Utica and Other Ordovician Shales: Exploration History in the Quebec Sedimentary Basins, Eastern Canada*

Jean-Sebastien Marcil¹, Peter K. Dorrins¹, Jérémie Lavoie¹, Nabila Mechti¹, and Jean-Yves Lavoie¹

Search and Discovery Article #10451 (2012)**
Posted October 22, 2012

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¹Junex Inc., Quebec-City, QC, Canada (js_marcil@junex.ca)

Abstract

Since the announcement in April 2008 about the potential of shale gas in the Staint Lawrence Lowlands in southern Quebec, 25 new wells have been drilled in the area. This announcement has created a small revolution in a region known worldwide for its hydroelectric potential but definitely not for its oil potential. The Ordovician calcareous shales of the Utica Group, rich in organic matter, are the main target of recent exploration efforts. This renewed interest marks a new stage in the history of oil exploration of sedimentary basins in Quebec.

The cradle of oil exploration in Canada, the Province of Quebec, has seen oil rigs searching this territory since the 1860s. Several exploration wells have been drilled without much success, but several gas shows were encountered in the shales. The first tests with the objective to assess the gas potential of the Ordovician shale were done in the early 1970s by Shell Canada and SOQUIP. Obviously, the tests did not met the expected economic goals. The same result was realized for the unsuccessful attempt to achieve a horizontal well in the Lorraine Shales in 1992. It was not until 2004, after using knowledge of successful development results in the Antrim Shale of Michigan and the Barnett Shale of Texas, that Junex initiated an evaluation of modern shale gas potential of the Ordovician of Quebec. In partnership with Forest Oil, the vertical well A250-Junex Becancour No.8, was drilled and tested using the technique of massive hydraulic fracturing during the year 2007. The positive results of these tests, that will be subsequently repeated by other operators in the basin, will launch a series of exploration wells to estimate the gas potential of the Utica Shales of the Saint Lawrence Lowlands.

Current knowledge of the geology of the region has led operators to subdivide the shale gas potential in different play types. To date, most operations were performed in about 1/3 of the shale basin in the deep thermogenic shale gas play (1000-2000 meters), located in the central plain of the Staint Lawrence Lowlands. With OGIP estimates ranging from 120 to 160 BCF per section, the deep play is considered promising.
Based on exploration work conducted in recent years in Quebec, five play types have been described: 1) thermogenic shale gas or liquid-rich shale at shallow to middle depth, 2) overthrust shale gas, 3) biogenic shale gas, and 4) intra-Appalachian sub-basin shale gas, and last but not least 5) the oil-rich shale of the Macasty Formation (Anticosti Basin).

The exploration history of Ordovician shales in Quebec includes a combination of science, intuition, perseverance and adaptability. But the premises of the story remain similar to those found in other sedimentary basins: the presence of brittle shale which acted as a major source rock. The people living in Quebec are energy intensive and more than half of this energy comes from oil and natural gas. The development of oil and gas potential of Québec will generate significant economic benefits for citizens and will have positive impacts on the competitiveness of its sources of supply.

Selected Reference

Utica and Other Ordovician Shales: Exploration History in the Quebec Sedimentary Basins, Eastern Canada

Jean-Sébastien Marcil, Exploration Manager, Junex inc.
Peter K. Dorrins, President and COO, Junex inc.
Jérémie Lavoie, Geophysicist, Junex inc.
Nabila Mechti, Petroleum Geologist, Junex inc.
and
Jean-Yves Lavoie, CEO, Junex inc.

41st Annual Eastern Section AAPG Meeting
Cleveland, Ohio
September 25th, 2012
Quebec's Utica & Macasty Shales in North America

5,750 mi² shale basin
Quebec is one of Canada’s largest energy markets: 300 Mboe/year

Daily oil consumption: 410,000 bbl (transport)

Annual gas consumption of 180 Bcf

80% of gas consumers are industrial and commercial

Gas network covers several areas in the Utica Shale Fairway

Infrastructures: 2 oil refineries; 3 gas storage facilities; pipeline network.
O&G Exploration in Quebec - Relatively “Immature”

- Total Number of Oil & Natural Gas Exploration Wells Drilled in Quebec
  - ~ 450 wells drilled since 1859 into Paleozoic-aged rocks
  - Most recent well finished drilling December 2010 – next well spudded late June 2012 by JNX (conventional oil)

* SPE Paper 7445 on Lowlands Gas Shales (Agullera, R., 1978)
* 1st Public Presentation on Utica Shale Potential (Junex, 2004)


