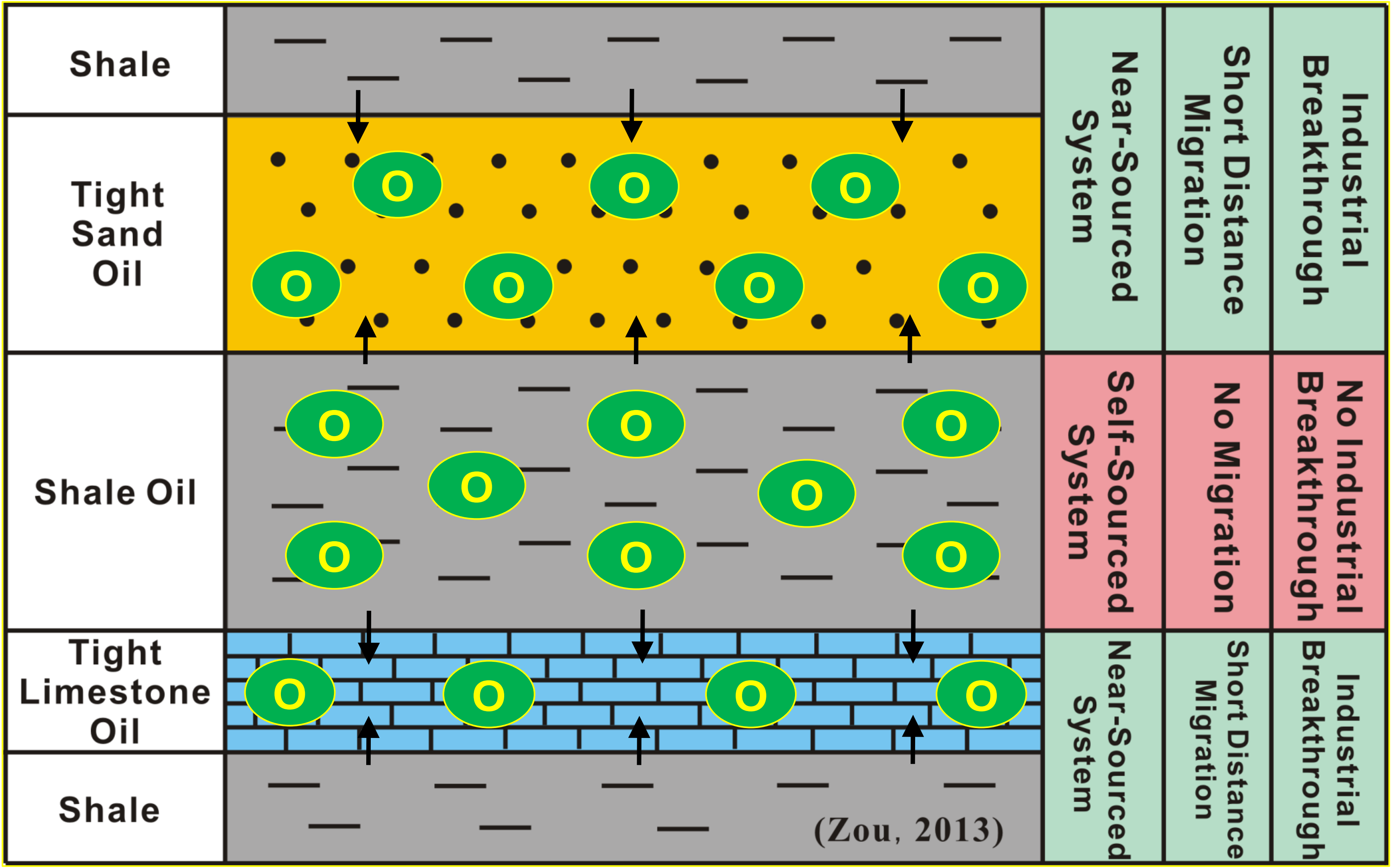
Marine facies shale

Commercial production of natural gas

Terrestrial shale ??

Commercial production of oil ??

Shale Oil: Self-sourced system without migration



What to do?

