Formation Mechanisms of Stratigraphic Reservoirs Below Hydrocarbon Source Rock in Depression-type Lacustrine of Continental Rift Basins – Upper Cretaceous Stratigraphic Reservoirs in South Songliao Basin, China*

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Abstract

A typical case of unconventional continuous oil reservoirs in Upper-Cretaceous Quantou (tight sands) Formation in south Songliao Basin in NE China is cited in this article, and geologic characteristics and hydrocarbon accumulation mechanisms on such type of unconventional reservoirs are summarized.

1. Geological characteristics: In post-rift-depression phase of the Late-Cretaceous, large-scale fluvial-deltaic Quantou sands and lacustrine Qingshankou mudstones were deposited in Songliao Basin which covers an area of 260 thousand km^2 in NE China, and a close reservoir-source contact construction formed, with a 200 to 500 meters thick cap rock above. Quantou sands are 110-120 meters thick, with porosity 5-12% and permeability lower than 10 mD, even pore throat diameter 20-200 nm, and excess pressure 6-14 MPa; Qingshankou mudstones are 100-150 meters thick, with TOC 1.06-2.68%, Ro 0.8-1.3%. Quantou reservoirs feature continuous tight sands distribution, oil-water inversion, non-Darcy infiltration flow, weak fluid differentiation, diverse oil saturation, no uniform oil/water or gas/water contacts and pressure system, excess pressure mainly from hydrocarbon generation and limited role of buoyancy, commonly lower production, but local enrichment.

2. Hydrocarbon accumulation mechanisms: As located in the center or slope of the basin, oil generated from the Qingshankou mudstone was blocked by seals above and forced to migrate downward to Quantou sands. This hydrocarbon accumulation model in deep tight sands in Songliao Basin can be called “Overpressure Hydrocarbon Reversed Accumulation Model”.

In the burial history, when the pressure generated by source rock maturation exceeded buoyancy and capillary pressure, oil was displaced downward to Quantou sands by the overpressure. In this process, overpressure from source rock, faults, and favorable sands are the factors which control the formation and distribution of large-scale continuous oil reservoirs.

3. Application: Oil pool with low or ultra-low permeability in the center or slope of Songliao Basin falls into typical unconventional continuous oil reservoir. Ordos Basin and many other similar basins in China have such hydrocarbon accumulation conditions. Using the theory of unconventional continuous oil reservoirs, more and more continuous tight oil reservoirs will be found in depression syncline areas.

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Formation Mechanisms of Stratigraphic Reservoirs Below Hydrocarbon Source Rock in Depression-type Lacustrine of Continental Rift Basins

———*An example of Upper Cretaceous stratigraphic reservoirs in south Songliao Basin*

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Gao Xiaohui, Song Li-zhong, et al.

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Sept., 2010 Calgary

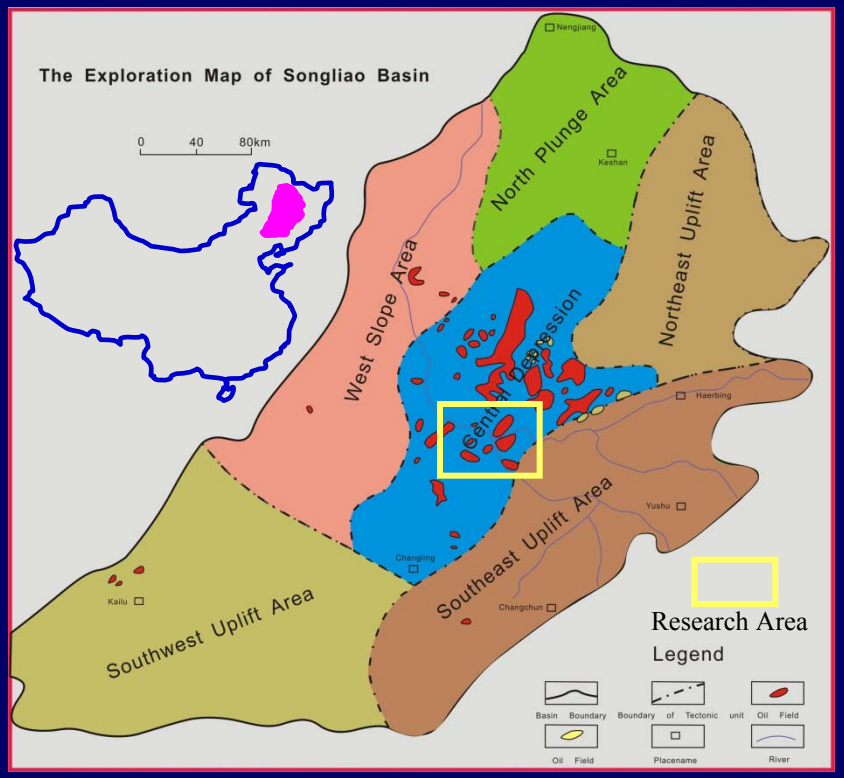
Outline

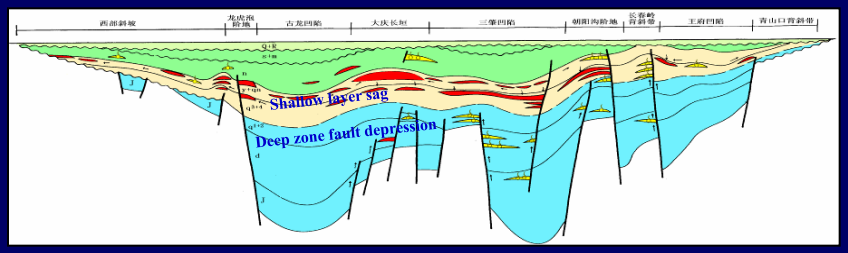
1. Geological Settings and Research Background

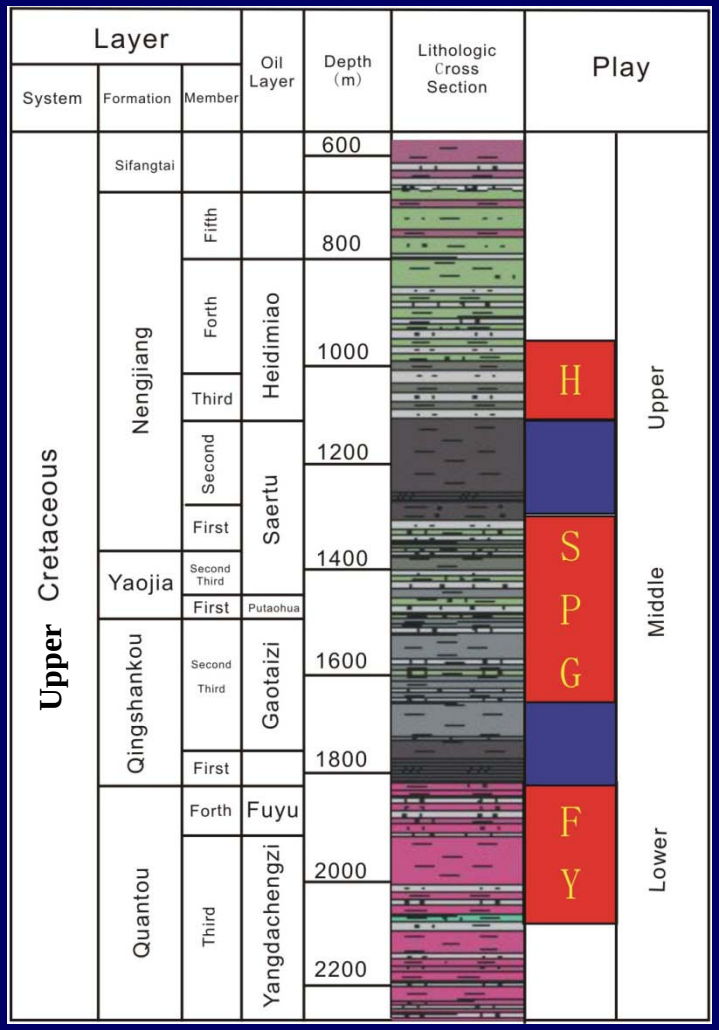
2. Hydrocarbon Accumulation Mechanism of stratigraphic Reservoirs below Hydrocarbon Source Rock