Strategic Environmental Evaluation on Shale Gas (ends Nov 2013)
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, 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))
Several gas show from water wells were mapped.
First Technical Evaluation of the Shale Gas Potential

Roberto Aguilera in 1978
Fractured Shale in the Villeroy Area

SPE 7445

LOG ANALYSIS OF GAS-BEARING FRACTURE SHALES IN THE SAINT LAWRENCE LOWLANDS OF QUEBEC

By Roberto Aguilera, Member SPE-AIME, PQQUIP

Extract from the paper:

Gas-in-place for the 150 sections mapped so far is estimated at 885 BSCF (25.06 x 10⁸ m³). Consequently, the 90 initial "development" wells are expected to recover 25.5% of the original gas-in-place in a 20 year period.

And from a recent interview with Roberto Aguilera (2009)
The New Era - Shale is a « play » now

Start with Junex in 2004 to 2006: Resource Play Identification

Gas encountered in the Lorraine & Utica Formation

Cross-Section of Bécancour’s Wells

Bécancour’s Field
Unconventional & Conventional Opportunities in the Province of Quebec, Canada

Offered by AMQUE, U.L.C.
NAPE February, 2007  Booth #1845
Presented by: Jim Morabito, AMQUE Partner
First Press Release of Positive Results (2008)

2008 Analyst Conference
New York City
April 1, 2008

Utica Shale - St. Lawrence Lowlands, Quebec

<table>
<thead>
<tr>
<th>Large Resource Potential and Acreage</th>
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<tr>
<td>4.1 Tcf of net resource potential</td>
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<tr>
<td>Low cost of entry</td>
</tr>
<tr>
<td>339,000 gross acres, ten year term</td>
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<tr>
<th>Excellent Rock Properties</th>
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<tbody>
<tr>
<td>Comparable to Barnett Shale</td>
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<tr>
<td>At least two prospective Utica horizons</td>
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<tr>
<th>Test Concept</th>
</tr>
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<tbody>
<tr>
<td>Test rates up to 1,000 Mcf/d</td>
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<tr>
<td>Significant gas content demonstrated</td>
</tr>
<tr>
<td>Next Step - Drill Horizontally</td>
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<tr>
<th>Existing Infrastructure and U.E. Market</th>
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<tr>
<td>Easy access to pipelines</td>
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<tr>
<td>Premium pricing to NYMEX</td>
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<table>
<thead>
<tr>
<th>Utica</th>
<th>Barnett</th>
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</thead>
<tbody>
<tr>
<td>Depth (ft)</td>
<td>2,300 - 6,000</td>
</tr>
<tr>
<td>Thickness (ft)</td>
<td>500</td>
</tr>
<tr>
<td>Clay Content (%)</td>
<td>15 - 26</td>
</tr>
<tr>
<td>TOC (%)</td>
<td>1.0 - 1.1</td>
</tr>
<tr>
<td>Gas-Filled Porosity (%)</td>
<td>3.2 - 17</td>
</tr>
<tr>
<td>Pressure Gradient (psi/ft)</td>
<td>.45 - .90</td>
</tr>
<tr>
<td>Maturity (Ro)</td>
<td>1.3 - 2.0</td>
</tr>
<tr>
<td>Gas Price ($)</td>
<td>NYMEX + $15</td>
</tr>
</tbody>
</table>

"Rock Properties Comparable To The Barnett Shale But With Premium Gas Price"
Past Events

- Forest Oil Announces Utica Discovery
- St-Édouard Completion Results
- Gasland Film Premieres
- Gov't Announces BAPE
- BAPE Report Made Public
- SEA Evaluation Starts
- SEA Completed

Possible Future Events

(i.e. predictions may be inaccurate)

- New Hydrocarbon Act?
- BAPE Hearings Start
- SEA Committee Mandate Begins
- EPA Shale Gas Drilling Study Initial Results
- Macondo Blowout
- Start of ENGO campaign
- JNX Villeroy #1 TD
- Quebec Provincial Election
- Today
- Quebec Provincial Election?

