Department of Mineral Resources
Lynn D. Helms, Director

SHALLOW NATURAL GAS OCCURRENCES IN QUATERNARY DEPOSITS IN NORTH DAKOTA

Fred J. Anderson[1], Edward C. Murphy[1], John P. Bluemle[2], and David W. Fischer[3]

Fred J. Anderson
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North Dakota Geological Survey
Edward C. Murphy, State Geologist
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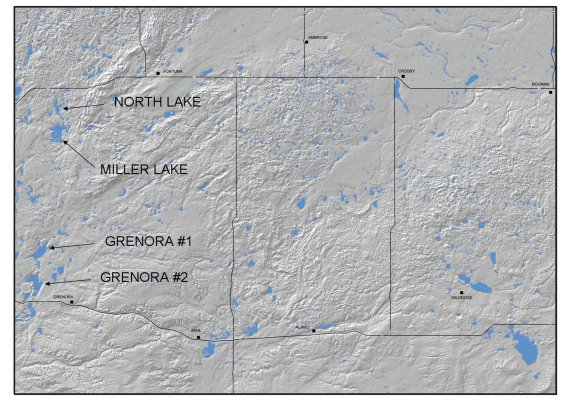
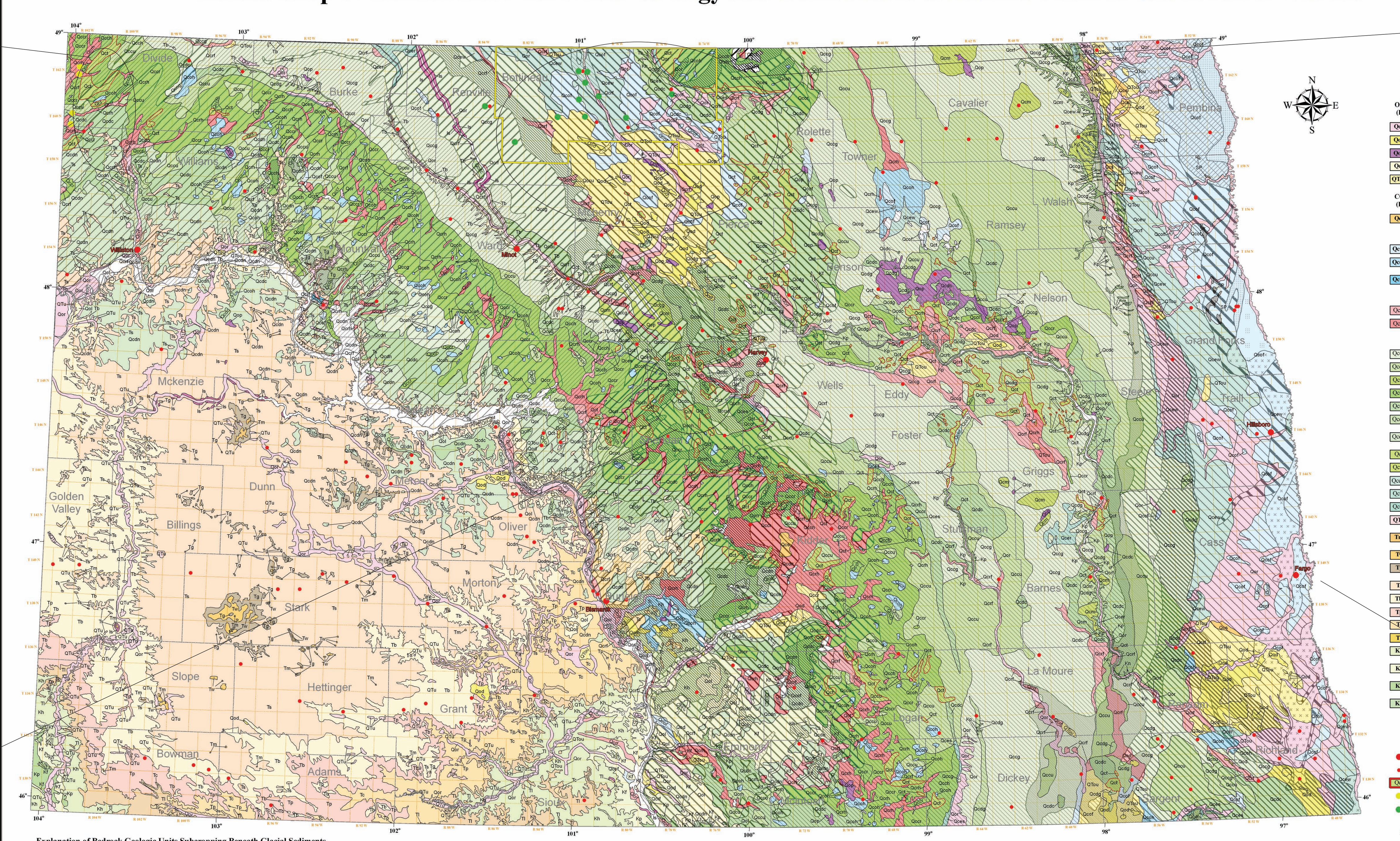
Natural Gas Generation within Playa Lakes in North Dakota



