Cretaceous Shale Gas Prospects of Southwestern Manitoba: Preliminary Results

Michelle P.B. Nicolas and James D. Bamburak

Manitoba Geological Survey
Winnipeg, Manitoba
Study Area

DEM of Manitoba, Canada
Project Purpose

• Does Manitoba have the right geological conditions for economic shale gas production?
  – What are the best target formations?

• Is the gas biogenic or thermogenic?
  – If it’s biogenic is it early-generation or late-generation?
<table>
<thead>
<tr>
<th>ERA</th>
<th>PERIOD</th>
<th>SOUTHWESTERN MANITOBA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td>glacial drift</td>
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<td>CENOZOIC</td>
<td>Quaternary</td>
<td>Peace Garden Member</td>
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<td>CRETAUCEOUS</td>
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<td>Pembina Member</td>
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<td>Carman Fossiliferous Member</td>
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<td>Boyne Member</td>
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<td>Lance Limestone</td>
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<td>Upper</td>
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<td>Fish Scales Zone</td>
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<td>Newcastle Member</td>
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<td>Skull Creek Member</td>
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<td></td>
<td></td>
<td>Swan River Formation</td>
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<td>JURASSIC</td>
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<td>S., Member</td>
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<tr>
<td></td>
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<td>Waskada Formation</td>
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<tr>
<td></td>
<td></td>
<td>Upper member</td>
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<td></td>
<td></td>
<td>Lower member</td>
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<tr>
<td>TRIASSIC</td>
<td></td>
<td>Upper (Evaipote) Member</td>
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<tr>
<td></td>
<td></td>
<td>Lower (Red Beds) Member</td>
</tr>
</tbody>
</table>

**Upper Cretaceous**
## Project Target Formations

<table>
<thead>
<tr>
<th>CRETAEOUS</th>
<th>SOUTHWESTERN MANITOBA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pierre Shale</td>
<td>Coulter Member</td>
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<tr>
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<td>Millwood Member</td>
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<td>Pembina Member</td>
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<td></td>
<td>Gammon Ferruginous Member</td>
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<tr>
<td>Carlile Formation</td>
<td>Boyne Member</td>
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<td></td>
<td>Morden Member</td>
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<tr>
<td>Favel Formation</td>
<td>Assiniboine Member</td>
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<td></td>
<td>Keld Member</td>
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<tr>
<td>Ashville Formation</td>
<td>Belle Fourche Member</td>
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<td></td>
<td>Westgate Member</td>
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<td></td>
<td>Newcastle Member</td>
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<td></td>
<td>Skull Creek Member</td>
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</tbody>
</table>
## Documented Gas Shows

### SOUTHWESTERN MANITOBA

<table>
<thead>
<tr>
<th>CRETAceOUS</th>
<th>Pierre Shale</th>
<th>Carlile Formation</th>
<th>Favel Formation</th>
<th>Ashville Formation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coulter Member</td>
<td>Boyne Member</td>
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<td>Gammon Ferruginous Member</td>
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</tbody>
</table>
Wallace and Greer (1927) reported natural gas being used for domestic lighting and cooking purposes at several sites in SW Manitoba.

Historical documents indicate up to 12 gas wells drilled in SW Manitoba between 1906 and 1933.

Most of these wells are now abandoned, but at least two wells remain capped.
Exploration History: 1906-1933

Two capped gas wells with pressures of ~ 276 kPa, near Manitou, Manitoba.
Exploration History: 1906-1933

Notre Dame de Lourdes, MB
Drilled in c. 1930
221 kPa initial pressure

Manitou, MB
Drilled in 1907
Well TVD: 396 m
Gas Depth: 183 m
276 kPa initial pressures
Modern Exploration: 2003-2006

2003 to 2006: Waskada Field area, north of Pierson Field, and the Manitou area

- 3 wells cased for production in the Favel Formation in the Waskada Field; now abandoned.
- 2 wells north of Pierson Field: cored, cased, stimulated.
- 1 well in Manitou area: cased, formation tested.
Outcrop and Core Sampling

- Geochemical and mineralogical analyses include:
  - Rock-Eval 6 ®
    - Including TOC and Tmax
  - X-Ray Diffraction (XRD)
  - Major and minor trace element bulk geochemistry (chemostratigraphy)
2008 Field Work

- Pembina Hills & Pembina Valley region

![Map of Manitoba showing Pembina Hills and Pembina Valley region with notable locations and symbols for oil fields and Cretaceous gas shows.](image)
Outcrop Sampling 2008

36 outcrop field stations examined and sampled.

