"Sweet areas (sections)" of continental shale oil in China

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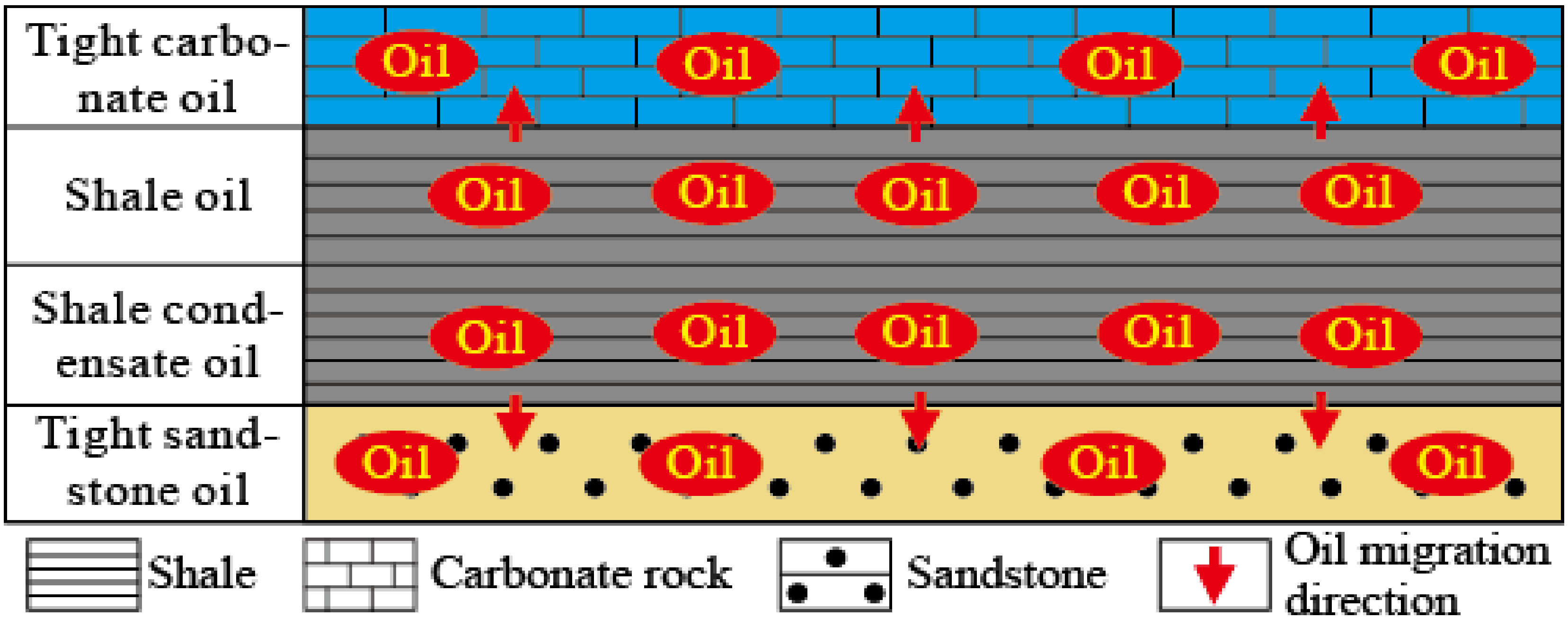
Definition: Shale Oil

- Shale oil refers to oil stored in organic-rich shale, including shale oil with lower R_o and shale condensate oil with higher R_o.
- Continuous distribution with no apparent trap limit, and no natural productivity



Schematic of formation and distribution of liquid-rich hydrocarbons in shale strata

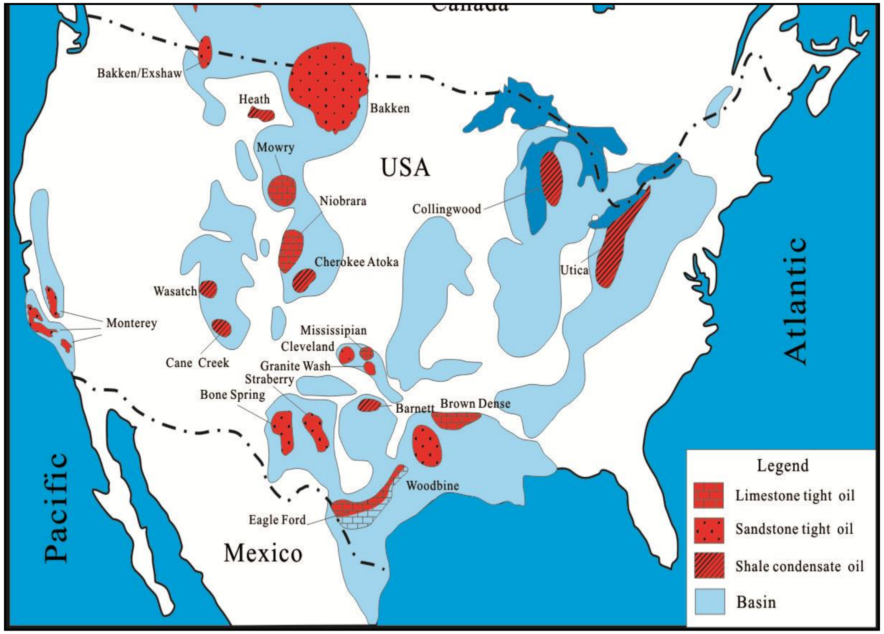
Two differences from tight oil：❶HC Generation ❷HC Migration

Outline

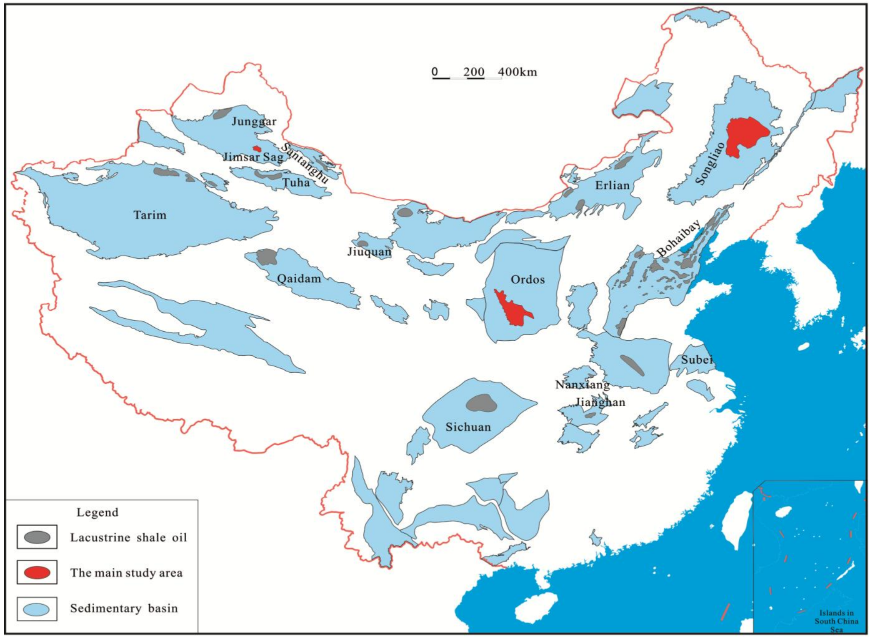
1. Introduction
2. “Sweet areas (sections)”
3. Resource Potential
4. Conclusions

TWO WHATS?

- What is "sweet area(section)"? What is resource potential?



