Located in the Gulf of St. Lawrence in Quebec, Anticosti Island extends over a length of 220 km and a maximum width of 56 km and covers an area of 7,943 km² (3,103 mi²). Anticosti is a large ESE-WNW oriented rhombohedral shaped structure situated along the Laurentia passive margin that extends from western Texas to Newfoundland. The geological units are of Paleozoic age, ranging from the Cambrian to the end of Silurian.

In 1970, ARCO drilled a stratigraphic well at the deepest point of the Island (3,838.2 m). It leads to the clear identification of a major source-rock, the middle Ordovician-aged Macasty Shale. Hydrocarbon expulsion from Macasty Shale reaches 75 billion bbl over the island with 2/3 generated in the "deep fairway". A second exploration phase targeted dolomitized carbonates located on the upper side of the Jupiter Fault zone. Shell Canada wells, drilled in the 90s, demonstrate the occurrence of HTD reservoir in Romaine and Mingan carbonates formation. The current exploration phase recognized the potential of the Macasty Shale as a liquid-rich resource play (potential for light oil/condensate production). Technical evaluation indicates that the level of thermal maturity observed thus far in the Macasty in the Deep Macasty Fairway compares favourably with published findings for the oil-rich Utica/Point Pleasant Shale and the Eagle Ford.

Resources assessment studies (P50 - Best Estimate) recently published by different groups corroborate the analytical results and the interpretation of the authors concerning the high hydrocarbon potential of the Anticosti Basin. In October 2009, a multidisciplinary team attached to the Geological Survey of Canada published a Petroleum Resource Assessment for the Paleozoic Succession of the St. Lawrence Platform. This report estimate the Resource in-place in the hydrothermally dolomitize carbonate at 957 million boe, mainly located in the Anticosti Basin. In July 2011, Corridor Resources published a Resource assessment report of the Macasty Shale. This report established the Total Resource Potential over an area of 1,550,000 acres at 33.9 billion boe, mainly located in the Shallow Macasty Zone. In September 2011, Junex Inc. published a Resource assessment report of the Macasty Shale situated in the Deep Fairway. This report established the Total Resource Potential over an area of 233,275 acres at 12.2 billion barrels.

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Nabila Mechti, Petroleum Geologist, Junex inc.
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and
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AAPG Annual Convention & Exhibition
Pittsburgh, Pennsylvania
May 20th, 2013
Located in the Gulf of St. Lawrence in Quebec, Anticosti Island extends over a length of 220 km and a maximum width of 56 km and covers an area of 7,943 km² (3,103 mi²). This presentation will cover the following key points regarding recent development of the Anticosti Basin exploration:

- Basin exploration history and review of the potential;
- Petroleum geology of the Anticosti Basin highlighted by recent research;
- The new structural map of Middle to Upper-Ordovician Carbonate sequence;
- Discussions on three different exploration plays in the Anticosti Basin;
- Perspectives and conclusions
<table>
<thead>
<tr>
<th>Topic</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Historical Data</strong></td>
<td>Review old well data, vintage aeromag, gravity &amp; seismic, reports</td>
</tr>
<tr>
<td><strong>Basin Geology</strong></td>
<td>Development of regional-scale basin models, local &amp; regional stratigraphy</td>
</tr>
<tr>
<td><strong>Shale Mineralogy</strong></td>
<td>XRD, Thin-section, SEM, Shale Gas Log, Frac Fluid Sensitivity</td>
</tr>
<tr>
<td><strong>Shale Petrophysics</strong></td>
<td>Coring (Porosity, Permeability, Density), Detailed petrophysics</td>
</tr>
<tr>
<td><strong>Organic Matter Type</strong></td>
<td>TOC/RE, Biomarkers, Kerogen thermal maturity</td>
</tr>
<tr>
<td><strong>Geochemistry</strong></td>
<td>Stable isotopes, composition, origin (biogenic vs thermogenic)</td>
</tr>
<tr>
<td><strong>Reservoir</strong></td>
<td>Initial pressure, Production test, DST, integrate RM and microseismic data</td>
</tr>
<tr>
<td><strong>Resource OIIP / OGIP</strong></td>
<td>Core analysis (Canister Desorption &amp; Adsorption Isotherms), GeoJar, TRAC</td>
</tr>
<tr>
<td><strong>Geophysics</strong></td>
<td>HRAM, FMI, CT-Scan, New Seismic (2D, Swath, 3D)</td>
</tr>
<tr>
<td><strong>Drilling</strong></td>
<td>Design, drilling fluids, well orientation, well evaluation, casing, cementing</td>
</tr>
<tr>
<td><strong>Completions</strong></td>
<td>Frac design (pressure, fluids, additives, proppants, pump rates, testing)</td>
</tr>
</tbody>
</table>
From the 60s to 2010, a total of 21 wells were drilled, some old one on geologically poorly-defined targets or more recently, on HTD sag targets identified with seismic data.