The Favel Formation to Pierre Shale were sampled.
Field Work Highlights

Carlile Formation, Boyne Member

SW of Roseisle, MB

brown shale

shaly siltstone and sandstone (2 m thick)

black shale
Field Work Highlights

- organic shaly siltstone with sandstone lenses
- black organic shale
Water and Gas Well Sampling

• Geochemical analyses include:
  – Dissolved gas composition
  – Free gas composition
  – Water chemistry
    • cations, anions, alkalinity, sulphates
  – Stable Isotopes
    • Sulphur, carbon, oxygen
Water and Gas Well Sampling 2008

- 13 domestic water wells sampled
- 5 free gas samples collected:
  - 2 gas wells
  - 3 domestic water wells
Rock Geochemistry & Mineralogy

• Results received & compiled:
  – Rock-Eval 6®:
    • A total of 355 samples analysed & compiled to date, includes:
      – 87 samples from new outcrop and core samples collected from this study and select samples from Nicolas (2009; GP2009-1)
      – Archive data from GSC Open File 4952
  – XRD
    • 47 samples analysed to date (Pembina Mb, Boyne Mb, Morden Mb, Assiniboine Mb)

• Results pending
  – bulk geochemistry
### Rock-Eval 6® Results: $T_{\text{max}}$

<table>
<thead>
<tr>
<th>Formation</th>
<th>Location</th>
</tr>
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<tbody>
<tr>
<td>Pierre Shale</td>
<td>Odanah, Millwood, Pembina, Gammon</td>
</tr>
<tr>
<td>Carlile Fm</td>
<td>Boyne, Morden</td>
</tr>
<tr>
<td>Favel Fm</td>
<td>Assiniboine, Keld</td>
</tr>
<tr>
<td>Ashville Fm</td>
<td>Belle Fourche, Westgate, Skull Creek</td>
</tr>
</tbody>
</table>

**Tmax (°C)**

- **380**
- **400**
- **420**
- **440**
- **460**

![Increasing Depth](arrow)

- **Oil window (435°C)**

[Image of a graph showing Tmax values for different locations and formations, with a vertical dashed line at 435°C indicating the oil window.]
### Rock-Eval 6® Results: TOC

Good source rock (2 wt.% min.)

<table>
<thead>
<tr>
<th>Formation</th>
<th>Sample Locations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pierre Shale</td>
<td>Odanah, Millwood, Pembina, Gammon</td>
</tr>
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<td>Assiniboine, Keld</td>
</tr>
<tr>
<td>Asheville Fm</td>
<td>Belle Fourche, Westgate, Skull Creek</td>
</tr>
</tbody>
</table>

TOC (wt.%)

Increasing Depth

0.0  5.0  10.0  15.0  20.0
Rock-Eval 6® Results: PI \( \{S_1/(S_1+S_2)\} \)

<table>
<thead>
<tr>
<th>Formation</th>
<th>Sites</th>
</tr>
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<tbody>
<tr>
<td>Pierre Shale</td>
<td>Odanah, Millwood, Pembina, Gammon</td>
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<td>Ashville Fm</td>
<td>Belle Fourche, Westgate, Skull Creek</td>
</tr>
</tbody>
</table>

Production Index (PI)

thermogenic minimum

Increasing Depth
## Rock-Eval 6® Results: Yield Ratio

The graph shows the yield ratio (kg HC/tonne)/TOC (wt.%), with increasing depth indicated by vertical dashed lines. The yield ratio is divided into three types:

- **Type III**
- **Type II**
- **Type II-I mixing**

### Yield Ratio

(Yield Ratio (kg HC/tonne)/TOC (wt.))

<table>
<thead>
<tr>
<th>Pierre Shale</th>
<th>Odanah</th>
<th>Millwood</th>
<th>Pembina</th>
<th>Gammon</th>
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</thead>
<tbody>
<tr>
<td>Carlile Fm</td>
<td>Boyne</td>
<td>Morden</td>
<td></td>
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<td>Favel Fm</td>
<td>Assiniboine</td>
<td>Keld</td>
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<tr>
<td>Ashville Fm</td>
<td>Belle Fourche</td>
<td>Westgate</td>
<td>Skull Creek</td>
<td></td>
</tr>
</tbody>
</table>

### Types

- **Type I**
  - Gas prone
  - Oil prone

- **Type II-I mixing**
- **Type II**

The graph highlights the depth at which each type transitions, providing insights into the yield ratio changes with depth for different formations.
Geochemistry Highlights

Carlile Formation, Boyne Member

- Black organic shale
  TOC = 3.11 wt.%

- Organic shaly siltstone and sandstone
  TOC = 10.55 wt.%

- Brown shale
  TOC = 6.51 wt.%

- Black organic shale
  TOC = 3.11 wt.%

SW of Roseisle, MB
Core Highlights

8-29-4-29W1
Carlile Formation, Boyne Member
Core interval: 420.0 – 463.95 m

TOC = 6.34 wt.%
TOC = 3.79 wt.%
TOC = 3.48 wt.%

- Black to brown organic shale
- Black organic shale
- Grey to brown shale
- Fractures
- Black to brown organic shale
XRD Results: Mineral Abundance

- Odanah
- Pembina
- Boyne
- Morden
- Assiniboine

Mineral Abundance (%)

- Quartz
- Calcite
- Exp.M.L.C or Smectite
- Mica or Illite (with biotite or phlogopite)
- K-feldspars (or sanidine)
- Na-feldspars (plagioclase)
- Kaolinite
- Gypsum
- Pyrite
- Chlorite
- Dolomite or Ankerite
- Opal
- Other
XRD Results: Quartz Content

