Concepts, Geological Characteristics and Evaluation Techniques for Continuous Petroleum Accumulations in China*

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Abstract

USGS presented the concept "continuous-type petroleum accumulations" for the purpose of resource assessment. And we have further studied the concepts, geological characteristics and evaluation techniques for continuous petroleum accumulations based on many cases in China basins:

1) Continuous petroleum accumulations are those oil or gas accumulations that exist in large spatial dimensional unconventional reservoir systems and are continuously distributed in "non-closed traps". "Continuous" stresses the continuous distribution of hydrocarbon in dimensions, and "petroleum accumulation" refers to the places where petroleum accumulated. Tight sandstone oil/gas, carbonate cavity reservoirs, coal-bed methane, shale oil, shale gas and gas hydrate all belong in the category of continuous petroleum accumulations;

2) Geological characteristics: (1) largescale continuous distribution, but local enrichment, (2) mainly unconventional reservoirs in large dimensions, (3) non-closed traps with indistinctly defined boundaries, large reservoir space, (4) in-source or near-source distribution, (5) no migration or mainly primary migration, (6) accumulated mainly by diffusion, limited role of buoyancy, (7) non-Darcy infiltration flow, (8) weak fluid differentiation, diverse oil or gas saturation, and complex distribution of oil, gas and water;

3) Techniques for continuous petroleum accumulations require more attention than conventional accumulations in many aspects, such as seismic reflectance, logging identification, oil or gas test measurement, reservoir transformation, exploitation evaluation, recovery improvement, assorted techniques, and so on;

4) Exploration and exploitation areas in China: (1) Realistic areas: tight-sand oil and gas with low/ultra-low porosity and permeability in Ordos Basin, Sichuan Basin and Songliao Basin, oil and gas in carbonate cavity reservoirs in Tarim Basin, bacterial gas in Chaidamu Basin, and coal-bed methane, (2) Preparatory areas: shale gas in South China, tight gas in deep strata in Songliao Basin, Bohai Bay Basin, Tarim Basin and Junggar Basin, and gas hydrate in South China Sea.

Continuous petroleum accumulations have been one of the most important fields for theory and technology research, and for the following exploration and exploitation. By the end of 2008, the continuous oil accumulations and continuous gas accumulations had reached 47% and 56% of the total geological reserves in China respectively, and the exploration potential will be greater in the future.

CNPC

Concepts, Geological Characteristics and Evaluation Techniques for Continuous Petroleum Accumulations in China

Zou Caineng, Tao Shizhen, Yuan Xuanjun, Zhu Rukai, Hou Lianhua, Jia Jinhua,

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April, 2010

AAPG U.S.A.

Caring for energy, caring for you

Outline

Ⅰ. Basic Concept of Continuous Oil and Gas Plays

Ⅱ. Geological Features of Continuous Oil and Gas Plays

Ⅲ. Assessment Technology of Continuous Oil and Gas Plays

I. Basic Concept of Continuous Oil and Gas Plays

Oil and gas exploration and its theoretical research has undergone four stages:

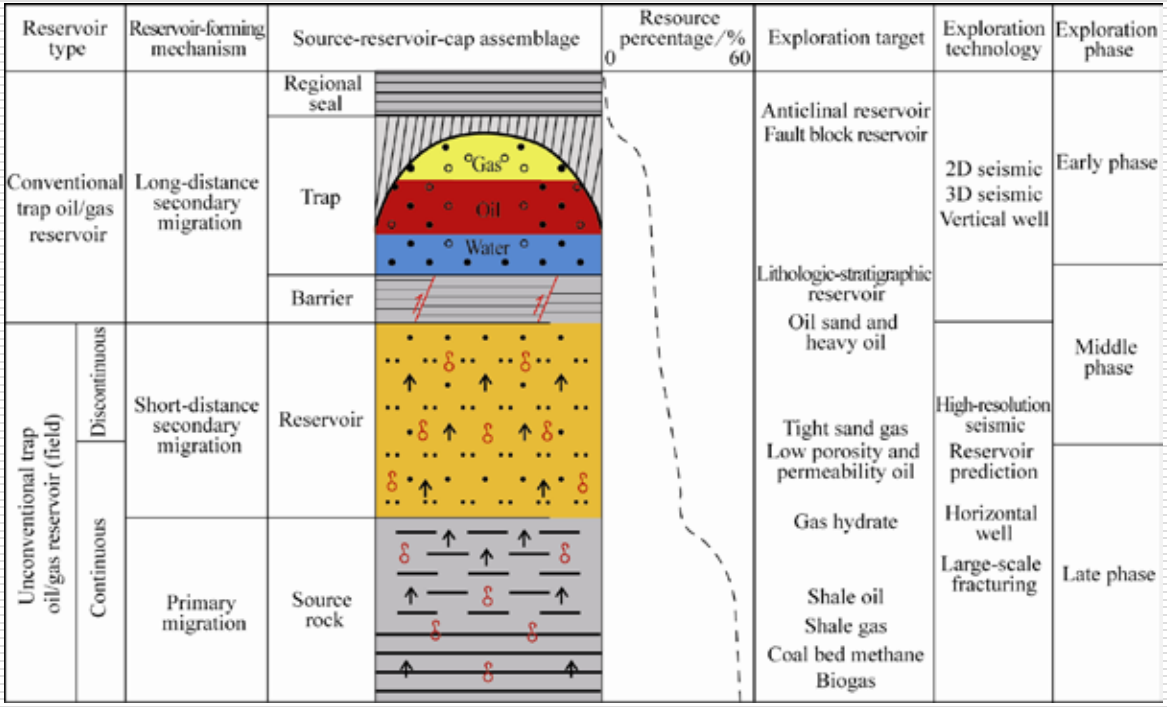
First stage: Oil & Gas Seepage

Second stage: Anticlinal Trap Theory

Third stage: Conventional Trap Oil/gas Reservoirs

Fourth stage: Unconventional Oil/gas plays

I. Basic Concept of Continuous Oil and Gas Plays



Based on whether trap configuration is obvious or not: there are 2 types of reservoirs (conventional and unconventional).

Conventional trap oil/gas reservoirs: anticlinal reservoir, etc. This type of reservoir experienced long-distance secondary migration, accounts for 10-20% of the total resource.

Unconventional oil/gas plays: there are 2 types (continuous and discontinuous).

Continuous: shale gas, tight gas sands, etc., which experienced primary migration and short-distance secondary migration, and accounts for 40-50% of the total resource.

Discontinuous: fracture-cavity interconnected carbonate oil/gas plays, etc., which experienced short-distance secondary migration, and accounts for 20-30% of the total resource.