Relationship of Surface and Subsurface Geology and Occurrences of Shallow Natural Gas in North Dakota

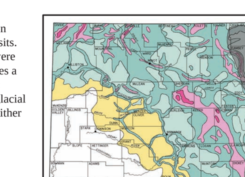


GIS Map Compilation by Elroy L. Kadrmas

Natural Gas Production from Outwash in North Central North Dakota

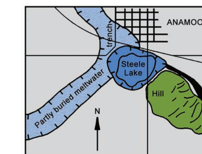
Possible Occurrence of Shallow Gas Resulting from Glacial Processes in the Northern Great Plains

There are many geologic factors that may bear consideration when looking for shallow gas in areas of thick glacial deposits. Some of these factors include glaciotectonic features that were observed and studied in North Dakota. This section provides a brief overview of the characteristics of a few glaciotectonic structures. Also, questions regarding the consideration of glacial processes when searching for occurrences of shallow gas, either in the glacial deposits themselves, or in the immediately underlying preglacial sediments, are highlighted.



Questions relating to isostatic rebound

- Does isostatic loading and rebound, and the resulting fractures that form, affect the location, extent or integrity of shallow-gas accumulations in subglacial strata?
- How deep were the subglacial sediments fractured during isostatic depression and rebound? Strain due to the weight of the overlying glacial ice – and due to unloading when the ice melted – could have resulted in fracturing to great depths. A significant hurdle that restricts gas production from coal and shale is low permeability. Fracturing caused by isostatic rebound may have increased the permeability, and might improve the delivery of gas through the formation to the well bore.
- Did stresses caused by the weight of the glacier cause differing sets of intersecting fractures? We don't know whether the flow direction of the glacier was an important factor influencing the kinds and directions of subsurface fractures that might have developed in the materials beneath the ice. Earlier glaciers advanced over the plains states and provinces from a variety of directions. The variety of stresses they caused may have resulted in differing sets of intersecting fractures. Repeated glaciations, with loading and unloading during each episode, could have had a cumulative effect on the overall fracture system.
- Did repeated glaciations have a cumulative effect on the overall fracture systems in the underlying materials? Repeated glacial advances, from a variety of directions, may have resulted in many different stress fields developing in the materials beneath the glaciers. In the Norwegian sector of the North Sea, changes in stress fields are thought to have caused repeated reactivation of faults during the Pleistocene glaciations, especially during the Weichselian (Wisconsinan) interglacials. Similarly, the array of fractures that formed in the bedrock materials beneath the glaciers in this area could be quite complex and the fracture systems extensive. The fractures, and movement of fluids within, may have been repeatedly reactivated during successive glaciations.



