Unconventional Resource Development in China

Opportunities and Challenges for the Canadian Oil and Gas Service Sector

February 27, 2014

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Topics to be Discussed

- Chinese Opportunity
  - Shale Gas Resource Potential and Distribution
  - The Players
    - State Owned Oil and Gas Companies
    - New Entry Companies

- The Market
  - Projected Demand and Central Government Plans
  - Company Activity and Growth Plans
  - Operating Conditions
    - Weather
    - Topography
    - Infrastructure

- Technology Trends and Gaps

- Canadian Service Sector Market Entry
  - Opportunities for Market Entry
  - Challenges to Market Entry
  - Market Entry Strategies
  - Competition

- Observations and Conclusions
China’s economic growth and shift towards middle class is leading to a growth in consumption.

Natural Gas Production and Consumption in China (2000 – 2012)

From EIA, 2013
Major Prospective Shale Basins in China
### Why China?

**The Size of the Prize**

- Total Gas in Place is estimated at 4,700 Trillion ft$^3$
- Recoverable resources are estimated at over 900 Trillion ft$^3$
- In 2012 530 Million ft$^3$ of shale gas was sold into the national pipeline system (0.0001 of China’s total gas consumption)

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<th>Unit</th>
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<th>Evaluation year</th>
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<td>2008</td>
<td>Emphatic basin and region</td>
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</table>
Who is Exploring and Developing Shale Gas in China

The major companies are State Owned Enterprises (SOE)
- China National Petroleum Company (CNPC) and subsidiary PetroChina
- Sinopec
- Yanchang Petroleum Group
- CNOOC

The new players (successful bidders in round 2 of shale gas block auction)
- Huadeng International Power Corporation (farm in on Chongqing Youyang block)
- Chongqing Mineral Resources Development
- Huadian Engineering Group
- Shenhua Geological Exploration Company
- Hunan Huasheng Energy and Investment Group
- Huaying Shanxi Energy Investment Group
- Beijing Taitan Gas Technology Group
- Hunan Shale Gas Development Company
- China Coal Geological Engineering Corp.
- Jiangxi Natural Gas Holdings
- Anhui Energy Group
- Henan Geological Exploration and Mine Investment
Technical and Financial Capacity of Exploration Companies

The SOE companies have invested significant capital in their blocks since 2007

- Most companies have completed a number of pilot projects and are moving towards commercial production
- Some companies have found international partners for technology cooperation and capital
- Companies have formed joint ventures or purchases in North America to capture technology as well as provide a hedge for gas production volumes
  - PetroChina partnered with Encana on Duvernay assets
  - Yanchang purchase of Novus
  - CNOOC purchase of Nexen

The successful bidders from Round 2 are still planning or initiating early exploration programs

- Most companies have limited unconventional resource exploration or development experience
- Completion of 2D seismic programs and initial stratigraphic drilling
- Now into 2\textsuperscript{nd} year of 3 year lease to complete work commitment expenditures
- Examining entering into the North American market to capture assets and technology
Challenge for 2\textsuperscript{nd} Round Bidders

- Successful bids for 2\textsuperscript{nd} round blocks were based upon $$ in work commitments.

- 2\textsuperscript{nd} round blocks tend to be remote, with difficult topography, limited surface infrastructure and complex subsurface geology where the prospective shale beds are often at depths greater than 3500 m.

- Terms of the 2\textsuperscript{nd} round leases are for a 3 year term. At term expiration and assuming that work commitments have been completed, companies can apply for up to two 2 year extensions prior to applying for a production license.

- If work commitments are not completed, company must relinquish percentage of leased land equivalent to the percentage of commitment not completed, back to the government.

  - Eg. If a company only spends 30\% of the initial work commitment $$ during the 3 year term of the lease, they must relinquish 70\% of lease area back to government.

- Existing pipelines are owned by CNPC and access is not guaranteed.

- Overall, the block winners committed to invest about $21 billion in geographical survey and exploration but now they are entering into year 2 of lease and many companies have not yet drilled a well (stratigraphic or horizontal production test).
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China’s Energy Demands

- The central government has determined that shale gas will be a critical part of the energy supply for the next 5 year plan
- This has resulted in an ambitious goal for production (Annual production of 6.5 Billion m$^3$ by 2015)

**229.5 Billion ft$^3$ per year or roughly 628 million ft$^3$/day**

Source: China NDRC, Bernstein analysis and estimates
Natural Gas Pricing

- In November 2012, MOF and NEA announced 0.4 RMB ($6.4 cents) per cubic meter subsidy for shale gas that is developed and consumed from 2012 to 2015.

