North Dakota Mineral Resources
Status and Outlook

House Natural Resources Committee

January 9, 2015

Lynn D. Helms, Director
Department of Mineral Resources
North Dakota Industrial Commission

Three-Dimensional Geologic Model of Northwestern North Dakota

Frac Proppant
Coal
Geothermal
Uranium

Salt-Water Disposal

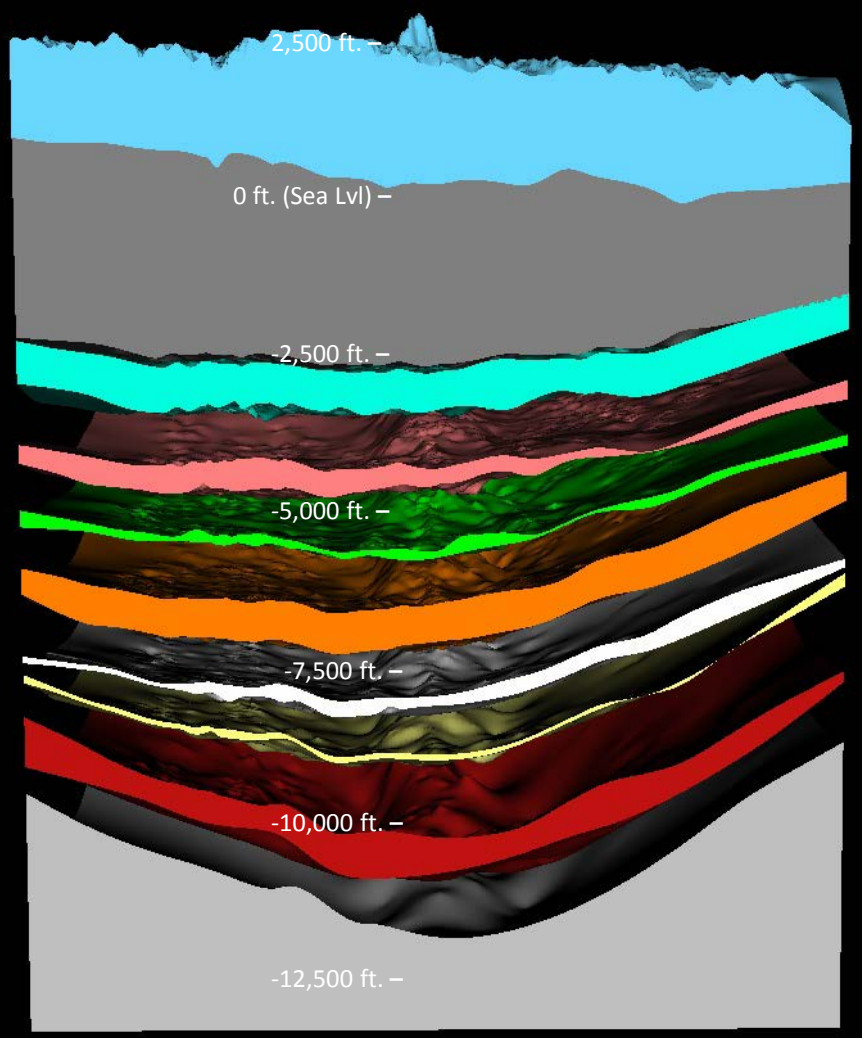
Oil & Gas

Oil & Gas

Oil & Gas

Oil & Gas
Potash

Deep Oil & Gas



Fresh Water Zone

Shallow Gas Zone

Dakota Group

Spearfish Formation

Tyler Formation

Madison Group

Bakken-Three Forks

Prairie Formation

Red River Formation

Precambrian Basement

WILSON M. LAIRD CORE AND SAMPLE LIBRARY

Oil companies are required by law to archive cores and samples (small pieces of rock ground up by the drill bit) in the Wilson M. Laird Core and Sample Library located on the University of North Dakota Campus in Grand Forks. The core library was constructed in 1980 and is quickly filling to capacity due to record-setting drilling activity in North Dakota. Current estimates are that the core library will be completely filled in 2017. The core library warehouse (13,200 square feet) will need to be tripled in size in order to accommodate future cores and samples.

EAPC was chosen as the architectural firm to draw plans and estimate costs for a core library expansion. The expansion costs were included in the Governor's Executive Budget for the 2015-2017 biennium.

The Wilson M. Laird Core and Sample Library on the campus of the University of North Dakota. The core library houses over 75 miles of core (132,000 boxes of core) and 30,000 boxes of samples.

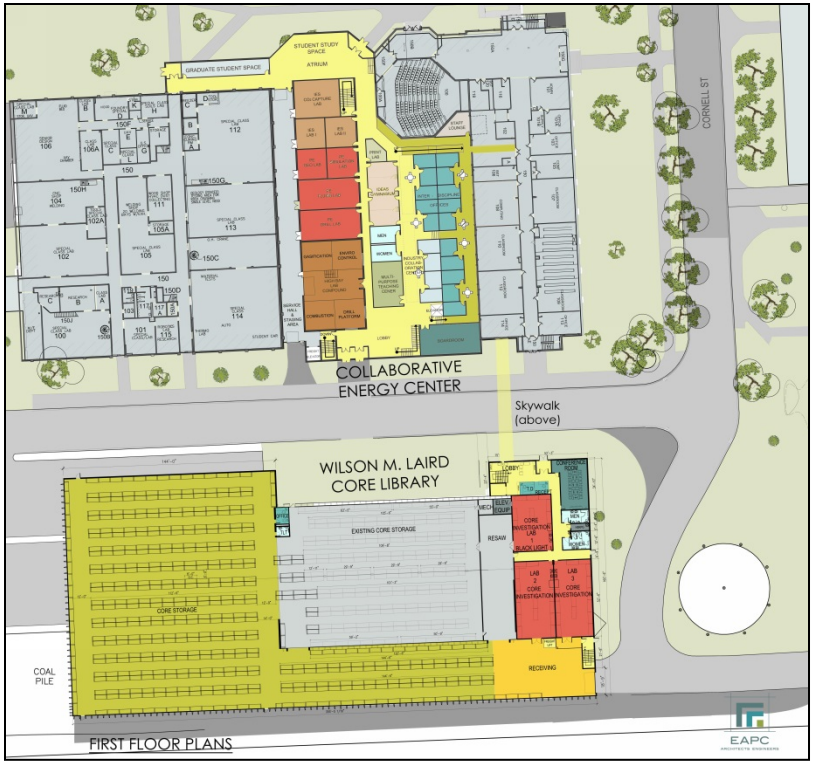
One of eight aisles in the Wilson M. Laird Core and Sample Library. Roughly 90% of the core in the core library have been reboxed in recent years resulting in a 30% space savings.

EXPANSION OF THE
WILSON M. LAIRD CORE AND SAMPLE LIBRARY (2015-2017)

EAPC determined it would cost $16,013, 441.96 to triple the size of the existing core library warehouse, increase from one laboratory to five (the original core library had two labs, but one had to be used for office space), increase office space, and add a conference room. We believe that will give us 50 years of storage space and provide much needed research space. University of North Dakota personnel were shown these plans as they developed and were asked for input. In addition, the Department of Mineral Resources and the University of North Dakota signed an MOA in 2014 regarding expansion of the core library on the UND campus and acknowledging the mutual benefit of locating it on the campus. The core library is located across the street from Leonard Hall (dept. of geology and geological engineering), Upson Hall (School of Engineering and Mines), and the proposed Collaborative Energy Center (CEC).

In order for construction to begin this summer, an emergency clause will need to be attached to this portion of the HB1014. Doing so, will enable demolition to be completed before classes begin for the fall semester.

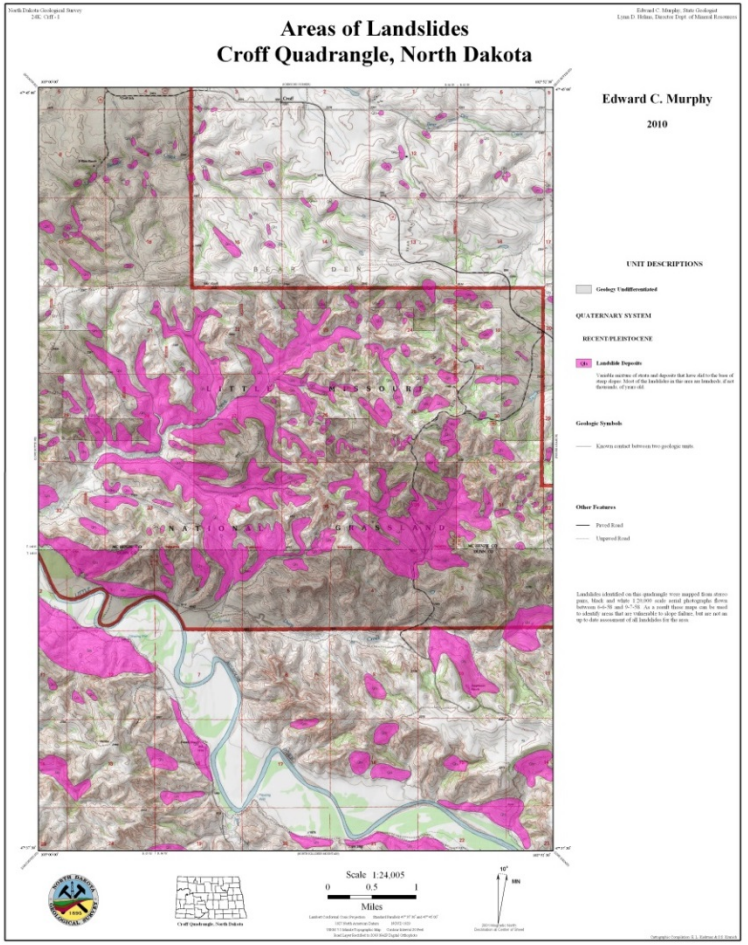
EAPC's drawing of the proposed expansion of the Wilson M. Laird Core and Sample Library. The skywalk leads from the core library to Leonard Hall.



EAPC's core library expansion plans. Existing buildings (the core library, Leonard Hall, and Upson Hall) are shown in gray. Areas and rooms within the expanded core library and the CEC are shown in a variety of colors.

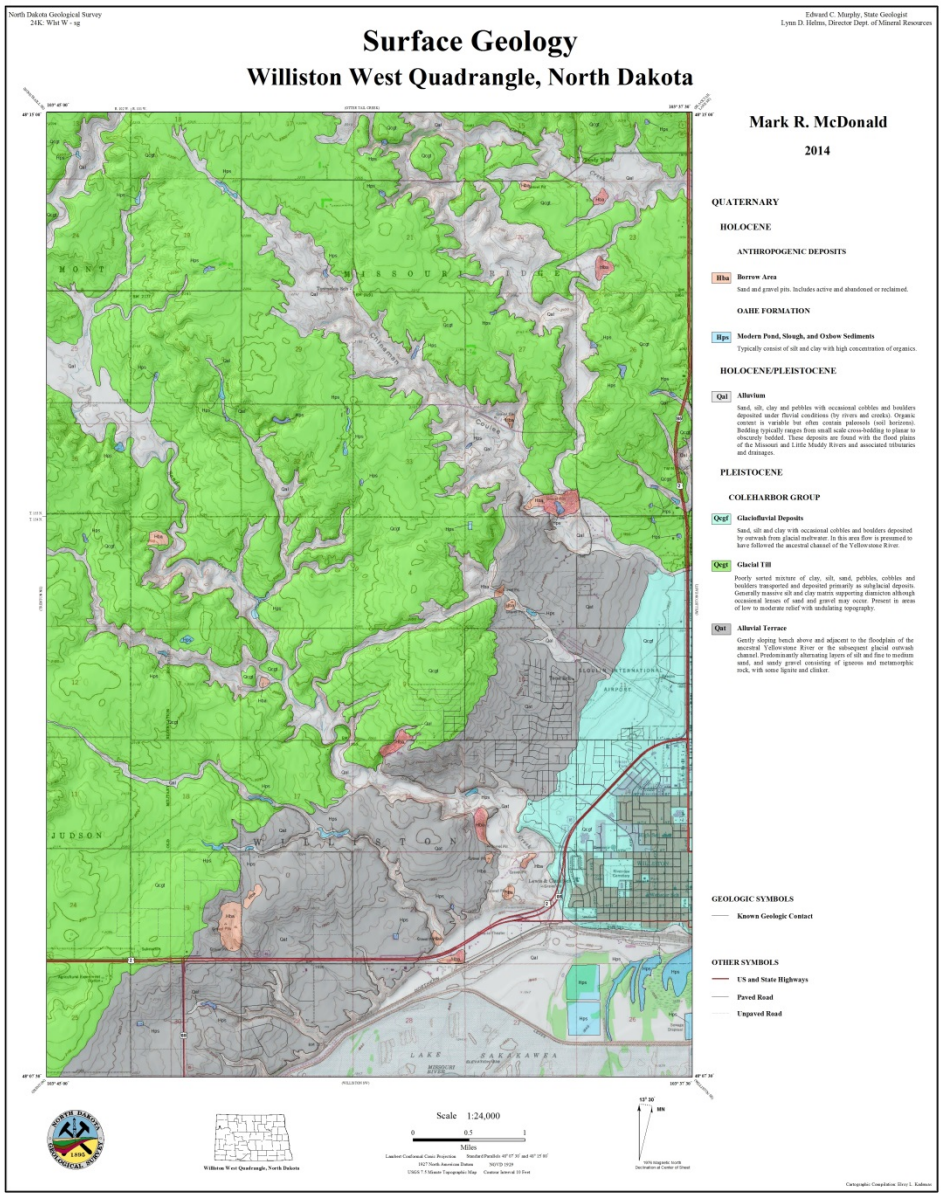
AERIAL PHOTOGRAPHY
GEOLOGICAL SURVEY (2015-2017)

