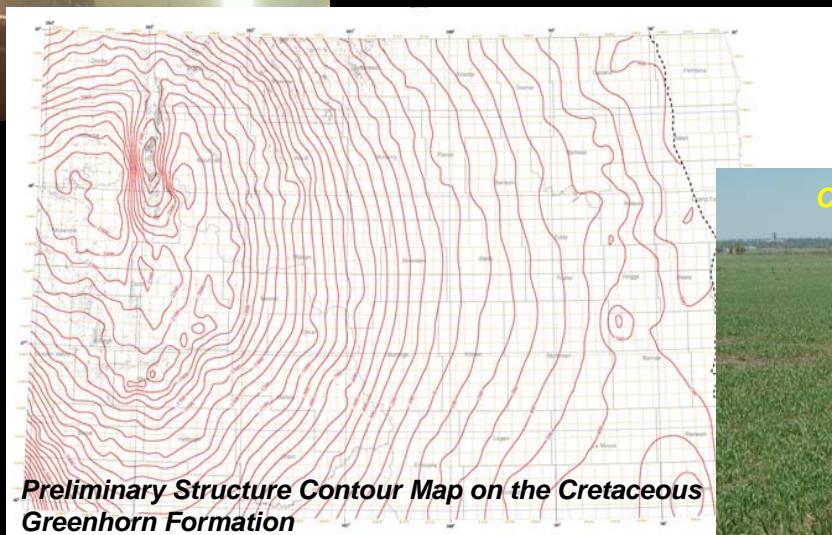
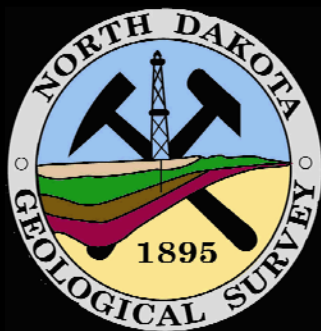


Drilling on the Welch 1-32



Staghorn, 2007

# Shallow Gas Exploration and Production in North Dakota



Preliminary Structure Contour Map on the Cretaceous Greenhorn Formation

CH<sub>4</sub> Field Screening in Burleigh County, ND



NDGS

**Fred J. Anderson, Geologist**  
North Dakota Geological Survey



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# Historical Shallow Gas Occurrence and Use in North Dakota



(NDGS)

Shallow gas flaring from the "Mohall Dome" in north-central North Dakota (ca. 1920s)



(NDGS)

Threshing operation on a farm near Mohall, North Dakota in 1919. Note the shallow gas wellhead in left foreground

*"Within the area covered by the "Mohall anticline" a large number of wells yield gas under pressure of over 100 pounds, the gas being found in Sandstones of the Fort Union Formation at a depth of 200 to 300 feet."*

*-N.D. State Geologist A.G. Leonard, 1920-*



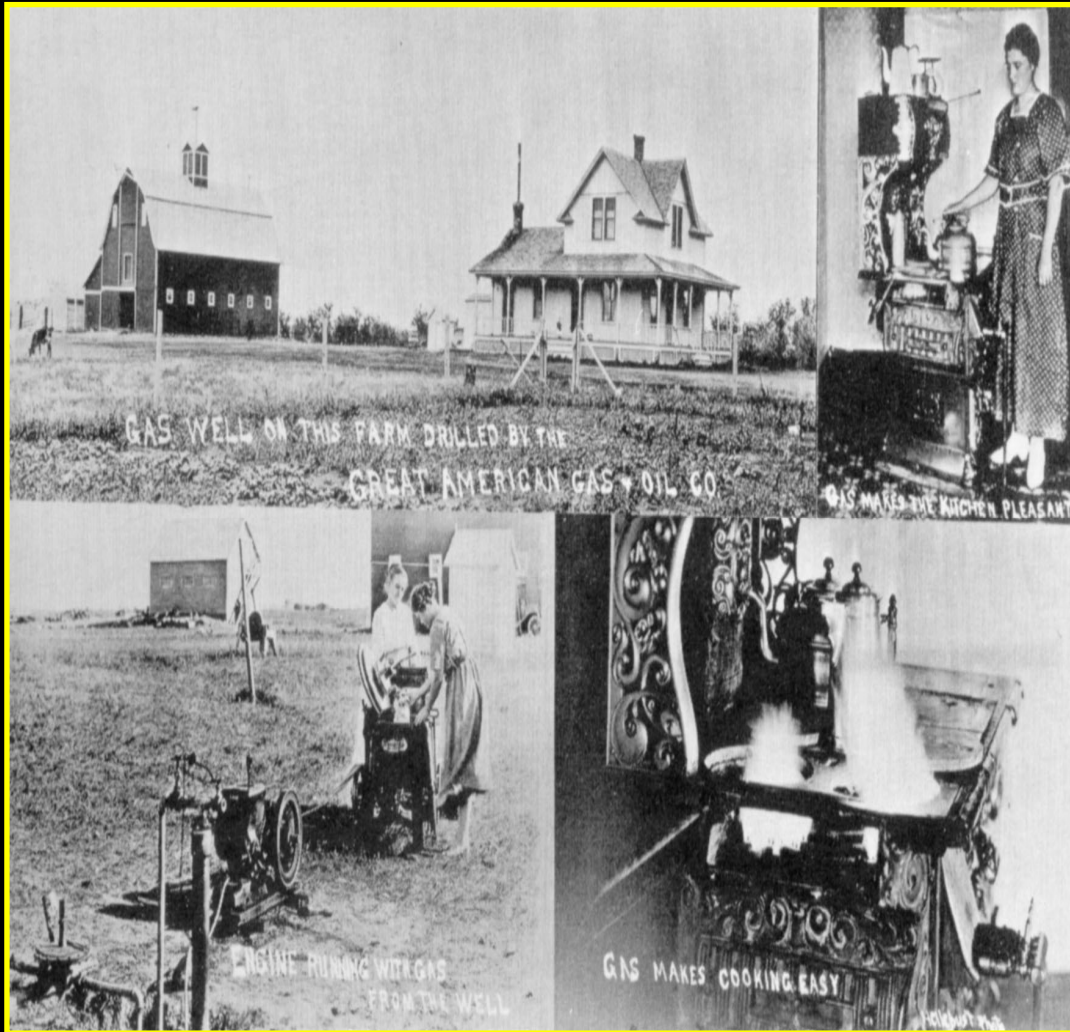
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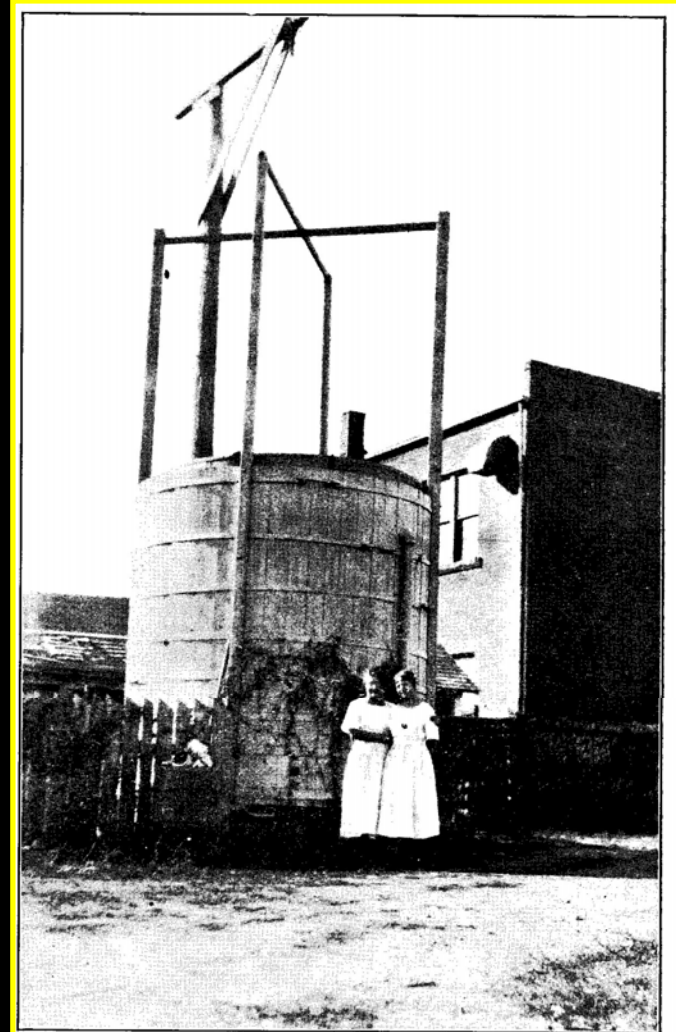
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# Historical Shallow Gas Use in North Dakota

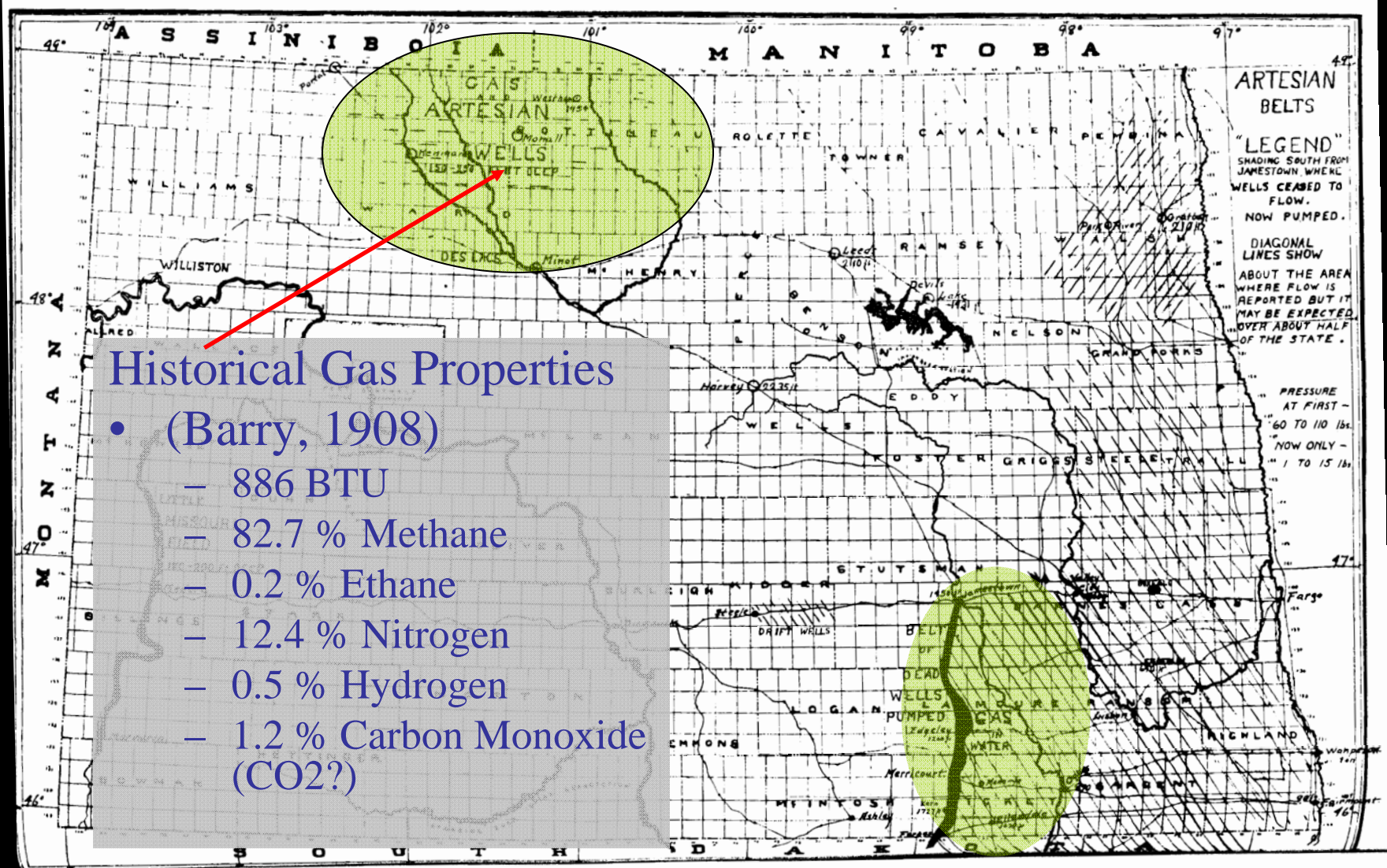


Examples of historic shallow natural gas use by North Dakotans likely near Mohall, in Renville County around 1919.



Gas storage tank at the Northern Hotel, Edgeley, LaMoure Co., around 1920

# Areas of Historical Shallow Natural Gas Occurrence



Modified from Hard, 1920

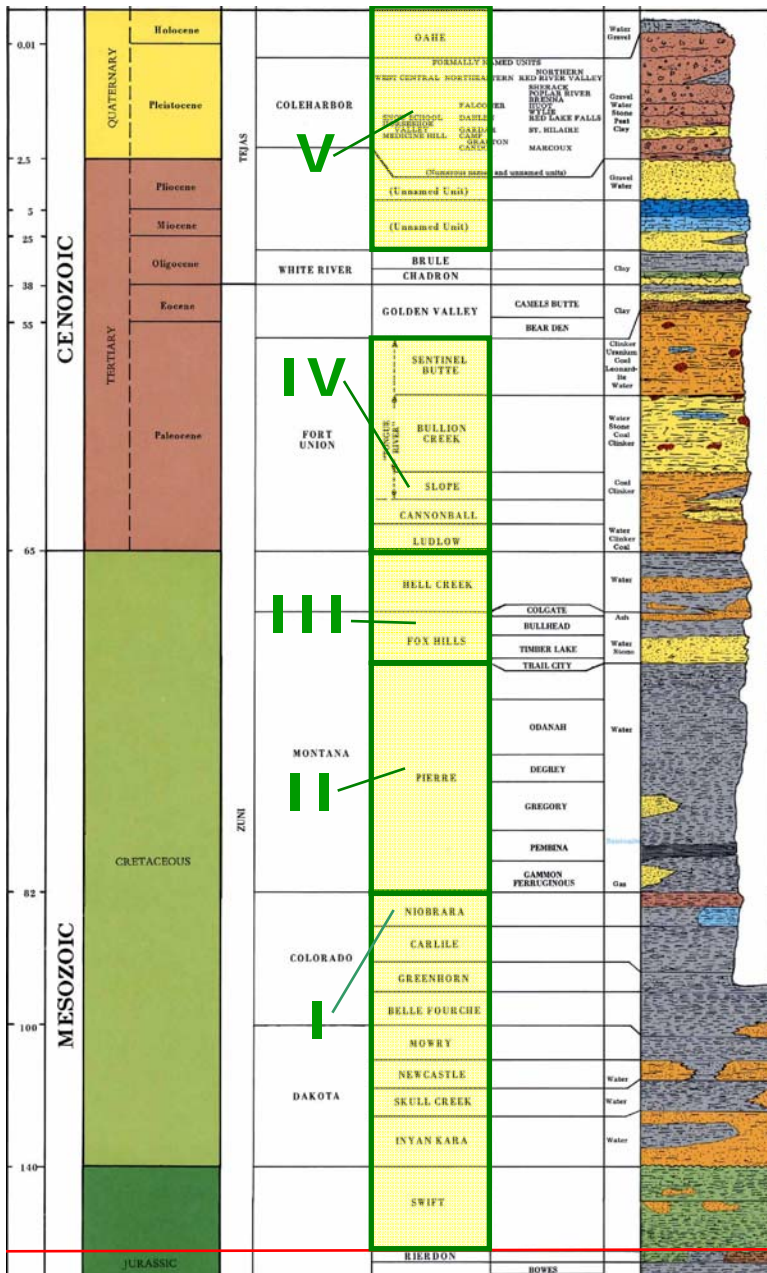


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# Definitions of Shallow Gas in North Dakota

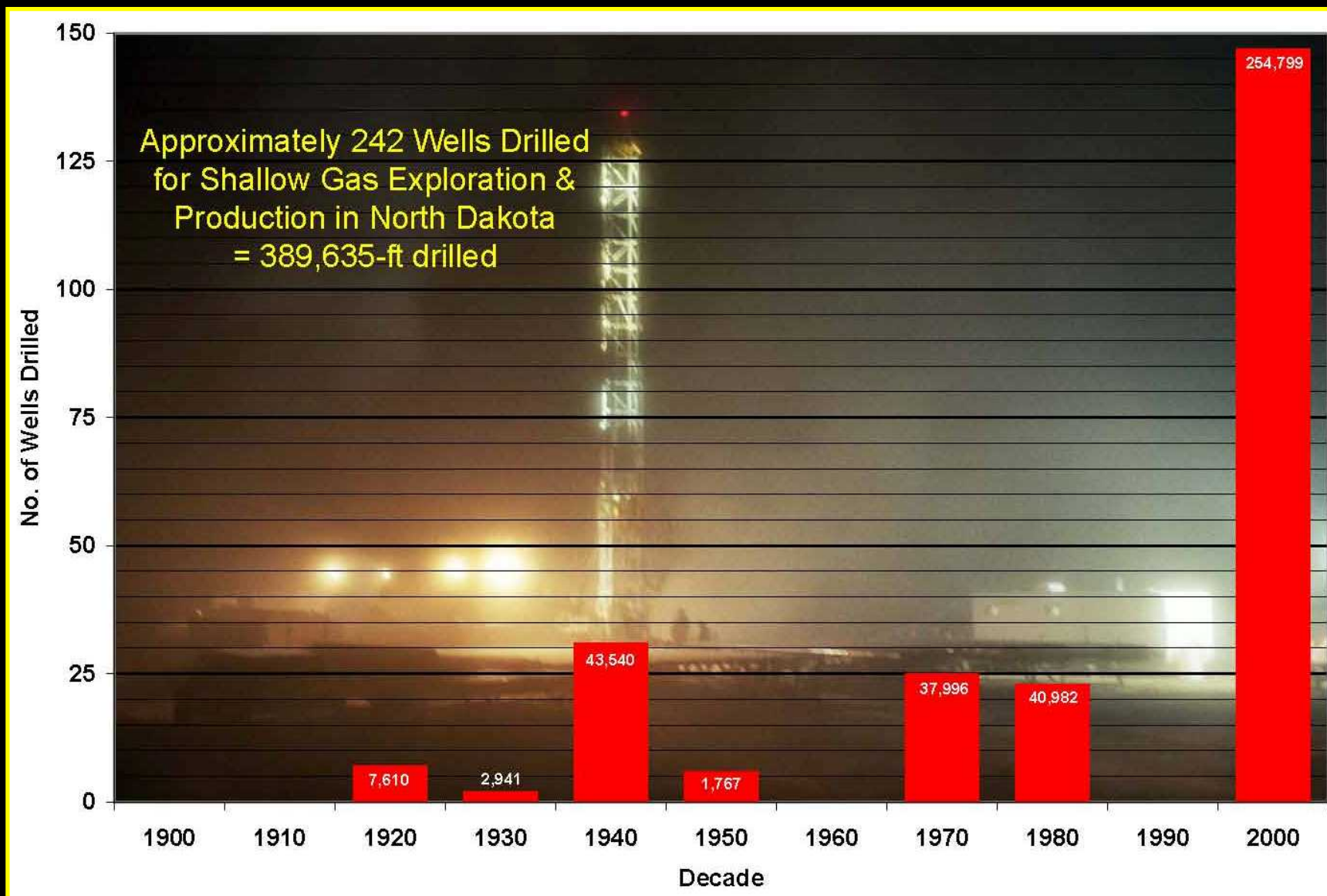
- **Geologic** - Natural gas that is generated and accumulated within the near surface geology of the state, typically sourced and contained within permeable organic laden Pleistocene glacial or Quaternary sediments or within Mesozoic fractured shale and sandstone reservoirs.
- **Regulatory** - Gas that 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).