I. Basic Concept of Continuous Oil and Gas Plays

~ **Concept of Continuous Oil and Gas Plays: Unconventional oil and gas is distributed in large-scale unconventional reservoir rock continuously. It is distinctly different from the traditional typical discrete conventional trap oil/gas reservoirs.**

~ **"Continuous": Emphasize on the continuous or quasi-continuous distribution of oil/gas.**

~ **"Oil and Gas Plays": Referring to the area where oil/gas accumulated.**

Outline

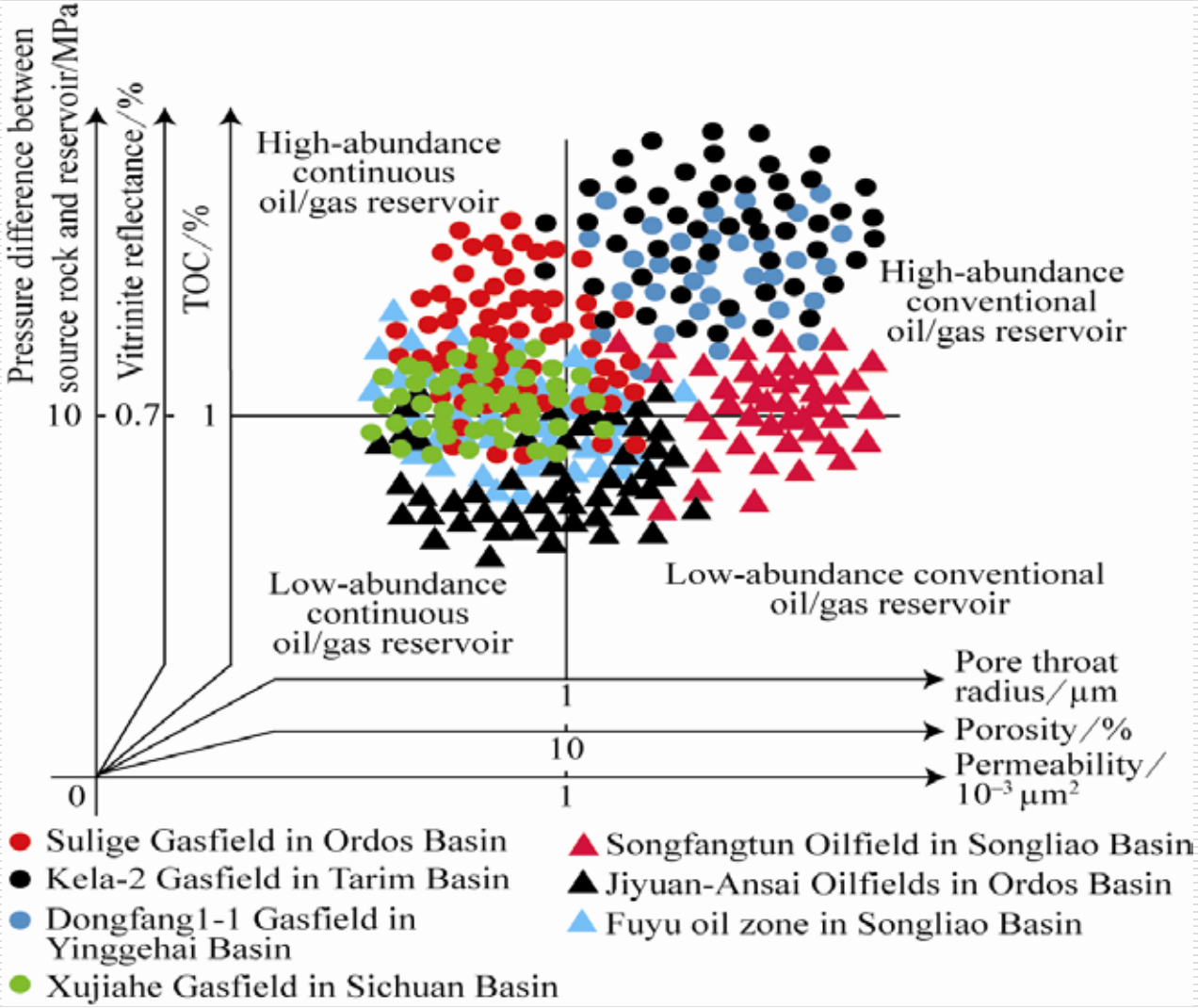
Ⅰ. Basic Concept of Continuous Oil and Gas Plays

Ⅱ. Geological Features of Continuous Oil and Gas Plays

Ⅲ. Assessment Technology of Continuous Oil and Gas Plays

Ⅱ. Geological Features of Continuous Oil and Gas Plays

~ **In general, average pore throat radius <1μm, porosity <10%, permeability <1md, TOC >1%, Ro >0.7%, and pressure difference between source rock and reservoir >10MPa are favorable for forming continuous oil/gas plays.**



Ⅱ. Geological Features of Continuous Oil and Gas Plays

7 types of continuous oil/gas plays in China:

No.	Type	Case
1	Low porosity and permeability sandstone oil/gas plays	Paleozoic gas of Sulige Gasfield and Mesozoic oil of Longdong Oilfield in Ordos Basin, Mesozoic sand oil and tight sand gas in Songliao Basin, upper Triassic gas of Xujiahe Formation in Sichuan Basin, etc.
2	Fracture-cavity-pore interconnected carbonate oil/gas plays	Ordovician oil & gas in Lunnan Oilfield, Tarim Basin; Lower Paleozoic gas in Ordos Basin, etc.
3	Fracture-cavity interconnected volcanic rock oil/gas plays	Volcanic oil/gas plays in Songliao and Junggar Basin, etc.
4	Coalbed methane	Coalbed methane in Qinshui Basin, Ordos Basin, etc.
5	Mud shale oil & gas	Paleozoic shale gas in Sichuan Basin, Cretaceous shale oil of Qingxi Oilfield in Jiuquan Basin, etc.
6	Biogas	Quaternary biogas in Qaidam Basin, etc.
7	Gas hydrate	South China Sea, etc.

Ⅱ. Geological Features of Continuous Oil and Gas Plays

10 differences between continuous oil/gas plays and conventional trap oil/gas reservoirs:

No.	Characteristics	Continuous unconventional oil/gas play	Conventional trap oil/gas reservoir
1	Distribution	Large-scale continuous distribution in basin center and slope area, enrichment in local area	Discrete trap, non-continuous distribution
2	Reservoir features	Mainly large-scale unconventional reservoir rock	conventional reservoir rock
3	Source and reservoir	Mainly self-generation and self-preservation	Diverse source-reservoir relationships
4	Trap features	Non-enclosed trap, nor obvious boundaries	Conventional enclosed trap with obvious boundaries
5	Migration	Primary migration or short-distance secondary migration	Long-distance secondary migration
6	Accumulation mechanism	Mainly depend on diffusion, with limited buoyancy in oil/gas accumulation	Depending on buoyancy in oil/gas accumulation
7	Seepage properties	Mainly non-Darcy flow	Darcy flow
8	Fluid properties	Bad fluid differentiation, no uniform oil/water or gas/water contacts and pressure system, oil & gas saturation varies greatly, usually forming the coexisting miscible oil-gas-water system	Top oil & gas, bottom water, with obvious oil/water or gas/water contacts
9	Resource properties	Low resource abundance, reserves assessed by well-control blocks	Reserves assessed by trap elements
10	Production techniques	Special production practice, need of pertinency techniques	Mainly conventional techniques, easy to exploit