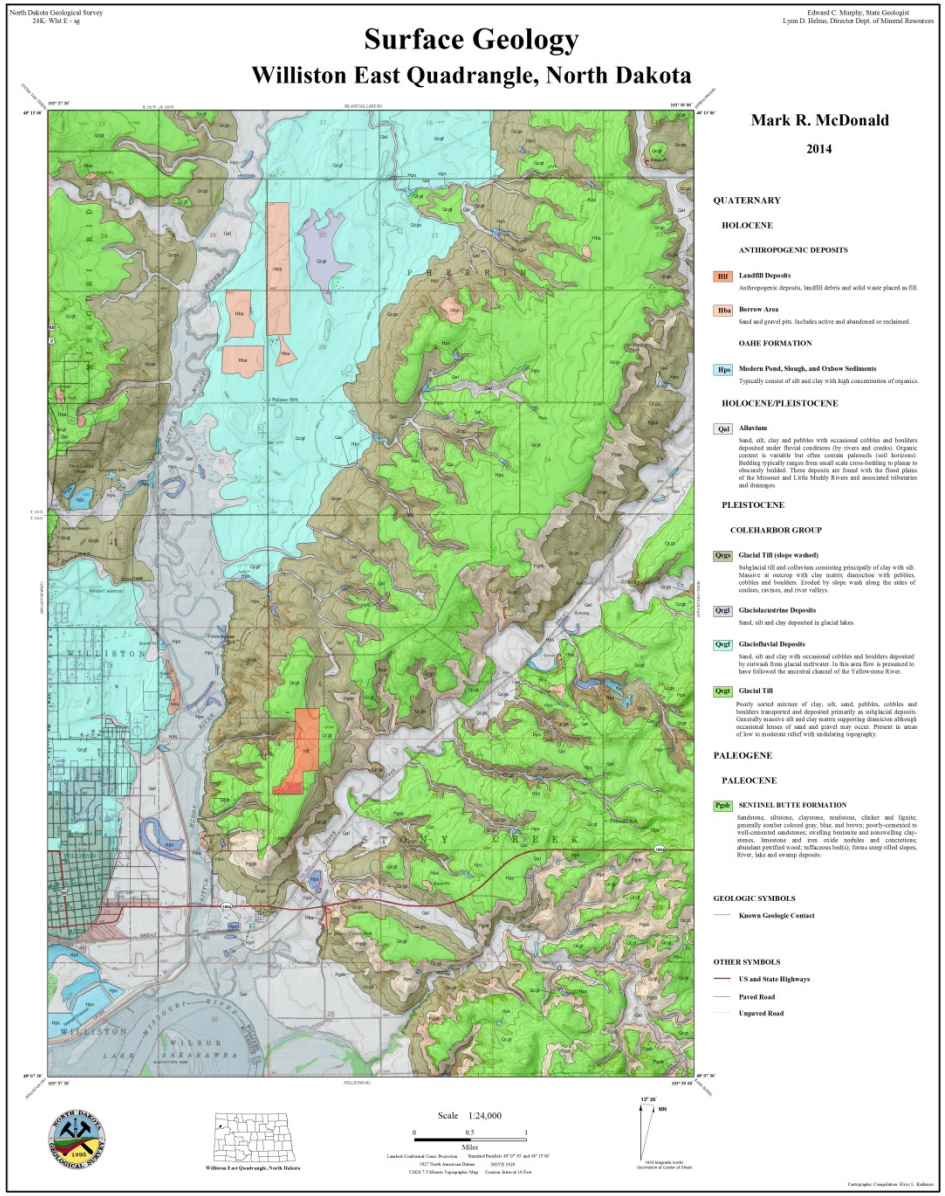
Aerial photographs are an important source of geologic information, the patterns observable in photographs often provide insight into the sediments or rocks that can be found at or near the surface. The Geological Survey has 50,000 aerial photographs flown between 1957 and 1962. This includes flight lines for all but two counties. In addition, almost every set in the remaining counties are missing photos. If we can purchase the 8,000 missing photographs, we will have a complete set of older photos to work from. We prefer older photographs because there are fewer buildings and infrastructure to obscure the surface geology. All of our aerial photographs are in stereo pairs which enable us to look at them through stereoscopes and see things in three dimensions.



Photograph above: Geologic contacts are identified through the stereoscopes, traced on the photos with grease pencil, the lines are transferred to the quadrangles, and the contacts are checked for accuracy in the field. On the right: Landslide map of the Croff Quadrangle. The landslides are mapped in pink.

WILLISTON


North Dakota Geological Survey
24K: Wst W - sg
Edward C. Murphy, State Geologist
Lynn D. Helms, Director Dept. of Mineral Resources
Surface Geology
Williston West Quadrangle, North Dakota
Mark R. McDonald
2014
QUATERNARY
HOLOCENE
ANTHROPOGENIC DEPOSITS
Hba Borrow Area
Sand and gravel pits. Includes active and abandoned or reclaimed.
OAHE FORMATION
Hps Modern Pond, Slough, and Oxbow Sediments
Typically consist of silt and clay with high concentration of organics.
HOLOCENE/PLEISTOCENE
Qal Alluvium
Sand, silt, clay and pebbles with occasional cobbles and boulders deposited under fluvial conditions (by rivers and creeks). Organic content is variable but often contains paleosols (soil horizons). Bedding typically ranges from small scale cross-bedding to planar to obscurely bedded. These deposits are found with the flood plains of the Missouri and Little Muddy Rivers and associated tributaries and drainages.
PLEISTOCENE
COLEHARBOR GROUP
Qcgf Glaciofluvial Deposits
Sand, silt and clay with occasional cobbles and boulders deposited by outwash from glacial meltwater. In this area flow is presumed to have followed the ancestral channel of the Yellowstone River.
Qcgt Glacial Till
Poorly sorted mixture of clay, silt, sand, pebbles, cobbles and boulders transported and deposited primarily as subglacial deposits. Generally massive silt and clay matrix supporting diamicton although occasional lenses of sand and gravel may occur. Present in areas of low to moderate relief with undulating topography.
Qat Alluvial Terrace
Gently sloping bench above and adjacent to the floodplain of the ancestral Yellowstone River or the subsequent glacial outwash channel. Predominantly alternating layers of silt and fine to medium sand, and sandy gravel consisting of igneous and metamorphic rock, with some lignite and clinker.
GEOLOGIC SYMBOLS
Known Geologic Contact
OTHER SYMBOLS
US and State Highways
Paved Road
Unpaved Road
Scale 1:24,000
Miles
Williston West Quadrangle, North Dakota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2014
QUATERNARY
HOLOCENE
ANTHROPOGENIC DEPOSITS
Hlf Landfill Deposits
Anthropogenic deposits, landfill debris and solid waste placed as fill.
Hba Borrow Area
Sand and gravel pits. Includes active and abandoned or reclaimed.
OAHE FORMATION
Hps Modern Pond, Slough, and Oxbow Sediments
Typically consist of silt and clay with high concentration of organics.
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PLEISTOCENE
COLEHARBOR GROUP
Qcgs Glacial Till (slope washed)
Subglacial till and colluvium consisting principally of clay with silt. Massive at outcrop with clay matrix diamicton with pebbles, cobbles and boulders. Eroded by slope wash along the sides of coulees, ravines, and river valleys.
Qcgl Glaciolacustrine Deposits
Sand, silt and clay deposited in glacial lakes.
Qcgf Glaciofluvial Deposits
Sand, silt and clay with occasional cobbles and boulders deposited by outwash from glacial meltwater. In this area flow is presumed to have followed the ancestral channel of the Yellowstone River.
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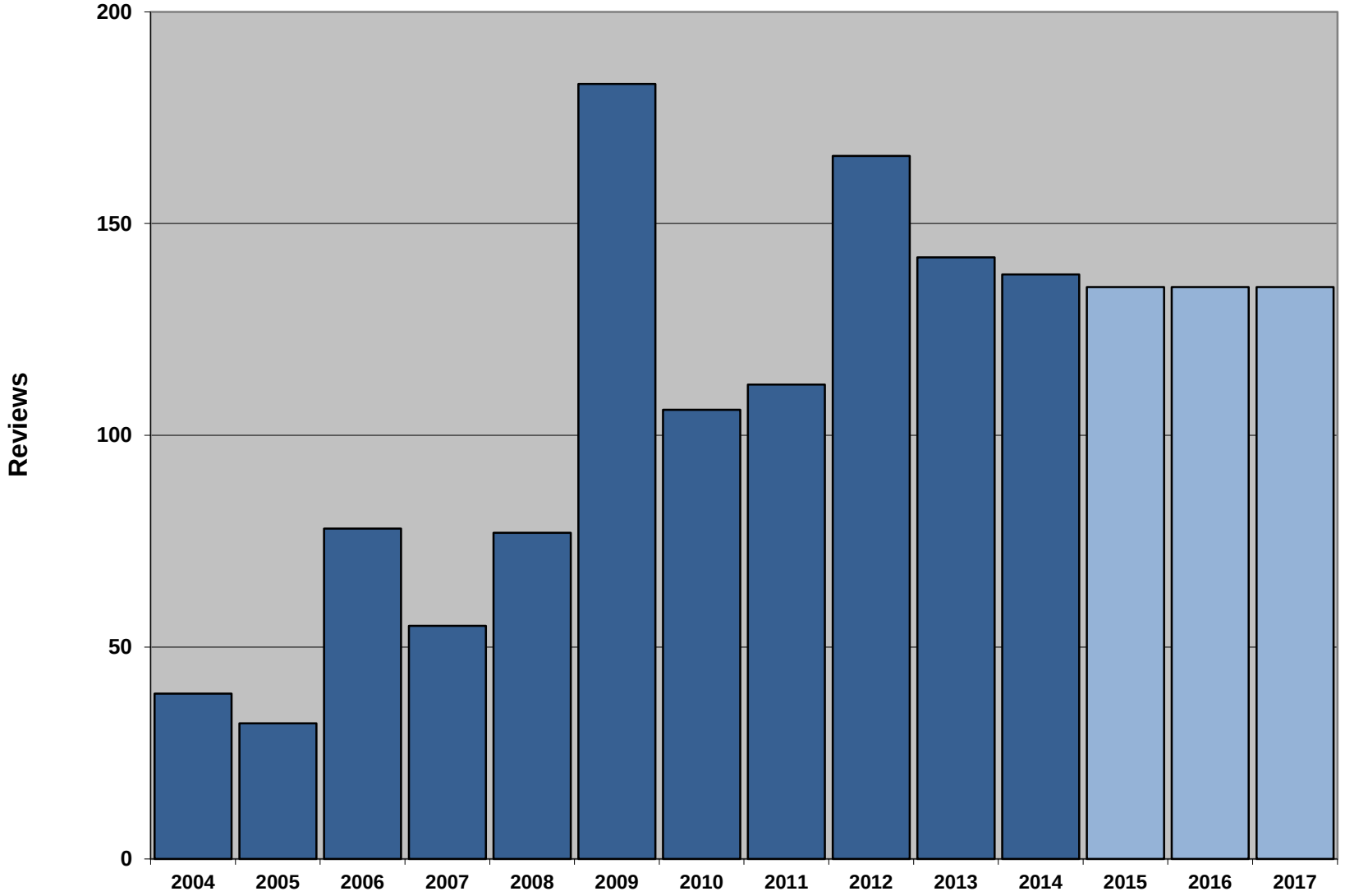
PALEOGENE
PALEOCENE
Pgsb SENTINEL BUTTE FORMATION
Sandstone, siltstone, claystone, mudstone, clinker and lignite; generally somber colored gray, blue, and brown; poorly-cemented to well-cemented sandstones; swelling bentonite and nonswelling clay-stones, limestone and iron oxide nodules and concretions; abundant petrified wood; tuffaceous bed(s); forms steep-tilled slopes. River, lake and swamp deposits.
GEOLOGIC SYMBOLS
Known Geologic Contact
OTHER SYMBOLS
US and State Highways
Paved Road
Unpaved Road
Scale 1:24,000
Miles
Williston East Quadrangle, North Dakota

