The Characteristics and Prospect of Giant Oil and Gas Fields in Marine Carbonate Sequence in China*

Jin Zhijun¹

Search and Discovery Article #20068 (2009)
Posted May 1, 2009

*Adapted from oral presentation at AAPG International Conference and Exhibition, Cape Town, South Africa, October 26-29, 2008.

¹Exploration & Production Research Institute, SINOPEC, Beijing, China

Abstract

The recent discoveries of the Puguang gas field in the Sichuan basin, southwestern part of China and the Tahe oil field in the Tarim basin, northwestern part of China indicates the great hydrocarbon potential of the marine carbonate sequence in China. The most promising exploitation and exploration prospects are the Ordos, the Tarim, and the Sichuan basins and adjacent regions. The characteristics of the giant oil and gas fields in marine carbonate sequences in China are as follows:

1. Under the Paleozoic extension scenario, the sediments developed in the cratonic basins, rifting basins and margins in the North China, the Yangtze and the Tarim blocks, have provided good source rocks for hydrocarbon generation;

2. The paleo-uplifts and marginal slopes of the cratonic basins are enriched hydrocarbon zones. They are favorable traps for hydrocarbon accumulation. These types of oil and gas fields have been found in the Sichuan, the Ordos, and the Tarim basins;

3. Reef, shoal sediments and pore-vuggy-fractured carbonate sequences are favorable reservoirs in marine carbonate sequences. The 480m Ordovician karstic carbonate sequence is the major reservoir in the Tahe oil field in the Tarim basin, in addition the 329m Triassic vuggy dolomite provides good reservoir in the Puguang gas field, in the Sichuan basin;

4. Thick dark mudstone, shale and evaporates formed good seals and caprocks for hydrocarbon preservation, i.e. the Mid-Lower Triassic evaporates in the Puguang gas field and the Carboniferous evaporate-mudstone in the Tahe oil field are very effective seals.

5. In the Tahe oil field, the plays were formed in multiple phases. Some of them were formed in early-Hercynian time, late-Hercynian time and Indosinian-early-Yanshanian time, and the major play was formed in the late-Yanshanian time and Himalayan time. In the Puguang gas field, the gas play was formed during the Himalayan orogeny.
The Characteristics and Prospect of Giant Oil and Gas Fields in Marine Carbonate Sequence in China

JIN Zhijun

China Petroleum and Chemical Corporation

Cape Town
October 29, 2008
Outline

1. The characteristics of giant oil and gas fields in marine sequences

2. Forecast of oil and gas distribution in marine sequences in China
1. The characteristics of giant oil and gas fields in marine sequences

1.1 Development of multiple source rock intervals with multiple episodes of petroleum generation and expulsion
1. The characteristics of giant oil and gas fields in marine sequences

1.1 Multiple source intervals

Geological processes are characterized by multiple episodes of generation and accumulation with subsequent readjustment.

Due to low geothermal gradients and short period of deep burial, liquid hydrocarbons could be preserved in Tazhong and Tabei areas.

Event chart of Cambrian and Ordovician petroleum systems in platform areas of Tarim Basin.
1. The characteristics of giant oil and gas fields in marine sequences

1.1 Multiple source intervals

Event chart of petroleum systems in Sichuan Basin

- **Strata**
  - **Age (Ma)**: 550, 500, 450, 400, 350, 300, 250, 200, 150, 100, 50
  - **Source Rock**: Source rocks not mature
  - **Reservoir**: Oil, gas, Oil, gas
  - **Regional Seal**: Silty shale, mudstone, silty shale, gypsum with halite, silty mudstone
  - **Deep burial & Intense diagenesis**: Silty mudstone
  - **Unconformity formation**: Trap formation
  - **Migration**: Accumulation and destruction
  - **Accumulation**: Preservation

Integrated Evaluation: Source rocks not mature
1. The characteristics of giant oil and gas fields in marine sequences

1.2 Paleo-high and paleo-slope controlled earlier HC accumulation and late entrapment.

Caledonian Leshan-Longnvsi PU controlled gas accumulation in Sinian-Ordovician successions while Indosinian Kaijiang and Luzhou PUs had a significant control on gas accumulation in C-Tr2 sequences.
1. The characteristics of giant oil and gas fields in marine sequences

1.2 Paleo-high and paleo-slope

(1) PUs were catchment areas of migrating petroleum

(2) PUs controlled development of karst carbonate reservoirs
PUs controlled development of karst carbonate reservoirs

1. The characteristics of giant oil and gas fields in marine sequences
1. The characteristics of giant oil and gas fields in marine sequences

1.2 Paleo-high and paleo-slope

(3) PUs controlled development of multiple types of traps (e.g. unconformity, drape anticline and pinchout).
1. The characteristics of giant oil and gas fields in marine sequences

1.3 Large faults and unconformities controlled petroleum migration and accumulation.

Relationship between high production wells and faults in Tahe Field

Large faults controlled development of karst reservoirs and they had a significant impact on oil and gas migration.
1. The characteristics of giant oil and gas fields in marine sequences

The distribution of oil and gas fields in the center of Tarim basin

Favorable place for prospection in Silurian

Favorable place for prospection in Ordovician
1. The characteristics of giant oil and gas fields in marine sequences

1.3 Large faults and unconformities

Faults controlled development of reservoirs and they also acted as migration pathways.
1. The characteristics of giant oil and gas fields in marine sequences

1.4 High quality reef and shoal facies on platform margins are favorable areas for HC enrichment.

Prediction of high quality reservoirs is very important and it’s the key for prospect evaluation. For example, once good reservoirs were found, discovery could be made for the upper play in NE Sichuan Basin.
1. The characteristics of Giant Oil and Gas Fields in marine sequences