3. Conclusions

1. Geological Settings and Research Background



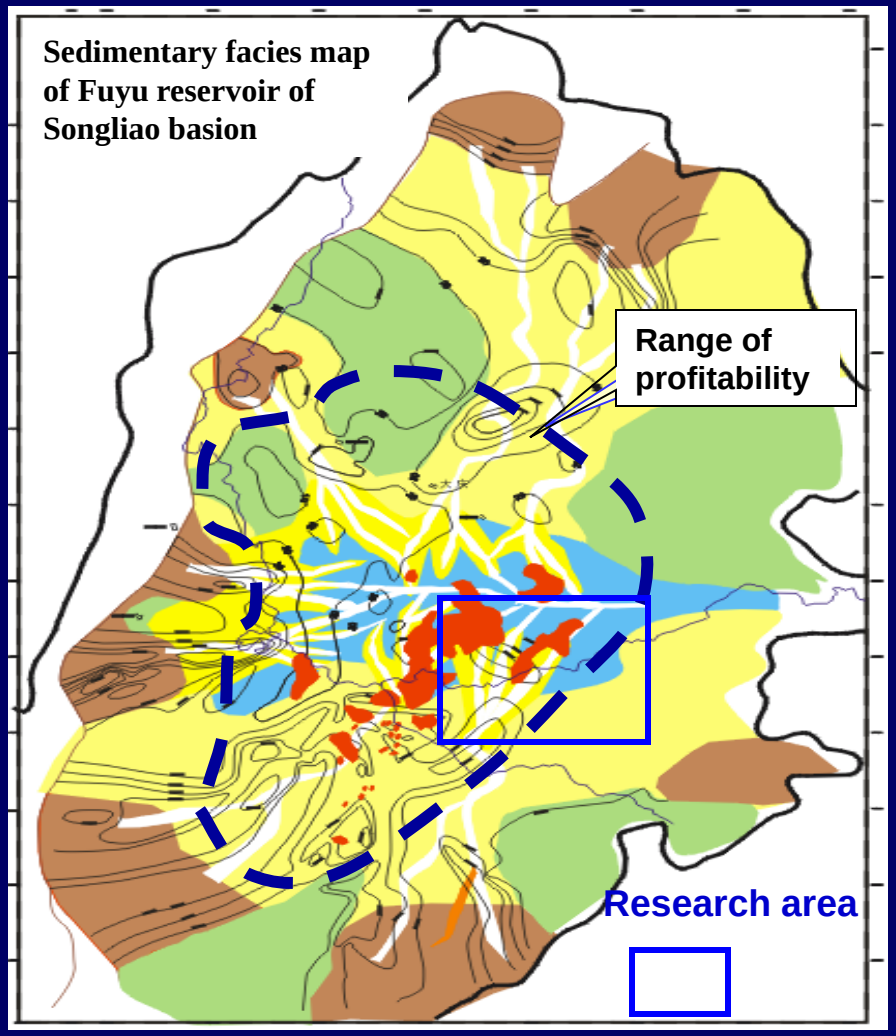




- Daqing placanticline: mainly SPG, proved reserves is 4.44 billion ton, 66% of the total. Proved reserves of peripheral zones is 2.31 billion ton, 34% of the total
- Peripheral zones of Daqing placanticline: mainly FY oil layer, 18% of the basin and more than 50% in south Songliao Basin

1. Geological Settings and Research Background

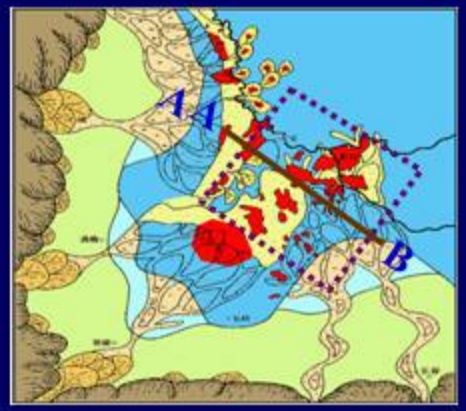
Exploration Survey of FY Oil Layer below Hydrocarbon source in Songliao Basin



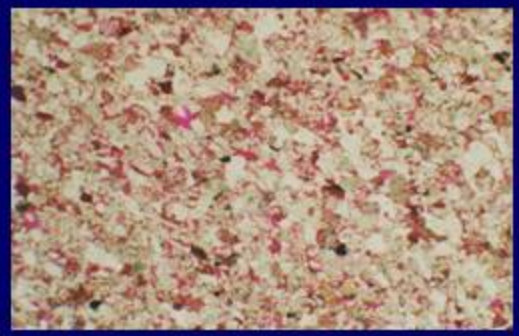
Resource of Favored Area of FY Oil Layer: 1.2—1.4 billion ton

- **Favored exploration area: 23,500 km^2**
- **Remain favored area: 13,500 km^2**
- **Reserves abundance: 0.3—0.4 million ton/km^2**

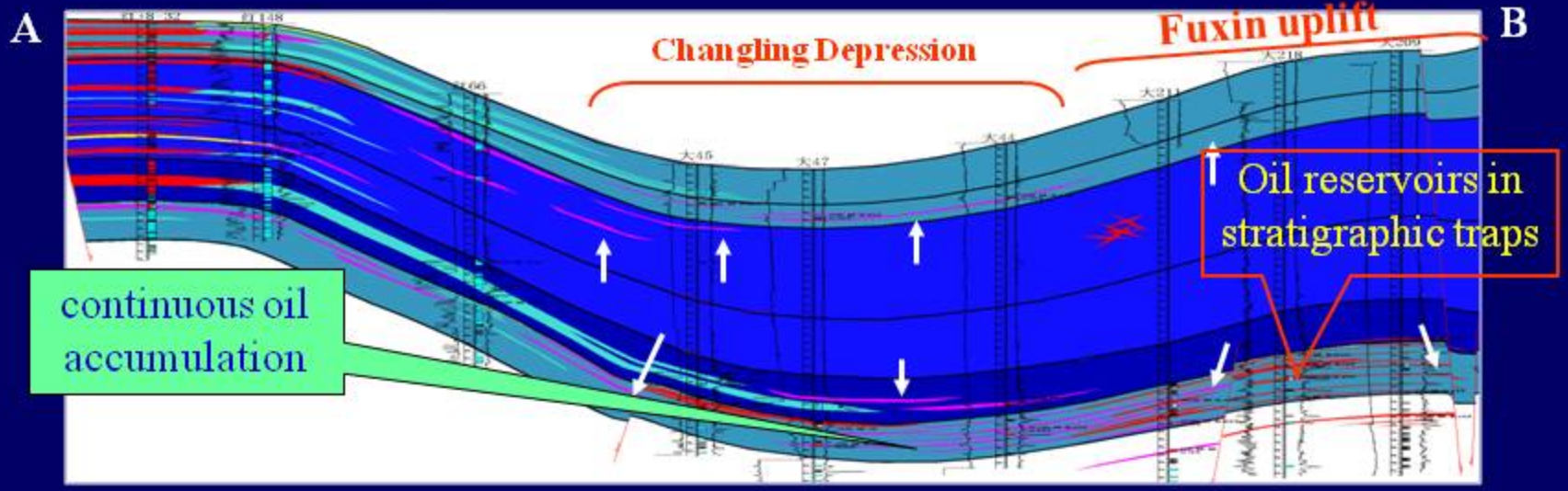
1. Geological Settings and Research Background