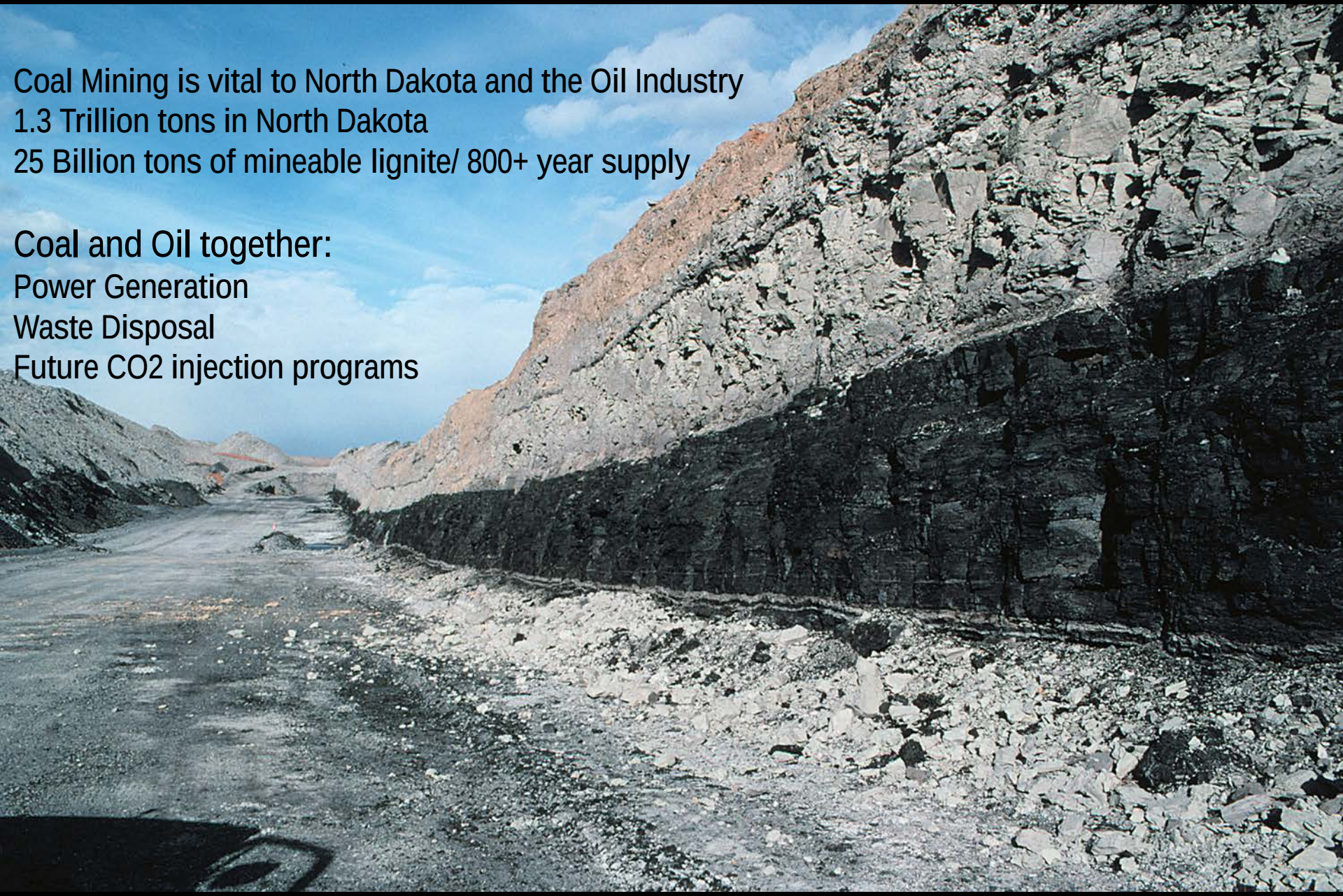
ENGINEERING & ENVIRONMENTAL REVIEWS

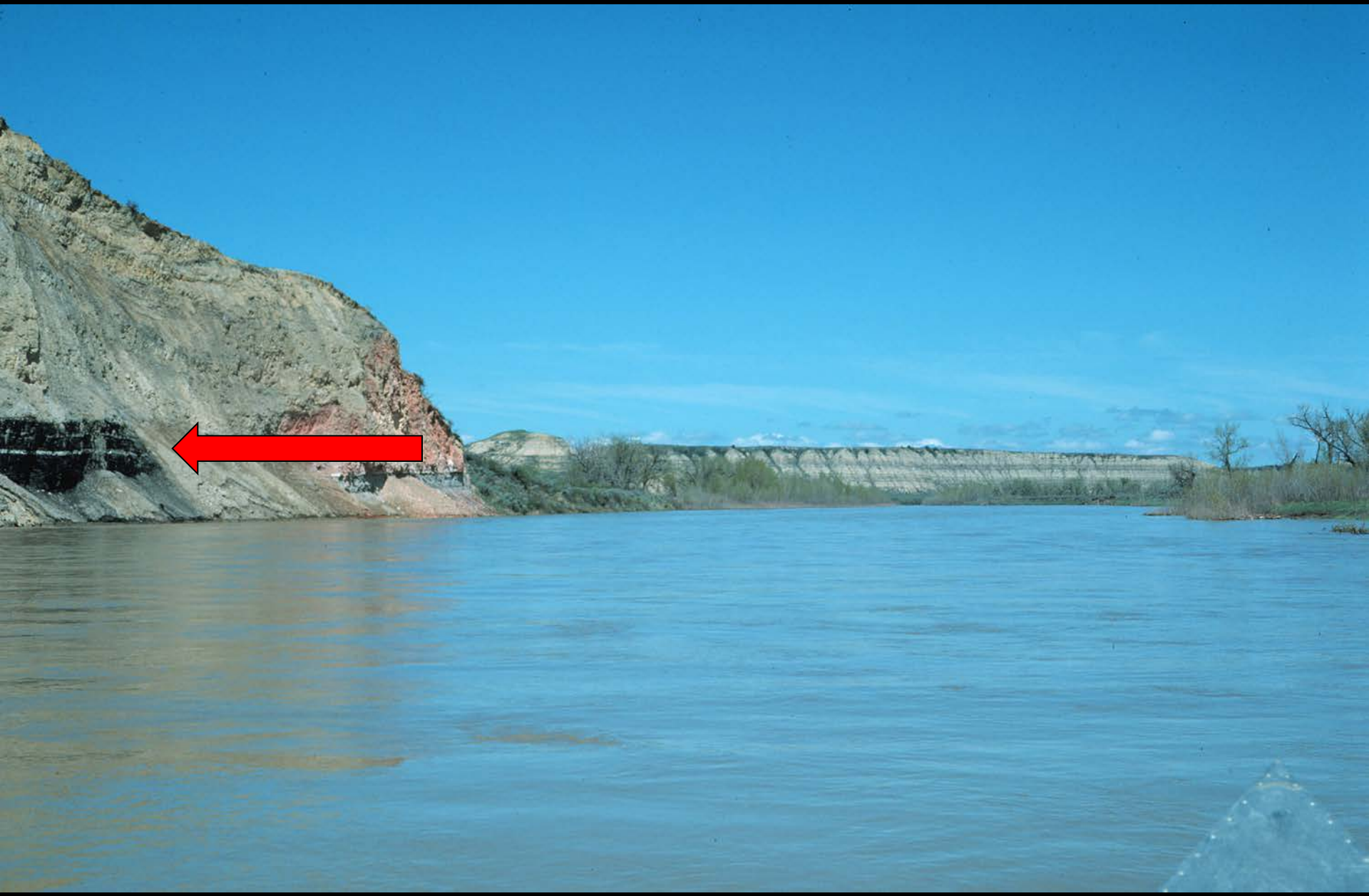
Geological Survey




EXIT

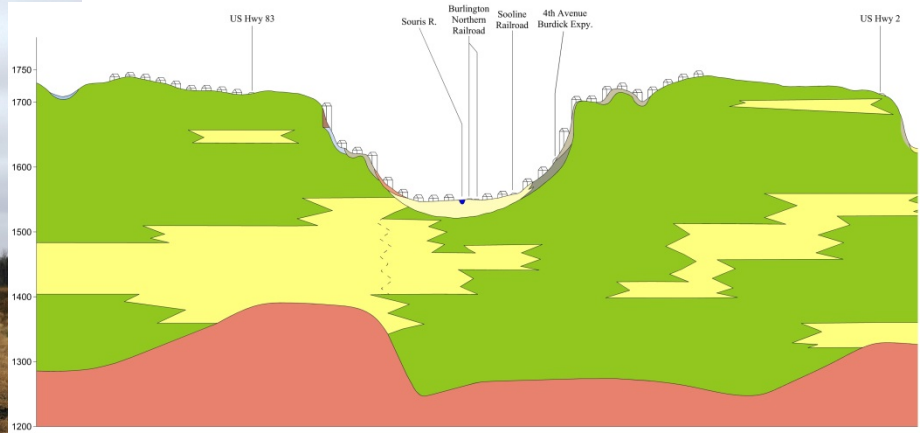
PUBLIC FOSSIL DIGS


Coal Mining is vital to North Dakota and the Oil Industry
1.3 Trillion tons in North Dakota
25 Billion tons of mineable lignite/ 800+ year supply
Coal and Oil together:
Power Generation
Waste Disposal
Future CO2 injection programs



SHALLOW DRILLING AND SAMPLING PROGRAM
GEOLOGICAL SURVEY (2015-2017)

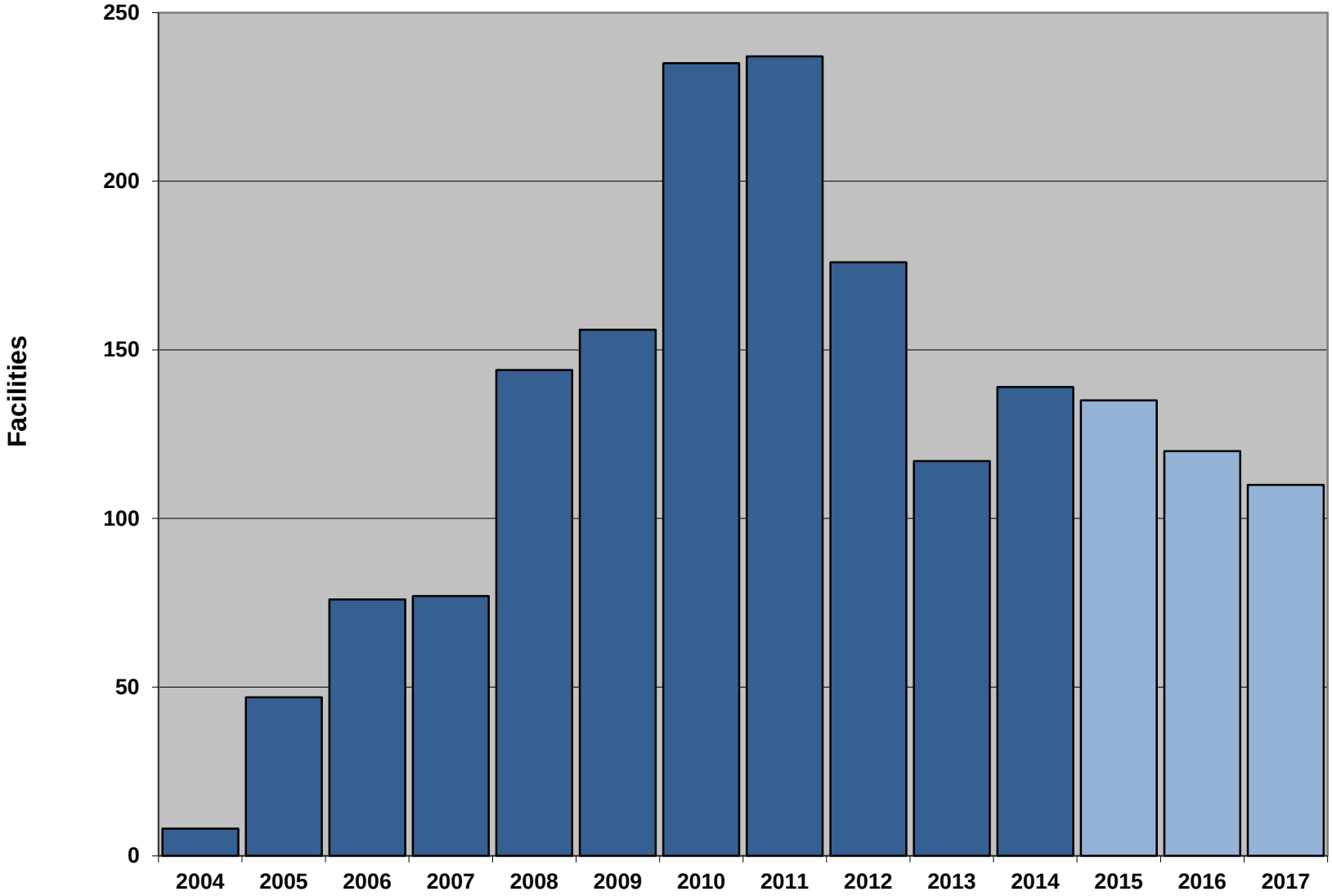
Shallow drilling is an important tool when surface mapping. It provides insight into the elevation of contacts and the changing lithologies in the top 50 or 100 feet of sediment and rock beneath the surface. Drilling enables a three-dimensional assessment of the resources (such as sand and gravel) or the potential hazards (such as swelling clays) beneath an area. Shallow coring costs are variable and can range from $15.00 to $75.00 per foot. We anticipate coring 1,500 or more feet and analyzing 500 sediment samples in the Red River Valley and eastern North Dakota. In addition to characterizing the lithology of the rocks and sediments, we are also going to determine the rare earth content of approximately 50 lignite samples from western North Dakota.



Left: This rotosonic truck-mounted rig is capable of coring depths in excess of 500 feet. *Right:* A shallow geologic cross section beneath Minot. Green is till, yellow bodies are sand, and pink is the Fort Union Group (alternating beds of mudstone, claystone, siltstone, sandstone, and lignite).

GEOTHERMAL INSTALLATIONS

Geological Survey



DEPARTMENT OF MINERAL RESOURCES – GEOLOGICAL SURVEY
WILLISTON BASIN TEMPERATURE PROFILE PROJECT

The burial history and temperature profile of the Williston Basin are important components when calculating areas within the basin where rocks are hot enough or were hot enough at one time in geologic history to generate oil. Temperature profiles can be obtained by temperature logging oil wells that have sat idle for several months thus allowing the fluid in the well to come to the same temperature as the surrounding rock.

This biennium we purchased a temperature probe and contracted with a wireline company to run the probe in 11 temporarily abandoned oil wells in western North Dakota. So far, we have logged five of those wells. We plan on purchasing a wire line unit so that we can log a hundred or so wells in the next several years. These temperature profiles, scattered across the basin, will enable more accurate estimates of where rocks in the Williston Basin were hot enough to generate oil (mature areas).

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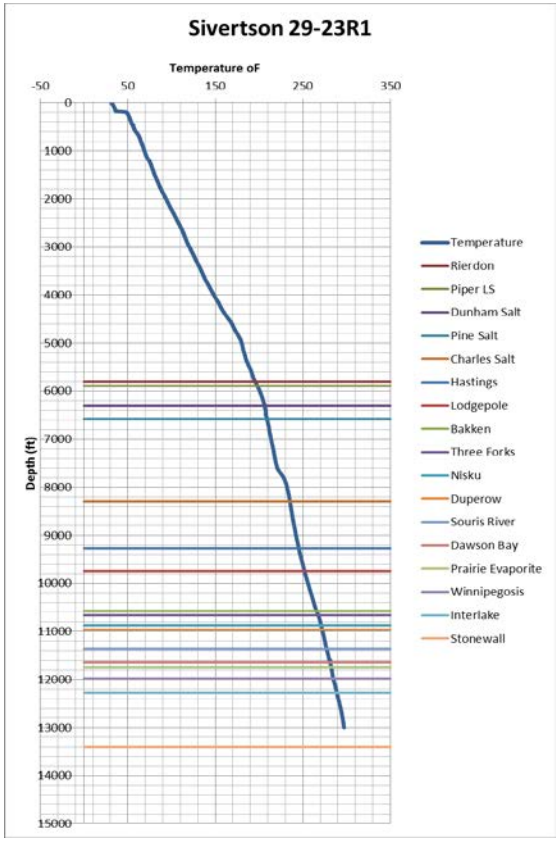
Graph on the right: Temperature profile of the Sivertson 29-23R1 in McKenzie County.