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Southern Quebec Shale Wells ’08 (Utica & Other)

Well
- Vertical
- Horizontal

Rates in mcf/d

Max 1000

H 100 - 800

2600 (700)

22,000 (5,300 - 30-day)

100

450

1800

800

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Southern Quebec Shale Wells’10 (Utica & Other)

Well
- Vertical
- Horizontal
Rates in mcf/d

Max 1000

H 100 - 800

UTICA BASIN

2600 (700)

22,000 (5,300 - 30-day)

457

APPALACHIAN BASIN

ORDOVICIAN SHALES

DEVONIAN SHALES

Montreal

NEW YORK

VERMONT

NEW HAMPSHIRE

MAINE

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Quebec Shale gas play history

Exploration Drilling activities

St. Lawrence Lowlands Shale Drilling History

First Gas Testing in the Shale  Shale Gas Exploration Wells (Vertical test)  First Horizontal Wells

Well length (TD-mkb)

0  500  1000  1500  2000  2500  3000  3500  4000

Gas Rate (mcmfd)

0  0,01  0,10  1,00  10,00  100,00


Well ID (MRNFP #)

1st publicly released results from a horizontal frac job

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GIS/Mapping tool helps land management of shale gas exploration

Main exploration operations performed to date in area with lower population density (0 to 10 persons/km²)
Green colors (Class 1-2-3) represent the area with the highest soil potential for agriculture.

Main Utica exploration operations to date mainly 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.

Southern Quebec Appalachian Shales in area of lesser agricultural potential than Lowlands.
 SOURCES: JUNEX

SAINT LAWRENCE LOWLANDS ORDOVICIAN SHALES GAS

Taconian Stage

(Lavoie et al, 2007)

Unconformity - Utica-Lorraine contact
Evidence of shallow water environment

SNC Soligaz, Montréal-Est No 3 (A206)
CENTIMÈTRES

FORELAND CARBONATE
DEEP FORELAND CLASTIC
PROXIMAL CLASTIC

PIGGY-BACK SEDIMENTATION

FORELAND CARBONATE
DEEP FORELAND CLASTIC
PROXIMAL CLASTIC

PIGGY-BACK SEDIMENTATION

CENTIMÈTRES

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Prospective Shale Intervals – Ordovician-aged Utica Formation & Lorraine Formation Shales

Industry is principally focused on Utica Shale at this time

Utica - mainly black, organic-rich, limey shale with significant gas content in many areas

Widespread in St. Lawrence Lowlands

>50% Clay
<10% Carb
40% QZ

25% Clay
60% Carb
15% QZ
St. Lawrence Lowlands

Play 1: Medium depth to Deep Shale Gas
Play 2: Shallow to Medium depth Shale Gas
Play 3: Structured Shale (Overthrusted)
Play 5: Biogenic Shale Gas

Other Basins*

Play 4: Intra-Appalachian Basin Shale Gas
Anticosti: Macasty Shale (Liquid-rich shale)
Gaspésie: Fortin Mudstone (dry gas shale)

* Less explored. Not all presented

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Yamaska Fault Zone

Logan’s Line

Quebec City/St-Augustin, Portneuf, Champlain/Batiscan, Assomption Blocks

Bécancour/Champlain, Nicolet, S Richelieu, St Simon, S Richelieu Blocks

Lyster and St-Simon Blocks

Utica Play Fairways

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“Liquids-Rich” Shallow to Medium Depth Thermogenic Shale Gas
- Thickness – 100 to 220 m
- TOC – 0.5 to 3%
- Maturity – gas condensate to dry gas
- Gas Type – thermogenic, liquids-rich
- Junex Acreage ~370,000 net acres

Medium to Deep Thermogenic Shale Gas
- Thickness – 150 to 400 m
- TOC – 0.5 to 2.5%
- Maturity – gas condensate to dry gas
- Gas Type – thermogenic
- Junex Acreage ~250,000 net acres

Structured Thermogenic Shale Gas
- Thickness – several slices of 100 to 200 m
- TOC – 1 to 5%
- Maturity – gas condensate to dry gas
- Gas Type – thermogenic
- Junex Acreage ~230,000 net acres
Oil molecule size ranges from 0.5 to 3 nm (0.0005 to 0.003 microns)

Methane molecule size is 0.4 nm (0.0004 micron)
Utica Shale Source Rock

- Majority of the biomarkers, as well as isotope ratios, suggest that the oil is connected to Ordovician Shale.
- The observed biomarker and isotope ratio differences are likely resulted from some facies changes within the source rock and/or maturity variations.

C27-C28-C29
\( \alpha \alpha \alpha R \) Steranes

m/z 217: Steranes

Type II Marine Kerogen
- TOC range from 2.5 - 5.0 wt.%
- Amorphous organic matter (amorphinite)
- Vitrinite reflectance equivalent is ~0.90%

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A good estimate of TOC\textsubscript{original} is an important element when using the mass balance approach for the calculation of OGIP / OOIP.