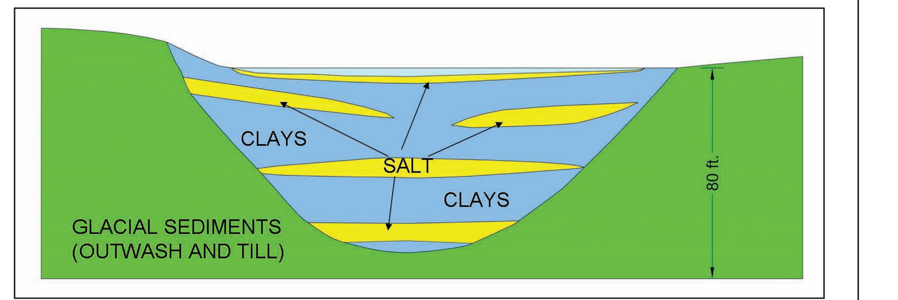
Ice-thrust hill near the village of Anamoose, west-central North Dakota. This is an ice-thrust hill – the greenish area – adjacent to a depression flooded by a lake. The location of a buried meltwater trench – an underground aquifer – is also shown. Glacier movement was from the upper left to the lower right. The material that now is in the hill came from the area that is now a depression flooded by Steele Lake. Probably 90 percent of the ice-thrust features observed are closely associated with buried aquifers. Thrusting occurs when high pore-water pressures build up beneath the glacier. During the thrusting process, the pore pressures within the involved and underlying strata, are greatly increased. As a result, the materials are forced upward into the path of the advancing glacier. The upward force essentially reduces the friction between an overlying slab of material and the material beneath so that, essentially, all the glacier has to do is move the material forward. In this way, slabs of material are pushed upward into the glacier's path and moved.

Questions About Glaciotectonic Structures

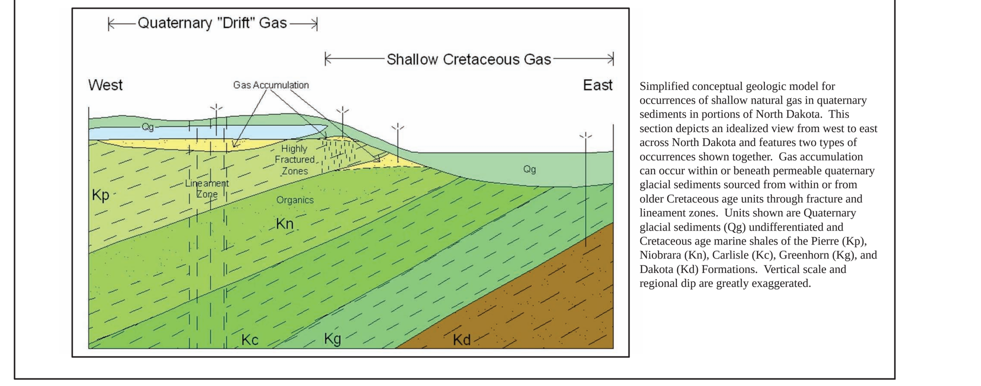
- Is there a relationship between glaciotectonic processes and the occurrence of shallow gas traps? An understanding of whether traps form as a result of glacial thrusting and whether the thrusting process influences gas movement (as it does porewater pressure) is needed. Certainly, large, buried ice-thrust slabs could serve as traps. Those ice-thrust features we have been able to identify are near the surface and likely represent only a small fraction of the structures present at depth. It is uncertain how far beneath the base of the glacier that sediments would be affected by glaciotectonic processes, but it may have been as much as several hundred meters.
- If such a relationship exists, might it be possible to search for gas traps by first identifying the locations of ice-thrust features? Many ice-thrust features can be easily identified on air photos, or topographic maps. Is it possible to search for gas traps by first identifying the ice-thrust features?
- Did changes in pore-water pressures due to thrusting have an effect on the occurrence of shallow gas accumulations? Could the altering of pore water pressures, in addition to causing glacial thrusting, also have had an effect on the occurrence of shallow gas accumulations?
- Could areas of near-surface ice-thrust materials be places where gas escaped during thrusting? As a converse consideration: could areas of ice-thrusting be places where gas escaped during thrusting and has continued to escape since then? Ice-thrust features might serve either as traps or as continuing conduits for the escape of gas.