Ⅱ. Geological Features of Continuous Oil and Gas Plays

~ **Extensive continuous distribution in basin center and slope area, forming giant oil/gas region.**

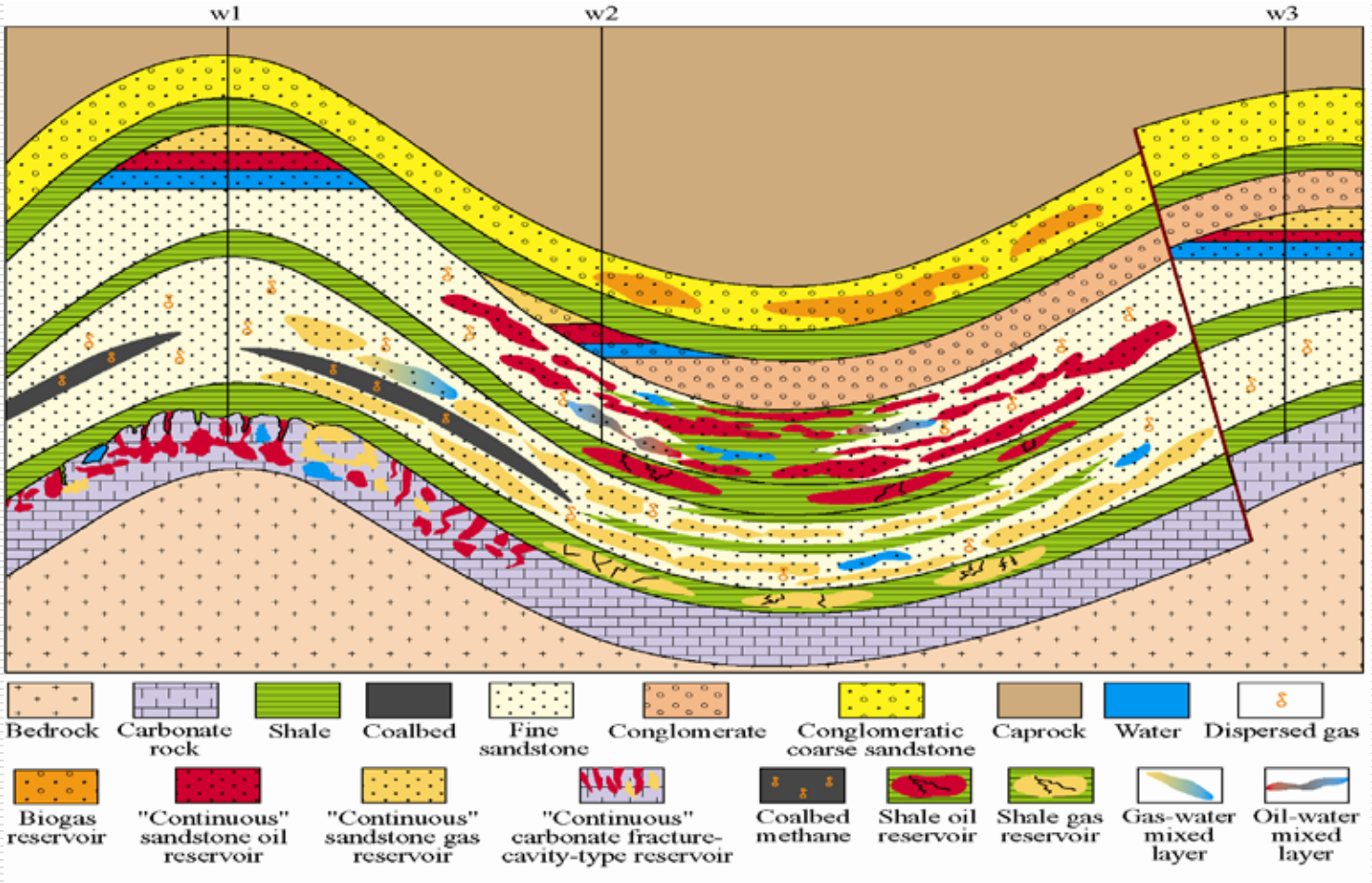
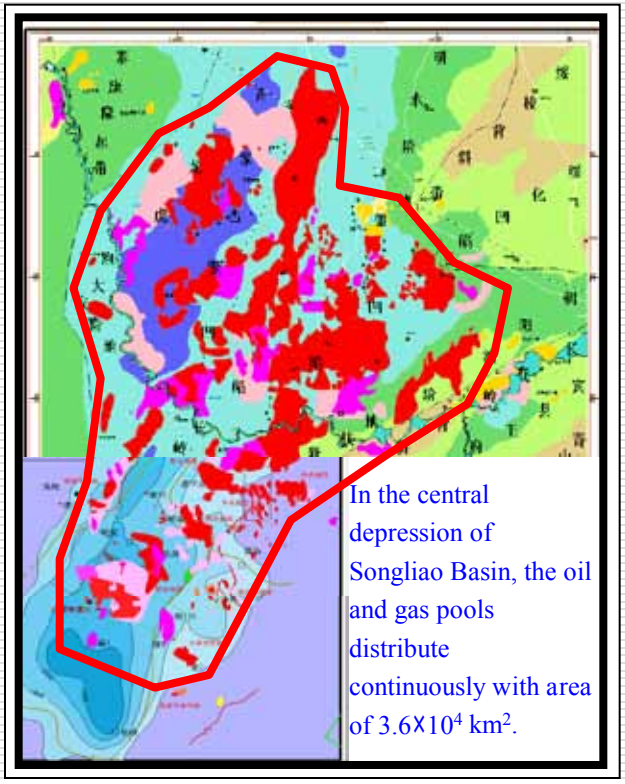
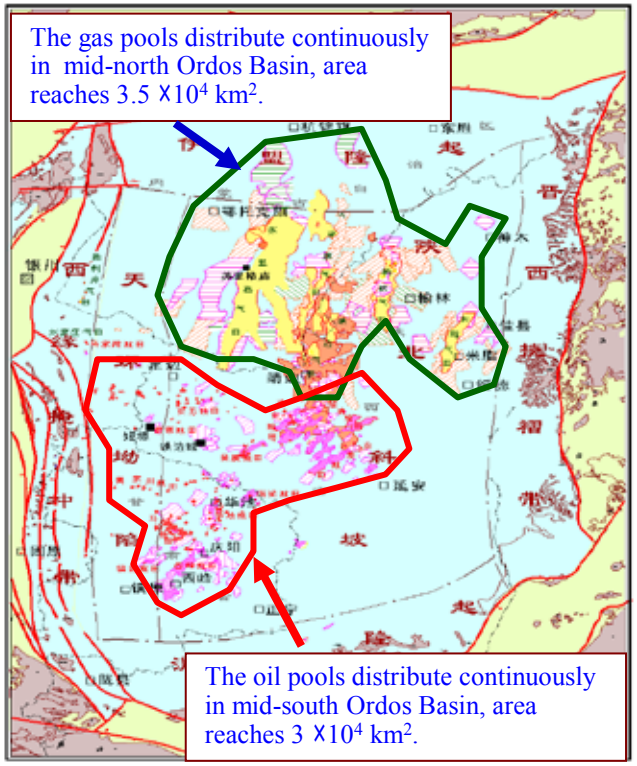