Liquid rich shale in USA



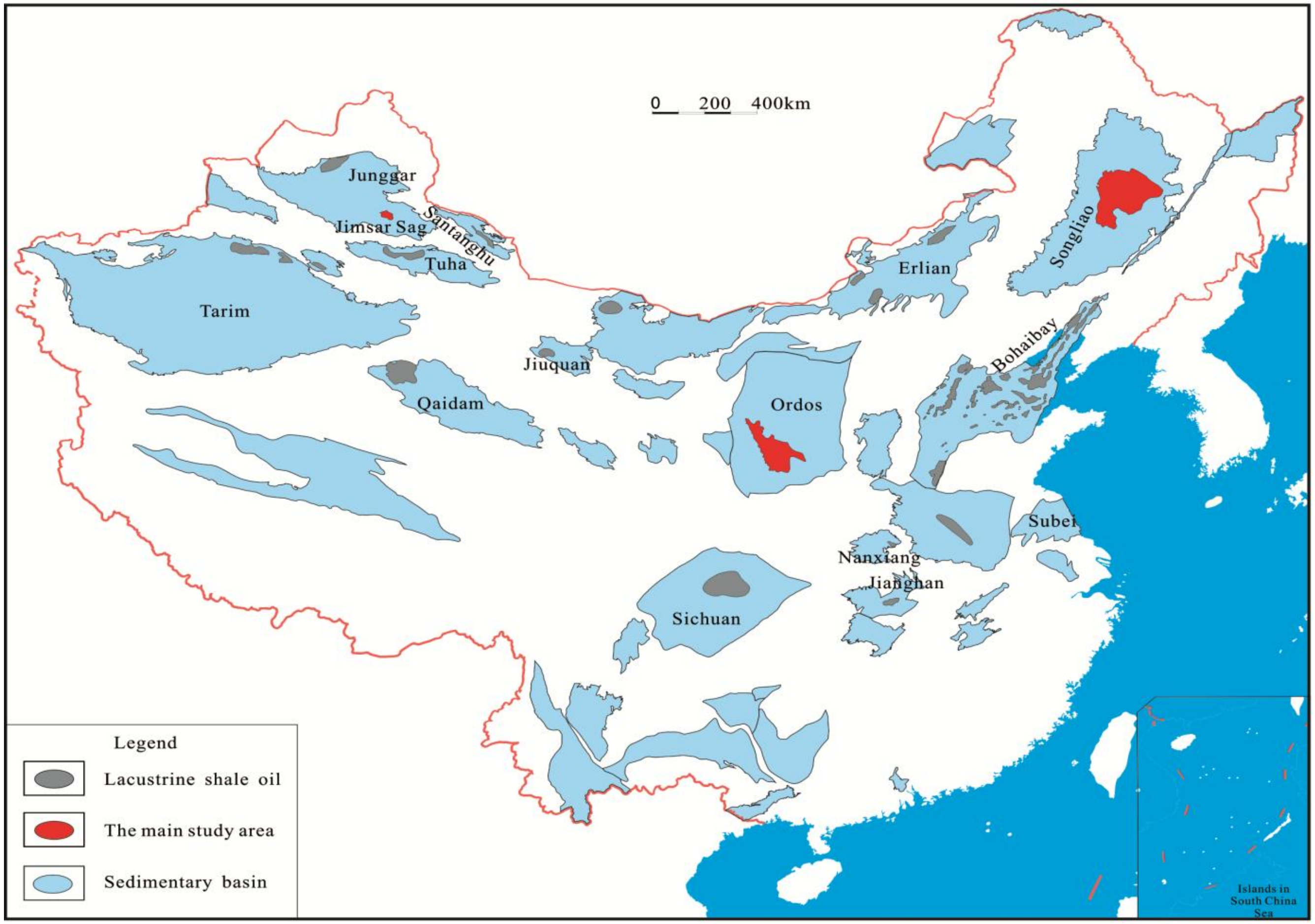
Shale oil in China

- 4 major marine basins
- 7.93 billion tons recoverable resources
- 310 million tons production in 2018
- Foreign oil dependence is 35%

- 3 major continental basins
- 2 billion tons recoverable resources
- 0.1 million tons production in 2018
- Foreign oil dependence is 70%

What are the study areas?

- National Key Basic Research and Development Program (973 Program), China (2014CB239000)(2013-2018)
- China National Science and Technology Major Project (2016ZX05046). (2016-2020)



3 study areas

- Ordos
- Songliao
- Junggar

Fig. 1. Oil-bearing lacustrine shale distribution in the main basins in China.

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"Sweet areas (sections)"

- The target areas (sections) that can be preferentially explored and developed in the oil bearing shale formations under current conditions.

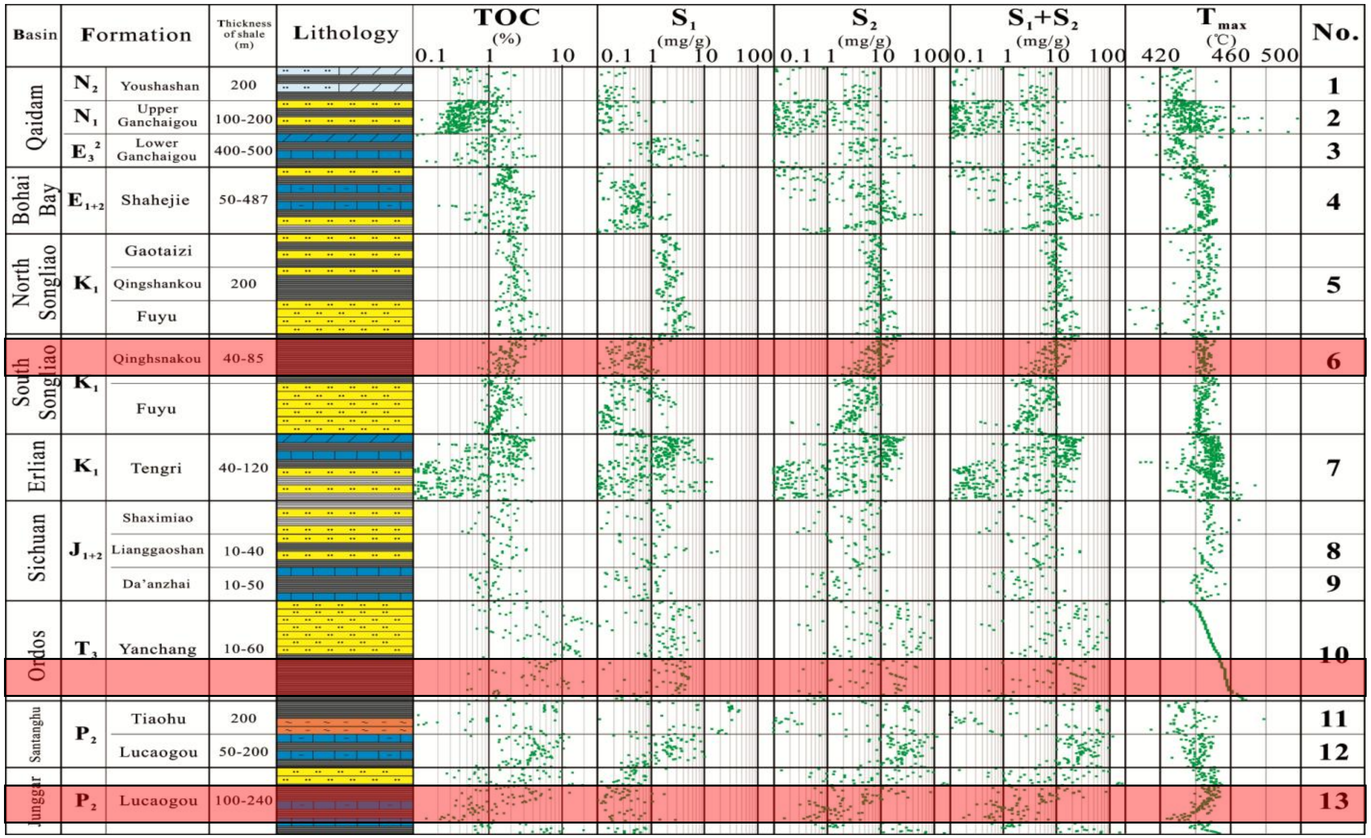


Fig. 2. Geochemical profile of lacustrine shale in the main basins in China.

3 key features

- multiple types
- wide age span
- large distribution

3 examples

- Ordos: T_3
- Songliao: K_1
- Junggar: P_2

"Sweet areas (sections)"

- The organic matter types I-II, the abundance of the organic matter varies greatly, and the thermal maturity is relatively low with Ro from 0.6 to 1.1%.

