HISTORY AND DEVELOPMENT
OF OIL AND GAS PLAYS OF
THE MICHIGAN BASIN

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(MGRRE)
Western Michigan University-Michigan Geological Survey
EARLY HISTORY OF MICHIGAN OIL AND GAS EXPLORATION

- Some wildcatting as early as 1861, no significant finds
- First commercial wells near Port Huron in 1886-1887, 21 wells by 1910 producing up to 10 barrels per day
- Smith, 1912 reported over 100 wells that had been drilled in southeastern Michigan had natural gas and was being used for domestic heating, mostly from Antrim Shale or Traverse Limestone
- By 1920, five wells in the Deerfield Filed were producing oil from the Trenton Formation
- The Saginaw Field was discovered in the Berea Sandstone in 1925 and had 320 oil wells, 3 gas wells and 62 dry holes by the end of 1927
- Oil and Gas Permitting began in 1927
- The Muskegon Field in 1927 (Traverse Lime) and the Mt. Pleasant Field in 1928 (Dundee) established that oil production was possible throughout Michigan
Locations of Oil and Gas wells drilled throughout Michigan

57,441 boreholes drilled as of 3/28/2017

Red – Natural Gas
Green – Oil
Black – Dry hole

1,205 – Brine Disposal Wells
22,459 – Dry Holes
13,480 – Gas or Cond. Wells
3,026 – Gas Storage Wells
885 – Gas/other OBS Wells
106 – Type Unknown
59 – LPG Wells
506 – Mineral Wells
14,817 – Oil Wells
886 – Injection Wells
Major Carbonate Reservoir Intervals in Michigan Basin

MAP OF OIL AND GAS WELLS FOR MICHIGAN’S LOWER PENINSULA CARBONATE RESERVOIR PLAYS

## OIL AND GAS FIELDS PRODUCTION HISTORY - MICHIGAN CARBONATE RESERVOIRS

<table>
<thead>
<tr>
<th>Formation</th>
<th>Number of Fields Reporting Production</th>
<th>Cumulative Oil Produced</th>
<th>Cumulative Gas Produced</th>
<th>Average Depth and Depth Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traverse</td>
<td>260</td>
<td>110 Million BBLS</td>
<td>13 BCF</td>
<td>2000 600 to 3400</td>
</tr>
<tr>
<td>Dundee</td>
<td>144</td>
<td>352 Million BBLS</td>
<td>42 BCF</td>
<td>3400 2200 to 4100</td>
</tr>
<tr>
<td>Detroit River/ Richfield</td>
<td>92</td>
<td>100 Million BBLS</td>
<td>120 BCF</td>
<td>4000 2000 to 5100</td>
</tr>
<tr>
<td>Niagaran</td>
<td>1187</td>
<td>450 Million BBLS</td>
<td>2500 BCF</td>
<td>5400 2300 to 7400</td>
</tr>
<tr>
<td>Trenton/Black River</td>
<td>19</td>
<td>140 Million BBLS</td>
<td>250 BCF</td>
<td>3900 2500 to 4700</td>
</tr>
</tbody>
</table>
MAJOR SILICLASTIC RESERVOIR INTERVALS IN MICHIGAN BASIN

MAP OF OIL AND GAS WELLS FOR MICHIGAN’S LOWER PENINSULA SILICLASTIC RESERVOIR PLAYS


Antrim Shale
PDC/ St. Peter Sandstone
Berea Sandstone
Michigan “Stray” Ss.
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<tbody>
<tr>
<td>Michigan “Stray”</td>
<td>82</td>
<td>5 Million BBLS</td>
<td>215 BCF</td>
<td>1200 900 to 1800</td>
</tr>
<tr>
<td>Berea Ss.</td>
<td>53</td>
<td>8 Million BBLS</td>
<td>16 BCF</td>
<td>1500 800 to 2400</td>
</tr>
<tr>
<td>Antrim Shale</td>
<td>36</td>
<td>none</td>
<td>3335 BCF</td>
<td>1300 500 to 2600</td>
</tr>
<tr>
<td>St. Peter/ PDC</td>
<td>70</td>
<td>15 Million BBLS</td>
<td>600 BCF</td>
<td>9500 7000 to 12000</td>
</tr>
</tbody>
</table>
USGS PETROLEUM SYSTEMS CLASSIFICATION

- Based on source rock formation
- May have multiple reservoir formations for same source rock
- May have multiple seals for the different reservoir units
- TPS 1 – PreCambrian Nonesuch – no commercial production
- TPS 2 – Ordovician Foster
- TPS 3 – Ordovician to Devonian Composite
- TPS 4 – Silurian Niagararan/Salina
- TPS 5 – Devonian Antrim Shale
- TPS 6 – Pennsylvanian Saginaw – trivial commercial production
TPS 2 – ORDOVICIAN FOSTER

- Ordovician Sandstones and Carbonates AU
- Source – Foster Formation
- Reservoir – St. Peter Ss. (aka. PDC) and thin sandstone beds within the upper Foster Fm.
- Seal – Shales in the Glenwood Fm., Tight Limestones of Black River Group
- Trap – Structural anticlines on basement structures
A) Black laminated mudstone with isolated burrows (arrows) 11,959 feet.

B) Laminated mudstone (dark) intercalated with laminar anhydrite 12,398 feet

C) Laminated dolomicrite (dark) with intercalated laminar anhydrite (light). Localized very fine sandstone with ripple cross laminae (arrows) 12,544 feet.