## Selected Shallow Gas "Intervals"

- **Interval I:** Formations of the Colorado and Dakota Groups (Niobrara and Greenhorn Fms.)
- **Interval II:** The Pierre Formation (en masse)
- **Interval III:** The Hell Creek – Fox Hills Formations
- **Interval IV:** Formations of the Fort Union Group
- **Interval V:** Quaternary Sediments & Pleistocene Glacial Sediments



# Historical Timeline of Shallow Gas Wells Drilled in North Dakota



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# 2007 ND Legislative Activities



North Dakota State Capitol Grounds, 2007

- Sunset provision removed from NDCC 57-51-02.4 (Oil and Gas Production Tax).
- Effectively making “permanent” the current 24-month shallow gas production tax exemption on wells completed or recompleted in a shallow gas zone after June 30, 2003.
- Exemption also includes gas produced during the testing phase prior to completion or connection to a pipeline (NDCC 57-51-02.4).



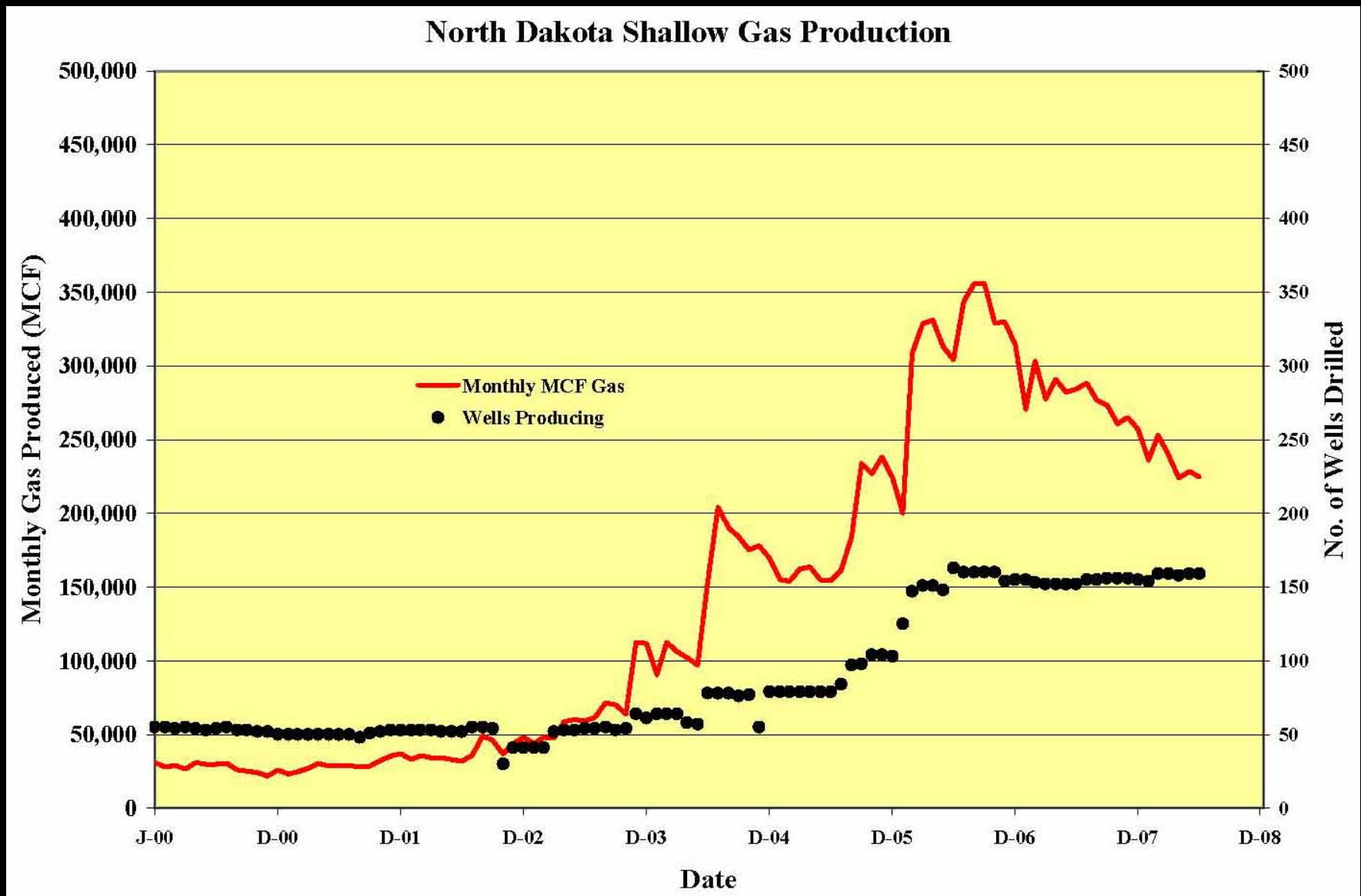
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# Current Shallow Gas Drilling & Production



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# *Types of Shallow Gas Occurrence in N.D.*

- **Thermogenic (Deep Gas)**
  - Producing zones within the Williston Basin
- **Biogenic (Shallow Gas)**
  - **Quaternary (Drift) Gas**
  - **Migrated Gas**
    - (Fox Hills/Hell Creek)
  - **Cretaceous Gas**
    - (Pierre Shale/Niobrara Fm.)
- **Playa Lake Setting**
  - Gas producing Muds
- **Anthropogenic (Landfills)**
  - Fargo Municipal Landfill (Active)
  - Grand Forks (Potential)



*Gas producing well in the Mohall, ND area around 1920*



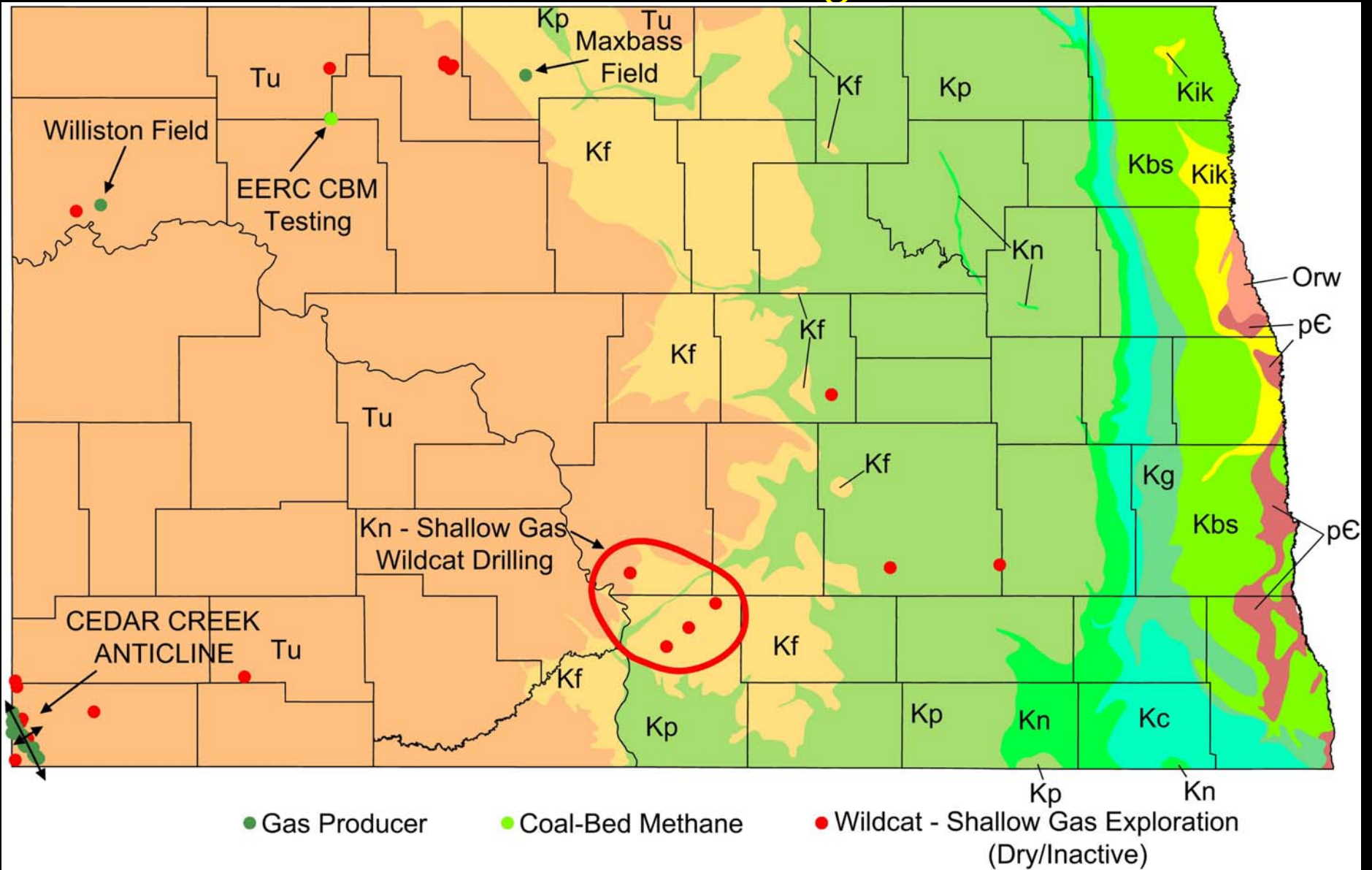
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# Shallow Gas Wells and Drilling in North Dakota



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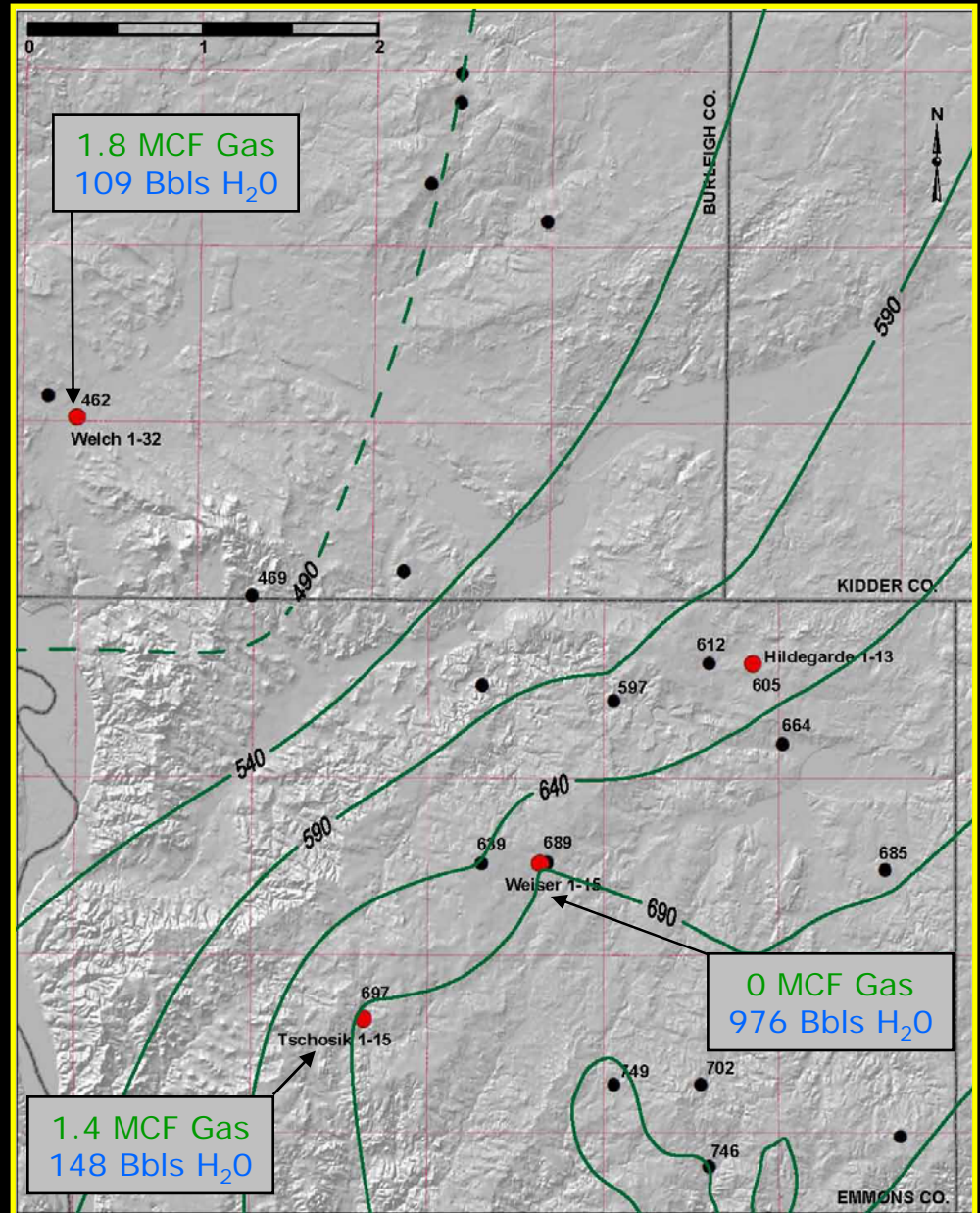
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# Recent Wildcat Activity Niobrara Test Drilling

- Six Locations Permitted by NDO&GD
- Four Wells Drilled: Traditional Mud-Rotary
  - Welch 1-32 (Burleigh Co.)
  - Tschosik 1-15 (Emmons Co.)
  - Weiser 1-15 (Emmons Co.)
  - Hildegarde 1-13 (Emmons Co.)
- Three Wells Completed
  - Depths of approx. 1,370-ft MD
  - Chalky Interval Niobrara Fm.
  - 10-ft Completion Intervals
  - Stimulation:
    - Sand-Gel-N<sub>2</sub> Foam Fracs
- Average gas production:
  - 1.5 MCF/day (Welch 1-32 & Tschosik 1-15)
  - w/128 Bbls H<sub>2</sub>O/day
- Weiser 1-15:
  - 0 MCF Gas w/976 Bbls H<sub>2</sub>O

*(Interval I)*



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# Niobrara Fm. Test Drilling – Core Properties Summary:



## Cored Intervals (MD):

- Welch 1-32
  - 495'-1,700'
- Tschosik 1-15
  - 440'-1,680'
- Weiser 1-15
  - 512'-1,689'



[CH<sub>4</sub>] >97%  
TOC = 0.41 % (734'-782')  
5.1 % (1,304'-1,393')  
Porosity = 34 %  
Permeability = 0.42 md  
Bulk Densities = 1.64(dry), 1.95(sat), 2.5(grain)

**Gas flaring from recently drilled Welch 1-32 Niobrara Fm.  
Shallow gas test in southern Burleigh County, ND.**



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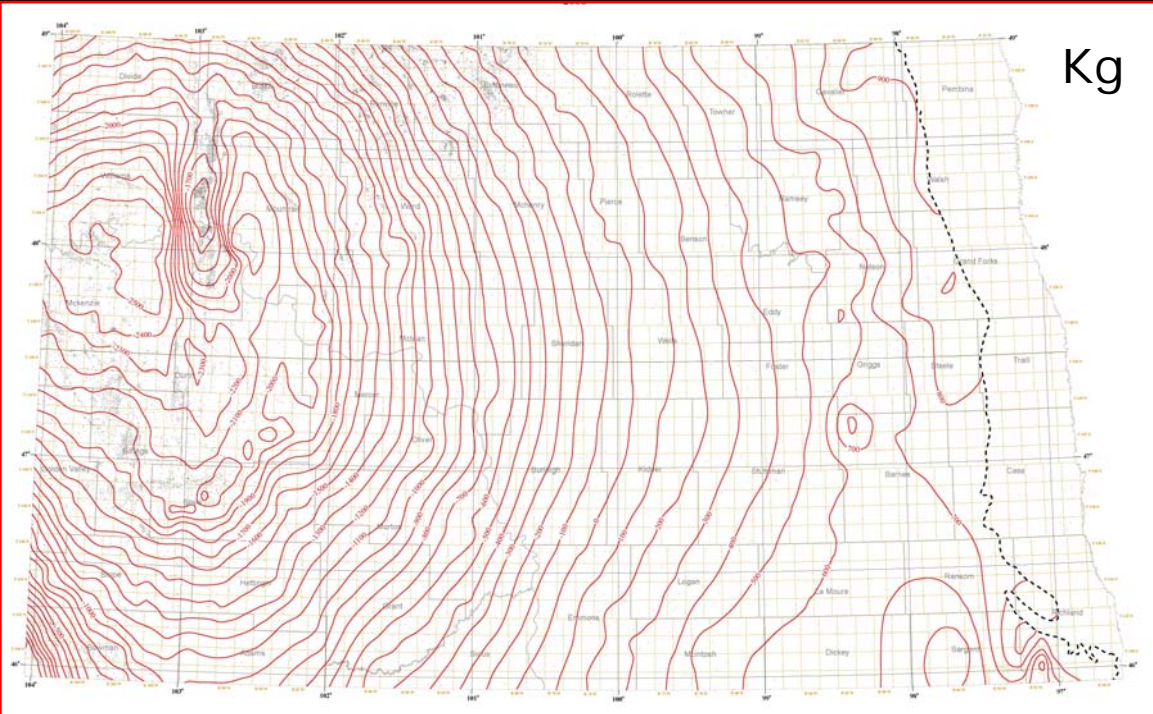
# Cretaceous Stratigraphic Units of Interest

NORTH DAKOTA CRETACEOUS STRATIGRAPHIC COLUMN								
AGE <sup>1</sup>	ERA	PERIOD	SEQUENCE	ROCK UNIT			MAX THICKNESS <sup>2</sup>	LITHOLOGY, DEPOSITIONAL ENVIRONMENTS AND OTHER CHARACTERISTICS
				GROUP	FORMATION	MEMBER		
65	MESOZOIC	CRETACEOUS	ZUNI	MONTANA	HELL CREEK		500 (150)	Sand, somber shades of light-gray to brownish-gray, and crossbedded sandstone with lignitic shale and dark-purple, manganese-oxide-stained concretions; river sediment and some estuarine sediment; forms rilled slopes except clayey member at the top forms smooth, rounded slopes; forms badlands topography.
					FOX HILLS	COLGATE	2 300 (700)	Silt and shale, sandy shale, sandstone, and siltstone, shades of buff to yellowish-brown; interbedded with lignitic shale laminae; some beds fossiliferous; intermittent sandstone at top is grayish-brown to white, fine, siliceous; silt and shale gradational downward with shale of the Pierre Formation; largely marine coastal sediment; forms gentle, rounded slopes.
						BULLHEAD		
						TIMBER LAKE		
						TRAILL CITY		
					PIERRE	ODANAH	2 300 (700)	Shale, light to medium-or dark gray, fissile, flaky to blocky, generally noncalcareous; marine offshore sediment. Four members are exposed in the Pembina Hills in the northeastern part of the state; they are: Odanah member, shale, medium-light gray, hard, siliceous, reddish brown stained joint faces; light-yellowish bentonite bed near the base; forms steep slopes in exposures; DeGrey member, shale, olive to dark-gray, flaky, noncalcareous; ironstone concretions; Gregory Member, shale, dark-gray to yellowish, soft, thinly bedded, slightly calcareous to marly, pyritic, some claystone; smooth, loose surface that tends to slump; Pembina Member, shale, grayish-brown to brownish-black, soft, noncalcareous; yellowish streaks of jarosite and gypsum-encrusted phosphate nodules; highly organic in the middle portion with abundant fish scales; light colored, waxy beds of montmorillonitic clay at the base; Gammon Ferruginous and Pembina Members. Two fine-grained, silty tongues are recognized in the subsurface in the westernmost part of the state; the upper of these may be equivalent to the Judith River Formation.
						DEGREY		
				GREGORY				
				PEMBINA				
				COLORADO	NIOBRARA	"Chalky Member"	250 (75)	Shale, medium-light gray to medium-gray, calcareous with white, limy inclusions (referred to by drillers as "First White Specks"); marly zone near the middle. Upper part is tan to yellowish or golden in weathered exposures; lower part weathers to grayish hues; steep slopes. Upper chalky member and lower calcareous shale member.
						"Calcareous Shale Member"		
					CARLILE	400 (120)	Shale, medium-dark-gray to black, noncalcareous, soft; large ellipsoidal concretions containing abundant gypsum (selenite); zone of fine, secondary gypsum crystals at the top. Rounded slopes in exposures.	
					GREENHORN	150 (45)	Shale, dark-gray, calcareous, soft; thin bedded shaly limestone; good electric and radioactivity log marker; referred to by drillers as "Second White Specks."	
				DAKOTA	BELLE FOURCHE	350 (105)	Shale, medium-to dark-gray, soft, micaceous, lumpy to massive, spongy; includes beds of light-bluish-gray bentonitic clay; sand and silt facies near base in parts of eastern North Dakota.	
					MOWRY	180 (55)	Shale, medium-to dark-gray, soft, flaky, spongy; traces of light-blue-gray bentonitic clay; top is marked by radioactive zone.	
					NEWCASTLE	150 (45)	Sandstone, light-gray, fine-to medium-grained angular quartz grains, some calcareous cement, silty; shale, medium-to dark-gray, soft, lumpy, fissile, micaceous; known also as "Muddy." Probably type "Dakota."	
					SKULL CREEK	140 (40)	Shale, medium- to dark-gray, micaceous, soft, flaky to lumpy; sandstone, fine-grained, friable, calcareous, light-gray, glauconitic, limited to east; traces of pyrite and white bentonitic clay.	
INYAN KARA	450 (135)	Upper part is mainly marine sandstone, light-gray, fine to coarse, quartzose; and shale, gray, silty, and lumpy. Lower part is mainly nonmarine sandstone, medium to coarse, angular to subrounded, quartzose; occasional lenses of gray, bentonitic shale commonly contains manganese-siderite spherulites (pellets).						
140								

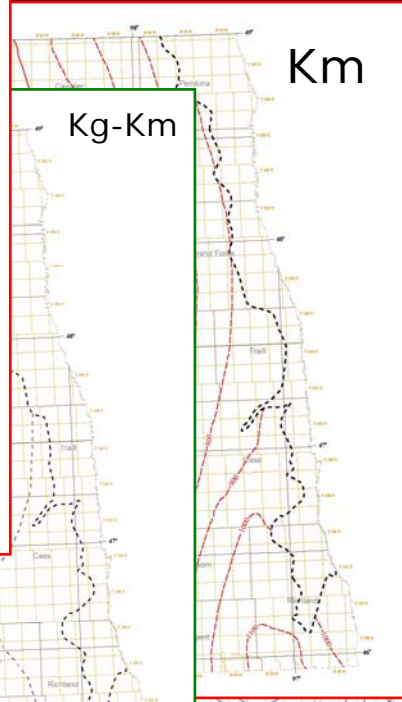
<sup>1</sup> Millions of years before present.



