TRENTON-BLACK RIVER HYDROTHERMAL RESERVOIRS OF THE MICHIGAN BASIN

Bill Van Sickel – Michigan
# Stratigraphic Column - Michigan

<table>
<thead>
<tr>
<th>Time</th>
<th>Formation/Unit</th>
<th>Michigan Equivalent</th>
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<tbody>
<tr>
<td>Precambrian</td>
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<td>Archean to</td>
<td>Oronto Gr</td>
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<td>Middle Proterozoic Eon</td>
<td>Copper Harbor Cgl</td>
<td>Precambrian Crystalline Basement Complex</td>
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<td>Cambrian</td>
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<td>Late</td>
<td>Munising Fm</td>
<td>Miners Castle Mbr</td>
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<td>Chapel Rock Mbr</td>
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<td>Chazyian</td>
<td>Au Train Fm</td>
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<td>Whiterockian</td>
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<td>Middle</td>
<td>Collingwood Sh</td>
<td>Black River Fm</td>
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<td>Trenton Fm</td>
<td>Groos Quarry Mbr</td>
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<td>Chandler Falls Mbr</td>
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<td>Bill’s Creek Sh</td>
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<td>Late</td>
<td>Richmond Gr</td>
<td>Utica Sh</td>
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<td>Cataract Gr</td>
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<td>Early</td>
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<td>Alexandria</td>
<td>Cabot Head Sh</td>
<td>Manhattan Dol</td>
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<td>Cabot Head Sh</td>
<td>Queenston Sh</td>
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Stratigraphic Nomenclature for Michigan, 2000
Early Ordovician
~ 480 Ma
Regional Trenton-Black River
S.E. Michigan

Cincinnatian

Utica Shale ~ 320' (98 m.)

Cap dolomite

Trenton ~ 370' (113 m.)

Black River ~ 320' (98 m.)

Van Wert

St. Peter ss / (PDC)
TRENTON-BLACK RIVER RESERVIOR

- Hydrothermal dolomite
- Seal – Utica shale (vertical), Tight limestone (lateral)
- Formed by transtensional stress on existing basement faults during Taconic Orogeny
- Chaotic mix of fractured dolomite/limestone with varying degrees of vugular and matrix porosity
- Solution Gas Drive

EVERY WELL IS DIFFERENT
Transtensional Stress on existing basement faults during Taconic Orogeny

Linear series of extensional, left-lateral wrench faults
**A) Trenton deposition**

- Trenton (argillaceous at base)
- Black River
- Prairie du Chien
- Mt. Simon
- Basement
- Preexisting basement faults

**B) Onset of faulting (Trenton deposition), cooling fluids leach limestone**

- Leached limestone (vugs form)
- Seal
- Reactivated as transtensional

**C) Faulting continues (Utica deposition); hotter fluids dolomitize leached matrix**

- Matrix dolomitization follows leaching
- Fluids remain hotter longer
- Continued transtensional

**D) Faulting continues (Utica, later?); Matrix fractured, vugs, breccias and fractures filled with saddle, etc.**

- Fluids remain hotter longer
- Continued transtensional

**Legend**

- **Shale**
- **Limestone**
- **Dolomite**
- **Sandstone**
- **Strike-Slip Toward**
- **Strike-Slip Away**

**Note:**

- **Fluid Flow**
- Hot Fluid Flow
- Cooling
Hydrothermal Fluid Migration

- Flow along path of least resistance
- Controlling Factors: Faults, fractures, shale barriers, bedding planes & facies
- These controls on porosity/permeability dictate where the hydrothermal fluids flow in both a vertical & horizontal directions.
Palatine Bridge Dolomite Outcrop, Mohawk Valley, New York
CONFIDENTIAL
Matrix porosity

Fracture/Vugular porosity

13%, 311 mD
16%, 2170 mD
MICHIGAN
TRENTON-BLACK RIVER
OIL & GAS FIELDS
TRENTON-BLACK RIVER HISTORIC FIELDS
S.E. MICHIGAN

ALBION-SCIPIO
Disc. 1957
125 MMBO
230 BCFG
608 Producers

STONEY POINT
Disc. 1982
13 MMBO
29 BCFG
96 Producers

NORTHVILLE
Disc. 1954
1.1 MMBO
14 BCFG
63 Producers

DEERFIELD
Disc. 1936
608 MBO
0.75 BCFG
38 Producers
1955 – Houseknecht #1
Originally drilled for Devonian gas – DRY
1957 – Deepened by advice of psychic friend
Encountered oil @ 3900’ – 140 BOPD
TRENTON-BLACK RIVER
RESURGENCE

RICE CREEK DISCOVERY
2006

West Bay Exploration Co.
West Bay programmed and shot a 7 ½ mi² 3-D seismic survey
NAPOLEON DISCOVERY
2008

West Bay Exploration Co.
SEI 2-D seismic

GAP
Explore with 2D Seismic
CONFIDENTIAL
Facies distribution relative to G/O & O/W contacts
Total 57 wells
53 producers, 4 dry
93% success rate

28 Horizontals, 29 Vertical

Cumulative Production
8,476,602 BO
11,224,259 MCFG
7,306,582 BW
TRENTON-BLACK RIVER
RECENT DISCOVERIES

Historic Production = 140 MMBO
Recent Production = 17 MMBO (2D/3D Seismic)
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Magnetic Survey – Second Vertical Derivative
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CONFIDENTIAL
Devonian Fault Re-activation Scenario

Trenton Time
- Compression along oblique-slip fault.
- Thin Trenton-BR section.

Utica Time
- Normal faulting commences during formation of extensional duplex (fault splays).
- Sagging on Trenton evident.
- Utica thickens.

Dundee Time
- Reactivation of extensional duplex.
- Faulting up into Salina.
- Pronounced sagging on Trenton.
- Thickened Devonian section.
WBE 1-22 thin sections

4070.3
3.6%, 0 mD

4063.6
7.4%, 14.4 mD

4089.1
13.0%, 311 mD

4082.95
19.8%, 14,000 mD
HCMA 1-27 thin sections

6058.5
1.0%, .0033 mD

6010
2.2%, .0014 mD

5912.5
3.2%, 16.8 mD

5942.5
3.5%, .0015 mD
Average porosity/permeability in Trenton (core data)

HCMA 1-27 (OAKLAND CO.)
2.3%, 1.3 mD

WBE 1-22 (NAPOLEON FIELD)
6.9%, 901 mD
CONCLUSION

- Trenton-Black River discovered in 1936 (Deerfield).
- Albion-Scipio discovered in 1957. It continues to be the largest oilfield in Michigan with cumulative production of 125 MMBO.
- Stoney Point (1985) was the last significant discovery until Rice Creek (2006).
- Rice Creek kicked off a resurgence in Trenton-Black River exploration utilizing both 2D & 3D seismic. Since Rice Creek, seven additional fields have been found cumulating 17 MMBO to date.
- Numerous tight reservoirs have hindered exploration in some areas. This is attributed to occlusion of existing porosity by HTD initiated by Devonian fault re-activation. **TIMING OF FAULTING CAN BE CRUCIAL!**
- Many areas unexplored due to high population density (e.g. Metro Detroit)