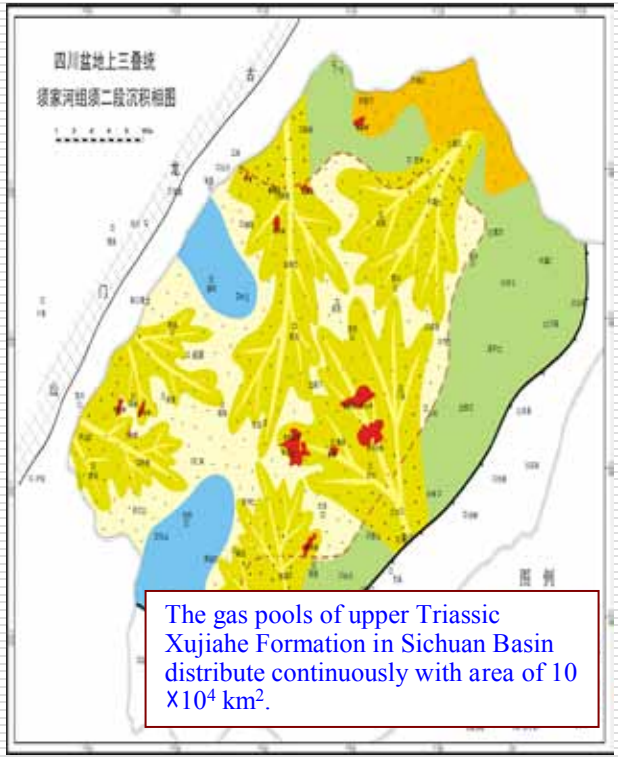
Diagram of distribution model of continuous oil/gas plays in China

Ⅱ. Geological Features of Continuous Oil and Gas Plays

~ **Extensive continuous distribution in basin center and slope area, forming giant oil/gas region.**





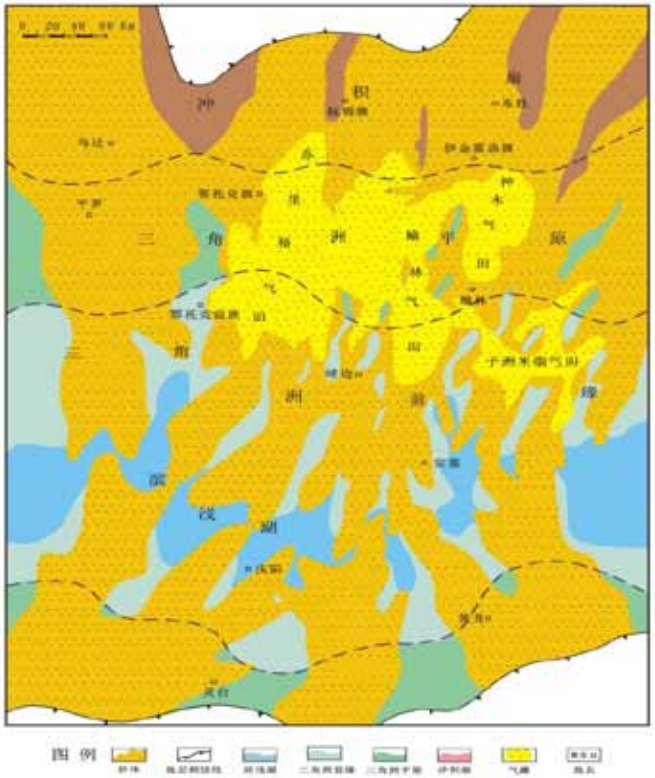


The distribution area of continuous oil/gas plays of depression basins has reached 3-10 X10^4 km^2.

Ⅱ. Geological Features of Continuous Oil and Gas Plays

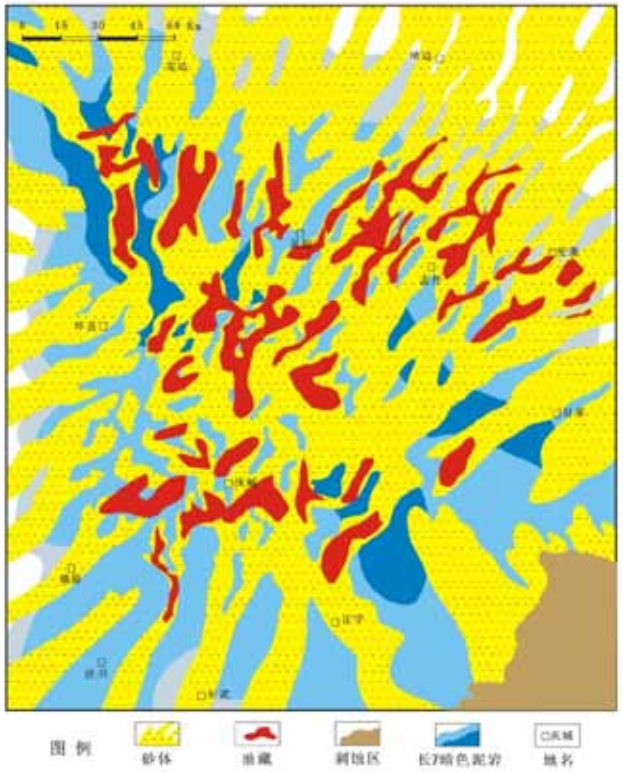
~ **Extensive continuous distribution in basin center and slope area, forming giant oil/gas region.**

Continuous tight sand gas in Ordos Basin:
Average single well production rate of 1,760 wells is 1.13 ×10⁴ m³ per day.



The depositional systems and gas pools distribution of He 8 Formation in Ordos Basin

Continuous tight sand oil in Ordos Basin:
Average single well production rate of 2,118 wells is 2.8 ton per day.



