Oil and Gas in Ontario: 152 Years of Exploration and Production

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Outline

- Industry overview
- History of petroleum development in Ontario
- Geology of Ontario
- Ontario oil and gas plays
- Lessons for western Newfoundland
Petroleum Industries

• Oil and Natural Gas
  – 1200 oil wells, 1300 gas wells, annual production 570,000 bo, 8.5 bcf natural gas, 96 different producers
  – 50 wells/yr, 27,000 well records

• Hydrocarbon Storage in Geological Formations
  – 250 bcf natural gas in 35 depleted reservoirs, 380 wells
  – 22 million bbl refined petroleum products in 71 solution-mined caverns at Sarnia-Windsor area refineries/petrochemical plants – 95 wells

• Salt Solution Mining
  – 250,000 tonnes/yr, 30 wells
Industry participants

• Oil & Gas
  – Historically and presently exploration and production is dominated by small (mostly), Ontario-based operators
  – History of periodic interest from large Calgary-based and international companies
  – Small companies are low-cost, maintain operations through down-cycles, generate new plays, raise local capital
  – Local companies have grown into large national and international corporations with long-term economic impact; Imperial Oil, Union Gas, and former McColl-Frontenac (Texaco Canada), British-American Oil Co. (Gulf Canada) and White Rose (purchased by Shell Canada)

• Hydrocarbon Storage
  – Natural gas storage dominated by two large multi-billion$ companies – Enbridge and Union Gas
  – All cavern storage operations owned by large multi-billion$ petrochemical companies

• Salt solution mining
  – Two operations owned by large multi-billion$ corporations
Ontario Oil and Gas History & Firsts

- 1858 - first commercial oil well in North America at Oil Springs (and first oil spills)
- 1866 – first salt solution mining well at Goderich
- 1870 – first oil exports to U.S
- 1873 – first export of technology – first Canadian drillers leave for Indonesia
- 1889 - commercial gas production at Kingsville and Welland
- 1891 – first export of natural gas to U.S.
- 1913 – first offshore well in Lake Erie
- 1915 – first subsurface injection of natural gas for storage
- 1924 – Well Driller’s Act
- 1985 - year of peak gas production
- 1995 - year of peak oil production
- Precambrian crystalline rocks of Canadian Shield form core of the North American continent, > 1 billion years old.

- Sedimentary rocks deposited on top of these crystalline rocks around edges of the continent.

- Oil and gas production only in Michigan & Appalachian basins.
Tectonic Setting

- St. Lawrence and Hudson platforms: Extent of preserved Paleozoic bedrock
- Canadian Shield (Precambrian)
- Appalachian Orogen

Extent of preserved Paleozoic bedrock

- AA = Algonquin Arch
- FA = Frontenac Arch
- OA = Ottawa Embayment
- CS = Chatham Sag

Structure contour on top of Precambrian

Appalachian Structural Front

Structural arch

OGS 1992
• Regional dip to SW and locally into basins, 3-12 m/km
• Marine sedimentary rocks: limestone, dolomite, sandstone, shale, evaporites, up to 1400 m thick
Stratigraphy
### Ontario Oil and Gas Plays

<table>
<thead>
<tr>
<th>Play</th>
<th>Description</th>
<th>Depth m.</th>
<th>Cum. production</th>
</tr>
</thead>
<tbody>
<tr>
<td>DEV</td>
<td>Structural traps in fractured Devonian carbonates and sandstone – structural domes related to differential salt dissolution</td>
<td>100 - 150</td>
<td>44.5 mmbo</td>
</tr>
</tbody>
</table>
| SAL  | middle Silurian carbonates  
- pinnacle, incipient and patch reefs  
- fault traps                      | 300 - 700 | 14.6 mmbo  
728 bcf  
250 bcf gas storage capacity |
| CLI  | Lower Silurian sandstones basin-centre stratigraphic trap                  | 150 - 500 | 0.05 mmbo  
461 bcf |
| ORD  | Ordovician carbonates – hydrothermal dolomite reservoirs                  | 800 - 850 | 23.1 mmbo  
41.2 bcf |
| CAM  | Cambrian sandstones – stratigraphic traps, fault traps                    | 700 - 1200 | 5.2 mmbo  
30.5 bcf |
Ontario Oil and Gas Plays