- Low natural gas price has been a disincentive for enterprises to join shale gas exploration and on July 10, 2013, NDRC increased the wholesale price of natural gas for non-residential users for the first time after 2010.

- The average natural gas price at gate stations (where trunk pipelines connect with local gas distribution networks) increased by around 15.4 percent to 1.95 yuan ($0.31) per cubic meter.

- Residential natural gas prices are set by local governments after public hearings. The new domestic price would be roughly $8.76 per mmBtu, though in many coastal provinces, the prices will be higher at up to $10 - $12 per mmBtu.

- China’s average LNG import price is still 40% - 60% higher than domestically produced natural gas price (China paid Qatar $18.77 per mmBtu for LNG in May, 2013).

- Sinopec is currently receiving 3.1 Rmb/m$^3$ (~$14.60/mcf) wellhead price for gas produced at their Fuling project (limited pipeline tariff due to proximity of customers.
Current Development Activity and Levels of Production

- To date approximately 150 wells have been drilled in the past 3 years
- Most activity has been directed towards Sichuan Province, (PetroChina and Shell), Chongqing Municipality, (Sinopec) and the Ordos Basin, (Yanchang Petroleum)
Current Industry Activity

**Sinopec Activity** (Fuling region of Chongqing Municipality)
- 27 wells drilled of which 21 fracture stimulated and 15 currently producing
- Current Sinopec total production is approximately than 53 million ft³/d
- Six wells are producing at an average IP rate > 6.3 million ft³/d
- Most prolific well reported to have IP of 19 million ft³/d

**PetroChina Activity** (Sichuan Province)
- Total of 47 wells drilled to date including vertical stratigraphic wells
- Currently 29 wells producing but small volumes
- In Sichuan province, an 8 well pad has been drilled of which 3 horizontal wells have been completed and hydraulically stimulated
- Currently building 90 km pipeline with a capacity of 160 mmcf/d for expected production extending to Shuanghe gas processing station and connecting to existing Sichuan Naxi to Yunnan Anbian pipeline

**Yanchang Petroleum** (Ordos Basin)
- Total of 30 wells drilled of which 23 have been hydraulically stimulated
- Gas shows from all wells and 10 wells currently producing (volumes unknown)
- Shale basin is of continental origin creating challenges for fracability
Government Support for Shale Gas

Both the central government and local governments have provided financial incentives to assist in the development of shale gas:

- Central government has introduced a shale gas subsidy of $0.4 RMB/m3
- Central government has designated shale gas as a special mineral to allow non state owned oil and gas companies to bid and develop shale gas resources
- Governments have guaranteed access to the shale gas resources to the block winners
- In Chongqing Municipality, the local government has established a research fund of $250 Million RMB for R&D into shale gas exploration and development
  - Established joint research projects with local universities
  - 3 research institutes created to conduct shale gas research
  - Institutes have signed cooperative agreements with E&P companies as well as Schlumberger and Halliburton
- Incentives to locate manufacturing facilities for shale gas exploration and development equipment in Liangjiang Industrial Park in Chongqing
Industry Plans for the next 2 years

**Sinopec Activity** (Fuling region of Chongqing Municipality)
- Plans to drill 200 to 300 wells over next two years with an additional 250 from 2015 to 2017
- Plans for 150 million m3 (5.3 Bcf)/d of capacity and annual production of 53 Bcf by 2015

**PetroChina Activity** (Sichuan Province)
- Plans to drill 122 horizontal wells with 113 wells on production
- Goal to reach 1.5 Bcm (53 Bcf) annually with daily production of 190 mmcf by 2015
- Pace of development is controlled by Shell (JV partner) who is wanting to go more slowly working towards improved economics and higher production

**Yanchang Petroleum** (Ordos Basin)
- Continuing to improve wellbore productivity in Ordos Basin and move towards commercial production

**Round 2 Bid Winners**
- Delineate resource potential and determine reservoir properties of shale formations within lease block
- Continue to explore for prospective areas within lease blocks
- Initiate pilot production tests on defined “sweet spots”

**CNOOC** --- ??????
It is apparent that the prime acreage in terms of:

- Geological Prospectivity
- Existing oil and gas Infrastructure
- Surface Access
- Topography

lies in the “heart” (red) of Chongqing Municipality and was offered to the SOE’s in the first round offering.

