Depositional Controls on Reservoir Quality in the Dundee-Rogers City Interval: Lithofacies and Production Characteristics*

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Abstract

The Dundee-Rogers City interval has been a prolific producer of hydrocarbons since the 1920's in the Michigan Basin with cumulative production of more than 360 million barrels of oil. Three general categories of reservoirs are found in the Dundee-Rogers City: 1.) primary and intercrystalline porosity in dolomites sealed by anhydrites (western central Lower Peninsula), 2.) vuggy and intercrystalline porosity in hydrothermal dolomite reservoirs (central Lower Peninsula), and 3.) primary porosity in limestone reservoirs (eastern Lower Peninsula). In the central and eastern basin, the Dundee-Rogers City reservoirs are sealed by a combination of tight limestone (Dundee-Rogers City) or shale (Bell Shale). The Dundee Formation consists of a paralic to open shelf carbonate deposits. The Dundee exhibits a trend of deeper water deposits to the east, with dominantly tidal flat, sabkha, and shallow lagoon deposits in the west, followed by sand shoals, patch reefs, and open shelf deposits in the central and eastern Lower Peninsula. The overlying Rogers City Formation represents a flooding event with deeper water outer shelf deposits laid on top of the Dundee. Grain-rich beach deposits bear both intergranular and open fenestral porosity. In the eastern basin, primary porosity includes intraskeletal (patch reefs), intergranular (shoals), and vugs. Dolomitization in the western Dundee was early and preserved primary depositional fabrics. In the central basin, primary porosity provided pathways for dolomitizing fluids to invade fractured Dundee-Rogers City limestones. Dolomitization enhanced the porosity generating both intercrystalline and vuggy porosity. This phase of dolomitization is not fabric preserving. Fracturing and fluid migration are linked to reactivation of basement structures during the Acadian and Alleghenian orogenies. Limestone and Dolomite Reservoirs
in the Dundee-Rogers City interval behave differently during production. Dolomite reservoirs maintain near virgin reservoir pressure throughout their production history. Strong bottom water drive pushes the oil-water contact up during production and produced water increases throughout the lifetime of wells in the dolomite reservoirs. Conversely, the limestone Dundee reservoirs tend to exhibit overall decrease in reservoir pressure during production. Water production is much lower in the limestone reservoirs. The limestone reservoirs are more productive during secondary production operations.

References Cited


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134 Cores in our collection – Dundee-Rogers City Interval!

Field Maps courtesy of Dave Barnes
**Hydrocarbon Producing Devonian Rocks in Michigan**

Devonian reservoirs include Antrim Shale, Traverse Limestone, Dundee Formation, Detroit River Group and Amherstburg Fm. Outcrop and Subcrop of these rocks shown in blue.
Regional Stratigraphy

Western Michigan

Bell Shale, Traverse Group
- Rogers City Formation
- “Reed City Anhydrite”
- “Reed City Dolomite”
- Dundee Formation

Eastern Michigan

Maximum Flooding Surface
- Rogers City Formation
- Dundee Limestone

Lucas Formation, Detroit River Group
Great Bahama Bank and Michigan at the same scale

Gardner, 1974

Enos and Perkins, 1976
Carbonate facies Mosaic – controlled by:
1. Bathymetric gradient – shallower water facies to west, deeper to east
2. Structural controls on bathymetry – shallower-water facies on pre-existing topography due to structures
Seals – low φ and K!

Algal-laminated mudstone
Associated sedimentary structures:
1. Mud cracks
2. Imbricated Rip-up intraclasts (storms, tides)
3. Soft-sediment deformation
4. Mottled Paleosols
5. Associated Anhydrites – bedded and nodular

“Reed City Anhydrite”

Nodular anhydrite in dolomudstone matrix – started out as gypsum.

MCGC LR83-2, 3545 ft., Osceola Co. (PN: 29261)

Peninsular Oil Connover Lake Trust #1-13
Newaygo Co. PN: 37265
Reed City Dolomite- Reed City Anhydrite Contact
Fenestal Carbonates – highly porous, grainy carbonates – beach deposits

Reservoir: When not cemented – decent $\phi$, low to moderate $K$

MCGC LR83-2, 3570 ft., Osceola Co. (PN: 29261)

Midwest Oil Productions Thelma Rousseau #1-12, 3949 ft., Mecosta Co. (PN: 35426)
Sun Oil Company McClintic #3
Isabella Co., MI
11-14N-3W
PN: 36367

Legend
- Dolomite
- Limestone
- Dolomite with Anhydrite Nodules
- Coral
- Stromatoporoid
- Bryozoan
- Brachiopod
- Indeterminate Skeletal Grain
- Crinoid
- Crossbedding
- Stromatolite
- Wavey Lamination
- Planar Lamination
- Hardground
- Fenestral Porosity
- Intracasts
- Phosphate Grains
- Wispy Stylolites
- Digitate Stylolites

Permeability (md)

Porosity (%)

Upper fenestral zone

Blue – K

Red - φ

Lower fenestral zone
Lagoonal carbonates – intensely bioturbated
Muddy and Pelletal
Skeletal grains – float in matrix – locally leached out

Moderate φ, but low K
Sand shoals

Near fairweather wave base

Mix of:
1. Oolitic grains
2. Skeletal material from nearby thickets (bryozoans, crinoids)
3. Debris shed from local patch reefs

