Shale Gas in Quebec’s Sedimentary Basins*

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Abstract

Keen interest for Shale Gas remains high in the Southern Quebec Lowlands. During 2009 to 2010, fifteen shale gas wells were drilled in the basin. The calcareous and organic-rich Middle Ordovician Utica Shale is the main target of this recent exploration effort. To date, most operations have been performed in the medium to deep depth thermogenic Shale gas play (1,000-2,000 meters), located in the central part of the Saint Lawrence Lowlands. With OGIP estimates ranging from 75 to 300 Bcf per section, the deep play is definitely considered to be promising. Publicly released information from the different tested areas in the basin expressed a potential gas-in-place over 200 Tcf (OGIP). After drilling exploration wells in order to delineate a “sweet spot”, companies have now focused their effort on determining the highest gas-prone unit within the Utica. Discussions concerning pilot-test projects are also beginning.

While testing the deep shale potential, JUNEX also has begun to evaluate the potential of the other shale gas plays. Only over the last two years, Junex started the evaluation of gas potential in three other shales:
1. Shallow to medium depth thermogenic shale gas;
2. Overthrusted shale gas;
3. Intra-Appalachians sub-basin shale gas.

The three plays are described based upon the data available regarding the basin geology, shale mineralogy, organic matter type, gas geochemistry, structural style and infrastructure access. The characteristics of the plays, from a geological, geochemical, structural and geophysical perspective, are reviewed. With the addition of the acquisition of a large geoscience database, new exploration efforts undertaken by JUNEX include:
Exploration well in the deep and shallow shale plays;
Propane frac stimulation in the shallow shale play;
Exploration in the new intra-Appalachian basin;
Scheduled for fall 2010: two exploration wells in the overthrusted shale play.

Selected References


Shale Gas in Quebec’s Sedimentary Basins

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Introduction: Exploring a large portofolio

• Created in 1999 & listed on the TSX Venture Exchange in June 2001 with a Quebec-based Management team & Board members (significant E&P, energy & business experience);

• First Mover in the St. Lawrence Lowlands Basin - built a strong land position >1.5 million acres from 2002 to 2005. Largest Landholder in the Utica Shale Gas Play - 1,064,644 gross acres in Utica Play (849,248 net acres);

• The first "pure play" shale gas partnership deal done in Quebec – JNX and Forest Oil in 2006 for the Bécancour Block;

• Significant exposure to all Shale Fairways (Utica Shallow, Deep & Structured, Appalachian Shales);

• JNX owns & operates two drilling rigs – better cost control & timely access to drilling equipment for its projects. JNX is largest E&P direct employer of Quebec residents: total of ~ 45 employees (15 office & ~ 30 field employees).
Southern Quebec Paleozoic Shale Gas
Geology and Play Types

- Two shale basins:
  - St. Lawrence Lowlands;
  - Appalachian.
- Four potential shales:
  - Utica Shales (Ord.);
  - Lorraine Shales (Ord.);
  - Beauceville Shales (Ord.);
  - St-Francis Shales (Dev.).
To date, most operations have been performed in the Play 1 - medium to deep depth Shale gas (1,000-2,000 meters) - located in the central part of St Lawrence Lowlands.

**Play 1: Medium to Deep depth thermogenic shale gas**
- Utica and Lorraine (500 to 2,500 m) - Thickness: 100 to 400 m
- TOC: 0.5 to 2.5%
- Thermal Maturity: Condensate to Dry Gas
- Low deformation, moderate depth and with significant OGIP

**Play 2: Shallow to medium depth thermogenic shale gas**
- Utica and Lorraine (100 to 500 m) - Thickness: 100 to 200 m
- TOC: 0.5 to 3.0%
- Thermal Maturity: Condensate to Dry Gas
- Lower Pressure & OGIP, Liquid-rich, Lower drilling & completion costs

**Play 3: Overthrusted shale gas**
- Utica and Laurier (500 to 3,000 m) - Thickness: 100 to 700 m (thrusted)
- TOC: 0.5 to 5.0%
- Thermal Maturity: Condensate to Dry Gas
- Lowlands deformed zone, area with the highest OGIP and TOC

**Play 4: Appalachians shale gas**
- Beauceville and St-Francis (500 to 3,000 m) - Thickness: >500 m
- TOC: 1.0 to 5.0%
- Thermal Maturity: Dry Gas
- Deformed zone, higher TOC, higher POR

**Play 5: Biogenic shale gas**
- Utica (100 m) - Thickness: 50 m
- TOC: ~2.0%
- Thermal Maturity: Variable
- Very local, restricted to faulted zone area
Play 1: Medium depth to Deep Shale Gas
Play 2: Shallow to Medium depth Shale Gas
Play 3: Structured Shale (Overthrusted)
Play 4: Intra-appalachian Basin Shale Gas
Play 5: Biogenic Shale Gas
### Strategy:
Explore to identify and evaluate the « Best » Zones

