OIL AND GAS PLAYS OF THE MICHIGAN BASIN, SOUTHERN ONTARIO

Terry Carter, Consulting Geologist
London, Ontario
Ontario Petroleum Industries

- **Oil and Natural Gas**
  - 1250 oil wells, 1200 gas wells, annual production 400,000 bo, 5.7 bcf natural gas, 100 different producers
  - 5 wells/yr, 27,000 well records

- **Hydrocarbon Storage in Geological Formations**
  - 270 bcf natural gas in 35 depleted reservoirs, 275 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, 18 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 one large +billion$ company
  - All cavern storage operations owned by large +billion$ petrochemical companies

- **Salt solution mining**
  - Two operations owned by large 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
- 1890 – first export of natural gas to U.S.
- 1913 – first offshore well in Lake Erie
- 1915 – first subsurface injection of natural gas for storage
- 1914 – Ontario Natural Gas and Oil Wells 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
Bedrock Geology of Southern Ontario
Paleozoic Stratigraphy of Southern Ontario
Oil and Natural Gas Fields of the Michigan and Appalachian Basins
Oil and Natural Gas Plays of the Michigan Basin, Ontario

DEV – structural traps in Devonian carbonates and sandstones

SAL – reefs and structural traps in Silurian carbonates;

ORD – hydrothermal dolomite traps in Trenton and Black Groups (U. Ordovician)
Oil and Natural Gas Fields of Ontario
Oil and Natural Gas Fields of the Michigan Basin, Ontario
# 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>45 mmbo</td>
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<tr>
<td>SAL</td>
<td>Silurian carbonates - pinnacle, incipient and patch reefs - fault traps</td>
<td>300 - 700</td>
<td>15 mmbo 748 bcf 250 bcf gas storage capacity</td>
</tr>
<tr>
<td>CLI</td>
<td>Lower Silurian sandstones basin-centre stratigraphic trap</td>
<td>150 - 500</td>
<td>0.05 mmbo 507 bcf</td>
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<tr>
<td>ORD</td>
<td>Ordovician carbonates – hydrothermal dolomite reservoirs</td>
<td>800 - 900</td>
<td>25 mmbo 43 bcf</td>
</tr>
<tr>
<td>CAM</td>
<td>Cambrian sandstones – stratigraphic traps, fault traps</td>
<td>700 - 1200</td>
<td>5.3 mmbo 32 bcf</td>
</tr>
</tbody>
</table>
DEV: Devonian structural traps

Devonian Play
SAL: Silurian carbonates
ORDOVICIAN HYDROTHERMAL DOLOMITE

Ordovician Play

- Sandstone
- Shale
- Carbonate
- Gas
- Oil
- Oil & Gas
- Salt
# POTENTIAL SHALE PLAYS

<table>
<thead>
<tr>
<th></th>
<th>Kettle Point</th>
<th>Marcellus</th>
<th>Collingwood-Blue Mountain</th>
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</thead>
<tbody>
<tr>
<td>Thickness</td>
<td>30-105</td>
<td>1-12</td>
<td>10-50</td>
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<tr>
<td>Max depth m.</td>
<td>143</td>
<td>225</td>
<td>1000</td>
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<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>
</tr>
</tbody>
</table>
DRILLING 1955 - 2015 Total Wells

- 431 wells in 1956
- Lake Erie 126 wells in 1980
Gas peaks in 1917, 1940, 1960, 1985 corresponding to technological advances in seismic and offshore drilling
126 wells in 1980
Oil peaks in 1895, 1966, and 1995 corresponding to successive discovery of deeper plays, seismic and new exploration models.
Oil, Gas and Salt Resources Library

- Not-for-profit centre for management of publicly accessible data on oil, gas, salt, hydrocarbon storage resources, and subsurface Paleozoic geology of Ontario
- Industry-operated
- Both free and fee-based access to data
- 669 Exeter Road, London, ON
- www.ogsrlibrary.com
Data Resources

- Petroleum well files 26,500 +20/yr
- Scanned well file images 500,000+
- Drill cuttings 11,000 wells +20/yr
- Drill core 1,100 +4/yr
- Monthly production reports 40,000 +2,000/yr
- Injection+disposal reports 10,000 +150/yr
- Maps & Reports 2,500 +10/yr
- Geophysical logs 21,000
- Oil and gas pool map
- Journals, reprints, government reports
- ArcGIS workstation
- Digital petroleum well database
- Oil, gas, water analyses, isotopic analyses
- Deep groundwater maps
  89 water type, 17 potentiometric
What Next?

- Large unexplored areas in Ordovician
- Undiscovered incipient reefs
- Low drilling density in Huron County
- Lake Huron reefs?
- Conversion of more depleted gas pools to storage
- Technological improvements in enhanced recovery from known oil reservoirs
- Historic Devonian oil pools now account for 20% of Ontario annual production – flat production decline
- New play concepts
- Unassessed shale gas/oil potential
- Excellent data availability at OGSR Library
QUESTIONS?