Assessment of the Shallow Natural Gas Resource Potential of North Dakota

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NDGS

(NDGS, 2006)
Introduction to Shallow Gas in North Dakota

- Definition of Shallow Gas
- Historical Occurrence and Production
- Geological Factors of Occurrence
- Anthropogenic (Landfill) Gas
- Current Investigations
- Recent Investigative Highlights
A Definition of Shallow Gas in North Dakota

- 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 reservoirs of Cretaceous age or combinations of each.

- Gas Properties (Barry, 1908)
  - 886 BTU
  - 82.7 % Methane
  - 0.2 % Ethane
  - 12.4 % Nitrogen
  - 0.5 % Hydrogen
  - 1.2 % Carbon Monoxide (CO2?)

Gas flare on the Mohall Dome in the early 1920’s.
Areas of Historical Shallow Natural Gas Occurrence

Modified from Hard, 1920
Bottineau County Historic Shallow Gas Occurrences

(Modified from Anderson, 2006)
Historical Shallow Gas Use in North Dakota

Examples of historic shallow natural gas use by North Dakotans likely near Mohall, in Renville Co. around 1919.

Gas storage tank at the Northern Hotel, Edgeley, LaMoure Co., around 1920
Types of Gas Occurrence in North Dakota

- **Thermogenic (Deep Gas)**
  - Producing zones within the Williston Basin

- **Biogenic (Shallow Gas)**
  - Quaternary (Drift) Gas
  - Migrated Gas
    - (Fox Hills/Hell Creek)
  - Cretaceous Gas
    - (Pierre/Niobrara Shale)

- **Anthropogenic (Landfills)**
  - Fargo Municipal Landfill (Active)
  - Grand Forks (Potential)

Gas producing well in the Mohall, ND area around 1920
Shallow Gas Conceptual Models

- Shale Gas (Niobrara Eastern WB Flank)
- Quaternary (Drift Gas)
- Upper Cretaceous Shallow Bedrock
Potential Niobrara Gas

(Modified from Anderson, 2006)
Quaternary “Drift Gas”

(Modified from Anderson, 2006)
Upper Cretaceous Shallow Bedrock

from Shurr 1998
Shallow Gas in Quaternary Deposits

- Playa Lake Setting in Northwest North Dakota
- Drift Gas in Pleistocene sediments in North Central North Dakota
- Influence of Glacirotectonic Ice-Thrusts
- Anthropogenic Methane (Landfill Gas)
North Dakota Playa Lake Setting

(Modified from Anderson and Murphy, 2005)
North Dakota Playa Lake Setting

(Modified from Anderson and Murphy, 2005)
North Dakota Playa Lake Setting

Generalized Lacustrine Stratigraphy

(Modified from Anderson and Murphy, 2005)
Borehole No. 2, Miller Lake, Divide County, ND

(Gas Bubbles)

(Modified from Anderson and Murphy, 2005)
Glaciotectonic Ice-Thrusts

(from Bluemle, 2005)
Glaciotectonic Ice-Thrusts

(fro Bluemle, 2005)
Glaciotectonic Ice-Thrusts

Anamoose (Steele Lake) Ice-Thrust in north-central North Dakota

(NDGS, 2005)
Facilities depicted here include all current permitted facilities which include: municipal solid waste, special waste, industrial, inert-permit by rule, and inert facilities (NDDH, 2005).

Geologic map modified from Clayton, et. al., 1980.
Generalized Near Surface Glacial Stratigraphy at Fargo, ND and Conceptual Landfill Construction

(Modified from Anderson and Murphy, 2005)
Estimation of Landfill Methane Generation Flow Rate

\[ Q_{\text{CH}_4} = L_0 R (e^{-kc} - e^{-kt}) \]

where,

- \( Q_{\text{CH}_4} \) = maximum expected methane generation flow rate (cubic meters per year)
- \( L_0 \) = methane generation potential (cubic meters per Megagram solid waste)
- \( R \) = average annual acceptance rate (Megagrams per year)
- \( k \) = methane generation rate constant (yr\(^{-1}\))
- \( t \) = age of the landfill (yr)