High energy environment – winnows away fines

Can be good reservoir quality if not cemented up!
Jordan Energy St. Buckeye “D” #1-36
Gladwin Co., PN: 41122
Depth: 3588 ft

Patch Reefs

Tabulate Coral – Dundee Formation,
Rogers City Quarry

Stromatoporoid – hydrocarbons plugging intraskeletal porosity
Reef debris – Stromatoporoids, colonial rugose corals (*Hexagonaria*), variety of tabulate corals

Both photos - Jordan Energy St. Buckeye “D” #1-36
Gladwin Co., PN: 41122 (3594 and 3599 ft)
Reef interval

Blue – K
Red - φ

Legend
- Dolomite
- Limestone
- Dolomite with Anhydrite Nodules
- Coral
- Stromatoporoid
- Bryozoan
- Brachiopod
- Indeterminate Skeletal Grain
- Crinoid
- Crossbedding
- Stromatolite
- Wavey Lamination
- Planar Lamination
- Hardground
- Fenestral Porosity
- Intraclasts
- Phosphate Grains
- Wispy Stylolites
- Digitate Stylolites

Facies Assemblage 4
Facies Assemblage 3
Facies Assemblage 2
Facies Assemblage 1

Wiser St. Buckeye “D” #1-36
Gladwin Co., MI
36-18N-1W
PN: 41122

Permeability (md)

Porosity (%)
Background sediment – likely intensely bioturbated. Skeletal grains floating in finer matrix

- Lower energy – below fairweather wave base, but above stormweather wave base
- Grainflows from higher on depositional ramp
- Background sedimentation – muddy or pelletal carbonates (± some clay)
- Fauna – lower diversity – dominated by crinoids ± brachiopods, gastropods, and sponges
- Depositional package – interlayered tempestites/grainflows with muddier background layers

**Reservoir Quality** – when dolomitized – vuggy, intercrystalline and fracture!
Seal when not dolomitized for underlying Dundee.

Cronus Development Tow 1-3-HD-1
Montcalm Co, PN: 50047
Depth = 3195.5 ft
Tension fractures

Cronus Development Tow 1-3-HD-1
Montcalm Co, PN: 50047
Depth = 3199 ft
Upper Dundee-Lower Rogers City – decent K, low φ, overlain by Bell Shale

Cronus Development Tow #1-3-HD-1
Montcalm Co., MI
3-10N-5W
PN: 50047

Legend

- Dolomite
- Limestone
- Dolomite with Anhydrite Nodules

- Coral
- Stromatoporoid
- Bryozoan
- Brachiopod
- Indeterminate Skeletal Grain
- Crinoid
- Crossbedding
- Stromatolite
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Facies Assemblage 4
Facies Assemblage 3
Facies Assemblage 2
Facies Assemblage 1
Dundee Reservoir Lithologic Types - Summary

• Limestone - depositional fabrics
  • Grainstone shoal sand bodies
  • Fenestral peritidal packstones and wackestones
  • Stromatoporoid/coral boundstone patch reefs

• Dolomite - burial diagenetic fabrics
  • Fractured, vuggy, hydrothermal dolomite
  • Matrix, intercrystalline and vuggy dolomite
  • Sucrosic, laminated, dolomite with anhydrite
<table>
<thead>
<tr>
<th></th>
<th><strong>Limestone</strong></th>
<th><strong>Dolomite</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>φ/K</td>
<td>Primary depositional control</td>
<td>Dolomitization-controlled – leaching and fracturing</td>
</tr>
<tr>
<td>φ/K and structure</td>
<td>Porous facies on structure, tight limestone regionally</td>
<td>Porous facies off structure – regional dolomitization</td>
</tr>
<tr>
<td>Initial Production</td>
<td>60% of wells – 250 Bbls/day</td>
<td>Fewer 250 Bbls/day wells – more 3000 Bbls/day wells</td>
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| Pressure Drive       | Solution gas/gas expansion  
As pressures decrease – primary recovery low, good secondary recovery potential | Bottom or lateral water drive  
Reservoir pressure doesn’t deplete much – limited secondary recovery |
Annual Oil and Water Production West Branch Field - Limestone - Grainstone

Production Year

Oil Production in Barrels

Water Production in Barrels

Begin Waterflood
Annual Oil and Water Production Crystal Field – Fractured Dolomite

![Graph showing annual oil and water production from 1935 to 1985. The graph plots oil production in red and water production in blue. The y-axis represents annual barrels of oil and water, ranging from 0 to 4,000,000, and the x-axis represents years from 1935 to 1985. The graph indicates a significant decline in oil production over the years, with a peak in water production in the mid-1960s.](image-url)
Dundee-Rogers City interval – Reservoir Conclusions

• Limestone Reservoirs
  • Primary fabric controlled – porosity from depositional fabrics if not cemented early; few fractures
  • Pressure depletes - decent primary production; good secondary recovery potential

• Dolomite Reservoirs
  • Templating of primary fabrics by dolomitizing fluids (K-conduits) + fracture-related dolomitization
  • Porosity off-structure from regional dolomitization
  • Little depletion of reservoirs - good early production; poor secondary recovery potential!
Voice and Harrison, 2017 References

