History and prospect of continental facial oil and gas resource development in China
Introduction

The development of oil and gas resources in China has made a remarkable history since 1950s.

Annual production rises from 0.07 MMT of oil in 1949 to 209.8 MMT of oil and 132.9 BCM of gas in 2014, which is supporting the rapid growth of Chinese economy continuously.
Outline

1. Resource Characteristics
2. Development History
3. Prospect Forecast
## Resource Characteristics

<table>
<thead>
<tr>
<th>Resource</th>
<th>OOIP</th>
<th>Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crude Oil</td>
<td>108.5 BMT</td>
<td>36 BMT</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>68 TCM</td>
<td>12 TCM</td>
</tr>
</tbody>
</table>

Major oil and gas bearing basins in China
Resource Characteristics

- Rich in faults and small blocks
- Great differences in distribution of oil and gas

HUANG HUA depression profile (Dagang Oilfield)

JI YANG depression horizontal distribution (Shengli Oilfield)
Resource Characteristics

- Frequently transformed sedimentary facies
- Small sand body and limited connectivity
- Thin layers with different characteristics
Resource Characteristics

- Microstructure: poor sorting, complicated pore structures, developed microcrack, low porosity and permeability

Daqing oilfield
500-1200mD

Changqing oilfield
0.3-5mD

Xinjiang oilfield
100-500mD

Jilin oilfield
1-30mD
Resource Characteristics

- Large ratio of kerogen and humus, high paraffin content, high freezing point and high viscosity
- NaHCO$_3$ type brine, low salinity

<table>
<thead>
<tr>
<th>Oilfield</th>
<th>Paraffin, %</th>
<th>Freezing point, °C</th>
<th>Density</th>
<th>API</th>
<th>Viscosity, 50°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>DA QING</td>
<td>28.7</td>
<td>30</td>
<td>0.857</td>
<td>32.8</td>
<td>23.79</td>
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<tr>
<td>LIAO HE</td>
<td>13.5</td>
<td>31</td>
<td>0.885</td>
<td>27.7</td>
<td>52.3</td>
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<tr>
<td>SHENG LI</td>
<td>7.0</td>
<td>28</td>
<td>0.946</td>
<td>17.5</td>
<td>498.0</td>
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<td>DA GANG</td>
<td>26.1</td>
<td>33</td>
<td>0.882</td>
<td>28.2</td>
<td>854.2</td>
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<td>YU MEN</td>
<td>8.3</td>
<td>15.5</td>
<td>0.853</td>
<td>33.0</td>
<td>12.9</td>
</tr>
<tr>
<td>XIN JIANG</td>
<td>6.8</td>
<td>10</td>
<td>0.857</td>
<td>32.8</td>
<td>15.05</td>
</tr>
</tbody>
</table>
Resource Characteristics

- Tight sandstone, carbonate, and volcanic rock contribute major gas reservoirs, characterized by complicated pore structure and strong heterogeneity.

- Tight sandstone (Sulige): PERM<1.0mD, low connectivity
- Carbonate rock (Jingbian): Multiplicity reservoir types and strong heterogeneity
- Volcanic rock (Xushen): Poor physical property, Strong heterogeneity; Fracturing is needed

Distribution of proved gas reserves
Outline

1. Resource Characteristics
2. Development History
3. Prospect Forecast
1. Early age Before 1949

- 29 MMT of OOIP, 33 wells and 70,000 tons of annual output
- 390 MCM of OGIP and 10 MCM of accumulated output

Miaoli Oil Bureau, 1878
Official petroleum factory in Yanchang, 1905
Laojunmiao Oilfield in Yumen, 1939
2. Production recovering (1949~1958)

- Central and western China: Qinghai, Karamay, Sichuan gasfield discovered
- Theory of continental oil source improved
- 147,000 tons of oil production in 1958

- Eastern China: Daqing, Shengli, Liaohe and Zhongyuan oilfield discovered
- Theory of continental oil source confirmed; E&P techniques developed
- Annual oil production climbed to 100 MMT in 1978

- Daqing, 1959 - Songji 3 well
- Shengli, 1961 - Hua 8 well
- Liaohe, 1966 - Liao 6 well
- Huabei, 1975 - Ren 4 well

The annual production of Daqing Oilfield reached 50 MMT in 1976, kept stable for 27 years. Production had accumulated 2.2 BMT until 2014.