Well Rang 24，1847m，20×10



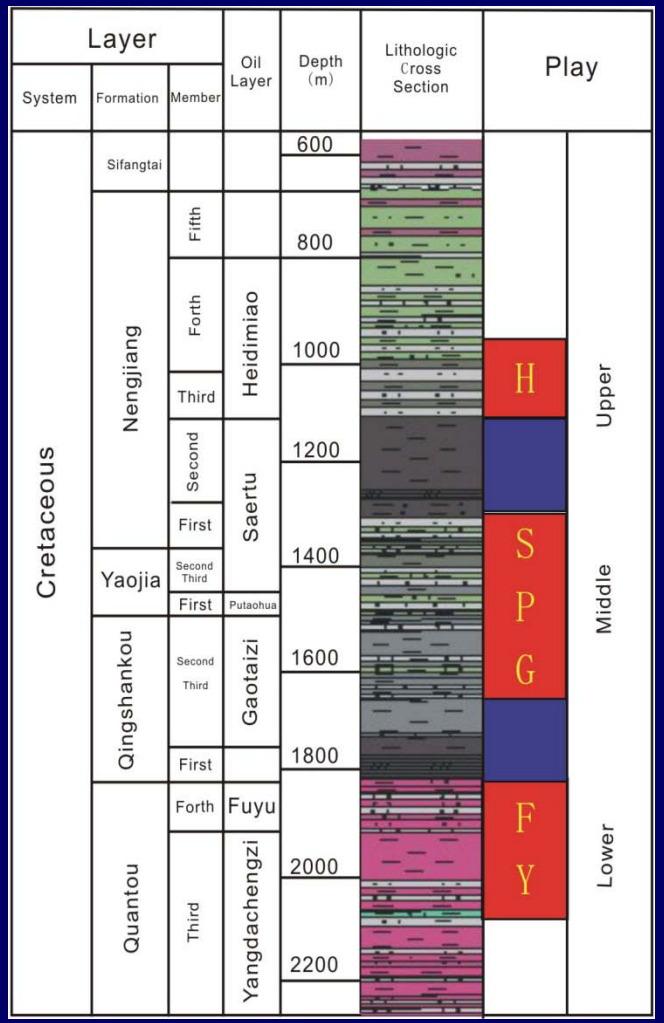
Well Xin 320，1760m，20×10



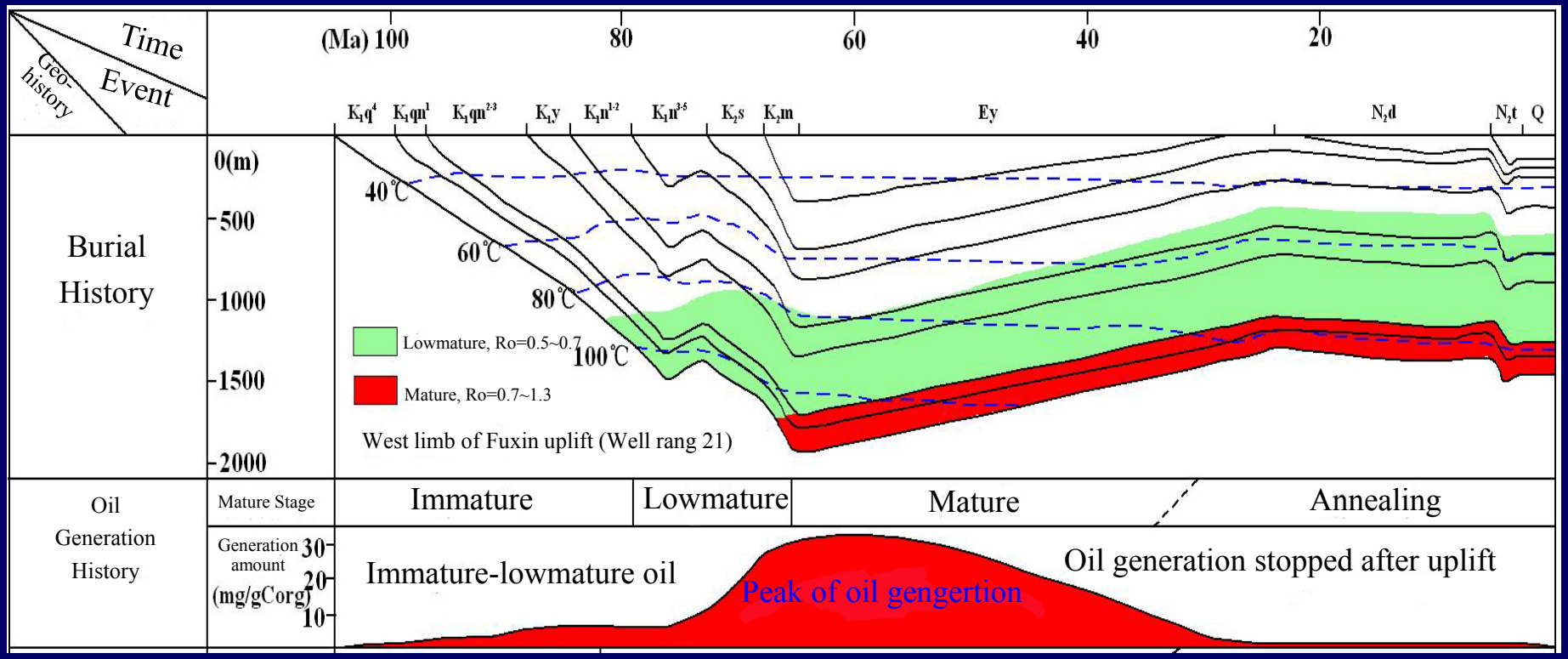
Thickness of Hydrocarbon Source Rock: 100～150 m，TOC: 1.06～2.68%，Ro=0.8～1.3%, Reservoir bed thickness of K_2q^4: 110～120 m，Φ=5～12%，K<10 mD，mean diameter of pore throat: n×10～n×100 nm，Pressure difference between source and reservoir: 6－14MPa。

Research Background

- Hydrocarbon accumulation mechanism of oil reservoirs inner (Saertu, Putaohua and Gaotaizi Oil Layer) and above (Heidimiao) hydrocarbon source is relatively cognitive
- Hydrocarbon accumulation mechanism of oil reservoirs below hydrocarbon source (Fuyu, Yangdachengzi Oil Layer) is impercipient
- It was suggested that oil came from lateral Changling depression（Miao Hongbo et al.，2005）
- In this paper, it is considered that the source of Fuyang oil layer in Fuxin Uplift comes from in-situ superjacent hydrocarbon source rock from which oil moved vertically downwards to form the oil layer