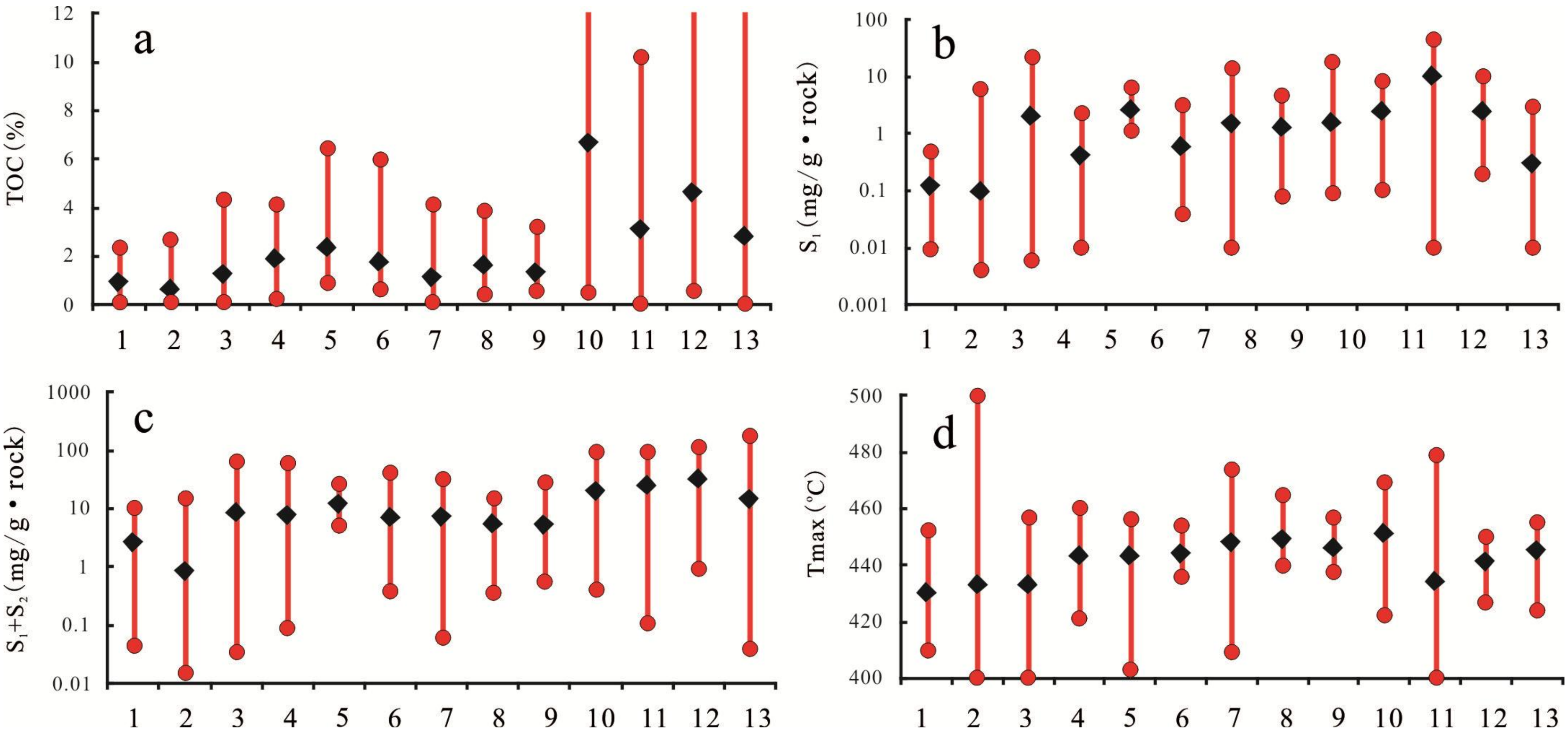


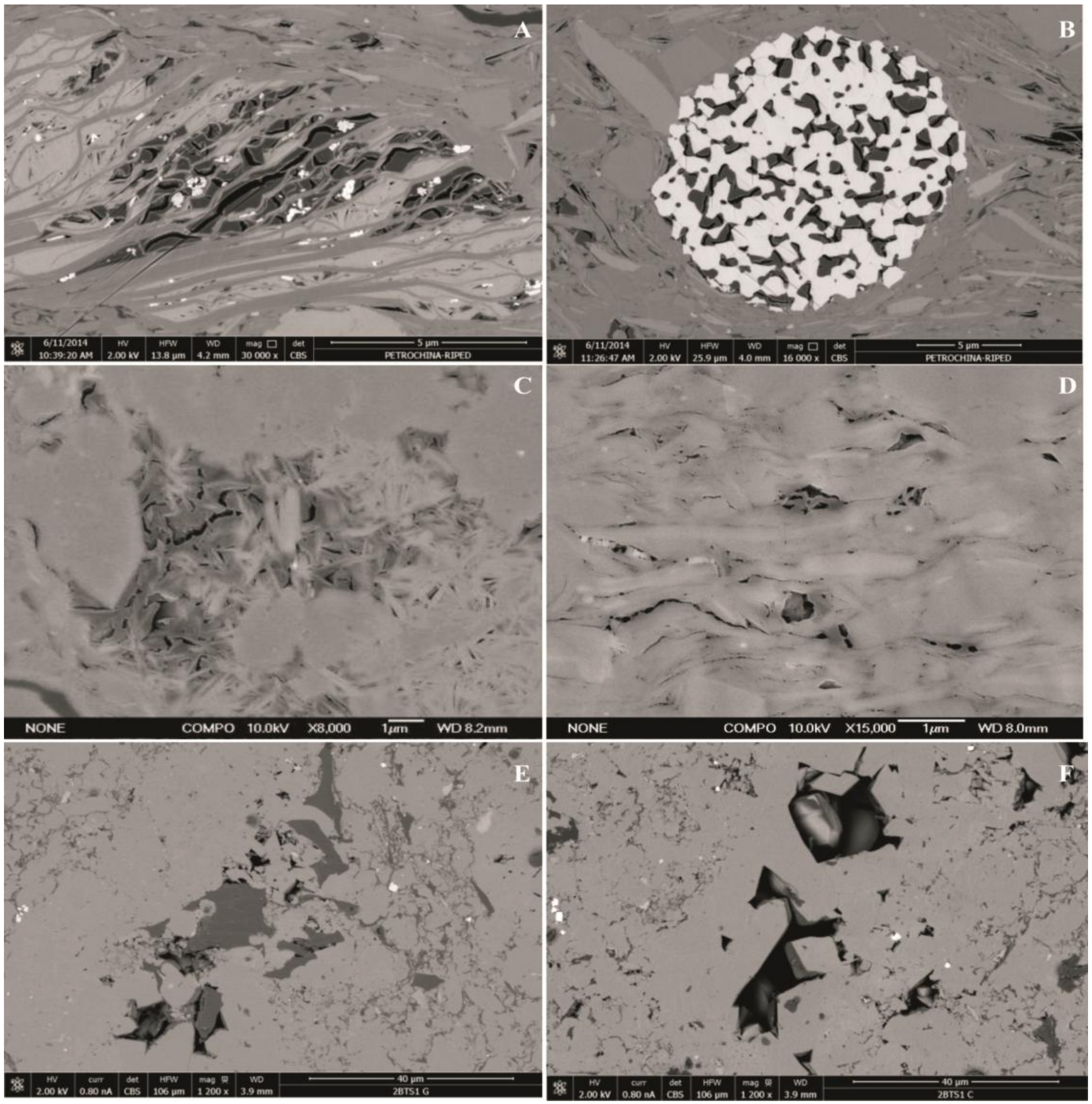
Fig. 3. Geochemical parameter cross-plot of contenental shale in China.