Conceptual Geologic Models of Shallow Natural Gas Occurrence

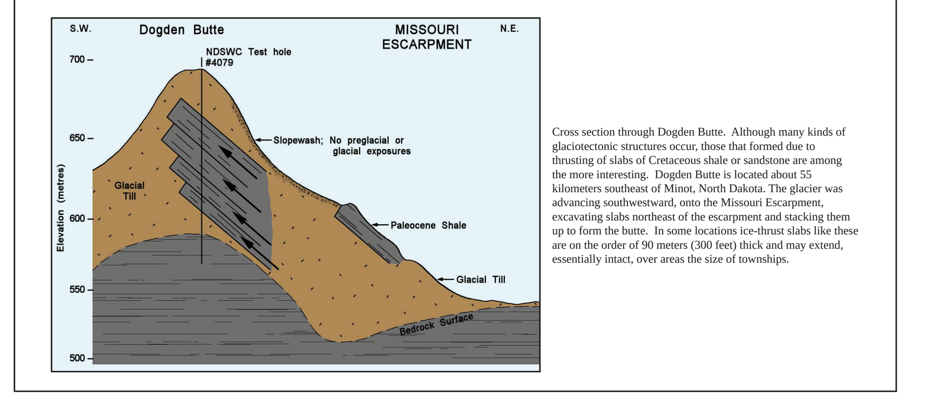
Playa Lake Setting in Northwestern North Dakota



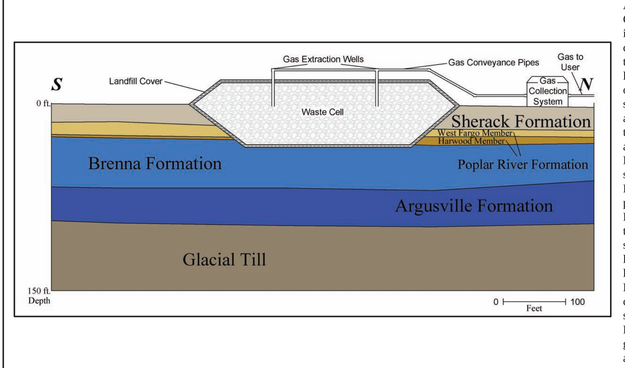
Glacial Drift and Shallow Cretaceous Geologic Setting



Glacio-Tectonic Ice Thrust Features



Anthropogenic Gas: Fargo Landfill in North Dakota



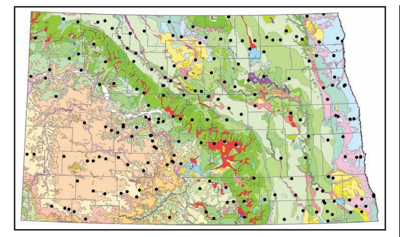
ABSTRACT

Shallow natural gas occurs within several near surface geologic environments in North Dakota. Occurrence has been observed or inferred to originate within glacial sediments accumulating as the result of glaciotectonic processes and anthropogenic means. Historically, gas has been produced from fields in Renville and Bottineau Counties. Geologic conditions and potential sourcing consist of a subcrop of Cretaceous marine sediments scoured and mantled by glacial sediments with contained organics as a potential source. Glaciotectonic ice-thrust masses, several square kilometers in areal extent, and structures within Cretaceous units, may impose structural control on shallow subsurface fluid flow. The advance and retreat of glacial ice across the northern Great Plains and subsequent sediment unloading may influence development of horizontal partings and vertical fracturing within glacial sediments and underlying sedimentary strata providing conduits for shallow gas flow. Gas-rich deposits of sodium sulfate up to 80 feet thick beneath 15 playa lakes in northwestern North Dakota consist primarily of black, organic-rich clays and crystalline layers of sodium sulfate of Holocene age. Borehole gas emanations and gas pockets beneath salt layers were observed along with gas escaping from vents on the bottom of Miller Lake in Divide County. Anthropogenic methane generation within landfills occurs in Minot, Harvey, Williston, Grand Forks, and Hillsboro representing a local gas resource with more than 400 cfm of gas extracted from a recently installed gas collection system in Fargo. Over 300 MCF of gas has been used locally, since system construction, as an alternative industrial fuel source.