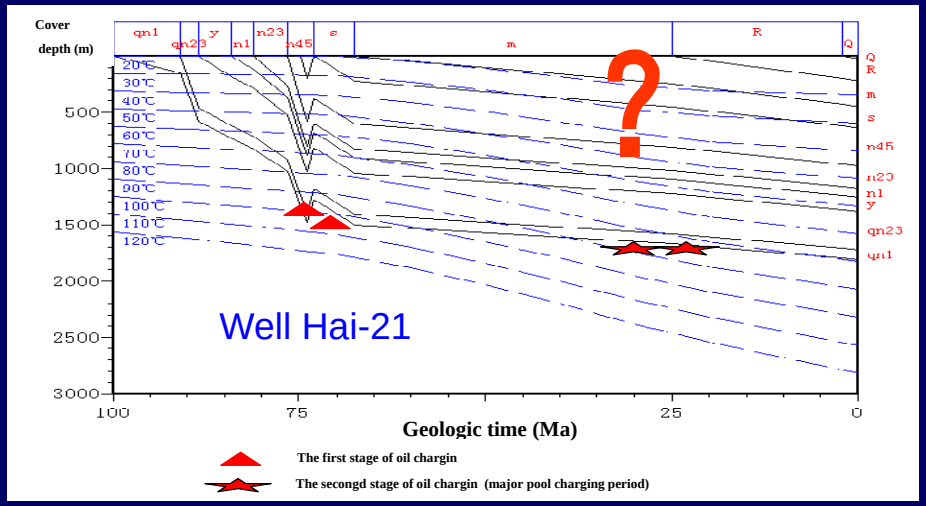


Hydrocarbon source rock of Upper Cretaceous generated oil abundantly in late Nengjiang formation stage (65Ma)



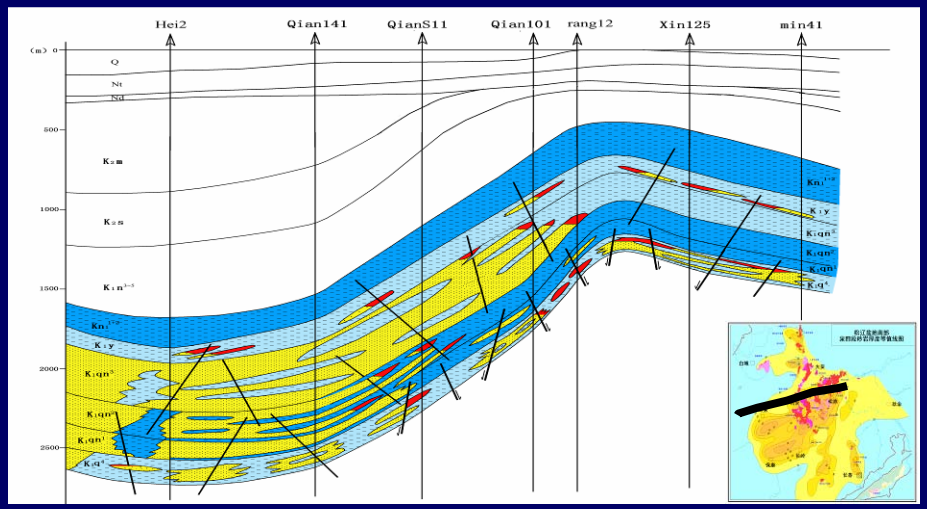
Integrated map of geological evolutional history of Fuxin Uplift in south Songliao Basin

Evolutional history of Fuxin Uplift



Questions existing in previous studies

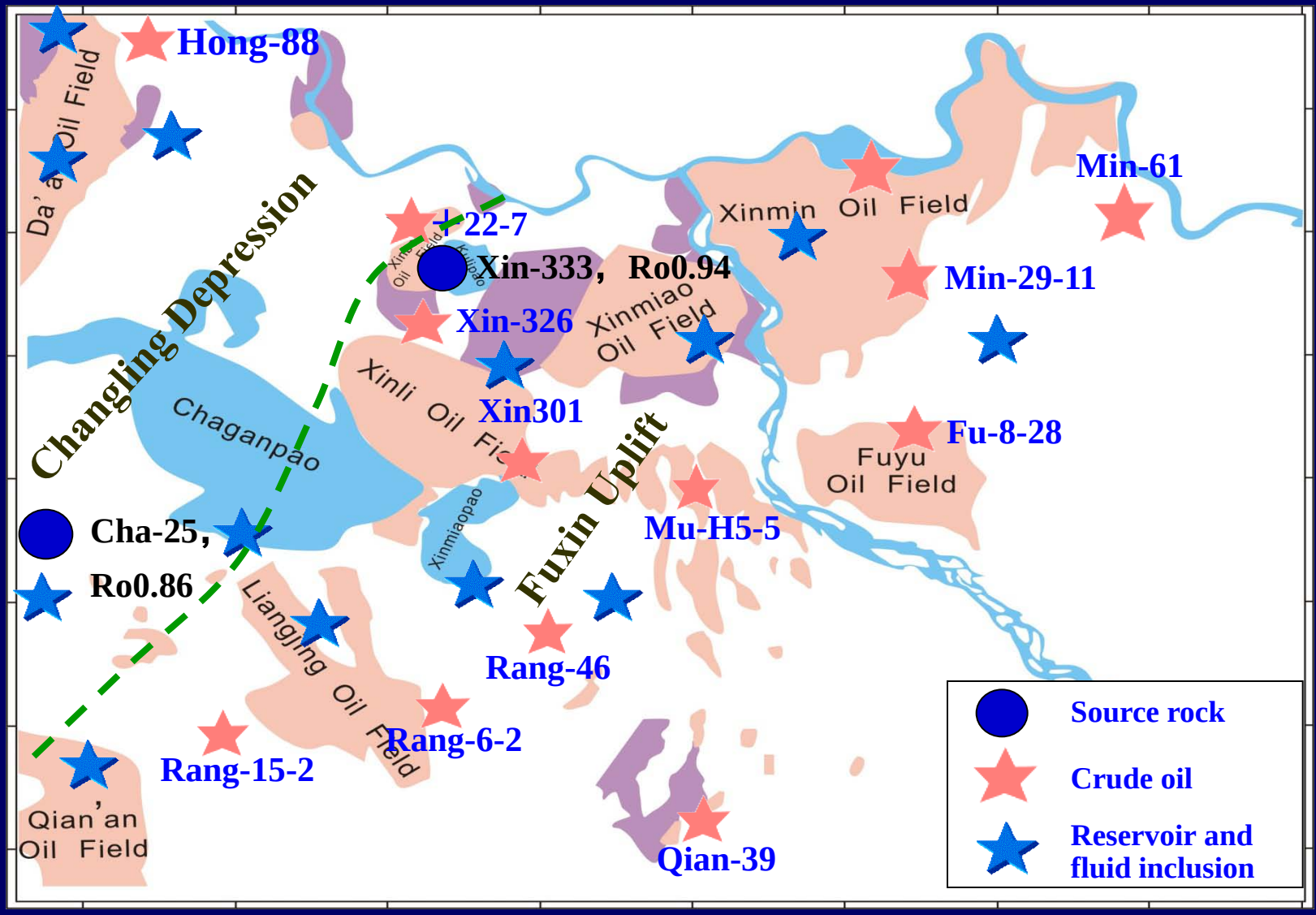
- Evolutional history of Yian member （Ey） has not been considered.
- Sedimentation after Nengjiang formation is consistent, but it is not true.
- The palaeogeothermal gradient is 7－8℃/100m, but it’s doubtful.



Points of the paper

- Fuxin Uplift began to bulge greatly in late Cretaceous.
- Fuxin Uplift formed after hydrocarbon was generated abundantly.

