Review of Hydrocarbon Production from the Stonewall and lower Interlake Formations: western North Dakota – Williston Basin

Timothy O. Nesheim
North Dakota Geological Survey
Stonewall Hydrocarbon Production

Cumulative North Dakota Oil Production by Formation

1) 1,952 MMBO – Bakken/TF
2) 1,018 MMBO – Madison*
3) 316 MMBO – Red River
4) 156 MMBO - Duperow
5) 86 MMBO - Tyler
6) 65 MMBO - upper Interlake
7) 61 MMBO - Lodgepole
8) 21 MMBO - Birdbear
9) 17 MMBO - lower Interlake/Stonewall
10) 10 MMBO - Winnipegosis

* Madison includes lower and upper Madison formations.
Each cycle is composed mostly of carbonate rock capped by nodular to bedded anhydrite and/or silty to sandy argillaceous dolomitic “marker” beds (e.g. upper and lower “t” marker beds).

However, while all the sedimentation cycles share some commonalities, they also display significant variations from one another both vertically and laterally.
Stratigraphy – Stonewall Formation

- Additional cycle in upper Stony Mtn. Fm. (Guntor Mbr)
- ~Regional GR marker bed
- Regional GR marker bed anhydrite (basin-centered)
- Regional GR marker bed anhydrite
- Regional GR marker bed anhydrite
- Regional GR marker bed anhydrite (basin-centered)
Stratigraphy – lower Interlake

Additional cycle in upper Stony Mtn. Fm. (Gulton Mbr)

Stony Mtn. Fm.

Stolon Mtn. Fm.

Regional GR marker bed
anhydrite (basin-centered)

(Putnam zone)

Regional GR marker bed
anhydrite (basin-centered)

(Salisbury zone)

Regional GR marker bed
anhydrite (basin-centered?)

North Dakota Geological Survey
Historical Production Trends: Stonewall Formation
Historical Production Trends: Stonewall Formation

#16629
33-105-01629-00-00
Sec. 2, T156N, R97W
Whiting Oil and Gas Corp.
Solberg 32-2
K.B. = 2,291 ft

<table>
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<th>Gamma Ray</th>
<th>Neutron Porosity</th>
<th>Density Porosity</th>
<th>Deep Resistivity</th>
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Cum. Oil Production (k = thousands of barrels)
- >400k
- 200-400k
- 100-200k
- 50-100k
- 10-50k
- <10k
Historical Production Trends: Stonewall Formation

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Cum. Oil Production
(k = thousands of barrels)
- >400k
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- 100-200k
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- 10-50k
- <10k

middle Stonewall
upper Stonewall
Commingled w/ lower Interlake
Historical Production Trends: Stonewall Formation

Main “fairway” of historical Stonewall production (vertical)
Historical Production Trends: lower Interlake Formation

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Hydrocarbon Production by Zone
- LI-2
- LI-1
- LI-1 & LI-2
S - Commingled with Stonewall
Historical Production Trends: lower Interlake Formation

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Cumulative Oil Production
(k = thousands of barrels)
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- 50-100k
- 10-50k
- <10k

Map showing geological formations and cumulative oil production data.
Historical Production Trends: lower Interlake Formation

- lower Interlake LI-1
- LI-1 & LI-2 mix
- lower Interlake LI-2

Cumulative Oil Production (k = thousands of barrels)
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- 10-50k
- <10k
Historical Production Trends: lower Interlake Formation

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Cumulative Oil Production (k = thousands of barrels)

- >400k
- 200-400k
- 100-200k
- 50-100k
- 10-50k
- <10k

Interlake Formation
- lower Interlake
- middle Interlake
- upper Interlake

Stonewall

LI-1
LI-2
Ness
Antelope anticline

0 15 Miles

North
- Organic-rich (0.5-5.2% TOC*) carbonate mudstone
- Commonly present at up to three stratigraphic intervals
- Source rock net thickness = ~6-8 ft.
- Tmax values 455-460° (late mature oil generation window) with HI values <150 mg HC/g TOC

*TOC values may be significantly depleted due to thermal maturation
Basics of Petroleum Reservoir Beds - Review

http://www.csun.edu/~psk17793/ES9CP/PoreSpace100.jpg - retrieved 5-18-2018
Basics of Petroleum Reservoir Beds - Review

- Minimal pore space (~non-reservoir)
- Large grains & lots of pore space (good reservoir rock)
- Small grains with smaller pore spaces (intermediate reservoir rock)