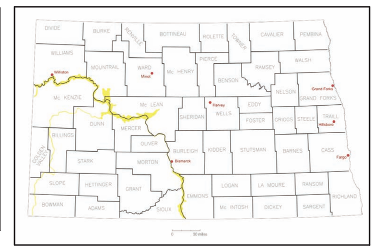
REFERENCES

Anderson, F.J., and Murphy, E.C., 2005, Two Unconventional Sources of Methane in North Dakota, Geological Society of America, Abstracts with Programs, North Central Section, Volume 37, Number 5, p. 28.
Barry, J.G., 1908, The Bottineau Gas Field, North Dakota Geological Survey, 5th Biennial Report, pp. 247-251.

Anthropogenic Methane Generation Potential at North Dakota Landfill Facilities



The locations of the numerous landfill facilities in North Dakota that are permitted and tracked by the North Dakota Department of Health are shown in the map at right. The majority of facility locations are located in areas that have been modified by glacial ice. Locations include: municipal waste, special waste, industrial, inert-permit by rule, and inert facilities.



There are six landfill facilitiy locations where direct evidence exists for landfill gas and methane generation based on previous documentation and observations made during geologic investigations. The locations are: the City of Fargo Landfill, the City of Grand Forks Landfill, the Hillsboro Landfill, the Williston (Sand Creek) Landfill, the Old Minot Landfill, and the Harvey Landfill.

Estimation of Landfill Methane Generation Flow Rate[1]

$$Q_{CH4} = L_o R \left(e^{-kc} - e^{-kt}\right)$$

where,

Q_{CH4} = maximum expected methane generation flow rate (cubic meters per year)

L_o = methane generation potential (cubic meters per Megagram solid waste)

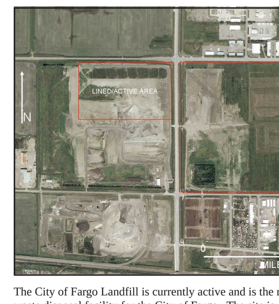
R = average annual acceptance rate (Megagrams per year)

k = methane generation rate constant (yr^{-1})

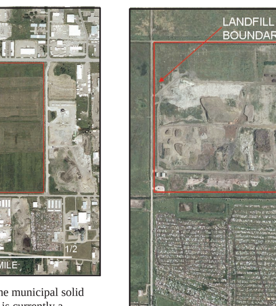
t = age of the landfill (yr)

[1] EPA, AP-42

Estimation of Methane Generation Potential. Site specific information for each of the selected landfill locations was collected and applied to an equation for the estimation of methane generation flow rate at each landfill facility. This equation was used at each of the selected locations, using best available site specific information on waste amounts, with a few assumptions, in order to estimate the maximum expected methane generation flow rate for each landfill.