2.Hydrocarbon Accumulation Mechanism of Stratigraphic Reservoirs below Source rock



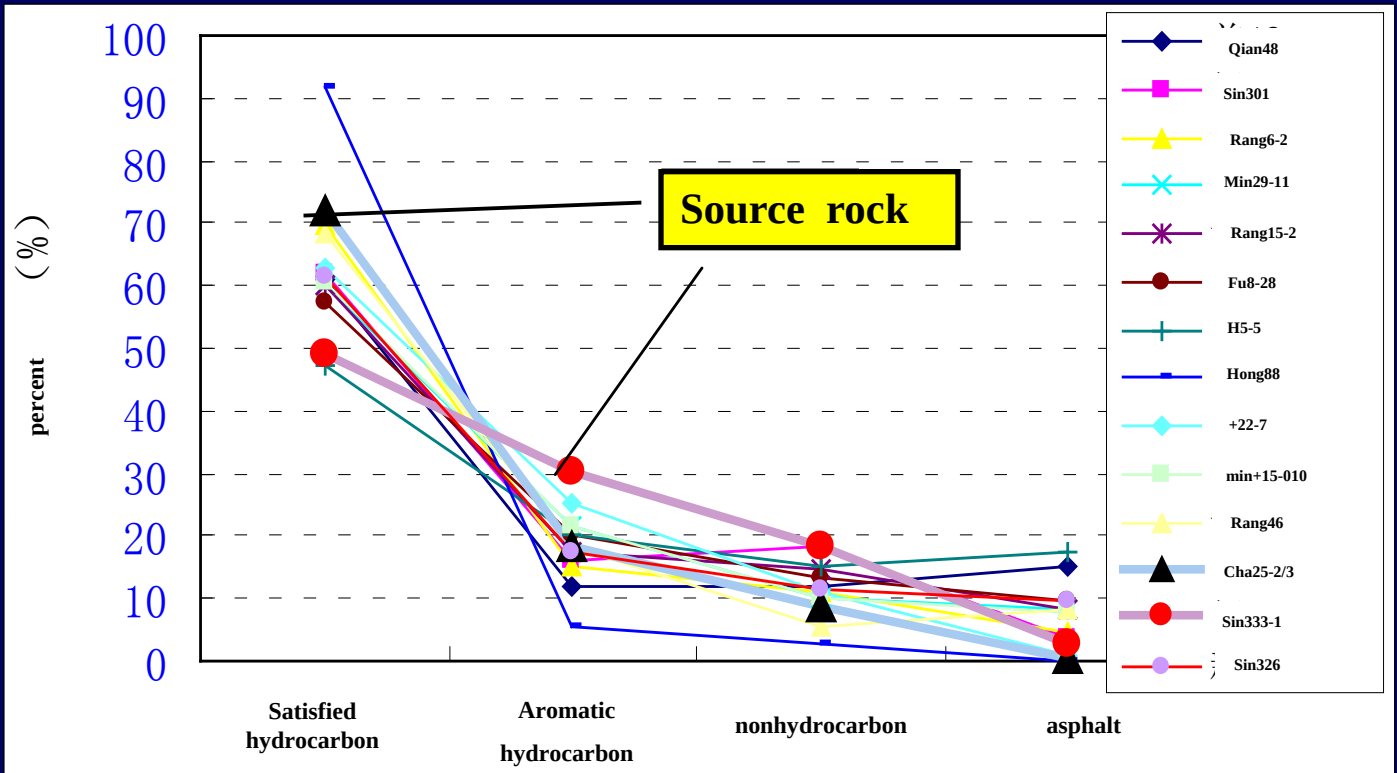
Distribution map of samples collected in Fuxin Uplift and periphery zones.

Carbon isotopes between oil of Fuxin uplift and source of Changling depression

sample	well name	Crude oil	Satisfied hydrocarbon	Aromatic hydrocarbon	nonhydrocarbon	Asphalt
crude oil	Qian48	-31.3	-32.1	-31.0	-30.4	-30.4
	Sin301	-31.0	-31.3	-30.0	-30.1	Not detected
	Rang6-2	-31.3	-31.5	-30.7	-29.6	-29.3
	Min29-11	-31.5	-31.6	-30.7	-29.6	-29.7
	Rang15-2	-31.0	-31.2	-30.4	-30.0	-29.7
	Fu8-28	-31.3	-31.7	-30.6	-30.1	-30.0
	H5-5	-31.2	-31.5	-30.7	-30.0	-30.2
	Hong88	-30.7	-30.7	-30.2	-29.3	Not detected
	Sin326	-31.1	-31.8	-30.5	-29.9	-30.2
	15	-30.3	-30.7	-29.4	-29.0	Not detected
	min+15-010	-31.3	-32.1	-30.5	-30.1	-29.8
	Rang46	-31.6	-32.2	-31.0	-30.3	-30.2
Source rock	Cha25-2/3	-30.3	-28.4	-29.1	-29.0	-27.5
	Xin333-1	-30.9	-28.8	-29.2	-28.5	-28.8

Carbon isotope of oil between depression and uplift is very close, suggesting there was no isotopic fractionation due to hydrocarbon migration and oil was from in-situ source.

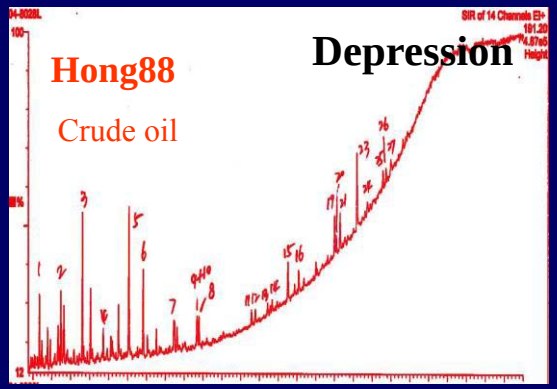
Chloroform bitumen “A” and cluster composition between depression and uplift are very close, suggesting there was no fractionation due to laterel hydrocarbon migration and oil came from in-situ source rock

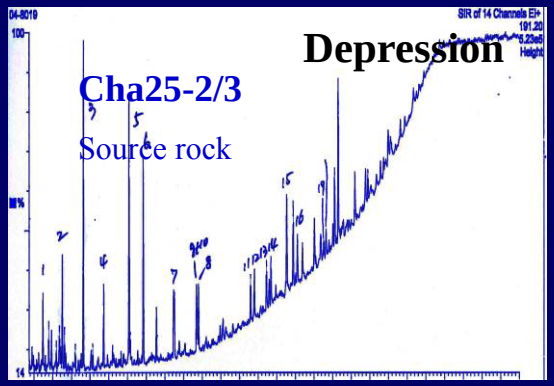


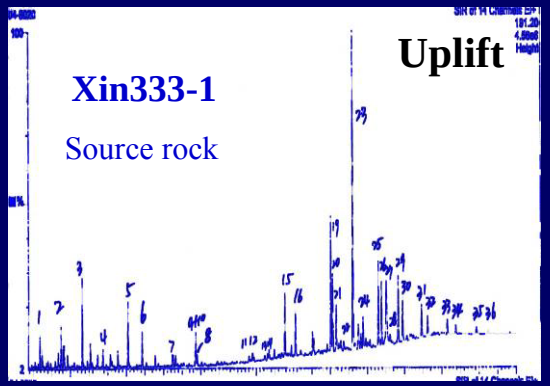
Chloroform bitumen “A” and cluster composition

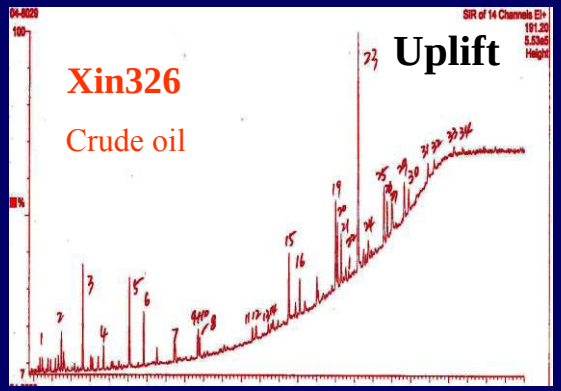
Chloroform bitumen “A” and cluster composition in Fuyu oil layer of Fuxin Uplift.