- 2nd round blocks have significantly greater challenges (blue) and are considered to be less desirable.

As with any “puppy” you hope that it will turn out to be the best pet ever.
Topographically the Chongqing municipality and the eastern part of Sichuan province lie in a topographic low surrounded by high plateaus to the north, west and south.
Weather

Weather constrained operations do not appear to be problematic although there is a definite rainy season which may impact operations due to the poor road conditions.

Southwest China
Average Annual Temperatures

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<th>Place</th>
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Southwest China
Average Annual Precipitation

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<td>Kunming</td>
<td>Yunnan</td>
<td>39.6</td>
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Topographic Challenges

All of the shale gas prospects have difficult terrain to work in:

- Access is limited to single lane roads or nonexistent
- Drill pad locations are small limiting the number of wells per pad
- Often any flat land is used for either houses or agriculture
- Water supplies, while available are difficult access
Concurrent operations, while possible, will remain smaller than in North America. Operational footprint is space constrained resulting in fewer number of wells per pad.
Pipeline infrastructure is marginal but will be completed based upon demand.

Chongqing has a population of over 32 million with a large industrial economic base.
Natural disasters may impact development sites as well as placement and stability of surface infrastructure.

The aftermath of the Wenzhou quake in 2008 that killed at least 70,000 people in Sichuan Province. Much of China's shale deposits lie in the earthquake-prone and mountainous southwest.
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Technology Trends and Gaps

- Major Chinese E&P companies have aligned themselves with major service providers such as Halliburton, Schlumberger, Baker Hughes and Weatherford.

- Provision of services such as horizontal drilling, completions, multi-stage fracture stimulation and pipeline and surface facilities construction and well tie-in are areas where the Chinese industry has made significant advances in the past 2 to 3 years.

- The SOE companies understand what equipment to use as well as the deployment and application of specific technologies.

- Evolution of development is now focused on reducing F&D costs.

- There is a significant need for technology and intellectual knowledge for the Round 2 block winners through technical alliances with North American service providers.
  - The challenge is that many of the Round 2 companies do not know what they need and are more focused on limiting the capital expenditure.
In operations the Chinese SOE’s and service companies are doing a good job

*Could they do better??*

From a North American perspective YES – improved efficiencies could yield reduced costs and perhaps improved productivity
The Focus is often “the more people the better” in Conducting Operations
Two Different Strategic Approaches for Development

**PetroChina**

- Partnered with Shell whereby Shell is paying all of the exploration costs and PetroChina has the option to back in for 51% should commercial production be achieved
- Shell is taking a methodical approach to development through improved technology and reduction of drilling/stimulation costs
- Currently it takes about 75 days to drill a well – an improvement from 132 days (target is 50 days per well)
- Target of 60,000 to 80,000 m³/d (2.1 to 2.8 mmcf/d) to be economic
- *Economics* of the project is Priority #1

**Sinopec**

- Determined to develop the project without partners
- Moving forward aggressively to drill, complete and tie in wells to achieve strategic volumes
- Currently taking about 90 days to drill a well (2400 m depth TVD and 1500 m lateral with 20 stage fractures stimulation
- Well costs currently $15 to 20 million USD
- *Volume* of gas production is Priority #1

*Both companies are striving towards improvement but Sinopec is developing their fields at a faster pace*

*Note: This is the authors personal opinions based upon discussions with both companies*
Technology Challenges

Subsurface Issues
- Understanding subsurface geological stress and the impact on wellbore productivity
- Understanding the complexity of the subsurface geology specifically geological structure and reservoir heterogeneity
- Effective use of microseismic modeling

Surface Issues
- Accessing the reservoir effectively due to limitations of locations and size of multi-well pads
- Long term frac fluid treatment and disposal
  - Subsurface injection disposal is not being considered at present
  - Water treatment costs ~$10.00 US per barrel (~$4 to $5/mcf)
- High population density (750 people/km²)
- Narrow access roads and safety issues for personnel to and from wells site

Operational Issues
- Long term sustainability of frac fluid disposal options
- Cost effective availability of frac sand and chemicals (both imported)
  - Currently a 100% duty on imported frac sand
- Availability of equipment and skilled labour should commercial operations proceed
- Improvement in fracing technology (size of fracs and number of pumping units)
- Limitations for concurrent operations
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- **Observations and Conclusions**
Opportunities for Market Entry for the Canadian Service Sector

The Chinese shale gas market is happening now!!!!