\(^1\) EPA, AP-42
City of Fargo Landfill (Active)

- Current Waste Amount: 2,696,775 Mg
- Average Annual Waste Acceptance Rate: 107,871 Mg/yr
- Landfill Age: 25
- Time Since Closure: 0
- Methane Generation Potential: 170 m$^3$/Mg
  - Methane Generation rate constant: 0.02 yr$^{-1}$
- Estimated Methane Generation:
  - 255M ft$^3$/yr
- Current Methane Generation of approx. 210 ft$^3$/yr
Landfill Gas – Old Minot Landfill

(Modeled from Anderson and Murphy, 2005)
Current NDGS Investigative Activities

- **Background Research**
  - Online Database of Shallow Natural Gas Occurrences in North Dakota.
  - Online Bibliography of Shallow Natural Gas References in North Dakota.

- **Subsurface Geology**
  - Preparation of Correlation Cross Sections through the Cretaceous units across North Dakota
  - Preparation of Structure Contour and Isopach maps of selected Cretaceous units in the state.

- **Hydrogeologic Data Compilation and Analysis**
  - Observation well field screening and sampling
  - Analysis of Ground-Water Geochemistry Data
  - Evaluation of the Influence of Hydraulic Head on Natural Systems
Structure on Cretaceous and Jurassic Units

Several Units Being Worked On by the NDGS:
Structure Contour Maps (1:1,000,000)
  Greenhorn Formation
  Mowry Formation
  Inyan Kara Formation
  Swift Formation
Isopach Maps (1:1,000,000)
  Greenhorn-Mowry
  Mowry-Inyan Kara
  Inyan Kara-Swift
Structure Contour Maps

Preliminary Structure Map On Top Of The Cretaceous Greenhorn Formation in North Dakota
3D Conceptual Structural Surfaces

Conceptual three-dimensional surface model view of the top of the Cretaceous Greenhorn Formation as interpreted from available stratigraphic tops data contained within North Dakota Department of Mineral Resources databases.
Stratigraphic Sections of Cretaceous Units

Proposed lines of stratigraphic and geologic section that will be constructed across Cretaceous stratigraphic units present in North Dakota. Several sections are planned that will interpret the Cretaceous geology across the state from south to north and west to east on a spacing interval of approximately one degree of latitude and longitude.
## Stratigraphic Sections of Cretaceous Units

<table>
<thead>
<tr>
<th>AGE</th>
<th>ERA</th>
<th>PERIOD</th>
<th>SEQUENCE</th>
<th>GROUP</th>
<th>FORMATION</th>
<th>MEMBER</th>
<th>MAX THICKNESS</th>
<th>LITHOLOGY, DEPOSITIONAL ENVIRONMENTS AND OTHER CHARACTERISTICS</th>
</tr>
</thead>
<tbody>
<tr>
<td>MESO</td>
<td>CRETACEOUS</td>
<td>ZUMI</td>
<td></td>
<td>MONTANA</td>
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<td></td>
<td>HELLCREEK</td>
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<td>500 (160)</td>
<td>Sand, siltstone, shale, fine sandstone, siltstone, and fine sand.</td>
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<td></td>
<td>COLGATE</td>
<td>BULLHILL</td>
<td>400 (120)</td>
<td>Sandstone, siltstone, fine sandstone, and siltstone.</td>
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<td></td>
<td></td>
<td>FOX HILLS</td>
<td>TIMBER LAKE</td>
<td>400 (120)</td>
<td>Sandstone, siltstone, fine sandstone, and siltstone.</td>
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<td>TRAIL CITY</td>
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<td>DEGREY</td>
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<td>GREGORY</td>
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<td>2,360 (700)</td>
<td>Sandstone, siltstone, fine sandstone, and siltstone.</td>
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<td>PEMBINA</td>
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<td>GAMMON FERRUGINOUS</td>
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<td>NICOBARA</td>
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<td>250 (75)</td>
<td>Sandstone, siltstone, fine sandstone, and siltstone.</td>
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<td>CARUL</td>
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<td>400 (120)</td>
<td>Sandstone, siltstone, fine sandstone, and siltstone.</td>
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<td></td>
<td>GREENHORN</td>
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<td>150 (45)</td>
<td>Sandstone, siltstone, fine sandstone, and siltstone.</td>
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<td>BELL FOURCHE</td>
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<td>350 (105)</td>
<td>Sandstone, siltstone, fine sandstone, and siltstone.</td>
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<td>MOYRY</td>
<td></td>
<td>190 (55)</td>
<td>Sandstone, siltstone, fine sandstone, and siltstone.</td>
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<td>NEWCASTLE</td>
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<td>150 (45)</td>
<td>Sandstone, siltstone, fine sandstone, and siltstone.</td>
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<td>SKULL CREEK</td>
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<td>140 (40)</td>
<td>Sandstone, siltstone, fine sandstone, and siltstone.</td>
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<td></td>
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<td></td>
<td></td>
<td>INYAN KARA</td>
<td></td>
<td>450 (125)</td>
<td>Sandstone, siltstone, fine sandstone, and siltstone.</td>
</tr>
</tbody>
</table>