# Preliminary K-unit Structure Contour and Isopach Maps

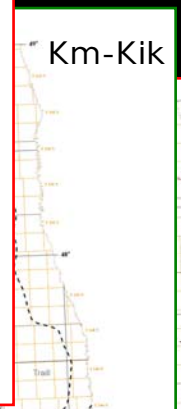


Kg



Km

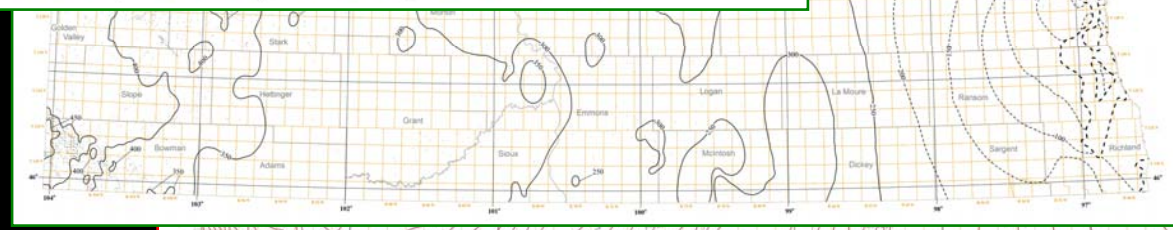
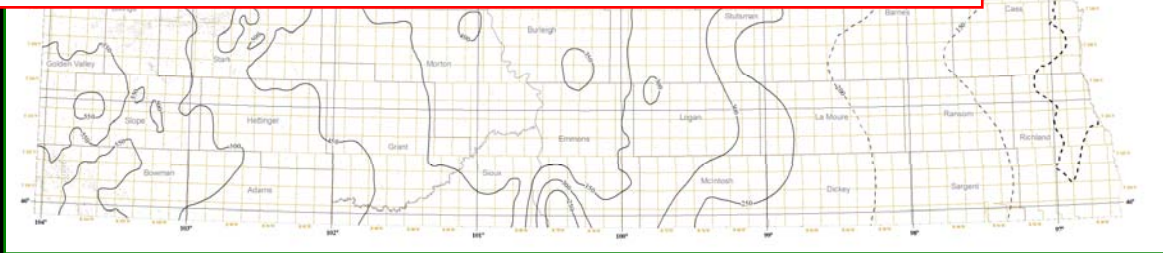
Kg-Km



Km-Kik



Kik



(modified from Anderson and Juenker, 2005-2007)



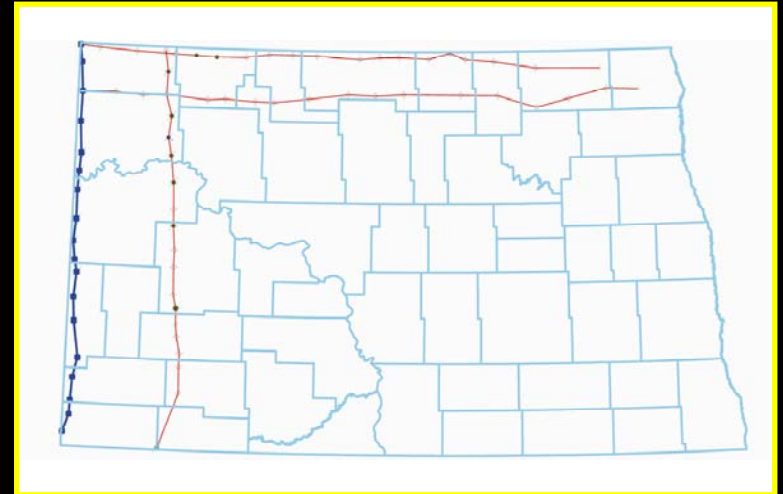
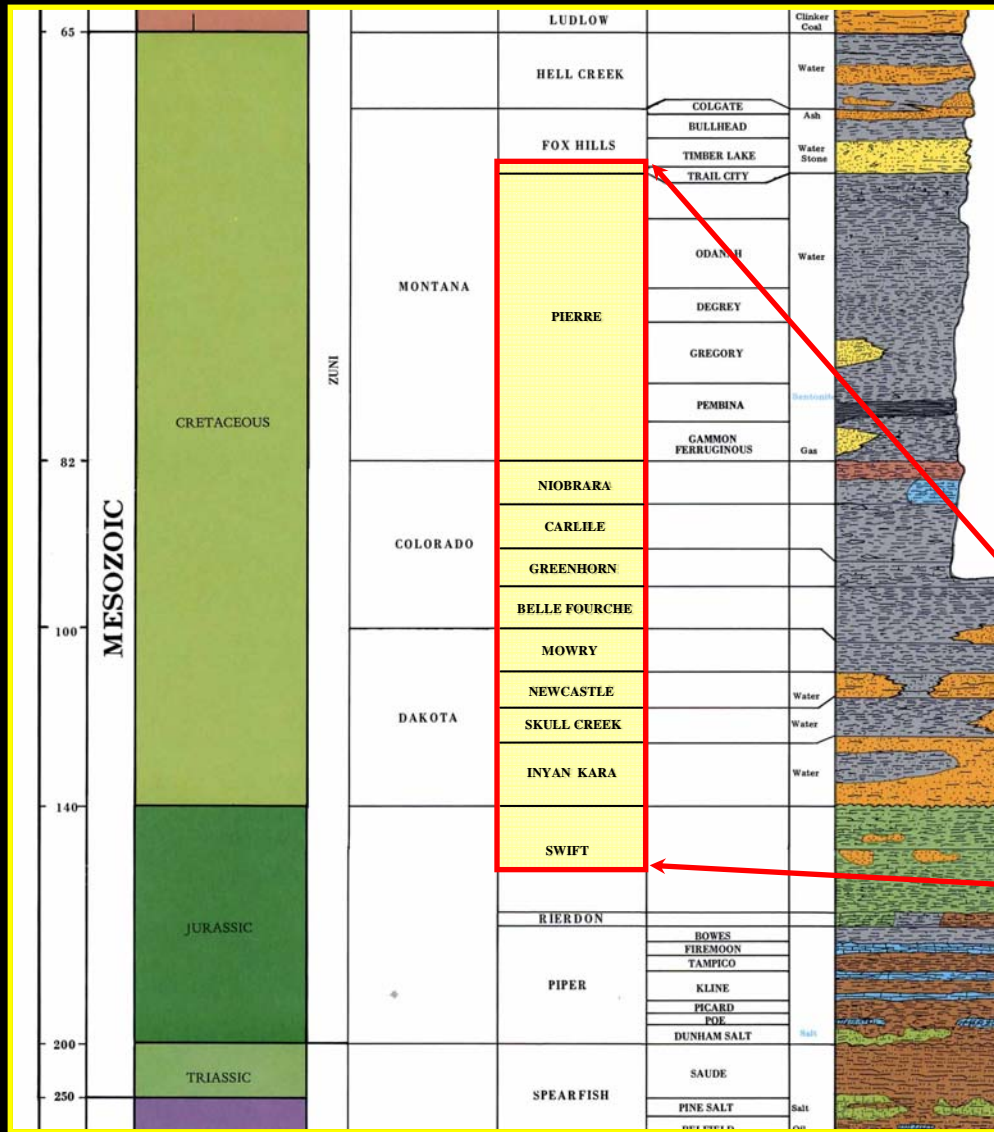
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# Preliminary Cretaceous Reference Logs & Cross-Sections



Four Preliminary Cross-Sections  
2 N-S 2 E-W

*LeFever and LeFever, 2007*  
*NDGS RI-107*

Cretaceous & Jurassic  
Formations Correlated:

Pierre, Niobrara, Carlisle, Greenhorn  
Belle Fourche, Mowry, Newcastle,  
Skull Creek, Inyan-Kara, and Swift



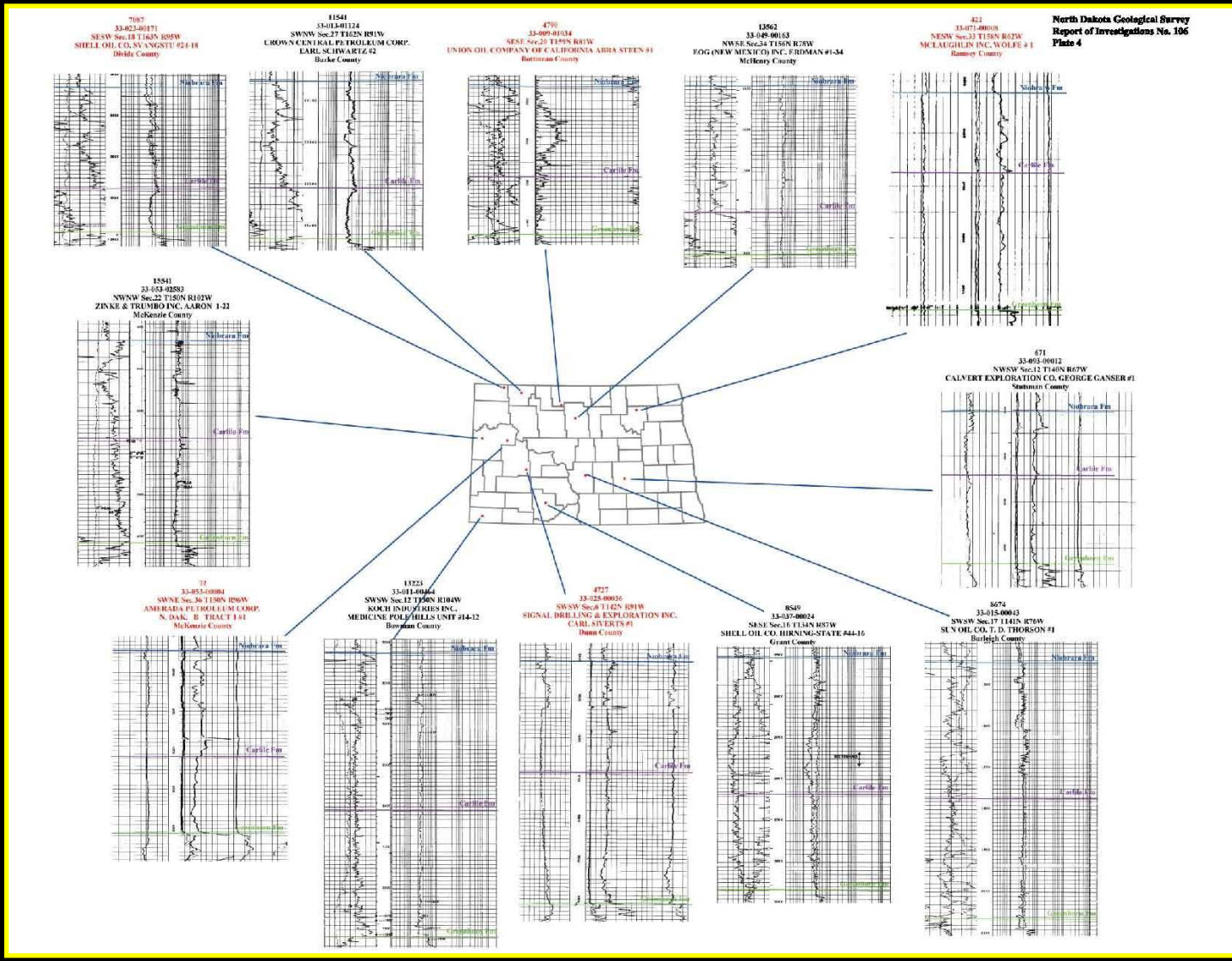
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# Cretaceous Reference Logs



- Examples of the formation tops picked from the geophysical logs from each well shown for each stratigraphic unit of interest.

- Kn – Niobrara Fm.
- Kc – Carlile Fm.
- Kg – Greenhorn Fm.

Modified from LeFever, 2007, NDGS RI-106



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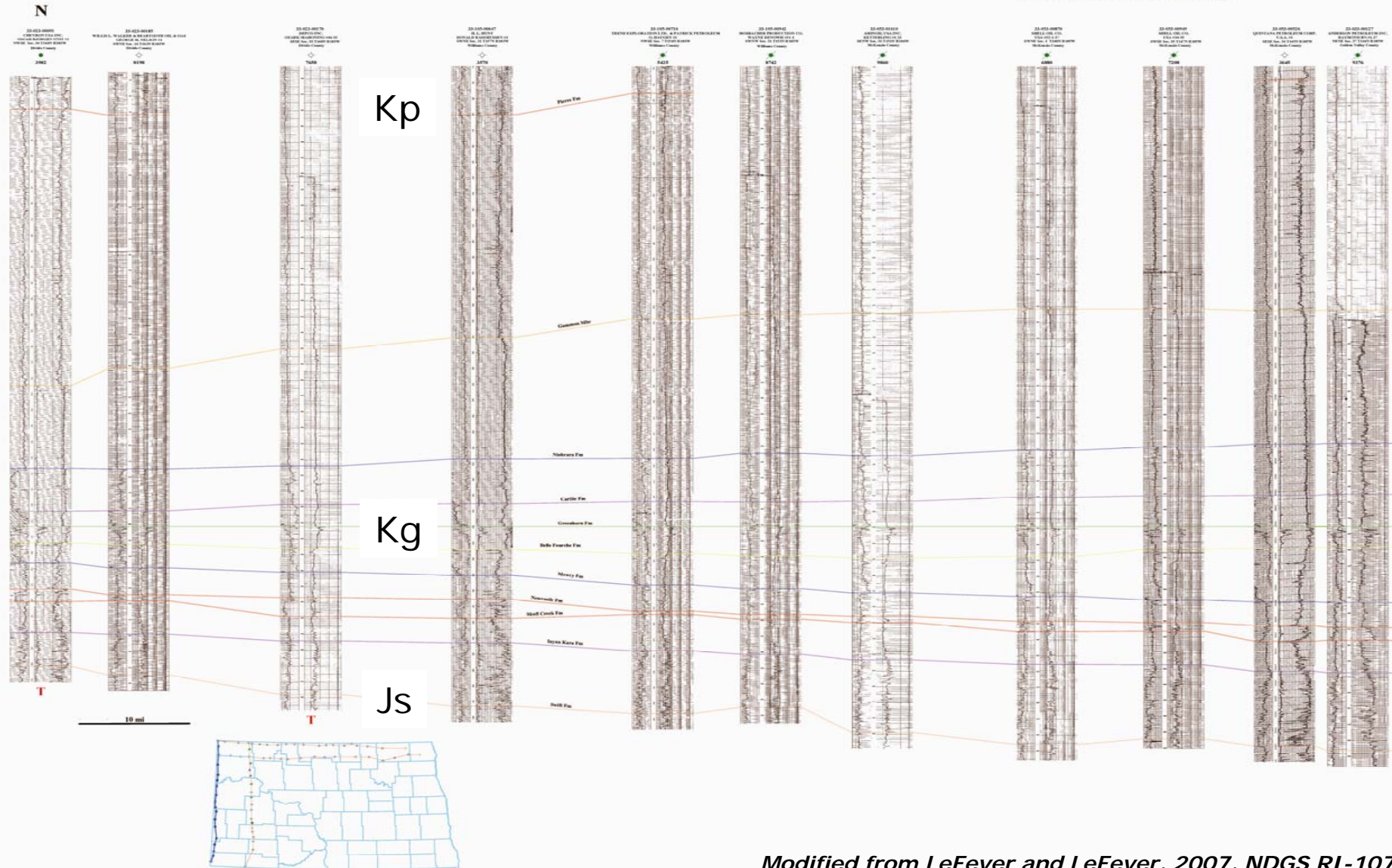
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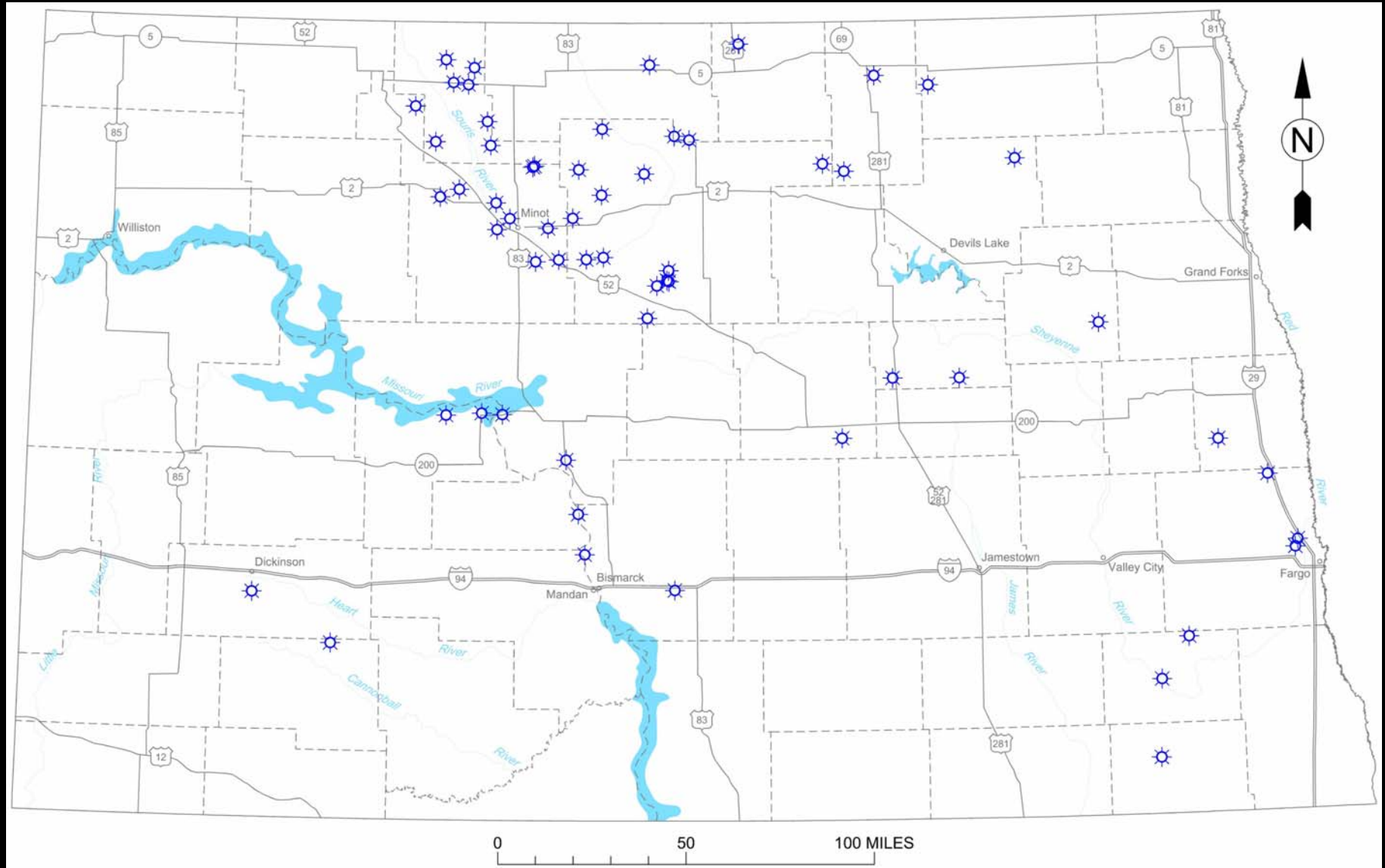
Preliminary Cross-Sections of Cretaceous Strata in North Dakota

Richard D. LeFever and Julie A. LeFever



Modified from LeFever and LeFever, 2007, NDGS RI-107

# Recent Anecdotal Shallow Gas Occurrences in North Dakota



Locations of water supply wells in North Dakota where a current or historic shallow gas occurrence was reported.