Annual production of Daqing

- Capacity construction
- Stabilization 50 MMT
- Stabilization 40 MMT
History


- Stabilize east and develop Tarim, Tuha and Tahe oilfield in western China
- Water cut control for matured fields and gas production technologies
- Annual oil/gas production: 160 MMT/23.3 BCM in 1998

Tarim, 1989—Lunnan 2 well  Tuha, 1991—Taican 1 well  Tahe, 1997—Sha 48 well

- Three major oilfields of CNPC in Xinjiang developed rapidly
- Annual oil output rose from 3.53 MMT in 1978 to 15.66 MMT in 1998

Oil production of three basins in Xinjiang

- Tuha
- Tarim
- Xinjiang

Discovery of Dushanzi Oilfield

Oil production of three basins in Xinjiang
History

5. Area expanding (since 1998)

- Technology innovation for unrecoverable reserves, matured oilfields and gasfields
- Ultra-low permeability reservoirs: lower limit extends from 5mD to 0.3mD.
- Changqing oilfield became a major oilfield producing 50 MMT oil and gas equivalent
- Annual oil production of EOR reached 34 MMT in 2014
Current status

By 2014, 27 oil and gas producing bases have been established.
Current status

- Annual oil production 209.8 MMT in 2014, ranking the 4th in the world
- Kept more than 200 MMT for five years

Recovering Age
- 4 oilfield including Yumen etc.

Fast-development Age
- strategic attention turned eastwards, Daqing Oilfield and Bohaiwan Oilfield etc.

Stabilization Age
- stabilize the eastern region, develop the western region, joint development of oil and gas
  - Low permeability Thermal recovery
  - 1.6 x 10^8 t
  - 1.05 x 10^8 t

Expanding Age
- technical innovation drives the exploration and development
  - Ultra-low permeability Chemical flood
  - 2.1 x 10^8 t

Annual oil production in China (in 10^8 t):
- 1.47 x 10^6 t
- 1.05 x 10^8 t
- 1.6 x 10^8 t
- 2.1 x 10^8 t

Theory of continental oil source

Water flooding
Current status

- Annual gas production grows from 27.2 BCM in 2000 to 132.9 BCM in 2014

- 2×10^{10} m^3 in 1996
- 10×10^{10} m^3 in 2011
Technologies

Oilfield development technologies

1. Continental sedimentation theory: proven reserve 32 BMT
2. Fine water injection: recovery 33%, annual output 106 MMT
3. Chemical flooding: recovery 10–25%, annual output 18 MMT
4. Thermal recovery: recovery 30%, annual output 14 MMT
5. Low permeability recovery: recovery 25%, annual output 71 MMT
6. Tight oil recovery: annual output 1 MMT
Technologies

Gas field development technologies

1. Low permeability-tight gas: annual output 34.2 BCM
2. High pressure-condensate gas: annual output 20 BCM
3. Carbonate gas reservoir: annual output 19 BCM
4. Unconsolidated sandstone gas: annual output 5.7 BCM
5. Volcanic rock gas reservoir: annual output 2.85 BCM
6. High sulfur gas reservoir: annual output 0.73 BCM

CNPC data only
Outline

1. Resource Characteristics

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Different with the countries with high quality resources, China is now facing two challenges: continental facial sedimentation and high water cut.

Technology innovation is the only way to make this breakthrough, whenever in history or in future, as was proved in the revolution of tight oil and shale gas by US.
Improve recovery of matured fields

- Fine water injection and chemical flooding has been developed which increases recoverable reserves by 900 MMT

- ASP flooding
  - Enhanced the oil recovery of 24.3%

- Polymer flooding
  - Enhanced the oil recovery of 12.1%

- Secondary development
  - Enhanced the oil recovery of 10%

- Final recovery: 70%
Profit improvement for low permeability oilfield

As the major resource, development of low permeability reservoirs is facing dual challenges technically and economically under low oil price.
Profit improvement for low permeability oilfield

CNPC is focus on functional water flooding, volume fracturing and CO₂ flooding for low permeability oilfields, by which 500 MMT more recoverable reserve is expected.

Enhanced oil recovery target and technical trategy

- Calibration recovery: 20%
- Foam flooding: 25%
- Functional water drive
- Joint network fracturing
- CO₂ flooding: 30%
- Target: 40%
Cost cut for heavy oil

- CNPC is focusing on multi-medium steam flooding, SAGD, in-situ combustion, expecting to increase recoverable reserves by 257 MMT.

Core oil saturation below 3%

Core photos before fire flooding

Development effect of auxiliary solvent SAGD
Tight oil development

- Tight oil resource in China is about 47.6 BMT, which is thin, low porosity, low mobility and relatively poor oil properties, compared with that in northern America.

**Continental tight sandstone oil**: thin reservoir thickness, poor continuity, low abundance.

**Marine tight sandstone oil**: reservoir thickness, good continuity, high abundance.

**Comparison between continental and marine tight sandstone reservoir profile**

**Western China**

**Northern America**
Tight oil development

- The annual production in 2014 climbs to 1 MMT with the support of resource recognition, volume fracturing and equipment.

Xinjiang Ji 172H Well:
- Water cut: 40%
- Stage oil production: 14,400 tons

Changqing Yangping 8 Well:
- Water cut: 9%
- Stage oil production: 11,200 tons
Thank you