**Evaluation** | **Authors**
--- | ---
Romaine | SOQUIP (1980)
Romaine-Mingan | Shell (1999)
Romaine-Mingan | CGC (2010)
Macasty | Petrolia (2011)

**Play** | **Potential**
--- | ---
Macasty Sh. OIIP | 46,100 MMboe
HTD Mingan/Romaine | +500 MMboe
Vauréal/Ellis Bay | ?
Exploration History of the Basin

Phase 1: Consolidated, ARCO, SOQUIP and the National Research Institute (INRS) - 1960’s to 1980’s

**Pioneering the oil and gas exploration over a 8000 km² island**
Objectives: Stratigraphic well and exploration for oil in carbonate reservoir
Major results: Clear identification of a major source-rock, the middle Ordovician-aged Macasty Shale (in wells only, not outcropping in the basin) INRS reported: Hydrocarbon expulsion from Macasty Shale reach 75 billion bbl over the island with 2/3 generated in the “deep fairway” (Bertrand, 1986 and 1990). Oil generation dated Early Devonian time.

Phase 2: Encal, Corridor, Shell Canada, Hydro-Quebec PG and the Geological Survey Canada (GSC) - 1990’s to 2000’s

**Finding onshore an offshore-size discovery**
Objectives: Dolomitized carbonates located on the upper side of the Jupiter Fault zone
Major results: Discovery of well developed dolomitized reservoirs in the Mingan and Romaine carbonates - but the reservoir were flushed and full of salty water. Oil expulsion and migration dated Middle Devonian (Acadian) time (Lavoie, 2005).

Phase 3: Corridor, Petrolia and Junex - 2010’s

**The independents never give up**
Objectives: Dolomitized carbonates and liquid-rich shale
Major results: Recognized the potential of the Macasty Shale as a liquid-rich resource play (potential for light oil/condensate production)

---

**Petroleum System** | Late Ordovician Macasty Shale
---|---
**Exploration** | 21 exploratory wells drilled
**Thermal Maturity** | 0.6 to 1.8 %Ro eq.  
Tmax : 440 to 458 °C
**Source-rock depth** | 1 600 to 2 500 m
**Play identified in the basin** | Conventional:
  - HTD Carbonates: 1,500 to 3,000m
  - Unconventional:
    - MacAsty (liquid-rich): 1,500 to 2,500m
  - Hybrid:
    - Vauréal/Ellis Bay (fractured reefal limestones): 500 to 2,000m
  - Offshore (shallow water):
    - Chicotte (reef system): 1,000m
Review of the Petroleum Potential

Resources assessment studies recently published by different groups corroborate the analytical results and the interpretation of the authors concerning the high hydrocarbon potential of the Anticosti Basin.

- In October 2009, a multidisciplinary team attached to the Geological Survey of Canada published a Petroleum Resource Assessment for the Paleozoic Succession of the St. Lawrence Platform. This report estimate the Resource in-place potential in the hydrothermally dolomitized carbonate at 957 million boe (P50 - Best Estimate) mainly located in the Anticosti Basin;
- In July 2011, Halifax-based Corridor Resources published a Resource assessment report of the Middle Ordovician Macasty Shale. This independent report completed by Sproule established the Total Resource Potential over an area of 1,550,000 acres at 33.9 billion boe (P50 - Best Estimate) mainly located in the Shallow Macasty Zone;
- In September 2011, Quebec-based Junex inc. published a Resource assessment report of the Middle Ordovician Macasty Shale. This independent report completed by Netherland, Sewell, and Associates inc. established the Total Resource Potential over an area of 233,275 acres at 12.2 billion barrels (P50 - Best Estimate) mainly located in the Deep Fairway.
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.
The Middle Ordovician Carbonate basins in Quebec

T_{\text{max}}, \text{Vitrinite eq, C}_3/C_1, \text{oil analysis and depth map of the undeformed platform}