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# Recently Completed and Current NDGS Projects

## Shallow Gas Field Screening in North Dakota



Methane bubbles in a shallow ground-water observation well in Bottineau County



Stock well in McKenzie County

## Historical Shallow Gas Occurrences in Cretaceous and Tertiary Aquifers in west-central North Dakota

## Investigation of a Potential Shallow Gas Source System in Eastern North Dakota



Conducting field work in SE Steele County



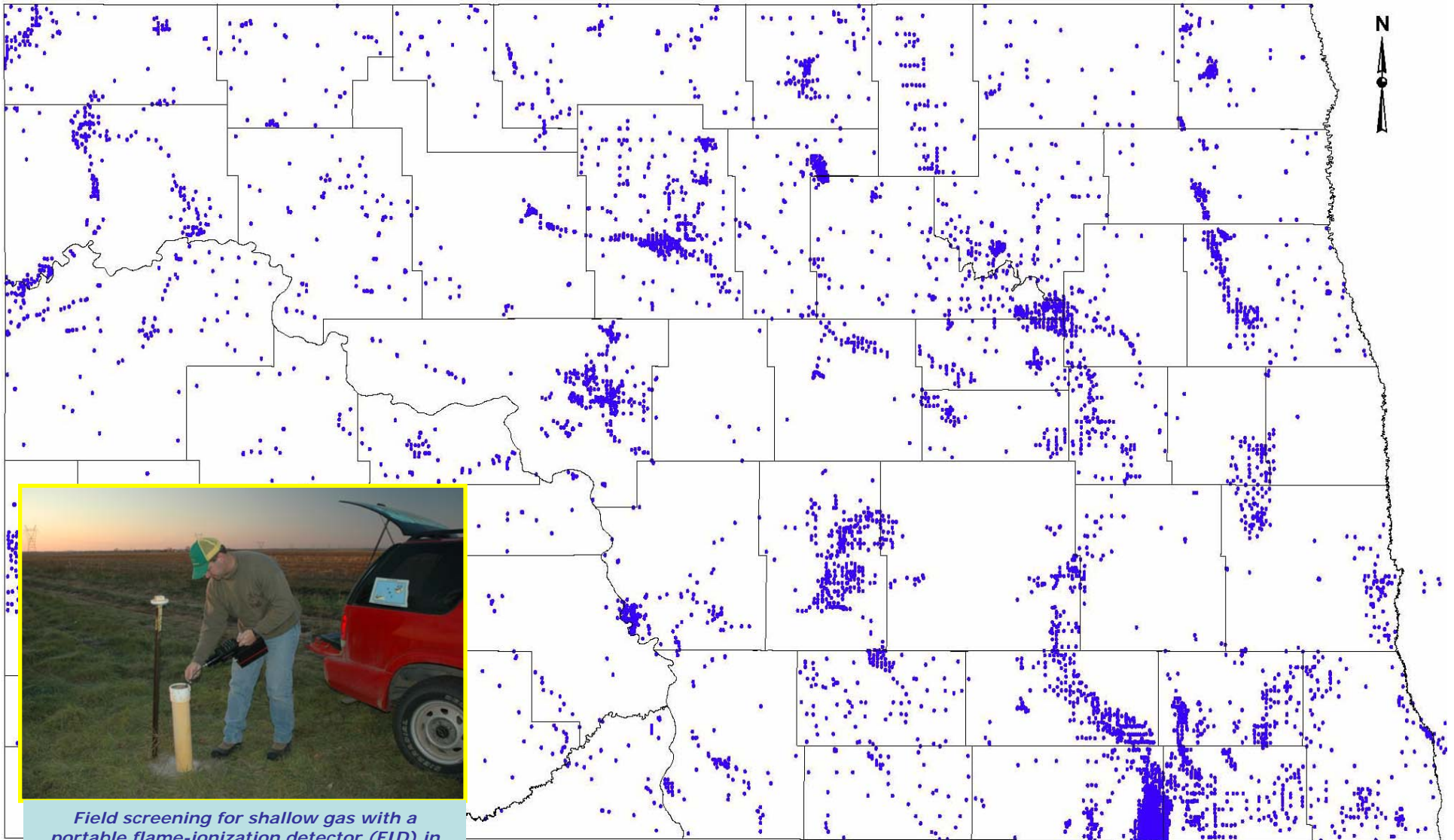
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# Locations of Ground-Water Observation Wells in North Dakota



Field screening for shallow gas with a portable flame-ionization detector (FID) in Emmons County N.D. in 2006.

Data from NDSWC



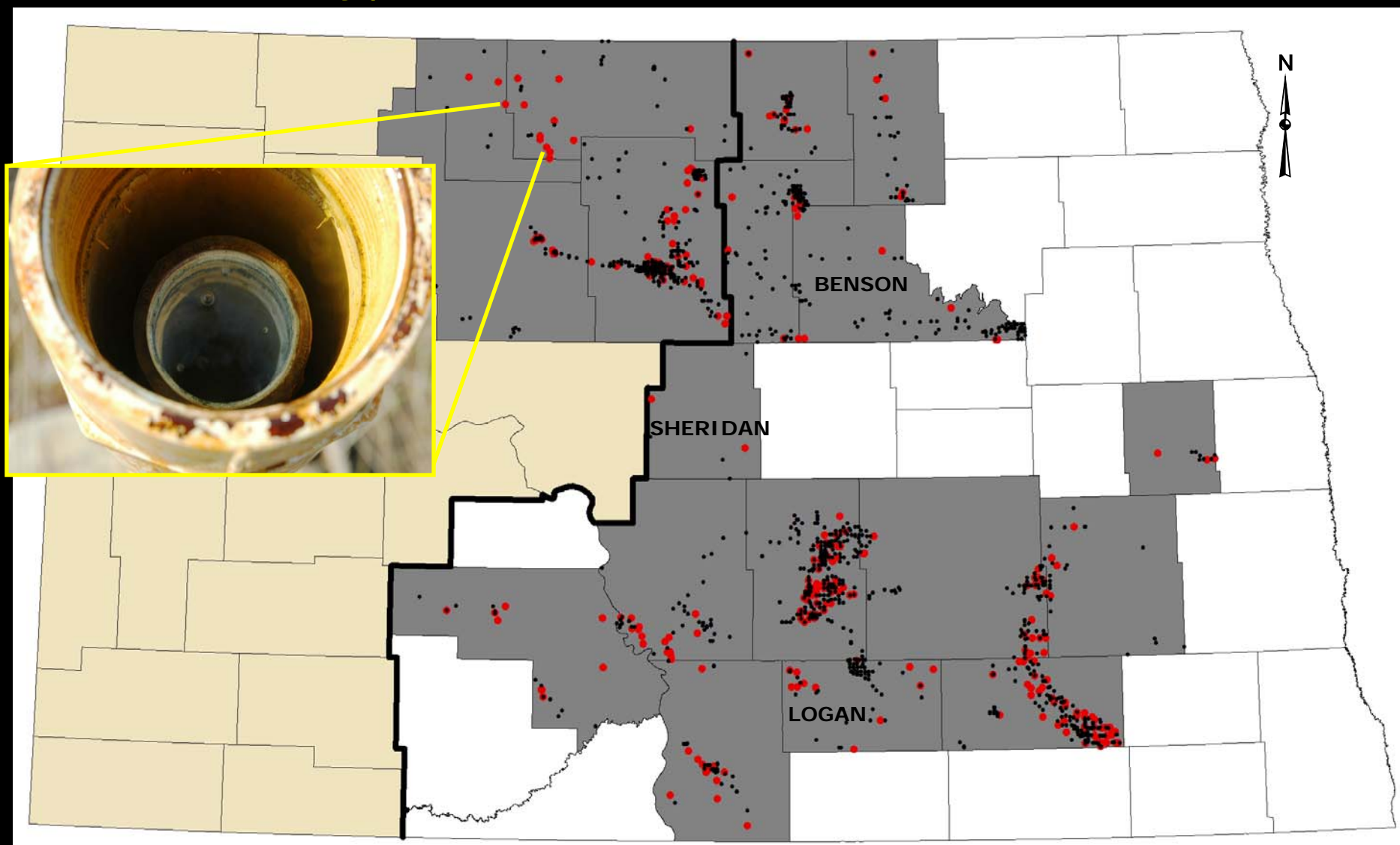
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# Field Screening for Shallow Gas in North Dakota – 2008 Update



Updated Field Screening Results for 2008. Wells with shallow gas occurrences found in 2006, 2007, and 2008 are shown in red. Other wells tested are shown in black. Counties completed in 2008 are labeled.



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# Field Screening for Shallow Gas in North Dakota – 2008 Update

Shallow Gas FID Field Screening Summary							
County	Wells Investigated Summary				Range of FID Instrument Response		
	Wells Investigated	Wells Field Screened	Wells with a positive FID response (>0.0)	Wells with no FID response (0.0)	Low (ppm as CH <sub>4</sub> )	High (ppm as CH <sub>4</sub> )	Mean (ppm as CH <sub>4</sub> )
Renville	34	8	3	5	20.6	28,000	9,420
Bottineau	110	33	11	22	2.4	30,362	3,102
Ward	151	79	27	52	0.2	50,000	2,352.7
Barnes	51	28	5	23	0.3	2,897	520.1
Morton	48	29	12	17	1.1	2,347	270.9
LaMoure	287	195	49	146	0.4	3,712	251.8
Burleigh	143	64	18	46	1.1	1,208	210.6
Emmons	109	50	12	38	1.6	775	196
McHenry	433	350	55	295	0.2	2,329	131.4
SE Steele	21	9	3	6	2	146.3	79
Kidder	451	377	63	314	0.2	840.5	41.1
Stutsman	170	107	21	86	0.4	182	27
Pierce	148	105	8	97	1.7	71.7	18.5
Towner	78	31	6	25	0.2	32.8	8
Rolette	114	52	10	42	0.6	15.2	5
Sheridan	71	7	2	5	1	538.3	269.6
Benson	341	127	9	118	0.5	223.7	44.4
Logan	127	75	12	63	3.4	41.5	16.2
<b>Totals</b>	<b>2,887</b>	<b>1,726</b>	<b>326</b>	<b>1,400</b>	<b>Mean = 2.1</b>	<b>Mean = 6,873</b>	<b>Mean = 942</b>



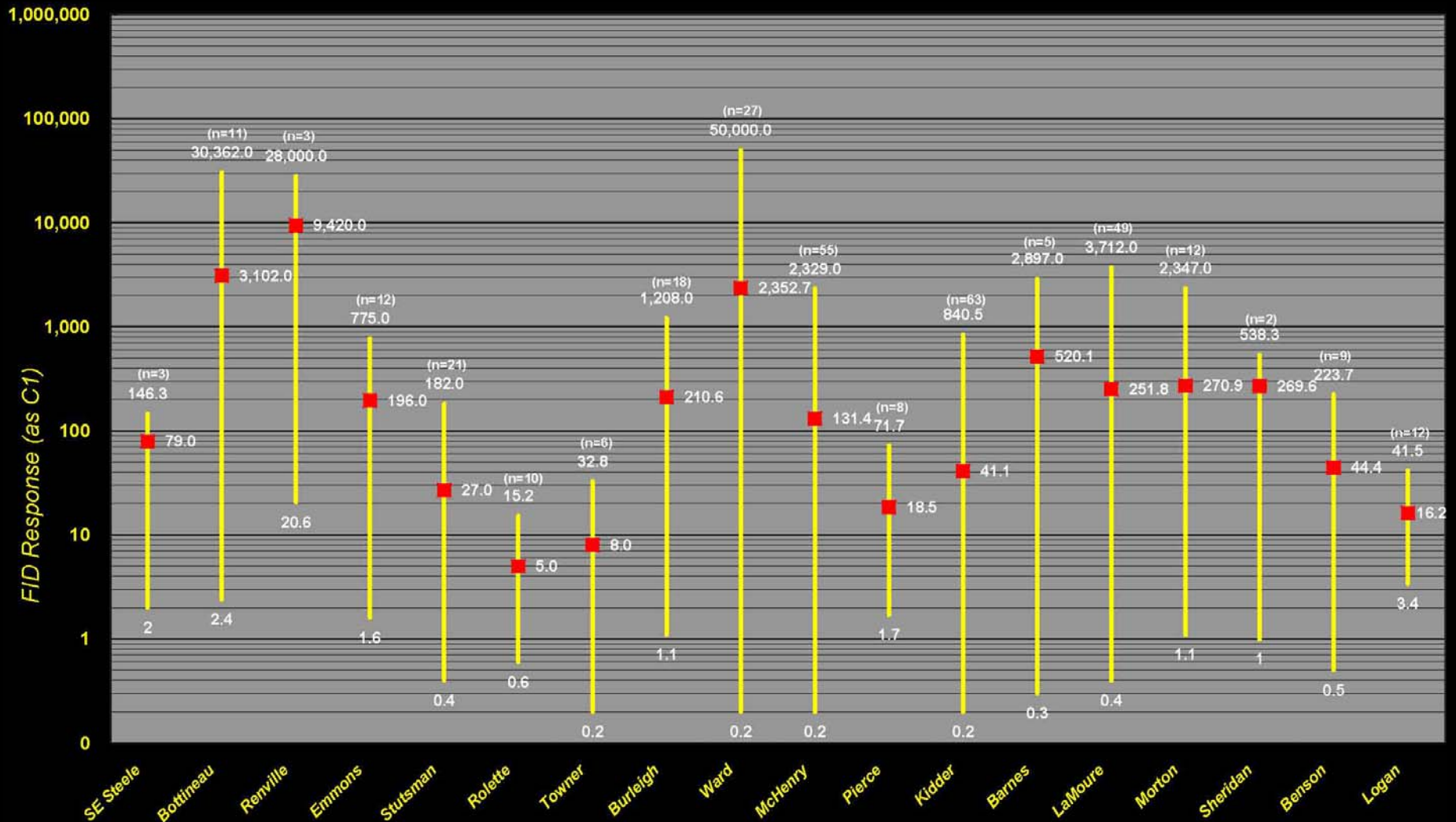
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# Field Screening for Shallow Gas in North Dakota – 2008 Update



Ranges and mean values of FID responses (as CH<sub>4</sub> in ppm) for all N.D. Counties field screened in 2006-2008. Data presented in relative order of field investigation.



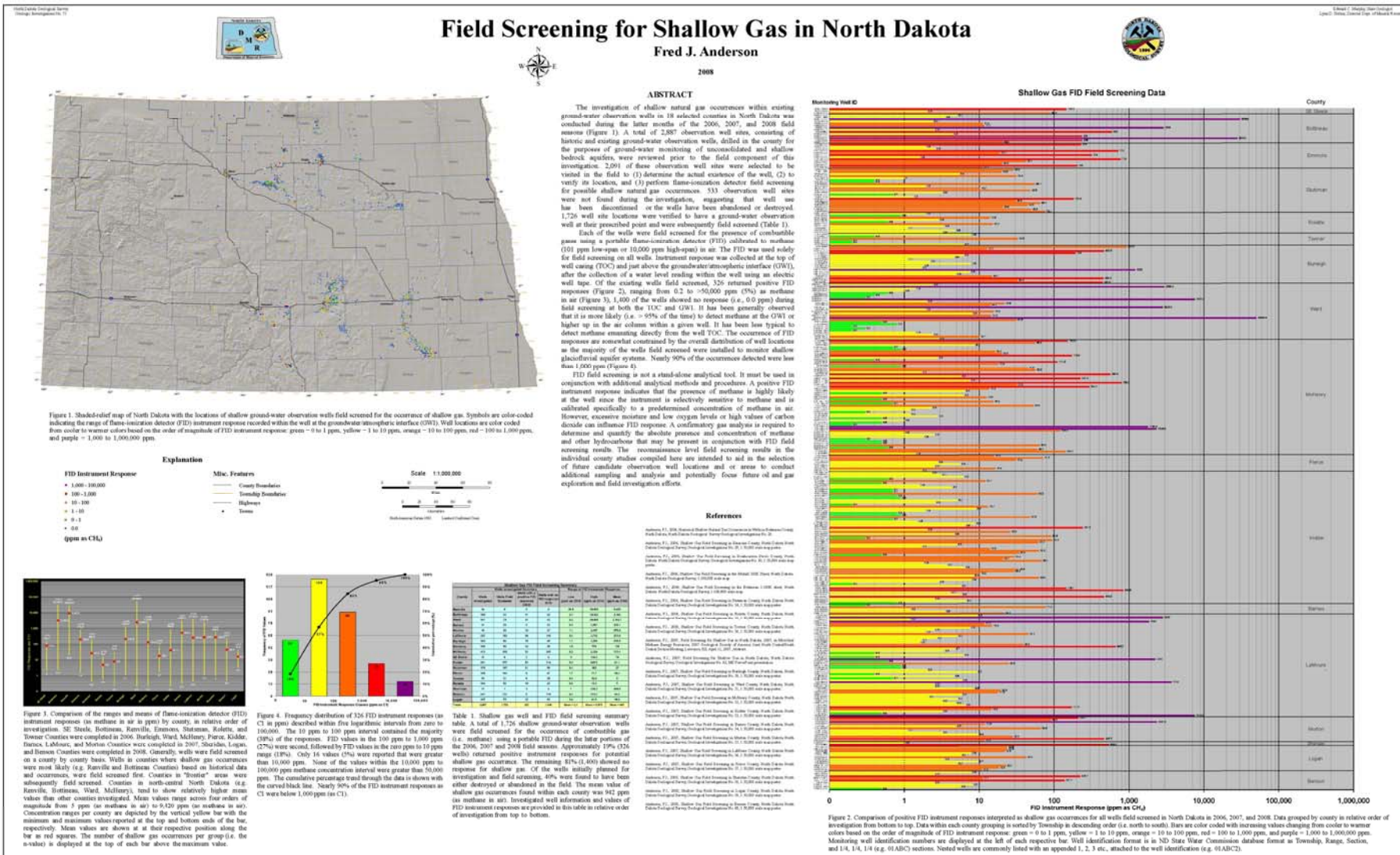
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# Field Screening for Shallow Gas in North Dakota - Summary Poster