Assuming an original S\textsubscript{2} of 12 kg\textsubscript{HC}/ton\textsubscript{Rock} with an average thickness of 150 m, the oil generation of the Quebec Utica Shale reach 16 MMbbl/section.
Defining the exploration fairways

PLAY TYPE
- SHALLOW AND MEDIUM DEPTH SHALE GAS
- DEEP SHALE GAS FAIRWAY
- STRUCTURED SHALE GAS WITH DEEP UNTESTED POTENTIAL

GAS NETWORK
- PROPOSED GAS NETWORK
- RECENT WELLS

UTICA BASIN

NEW YORK

VERMONT

NEW HAMPSHIRE

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Pressure gradient data for some Shale zones over the Lower Décollement

Increasing pressure gradient with depth

Shale Units are largely overpressured

Pression gradient map important to identify favorable areas, as demonstrated in the Haynesville Shale (Brittenham, 2010)

(modified from Lavoie et al, 2010)
Talisman St-Edouard and Leclercville wells
12 mmcf/d IP (5.3 mmcf/d 30-day)

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?

Microseismic events confined to +/- 50 m of wellbore

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North American Shale Plays - Quality Comparison

- Overpressurized: gradient > 0.45 psi/pi;
- Gas in place (GIP) > 75 Bcf/section;

Some shale plays are economically viable below these conditions.
North American Shale Plays - Potential Recoverable Gas*

Locally in the Oil to Condensate Fairway
QC Utica Wet Gas to Oil Window Shale Play
16.6 MMBOE OOIP/section

*Risked Recoverable (Tcf)

From the EIA report but excluding the Mexican Eagle Ford and Marcellus Shales; totaling over 800 Tcf
Coincidence of Liquids-Rich Belt with part of Shallow-Medium Depth Shale Gas Fairway (mostly JNX land)

Liquids-rich gas found in the NE Lowlands

Condensate/Gas Belt overlaps portions of all three fairways

Isotopic analyses indicate gas found in other water wells or seeps are thermogenic, Utica shale sourced

Condensate to Dry gas
80 to 98% C$_1$

Liquid-rich gas
Mud gas, Geojar and core analysis correlations

St-Augustin #1A/B - Cutting Oil Crossover

St-Augustin Well Geochemistry

From Humble/Weatherford Geochemical Logs

“Oil Effect”
- when oil crosses TOC in absolute value, producible oil or gas may be found
- this suggests that around 100 mg HC/g TOC is the saturation threshold for oil

Ref: Javie (2010)

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Propane frac of Liquids-Rich Utica

- Propane frac selected due to presence of liquids-rich gas in Utica
- Little formation damage should be induced (propane already present in gas, no phase trapping)
- Rapid frac fluid clean-up with high recoveries
- Possible improvements in productive capacity (no frac fluid left behind)

- Zero frac water to dispose of
- If frac results fall below expectations, then other frac methods, such as Slick Water fracs, can still be done in the same wellbore
- First propane frac of a Gas Shale in Eastern Canada

October 2009

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NEAmerica – Ordovician Shale Correlation

Ohio State
Tuscawaras County, Central Ohio
Ohio Geological Survey Co2 No. 1
APR 3415723334

New York State
Northern Otsego County, Central New York
Richelieu Valley, SW Lowlands

Province of Quebec
Bécancour Area, Central Lowlands
Anticosti Island, Northeastern Lowlands

Source: Martin (2010)

Logs vertical and horizontal scales different between Ohio, New York and Quebec

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Ordovician Shale Thermal Maturity Zonation

*OOIP*: 33,5 MMbbl/mi²

*From September 2011 - Netherland Sewell and Associates Inc Resource Estimates Independent Report for South Anticosti Island*
JNX has significant land position of 233,275 net acres, mostly in the Deep Macasty Fairway.

12.2 Billion Barrels Undiscovered Shale Oil Initially-in-Place ("OIIP") (NSAI P50) on JNX lands.

225 line-km seismic survey completed.
• Macasty Shale is the stratigraphic equivalent of the Utica Shale Lowlands

• Thicker in Deep Macasty Fairway than on other side of Jupiter Fault zone (ave. 80m vs 40m at Chaloupe well)

• “Brittle” mineralogy - ave. 50% Quartz + Feldspar, 35% Carbonate, and 15% Clays

• Good to Excellent Organic Richness with an average TOC content of 2.6 wt % (range of 1.2 to 3.7 wt %)

• Good Porosity – average porosity of 6.3% (range of 4.0 to 8.6%)

• Deep Fairway – dominantly in Oil window of thermal maturity

• Higher reservoir pressure = greater reservoir energy in Deep Macasty Fairway
Macasty Shale - Seismic Profile