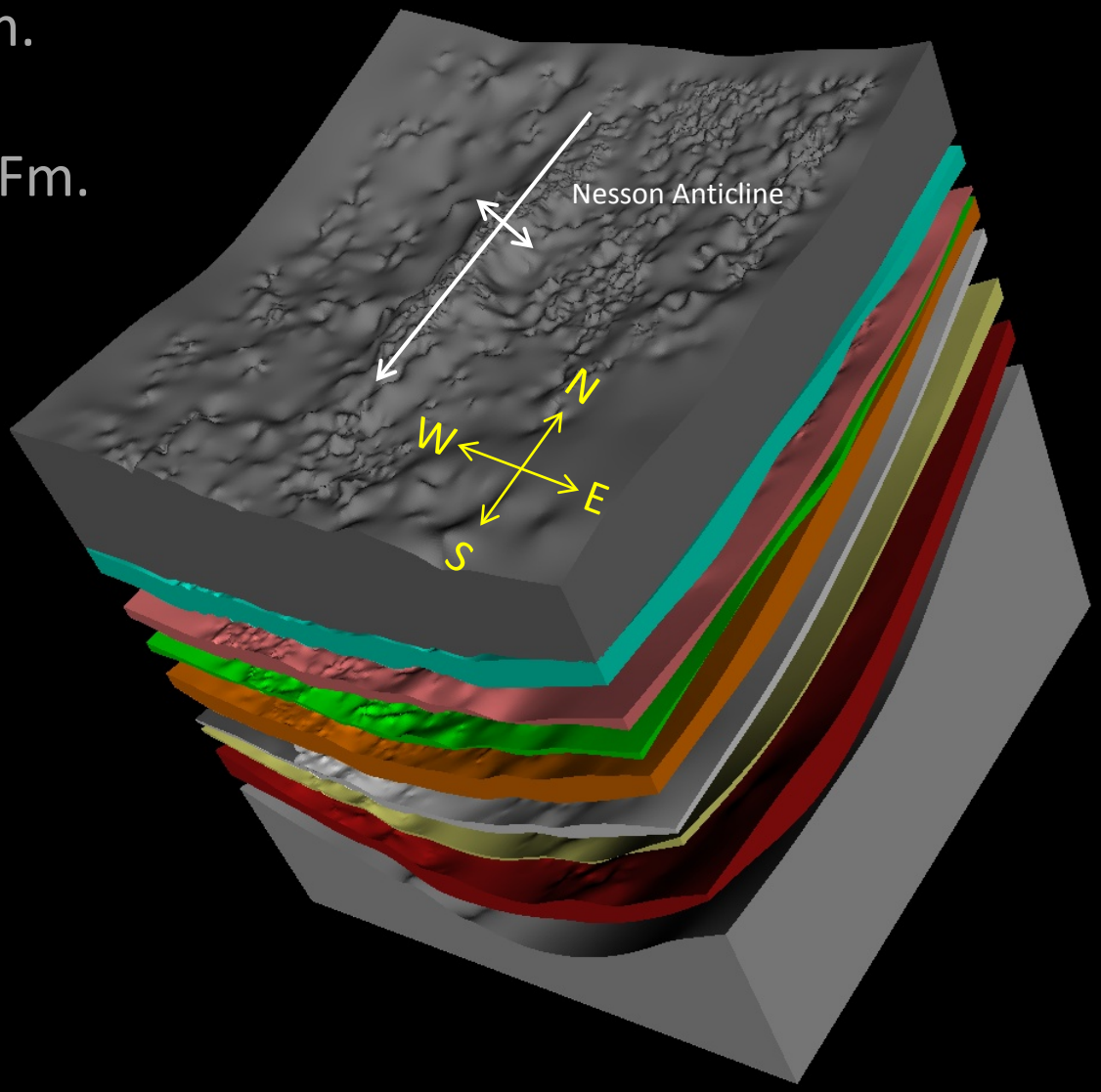
Shallow Gas Prospects

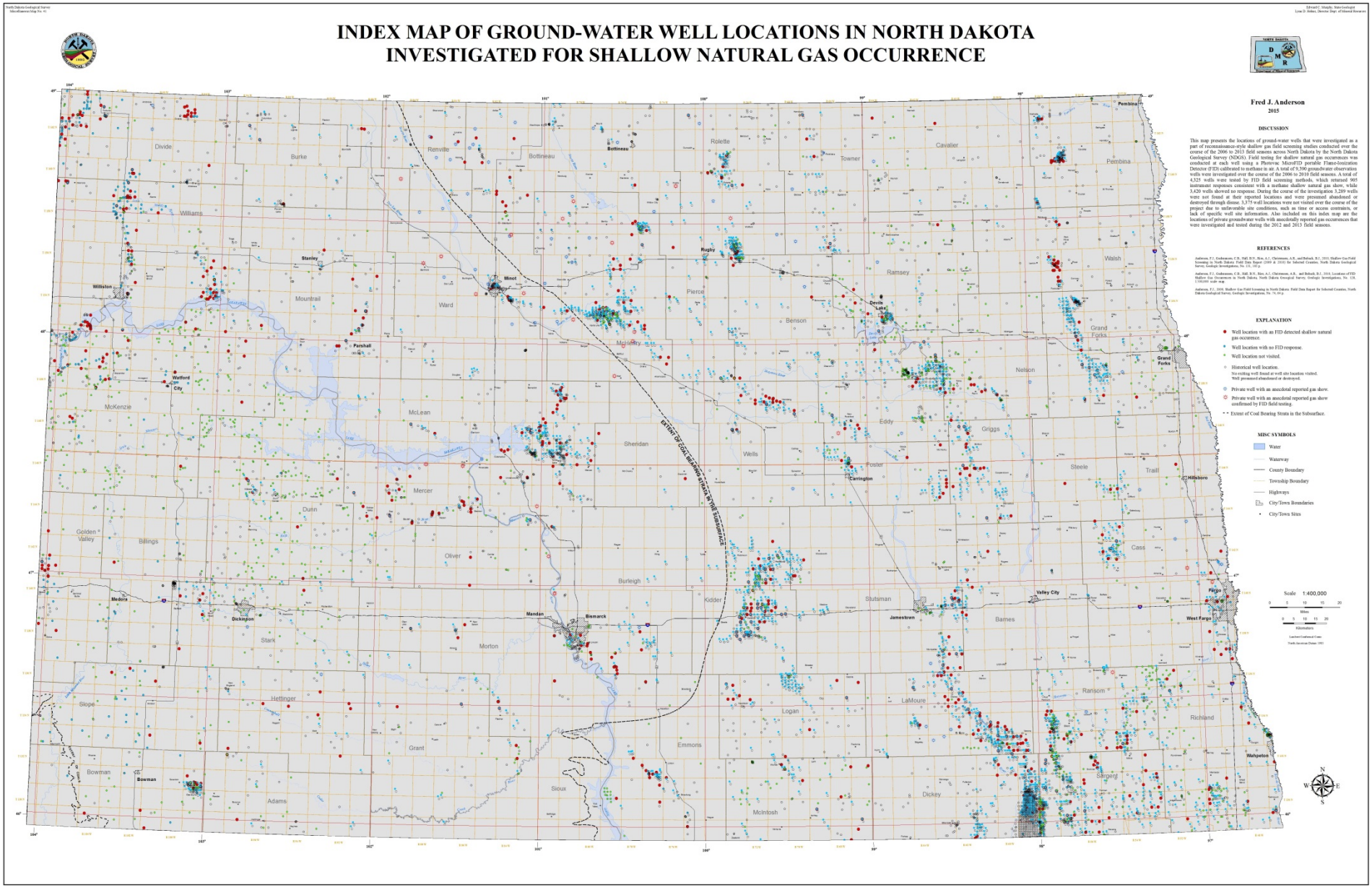
-Pierre Fm.

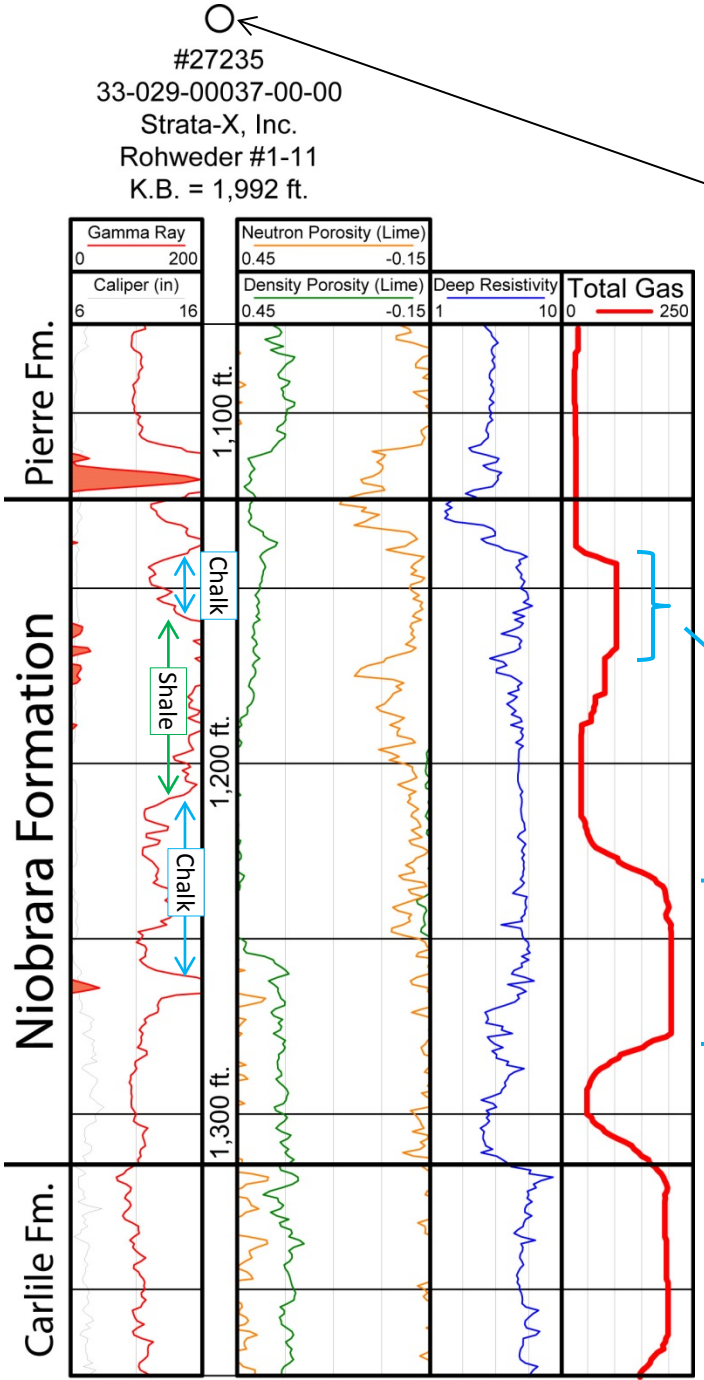
-Niobrara Fm.

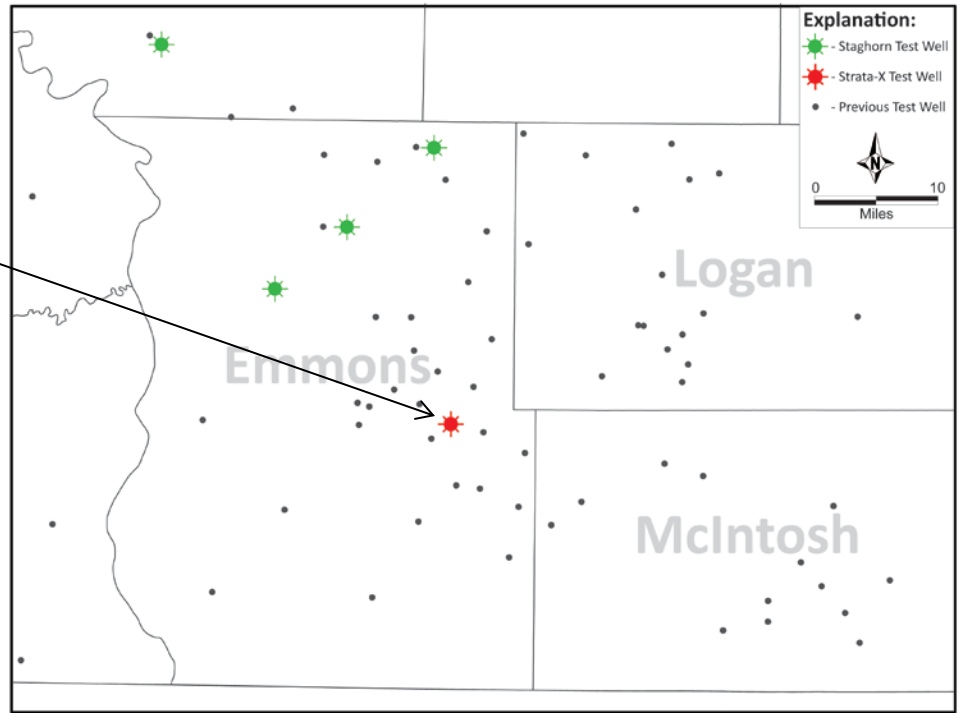
-Carlile Fm.

-Greenhorn Fm.




INDEX MAP OF GROUND-WATER WELL LOCATIONS IN NORTH DAKOTA
INVESTIGATED FOR SHALLOW NATURAL GAS OCCURRENCE
Fred J. Anderson
2015
DISCUSSION
This map presents the locations of ground-water wells that were investigated as a part of reconnaissance-style shallow gas field screening studies conducted over the course of the 2006 to 2013 field seasons across North Dakota by the North Dakota Geological Survey (NDGS). Field testing for shallow natural gas occurrences was conducted at each well using a Photovac MicroFID portable Flame-Ionization Detector (FID) calibrated to methane in air. A total of 8,390 groundwater observation wells were investigated over the course of the 2006 to 2010 field seasons. A total of 4,325 wells were tested by FID field screening methods, which returned 905 instrument responses consistent with a methane shallow natural gas show, while 3,420 wells showed no response. During the course of the investigation 3,289 wells were not found at their reported locations and were presumed abandoned or destroyed through disuse. 3,375 well locations were not visited over the course of the project due to unfavorable site conditions, such as time or access constraints, or lack of specific well site information. Also included on this index map are the locations of private groundwater wells with anecdotally reported gas occurrences that were investigated and tested during the 2012 and 2013 field seasons.
REFERENCES
EXPLANATION
Well location with an FID detected shallow natural gas occurrence.
Well location with no FID response.
Well location not visited.
Historical well location.
No existing well found at well site location visited.
Well presumed abandoned or destroyed.
Private well with an anecdotal reported gas show.
Private well with an anecdotal reported gas show confirmed by FID field testing.
Extent of Coal Bearing Strata in the Subsurface.
MISC SYMBOLS
Water
Waterway
County Boundary
Township Boundary
Highways
City/Town Boundaries
City/Town Sites
EXTENT OF COAL BEARING STRATA IN THE SUBSURFACE
Scale 1:400,000
Miles
Kilometers
Divide
Burke
Renville
Bottineau
Rolette
Towner
Cavalier
Pembina
Williams
Mountrail
Ward
Pierce
Ramsey
Walsh
Benson
McHenry
Nelson
Grand Forks
McKenzie
McLean
Sheridan
Wells
Eddy
Griggs
Steele
Traill
Mercer
Dunn
Foster
Billings
Golden Valley
Oliver
Burleigh
Kidder
Slutsman
Cass
Stark
Morton
Barnes
Hettinger
Slope
Logan
LaMoure
Ransom
Richland
Grant
Emmons
Bowman
Sioux
Adams
McIntosh
Dickey
Sargent
Wahpeton
Williston
Stanley
Minot
Rugby
Devils Lake
Parshall
Watford City
Carrington
Grand Forks
Hillsboro
Medora
Dickinson
Mandan
Bismarck
Jamestown
Valley City
Fargo
West Fargo
Bowman





-Gas "shows" of over 100 units (1,140-1,170 ft.) and 200 units (1,230-1,280 ft.) were encountered while drilling through the Niobrara Formation within the Rohweder #1-11.

-Four previous shallow gas test wells were drilled by Staghorn Energy further north during 2006-07, two of which produced small amounts of gas from the lower Niobrara Fm.

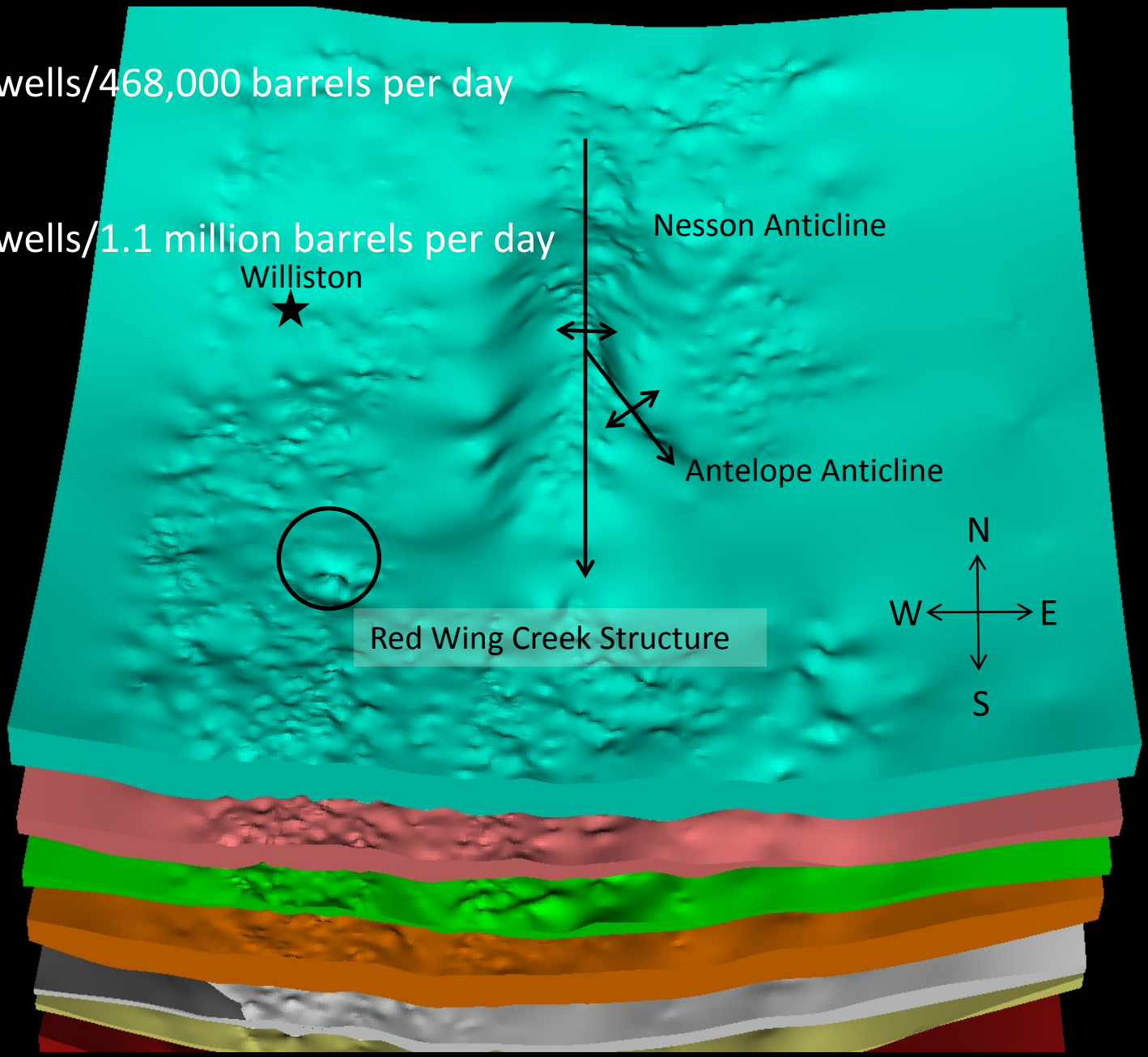
-Shale within the Niobrara Fm. contains 4-7% Total Organic Carbon (TOC), >2% TOC = excellent quality source rock.