“Sweet areas (sections)”

Table 1 Geochemical parameter statistics of lacustrine shale in the main basins in China

No.	Basin	Formation	Sample numbers	Depth (m)	TOC (%)	S_1 (mg/g rock)	S_2 (mg/g rock)	S_1+S_2 (mg/g rock)	Tmax (^oC)
1	Qaidam	N_2(Youshashan)	49	2292-2953	0.09-2.38(av.0.92)	0.010-0.491(av.0.121)	0.035-9.927(av.2.491)	0.046-10.418(av.2.612)	410-452(av.430)
2	Qaidam	N_1(Upper Ganchaigou)	343	2679-3474	0.10-2.68(av.0.61)	0.004-5.955 av.(0.096)	0.011-12.874(av.0.751)	0.015-14.660(av.0.847)	301-565(av.433)
3	Qaidam	E_3^2(Lower Ganchaigou)	81	3215-3958	0.11-4.32(av.1.24)	0.006-22.74(av.2.013)	0.028-41.416(av.6.492)	0.034-64.157(av.8.51)	386-457(av.433)
4	Bohaibey (Shulu Sag)	E_{1-2}(Shahejie)	181	2268-4365	0.21-4.13(av.1.87)	0.01-2.32(av.0.41)	0.07-57.08(av.7.31)	0.09-59.4(av.7.72)	421-460(av.443)
5	North Songliao	K_1(Qingshankou)	124	2045-2111	0.88-6.41(av.2.35)	1.13-6.31(av.2.59)	3.7-20.43(av.9.18)	5.24-26.74(av.11.77)	403-456(av.443)
6	South Songliao	K_1(Qingshankou)	232	1048-2612	0.66-6.01(av.1.73)	0.04-3.11(av.0.59)	0.38-40.14(av.6.45)	0.38-40.14(av.7.04)	436-454(av.444)
7	Erlian (Anan Sag)	K1(Tengri)	401	1390-1635	0.08-4.13(av.1.13)	0.01-13.91(av.1.47)	0.04-27.31(av.5.65)	0.06-31.52(av.7.13)	409-474(av.448)
8	Sichuan	J(Lianggaoshan)	37	1328-2586	0.44-3.86(av.1.62)	0.08-4.64(av.1.28)	0.28-12.38(av.4.19)	0.36-15.51(av.5.47)	440-465(av.449)
9	Sichuan	J(Daanzhai)	44	1167-3211	0.56-3.23(av.1.31)	0.09-17.75(av.1.54)	0.42-14.44(av.3.66)	0.56-28.09(av.5.20)	438-457(av.446)
10	Ordos	T_3(Yanchang)	113	1717-2906	0.52-25.27(av.6.67)	0.10-8.14(av.2.45)	0.3-91.38(av.17.43)	0.4-97.27(av.19.88)	422-469(av.451)
11	Santanghu	P_2(Tiaohu)	52	2123-2960	0.01-10.2(av.3.10)	0.01-45.44(av.10.11)	0.01-58(av.14.59)	0.01-94.39(av.24.71)	389-479(av.434)
12	Santanghu	P_2(Lucaogou)	77	2219-3501	0.57-12.57(av.4.61)	0.2-10.18(av.2.43)	0.74-114.71(av.30.82)	0.94-116.42(av.32.25)	427-450(av.441)
13	Junggar	P_2(Lucaogou)	149	3109-3782	0.03-19.77(av.2.79)	0.01-2.91(av.0.30)	0.02-176(av.14.23)	0.04-176.65(av.14.54)	424-455(av.445)

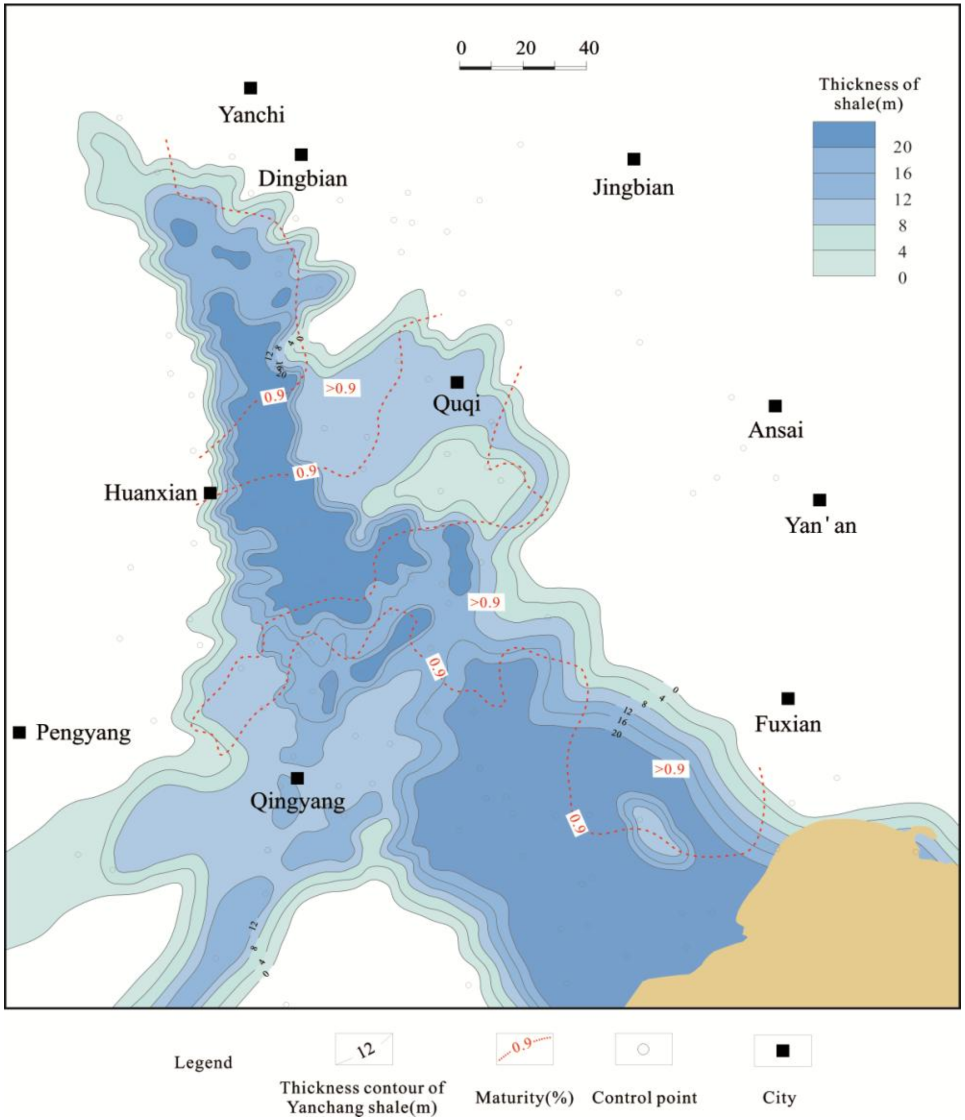
“Sweet areas (sections)”



- Large-scale reservoirs have continuous microscale and nanoscale reservoir spaces, which are the basis for continuous shale oil distribution.

Fig. 4. SEM images of typical continental oil-bearing shale in China.

Case 1: Ordos Basin



Sweet area

- Thickness is greater than 15m
- Ro is greater than 0.9%

Fig. 5. Overlay of the shale thickness and vitrinite reflectance of the Triassic Yanchang Formation in Ordos basin, China.