1. Choose samples

- Important source rocks
- Oil window

2. Evaluate reservoir potential

- Mineralogy
- Pore-throat system
- Physical property

Methods

- TOC
- Rock Eval

- SEM, Nano-CT
- Mercury injection
- N_2 adsorption
- GRI

3. Get the conclusions with uncertainties listed

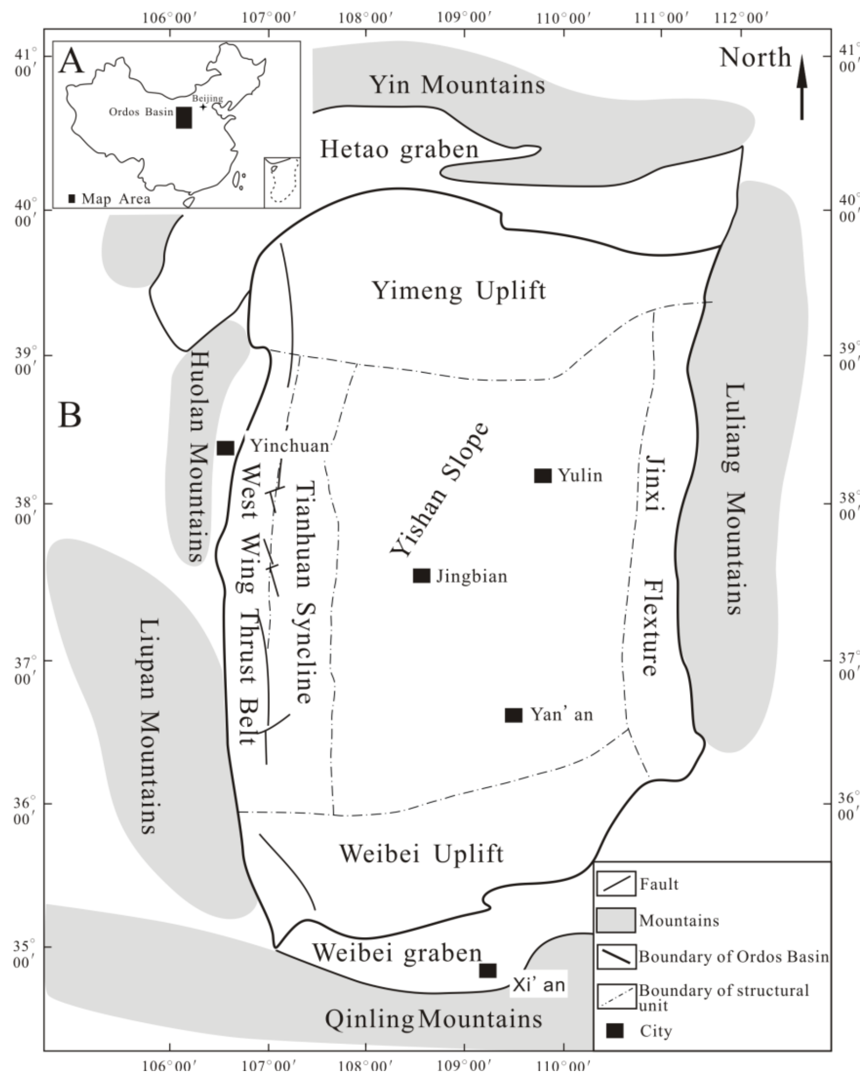
Part 1

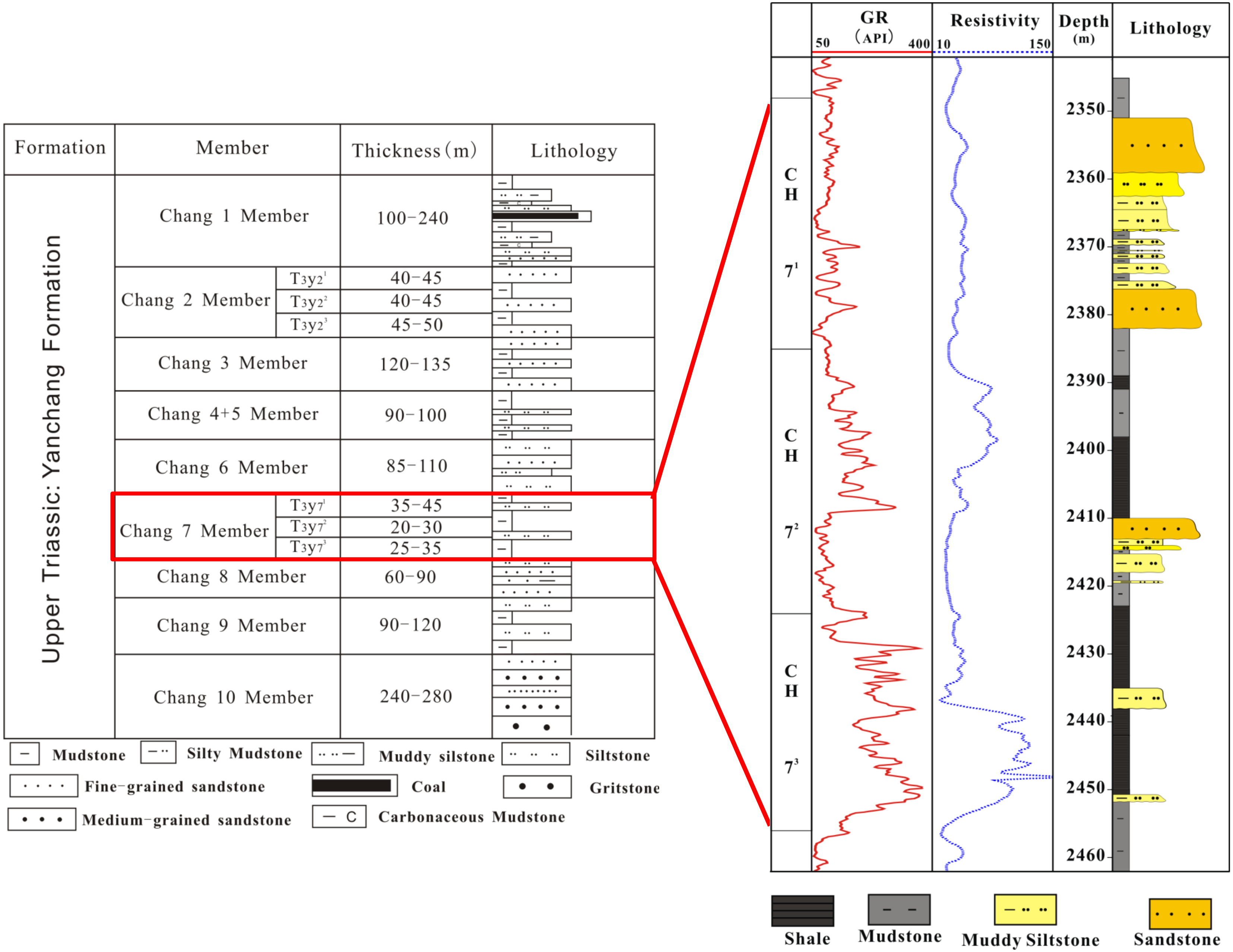
Choose Sample

Samples: Chang 7 shale in the Ordos Basin

Location

- North-Central China
- 2nd largest basin in China



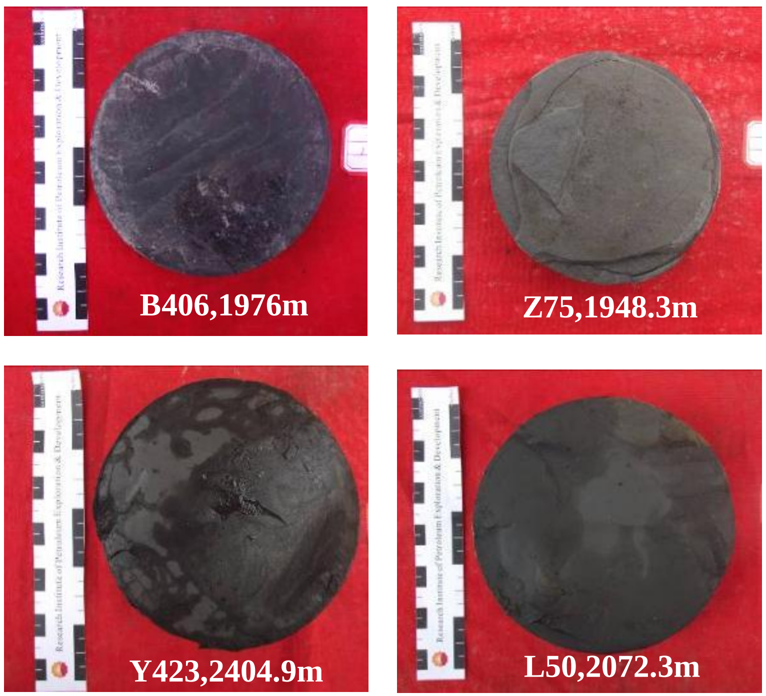


Formation
Member
Thickness (m)
Lithology
Upper Triassic: Yanchang Formation
Chang 1 Member
100–240
Chang 2 Member
T3y2¹
40–45
T3y2²
40–45
T3y2³
45–50
Chang 3 Member
120–135
Chang 4+5 Member
90–100
Chang 6 Member
85–110
Chang 7 Member
T3y7¹
35–45
T3y7²
20–30
T3y7³
25–35
Chang 8 Member
60–90
Chang 9 Member
90–120
Chang 10 Member
240–280
Mudstone
Silty Mudstone
Muddy silstone
Siltstone
Fine-grained sandstone
Coal
Gritstone
Medium-grained sandstone
Carbonaceous Mudstone
C
GR (API)
50
400
Resistivity
10
150
Depth (m)
Lithology
CH 7¹
CH 7²
CH 7³
2350
2360
2370
2380
2390
2400
2410
2420
2430
2440
2450
2460
Shale
Mudstone
Muddy Siltstone
Sandstone