1.4 High quality reservoirs

Dolomitized shoal oolite reservoirs in Puguang Field

A. superposition of shoal facies led to formation of thick reservoirs

B. Mixed dolomitization

C. 3 episodes of dissolution

1st: formation of moldic and intra-oolite porosity, partly filled with calcite and dolomite

2nd: non-selective dissolution in deep burial diagenetic setting, formation of dissolution porosity, filled with bitumen

3rd: porosity formed by non-selective dissolution in late deep burial prior to gas charging, most unfilled and thus provide pore spaces for gas to accumulate
1. The characteristics of giant oil and gas fields in marine sequences

1.5 Effectiveness of preservation conditions is the key for the formation and preservation of significant oil and gas accumulations

Distribution map of gas fields and Tr1-2 evaporate seal in Sichuan Basin
1. The characteristics of giant oil and gas fields in marine sequences

1.5 Effectiveness of preservation conditions

Legend

- Regional stress
- Paleo-kast pores
- Early accumulations
- Intermediate accumulations
- Late accumulations
- Fault
- HC migration
1. The characteristics of giant oil and gas fields in marine sequences

1.5 Effectiveness of preservation conditions
1. The characteristics of giant oil and gas fields in marine sequences

1.5 Effectiveness of preservation conditions

<table>
<thead>
<tr>
<th>Fm</th>
<th>地层剖面</th>
<th>储层组合</th>
<th>Erosion and oil/gas pay zone</th>
</tr>
</thead>
<tbody>
<tr>
<td>T₃x</td>
<td>...</td>
<td>...</td>
<td></td>
</tr>
<tr>
<td>T₂l</td>
<td>...</td>
<td>...</td>
<td></td>
</tr>
<tr>
<td>T₁J⁶</td>
<td>2 1</td>
<td>...</td>
<td></td>
</tr>
<tr>
<td>T₁J⁴</td>
<td>4 3 2</td>
<td>...</td>
<td></td>
</tr>
<tr>
<td>T₁J³</td>
<td>2 1</td>
<td>...</td>
<td></td>
</tr>
<tr>
<td>T₁J²</td>
<td>3 2</td>
<td>...</td>
<td></td>
</tr>
<tr>
<td>T₁J¹</td>
<td>...</td>
<td>...</td>
<td></td>
</tr>
<tr>
<td>T₁f</td>
<td>...</td>
<td>...</td>
<td></td>
</tr>
</tbody>
</table>

Legend:
- Reservoir
- Seal
- Pay
- Erosion
Outline

1. The characteristics of giant oil and gas fields in marine sequences

2. Forecast of oil and gas distribution in marine sequences in China
2. Forecast of oil and gas distribution in marine sequences in China

2.1 Exploration plays for the Lower Paleozoic carbonates in Tarim Basin

Within $\in_2$, an evaporate sequence was developed with a thickness of over 1000m

Lower-Middle Cambrian stratigraphic correlation cross-section through Tong 1-Kong 2-Fang 1-Hetian 1-Tacan 1-Zhong 4 wells.
2. Forecast of oil and gas distribution in marine sequences in China

2.1 Exploration plays for the Lower Paleozoic carbonates in Tarim Basin

![Map showing evaporites coverage](image)

Evaporites cover an area of about $230 \times 10^3 \text{km}^2$
2. Forecast of oil and gas distribution in marine sequences in China

2.1 Exploration plays for the Lower Paleozoic carbonates in Tarim Basin

Integrated evaluation map for Cambrian sub-salt play in Central Uplift of Tarim Basin

Large anticline traps were developed below Cambrian salt.
Evaporites in the Lower-Middle Triassic constitute direct seals and Upper Triassic mudrocks make up regional seals.
2. Forecast of oil and gas distribution in marine sequences in China

2.2 Exploration plays for the Mesozoic carbonates in Sichuan Basin

Integrated evaluation map for Tr2
Leikoupo Fm in western Sichuan B

Integrated evaluation map for Tr1
Jialingjiang Fm in western Sichuan B

Xiaoquan Shoal
- Long axis: 95.4km
- Short axis: 23.6km
- Volume: 974.8km³

Jintang Shoal
- Long axis: 59.1km
- Short axis: 15.0km
- Area: 965km²

Luodai Shoal
- Long axis: 55.6km
- Short axis: 14.0km
- Area: 740km²

Xiaoquan Shoal
- Long Axis: 65.3 km
- Short axis: 23.1 km
- Area: 906km²
2.2 Exploration plays for marine carbonates in Sichuan Basin and adjacent areas

Tr1-2 evaporate seal is the key for gas enrichment in Sichuan B. Its overlying non-marine overburden (seal) sequences played an essential role in enabling source rocks to enter HC generation window for “2nd time” or in entrapment of late-formed HCs.
2. Forecast of oil and gas distribution in marine sequences in China

Isopach map of Lower Cambrian mudstone seal rocks in South China

200m to over 400m thick

200 ~ 400m with a maximum of 800m
2. Forecast of oil and gas distribution in marine sequences in China

- Tahe oil field, discovered in 1997, O₁₂, proven reserves 0.7b.t Tarim
- Jingbian gas field, O₁₃, discovered in 1988, proven reserves 433 b.m³ Ordos
- Tazhong No.1 fault zone oil fields, O₂₃, discovered in 2005, Proven reserves 780 m.t Tarim
- Puguang gas field, T₁f, discovered in 2003, proven reserves 381 b.m³ Sichuan
- Weiyuan gas field, Z₂dn, discovered in 1964, proven reserves 41 b.m³ Sichuan
Thanks