We need to take off our North American hat and put on a Chinese hat

The focus is not on economics and rate of return but rather on volumes and meeting the central government’s 5 year goal of 60 Billion m³/yr (2.1 Tcf/yr) by 2020

There are a number of services that have been identified that are needed in China

- horizontal drilling
- multi stage hydraulic fracturing: supervision, technical expertise, knowledge sharing
- microsiesmicity - data analysis
- frac analysis
- proppant and fluid chemistry
- drilling and frac fluids
- down hole tools, rotary steering systems
- specialized niche services
- environmental, water management services
- lean manufacturing, completion efficiencies
- multi well pad planning, drilling programs well design
Challenges to Market Entry

The China Shale Gas market has the potential to be huge and at present, the indigenous service sector does not have the capacity to provide the volumes and levels of services required.

There are however a number of challenges to market entry:

- **Language barrier and distance to market**
  - To be successful you will need to have a local presence both physically and linguistically.

- **Intellectual and proprietary protection of technology and knowledge**
  - The Chinese business model is typically to copy and reproduce key technologies at a lower cost often at the expense of quality. *This mindset is changing albeit slowly.*

- **Cost of services**
  - The Chinese model is to do everything cheaper than North America and for intellectual services such as knowledge transfer, it is difficult to charge North American consultancy rates and still be competitive.

- **Relationship Building**
  - Most successful Chinese business ventures are built upon a long term relationship that has often taken a number of years to build.

- **Timing of market entry**
Market Entry Strategies

There are a number of market entry strategies that have been identified. All of them have both positive and negative features and a company will need to decide which is best based upon available capital, market confidence, product and risk tolerance.

- Joint Venture or Partnership with an Existing Chinese Technology/Service Sector Company
- Establishment of a Chinese Service Sector Company
- Provision of Services through a larger Service Sector Company that already has Existing Client Relationships Eg. Halliburton, Schlumberger
- Development of Relationship with 2nd Round bidders through Canadian Equity Investment
- Creation of a Canadian consortium of technical expertise to provide a broader range of services to prospective clients
- China Shale Gas
Chinese and International Competition

- In the unconventional resource service sector most new market entries into China will face competition from both local Chinese companies as well as services provided by the Big 4 – Halliburton, Schlumberger, Baker Hughes and Weatherford

- Exploration for shale gas and the import of advanced technologies has been ongoing since 2007. The major SOE’s understand the technologies and are applying them (perhaps not as efficiently as in North America)

- It will be difficult for a new company that offers similar services to the Big 4 to enter into the Chinese market at this stage

- There are market opportunities for niche products or services

- Chinese companies are still looking for partners with North American technologies to attempt to compete with the Big 4 or provide expanded services to their existing clients

While competition does exist, should the Chinese market expand to the projected levels, there will be a significant demand for additional services

- There are plans to drill between 300 and 400 wells over the next 2 years from PetroChina and Sinopec alone
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Observations and Conclusions
Or
What Does All This Mean ????

- China shale gas if real and is happening now!
- Even though there are operational challenges and well costs are high, the resource is being developed primarily by the SOE’s
- Surface topography is challenging to say the least and presents the greatest challenge to full scale development (operation efficiency as well as safety issues)
- Fracture fluid treatment and recycling appears to be an area of great opportunity as subsurface disposal is not considered an option
- 2nd Round block owners face a large number of challenges to achieve commercial shale gas production including short duration of leases, topography, infrastructure and subsurface geological complexity
- Successful market entry will need to address language barriers and the need to be “on the ground” in China
- Niche products or services will probably have a greater chance of success as compared to the core technologies that are provided by the Big 4 that already have a market presence
Unconventional Resource Development in China

Opportunities and Challenges for the Canadian Service Sector

Thank You for Your Attention!