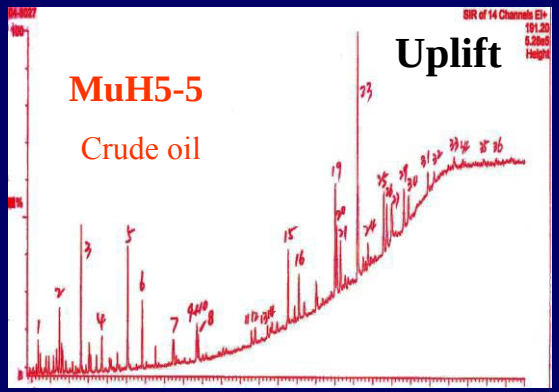
Terpane from crude oil and source rock

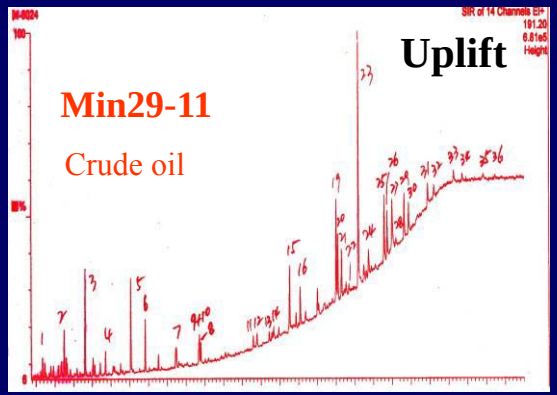






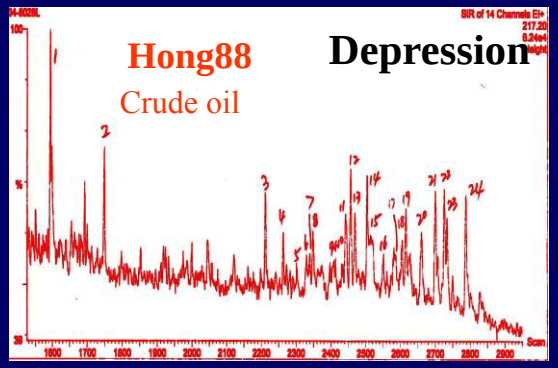


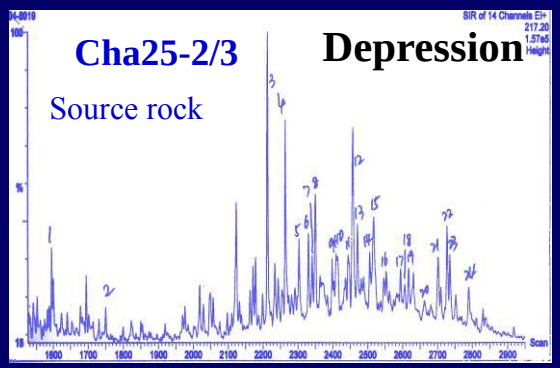


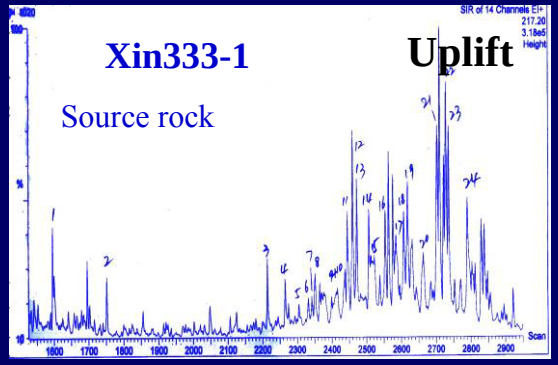


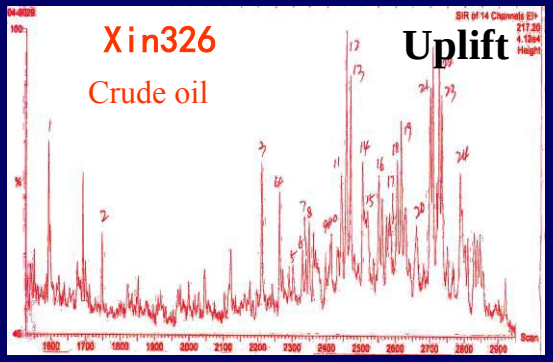
Oil of Fuyu oil layer of Fuxin Uplift has good comparability with in-situ source rock, and has a bad comparability with source rock from Changling depression. Oil mainly came from in-situ source rock rather than that of Changling depression.

