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*

Shi-zhen Tao¹, Cai-neng Zou¹, Zhi Yang¹, Xiao-hui Gao¹, Xuan-jun Yuan¹, and Li-zhong Song¹

Search and Discovery Article #10302 (2011)  
Posted February 21, 2011

*Adapted from oral presentation at AAPG International Conference and Exhibition, Calgary, Alberta, Canada, September 12-15, 2010

¹Department of Petroleum Geology, PetroChina Research Institute of Petroleum Exploration and Development, Beijing, China (tsz@petrochina.com.cn)

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 km² 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.
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

Tao Shi-zhen, Zou Cai-neng, Hu Suyun,
Gao Xiaohui, Song Li-zhong, et al.

Petroleum Geology Department, Research Institute of Petroleum Exploration & Development of Petrochina

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 km²
- Remain favored area: 13,500 km²
- Reserves abundance: 0.3—0.4 million ton/km²
1. Geological Settings and Research Background

Thickness of Hydrocarbon Source Rock: 100～150 m, TOC: 1.06～2.68%, Ro=0.8～1.3%, Reservoir bed thickness of K2q4: 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.
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.
2. Hydrocarbon Accumulation Mechanism of Stratigraphic Reservoirs below Source rock

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

Integrated map of geological evolulutional history of Fuxin Uplift in south Songliao Basin
2. Hydrocarbon Accumulation Mechanism of Stratigraphic Reservoirs below Source rock

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°C/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
2. Hydrocarbon Accumulation Mechanism of Stratigraphic Reservoirs below Source rock

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

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

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.
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.
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 

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

- 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.

Temperature Distribution of crude oil from Fuyu oil layer of 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

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

\( \Delta P \) — pressure difference between source and reservoir, MPa;

\( \rho_w \) — water density, g/cm\(^3\);

\( \rho_{bw} \) — 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
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 $\Delta P$ 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 $\Delta P$ value of 8-12MPa and maximum depth range of 270-340 m below source rock.
Tao Shizhen

**Organization:** Research Institute of Petroleum Exploration & Development, CNPC

**Position:** deputy chief of research office

**Professional Title:** senior geologist

**Speciality:**

- Fluid Inclusion and its application in petroleum geology,
- Formation Mechanisms and distribution regulation of oil/gas Reservoir

**Program:** deputy subject Chief of “Lithologic-stratigraphic oil/gas accumulation regulation, key technology and target evaluation” in China

**Publications:** Published more than 70 papers and 4 monographs

**Address:** No.20 Xueyuan Road, Beijing, P. R. China

**E-mail:** tsz@petrochina.com.cn