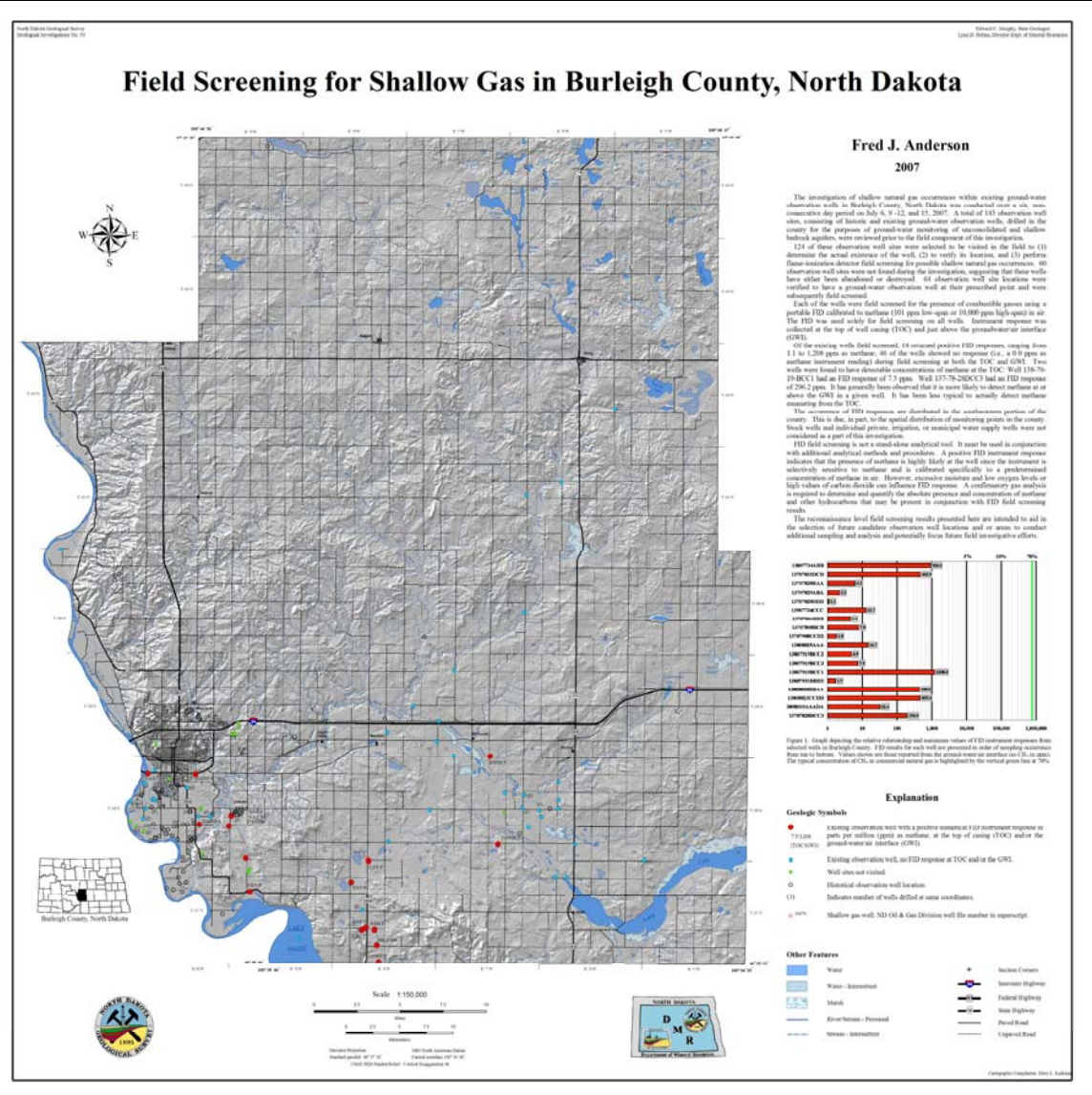




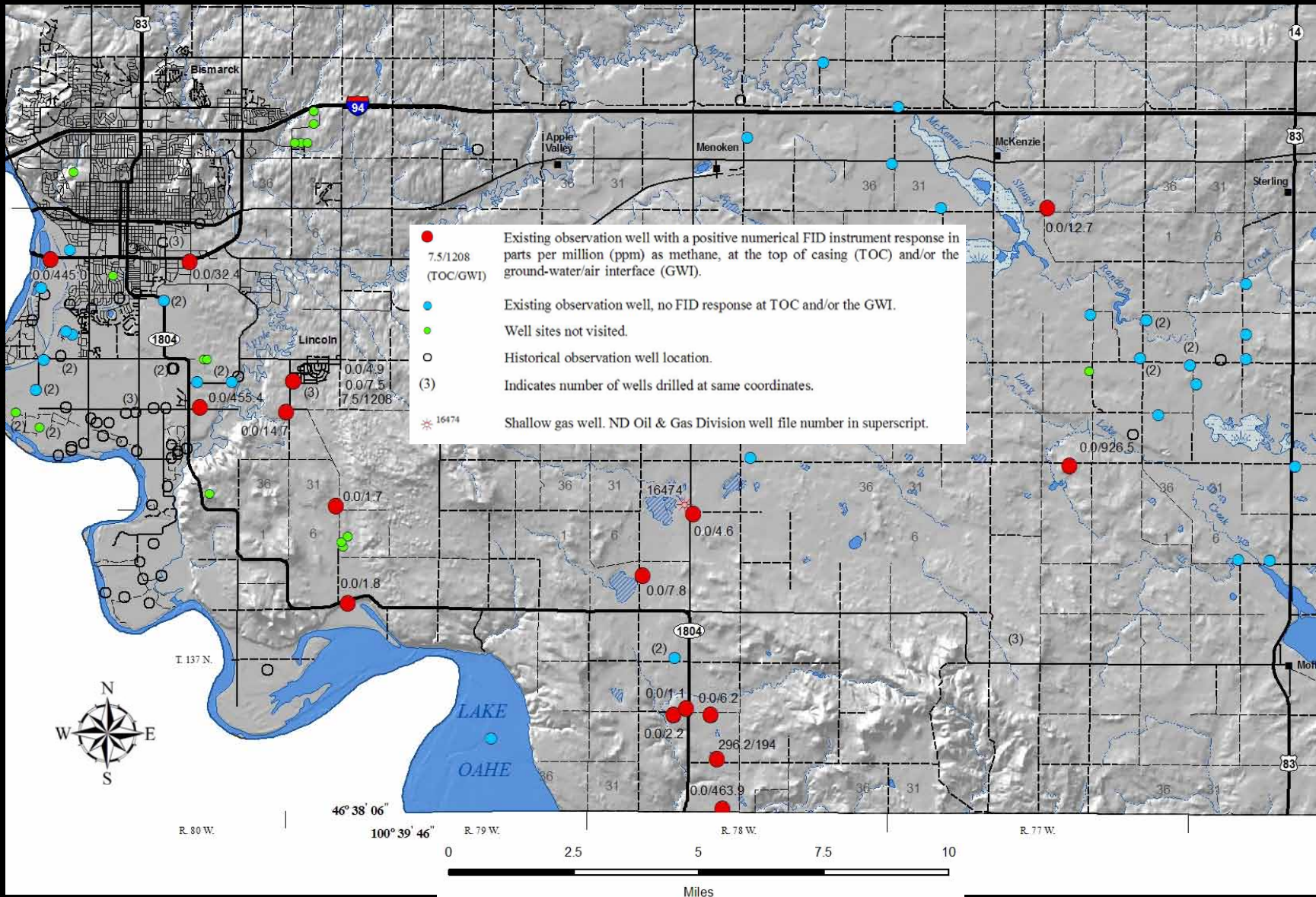
# Shallow Gas FID Field Screening in Burleigh Co., North Dakota



Field screening for shallow gas with a portable flame-ionization detector (FID) equipped with a an extended sample probe in Burleigh County N.D. in 2008.



# Shallow Gas FID Field Screening in Burleigh Co., North Dakota



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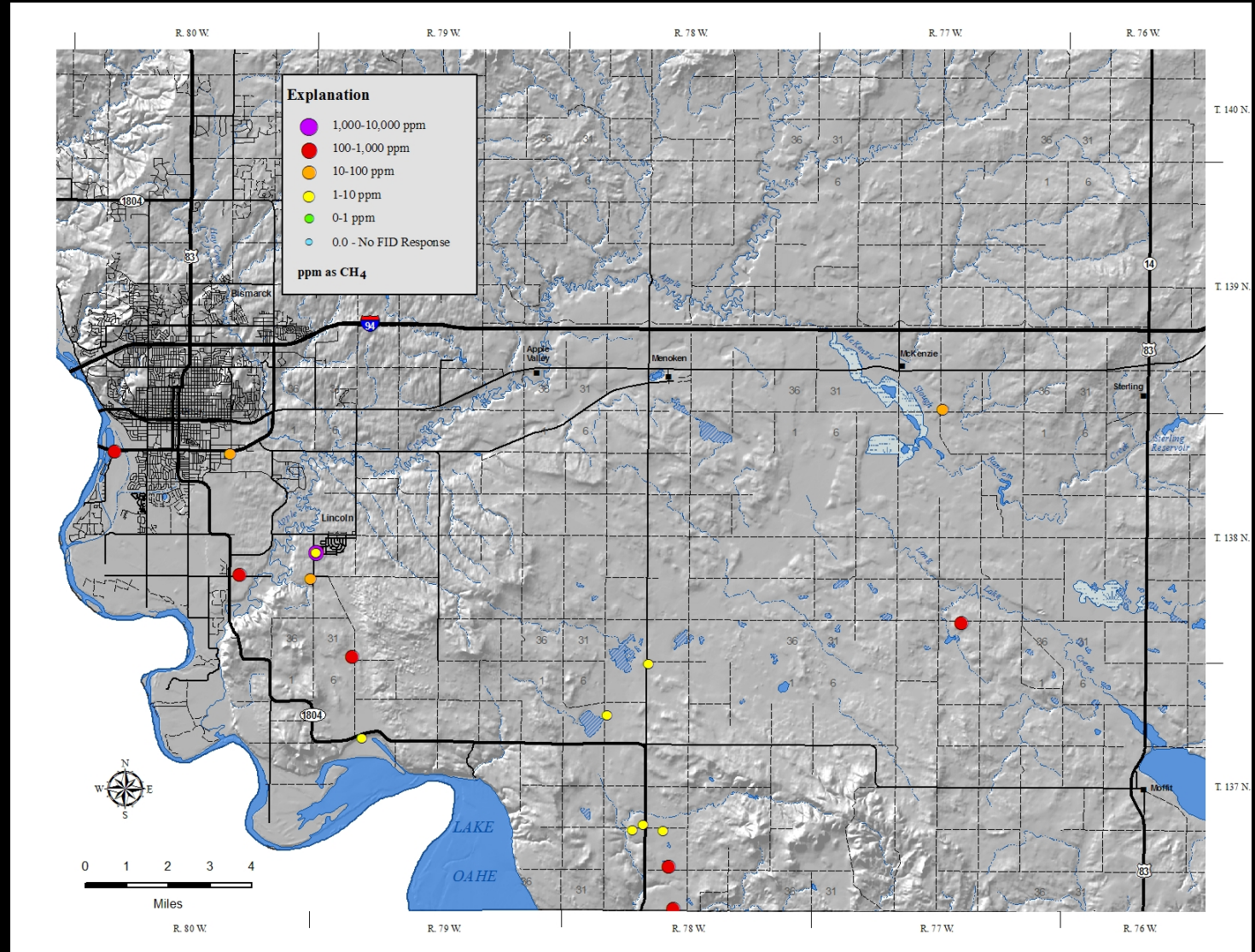
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# Shallow Gas FID Field Screening in Burleigh Co., North Dakota

1st Run

July 10, 2007



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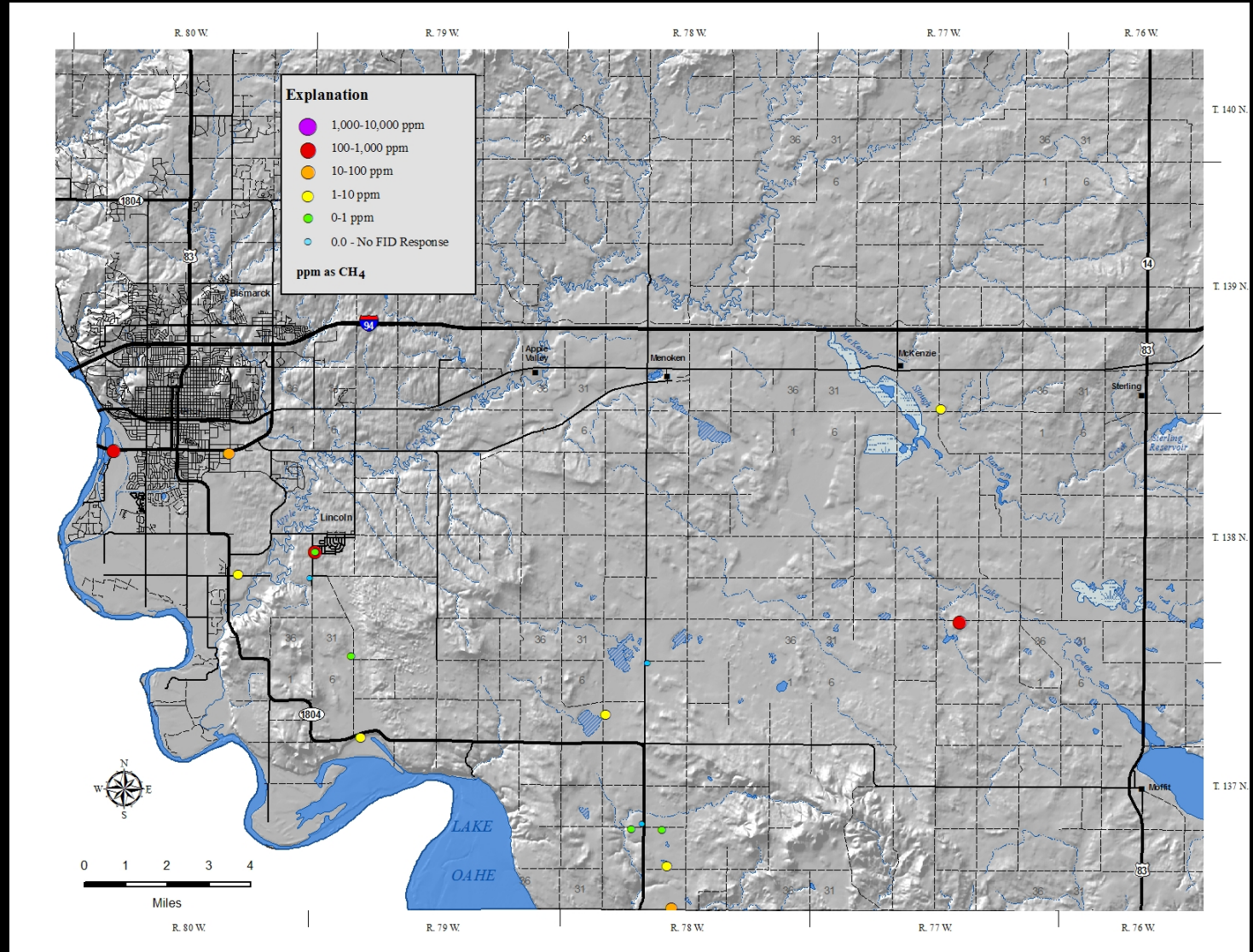
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# Shallow Gas FID Field Screening in Burleigh Co., North Dakota

2<sup>nd</sup> Run

Sept. 11, 2007



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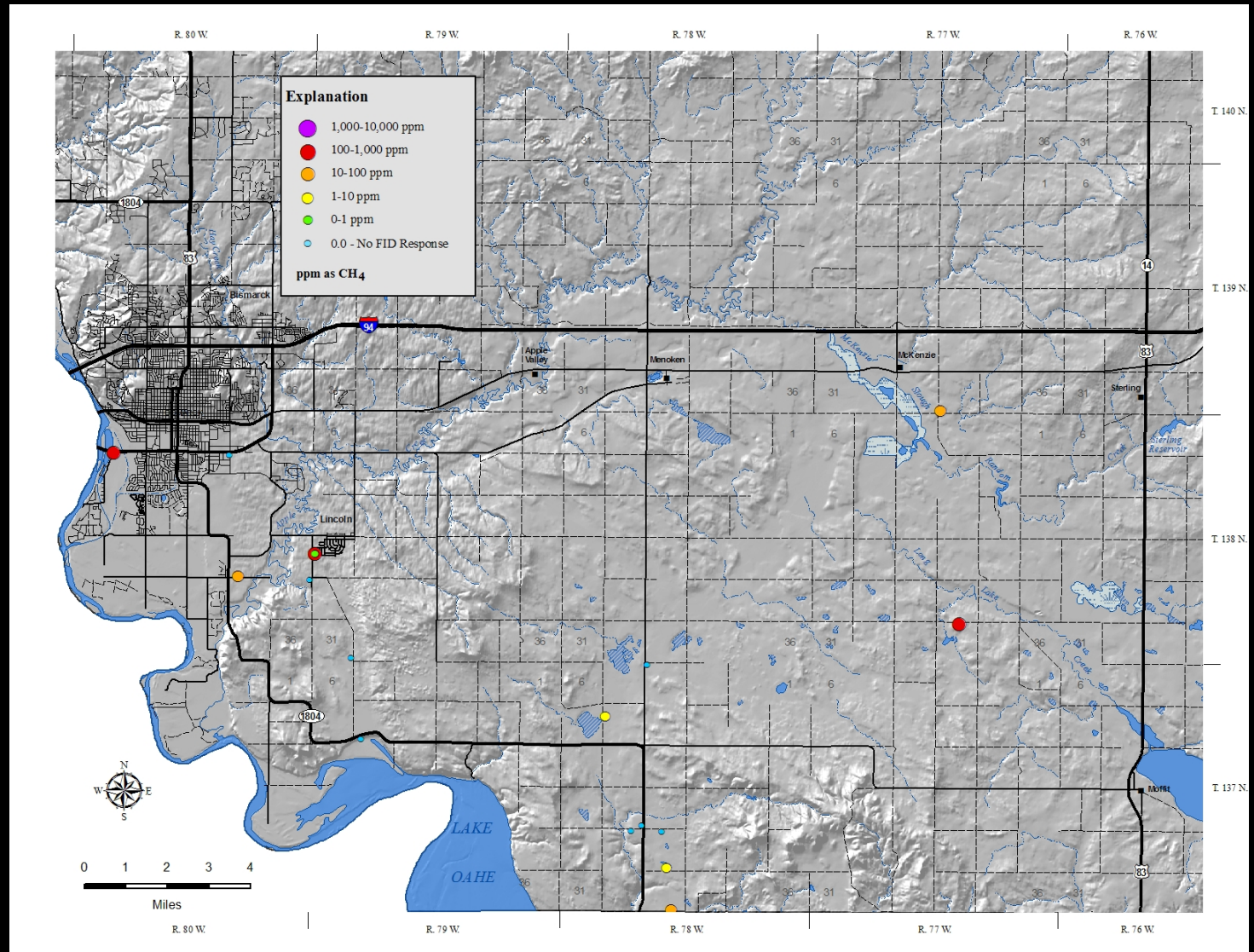
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# Shallow Gas FID Field Screening in Burleigh Co., North Dakota