The depositional systems and oil pools distribution of Yanchang Formation in Ordos Basin

Ⅱ. Geological Features of Continuous Oil and Gas Plays

~ **Large-scale low and ultra-low porosity and permeability unconventional reservoir rock (Φ: <10%, K: < 1md)**

Reservoir physical property statistics of He 8 Formation of Sulige in Ordos Basin

Region	Pore type (%)				Physical properties	
	Debris dissolution pore	Intergranular dissolution pore	Intercrystal pore	Others	Even Porosity (%)	Even Permeability (mD)
East Sulige	44.7	13.1	24.8	17.4	8.8	0.83
Central Sulige	43.7	15.9	20.7	19.7	8.6	1.51
West Sulige	45.9	15.1	21.5	17.5	8.3	0.98
Gaoqiao	47.5	14.2	18.4	19.9	8.4	0.81

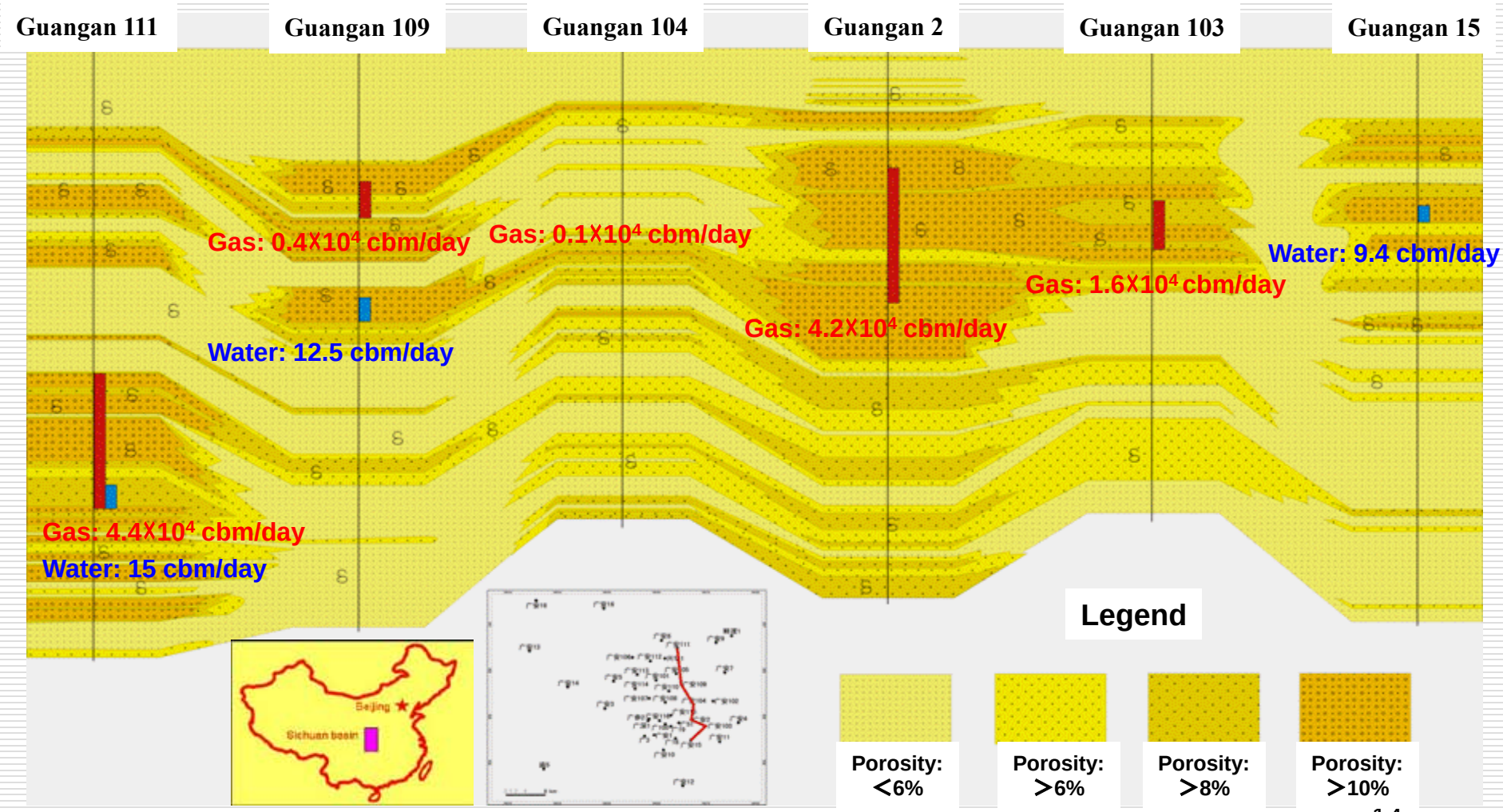
Reservoir physical property statistics of Chang 8 Formation in Ordos Basin

Region	Target Formation	Porosity (%)	Permeability (mD)
Jiyuan	Chang 8	8.7	0.72
Xifeng	Chang 8	11.0	1.50
Huaqing	Chang 8	8.9	0.86

Average porosity: 8.5 %, average permeability: 0.98 md

Ⅱ. Geological Features of Continuous Oil and Gas Plays

~ **No obvious trap boundaries and seals, depending on reservoir-fracture interconnection to form continuous oil/gas plays.**