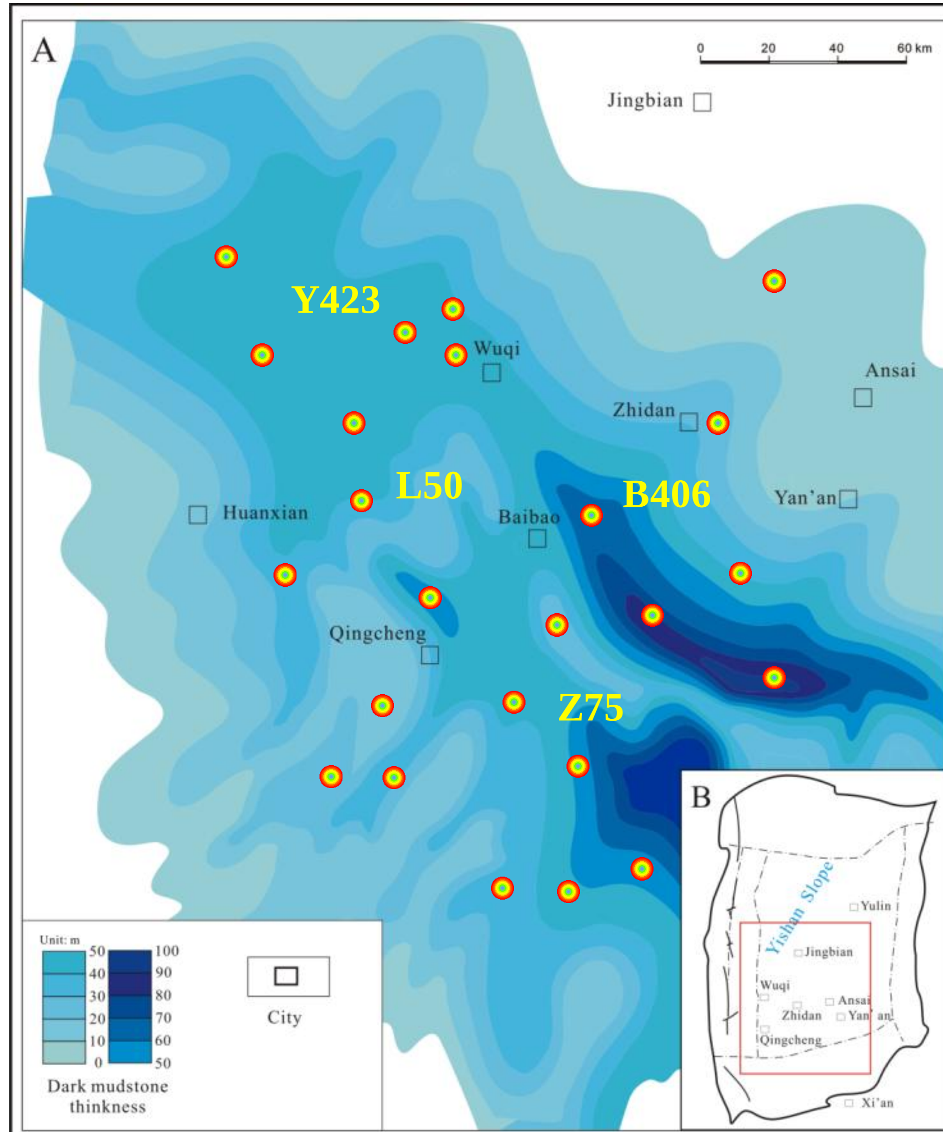
Samples: Chang 7 shale in the Ordos Basin