1. Millions of years before present.
2. Maximum thickness is in feet. Values in parentheses are in meters.
Several stratigraphic units are planned to be evaluated in North Dakota. These five units consist of three Cretaceous age stratigraphic units (Greenhorn, Mowry, and Inyan Kara) and two Jurassic age stratigraphic units (Swift and Rierdon Formations). Structure contour maps drawn on each stratigraphic unit along with corresponding isopach maps at scales of 1:1,000,000 are planned.
Recent Investigative Highlights

• Steele County
  Niobrara Shale Gas Concept
  Results

• Bottineau County
  Combined “Drift Gas” and Upper Cretaceous
  Shallow Bedrock

• Renville County
  Continuation of Bottineau Area Trend
Reconnaissance Field Screening Studies

- Screening of existing monitoring points with portable instrumentation:
  - Flame Ionization Detectors (FIDs)
  - Multi-Gas Meters
  - Oxygen
  - Carbon Dioxide
  - Hydrogen Sulfide
NDGS Reconnaissance Observation Well Field Screening Investigations
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.)
Recent FID Field Screening Results

GROUND-WATER OBSERVATION WELL SHALLOW GAS FID FIELD SCREENING
BOTTINEAU COUNTY, NORTH DAKOTA

AREA OF SHALLOW GAS OCCURRENCES

NDGS, 2006
Bottineau & Renville County, North Dakota

Continuation of the Historical Bottineau Area Trend

Recent Preliminary Shallow Gas Occurrences

NDGS, 2006
Hydrogeologic Data Assessments
Assessment and Interpretation of Ground-water Geochemistry

Relationship of Historic Wells with Gas Shows to [Sulfate]

(Modified from Anderson, Shurr, and Fischer, 2006)
Hydrogeologic Data Assessments

Assessment and Interpretation of Ground-water Geochemistry

Relationship of Historic Wells with Gas Shows to [Bicarbonate]

(Modified from Anderson, Shurr, and Fischer, 2006)
Remote Sensing and Geomorphic Analysis

LANDSAT Imagery modified from USGS – NASA
Planned Focused Field Investigations

- Shallow Monitoring Wells
- Air and Ground-Water Sampling
- Isotope C Geochemistry
- Ground-Water Geochemistry
- Methanogens
Recent NDGS Publications of Interest Related To Shallow Gas

- NDGS Geological Investigation No. 25 (GI-25)
Recent NDGS Publications of Interest Related To Shallow Gas