3<sup>rd</sup> Run

May 28, 2008



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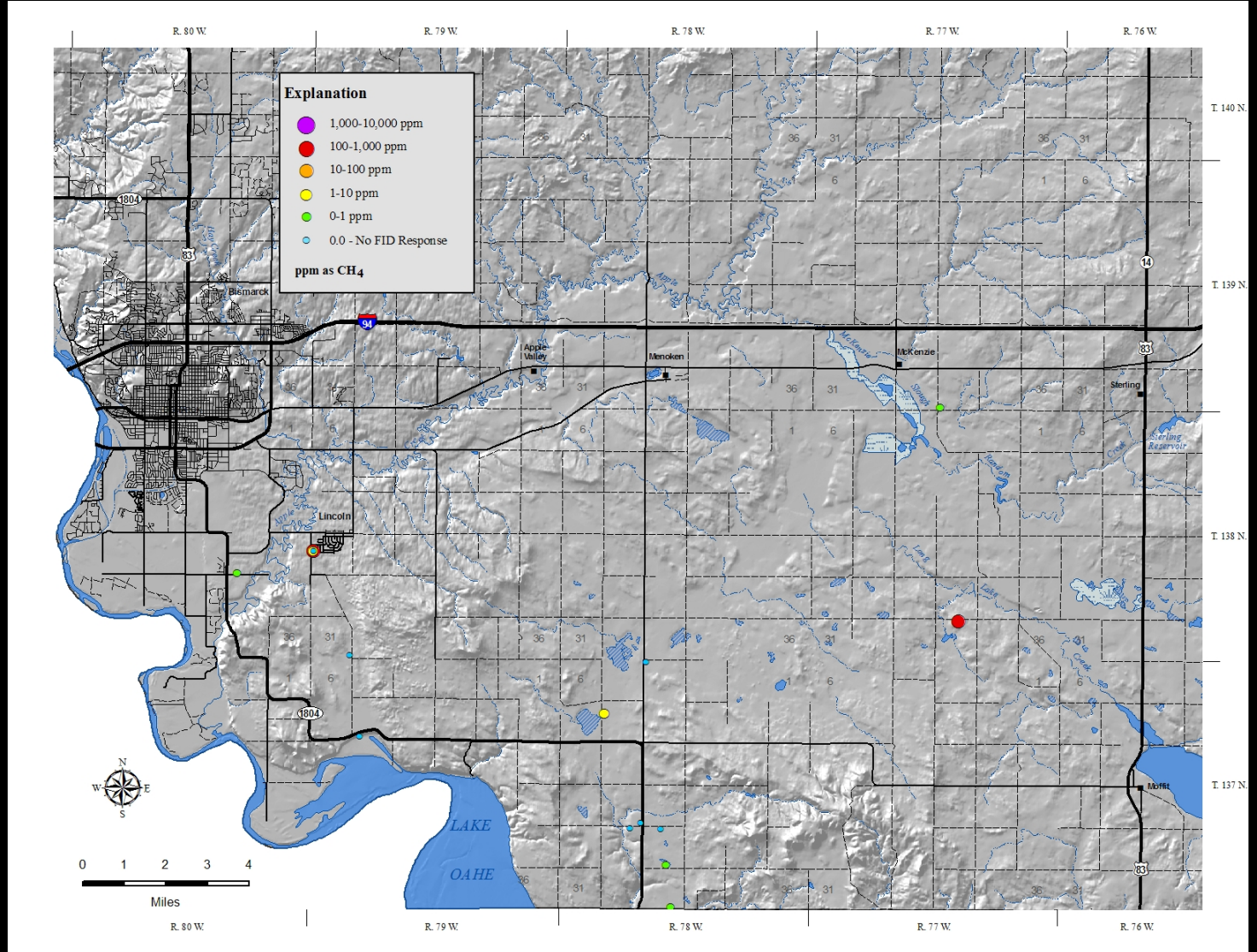
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# Shallow Gas FID Field Screening in Burleigh Co., North Dakota

4<sup>th</sup> Run

Aug. 5, 2008



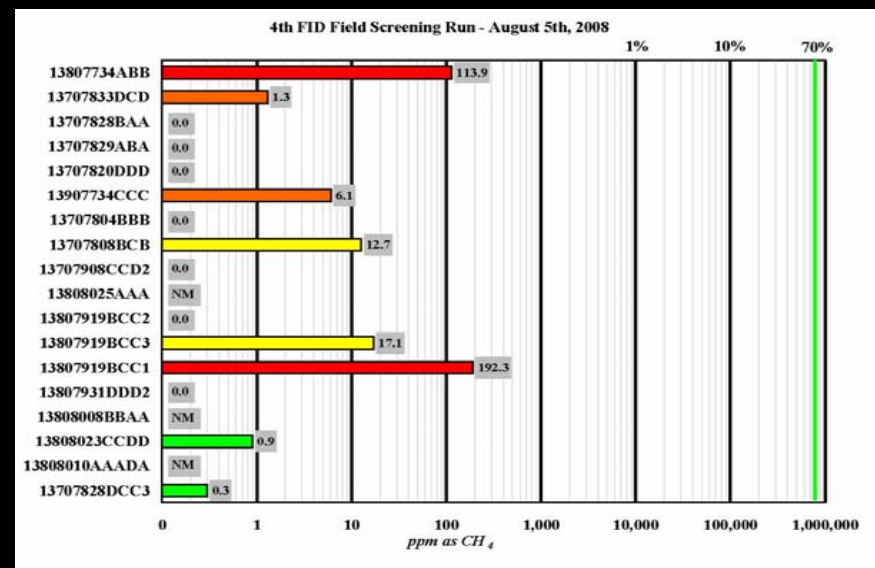
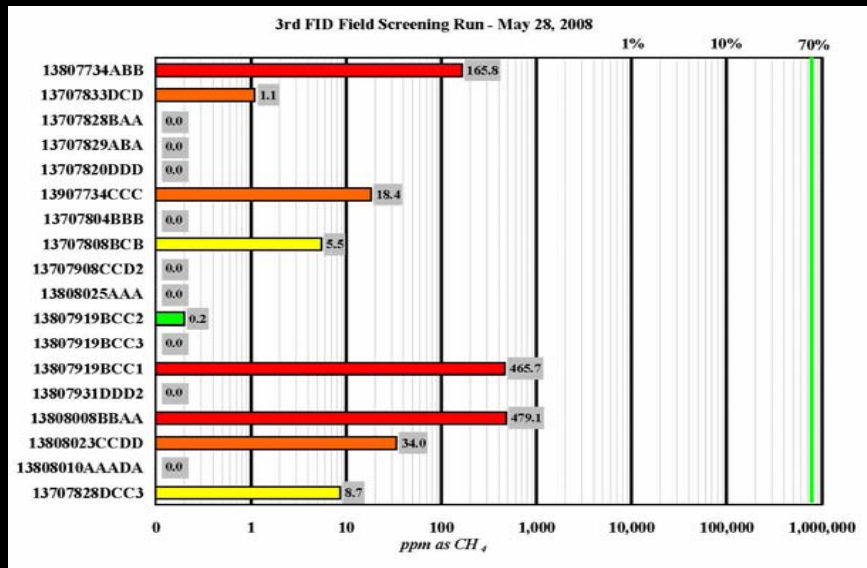
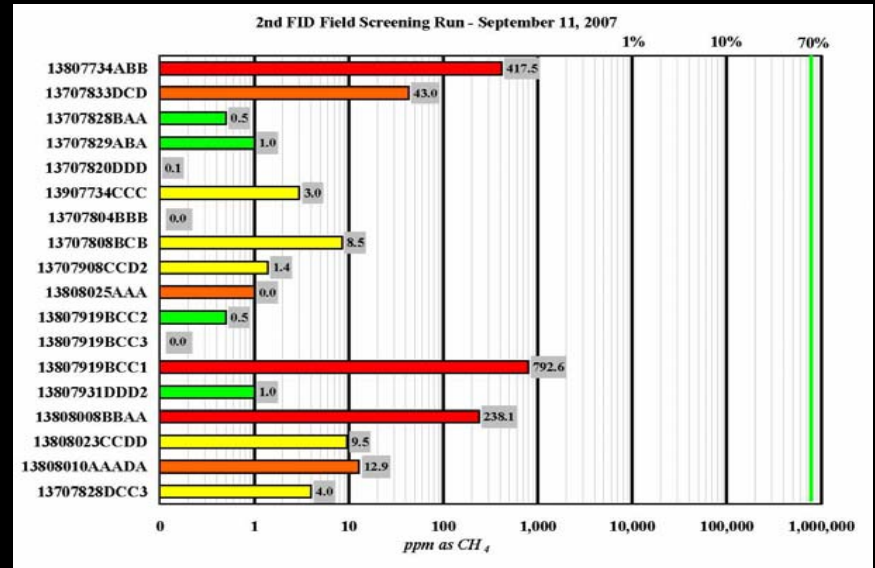
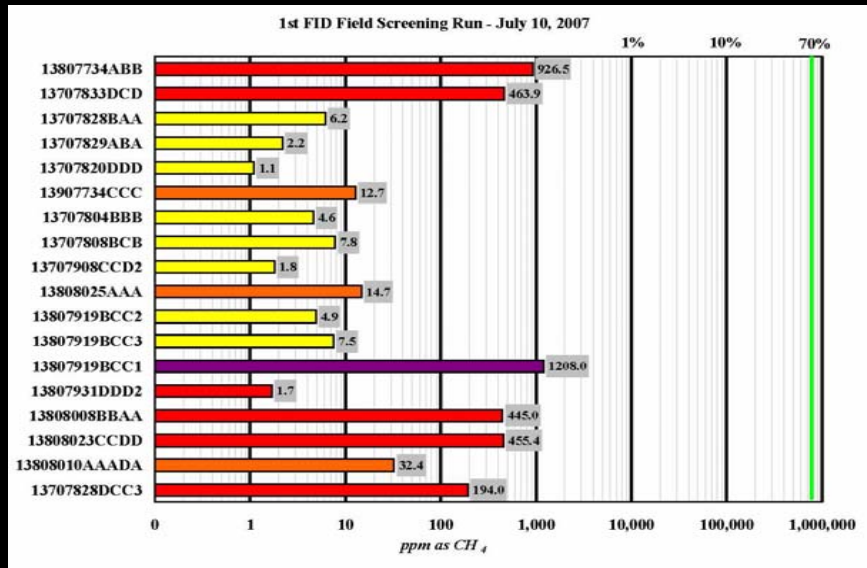
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# FID Field Screening Results in Burleigh Co., North Dakota



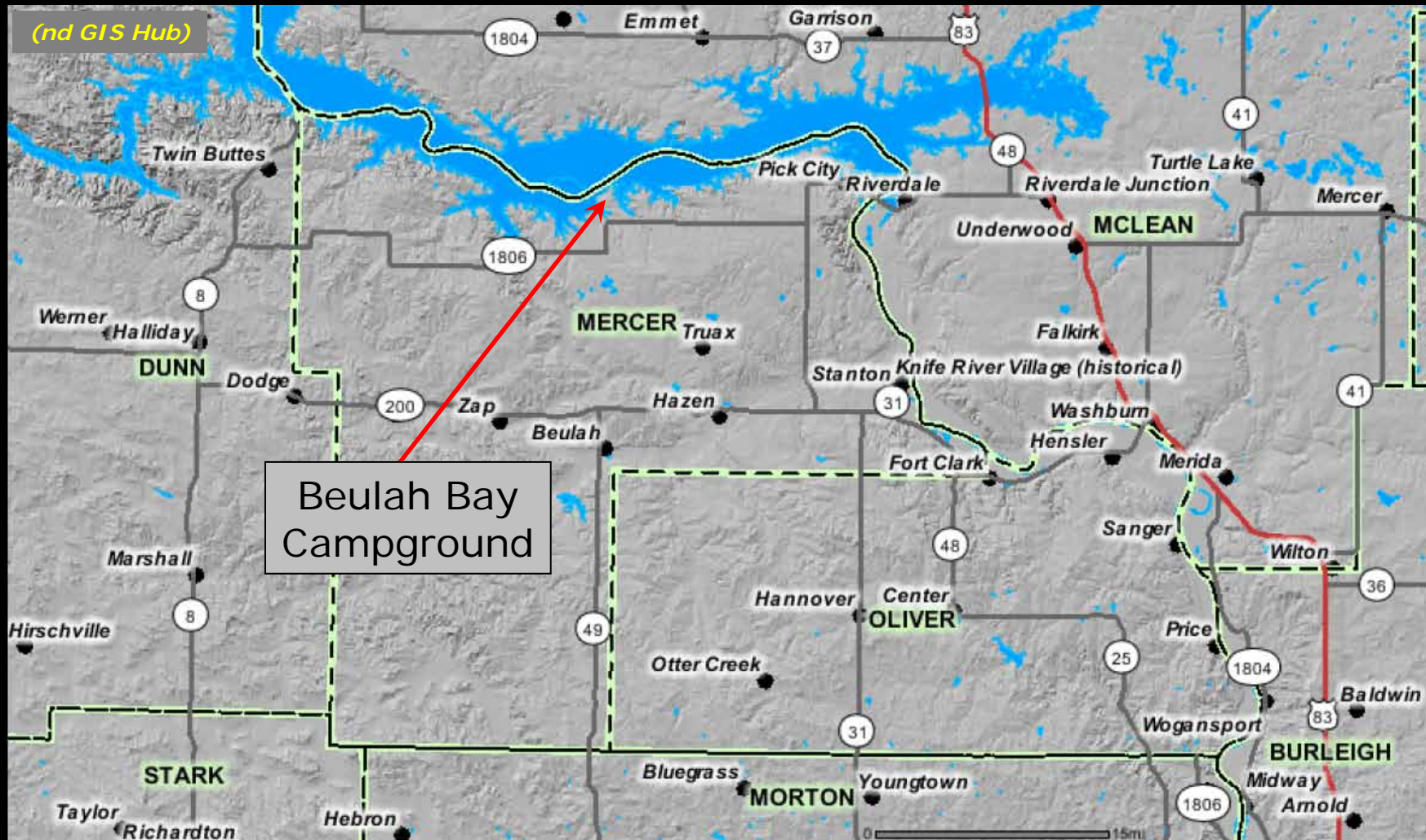
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# Recent Coalbed Methane Occurrences in North Dakota



Locations of water supply wells in Mercer Co., North Dakota where recent shallow gas occurrences were reported.



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# Recent Coalbed Methane Occurrences in North Dakota



Locations of water supply wells at the Beulah Bay Campground where recent shallow CBM occurrences were reported.



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# *NDGS Publications Related to Coal Gas*

**NDGS**

**Open File Report 98-1**

**(OF-98-1)**

## **THE COALBED METHANE POTENTIAL OF NORTH DAKOTA LIGNITES**

by  
Edward C. Murphy and Gerard E. Goven



Open File Report 98-1  
North Dakota Geological Survey  
John P. Bluemle, State Geologist  
1998



**North Dakota Department  
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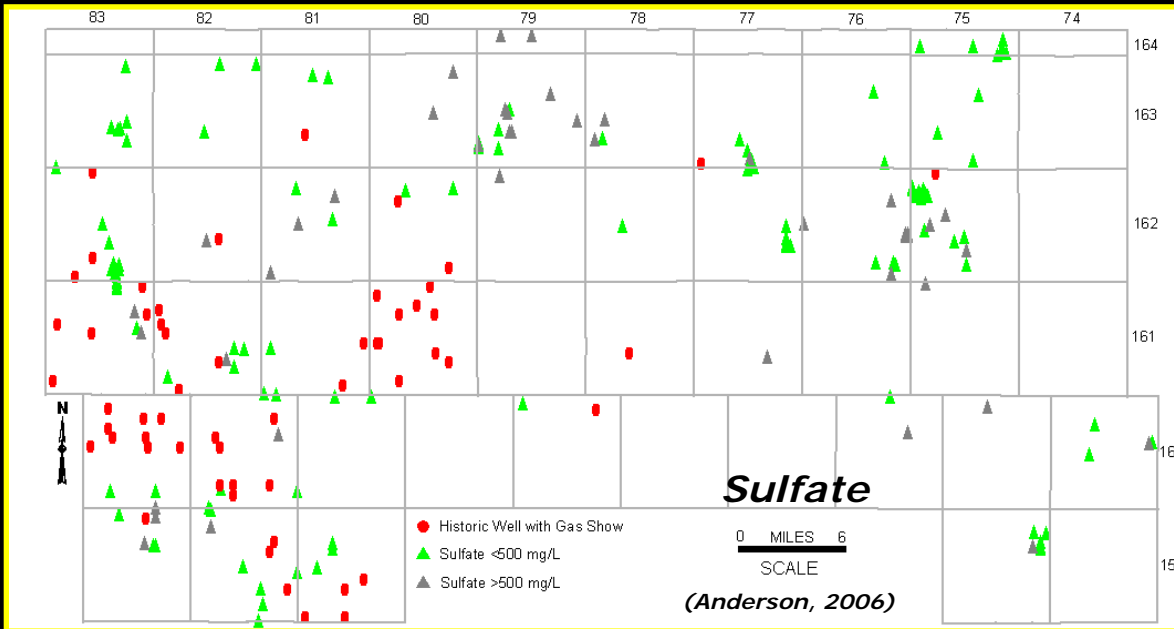
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# Relationships of Ground-Water Geochemistry and Shallow Gas Occurrences in north-central North Dakota

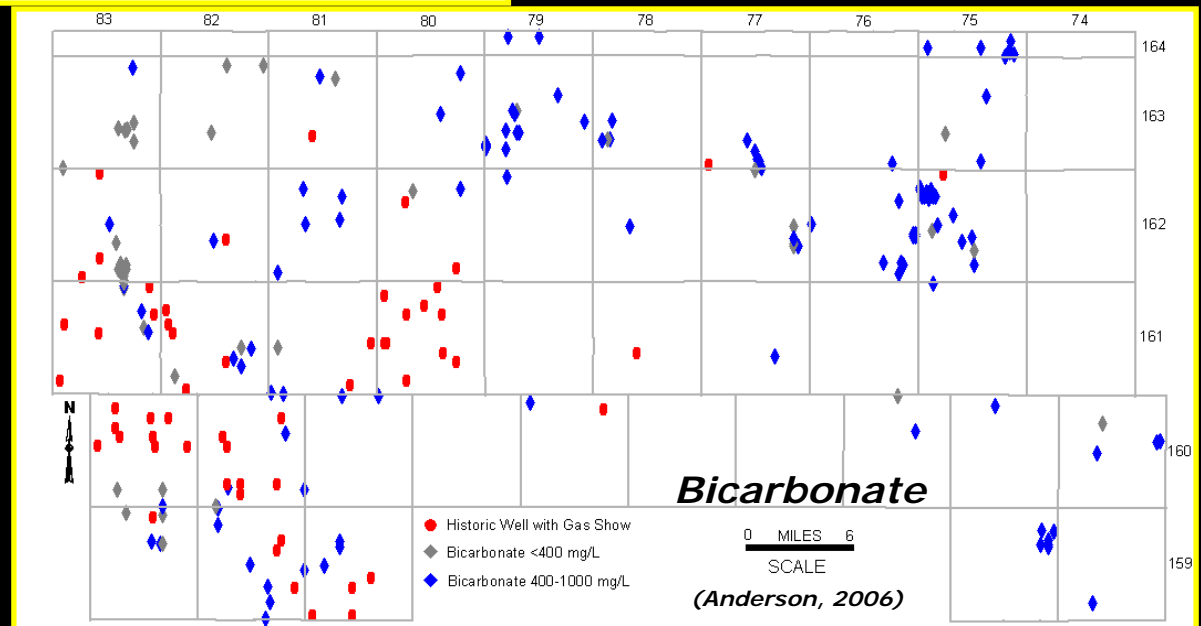
(Examples from Bottineau Co.)



Spatial relationship of sulfate [ $SO_4$ ] to shallow gas occurrences

Geochemistry of Quaternary "Drift" Wells compared to wells with shallow gas occurrences

Spatial relationship of bicarbonate [ $HCO_3$ ] to shallow gas occurrences



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## *Some Potential Indicators for Exploration*

- Direct Detection of Methane in Shallow Wells
  - Observation Wells
  - Stock (farm and ranch water supply)
  - Water Supply (private and municipal)
- Ground-water Geochemistry
  1. Sulfate and Bicarbonate
  2. Others?
    1. Iron
    2. Dissolved Oxygen (D.O.)