Lithology: black shale, mudstone
silty mudstone

Location: semi-deep/deep lacustrine



Core photos

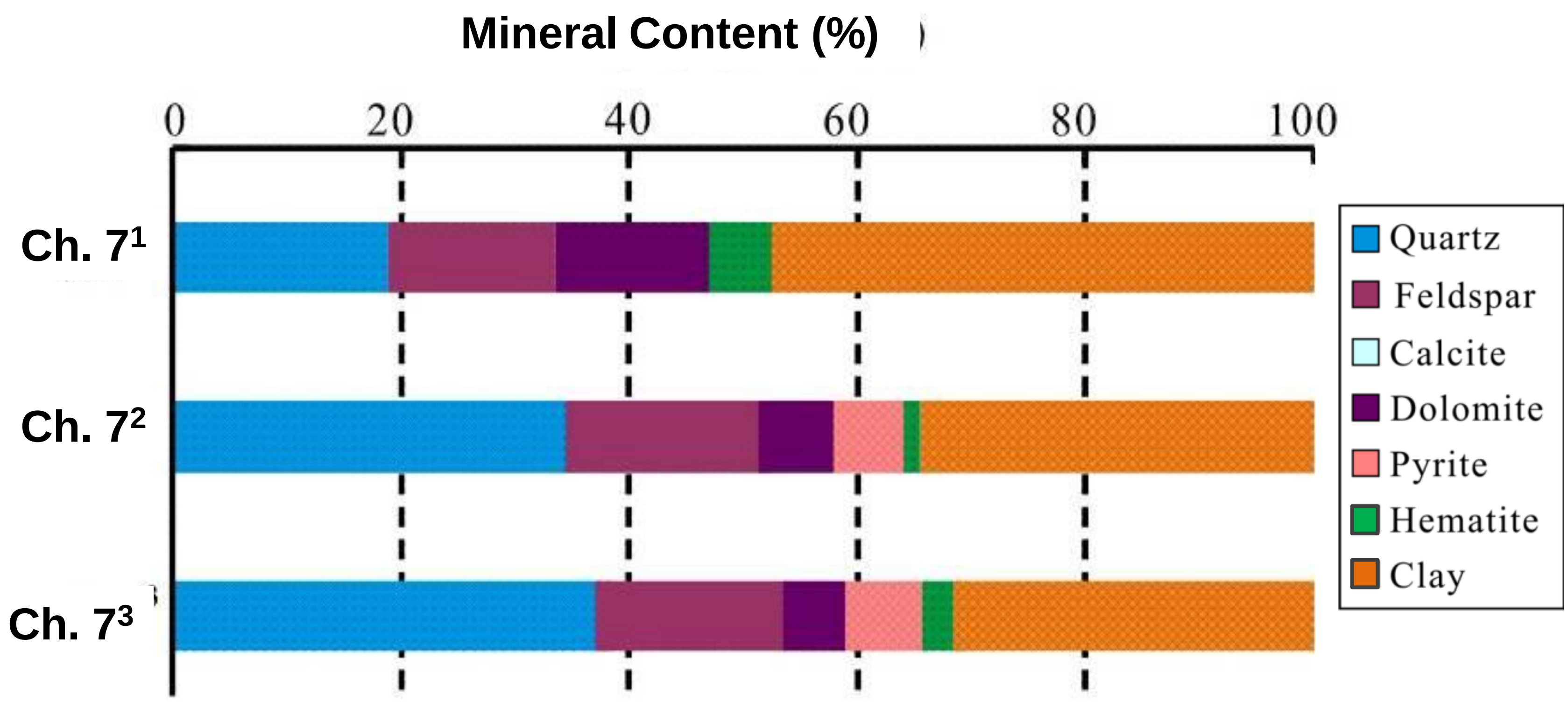


Part 2

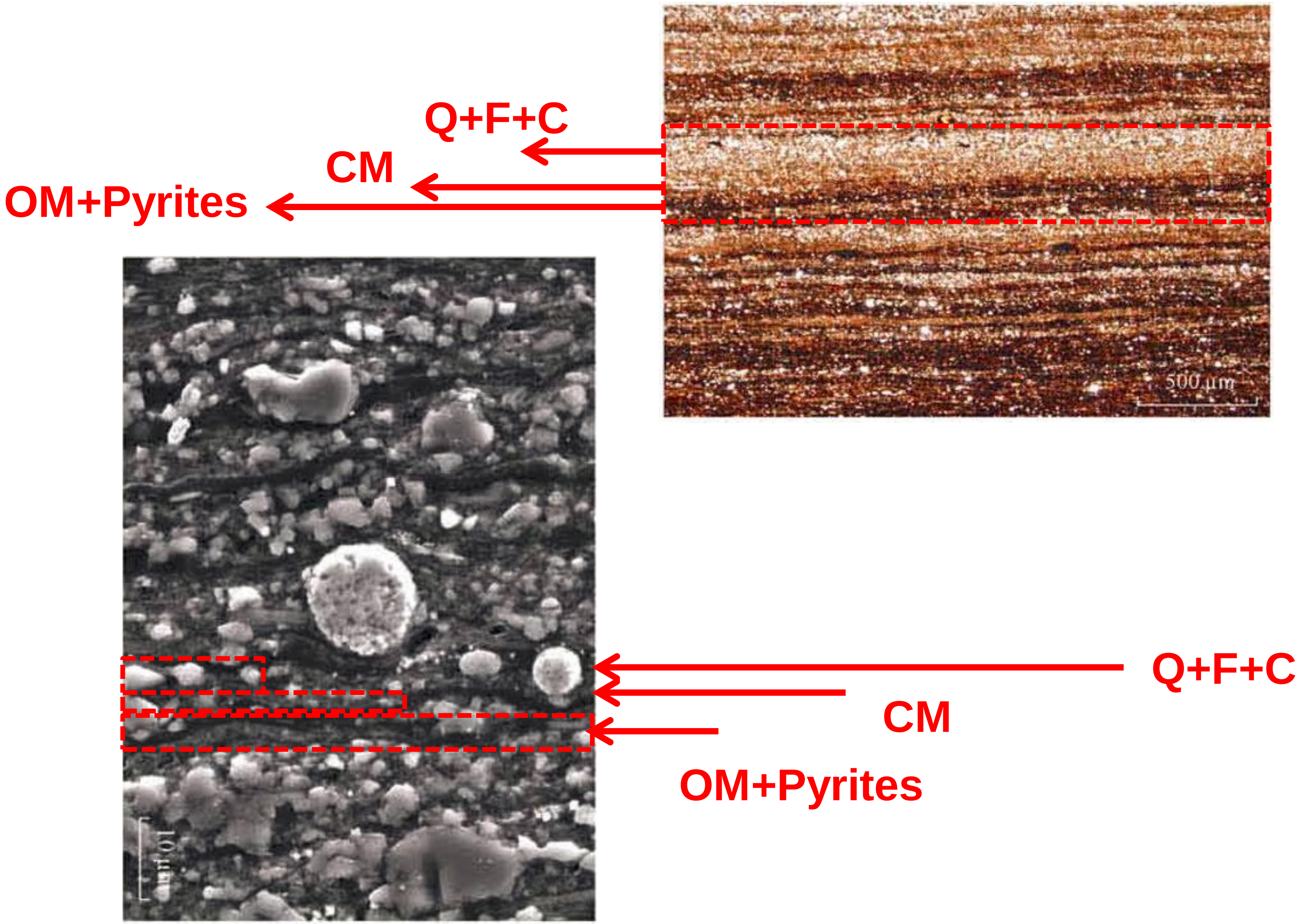
Evaluate reservoir potential

Mineralogy: High brittle mineral content

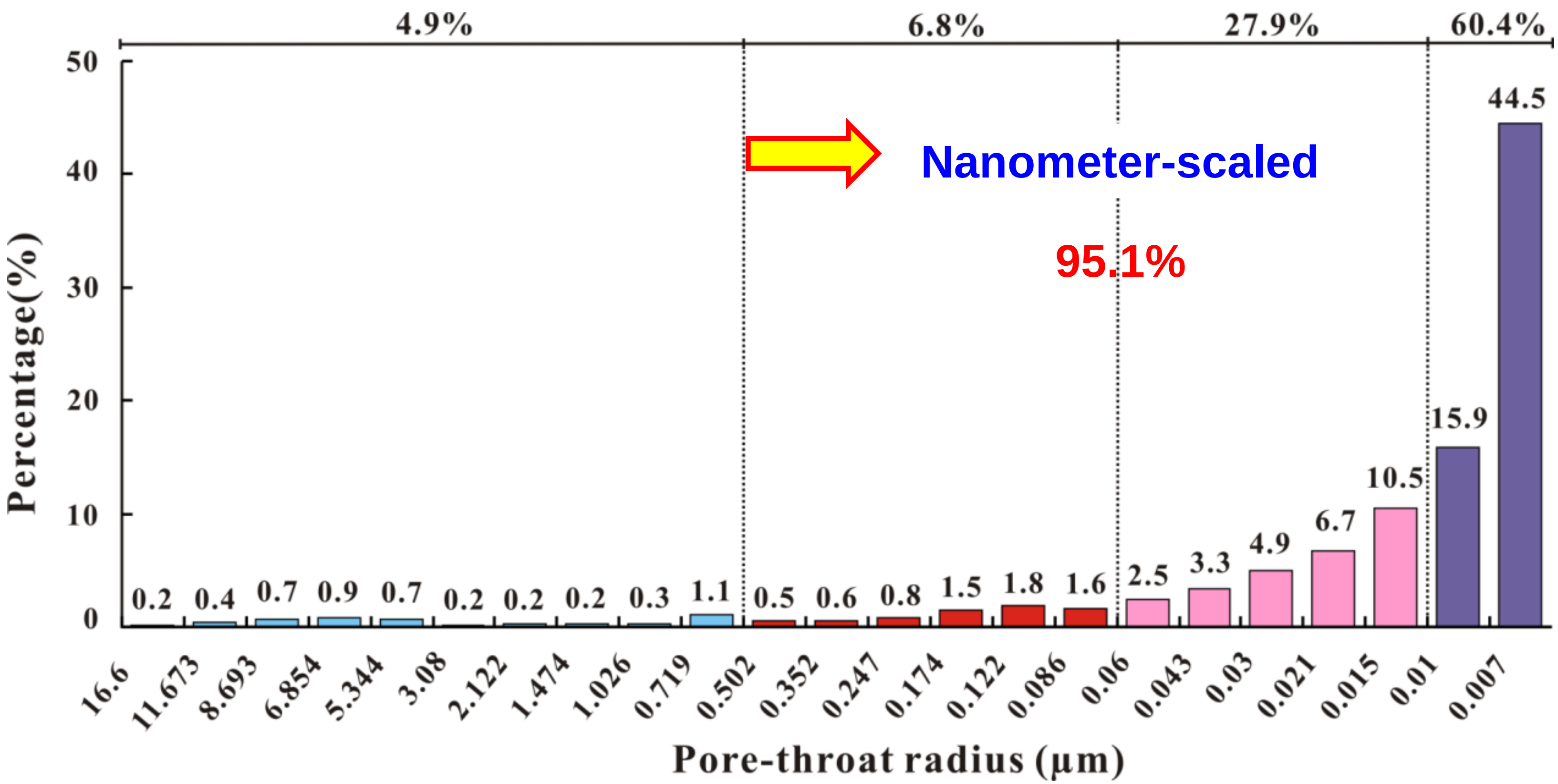
Quartz + Feldspar + Carbonate：45~59%, avg. = 53%