Case Study for Stonewall Formation Production:
Elk-Indian Hills Field area – northern McKenzie County

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![Graph and map of Stonewall Formation Production](image-url)
Vertical (Conventional) Well Production: Elk-Indian Hills field area

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Interlake Formation

Lower Interlake

Middle Interlake

Upper Interlake

Stony Mtn Fm

Gunton Mbr

? Stonewall Fm

Oil migration

Non-productive Stonewall well penetrations

Productive Stonewall well
Vertical (Conventional) Well Production: Elk-Indian Hills field area

Anticlinal folding/structural "bumps"
Stonewall Reservoir: Burrow-mottled dolomite - heterogeneous

*Key Point:* Porous dolostone reservoir beds undergo lateral facies changes into non-porous limestone/dolostone
Vertical (Conventional) Well Production:
Elk-Indian Hills field area

*Key Point:* the reservoir of each sedimentation cycle has a unique porosity development trend/distribution

Best overall vertical well production
- Both reservoir horizons are moderately to highly porous
- Positioned along anticlinal crest

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Vertical wells

- Cycle #3: Low porosity
- Cycle #4: Intermediate porosity

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*Key Point:* the reservoir of each sedimentation cycle has a unique porosity development trend/distribution

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Interpretation of log data:

- **#9102**
- 33-053-01433-00-00
- Gulf Oil Corp.
- Gajewski #1-2-1A
- K.B. = 2,152 ft.

- **Stonewall Formation**
  - Lower: 1,100 ft.
  - Middle: 13,100 ft.
  - Upper

- **Gamma Ray**
- **Caliper (in)**
- **Neutron Porosity (Lime)**
- **Density Porosity (Lime)**

---

*Key Point*: the reservoir of each sedimentation cycle has a unique porosity development trend/distribution
Horizontal (“Unconventional”) Potential

- ~23 ft. net thickness
- Porosity: ~4-10% - w/ Permeability: 0.1<10.0 md
- Core plug saturations: 20-50% oil with <25% water
- OOIP: 4-6 MMBO/640 acres (8-12 MMBO/1280 acres)

*Key Point: the upper Stonewall can contain notable quantities of hydrocarbon-charged, unconventional quality reservoir

*#10407 vertical well perforations cumulatively produced 53.7 MBO & 70.6 MMCF gas with ~6% water cut from a fractured reservoir
Hydrocarbon Accumulations: lower Interlake Formation
lower Interlake Production: 
Stoneview field area

Structure Contours (feet below sea level): 
LI-1 top
lower Interlake Production:
Stoneview field area
lower Interlake Production:
Stoneview field area
lower Interlake Production: Stoneview field area

*Key Point:* Porous dolostone reservoir beds undergo lateral facies changes into non-porous limestone/dolostone (similar to the Stonewall Formation reservoirs)
lower Interlake Production: Stoneview field area

- Stratigraphic/diagenic trap overlaying structure. High porosity dolomite transitions laterally into low porosity dolomite moving up-dip.

*Key Point:* Porous dolostone reservoir beds undergo lateral facies changes into non-porous limestone/dolostone (similar to the Stonewall Formation reservoirs)
11 initial vertical wells were drilled and completed in the lower Interlake during the early 1990’s.
• Beginning in 1999, 11 additional horizontal wells have been drilled (solid black lines) and completed plus 3 horizontal re-entries of pre-existing vertical wells (dotted lines).

• Horizontal wells are open-hole completions (no hydraulic fracture stimulation).

• Horizontal re-entry attempts did not appear very successful.

• Majority of the new horizontal wells have been successful (200-400+ MBO).
lower Interlake Production:
Stoneview field area – Reservoir Rock

Relatively homogeneous reservoir that can respond positively to water flooding
Concluding Remarks:

- Six cycles of sedimentation comprise the Stonewall and lower Interlake Formations
- Each cycle contains discontinuous hydrocarbon reservoir beds each with unique porosity trends
- Stonewall-lower Interlake hydrocarbon production appears to be primarily a function of stratigraphic trapping of hydrocarbons due to discontinuous reservoir quality (facies change)
- Structural features along stratigraphic/porosity pinch-outs may further enhance production potential
- Reservoir facies varies between the two units: Stonewall = burrow-mottled dolostone (heterogeneous = hydraulic fracture candidate?), lower Interlake = massive to laminated dolostone
Thank you for your time!

Questions?

Timothy Nesheim
tonesheim@nd.gov