### Building a large database

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<td>XRD, Thin-section, Shale Gas Log, Frac Fluid Sensitivity, Cap suction</td>
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<td>Coring (Porosity, Permeability, Density), Well log for Shale Gas</td>
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<td>HRAM, FMI, Cat-Scan, New Seismic (2D, Swath, 3D)</td>
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Three Shale Gas plays of the Quebec St Lawrence Lowland

Zone 1: Medium depth to Deep Shale Gas
Zone 2: Shallow to Medium depth Shale Gas
Zone 3: Structured Shale (Overthrusted)

• Average thickness = 180m
• Increased thickness to SE
Lower Lorraine and Utica Shales Gas

Gas in shales in the St. Lawrence Lowlands known for decades – however low gas prices, little infrastructure, and lack of pertinent technologies to "unlock" the gas precluded its development.

Dr. Roberto Aguilera, world-renowned petroleum engineer, expert in fractured reservoirs & member of JNX’s board, first published about the St. Lawrence gas shales in 1978 ("Log Analysis of Gas Bearing Fracture Shales in the Saint Lawrence Lowlands of Quebec," Paper SPE 7445 (1978))
Quebec’s Shale gas plays
Exploration activities

2006 to 2010
• 27 wells;
• 10 horizontal;
• Over $200 million invested;
• Emerging play;
• First pilot to start in 2011;
• Shale basin : 5,750 mi²

Operators : 
• Talisman (10 wells)
• JUNEX (6 wells)
• Forest Oil (2 wells)
• Canbriam (6 wells)
• Gastem (2 wells)
• Questerre (1 well)
Quebec Shale gas play history
Exploration Drilling activities

1st publicly released results from a horizontal frac job

... Frac job pending
General Stratigraphy of St Lawrence Lowlands Basin

Lorraine Shales:
- 600 to 2000 m
- Arenaceous shales/siltstones
- Sandstone interbed

Utica Shales:
- 100 to 500 m
- Dark brown to black calcareous shale

Importance of mineralogy for:
- Geological setting;
- Fracability measurement.

>50% Clay
<10% Carb
40% QZ

25% Clay
60% Carb
15% QZ

JUNEX (2008) modified
Analysis from Lowlands wells:
Results reported only for the Shale gas zone with the highest TOC

Northeastern Lowlands:
Utica with the highest TOC and Lower Maturity

Southwestern Lowlands:
Lorraine with the highest TOC

Appalachian Shale:
Highest TOC in the Beauceville
Permeability and Porosity

CT-Scan:
- Measure porosity;
- Characterized fracture network;
- Highlight sedimentary pattern.

Good permeability and porosity for a shale.
• Dissolution and dolomitization of calcite in Utica Shales will be a positive factor on porosity and permeability.

Meso-scaled fractures
• Micro-scaled fractures is possibly responsible for higher permeabilities in Utica Shales.
Isotope is presently the more accurate tool for thermal maturity evaluation in pre-Devonian basins explored in Quebec.

- Calculation is made on pre-Devonian rock to find the Vitrinite Reflectance equivalent.
Gas Geochemistry
Ethane Carbon Isotope Rollover

- Ethane Isotope Rollover is characteristic of high production zone;
- Ethane Isotope Rollover mapping constrains the best potential zone.
Biogenic Shale Gas

- Only one location recognized;
- Based on isotope analyses, gas found in other water wells or seeps are thermogenic Utica shale sourced.
- Mainly **Dry gas** with 80 to 98% methane;
- Liquid-rich gas found in the northeastern Lowlands area.
• Drilled in 2008 - Core taken in four shale zones;
• Mud gas, Geojar and core analysis correlations;
• Hydrocarbon analysis: Gas rich in propane and butane, significant presence of light crude oil (37°API);
• Shale Gas Propane Frac Stimulation in Fall 2009 – First time in Eastern Canada.
• First Shallow fracture stimulation of the Utica Shales (depths 436.5 to 473.5 meters).
• Perforations with 1 m³ of acid;
  Followed by injection of 61 tons of sand propelled by 251,000 L of propane;
• Production of 47 bbl oil and a gas flow (natural gas + propane) of 467 mcf/day – first 109 hours. Following this, the oil flow practically stopped and the average gas flow was 92 mcf/day. No sand or water was observed during the test;
• Demonstration that it is possible to adequately and safely frac the Shallow Utica Shales.
Overthrust Shale Gas Play

- Several gas occurrences in well drilled in 70’s-80’s (one producing field);
- Thick sequence of overthrusted shales and carbonates;
- Shale units:
  - Laurier Black Shale >1000 m : 1% TOC
  - Utica & Lorraine

St-Flavien Field
(7 bcf from Beekmantown Dol.)