Case 1: Ordos Basin

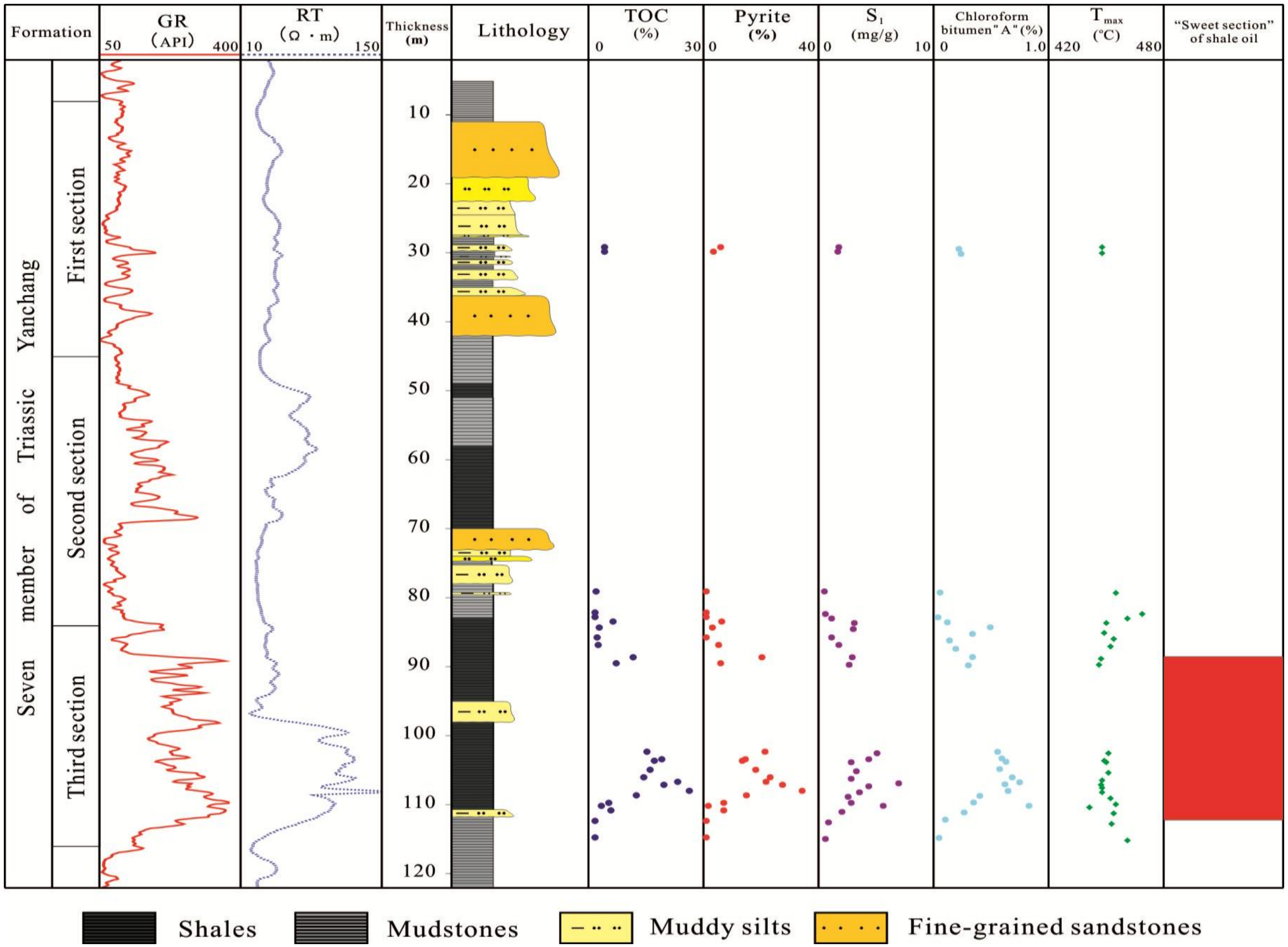


Fig. 6. Geochemical depth profile of Triassic Yanchang Formation lacustrine shale in Ordos basin, China.

Sweet section

- Lower part

Case 1: Ordos Basin

- The TOC content has a positive correlation with the development level of the shale lamellae, and shale oil is extensively present in these lamellar planes or parallel microfractures.

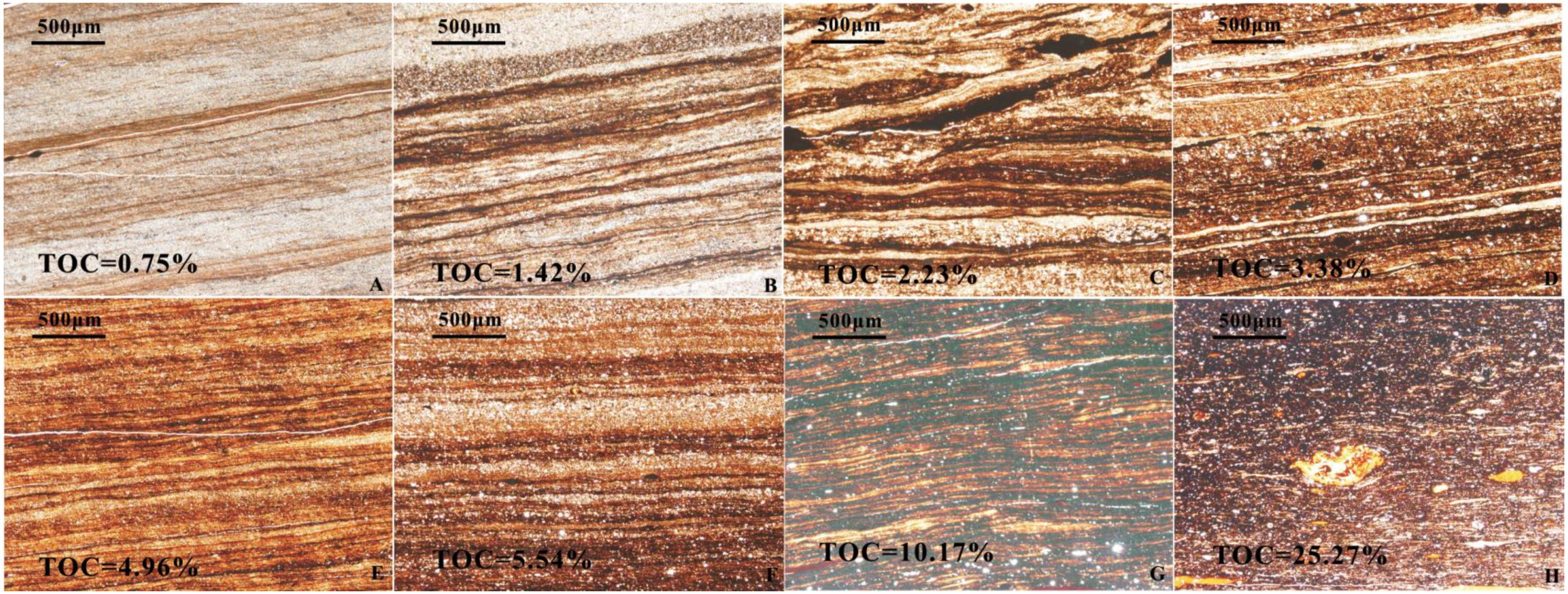
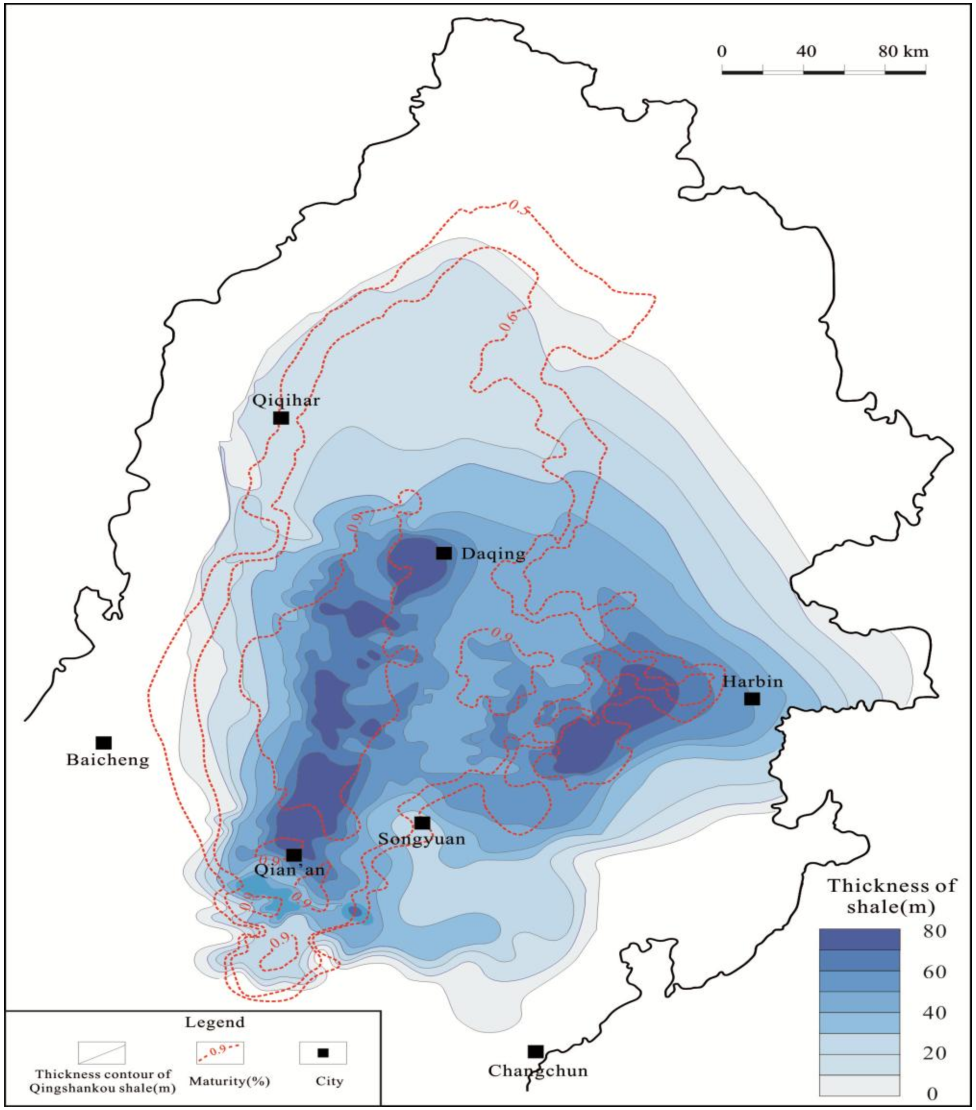