Mike Dawson
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Mark Sakeld
Petroleum Services Association of Canada

February 27, 2014
To achieve economic production companies require:

- Strong commodity prices
- Ideally existing infrastructure (pipelines, processing facilities etc.) to lower capital costs
- Advanced technologies to optimize productivity while lowering costs
- Availability of equipment and materials in sufficient quantity and stability of supply

Shale gas exploration is capital intensive with large volume of investment in the early stages and return on investment throughout the life of the project.

**Typical Investment Profile for Unconventional Resource Development**

- Investor Cash Flow
- Tax Paid
- Operating Expenditure
- Capital Expenditure
- Production

Each bar = 1 year

From Shell E&P Technology, 2009
Other Aspects of Unconventional Resource Development

- Production declines are relatively steep (60 to 80% in the first year)
- Companies are compelled to be on a drilling treadmill to offset production declines while at the same time growing production
- As a result large land tracts of mineral tenure are required to allow for the planning of an inventory of drillable locations
Determination of reservoir properties along with stimulation and production optimization requires a number of years of testing and pilot projects.

Pace of development is largely dependent on technical success, economics and market conditions and availability of equipment and materials.

**Stage 1: Identification of UCG Resource**
- Preliminary geological assessment to determine potential for hydrocarbons

**Stage 2: Early Evaluation Drilling**
- Vertical drilling to obtain core samples for reservoir properties along with estimation of resource potential and geographic limits of potential field

**Stage 3: Pilot Project Drilling**
- Early horizontal drilling to evaluate well performance with varying hydraulic fracturing technologies along with continued reservoir testing to determine engineering properties

**Stage 4: Pilot Production Testing**
- Advanced hydraulic fracturing testing and improvements of productivity with reduced expenditure

**Stage 5: Commercial Development**
- Project Reclamation

Exploration Tasks
- Determination of reservoir properties along with stimulation and production optimization requires a number of years of testing and pilot projects.
- Pace of development is largely dependent on technical success, economics and market conditions and availability of equipment and materials.
Micro-seismic monitoring of the multi-stage fracture stimulation program allows:

- Visualization in real time of fracture propagation enabling adjustments to be made during the stages to ensure that the fractures are staying within zone
- Identification of previously unrecognized geological barriers
- Determination of optimal horizontal well spacing
- Determination of stimulated rock volume (SRV) for reserve determination

Dots represent individual micro-seismic events that occur during the fracturing of the reservoir.

Track of the horizontal wellbore

Micro-seismic monitoring of fracture events for each staged stimulation allows the lateral and vertical envelope of the fracture stimulated rock to be determined.

Courtesy of Nexen, 2011
Other Challenges that may impact the growth of the unconventional resource industry in Mexico

✓ Permitting and Bureaucratic Delays
✓ Environmental standards

Infrastructure
✓ High number of personnel and drilling rigs
✓ Daily fracturing services
✓ Intensive traffic of drilling rigs and heavy equipment
✓ Liquids separation plants

Safety and Environment
✓ Safe operations
✓ Wildlife protection and restoration of areas
✓ Aquifer protection, recycling water, metal containers, deep latrine wells
Increased expectations for environmental standards has increased the cost of shale gas exploration and development.

Industry is expected to adopt much more rigorous operational and environmental standards than have been the norm in the past all of which add to the F & D cost of any project.
Effective exploration practices require modern technologies to optimize productivity and manage costs.

State of the art drilling and completion equipment will be necessary to effectively explore and develop the unconventional resource potential – This technology and expertise in most cases, will need to be sourced from outside Mexico.
Development of Canada’s unconventional resources has embraced technology and innovation as well as addressing market challenges and environmental considerations.

2004-2006
- Reservoir Characterization
  “Science of the reservoir”

2006-2008
- Technological Application
  “How do we produce the resource”

2009-2010
- Technological Evolution
  “How do we produce the resource at economic rates given the North American market issues”

2011-2012
- Technological Innovation
  “How do we produce the resource in a responsible manner that respects industry commitment to society and the environment”

2013 - ?
- Technological Transfer
  “How can we transfer our knowledge to new plays in different geological settings as well as geographic environments”

Technological progression in resource development is based upon continuous improvement to achieve greater economic returns but influenced by outside forces such as market, environment and opportunity.