**Oil Window**
- \( T_{\text{max}} \approx 450^\circ \)
- \( C_3/C_1 \approx 0.17 \) (core data)
- Oil = 35.5 API

**Condensate window**
- \( T_{\text{max}} \approx 458^\circ \)
- Ro eq \( \approx 1.4\% \)
- C3/C1 \( \approx 0.01 \) (core data)

*From Pétrolière Press release, 2011/02/09
Data from Junex database and Thériault (2008)
Ordovician Shale Thermal Maturity Zonation

St-Augustin Shale Oil

OOIP*: 33,5 MMbbl/mi²

* From September 2011 — Netherland Sewell and Associates Inc. Ressource Estimates Independant Report for South Anticosti Island
Anticosti Basin

“Onshore Exploration with Offshore Potential”
Christian Viau, VP-Exploration of ENCAL (2001)

Area of exploration
Onshore: 25,000 km² (10,000 mi²) including 8,000 km² Anticosti Island
Offshore: 125,000 km² (49,000 mi²)
The geological units forming the island are of Paleozoic age, ranging from the Cambrian to the end of Silurian. The Middle Ordovician Macasty Shale is identified as the source rock of the hydrocarbon of the basin.
Anticosti Stratigraphy – 4000m of Carbonates
Stratigraphic Importance of the Atlantic Richfield Anticosti #1 well (TD: 12,620 fkb)

• Drilled as a deep stratwell, based on gravity data:
  • Reached the Grenville basement at 12,593 fkb;
• The well have been one of the more studied well in province of Quebec:
  • Including several new research techniques used in the 70's by the Petroleum National Institute (INRS-Petrole);
• Available data from the study of this well are priceless for exploration:
  a) Macasty Shale at this location shows the highest maturity attain by the source-rock over the island;
  b) The stratigraphic sequence penetrated by the well represents the thickest sedimentary succession available onshore;
  c) In the region of the well, it is possible that some post-Macasty units reach their maximum thickness (Jolliet and Jupiter Groups);
  d) The well encountered liquid and wet gas zone in Vauréal Limestones;
  e) The well encountered and tested a gas zone in the Romaine Dolomites (eq. Beekmantown/Ellenburger Formation);
  f) Bottom-hole temperature at 160°F, implying that the average temperature of the shale is greater than 100°F.
Due to the lack of well data and poor seismic data quality, questions remain concerning the interpretation of the deformed zone.
Geophysical coverage – pre-2010
Deep fairway X-Section Based on Regional Transect
2012 – Deep Fairway Geophysical Survey
2012 – Deep Fairway Geophysical Survey

Aerogravity Survey
2012 Seismic Lines
Accommodations
Exploration Wells

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2012 – Deep Fairway Geophysical Survey

- 225 line-km of 2D seismic survey completed;
- Numerous prospects identified (top 6 to be permitted);
- Position of the Jupiter Fault Zone in the subsurface is better defined.
Play 1: Dolomitized Ordovician Carbonates

Lavoie et al. (2009)
Work done by Shell and its partners at the end of the 90's led to the identification several seismic anomalies. Five of them were drilled and excellent quality HTD reservoir were discovered in the Ordovician carbonates.

Shell et al. Chaloupe #1 well seismic anomaly located in the shallow fairway
A DST from the Romaine Formation (1265-1305 m) demonstrated excellent permeability with formation water flow equivalent to 1651 barrels water/day. Intercrystal, vuggy, and fracture porosity occur in a 42 m (gross) interval.

Vuggy porosity seen in sidewall core (1258 m) from Chaloupe well.

Lavoie et al. (2009)

Lynch (2001)
Play 1: Preferred facies to chase
Play 2 - Macasty Shale

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Macasty Shale - Geology

- Macasty Shale belong to the Upper Ordovician Shale Sequence (Utica eq.)
- Thicker in Deep Fairway, southwest of the Jupiter Fault zone
- “Brittle” mineralogy - ave. 50% Quartz + Feldspar, 35% Carb., and 15% Clays
- Good to Excellent Organic Richness with an average TOC content of 2.6 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
"The Macasty Formation, for the entirety of Anticosti Island, could have generated the equivalent of about 178 billion barrels of hydrocarbons" (1987, Bertrand)

"The total quantity of hydrocarbons expelled from the source rock, and could have consequently migrated towards reservoirs, is evaluated to be the equivalent of about 75 billion barrels. Two-thirds of these hydrocarbons (67%) are sourced from the southeastern portion of Anticosti Island, in the area near the ARCO well, where the Macasty is presently buried at more than 1.5 km." (1987, Bertrand)