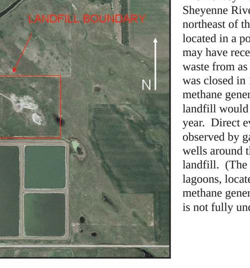
The City of Fargo Landfill is currently active and is the municipal solid waste disposal facility for the City of Fargo. The site is currently a 160-acre site that began operations in 1991 that consists of an unlined/closed area and a lined active area. Around 1,000,000 tons of waste have been placed in the unlined/closed area, 1,700,000 tons of waste have been placed in the lined area for a total of 2.7M tons of waste in-place. Gas extraction system components consist of twenty wells with 18 in the lined area and 2 in the unlined areas that were installed in 2001. From June 2002 through August 2003 the City of Fargo has sent approximately 146M cubic feet of landfill gas to local industry for use as an alternative fuel source. It has been estimated that the methane generation flow rate potential for this landfill would be around 255 million cubic feet per year.



The City of Grand Forks Landfill is located on the western edge of the City of Grand Forks. The landfill began operations in 1965 and has received many different types of solid waste (MSW, inert, yard waste, etc.) throughout its history, and is currently active. It has been estimated that the methane generation flow rate potential for this landfill would be around 273 million cubic feet per year.

The Hillsboro Landfill is located in central Traill County around three miles northwest of the City of Hillsboro. The landfill covers a relatively small area of approximately 4.5 acres. The landfill began operations in 1976 and closed in 1987 and received a variety of wastes. Further, it has

View to the North/Northeast of the Williston Landfill. The Williston landfill is located approximately one mile west of the City of Williston situated within a north-south trending ravine on a hillside overlooking Sand Creek. The landfill covers approximately 18 acres and has received an estimated 190,000 tons of solid waste, to include oilfield wastes, and was in operation from 1969 to 1987. Waste placement occurred within the central portion of the drainage ravine. Erosion has occurred along the central portion of the covered surface. It has been estimated that the methane generation flow rate potential for this landfill could be around 12 million cubic feet per year. Heavy moisture infiltration across the waste placement area has also been observed which could lead to more favorable conditions for methane generation within the waste cell.