Macasty Shale

JPZ
<table>
<thead>
<tr>
<th>Period</th>
<th>Epoch or Age</th>
<th>Group</th>
<th>Formation</th>
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<tbody>
<tr>
<td>Tremadocian</td>
<td>Lower Tremadocian</td>
<td>Lower Tremadocian</td>
<td>Lower Tremadocian</td>
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<tr>
<td>Ordovician</td>
<td>Lower Ordovician</td>
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<td>Lower Ordovician</td>
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<tr>
<td>Silurian</td>
<td>Lower Silurian</td>
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<tr>
<td>Devonian</td>
<td>Lower Devonian</td>
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</tr>
<tr>
<td>Carboniferous</td>
<td>Lower Carboniferous</td>
<td>Lower Carboniferous</td>
<td>Lower Carboniferous</td>
</tr>
</tbody>
</table>

**Macasty Formation**
Massive black shale unit

**TOC (wt%)**
- 2011 Data (UNEX)
- 1980 Data (INRS)
- 1980 Data (Shell-GSC)

**Macasty shale sampling**
- Pre-Junex: ~4 samples
  - Upper Macasty only
- Junex (2011): 8 samples (2x)
  - All unit covered

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Anticosti Island - Macasty Shale Oil Potential

Utica-Point Pleasant and Macasty Potential vs Top 20 US Giant Oil Field Discoveries

Macasty Shale Oil Potential competes with the largest Oil Discoveries

Possible Upside
Higher REC + Thickness


October 6th, 2011

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- **Remaining Hydrocarbons**
  - S1 – amount of free oil and gas already generated in the rock
  - S2 – amount of hydrocarbon generated from thermal cracking of non-volatile organic matter (kerogen)
- **Tmax** – temperature of maximum release of hydrocarbons

- **Production Index** – $S1 / (S1 + S2)$
  - Ratio of Already Generated hydrocarbons to Potential Hydrocarbons
  - Low ratio – immature or extremely post-mature
  - High ratio – mature stage or contamination
Comparison of Macastty to Utica & Eagle Ford

KEROGEN CONVERSION AND MATURITY (Tmax) - EAGLE FORD SHALE (TX)

- Immature
- Oil window
- Condensate - Wet Gas Zone
- Dry Gas Window

- Stained or contaminated
- Intensive Generation
- Expulsion
- Oil to Wet Gas Window Wells
- Gas Window Wells
- Hawkville Field
- Oil Window Wells

- Low Level Conversion
- High Level Conversion
- Overmature

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Comparison of Macasty to Utica & Eagle Ford

KEROGEN CONVERSION AND MATURITY (Tmax) - UTICA (QC)

- Immature
- Oil window
- Condensate Wet Gas Zone
- Dry Gas Window

Production index (PI)

Tmax (°C)

Stained or contaminated

Intensive Generation

St-Augustin Shale Oil Wells

Shallow Wells

Becancour Condensate Wells

Becancour Deep Dry Gas Wells

Low Level Conversion

High Level Conversion

Overmature

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Comparison of Macasty to Utica & Eagle Ford

KEROGEN CONVERSION AND MATURITY (Tmax) - MACASTY (QC)

- Immature
- Oil window
- Condensate - Wet Gas Zone
- Dry Gas Window

Production index (PI)

- Arco Well
- Deep Fairway
- Roliff Well
- Shallow Wells
- Stained or contaminated

Tmax (°C)

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The Shales in Province of Québec are promising plays:

- Widespread source rocks - Utica, Lorraine & Maasty Shales
- Utica Estimated (average) OGIP for the most advanced area: +100 Bcf/section
- Maasty Shale OIIP potential about 40 billion barrel of oil

**Utica Shales solely:**

- High-quality resources - High BTU (heating value) Liquids-rich Gas and Oil
- Demonstration of gas production rates (Utica)
- Existing infrastructures & local market
- Utica Shales: Proven fracturability in verticals & horizontals

**Impacts on the Resources Exploration all over the province:**

- Re-looked at the Anticosti, Appalachian and Gaspesie Basins Potential
- Paradigm Shift in the way Quebeckers see the energy potential of their land
- New Hydrocarbon and Mining Act

**SEA Report current works:**

- Science reports recently released (http://ees.gazesthiste.gouv.qc.ca/en/)

**Newly Elected Government:**

- With a strong desire to increase the Energy Independence of the province in a very high level Environmental protection.
Acknowledgments

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Nabila Machtli, exploration geologist
Bertrand Marcotte, field geologist
Daniel Cantin-Plante, mapping specialist
Luc Massé, reservoir engineer

Geological Survey of Canada – Quebec City office
Denis Lavoie, Geologist and Research Scientist

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