3-element texture: Q+F+C—CM—OM+P

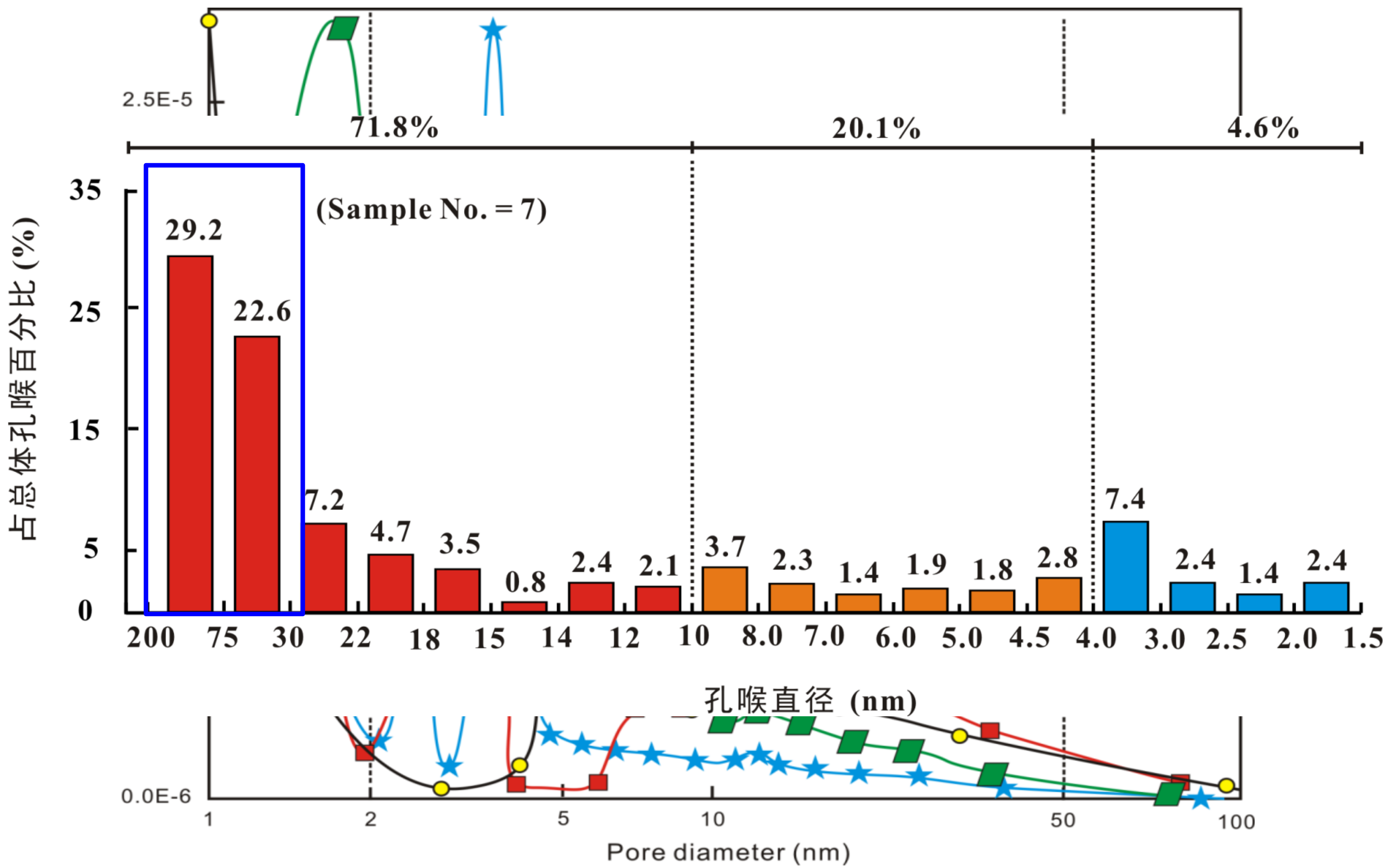


Mercury injection data: nanometer-scaled pore-throats dominate



Sample No.	TOC (%)	S_1+S_2 (mg/g)	Ro (%)	Φ (%)	K (mD)
S001	5.60	6.85	0.73	0.6	0.00072
S002	14.30	22.95	0.97	2.3	0.0023