Fig. 7. Microscopic photos under polarized light of lamina and organic matter in the Triassic Yanchang Formation in the Ordos Basin.

Case 2: Songliao Basin

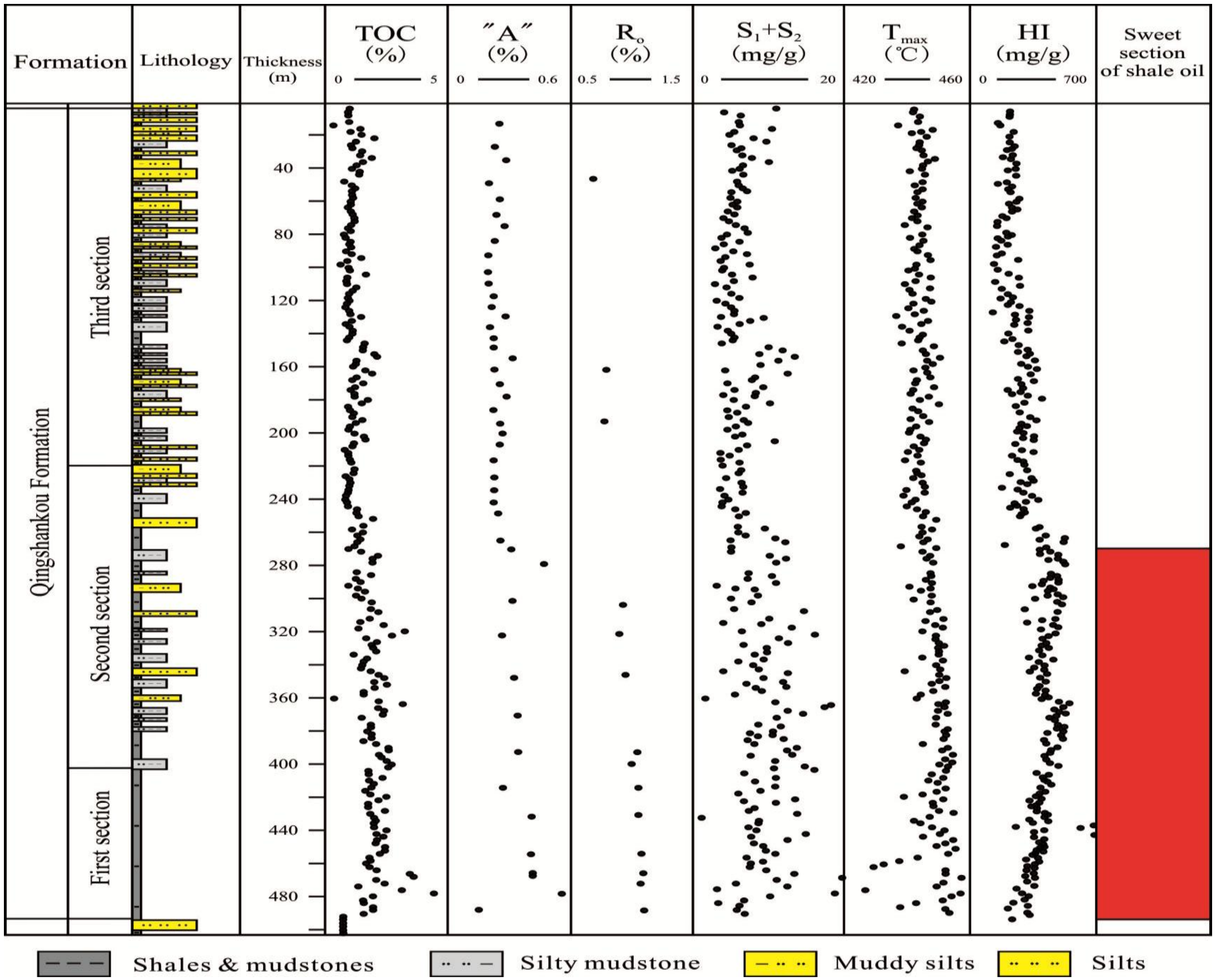


Sweet area

- Thickness is greater than 40m
- Ro is greater than 0.9%

Fig. 8. Overlay of the shale thickness and vitrinite reflectance of the Cretaceous Qingshankou Formation in the Songliao basin, China.

Case 2: Songliao Basin



Sweet section

- Middle and lower part

Fig. 9. Geochemical depth profile of Cretaceous Qingshankou Formation lacustrine shale in the Songliao basin, China.