"Although the value of Tmax is abnormally low (447°C) in the Macasty Formation in the ARCO well, a value of 489°C is observed just below, at the top of the Mingan Formation (Trenton / Black River). This suggests that the Macasty Formation is fully within the (dry) gas zone (Ro vitrinite > 1.35%)…" (1987, Bertrand)
• Gamma Ray shows less high values due to organic matters transformation
• Macasty shale is thickening toward south-west

Thickness of the shale

<table>
<thead>
<tr>
<th></th>
<th>Carbonate</th>
<th>Quartz</th>
<th>Clay</th>
</tr>
</thead>
<tbody>
<tr>
<td>D007</td>
<td>33</td>
<td>49</td>
<td>18</td>
</tr>
<tr>
<td>D005</td>
<td>33</td>
<td>49</td>
<td>18</td>
</tr>
<tr>
<td>D013</td>
<td>33</td>
<td>49</td>
<td>18</td>
</tr>
<tr>
<td>D014</td>
<td>25</td>
<td>54</td>
<td>21</td>
</tr>
<tr>
<td>D010</td>
<td></td>
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</tbody>
</table>
• $T_{max}$ can define a general trend
Comparison of Macasty to Utica & Eagle Ford

**Comparison of Macasty to Utica & Eagle Ford**

**KEROGEN CONVERSION AND MATURITY (Tmax) - SHALE**

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

- Stained or contaminated
- Intensive Generation
- Expulsion

**Eagle Ford Shale**
- Stabilized Production References (74 wells)
- 3500m: Wet Gas Window (Newark)
  - 10,000 - 120,000 bbls/d
  - 30 - 40 MCF/d

**Ohio Utica Shale Oil**
- Chesapeake Initial Testing (Peak rates)
- 2000-2500m: Wet Gas Window
  - 900 - 1400 bbls/d
  - 3.0 - 9.5 MMCF/d

- JUNEX Macasty Shale
- Deep Fairway
- Anticosti Island
- Ohio State Utica Shale Liquid Production

- Outside of Deep Fairway (shallow side of Jupiter Fault)
- Low Level Conversion
- Shallow Macasty

- High Level Conversion
- Overmature

Production index (PI) \( \frac{S_1}{S_0 + S_2} \)

**Tmax (°C)**

- JUNEX
- Shallow Macasty
- Deep Fairway

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Fluid Inclusions Compared to Tmax

- Wet gas / Condensate window
- From Tmax
  - ~1600 to ~2600 mkb
- From Fluid Inclusion
  - ~ 1800 to ~2800 mkb

(Fluid inclusions from Lynch, 2000)
• Pressure is preserved by the fault and thickness of overlying shale

Lowlands  Anticosti- Arco

250 m of shale  250 m of shale

Mud increase to 1.6 kg/L (gradient of 15.6 kPa/m)  Mud increase to 1.12 Kg/L

Modified from Chi et al., 2010

Overpressure from HC Generation

From the independent assessment completed by Netherland Sewell and Associates in 2011, 12.2 Billion Barrels Undiscovered Shale Oil Initially-in-Place ("OIIP") (NSAI P50) on this lands (33.5 million bbls/mi² OIIP).
Both maps are at same scale
Both are Top Utica Structure Maps
Both have same contour interval (& color shading)
Black polygons at same scale on both maps
Deep Fairway: Higher reservoir pressure = greater reservoir energy
Deep Fairway compares favorably with Ohio Utica light oil belt (sufficient maturity in oil window as defined by geochemistry)
Play 3: Late Ordovician to Silurian Reefs

Copper (2001)

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Play 3: Late Ordovician to Silurian Reefs

Anticosti Reef Plays

<table>
<thead>
<tr>
<th>Formation</th>
<th>Siliciclastic CLASS</th>
<th>Siliciclastic OTHERS</th>
<th>Water Depth in metres</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chicotte Fm</td>
<td></td>
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<tr>
<td>Jupiter Fm</td>
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<td></td>
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<tr>
<td>Gun River Fm</td>
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<tr>
<td>Merrimack Fm</td>
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<tr>
<td>Beecscie Fm</td>
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<tr>
<td>Ellis Bay Fm</td>
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<tr>
<td>Vaureal Fm</td>
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</tr>
</tbody>
</table>

LEGEND:
- <0.1% Absent
- 0.1%-5.0% Rare
- 5%-10% Common
- 10%-50% Abundant
- >50% Abundant

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Play 3b: Offshore Silurian

Model and seismic example of Barrier reef complex (?) in Early Devonian strata, northern Gulf of St. Lawrence

Barrier reef complex

Anticosti

Preserve Porosity

hinge or shelf margin?