N_2 adsorption: nanometer-scaled pore-throats dominate

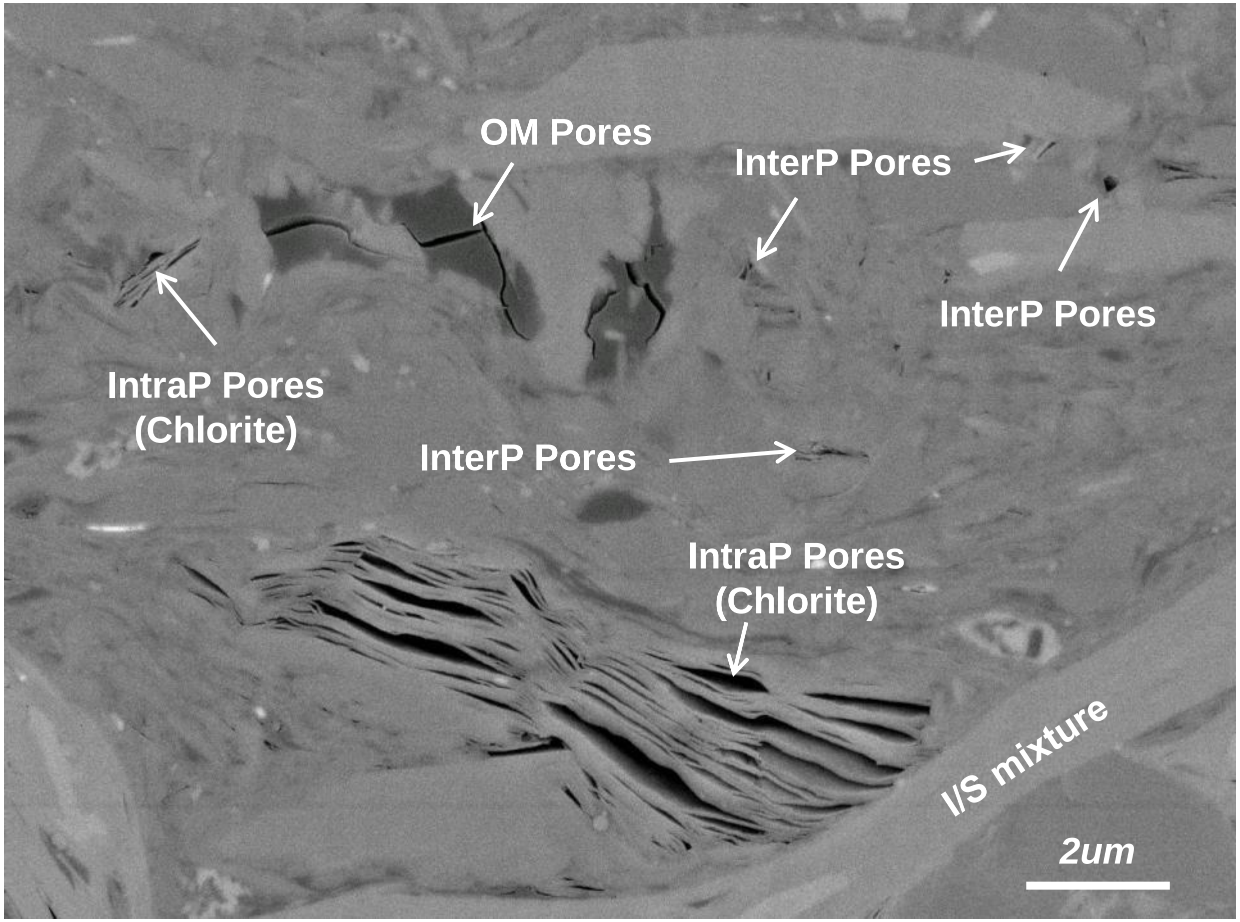


Nanometer-scaled Pore system

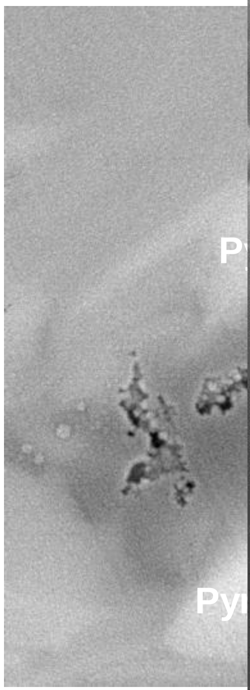
Pore Types

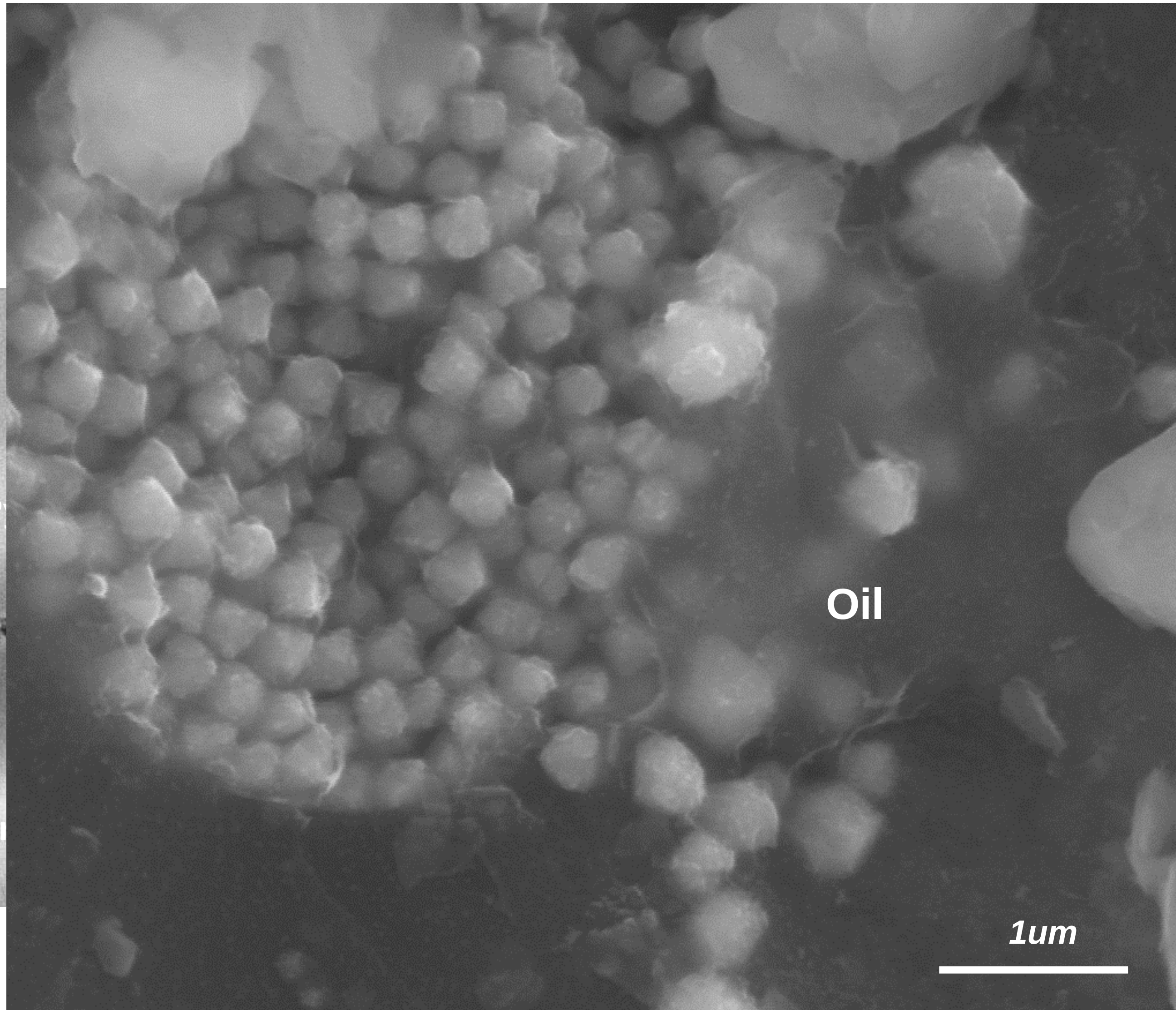
- Inter-particle Pores
- Intra-particle Pores
- OM Pores