Case 3: Junggar Basin

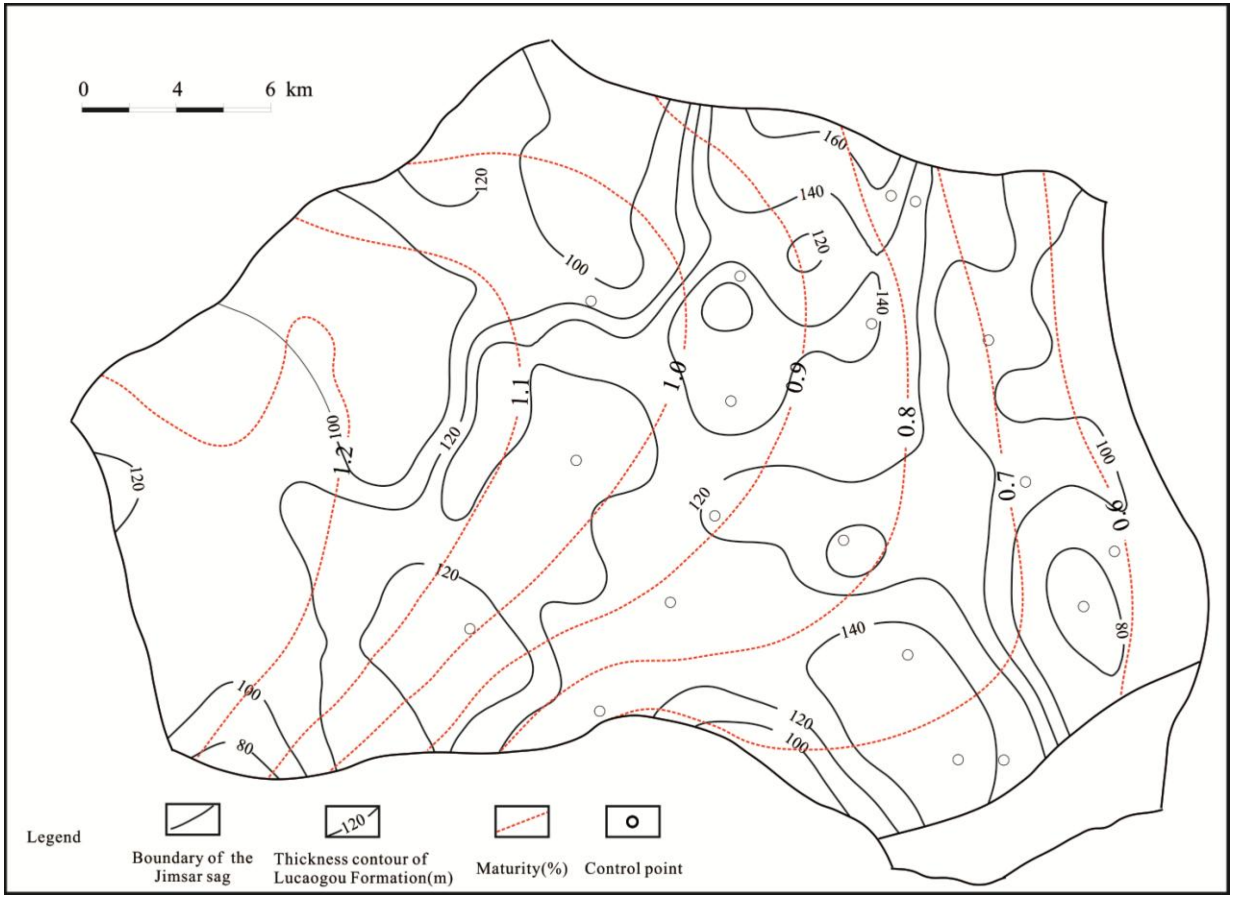
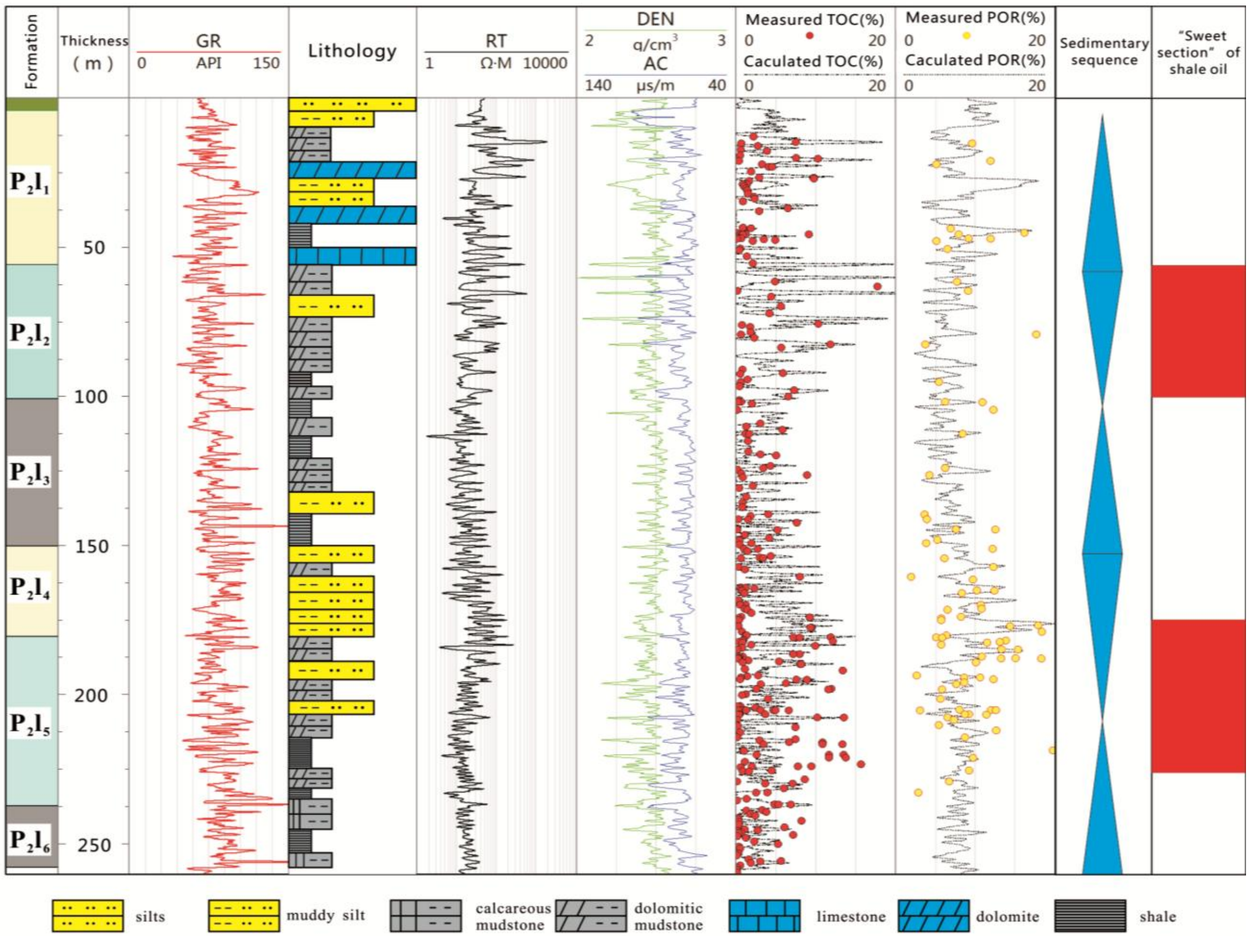


Fig. 10. Overlay of the shale thickness and vitrinite reflectance of the Permian Lucaogou Formation in the Jimsar Sag, Junggar basin, China.

Sweet area

- Middle of sag

Case 3: Junggar Basin



Sweet section

- P_2l^5
- P_2l^5

Fig. 11. Stratigraphic histogram of the Permian Lucaogou Formation lacustrine shale in the Junggar basin, China.

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Medium to high mature shale

- Using SRV , if EUR 2%, about 7 billions shale oil may be recoverable.

Table 2 Continental shale oil resource potential evaluation of the main basins in China

Basin	Formation	Oil generation (10^8t)	Oil expulsion (10^8t)	Oil detention (10^8t)	Shale oil recoverable (10^8 t)		
					2%	5%	10%
Songliao	Cretaceous	1100	400	700	14	35	70
Bohai Bay	Paleogene	1400	500	900	18	45	90
Ordos	Triassic	1300	450	750	15	38	75
Junggar	Permian	800	250	550	11	28	55
Sichuan	Jurassic	300	100	200	4	10	20
Qaidam	Paleogene, Neogene	300	100	200	4	10	20
Erlian	Cretaceous	200	50	150	3	8	15
Santanghu	Permian	45	15	30	1	2	3
Jiuquan	Cretaceous	50	15	35	1	2	4
Nanxiang	Paleogene	30	12	18	0	1	2
Subei	Paleogene	115	17	98	2	5	10
Jianghan	Paleogene	82	11	71	1	4	7
Total		5722	1920	3702	74	185	370