**ASSESSMENT OF POTENTIAL SHALLOW NATURAL GAS RESOURCES IN NORTH DAKOTA**

- **NDGS Shallow Gas Investigations Activities Completed and Planned**
  - January 2005: North Dakota Geological Survey conducts a research planning and initial report shallow gas investigations work in North Dakota.
  - May 2005: Survey geologists Fred J. Anderson and Edward C. Murphy present results of studies regarding unconventional resource potential in North Dakota at the 39th Annual Meeting of the North Central Section of the Geological Association of America in Minneapolis, Minnesota.
  - February 2006: North Dakota Geological Survey launches shallow gas investigations web page and user interface for the collection of research information on shallow gas occurrences in North Dakota.
  - March 2006: Presentation on Historical Shallow Gas Occurrences in North Dakota given to the North Dakota Water Well Drillers Association 2006 convention in Minot.
  - May 2006: Survey presents Preliminary Structure Contour Maps at scale of 1:1,000,000 for the state of North Dakota and 1:100,000 for Dawson, Sibley, and Towner Counties.
  - Q1 2006: Survey plans to complete Preliminary Structure Contour Maps, 1:100,000 maps, and Geologic log sections on the Cretaceous Greenhorn, Minn, and Jiyem Kusa Formations across North Dakota.
  - Q1 2007: Survey plans to complete an analysis of structural cross sections and Geologic log sections on the Cretaceous across North Dakota.

- **NDGS Geological Investigation No. 26 (GI-26)**

North Dakota Department of Mineral Resources  
North Dakota Geological Survey  
Geological Investigations No. 32
Recent NDGS Publications of Interest Related To Shallow Gas

- NDGS Geological Investigation No. 28 (GI-28)
Recent NDGS Publications of Interest Related To Shallow Gas

- NDGS Geological Investigation No. 29 (GI-29)
Recent NDGS Publications of Interest Related To Shallow Gas

• NDGS Geological Investigation No. 30 (GI-30)
NDGS Publications Related to Coal Gas

NDGS

Open File Report 98-1

(OF-98-1)
Report of Investigations No. 104

THE LIGNITE RESERVES OF NORTH DAKOTA
by
Edward C. Murphy

25 Billion Tons of Mineable Lignite
1.3 Trillion Tons of Coal in North Dakota
The NDGS Shallow Gas Project web page (currently under construction) is the focal point for the access of geologic information on shallow gas occurrences in North Dakota. The web page contains useful historical background information on shallow gas exploration and development, in addition to recent publications and online databases and maps. It is planned to be updated each quarter with new information including data and map additions as they are completed.
Link to Shallow Gas Project Page

http://www.state.nd.us/ndgs/
SHALLOW NATURAL GAS OCCURRENCES IN NORTH DAKOTA

The North Dakota Geological Survey, a division of the North Dakota Department of Mineral Resources, is conducting an assessment of the Shallow Natural Gas Resource Potential of North Dakota.

A valuable component of the research portion of this investigation is the collection of anecdotal information about occurrences of shallow natural gas across the state. This anecdotal information may be in the form of a story or personal account of gas emanating from a well, or gas encountered while digging or drilling a private residential or farm well, or while conducting general excavation.

Your story may be very significant! We would encourage you to share your story with us by way of this website page and link. Simply click on the submit your story link below and send us an email message with your story or other information. Individual submissions will be reviewed by the geological staff of the Survey for inclusion into the North Dakota Geological Survey Online Database of Shallow Natural Gas Occurrences in North Dakota that will be available soon on this website.

Please include your contact information with your submittals so that our staff can follow-up with you on a one-on-one basis. We look forward to hearing your stories. Perhaps it will be your story that leads to the next great shallow natural gas discovery in our state!

Please click on the submit your story link to email your information to us.

Thank you!

Shallow Natural Gas Stories
Further questions to be answered

• In what geologic framework is gas being generated and/or accumulated?

• What is the timing associated with initial gas generation and/or the rates of gas generation?

• What are the underlying and overlying structural conditions influencing generation, migration, and accumulation?
Some Potential Indicators for Exploration

• Direct Detection of Methane in Shallow Wells
  Observation
  Stock
  Water Supply (private and municipal)

• Ground-water Geochemistry
  Sulfate and Bicarbonate
  Others?
North Dakota Department of Mineral Resources
North Dakota Geological Survey
North Dakota Geological Survey Paleontology Lab
North Dakota Geological Survey Geological Investigations No. 32

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Email Contact: fjanderson@nd.gov

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North Dakota Geological Survey Municipal Logo

North Dakota Geological Survey Municipal Logo
Subsurface Geologic Map of North Dakota

(Modified from Bluemle, 1983)
Surface Geologic Map of North Dakota

(Modified from Clayton et al, 1980)