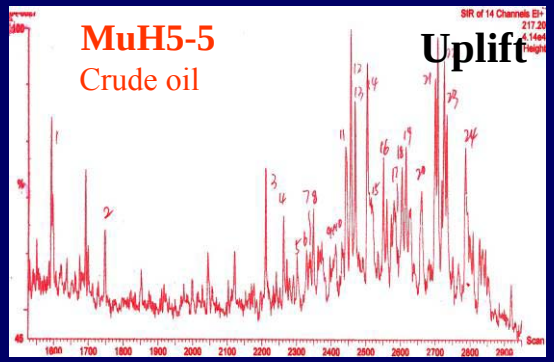
Sterane from crude oil and source rock

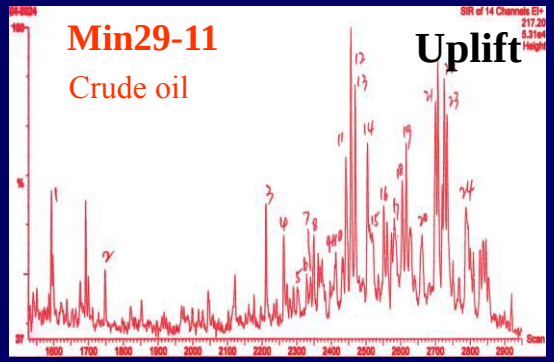








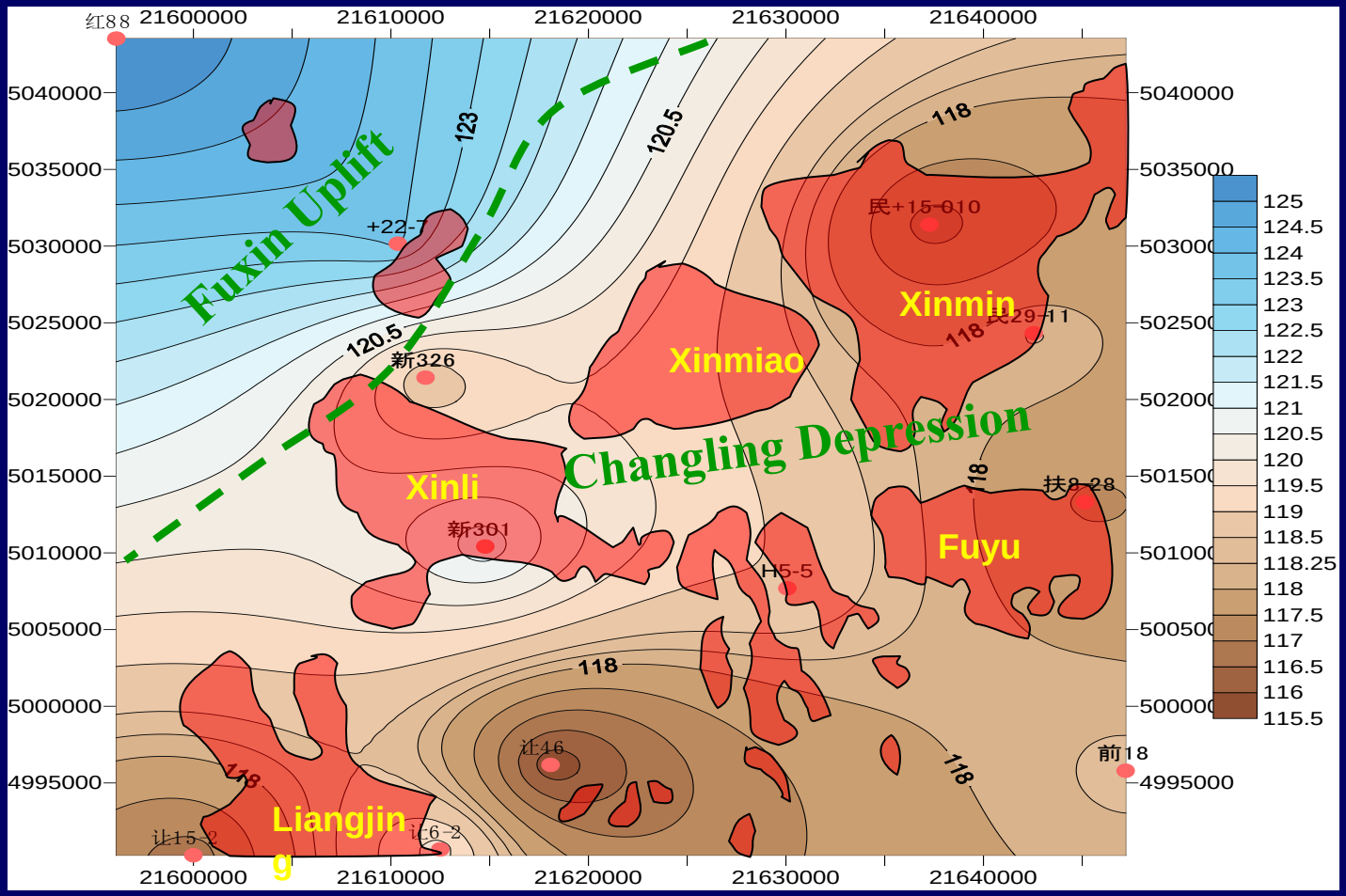




Crude oil from Fuxin Uplift has a bad comparability with source rock from Changling depression, but has a good comparability with in-situ source rock. Fuyu oil layer of Fuxin Uplift originates from in-situ source rock.

Formation temperature of crude oil converted by gas chromatogram of light hydrocarbon

$T = 140 + 15[\ln(2,4\text{-DMP}/2,3\text{-DMP})]$

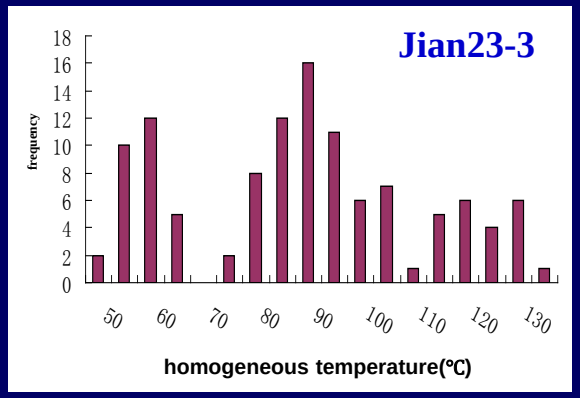


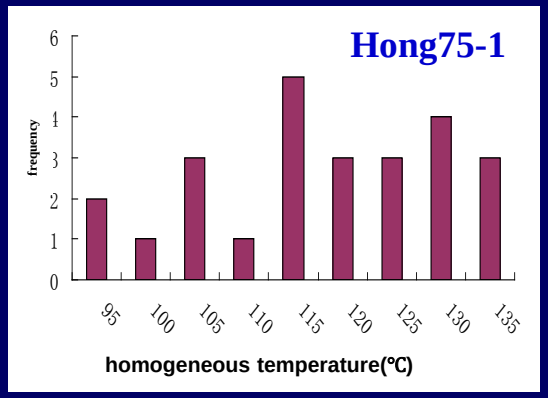
Temperature Distribution of crude oil from Fuyu oil layer of Fuxin Uplift and Changling Dpression

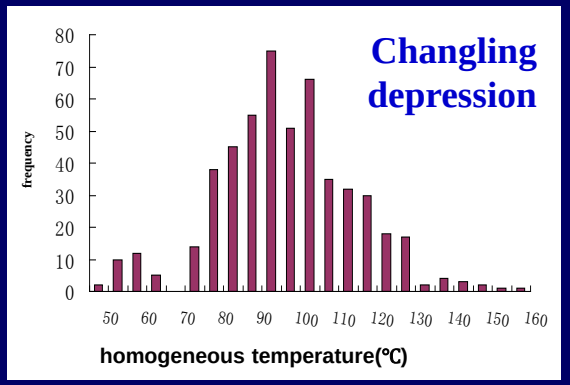
viewpoint

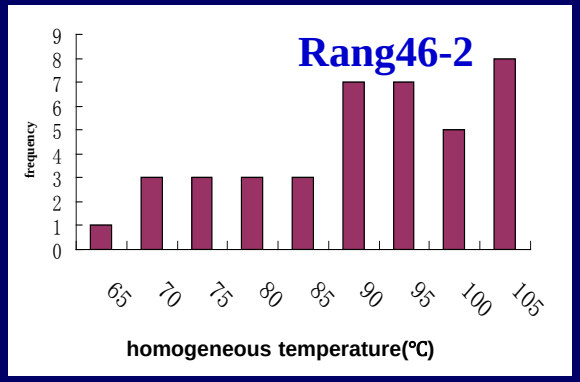
- No large difference among temperatures of crude oil indicates they have a similar maturity
- Oil comes from in-situ source rock and began to charge before bulging of Fuxin Uplift

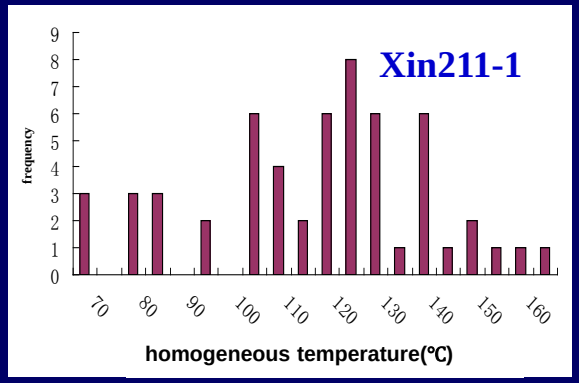
homogeneous temperature between Fuxin Uplift and Changling depression