*Field screening for shallow gas with a portable flame-ionization detector (FID) in Emmons County N.D. in 2006.*



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# Recently Completed and Current NDGS Projects

## Shallow Gas Field Screening in North Dakota



*Methane bubbles in a shallow ground-water observation well in Bottineau County*



*Stock well in McKenzie County*

**Historical Shallow Gas Occurrences in Cretaceous and Tertiary Aquifers in west-central North Dakota**

## Investigation of a Potential Shallow Gas Source System in Eastern North Dakota



*Conducting field work in SE Steele County*



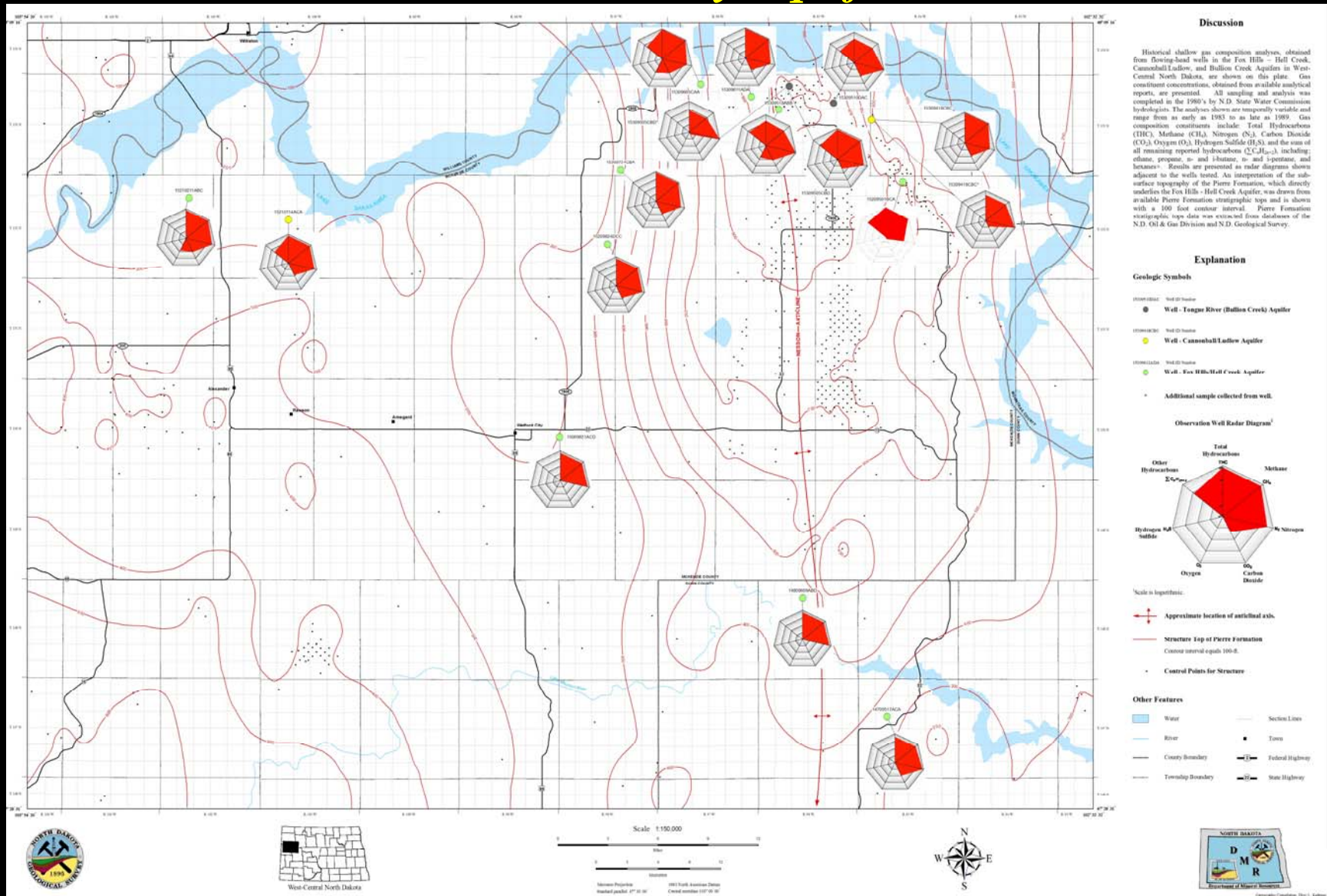
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# Shallow Gas in Cretaceous & Tertiary Aquifers in West-Central N.D.



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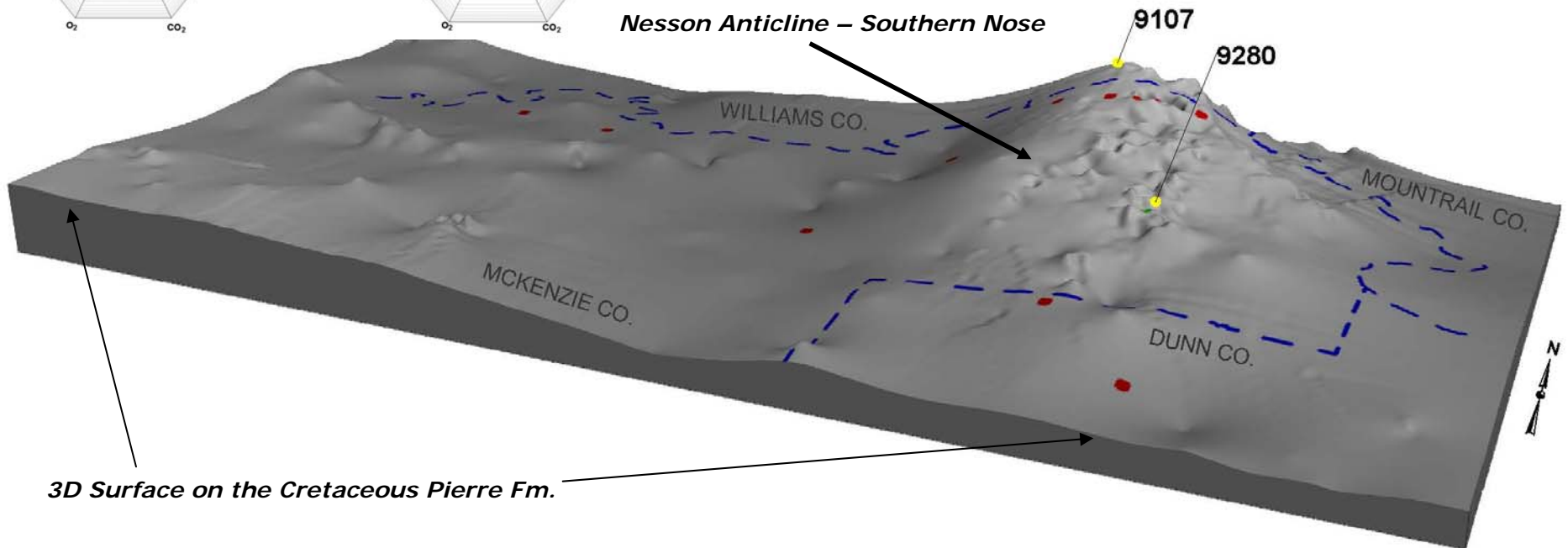
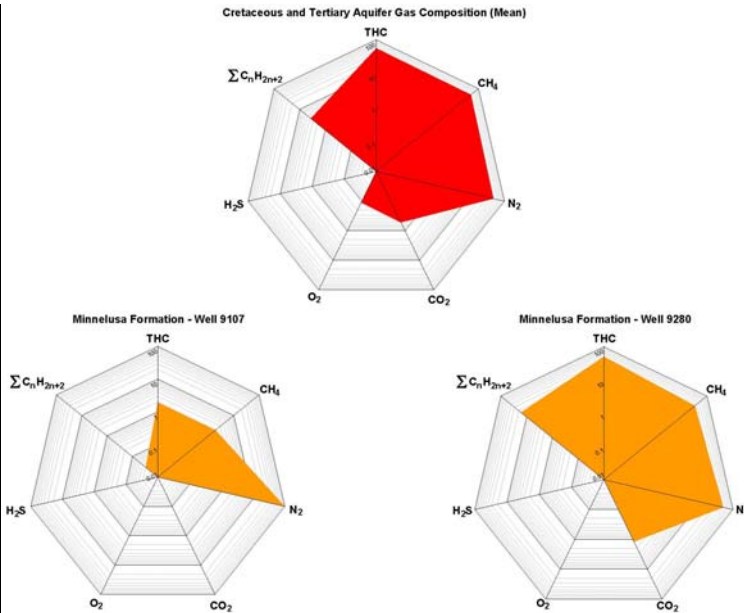
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# Shallow Gas in Cretaceous & Tertiary Aquifers in West-Central North Dakota

Gas composition data compared from wells in Cretaceous/Tertiary Aquifers to gas data from "deeper" potential sources (e.g. Minnelusa Fm.) found in the NDIC/PCOR Deep Gas Database (EERC, 2008).



# Recently Completed and Current NDGS Projects

## Shallow Gas Field Screening in North Dakota



*Methane bubbles in a shallow ground-water observation well in Bottineau County*



*Stock well in McKenzie County*

## Historical Shallow Gas Occurrences in Cretaceous and Tertiary Aquifers in west-central North Dakota

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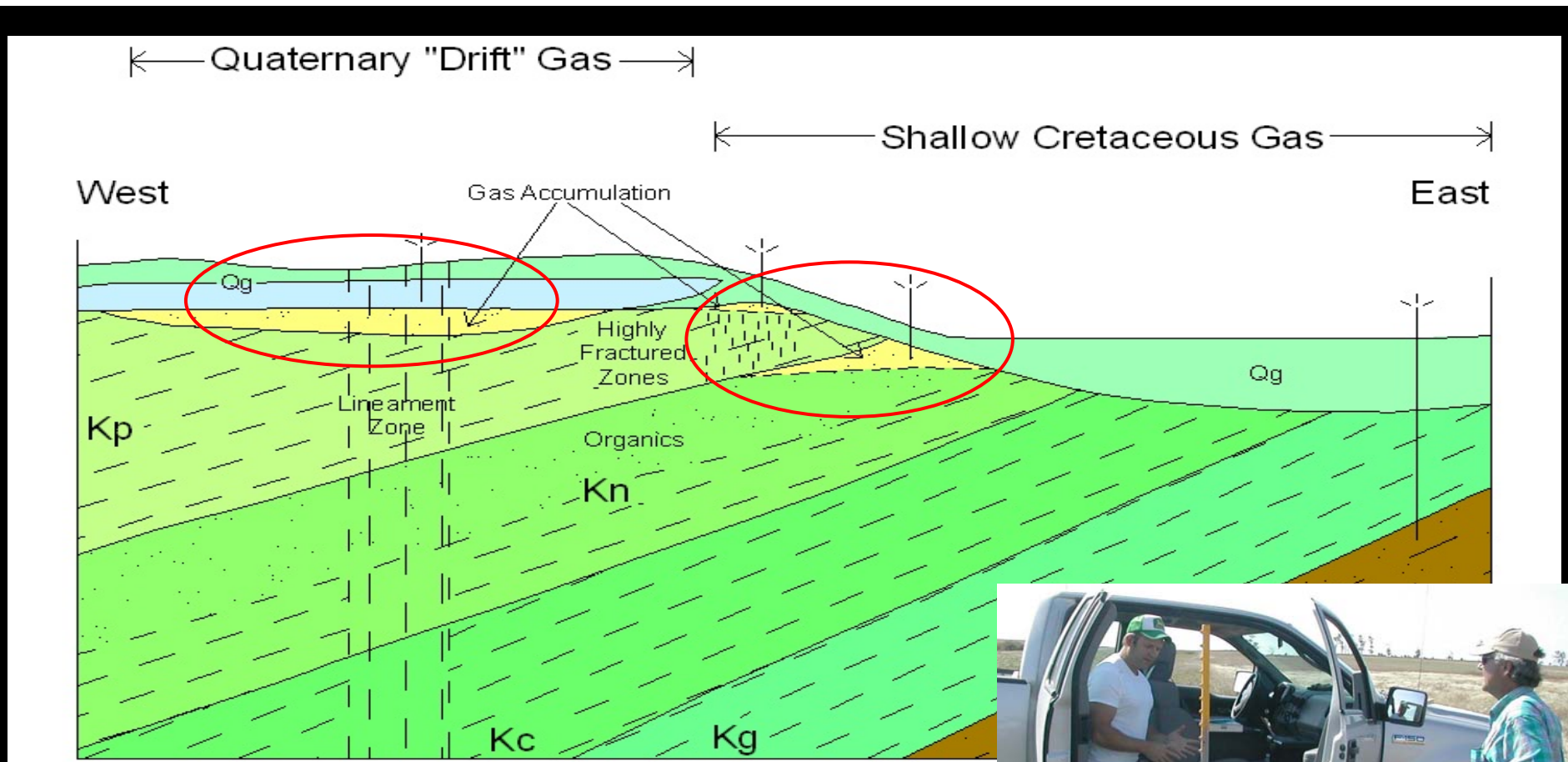
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*Conceptual Geologic Section in eastern North Dakota*

# *Investigation of a Potential Shallow Gas Source System in Eastern North Dakota*

*(Funded, in part, by the N.D. Oil and Gas Research Council)*



*Field screening for shallow gas in eastern ND*

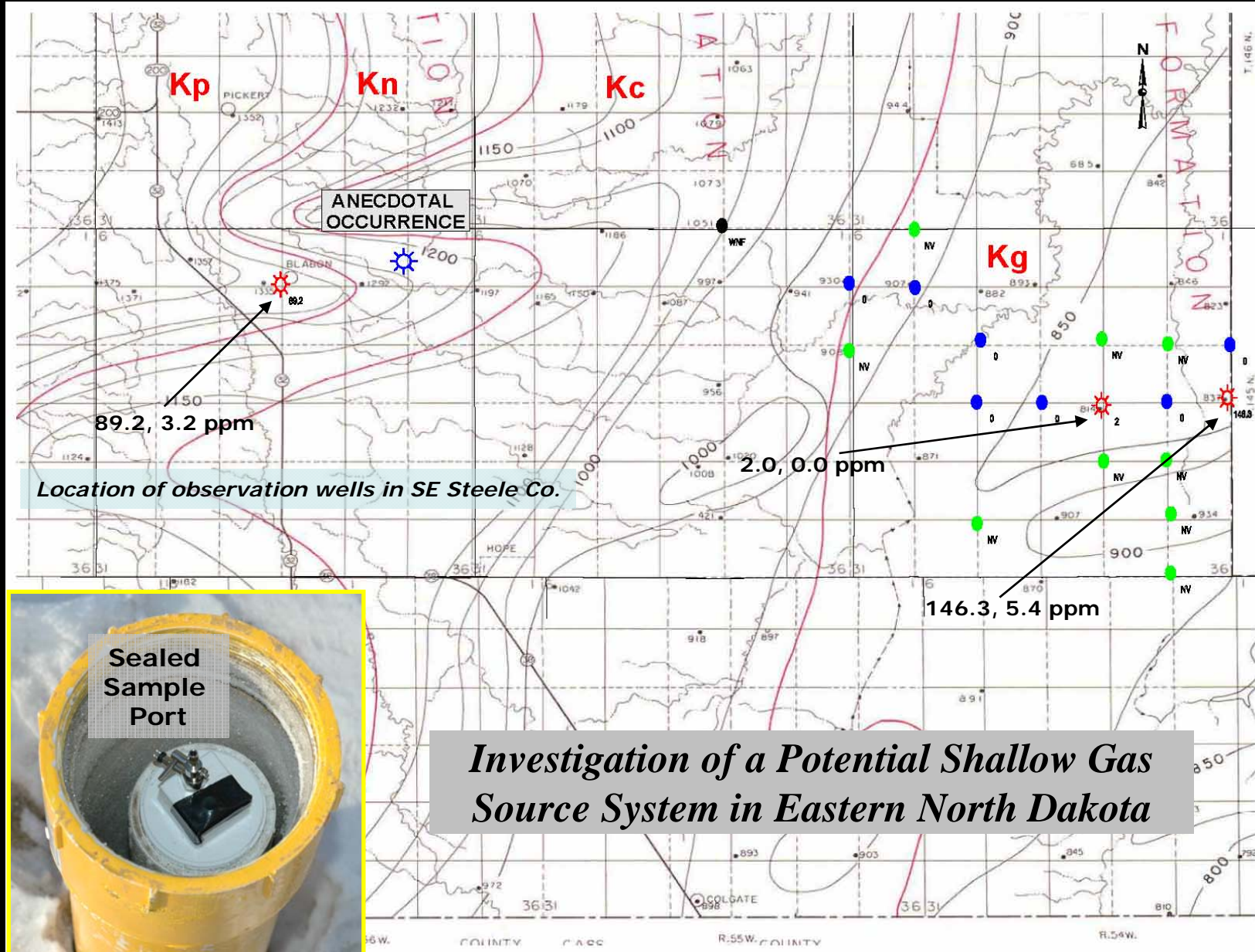


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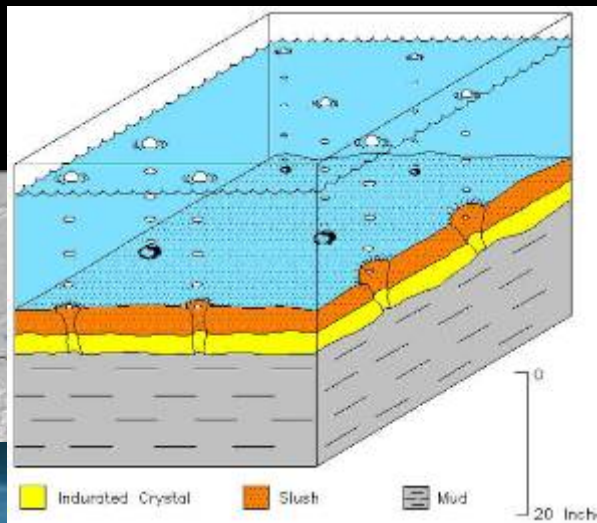
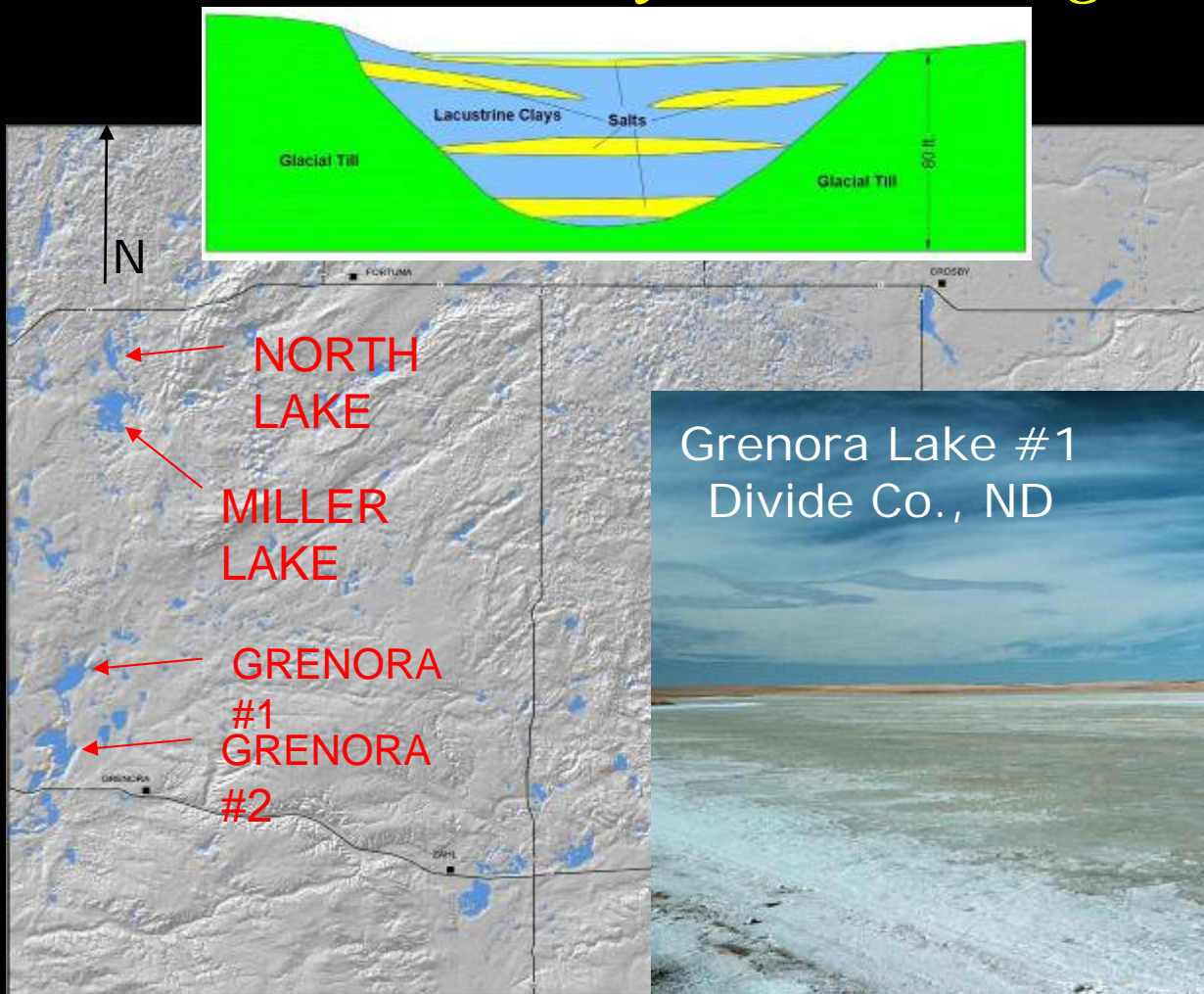
*Investigation of a Potential Shallow Gas Source System in Eastern North Dakota*