-Chalk within the Niobrara Fm. contains 30-40% porosity, which is very high, but observed permeability values have been low.

Dakota Group -New Castle Fm. - Skull Creek Fm. - Inyan Kara Fm.

2012:
351 SWD wells/468,000 barrels per day

2014:
484 SWD wells/1.1 million barrels per day



Saltwater Disposal & Rare Earths

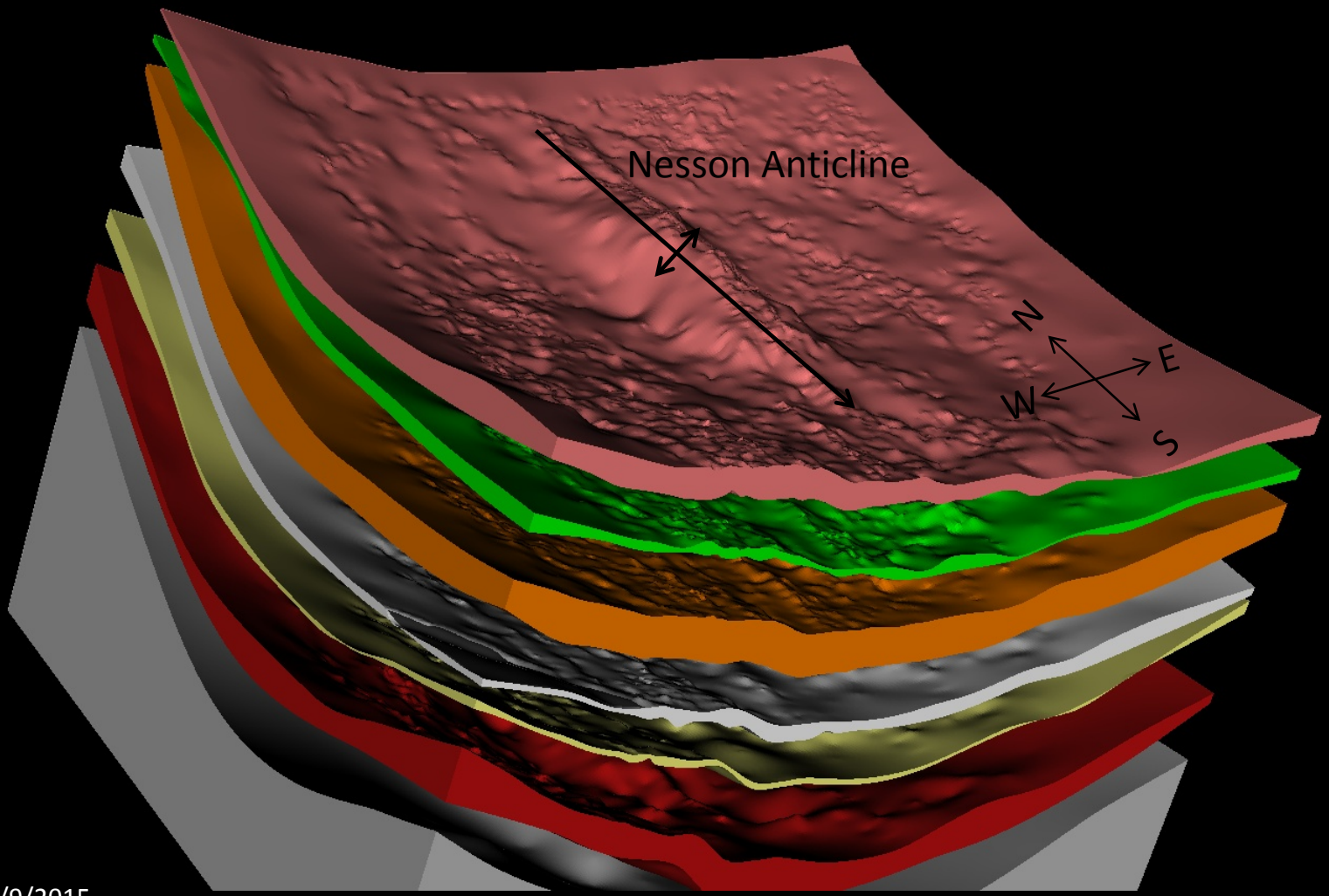
Element	Symbol	Atomic Number	%	Economic Class
Lanthanum	La	57	17.8	Uncritical
Cerium	Ce	58	38.0	Excessive
Praseodymium	Pr	59	4.2	Uncritical
Neodymium	Nd	60	15.4	Critical
Promethium	Pm	61	<0.1	Uncritical
Samarium	Sm	62	2.7	Uncritical
Europium	Eu	63	0.5	Critical
Gadolinium	Gd	64	2.3	Uncritical
Terbium	Tb	65	0.4	Critical
Dysprosium	Dy	66	2.1	Critical
Holmium	Ho	67	0.5	Excessive
Erbium	Er	68	1.4	Critical
Thulium	Tm	69	0.2	Excessive
Ytterbium	Yb	70	1.3	Excessive
Lutetium	Lu	71	0.2	Excessive
Yttrium	Y	39	13.1	Critical