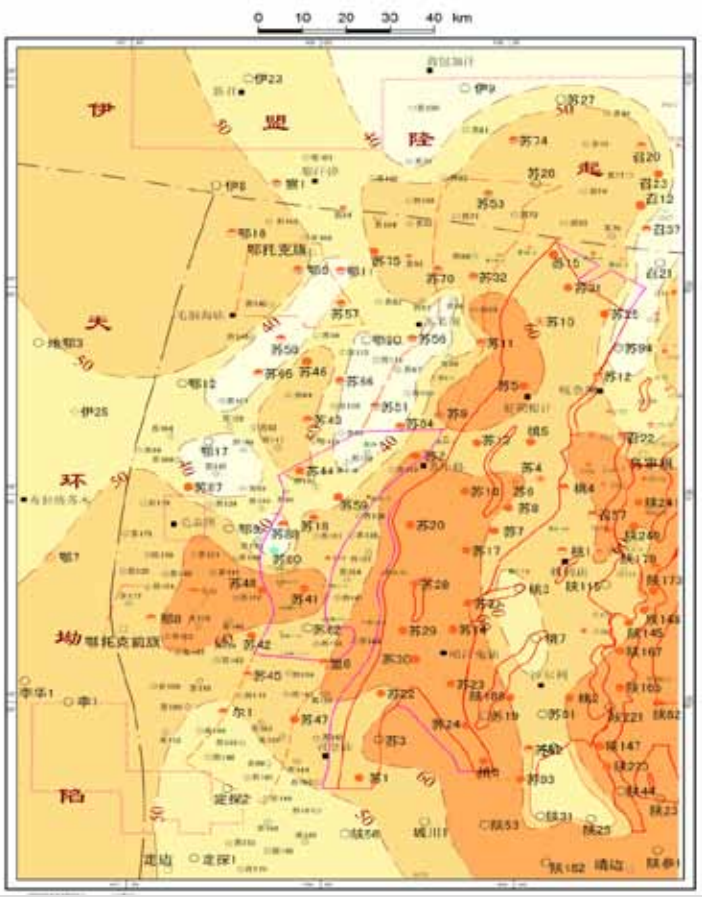


Profile of upper Triassic gas play, Xujiahe Formation, Sichuan Basin

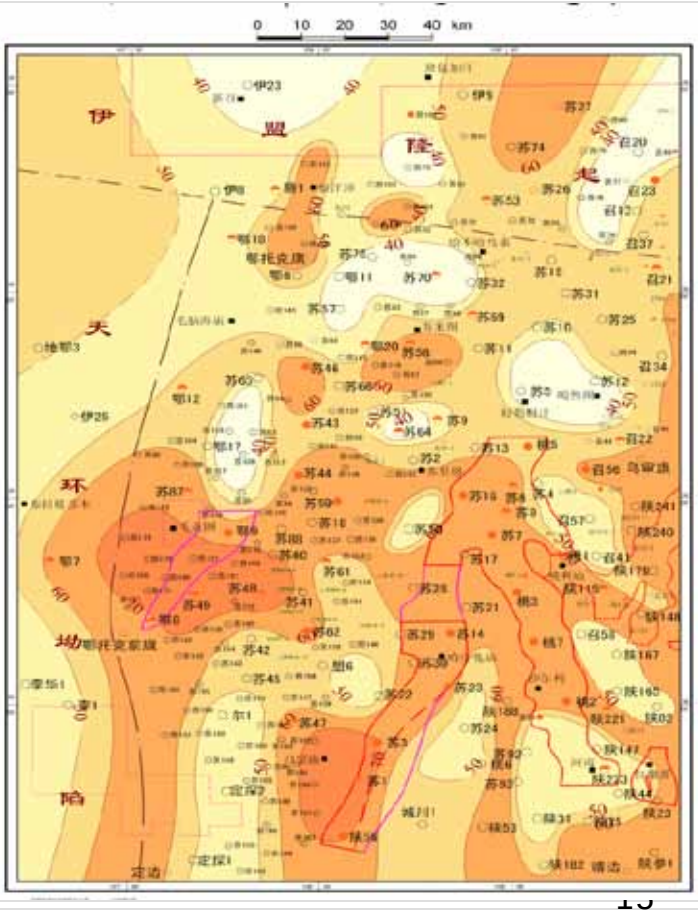
Ⅱ. Geological Features of Continuous Oil and Gas Plays

~ **Bad fluid differentiation, oil & gas saturation varies greatly, usually forming the coexisting miscible oil-gas-water system**

Gas saturation distribution of He 8 Formation in west Sulige area, Ordos Basin

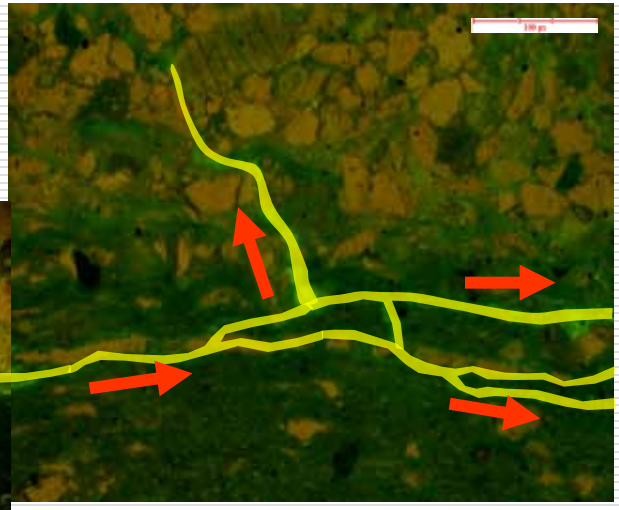


Gas saturation distribution of Shan 1 Formation in west Sulige area, Ordos Basin

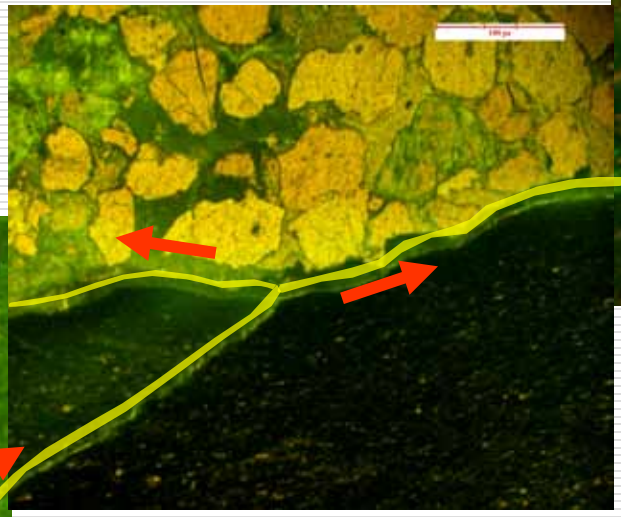


Ⅱ. Geological Features of Continuous Oil and Gas Plays

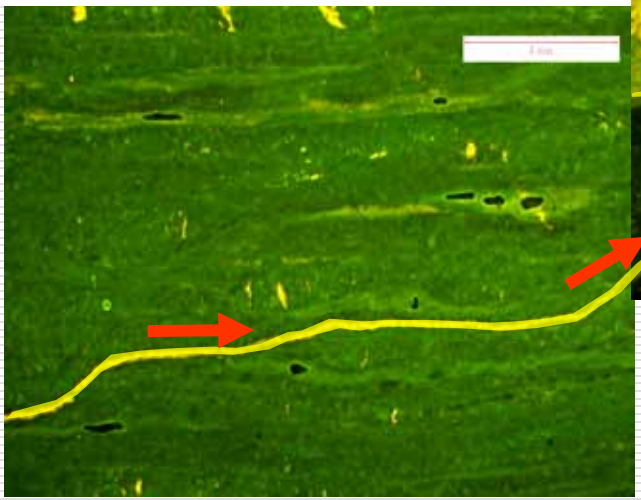
~ Mainly primary migration or short-distance secondary migration, characterized by non-Darcy flow



Su6-j1, 3328.38m, upper is single polar×50, lower is fluorescence×50



Su121, 3732.43m, fluorescence×50



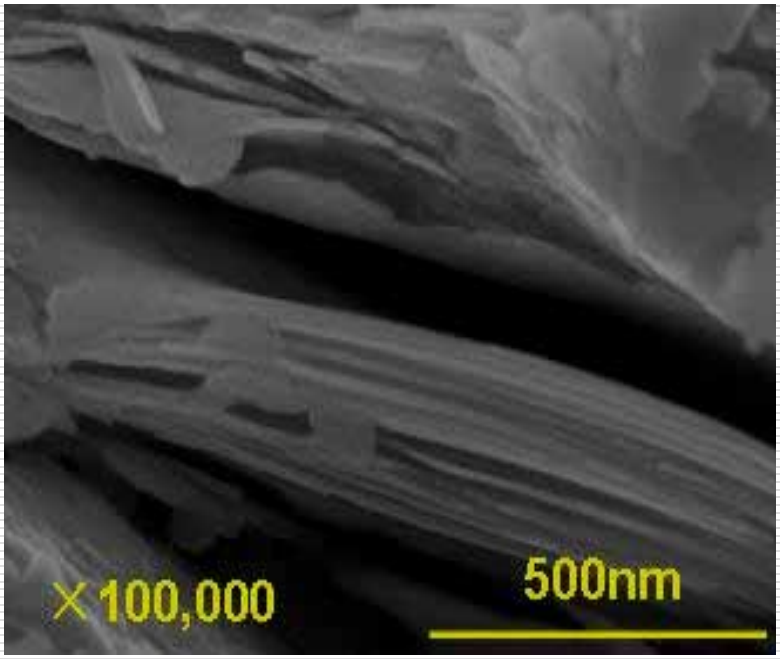
Su76, 3226.94m, fluorescence×25

Oil/gas in micro-fracture charging channels presents fluorescence color of yellow, yellow green and brown