Line 82-1

Time in Seconds

100 km

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Very porous, lower Silurian (Llandoverian) limestones of the Chicotte Fm crop out in a narrow zone along the southwestern shore of Anticosti Island (Desrochers, 2006). These limestones consist of a dominant encrinite facies associated with microbial mud mounds. Multiple sub-aerial exposures punctuate the unit; nevertheless, the origin of the significant porosity in the encrinites (25 to 30 % in two grab samples) remains unknown. In the offshore part of the Anticosti basin, the nature and age of the sedimentary units overlying the Chicotte Formation are presently unknown. (Lavoie, 2009)
The Anticosti Basin present a high hydrocarbon potential with promising plays

Macasty Shales is a major source-rock with over 75 billion barrels generated

Play 1: Dolomitized carbonates (million barrels potential OIIP)

Reservoir potential proven in wells drilled in 90’s

Play 2: Liquid-rich shales (billion barrels potential OIIP)

Over 46 Millions of barrel of undiscovered oil in place has been defined (P50) on Anticosti island

Based on geological feature, the southwest part of the island show better potential:

- In the late oil/condensate window with possible higher pressure;
- Thicker shale section with a higher OIIP (33.5 MMbbl/section based on NSAI P50)

Play 3: Reefs/Bioclastics Limestones (potential to be studied)

New exploration opportunity to be tested

Offshore exploration still under moratorium
Question to be answered by well drilled in the deep fairway

Is the petroleum system correctly sealed and overpressure?

What type of hydrocarbon remain in the system?

Maintain the Technical Toolbox

Differentiate between data & interpretations

Re-visit and question these in light of evolving technologies

In an ideal world, all different types of data (geology, geophysics, geochemistry, engineering) pertaining to the same rocks should tell the same story...if not, then dig deeper — (i.e. sort-out discrepancies)

Well-tuned geochemistry tied to well data & other data can aid in identifying prospective areas

Social and political impact of the last ten years of exploration in the province

Paradigm Shift in the way Quebecers see the energy potential of their land
Acknowledgments

Junex Inc., Management and Technical Staff:
Peter K. Dorrins, geologist and President-COO
Jean-Yves Lavoie, geological engineer and CEO
Jean-Sébastien Marcil, geologist and Exploration Manager
Jeremie Lavoie, geological engineer and geophysicist
Nabila Mechti, 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

Université d’Ottawa – Geology Department
André Desrochers, Director and Professor

Schulich School of Engineering, University of Calgary
Roberto Aguilera, Professor and President of Servipetrol
Reefs during the multiple crisis towards the Ordovician–Silurian boundary: Anticosti Island, eastern Canada, and worldwide

Petroleum prospectivity of the onshore Gaspe and offshore Anticosti Basins, Eastern Canada

Hydrocarbon systems in the Paleozoic basins of eastern Canada — Presentations at the Calgary 2007 workshop
GEOLOGICAL SURVEY OF CANADA - OPEN FILE 5980


Dolomitization, platform collapse, and reservoir development in Ordovician carbonates of Anticosti Island, Gulf of St. Lawrence

Basin evolution in western Newfoundland: New insights from hydrocarbon exploration


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


Lower Paleozoic foreland basins in eastern Canada: tectono-thermal events recorded by faults, fluids and hydrothermal dolomites.

Anticosti Basin: Fairway Identification in an Emerging Shale Play using Basin Analogues and Recent Geophysical Data


Hydrothermal Dolomitization in Paleozoic Carbonates - Enhanced Fluid Flow and Foreland Basin Processes
D. Lavoie and G. Chi, Search and Discovery Article #50049 (2007)
Thanks and congratulation to Junex ‘s employees
Many thanks to our dedicated field geologist

« Discovery consists of seeing what everybody has seen, and thinking what nobody has thought. »

[Albert Szent-Györgyi]

In memory of Bertrand Marcotte, a passionate geologist and respected member of our community, who contributed to the advancement of our field and touched the hearts of many.

Bertrand Marcotte (1975-2013)