Field Screening for Shallow Gas in North Dakota

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North Dakota Department of Mineral Resources
Geological Investigations No. 42
North Dakota Geological Survey
**Geologic** - Natural gas that is generated and accumulates within the near surface geology of the state typically sourced and contained within permeable organic laden glacial sediments or within fractured shale and sandstone reservoirs of Cretaceous and Jurassic age or combinations of each (Anderson, 2005).

**Regulatory** - Gas that is produced from a shallow gas zone that consists of a strata or formation, including lignite or coal strata or seam, located above the depth of five thousand feet (1,524 meters) below the surface, or located more than five thousand feet (1,524 meters) below the surface but above the top of the Rierdon Formation (Jurassic), from which gas may be produced (NDO&GD, 2005).

**Early Gas Properties (Barry, 1908)**
- 886 BTU
- 82.7% Methane
- 0.2% Ethane
- 12.4% Nitrogen
- 0.5% Hydrogen
- 1.2% Carbon Monoxide (CO₂)
Areas of Historical Shallow Natural Gas Occurrence

Modified from Hard, 1920
Bottineau County Historic Shallow Gas Occurrences

HISTORIC OCCURRENCES

(Modified from Anderson, 2006)
Conceptual Shallow Gas Systems in North Dakota

(a) North-Central North Dakota.

Conceptual diagrammatic geologic sections depicting typical potential shallow gas settings in north-central (a) and eastern (b) North Dakota.

(b) Eastern North Dakota.
Typical Log Characteristics and Stratigraphic Relationships

Low permeability glacial sediment (till or glaciolacustrine sediments).

Basal outwash sands (detrital lignite common).

Underlying permeable Cretaceous bedrock (Fox Hills/Hell Creek Formation).

Deeper basal Cretaceous marine shales (Pierre Fm).

(Modified from Randich and Kuzniar, 1984)
Location of Ground-Water Observation Wells in North Dakota

Data from NDSWC, 2006
Reconnaissance Level Field Screening Investigation

- Screening of existing monitoring wells with portable analytical instrumentation:
  - **Flame Ionization Detector (FID)**
  - **CH$_4$**
  - **Multi-Gas Meters**
    - **O$_2$**
    - **CO & CO$_2$**
    - **H$_2$S**
Field Screening Investigative Highlights

- **Steele County**
  Pierre/Niobrara Shale Gas Conceptual Model
- **Bottineau County**
  Combined “Drift Gas” and Upper Cretaceous Shallow Bedrock
- **Renville County**
  Continuation of Bottineau Area Trend
- **Emmons County**
  - Cretaceous Fox Hills/Hell Creek Formation
- **Stutsman County**
- **Rolette County**
- **Towner County**
NDGS Reconnaissance Observation Well Field Screening Investigations

ND Counties Investigated
Steele County - North Dakota

- Historical anecdotal occurrence prompted investigation
- 21 Wells Investigated
- 9 Wells Field Screened
- 3 Wells with a positive numerical response for CH₄
- 6 wells with no FID response
- FID response range of 2.0 – 146.3 ppm as CH₄
- 11 wells not visited
- Well screened in Pierre Shale produced an 86 ppm CH₄ FID response
Bottineau County - North Dakota

- Historical occurrence and production prompted investigation
- 110 Wells Investigated
- 33 Wells Field Screened
- 11 Wells with a positive numerical response for CH₄
- 22 wells with no FID response
- FID response range of 2.4 – 30,362 ppm as CH₄
- 10 wells not visited
- Flowing head well screened in Cretaceous sandstones produced an 236 ppm CH₄ FID response and associated [8.3 mg/L CH₄] in groundwater
Recent Shallow Gas Occurrences

- Observation Well: 162-83-15CCC
- FID Instrument Response = 236 ppm (as methane)
- Flowing head well (<1 gpm)
- [Methane] in groundwater = 8.3 mg/L
- Located in area of historic shallow natural gas occurrence (western Bottineau Co.)
- Bubbling continuously at top of well (approx 2-3 bubbles/5 sec.)
Renville County, North Dakota

- 34 Wells Investigated
- 8 Wells Field Screened
- 3 Wells with a positive numerical response for CH₄
- 5 wells with no FID response
- FID response range of 20.6 – 28,000 ppm as CH₄
- 6 wells not visited