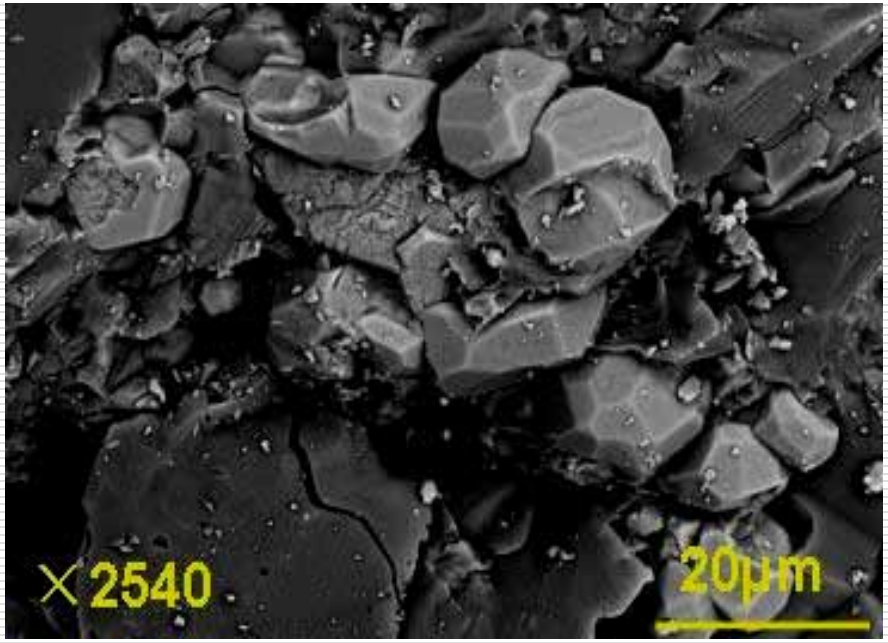
Source rock migration analysis of Ordos Basin

Ⅱ. Geological Features of Continuous Oil and Gas Plays

~ **Continuous shale gas reservoir rock develop pore space in Sichuan Basin**



illitic interlayer gap, 1534m, S_1l, Wei 201 well, Sichuan Basin



Quartz grows on the grain boundary of pyrite. Wei 201 well, P_1l, Sichuan Basin

Outline

Ⅰ. Basic Concept of Continuous Oil and Gas Plays

Ⅱ. Geological Features of Continuous Oil and Gas Plays

Ⅲ. Assessment Technology of Continuous Oil and Gas Plays

Ⅲ. Assessment Technology of Continuous Oil and Gas Plays

1.Unconventional resources dimensional prediction and assessment methods

2.High resolution large-area seismic data acquisition technique

3.Sequence stratigraphy industrial application technology

4.Gravitational-magnetic-electrical volcanic reservoir prediction technology

5.Pre-stack seismic reservoir fluid prediction technology

6.Fracture-cavity characterization technology of carbonate reservoir rock

7.Drilling technology such as horizontal drilling, multi-lateral drilling, etc.

8.Stimulation technology, such as coiled tubing fracturing, etc.

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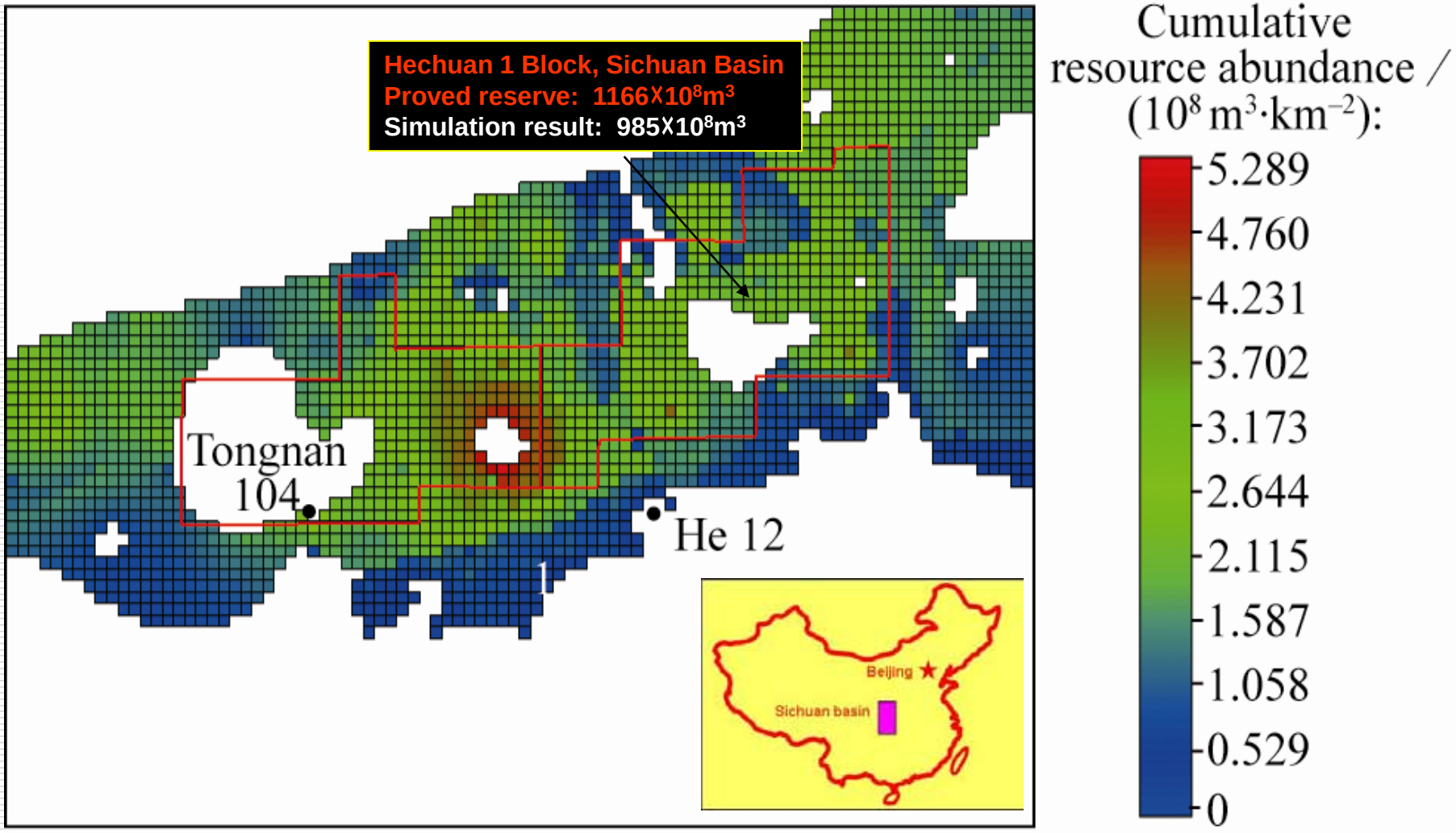
Ⅲ. Assessment Technology of Continuous Oil and Gas Plays