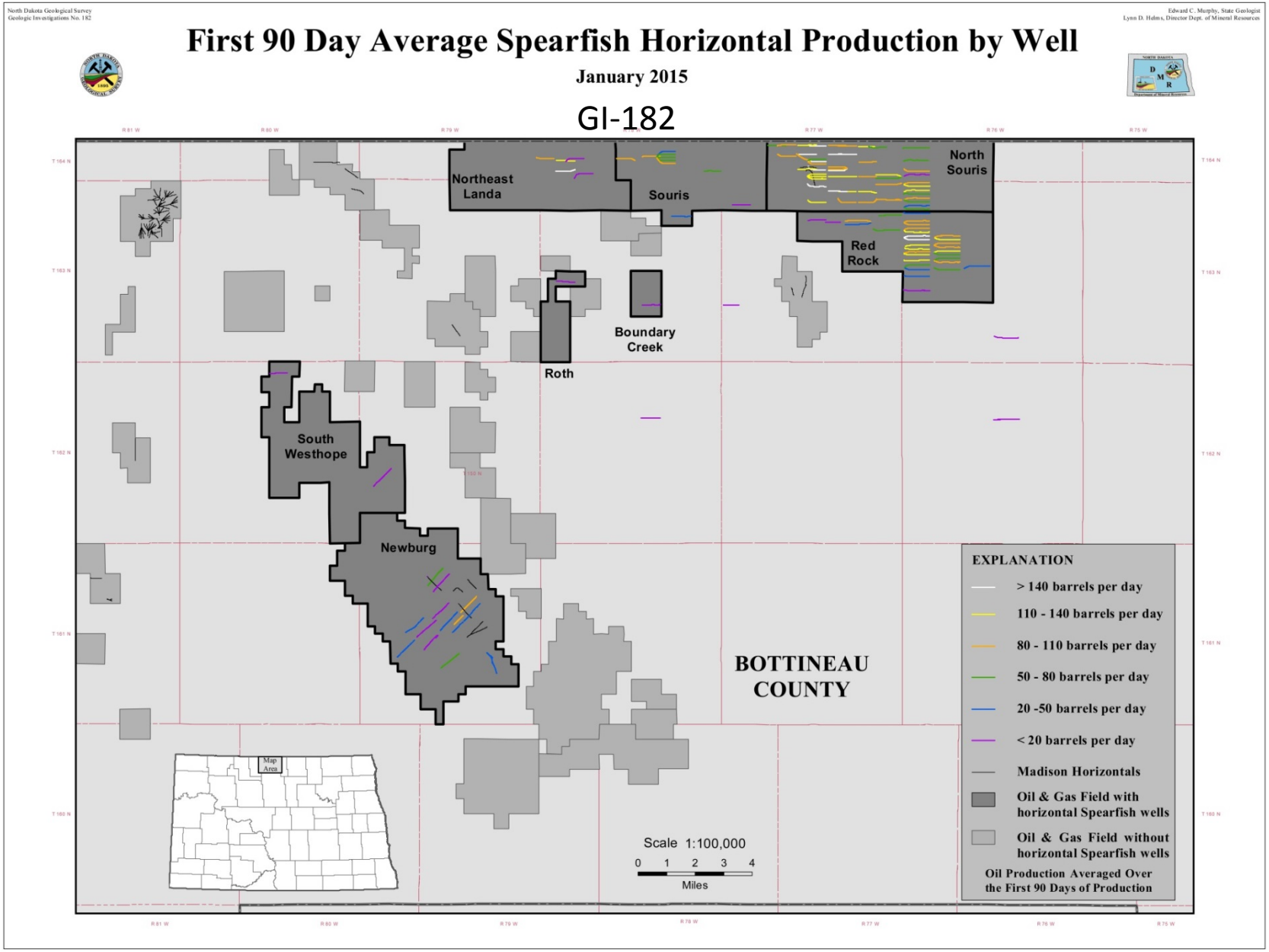
Light Rare Earths

Heavy Rare Earths

Spearfish Formation

4,500 Barrels oil per day

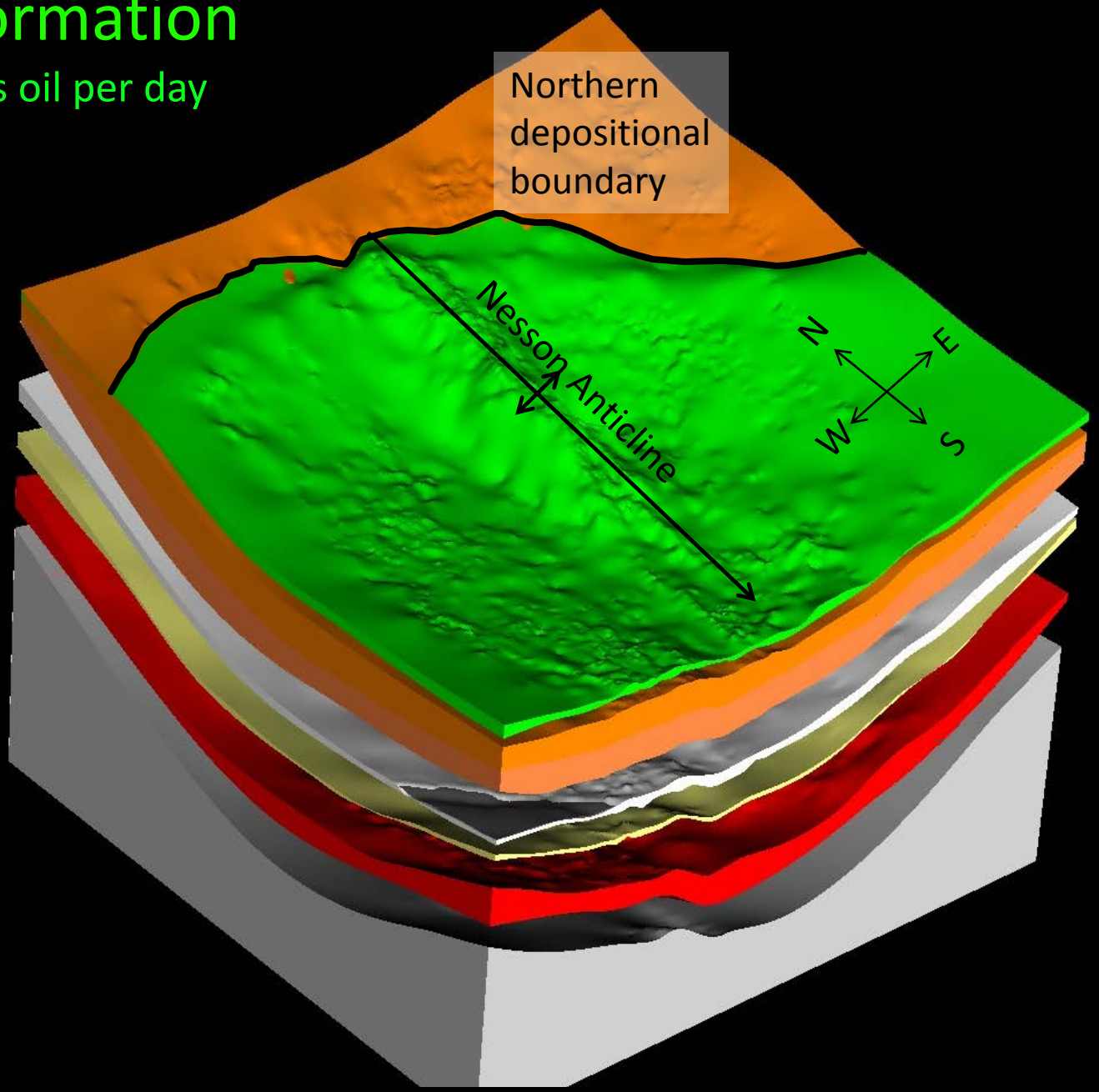


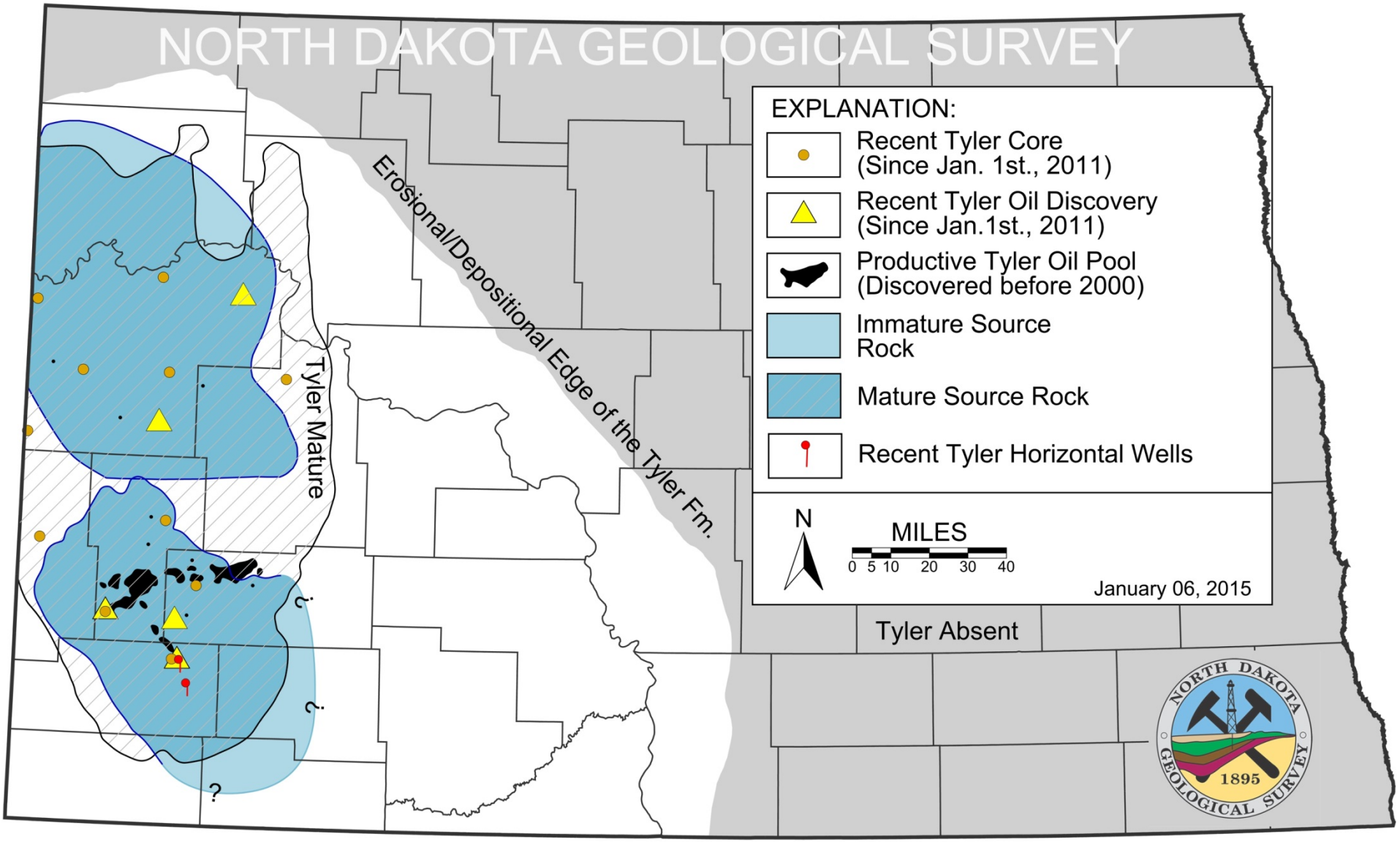


Several productive horizontal Spearfish wells drilled within the Northeast Landa and Newburg Fields during 2014. Approximately 120 horizontal Spearfish wells have been drill to date, most of which have been drilled in the last 3 years.

Tyler Formation

1,060 Barrels oil per day

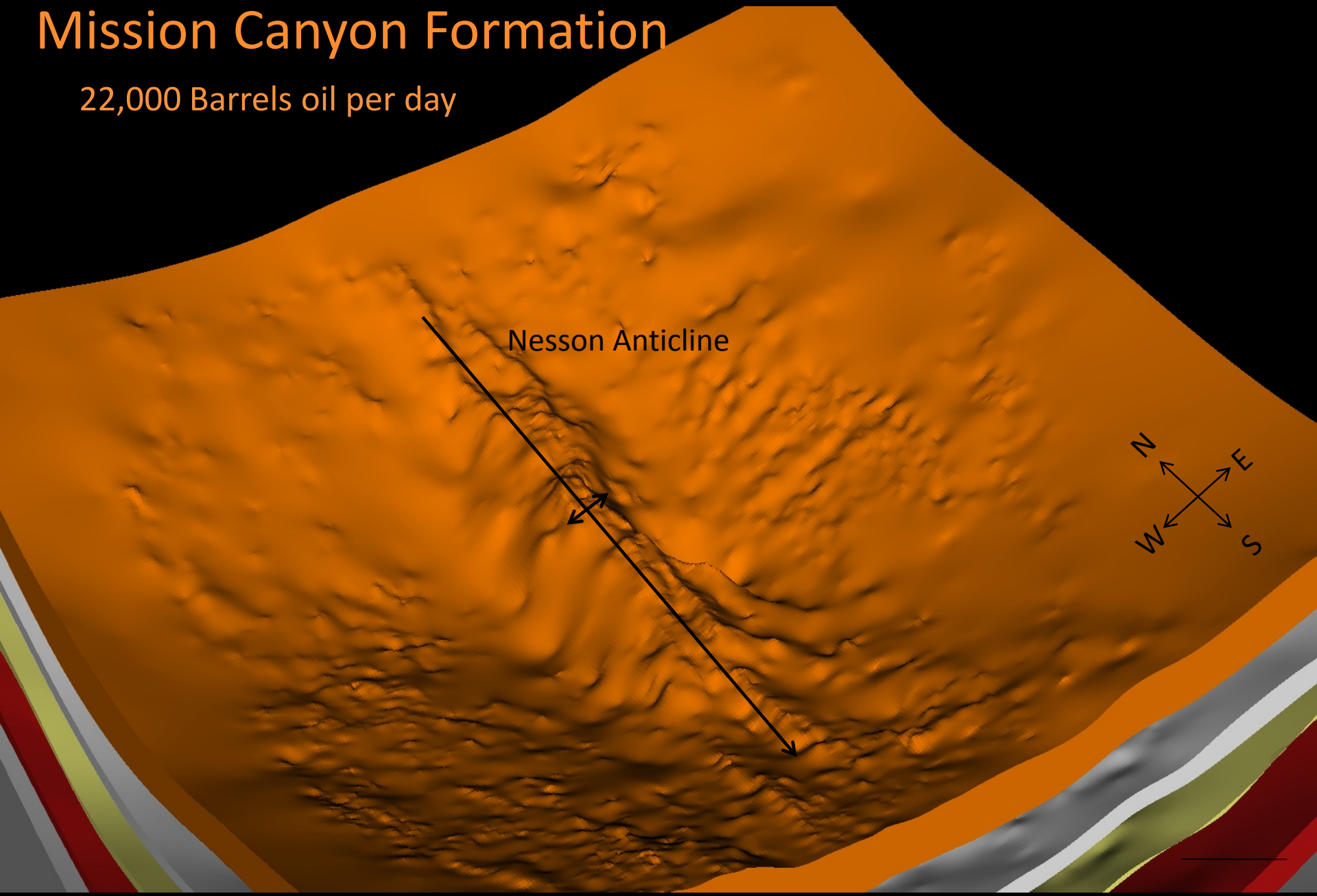




Since the beginning of 2011, there have been five discovery wells completed in the Tyler Formation and over 1,100 ft. of Tyler core collected by industry.

Mission Canyon Formation

22,000 Barrels oil per day

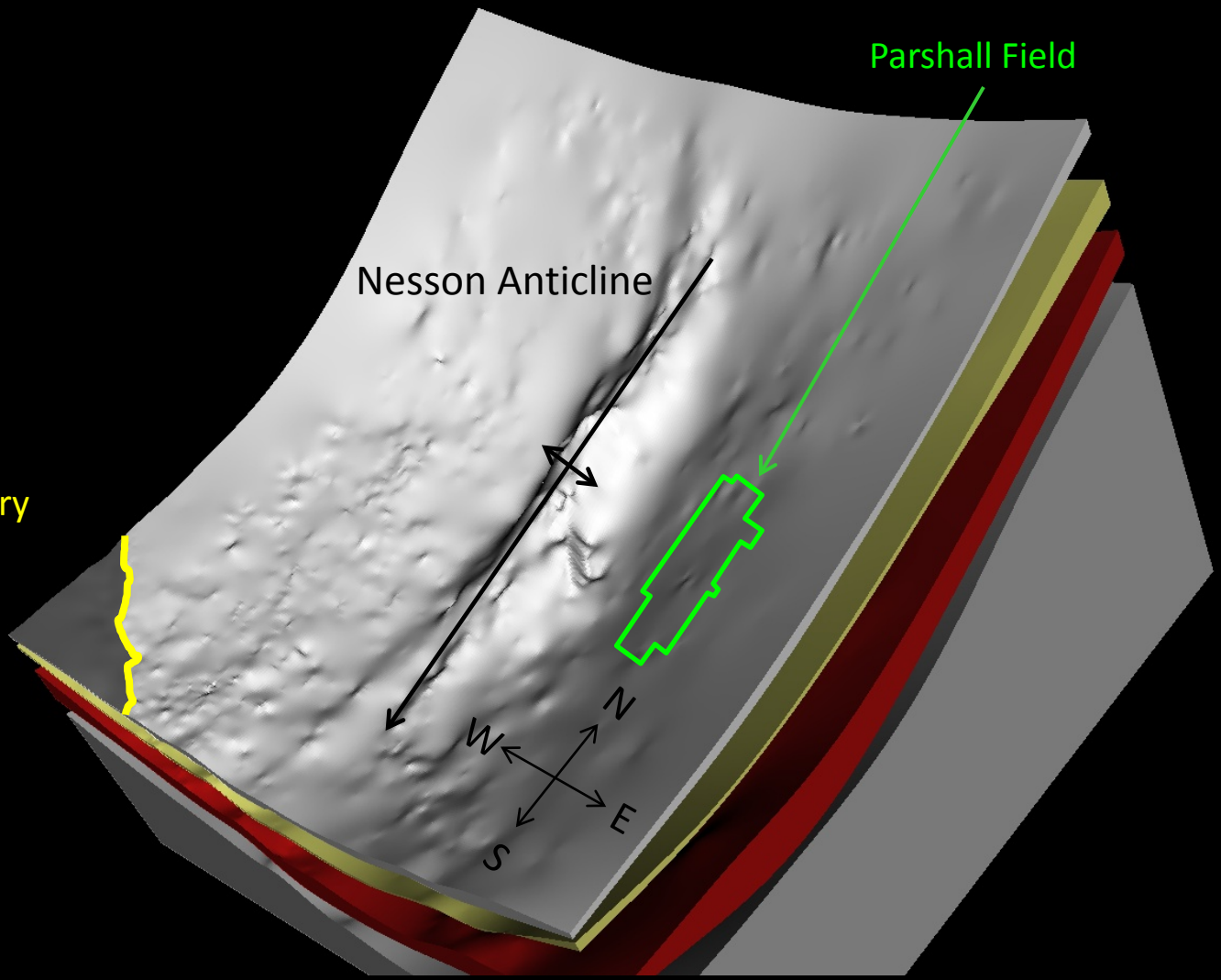


Bakken-Three Forks

-Bakken Fm. (light grey)

-Three Forks Fm. (dark grey)