## *Current (QIV-2008) NDGS Shallow Gas Projects*

- Potential Shallow Gas Sands Mapping:
  - Griggs & Steele Counties, N.D.
- Shallow Gas Sampling and Compositional Analysis of Selected Wells in North Dakota
  - Selected wells identified during FID field screening to be sampled and analyzed for CH<sub>4</sub>, CO<sub>2</sub>, O<sub>2</sub>, C<sub>2</sub>-C<sub>6</sub>, N<sub>2</sub>



# North Dakota Playa Lake Setting



(modified from Anderson and Murphy, 2005)



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# Alternative Gas Sources - City of Fargo Landfill

- Current Waste Amount: 4,000,000 tons in-place waste.
- Average Annual Waste Acceptance Rate: 107,871 Mg/yr
- Life Expectancy: 13 yrs
- Methane Generation Potential: 170 m<sup>3</sup>/Mg SW
- Methane Generation rate constant 0.02 yr<sup>-1</sup>
- Estimated Max Methane Generation: 450 M ft<sup>3</sup>/yr
- Current Methane Generation of approx. 236 M ft<sup>3</sup>/yr



Modified from Ambrosie, 2007



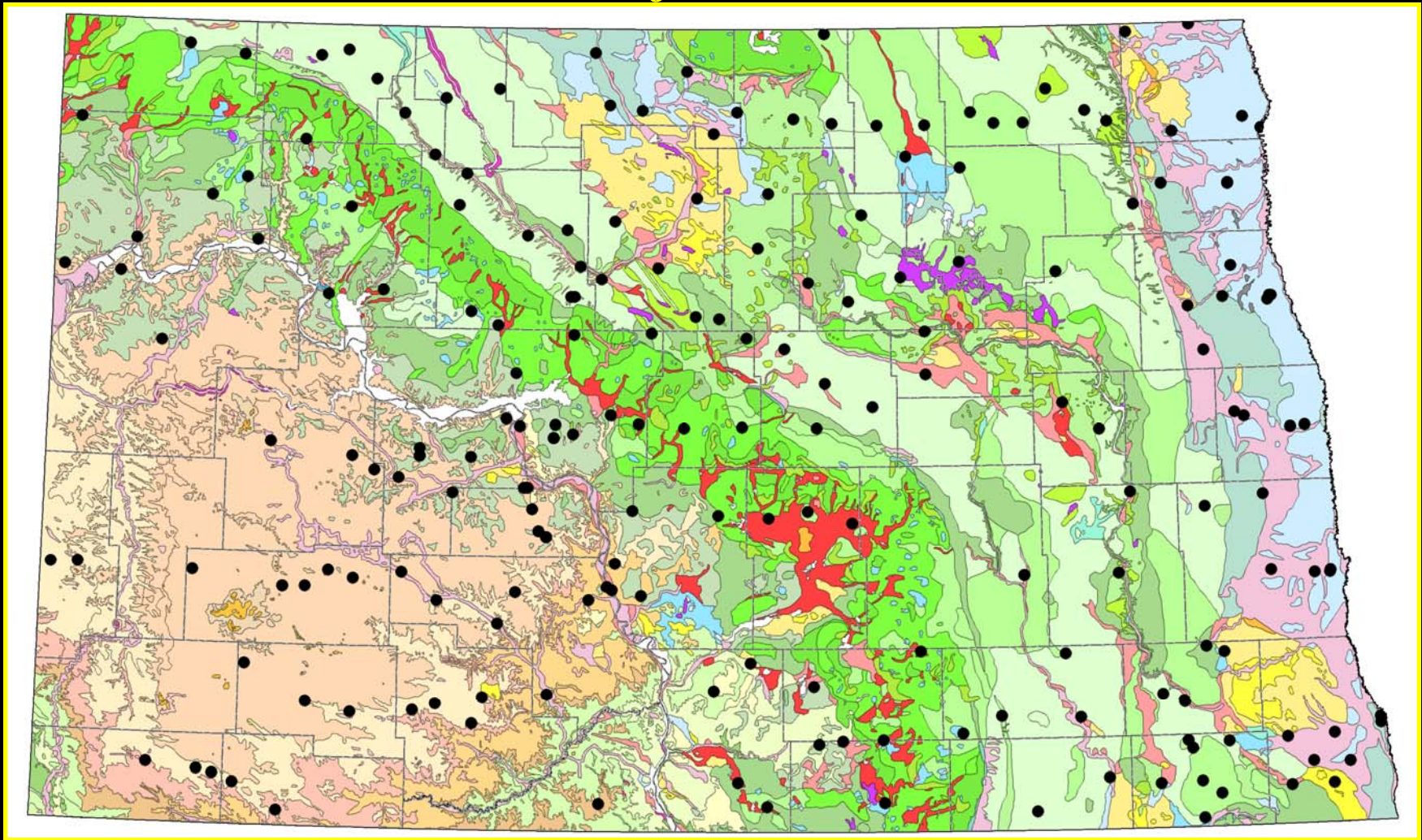
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# *Additional Landfill Locations in ND*



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

*Geological Map Modified from Clayton, et. al., 1980*

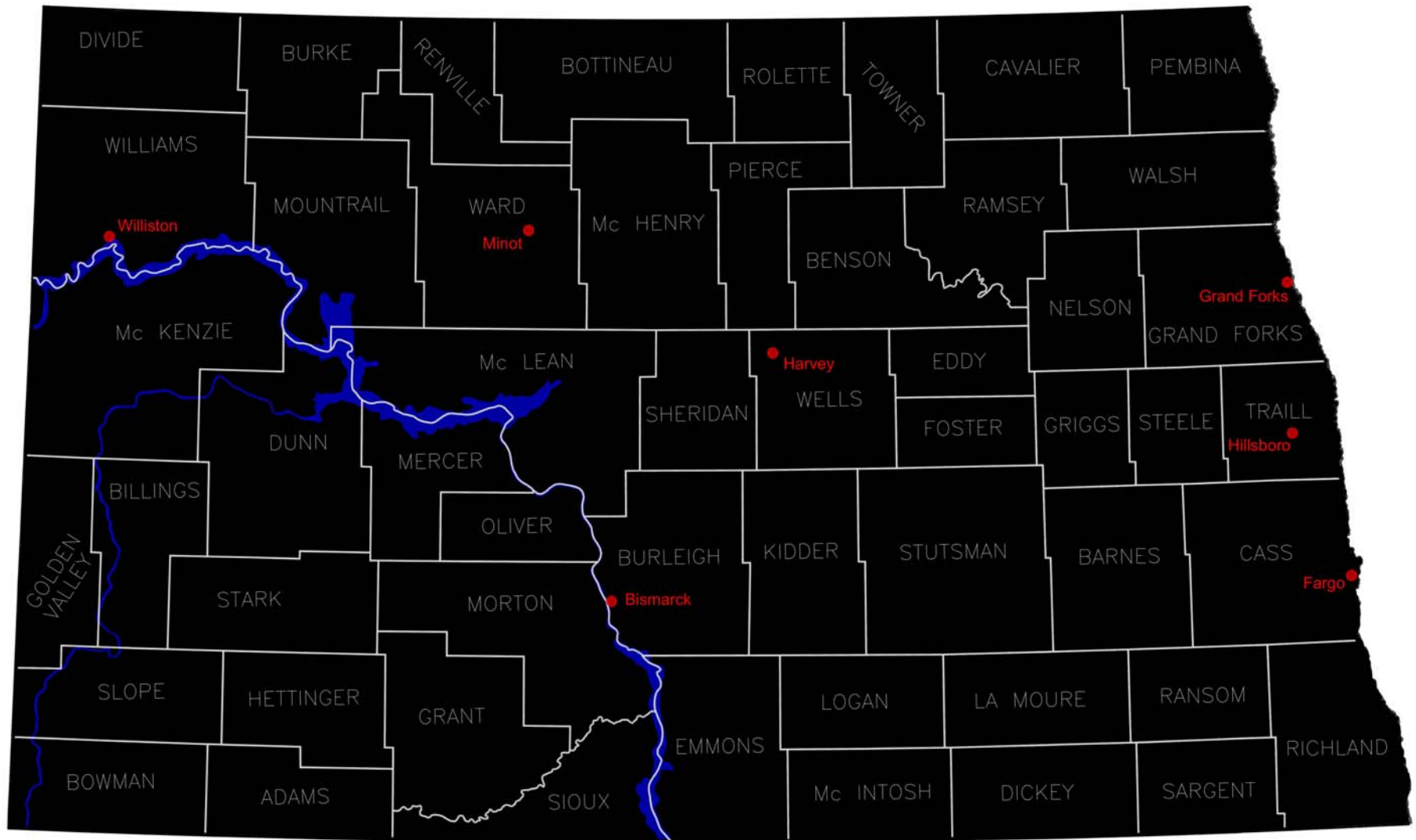


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**Location of MSW landfills in North Dakota with evidence for CH<sub>4</sub> Generation.**

0 30 miles

*Modified from Anderson and Murphy, 2005*



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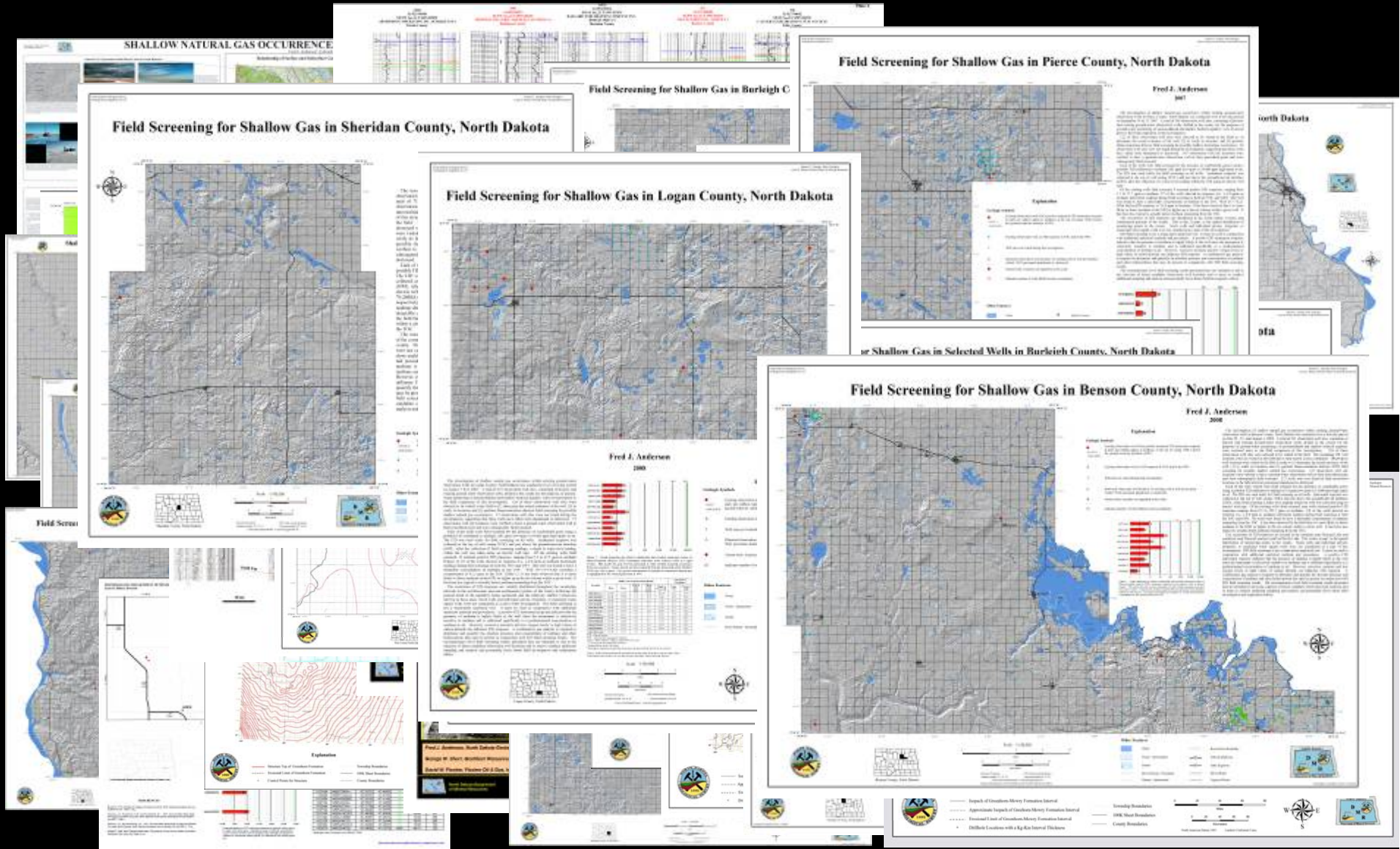
*Soon to be completed **shallow gas projects and reports:***

- NDGS Geological Investigation: *Shallow Gas Field Screening Data Report*
- NDGS Geological Investigation: *Shallow Gas Wildcat Drilling in southeast-central North Dakota.*
- NDGS Geological Investigation: *Potential Shallow Gas Sands in Griggs and Steele Counties, North Dakota.*
- NDGS Geological Investigation: *Gas Composition Sampling and Analyses of Selected Wells in Central and Eastern North Dakota*





# Recent NDGS Shallow Gas Publications



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# Shallow Gas Publication Fact Sheets



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# Shallow Gas Program Web Page

Department of Mineral Resources Geological Survey - Windows Internet Explorer  
https://www.dmr.nd.gov/ndgs//shallowgas/sgas.asp

North Dakota [nd.gov](http://nd.gov) Official Portal for North Dakota State Government

ASSESSMENT OF THE SHALLOW NATURAL GAS RESOURCE POTENTIAL OF NORTH DAKOTA



[SHALLOW GAS STORIES](#)

[RECENT PUBLICATIONS](#)

[CURRENT INVESTIGATIONS](#)

ONLINE DATABASE OF SHALLOW NATURAL GAS OCCURANCES

ONLINE BIBLIOGRAPHY

BACKGROUND

SHALLOW GAS FIELD SCREENING

[FACT SHEETS](#)



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Storage tank for natural gas at the Northern Hotel in Edgeley, LaMoure County, North Dakota around 1920. This tank was once used to collect gas from an artesian well in the area. The gas was used to light the hotel (from Hard, 1920).

[Home Page](#)

North Dakota Geological Survey  
Last modified: November 26, 2007

[www.dmr.nd.gov/ndgs//shallowgas](http://www.dmr.nd.gov/ndgs//shallowgas)



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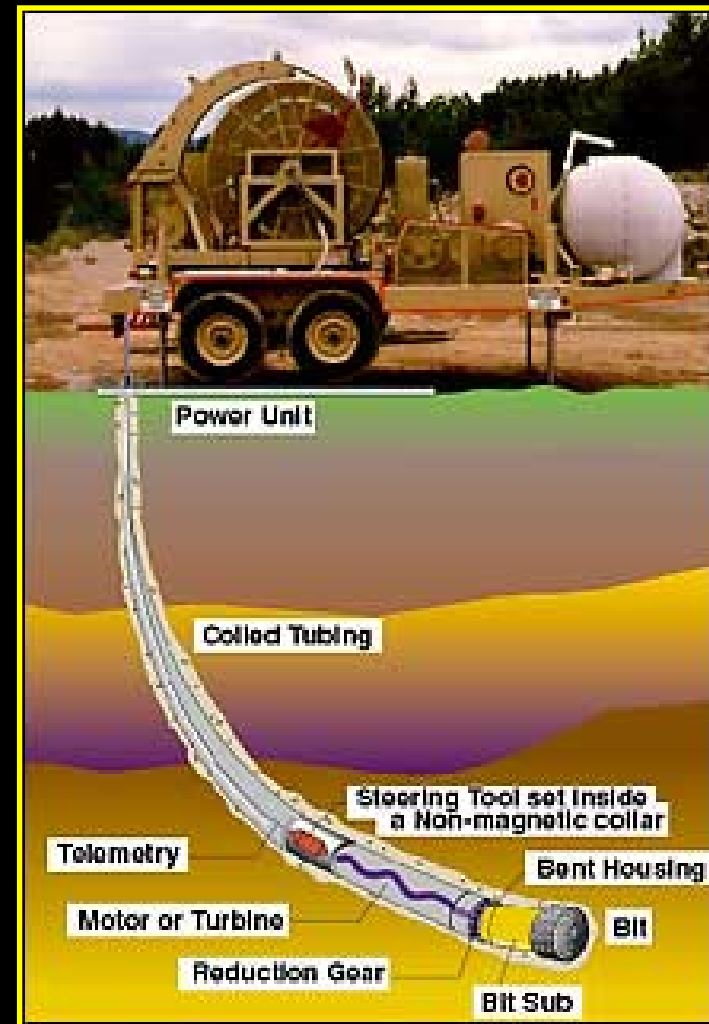
# *Recommendations for Future Work*

- *Multi-source shallow drilling investigations, utilizing cost-effective shallow well drilling technology should be conducted contemporaneously into the Quaternary glacial drift, sub-glacial sediments, and Cretaceous sedimentary environments (Fox Hills, Niobrara, etc.) in order to investigate potential shallow gas sourcing and accumulation in central and eastern North Dakota (a multi-unit resource approach).*
- *Investigations into the site specific geologic, anthropogenic, and economic factors associated with methane generation and potential extraction for each and every North Dakota landfill location (past and present) should be conducted.*
- *Investigations into the quantity and quality of observed gas generation with the playa lake setting associated with sodium sulfate deposits should be conducted in an effort to more fully characterize gas in these playa lake settings.*



# Drilling Investigation Recommendations

- *A single hole, multi-level completion shallow drilling investigation, utilizing cost-effective and appropriate shallow well drilling technology and completion techniques, designed specifically for the depths to be investigated and characterized, should be conducted contemporaneously into all potential shallow gas intervals in order to investigate potential shallow gas sourcing, accumulation, and potential production, in central and eastern North Dakota (a simultaneous multi-depth resource development and extraction approach).*



*Microhole coiled tubing rig designed for oil & gas applications (USDOE)*



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# NORTH DAKOTA GEOLOGICAL SURVEY

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