Carlile Formation, Boyne Member

- brown shale: Qtz = 45%
- organic shaly siltstone and sandstone: Qtz = 56%
- black organic shale: Qtz = 89%

SW of Roseisle, MB
XRD Results: Quartz Content

8-29-4-29W1
Carlile Formation, Boyne Member
Core interval: 420.0 – 463.95 m

Qtz = 82%
Qtz = 81%
Qtz = 8%
Qtz = 82%

black to brown organic shale
grey to brown shale
black organic shale
Water and Gas Geochemistry

• Results received:
  – Dissolved gas compositions
  – Free gas compositions

• Results pending:
  – Water chemistry
  – Stable isotopes
### Water and Gas Geochemistry

- Notre Dame de Lourdes, MB
  (1930 water/gas well)

<table>
<thead>
<tr>
<th>Gas Component</th>
<th>Percentage</th>
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<tbody>
<tr>
<td>methane ($\text{CH}_4$)</td>
<td>81.87 %</td>
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<tr>
<td>nitrogen ($\text{N}_2$)</td>
<td>16.79 %</td>
</tr>
<tr>
<td>oxygen ($\text{O}_2$)</td>
<td>0.460 %</td>
</tr>
<tr>
<td>carbon dioxide ($\text{CO}_2$)</td>
<td>0.37 %</td>
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<tr>
<td>ethane ($\text{C}_2\text{H}_6$)</td>
<td>0.219 %</td>
</tr>
<tr>
<td>argon (Ar)</td>
<td>0.151 %</td>
</tr>
<tr>
<td>helium (He)</td>
<td>0.1350 %</td>
</tr>
<tr>
<td>propane ($\text{C}_3\text{H}_8$)</td>
<td>0.0038 %</td>
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Water and Gas Geochemistry

- Manitou, MB
  (1933 gas well)

<table>
<thead>
<tr>
<th>Compound</th>
<th>Percentage</th>
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<tbody>
<tr>
<td>methane (CH₄)</td>
<td>89.69 %</td>
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<td>nitrogen (N₂)</td>
<td>9.34 %</td>
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<tr>
<td>oxygen (O₂)</td>
<td>0.375 %</td>
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<td>ethane (C₂H₆)</td>
<td>0.260 %</td>
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<td>carbon dioxide (CO₂)</td>
<td>0.180 %</td>
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<tr>
<td>argon (Ar)</td>
<td>0.0896 %</td>
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<tr>
<td>helium (He)</td>
<td>0.0379 %</td>
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<tr>
<td>propane (C₃H₈)</td>
<td>0.0171 %</td>
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<tr>
<td>iso-butane (C₄H₁₀)</td>
<td>0.0063 %</td>
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</table>
### Water and Gas Geochemistry

- Manitou, MB
  (domestic water well)

<table>
<thead>
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<th>Gas</th>
<th>Percentage</th>
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<tbody>
<tr>
<td>methane ($\text{CH}_4$)</td>
<td>84.80 %</td>
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<tr>
<td>nitrogen ($\text{N}_2$)</td>
<td>13.34 %</td>
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<tr>
<td>carbon dioxide ($\text{CO}_2$)</td>
<td>1.40 %</td>
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<tr>
<td>argon (Ar)</td>
<td>0.249 %</td>
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<tr>
<td>oxygen ($\text{O}_2$)</td>
<td>0.192 %</td>
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<tr>
<td>helium (He)</td>
<td>0.0118 %</td>
</tr>
<tr>
<td>ethane ($\text{C}_2\text{H}_6$)</td>
<td>0.0028 %</td>
</tr>
</tbody>
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2009 Field Work

DEM of Manitoba, Canada

Winnipeg
Swan River
Brandon
Virden
Manitou

Manitoba Escarpment
Conclusions

• Manitoba has a vast shale gas resource that has not been adequately explored with modern technology.

• Manitoba is not “just shale”, siltstone and sandstones do occur in the east.

• Manitoba does have the right geological conditions for shale gas.
  – Is it economic?
Conclusions

• Best Cretaceous shale gas targets:
  – Carlile Formation
  – Favel Formation
  – Ashville Formation, Belle Fourche Membre

• Geochemistry results support that this is an unconventional biogenic shallow gas play.
  – still need stable isotope confirmation

• Likely a combination of early-generation and late-generation gas.
Want to know more?

• Manitoba exhibit booth

• Report of Activities 2008
  • Nicolas (2008): GS-16
  • Bamburak (2008): GS-17

• TGI II Manitoba Mesozoic Report
  • Nicolas (2009): GP2009-1

• Order online or download for free at:
  www.manitoba.ca/minerals
Acknowledgement

• Geological Survey of Canada – Calgary
  Martin Fowler
  Kirk Osadetz
  Steve Grasby

• Manitoba Water Stewardship, Water Resources Branch
  Bob Betcher
  Tobin Harrison
The end.