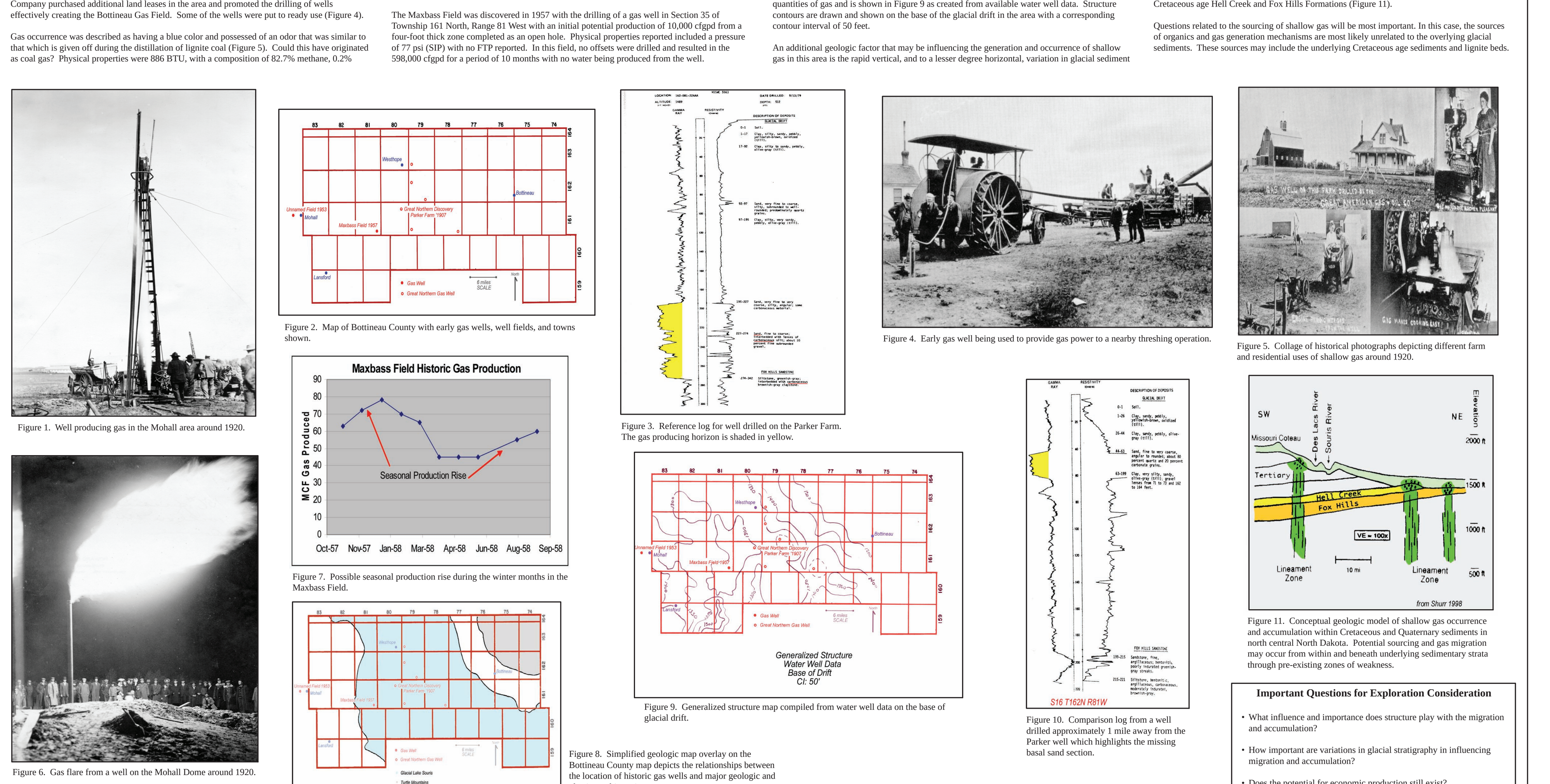
The Harvey Landfill is located on the edge of the Sheyenne River valley around a mile and a half northeast of the City of Harvey. The landfill was located in a portion of an abandoned gravel pit and may have received as much as 170,000 tons of waste from as far back as the 1930's. The landfill was closed in 1988. It has been estimated that the methane generation flow rate potential for this landfill would be around 6 million cubic feet per year. Direct evidence for methane generation was observed by gas bubbling from within monitoring wells around the north-northwest portion of the landfill. (The potential effect of the wastewater lagoons, located to the south of the landfill, on methane generation within the shallow groundwater is not fully understood).

Estimated Maximum Potential Methane Generation for Selected ND Landfills

Landfill Location	Waste Amount[1] (Mg)	Average Annual Acceptance Rate R (Mg/yr)	Landfill Age t (yr)	Time Since Closure c (yr)	Methane Generation Factor[2] ($e^{-kc}-e^{-kt}$)	Max. Expected Methane Generation Q_{CH4} (Mft^3/yr)
City of Fargo (Active)	2,696,775	107,871	25	0	0.39	255
City of Grand Forks (Active)	3,636,364	82,727	40	0	0.55	273
Old Minot Landfill	249,113	24,911	44	34	0.09	14
Hillsboro	73,361	6,669	45	18	0.29	12
Williston (Sand Creek)	172,900	9,606	35	18	0.20	12
Harvey	155,711	3,114	50	17	0.34	6

[1] Methane generation potential L_o (m^3/Mg sw) = 170
[2] Methane generation rate constant k (yr^{-1}) = 0.02

A summary table of the values used for the variables in the methane generation flow rate estimation equation. Each of the landfills looked at in this work are presented here in descending order of methane generation flow rate. It is interesting to note the difference between the rates in methane generation between the active and closed facilities – the active facilities capable of considerably higher amounts of landfill methane over time.



The mission of the North Dakota Geological Survey is threefold:

Investigate and report on the geology of North Dakota, emphasizing the state's energy and mineral resources, and applied research leading to economic benefits or quality of life improvements for the people of North Dakota.

Provide public service, and to collect, create, and disseminate geologic and map-related information, and