¢ **Matching rate reaches 90%:**

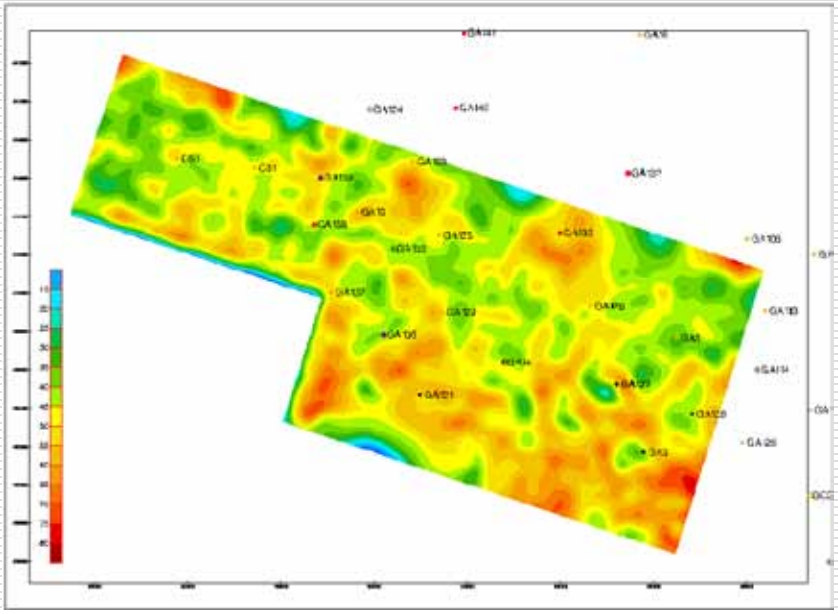
Continuous gas play dimensional distribution simulation technology applied in Sichuan Basin



Ⅲ. Assessment Technology of Continuous Oil and Gas Plays

¢ **Matching rate reaches 88%:**

Pre-stack seismic gas zone detection technology applied for upper Triassic tight gas of Xujiahe Formation in Sichuan Basin



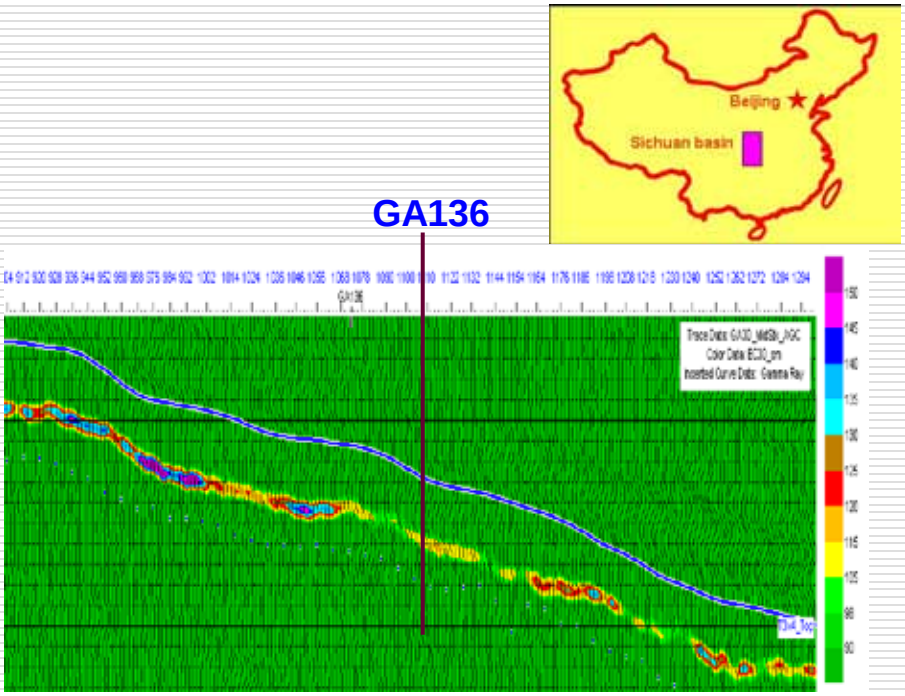


Figure of gas saturation of Xujiahe 4 Formation in Guang'an region, Sichuan Basin

Daily natural gas production rate: 2.02 ×10^4 m^3

Ⅲ. Assessment Technology of Continuous Oil and Gas Plays

After fracturing, the single well daily natural gas production rate of upper Triassic tight gas sands of Xujiahe formation in Sichuan Basin is more than 10-20 times of the natural gas production before fracturing.

Well No.	Target Formation	Testing production($10^4 m^3/d$)	
		Before fracturing	After fracturing
Guangan 002-35	Xu 6	2.19	18.76
Guangan 002-39	Xu 6	0.1	21.28
Guangan 002-29	Xu 6	0.1	11.25
Guangan 002-32	Xu 6	0.1	23.12
Guangan 002-33	Xu 6	0.47	14.8
Guangan 002-X45	Xu 6	0.1	13.29
Guangan 002-X22	Xu 6	0.1	8.78
Guangan 002-25	Xu 6	0.1	30.03
Guangan 002-X34	Xu 6	3.05	20.38
Guangan 002-X36	Xu 6	0.65	39.39
Guangan 002-27	Xu 6	0.1	18.04

Conclusions and Outlook

~ Continuous oil/gas play has no obvious trap boundaries and has large distribution area. Its huge reserve make it the future strategic alternative area worldwide.

~ The proved reserves of oil/gas in place of continuous plays account for 47% and 56% of the total reserves respectively in China.

~ The perspective resources of continuous natural gas in China is 10 times of conventional natural gas resource (of which coalbed methane is $40 \times 10^{12} m^3$, tight sand gas is $30 \times 10^{12} m^3$, shale gas is $100 \times 10^{12} m^3$, and gas hydrates is $500 \times 10^{12} m^3$).

Unconventional resources nothing is impossible

- Thank you for your attention
- Welcome you all to visit RIPED for technical exchanging and future cooperation

Zou Caineng

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