## USA vs China Shale Gas Plays

<table>
<thead>
<tr>
<th>Item</th>
<th>China</th>
<th>USA</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Geology</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Structure depositional</td>
<td>Heterogeneous, easily frangible</td>
<td>Homogeneous, very thick</td>
</tr>
<tr>
<td></td>
<td>Marine, lacustrine and transitional</td>
<td>Marine</td>
</tr>
<tr>
<td>TOC</td>
<td>Mostly 1% - 5%</td>
<td>5% - 10%</td>
</tr>
<tr>
<td>Gas content</td>
<td>Average 1 - 3 m³/t</td>
<td>3 - 6 m³/t</td>
</tr>
<tr>
<td></td>
<td>Marine - $R_0 &gt; 2%$</td>
<td>$R_0: 1.1% - 2.0%$</td>
</tr>
<tr>
<td>$R_0$</td>
<td>Lacustrine - $R_0 &lt; 1.3%$</td>
<td></td>
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<tr>
<td><strong>Development</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Depth</td>
<td>&gt;3500 m (mostly)</td>
<td>1500 - 3500 m</td>
</tr>
<tr>
<td>Surface</td>
<td>Mountain areas, limited water</td>
<td>Flat plain, good water resources</td>
</tr>
<tr>
<td>Pipelines</td>
<td>Limited</td>
<td>Good network</td>
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</tbody>
</table>
Challenges in Shale Gas Development in China

1. Limited evaluation of geological resources and reserves;
2. Key development and production remains breakthrough;
3. Surface facilities are not established;
4. Environmental, safety and water supply issues.
Technology Advances in North America

R&D Initiatives started in the 1970s in North America
Barnett Shale Gas Development

**Barnett Shale Drilling From 1981 to 2010**
Ft. Worth Basin, Texas

**Barnett Shale Events**
- 1981: 1st production; foam fracs
- 1985: Massive gel fracs
- 1997: Core analysis: gas-in-place = 3 x previous estimates
- 1997: Water fracs lower costs
- 1999: Refracs restore production
- 2003: Horizontal drilling expands

**Barnett Shale Production**

![Map of Barnett Shale Drilling from 1981 to 2010]
Bakken Tight/Shale Oil Development

Bakken Shale Production
1985-2010
Williston Basin, ND & MT

- Bakken Shale Producing Wells
  - Oil per Day (Mean per Quarter)
    - 0 – 100
    - 101 - 500
    - > 500
- Gas-Oil Ratio (Mean per Quarter)
  - 0 – 1,000 (Oil Bbl = Gas BOE)
  - 1,001 - 5,000 (Oil Bbl > Gas BOE)
  - > 5,000 (Gas BOE > Oil Bbl)

2006: Middle Bakken
Vertical well Tests
Elm Coulee Field

2006: Elm Coulee
Middle Bakken
Horizontal wells
Discovery

1977: Upper Bakken Shale
Vertical wells
Bilings Nose

1976: Upper Bakken Shale
Horizontal Wells
Bilings Nose

- S: SD
- WY
- ND
- NE
- Canada

- Miles
  - 0
  - 20
  - 40
What are Really Lacked?

- Geology
- R&D
- Production
Unconventional Oil and Gas Research Center

Global Initiative for Research in Unconventional Oil & Gas:
The Beijing Site, University of Calgary, Alberta, Canada
Shandong Kerui Group
Opening Ceremony for the Beijing Site

Research Summit for Unconventional Oil & Gas

October 23 and 24, 2014
Lab Facilities in Unconventional Oil and Gas

- Petrophysics
- Geochemistry
- Imaging
- Formation stimulation
- Rock mechanics
- Reservoir simulation
Lab Personnel

Trailblazers

Roberto Aguilera (SSE), John Chen (SSE), Chris Clarkson (Science), Mingzhe Dong (SSE), David Eaton (Science), Ian Gates (SSE), Stephen R. Larter (Science), Larry Lines (Science), Brij Maini (SSE), Frank Maurer (Science), Sudarshan (Raj) A. Mehta (SSE), Gordon Moore (SSE), Pedro Pereira (SSE), Mario Costa Sousa (Science), and Uttandaraman (U.T.) Sundararaj (SSE)

Perpetuators

Usman Alim (Science), Nancy Chen (SSE), Hassan Hassanzadeh (SSE), Hossein Hejazi (SSE), Stephen Hubbard (Science), Haiping Huang (Science), Per Pedersen (Science), and Xin Wang (SSE)
Lab Facilities

1. Geophysics

- **Lithology analysis** including porosity, absolute permeability, oil and water saturations, capillary pressure curves, relative permeability curves;
- Analysis for **fluid properties** including density and viscosity and their variation with temperature, surface and interfacial tension, and rheology;
- **Special lithology** analysis including reservoir sensitivity, shale gas adsorption, desorption, diffusion, rock pore throat structure analysis and evaluation of unconventional oil and gas reserves.
Lab Facilities

- Geochemical lab analyzes **hydrocarbon source rocks** and oil, gas and water chemical composition and properties.
- Source rock study aimed to determine **organic matter** abundance, type and maturity.
- Oil analysis studies the **physical properties** of crude oil (density, viscosity, sulfur content, wax content, freezing point, etc.), **composition**, **sources** of crude oil, **maturity** and oil possession of various secondary changes.
- Gas analysis is based on natural gas **composition** and isotopic to determine its **origin** (biogas vs thermogenic gas, and source rock pyrolysis gas vs oil cracking gas), hydrocarbon dynamics and occurrence (**adsorbed hydrocarbons** and **free hydrocarbons**).
• By GAMA scanning, one acquires the composition of clay content of an entire core segment and an overall understanding of a reservoir interval.
• Through micro-nano and CT scanning, scanning electron microscope, polarizing microscope thin sections, X diffraction analysis and other testing means, one studies shale layers foliations, pore structure and mineral composition to obtain a comprehensive understanding of the microscopic structure of a reservoir.
• Simulation of fluid flows at micro scales.
More Efficient in Oil & Gas Extraction

Lab Facilities

• Performing **stress analysis, triaxial compression, and pure shear lab simulation**;
• Through the core segments of different layers, simulating the actual geological conditions underground and performing **rock mechanics experiments**.
Combining reservoir physics, chemistry, microstructure and geomechanics lab analyses, one studies fracturing fluids and proppants and promotes their field applications.
Modeling and Simulation Research Lab

- Integrated interpretation
- Reservoir simulation
Modeling and Simulation Research Lab

- For exploration of unconventional oil and gas reservoirs, seismic data is processed and interpreted, combined with comprehensive geological studies;
- Integrated projects of reservoir development and production engineering are designed.
• According to the experimental results, all data are integrated and used in **numerical simulation**;
• Based on **geological models, hydraulic fracturing model, and production models**, a full range of **numerical simulators** are established to guide ultimately on-site hydraulic fracturing jobs and **design and optimize** development and production.
Comments

1. **Conventional vs unconventional oil and gas**: Reservoir generation and preservation, fluid flow, development and production theory, design, and scheme, reservoir management and associated technologies significantly differ.

2. **US vs China**: China shale gas plays vary significantly, much challenging to explore, develop and produce.

3. Based on past 30+ years R&D programs.
MORE EFFICIENT IN OIL & GAS EXTRACTION