Recent Preliminary Shallow Gas Occurrences

Continuation of the Bottineau Area Trend
Emmons County
North Dakota

- 109 Wells Investigated
- 92 Wells Field Screened
- 12 Wells with a positive numerical response for CH$_4$
- 38 wells with no FID response
- FID response range of 1.6 – 775 ppm as CH$_4$
- 17 wells not visited
Stutsman County - North Dakota

• 170 Wells Investigated
• 106 Wells Field Screened
• 21 Wells with a positive numerical response for CH₄
• 86 wells with no FID response
• FID response range of 0.4 – 182 ppm as CH₄
• 40 wells not visited (access and time restraints)
Rolette County - North Dakota

- 114 Wells Investigated
- 52 Wells Field Screened
- 10 Wells with a positive numerical response for CH₄
- 42 wells with no FID response
- FID response range of 0.6 – 15.2 ppm as CH₄
- 16 wells not visited
Towner County - North Dakota

- 78 Wells Investigated
- 31 Wells Field Screened
- 6 Wells with a positive numerical response for CH$_4$
- 25 wells with no FID response
- FID response range of 0.2 – 32.8 ppm as CH$_4$
- 4 wells not visited
# Summary of Field Screening Results

<table>
<thead>
<tr>
<th>County</th>
<th>Wells Studied</th>
<th>Wells Field Screened</th>
<th>Positive FID response</th>
<th>No FID response</th>
<th>Range of FID Response (ppm as CH₄ in air)</th>
<th>Wells Not Visited</th>
</tr>
</thead>
<tbody>
<tr>
<td>SE Steele</td>
<td>21</td>
<td>9</td>
<td>3</td>
<td>6</td>
<td>2.0 – 146.3</td>
<td>11</td>
</tr>
<tr>
<td>Bottineau</td>
<td>110</td>
<td>33</td>
<td>11</td>
<td>22</td>
<td>2.4 - 30,362</td>
<td>10</td>
</tr>
<tr>
<td>Renville</td>
<td>34</td>
<td>8</td>
<td>3</td>
<td>5</td>
<td>20.6 – 28,000</td>
<td>6</td>
</tr>
<tr>
<td>Emmons</td>
<td>109</td>
<td>92</td>
<td>12</td>
<td>38</td>
<td>1.6 - 775</td>
<td>17</td>
</tr>
<tr>
<td>Stutsman</td>
<td>170</td>
<td>106</td>
<td>21</td>
<td>86</td>
<td>0.4 - 182</td>
<td>40</td>
</tr>
<tr>
<td>Rolette</td>
<td>114</td>
<td>52</td>
<td>10</td>
<td>42</td>
<td>0.6 – 15.2</td>
<td>16</td>
</tr>
<tr>
<td>Towner</td>
<td>78</td>
<td>31</td>
<td>6</td>
<td>25</td>
<td>0.2 – 32.8</td>
<td>4</td>
</tr>
<tr>
<td><strong>Totals</strong></td>
<td><strong>636</strong></td>
<td><strong>331</strong></td>
<td><strong>66</strong></td>
<td><strong>224</strong></td>
<td><strong>0.3 – 30,362</strong></td>
<td><strong>104</strong></td>
</tr>
</tbody>
</table>
Ranges of FID Responses from Observation Wells in Selected North Dakota Counties

ND County Investigated

- SE Steele
- Bottineau
- Renville
- Emmons
- Stutsman
- Rollete
- Towner

FID Instrument Response ppm as CH₄

- North Dakota Department of Mineral Resources
- Geological Investigations No. 42
- North Dakota Geological Survey
Recent ND FID Field Screening Results Summary
FID Response vs. Si to Subcrop Depth

FID Response as CH₄ (ppm)

Bottom of Screened Interval to Bedrock Subcrop Depth (ft)
FID Response vs. SI with Detrital Lignites

FID Response as CH₄ (ppm)

Screened Interval Depth (ft)

= Values with associated detrital lignites
Influence of Detrital Lignites on $[\text{CH}_4]$  