D) Laminated dolomicrite, cyanobacterial mats and anhydrite. Nodules of displacive anhydrite (arrow) 11,731 feet.
ST. PETER (AKA PRAIRIE DU CHIEN) SANDSTONE - RESERVOIR

Cross-bedded and burrowed, Moderately sorted sandstone
TPS 3 – ORDOVICIAN TO DEVONIAN COMPOSITE SYSTEM

- Ordovician Trenton/Black River AU
- Ordovician Collingwood Shale Gas AU
- Silurian Burnt Bluff AU
- Middle Devonian Carbonates AU
- Devonian Antrim Continuous Oil AU
- Devonian to Mississippian Berea/Michigan Sandstone AU
TPS 3 – ORDOVICIAN TO DEVONIAN COMPOSITE - ORDOVICIAN TRENTON/BLACK RIVER AU

- **Source** – Shale beds within the Trenton/Black River, Collingwood Fm., Utica Shale
- **Reservoir** – Fractured, vuggy and intercrystalline dolomite in T-BR
- **Seal** – Utica Shale or tight limestone of the Trenton/Black River
- **Trap** – Stratigraphic occurrence of porous Dolomite surrounded by tight Limestone
COLLINGWOOD FM. SOURCE ROCK AND UTICA SHALE SOURCE ROCK & SEAL

JEM- Bruggers #3-7 Core Missaukee Co., MI

Collingwood

Petoskey Exploration – State Pioneer #1-3 Missaukee County

Utica Shale
TRENTON-BLACK RIVER RESERVOIR
Source – Amherstburg and Lucas Fms.

Reservoir – Open marine shelf carbonates of the Traverse, Dundee and Amherstburg Limestones, Fractured and vuggy dolomite in the Traverse and Dundee and restricted carbonate facies in the Detroit River Group

Seal – Bell Shale, Squaw Bay Fm., Antrim Sh., Tight Limestone, Anhydrite and Halite in the Lucas and Anhydrite in the Reed City

Trap - Structural anticlines on basement structures, Porous Limestone from original depositional facies, porous dolomite from hydrothermal alteration, sucrosic dolomite from evaporative reflux
HYDROCARBON PRODUCING MIDDLE DEVONIAN ROCKS IN MICHIGAN

Middle Devonian
Traverse Lime, Dundee Fm., Detroit River Group and Amherstburg Fm. Outcrop and Subcrop of these rocks shown in blue.

AMHERSTBURG FM. – SOURCE ROCK AND RESERVOIR

Core Energy-St Charlton #4-30, Otsego Co.  

Hunt-McGuire #1-22, Oscoda Co.
TRAVERSE LIMESTONE RESERVOIRS – FRACTURED AND VUGGY DOLOMITE
DUNDEE RESERVOIRS – LIMESTONE OR DOLOMITE

MichCon-LoReed #LR 83-2 Osceola Co.  Wiser-Sturm #4-0 Gladwin Co.

Cronus Dev. #1-3 Montcalm Co.

Laminated and Fenestral Wackestone and Mudstone
Reef and Reef Skeletal Debris
Skeletal Grainstone
BELL SHALE SEAL

Dart-Hamming #1-22, Missaukee Co. _3886-3892 feet
LUCAS FM. RESERVOIR AND SEAL

Dart-Porter Hogan #1-17, Roscommon County
Source – Antrim, Ellsworth and Sunbury Shales


Seal – Sunbury and Coldwater Shale, shales and anhydrite in the Michigan Fm.

Trap - Structural anticlines on basement structures – mostly primary intergranular porosity, with minor cementation
MICHIGAN “STRAY” AND BEREA SANDSTONE RESERVOIRS

MichCon SL-175-A Six Lakes Field, Montcalm, Co  Wood-Mieske #1-6 Williams Field, Bay, Co

Michigan “stray” Ss.  Berea Ss.
TPS 4 – SILURIAN NIAGARAN/SALINA

- Silurian Niagara AU
- Silurian A-1 and A-2 Carbonate AU
- Devonian Sylvania Sandstone AU
- No commercial production has been established in the Devonian Sylvania Ss. AU, so it was not quantitatively assessed
- Source – Salina A-1 Carbonate
- Reservoir – mostly Dolomitized Niagaran pinnacle reefs and associated facies
- Seal – Salina A-1 and A-2 Anhydrite and Halite
- Trap – Stratigraphic trap of carbonate buildups surrounded by draping evaporites. Most reservoir quality is in Dolomitized facies, minor porosity in Limestone
NIAGARAN REEF RESERVOIR

MichCon – Washington #6-17 OBS
Washington 10 Gas Storage, Macomb Co.
SALINA A-1 CARBONATE SOURCE/RESERVOIR

Organic-rich “poker-chip” facies Source rock

Fractured and vuggy potential Reservoir

Rosetta Resources-Christensen #1-21P, Ionia County
TPS 5 – DEVONIAN ANTRIM SHALE

- Devonian Antrim Shale Continuous Gas AU
- Source – Antrim Shale
- Reservoir – Antrim Shale
- Seal – Antrim Shale and Ellsworth laterally and vertically
- One of the first Shale gas producing formation in the U.S.
- Trap – Hydrodynamic, Gas is adsorbed to rock and desorbs into fractures as reservoir pressure is lowered. Reservoir has leaked into the glacial drift where it subcrops and charges some of the unconsolidated sands.
ANTRIM SHALE RESERVOIR AND SOURCE

Amoco-Conn D-2, Shiawassee County
**CONCLUSIONS**

- Michigan Basin Hydrocarbon exploration and production extends back to the 19th century
- Serious commercial production began in the 1920’s
- Over 2200 fields are known from over 57,000 wells
- Most production is from carbonate reservoirs
- Total Michigan production is over 1.34 billion bbls oil and 8.0 TCF gas
- Michigan also leads the U.S. in underground Natural Gas storage, both working gas and total gas volumes
- Michigan reservoirs can be classified by the Total Petroleum System of source, reservoir and seal (U.S. Geological Survey)