1.1 million barrels oil per day



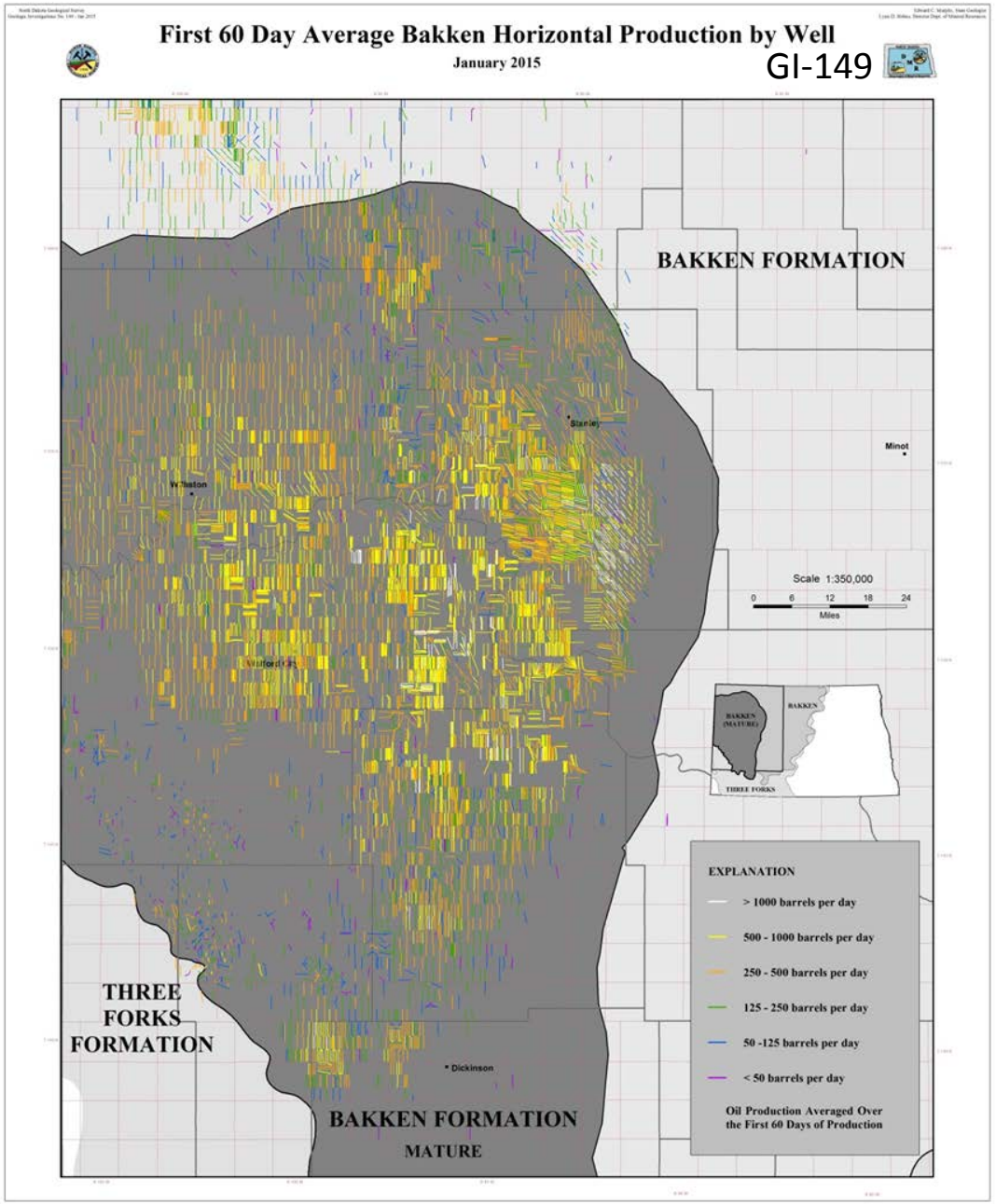
Bakken Limit

-Depositional Boundary

Production:
1,118,010 bopd or 95% from Bakken/Three Forks

64,164 bopd or 5% from Legacy conventional pools

Well Count : 11,892
8,406 well are Bakken/TF
3,486 wells are legacy pools



DEPARTMENT OF MINERAL RESOURCES – GEOLOGICAL SURVEY
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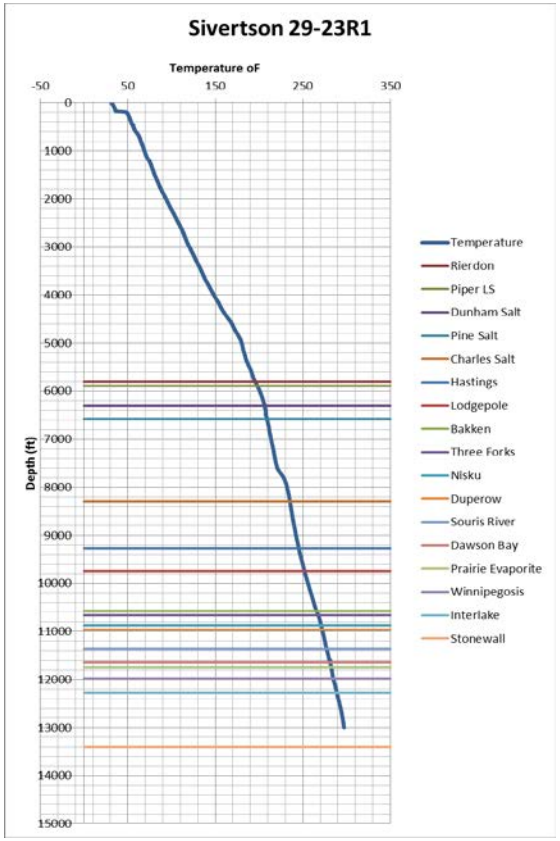
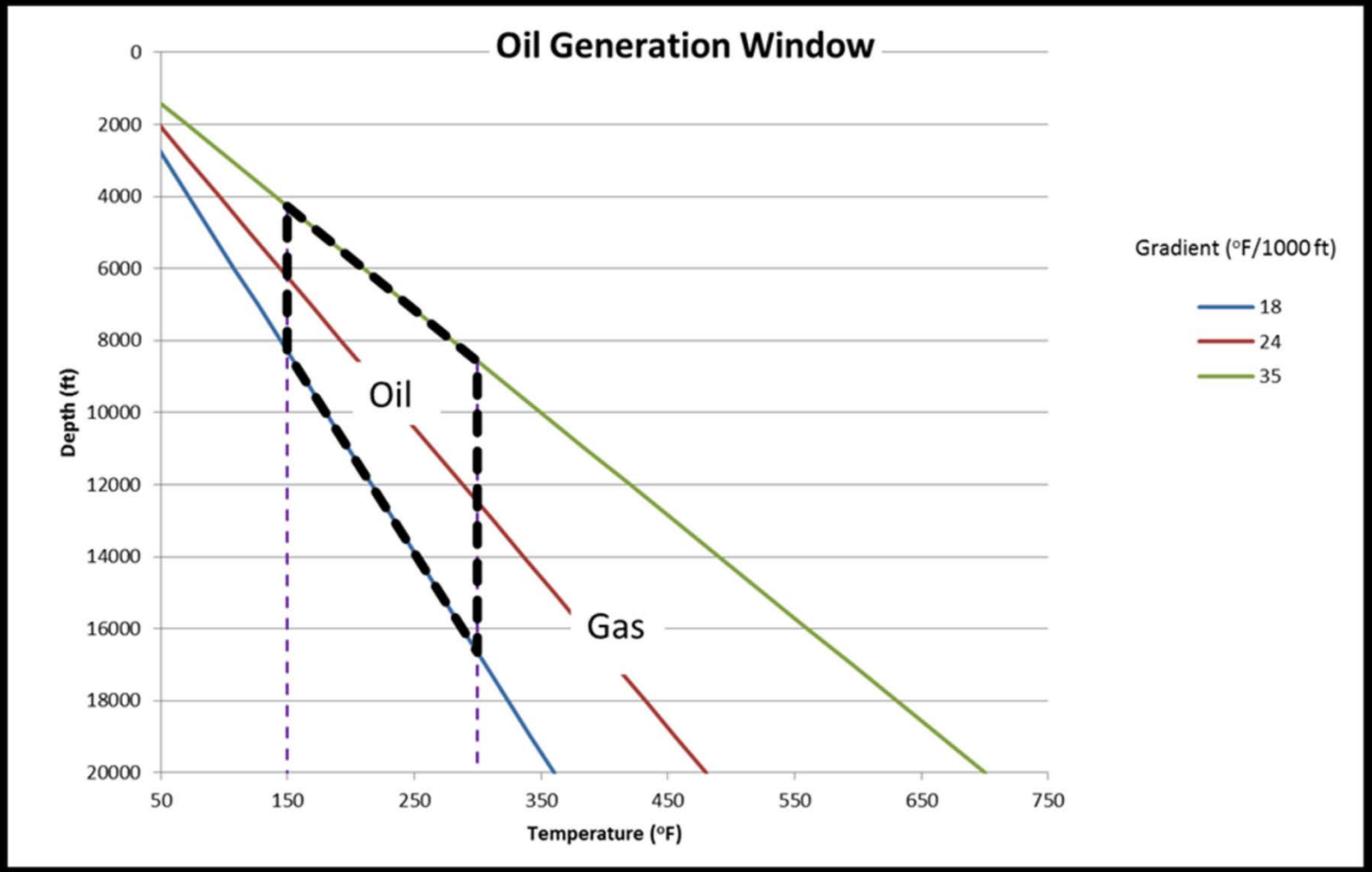


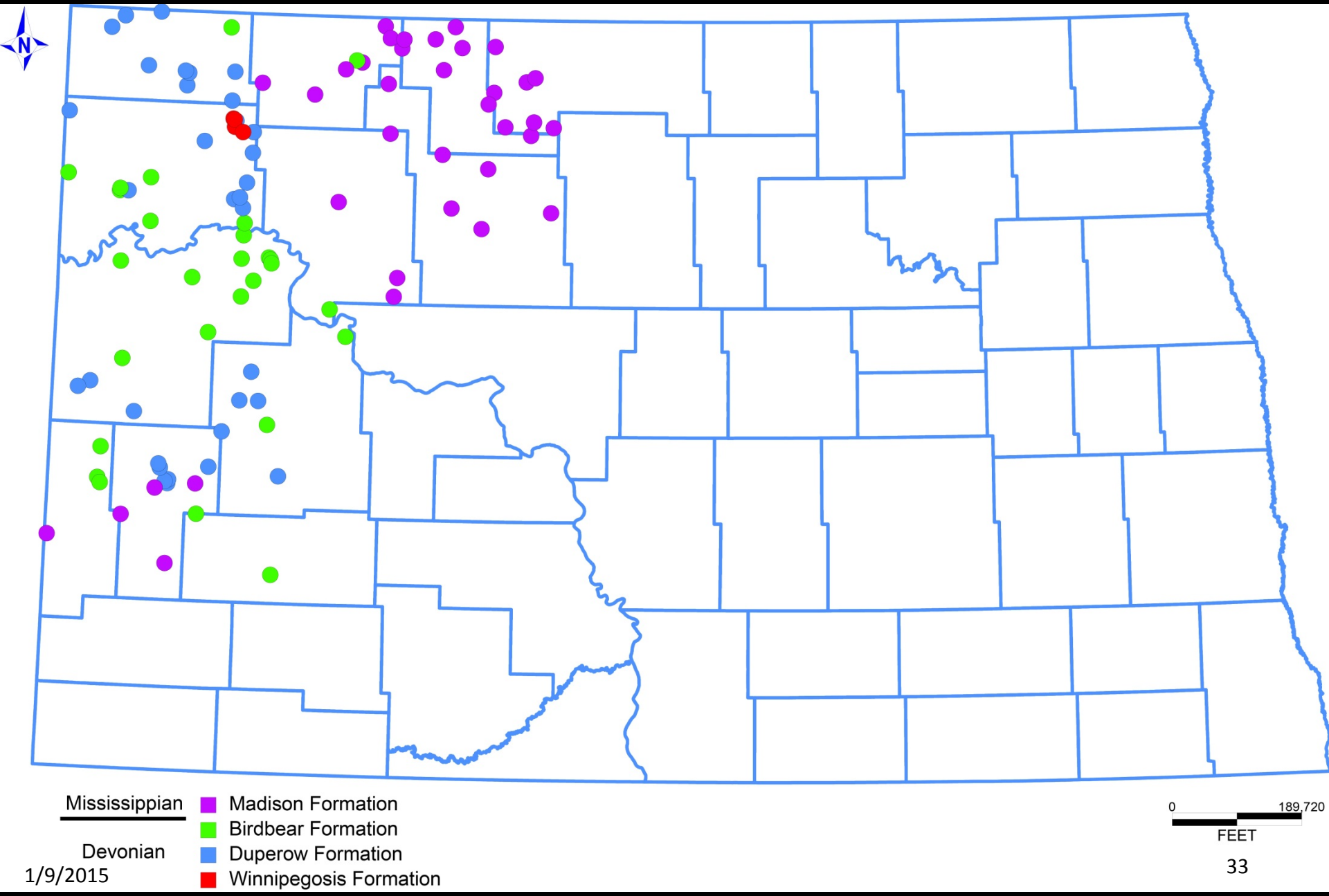

Oil Generation Window
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
20000
Depth (ft)
Oil
Gas
50
150
250
350
450
550
650
750
Temperature (°F)
Gradient (°F/1000 ft)
18
24
35

DEPARTMENT OF MINERAL RESOURCES – GEOLOGICAL SURVEY
OIL-BEARING ROCK ANALYSIS PROJECT (2013-2015)

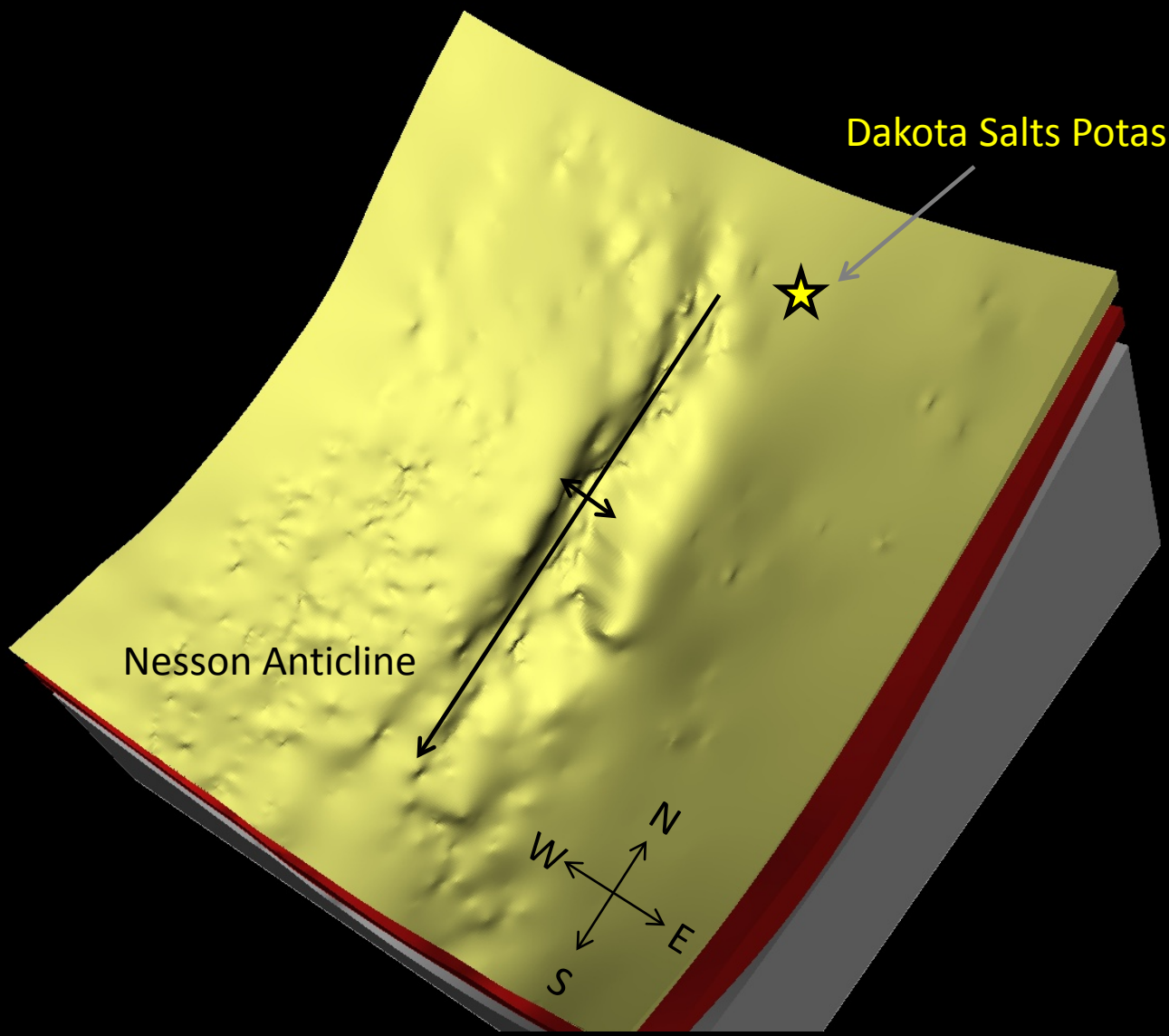
In the 2013-2015 biennium, the Geological Survey shifted emphasis from rocks above the Bakken to rocks below the Bakken and Three Forks Formations. This biennium, the Geological Survey has obtained 1,088 rock samples from core in the Icebox, Red River, Stonewall, Winnipegosis, Duperow, Birdbear, and Madison Formations for total organic carbon and RockEval analysis. So far, the results indicate several more potential source beds within these rocks than previously known. In some of these formations the oil-generating potential of the source beds is very localized and in other formations they appear to have consistent oil-generating potential over larger areas. We are continuing to sample these rocks to enable us to identify regional patterns.