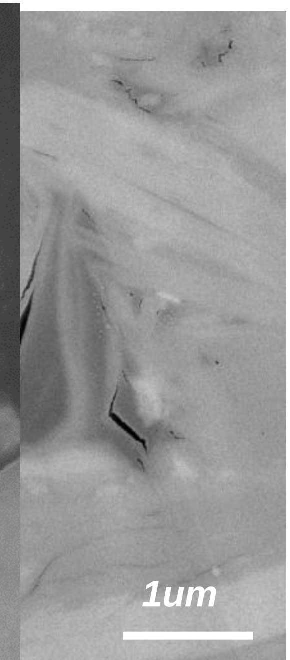
D: 30~200nm



Nanometer-scaled Pore system

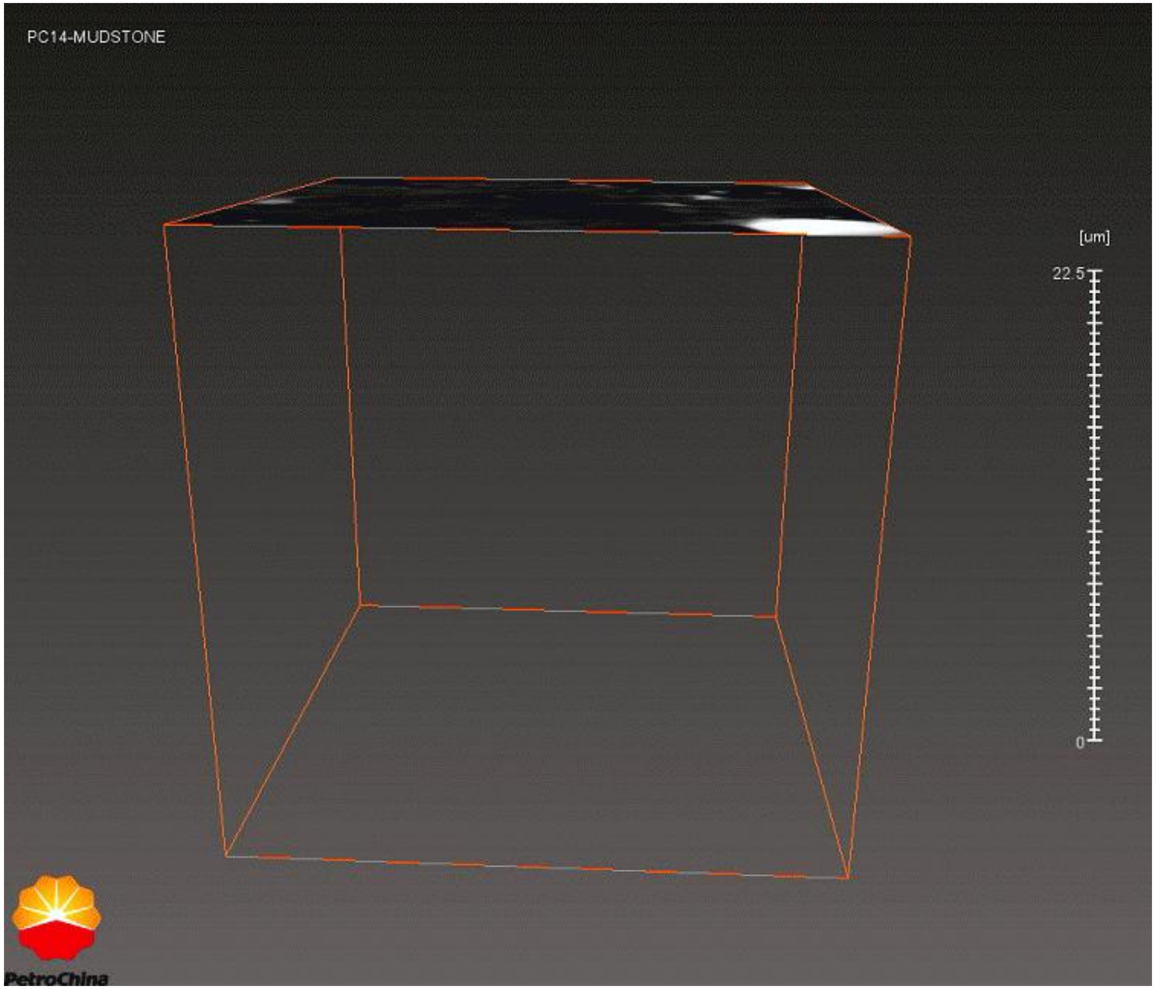




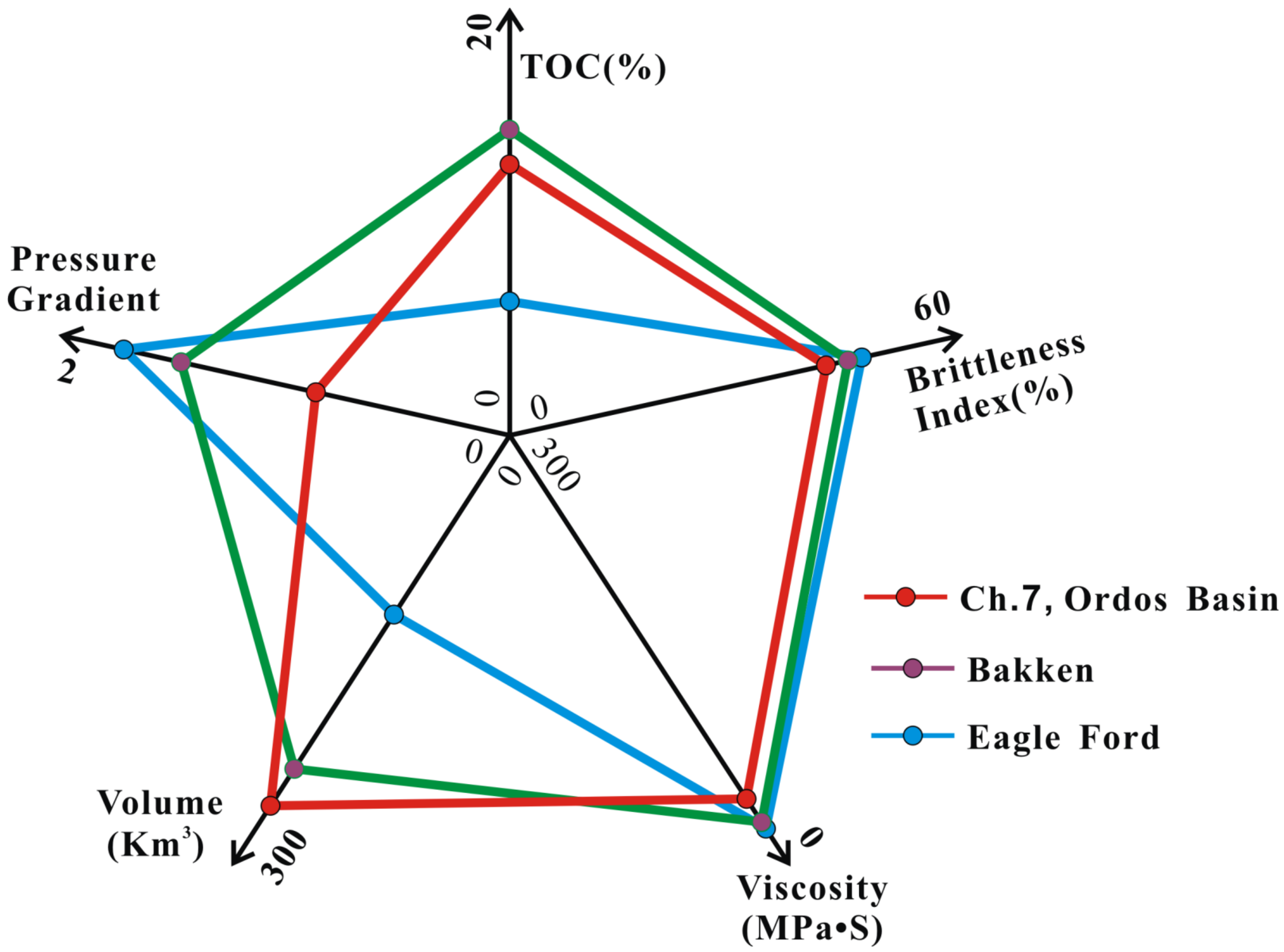


Nanometer-scaled Pore system

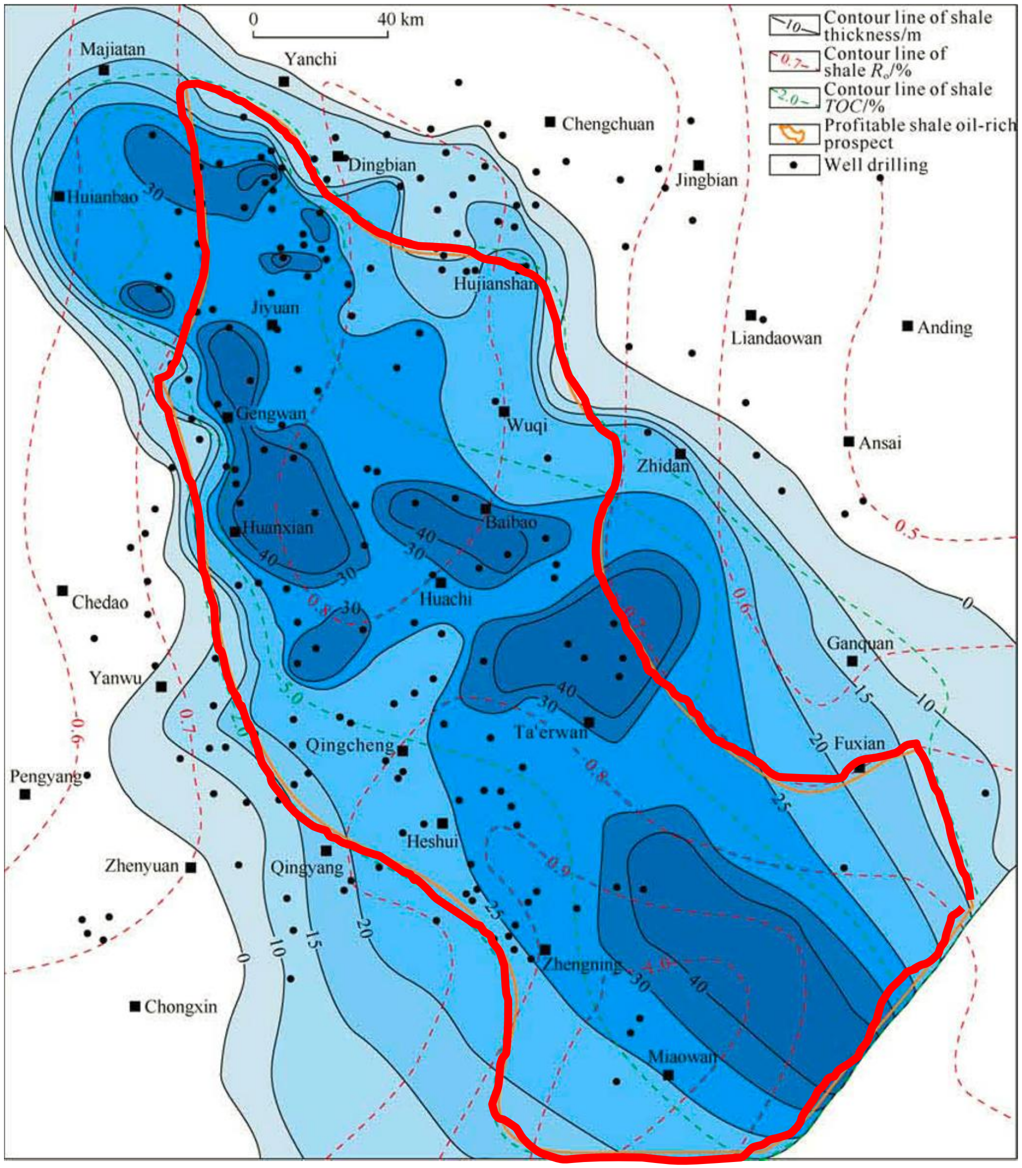
Nano-CT: medium connectivity with some isolated pores



Comparable with Bakken & Eagle Ford



Rough resource estimation: $>1.0\times10^9$ t



Favorable Shale Oil Play

- Kerogen type: I & II_A
- R_o: 0.7%-2.0%
- TOC: >2.0%
- Thickness: >10 m

Area: 20×10^3 km^2

$$Q = Sh\rho q$$

Q—shale oil resources, t
S—effective area, m^2
h—effective thickness, m
ρ—shale density, 10^3 kg/m^3
q—total shale oil content (per unit weight of shale), %

Part 3

Conclusions & Uncertainties

Conclusions & Uncertainties

Chang 7 shale has the potential to act as oil reservoir

- High brittle mineral content (avg.=53%) is favorable for fracturing
- Nanometer-scaled (3~200nm) pore-throat system with relatively good connectivity
- Relatively high porosity & permeability

- Some problems remain to be answered:

  (1) Fluid flow mechanism + HC occurance; (2) Abnormal low pressure; (3) OIP evaluation; (4) Reservoir simulation

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