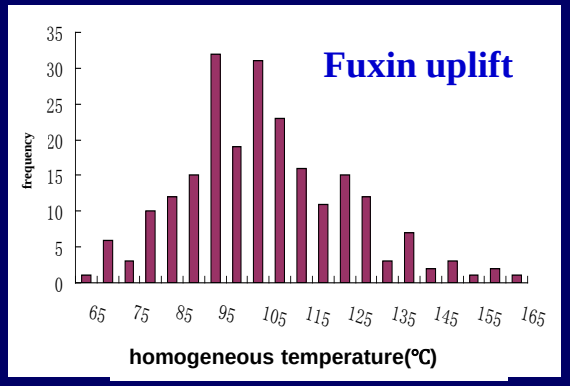






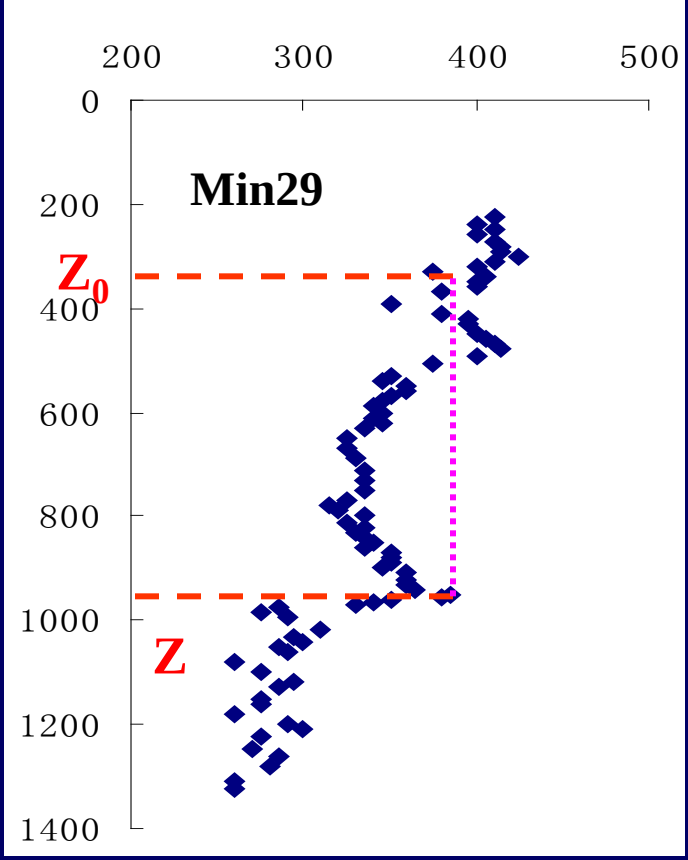






The bulk temperature of inclusions between the Fuxin Uplift and Changling depression is close, reflecting oil charge happened before uplifting and had a close strata temperature in the process of oil charge.

Evaluation of pressure difference between source and reservoir in Fuxin Uplift and its peripheral zones



Acoustic time in Well Min-29 of Fuxin Uplift

$$\Delta P = \rho_w \frac{Z_0}{Z} + (\rho_{bw} - \rho_w)\frac{Z - Z_0}{10}$$

△P—pressure difference between source and reservoir, MPa;

ρ_w—water density, g/cm^3;

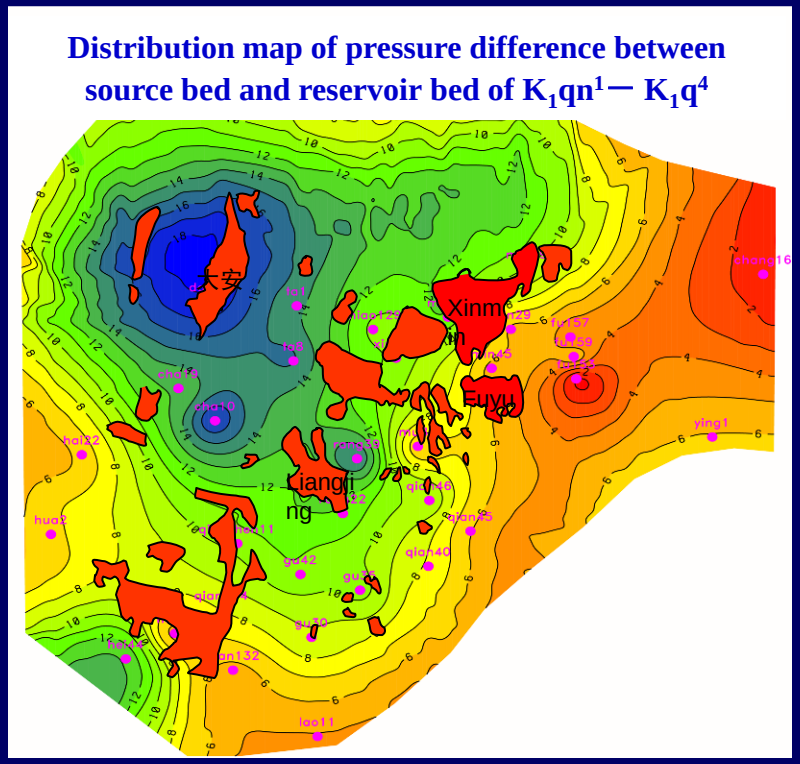
ρ_{bw}—average density of strata framework, g/cm^3 ;

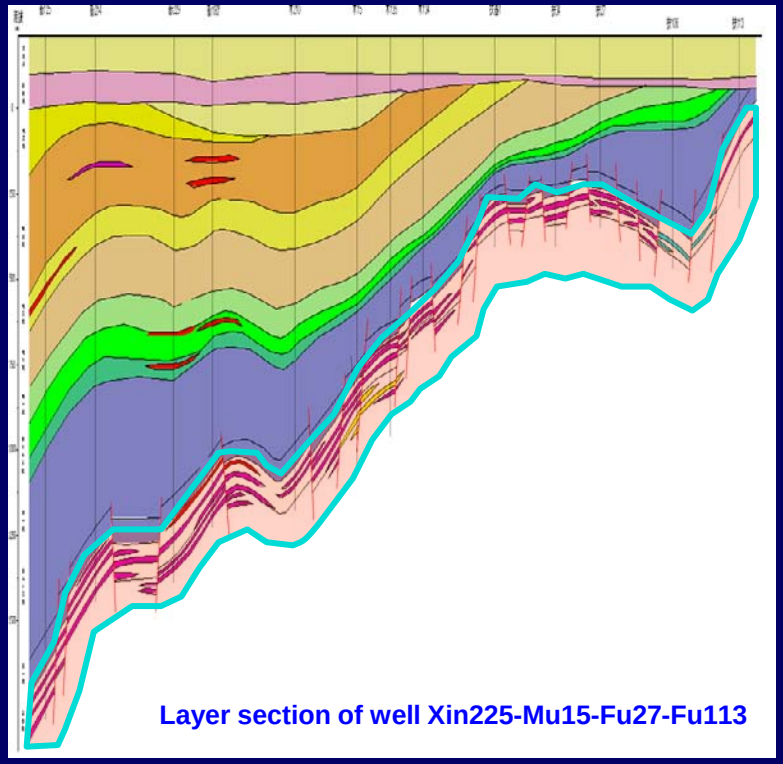
Z—point depth of residual pressure, m;

Z_0—equivalent point depth, m;

3. Distribution of stratigraphic Reservoirs below Source rock

Distribution of stratigraphic reservoir in layers of Fuyu and Yangdachengzi





- horizontally：stratigraphic and structural-stratigraphic composite trap reservoir are mainly distributed in the region with a range of △P value of 8—12MPa
- vertically：favorable exploration region with maximum effective depth between 270 and 340 meters below Member One of Qingshankou Formation.

3. Conclusions

Conclusions on oil accumulation in Fuxin Uplift

- Fuxin Uplift began to bulge greatly until in Early Paleogene.
- Source rock has become mature in the uplifting and can supply hydrocarbon downwards effectively.
- Hydrocarbon in Fuxin uplift is mainly from overlying in-situ source rock.
- Reservoirs are mainly distributed in the region with a range of △P value of 8-12MPa and maximum depth range of 270-340 m below source rock.

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