Medium to low mature shale

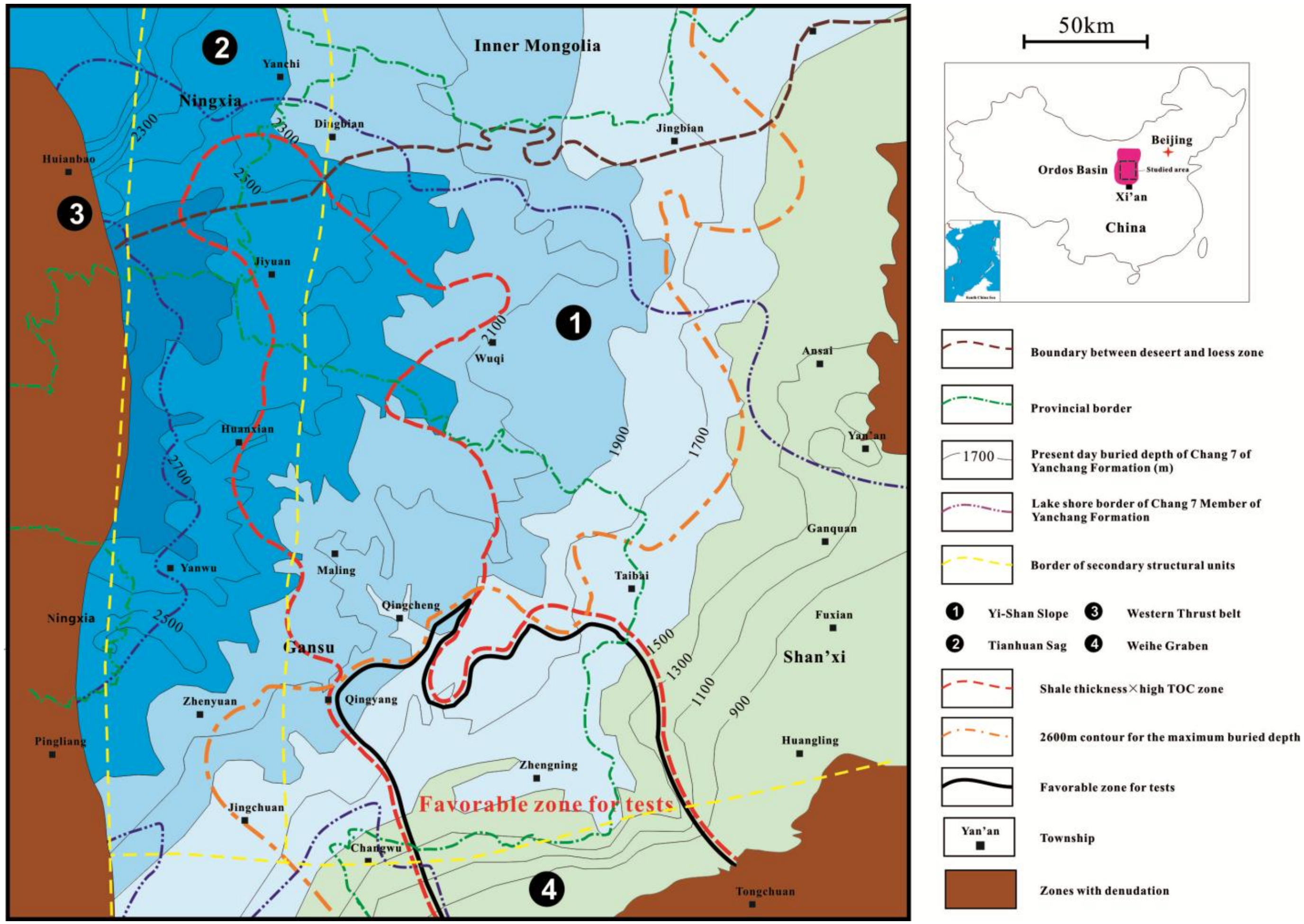

Fig. 12. Comprehensive evaluation of the favorable pilot area for the Triassic Yanchang Formation shale in Ordos basin in China using ICP technology.

3 key factors

- The scale (area, thickness×TOC)
- Max burial depth
- Present depth

- Area:12 000 km^2
- Thi×TOC: >100
- Ro: <0.8%
- Depth: 700-1700m

- In China, recoverable oil is 40 to 50 billion tons.

Man-made shale oil reservoir

- Using technologies such as SRV and ICP, an underground fracture network with "man-made permeability" is constructed, with which continental shale oil may be another revolution of unconventional oil and China the first successful one.

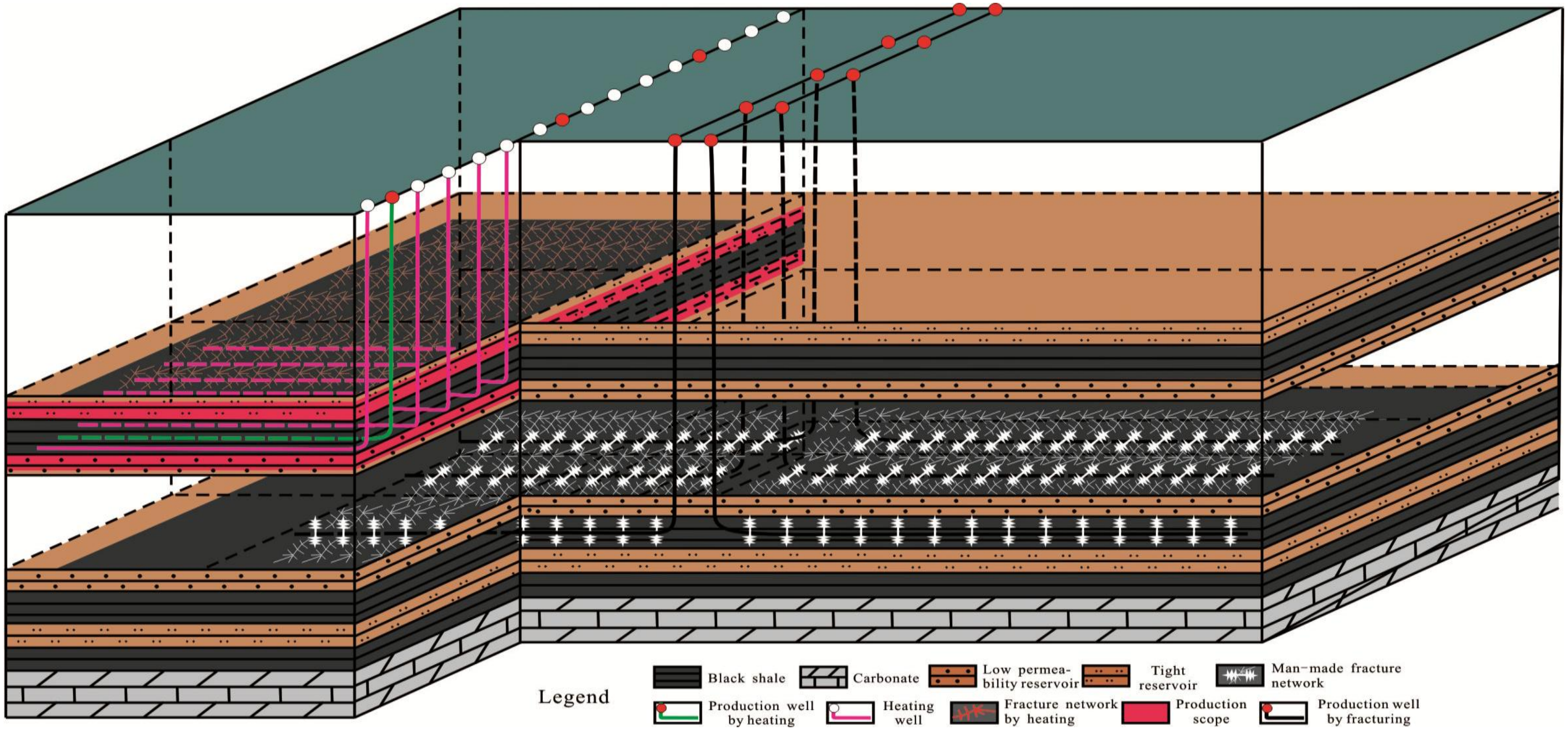

Fig. 13. "Man-made shale oil reservoir" exploitation model.

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Conclusions

- "Sweet areas (sections)"：
  - "Sweet areas" of shale oil with medium-high maturation are mainly located in thick shales with a Ro greater than 0.9%.
  - "Sweet sections" are mainly located in the middle and lower parts of the shale formation.
- Resource Potential：
  - Using SRV, 370 billion tons of geological resources.
  - Using ICP, 40 to 50 billion tons of recoverable part.
  - "Man-made reservoir" is proposed.

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Thanks！

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