<table>
<thead>
<tr>
<th>Instrument Response Type</th>
<th>Minimum (ppm)</th>
<th>Maximum (ppm)</th>
<th>Range (ppm)</th>
<th>Mean (ppm)</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>FID CH$_4$</td>
<td>0.2</td>
<td>238</td>
<td>237.8</td>
<td>32.3</td>
<td>34</td>
</tr>
<tr>
<td>FID CH$_4$-DL</td>
<td>0.4</td>
<td>2896</td>
<td>2895.6</td>
<td>243.3</td>
<td>25</td>
</tr>
<tr>
<td>FID CH$_4$</td>
<td>0.2</td>
<td>30362</td>
<td>30,361.8</td>
<td>625.7</td>
<td>60</td>
</tr>
</tbody>
</table>

1 Anomalously high value of 30,362 ppm removed from the data set w/out detrital lignite for analysis and comparison.
Statistical Summary of FID Response Data as CH$_4$

All Data

$\bar{X} = 625.7$ ppm

$n = 60$
Comparison of FID response as [CH4] for all wells sampled and wells with and without Detrital Lignites

FID Response as CH₄

All Data  W/DL  WO/DL
### Field Instrumentation

<table>
<thead>
<tr>
<th>Feature</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Size</strong></td>
<td>43.4 cm (17.1&quot;) long, 9.8 cm (3.85&quot;) wide, 18.8 cm (7.4&quot;) high</td>
</tr>
<tr>
<td><strong>Weight</strong></td>
<td>8.1 lb (3.7 kg)</td>
</tr>
<tr>
<td><strong>Operating Temperature Range</strong></td>
<td>41°F to 105°F (5°C to 45°C)</td>
</tr>
<tr>
<td><strong>Operating Humidity</strong></td>
<td>0-100% Relative Humidity (non-condensing)</td>
</tr>
<tr>
<td><strong>Operating Concentration Range (Low Range):</strong></td>
<td>0.5 PPM to 2000 PPM methane equivalent (Low Range)</td>
</tr>
<tr>
<td><strong>Operating Concentration Range (High Range):</strong></td>
<td>10 PPM to 50,000 PPM methane equivalent (High Range)</td>
</tr>
<tr>
<td><strong>Accuracy</strong></td>
<td>0.5 PPM methane within ± 0.5 PPM or ± 10% of actual methane concentration (0.5 PPM to 2000 PPM range)</td>
</tr>
<tr>
<td><strong>Precision</strong></td>
<td>+/-0.3 ppm or +/-5% (0.5 to 2000ppm range) and +/-3 or +/-5% (10 to 50,000 ppm methane range)</td>
</tr>
<tr>
<td><strong>Response Time</strong></td>
<td>Less than 3 seconds Methane (after calibration with zero air and 500 PPM methane gas)</td>
</tr>
</tbody>
</table>
Field Screening a typical observation well at the Top of Casing (TOC) in Emmons County, North Dakota.
Collecting a depth to water measurement after initial TOC field screening.
FID field screening at the GWI via an extended sample probe.
Field Equipment Setup

- Field Laptop
- Sample Hose
- Cal Gases, etc.
- Distilled H₂O
- Field Map
- Field Book/Logs
- Cal Bag
- WLI
- FID

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Conclusions

• Portable analytical instrumentation can be used to detect and measure [CH₄] in ground-water monitoring wells, in the shallow subsurface, in central and eastern North Dakota.

• Detectable [CH₄] were discovered in two distinct shallow gas systems; those within shallow ground-water monitoring wells screened solely in Pleistocene glacial sediments and from wells screened in slightly deeper upper-Cretaceous bedrock zones. Detrital lignite was found to be present in both systems.

• The presence of detrital lignites within a monitored zone provides a source of organics for methanogenesis and is in part responsible for a portion of the CH₄ present in these systems.

• Shallow gas is also found within wells screened in shallow upper-Cretaceous bedrock and Pleistocene glacial sediments, with little or no accumulated organics, suggesting sourcing and migration from underlying upper-Cretaceous shales present in the shallow subcrop.

• The [CH₄] detected were higher, on average, by a factor of 7.5, in wells where detrital lignite was present.

• Further investigation into overall gas compositions and character of carbon isotopes present is required to fully understand sourcing and migration mechanisms and pathways.