Devonian carbonate structural traps

middle Silurian carbonate reefs & structural traps

Lower Silurian sandstone

Ordovician hydrothermal dolomite

Cambrian sandstone
DEV: Devonian structural traps

Devonian Play
Devonian structural traps
SAL: middle Silurian carbonates - reefs
Silurian Reefs

- MICHIGAN BASIN
  - Lake Huron
  - Lambton County

- ONTARIO PLATFORM
  - Kent County
  - Essex County
  - Pinnacle Reef Belt
  - Basin Slope
  - Huron County
  - Barrier Reef Complex

- APPALACHIAN BASIN
  - Lake Erie

- 50 km scale

The map shows the geographical distribution of Silurian Reefs, highlighting major basins and reef complexes in the region.
Silurian – Pinnacle reef trap
Pinnacle Reefs in Lambton County
CLI: Lower Silurian sandstone
Silurian Clinton-Cataract traps

Western Lake Erie
- green shales
- fine white sands
- red sands
- Cabot Head: grey-green and green shales, silts and fine grey and white sandstones

Channels
- sand bars
- usually sharp colour contrast at boundary

Eastern Lake Erie
- Irondequoit - Reynales Carbonates
- Thorold Sandstones
- Grimsby red shales and red and pink sandstones
- Cabot Head: Whirlpool Sandstone
Silurian Clinton-Cataract Sandstone
Ordovician hydrothermal dolomite

[Diagram of stratigraphy with depth markings and a map labeled Ordovician Play]
Reservoir Model 3D View

Hydrothermal dolomite
Reservoir facies

Vertical wrench?
faults & fractures

Trenton Group

Black River Group

vertical extent of reservoir

Cambrian sands
10 to 20 m. depression
400 to 1200 m. width
14 km long
production from Trenton
Largest TBR oil pool – 6 mmbo

Goldsmith-Lakeshore Oil Field
Structure Top Trenton Group

Geology by R.A. Trevail and T.R. Carter, 2005
CAM: Cambrian sandstone

Cambrian Play
Cambrian traps
Cambrian sandstone

Map showing the distribution of Cambrian sandstone in the Michigan Basin and Appalachian Basin. The Algonquin Arch is labeled with a note indicating that Cambrian sediment is absent in this area. The map also includes symbols for Cambrian Pools and Cambrian Wells.
Shale gas potential in Ontario

Same plays as in NE U.S. and Quebec

Best potential in:
- U. Devonian Kettle Point Fm (Antrim shale equivalent)
- M. Devonian Marcellus Formation
- U Ordovician Blue Mountain Formation and Collingwood shale (Utica equivalents)

• Gas shows, gas in water wells, past production
• Unexplored (only one shale gas exploratory well)
• Large prospective areas
Kettle Point (Antrim)
Marcellus
Collingwood – Blue Mountain
## Shale Gas Plays

<table>
<thead>
<tr>
<th></th>
<th>Kettle Point</th>
<th>Marcellus</th>
<th>Collingwood-Blue Mountain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thickness</td>
<td>105</td>
<td>12</td>
<td>50</td>
</tr>
<tr>
<td>Max depth m.</td>
<td>143</td>
<td>225</td>
<td>1000</td>
</tr>
<tr>
<td>Area km³</td>
<td>9500</td>
<td>4700</td>
<td>70,000</td>
</tr>
<tr>
<td>TOC</td>
<td>3 – 15%</td>
<td>1 – 11%</td>
<td>1 – 11%</td>
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What Next?

- Large unexplored areas with undiscovered potential in Ordovician, Cambrian
- Need reliable seismic model for targeting incipient reefs
- Infill drilling in Lake Erie – average well spacing one mile
- Conversion of more depleted gas pools to storage
- Technological improvements in secondary/tertiary recovery from known oil reservoirs
- New play concepts
- Unassessed shale gas potential
Production history: The next gas peak in Ontario?

- Tilbury: 1917
- seismic: 1960
- Lake Erie: 1985

Chart showing gas production levels over the years from 1900 to 2000.
Lessons for western Newfoundland

- Small local investments in the early oil fields in Ontario grew into large national and multi-national companies with long-lasting economic benefits – the same could happen in other plays in early stages of development
- Use new technologies and new play concepts
- Be optimistic and be persistent!