Lyster Project

1. TOC = 5%
2. TOC = 3%
3. UTICA & LORRAINE
• Shale units in the condensate to dry gas window;
• Good correlations between higher TOC Shales and mud gas shows;
• Lyster Project - Two wells planned in 2010 - Multi-target play:
  • Target 1: Utica Shale (and equivalent thrusted shales)
  • Target 2: Thrusted dolomitized/fractured carbonates
  • Target 3: Deep Overpressurized Utica Shales

TOC(%) vs Depth(ft)

Ordovician Shales

Devonian Shales

TOC of Appalachian Shales, Southern of Quebec

Beauceville Shale
• Organic-rich shale;
• Dry gas window;
• Amorphous kerogen (Type II);
• Rapidly subsiding deep marine sedimentation;
• Good organic recovery;
• Bitumen particles are noted (some liquid hydrocarbon generation occurred);
• Pre-vitrinite time;
• Gas infrastructures;

Appalachian Shale Gas Play

Lower Devonian Shales
St-Francis Group
Poorly known stratigraphy

Middle Ordovician Shales
Beauceville Shale
Well recognized unit
• **Beauceville Shale**: Organic-rich quartzitic black shale

<table>
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<tr>
<th>ROUTINE CRUSHED CORE ANALYSES</th>
<th>Average</th>
<th>Variation</th>
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<tbody>
<tr>
<td>Density</td>
<td>2.62 g/cc</td>
<td>2.4@2.82</td>
</tr>
<tr>
<td>Gas Porosity</td>
<td>4.6%</td>
<td>0.7@9.6</td>
</tr>
<tr>
<td>Permeability</td>
<td>326 nD</td>
<td>46@749</td>
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</tbody>
</table>
Recently reported results for various tests

- The results revealed indicate production potential comparable to those of other basins;
- Over the next year, the results from eight new wells should be made public.

**Learning Curves Comparison between the Fayetteville and the Utica Shales**

(Source: Web Sites of Companies Operating in Shale Gas Reservoirs, Questerre, Chan et al., 2010).
Pressure Gradient Variation

Talisman St-Edouard and Leclerville wells

Overthrusted Shales

12 MMcfd Initial Production
First long-term testing
Stimulated Horizontal Well - Deep Shale

Talisman St-Edouard HZ No1
St. Lawrence Lowlands Shales

Possible gas rate after one year to be 1 MMcf/d?
Evolution of the OGIP Calculation for St. Lawrence Lowlands Shales

- **Zone of Interest**: Best Estimate OGIP

**OGIP (Bcf/section)**

- 250
- 200
- 150
- 100
- 50
- 0

**Sources**:
- Aguilera (1978)
- Encana (2007)
- Forest Oil (2008)
- Talisman Energy (2008) Lorraine
- Talisman Energy (2008) Utica
- Quaterre (2009)
- Junex (2009) Nicolet
- Junex (2010) Regional
- Chan et al. (2010)

**Average**: 116 Bcf/sect.
Land Management Challenges
Population density and shale gas exploration

- GIS/Mapping tool help the land management of shale gas exploration;
- Main exploration activities occurred in area with less density of population (0 to 10 persons/ km²);
Land Management Challenges
Agriculture and shale gas exploration

- Green colors (Class 1-2-3) represent the area with the highest soil potential for agriculture;
- Main exploration activities occurred in Class 4 area;
- Soils in Class 4 have very serious limiting factors that restrict the range of crops or require special conservation measures or have two disadvantages.
- Soils in Class 5 to 8 have less potential.
1. The Shale Gas in Province of Québec are promising plays:
   - Widespread source of gas – Utica and Lorraine Shales;
   - Utica Shales: Proven fracturability in horizontal lateral: IP rate for 30 days exceed 5,000mcfd;
2. High potential Utica Shale Gas:
   - Estimated (average) OGIP for the most advanced area: 116 Bcf/section;
   - Pilot tests scheduled in 2011;
3. JUNEX is present in the heart of the action and develops new areas:
   - St Lawrence Lowlands:
     - Currently evaluating shale gas potential of the overthrusted play;
     - Continually analyzes data to identify new drill targets;
   - Appalachian Shales: geochemistry, seismic and strat-well;
4. Creation of the Quebec Oil and Gas Association (QOGA), and also, development of a Shale Research Consortium with the National Research Institute (INRS-GSC);
5. We shall have to work with population and keep them well informed of our progress to get social acceptability.
Acknowledgments

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Luc Massé, reservoir engineer.

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Source: JUNEX (2009)