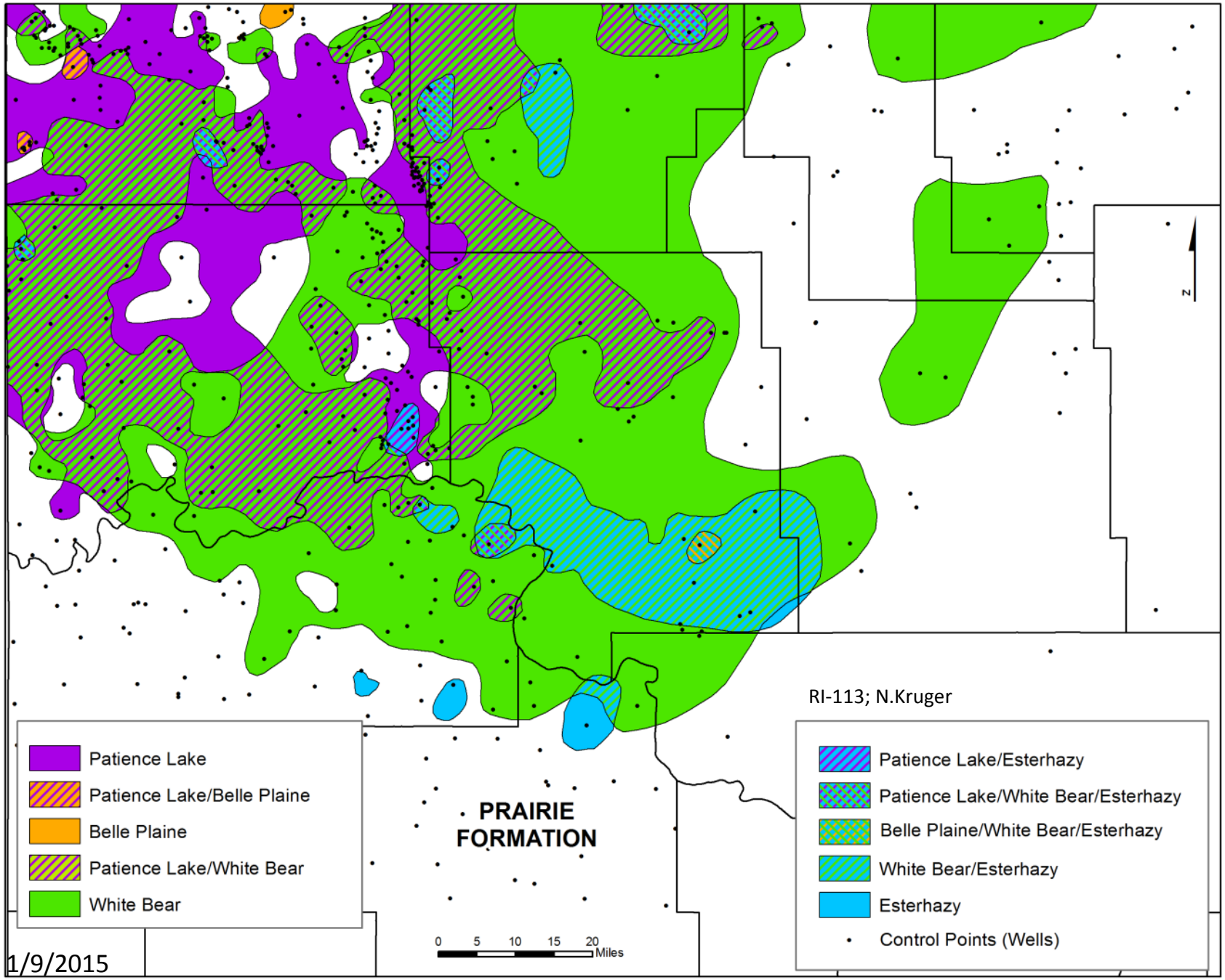
Thirty-six feet of Red River core (10,149 – 10,187 feet) from the Urlacher State Unit #1 in Hettinger County. The base of the Red River "C" is much more organic rich than the underlying limestone.

WELL CORES SAMPLED FOR TOC & ROCKEVAL



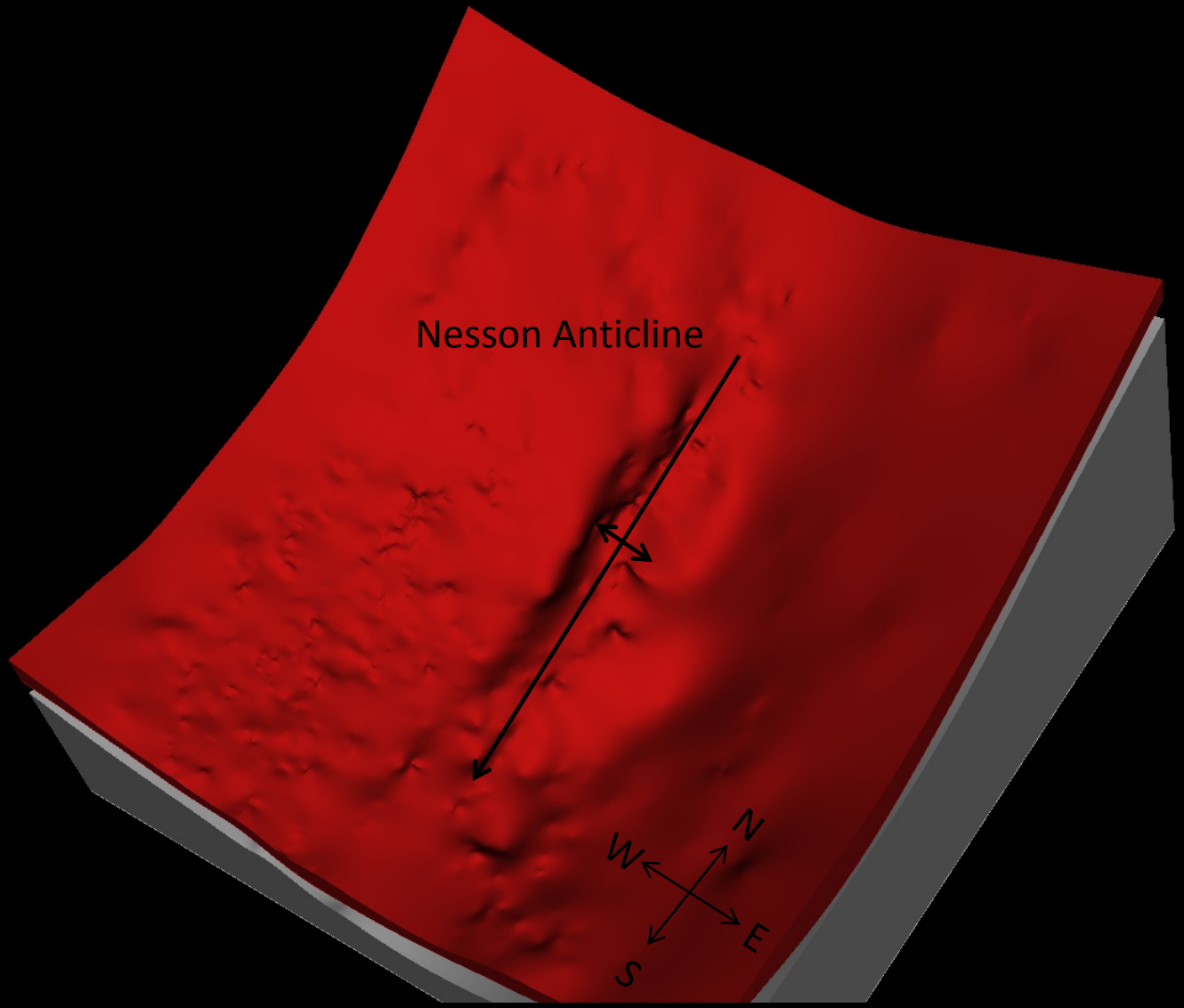
Prairie Formation




RI-113; N.Kruger
Patience Lake
Patience Lake/Belle Plaine
Belle Plaine
Patience Lake/White Bear
White Bear
PRAIRIE FORMATION
0 5 10 15 20 Miles
Patience Lake/Esterhazy
Patience Lake/White Bear/Esterhazy
Belle Plaine/White Bear/Esterhazy
White Bear/Esterhazy
Esterhazy
Control Points (Wells)
N

Red River Formation

27,000 Barrels oil per day



Enhanced Oil Recovery 2014

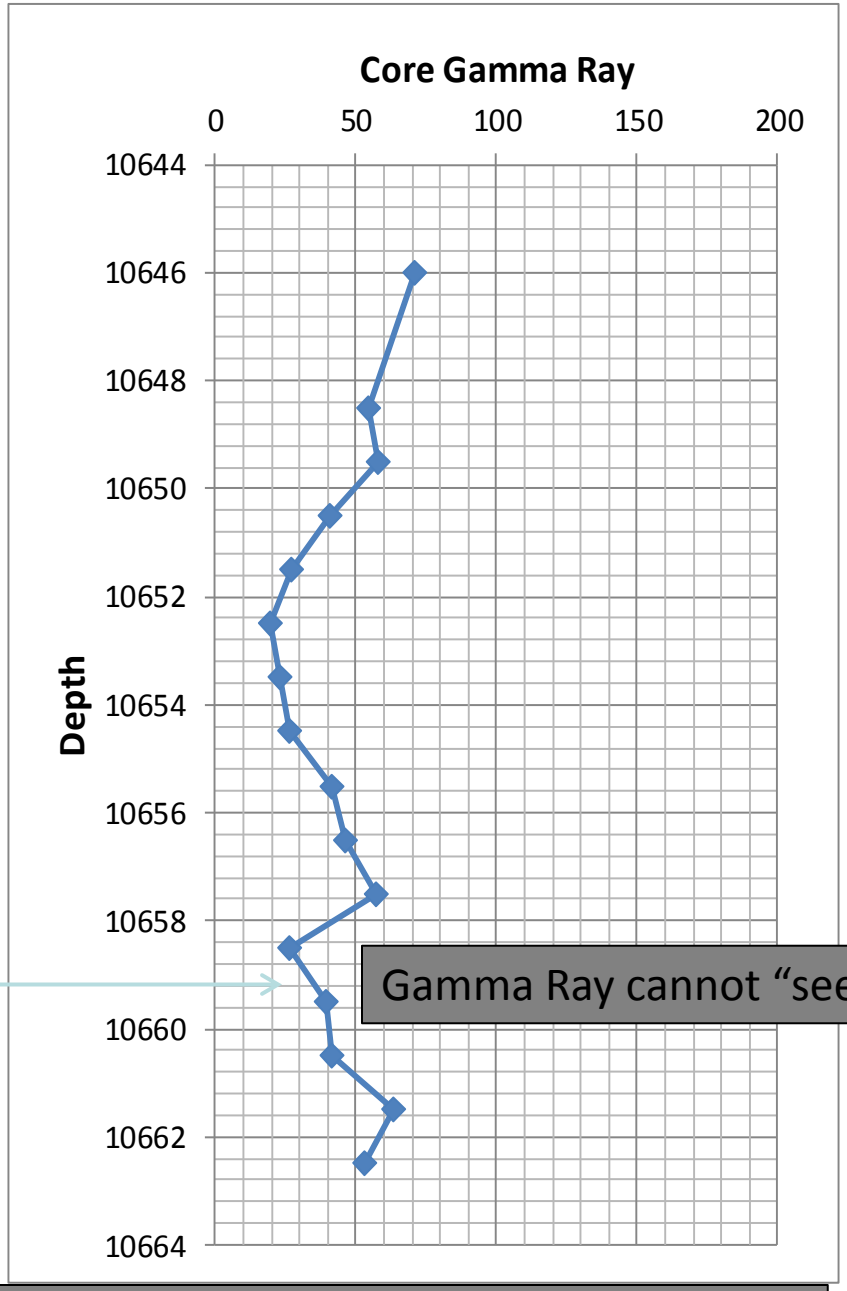
631 Injection wells

325,500 barrels of water per day

29,700,000 cubic feet of air per day

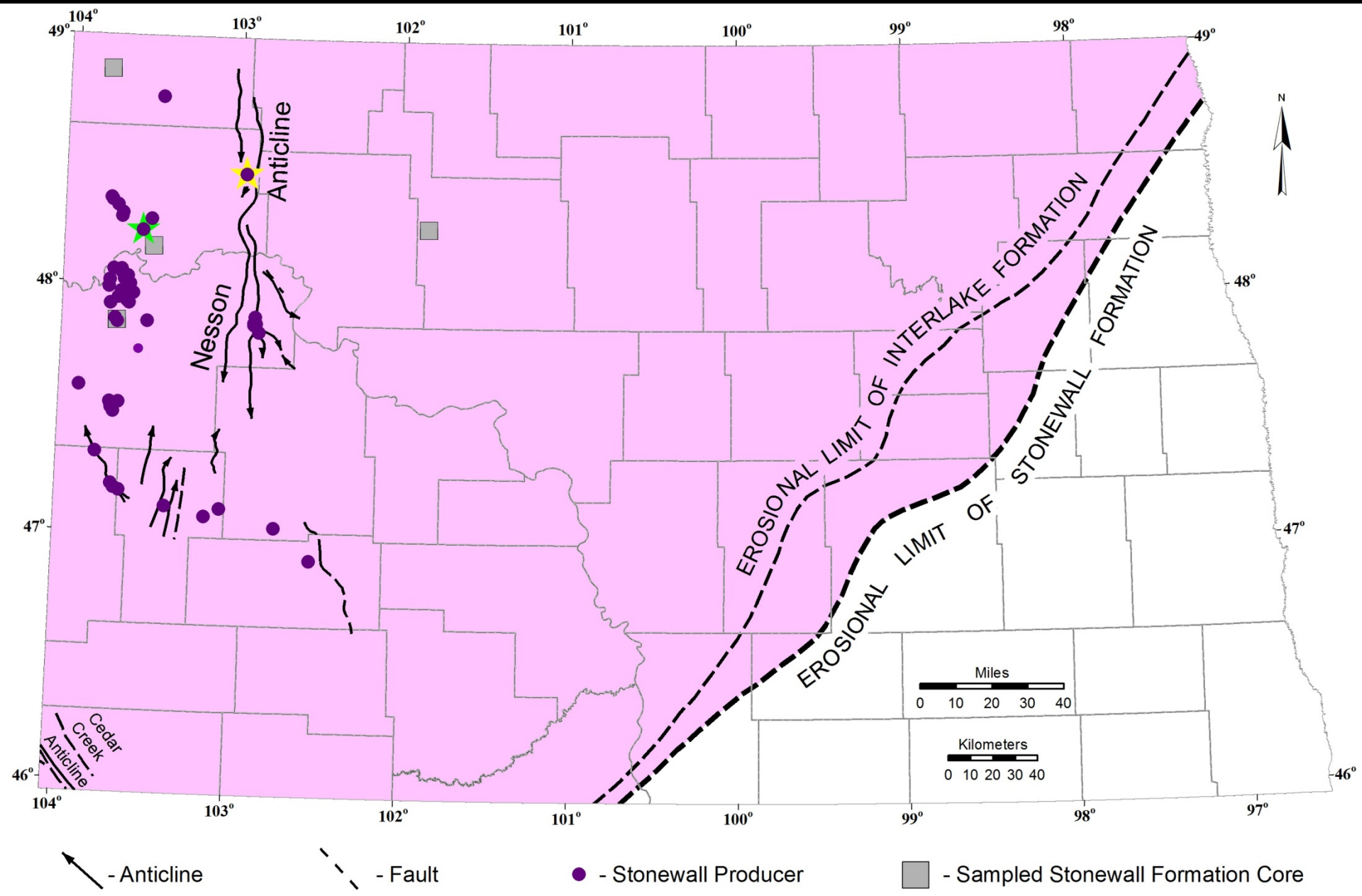
Kremers 21-22 Core Gamma Ray

Sample ID	6272-10659.1
Well Name	Kremers 21X-22R
Depth	10659.1
Formation	Red River
TOC (wt.%)	10.25
S_2 (mg/g)	57.65
T_{max} (^oC)	455
HI	562
OI	5

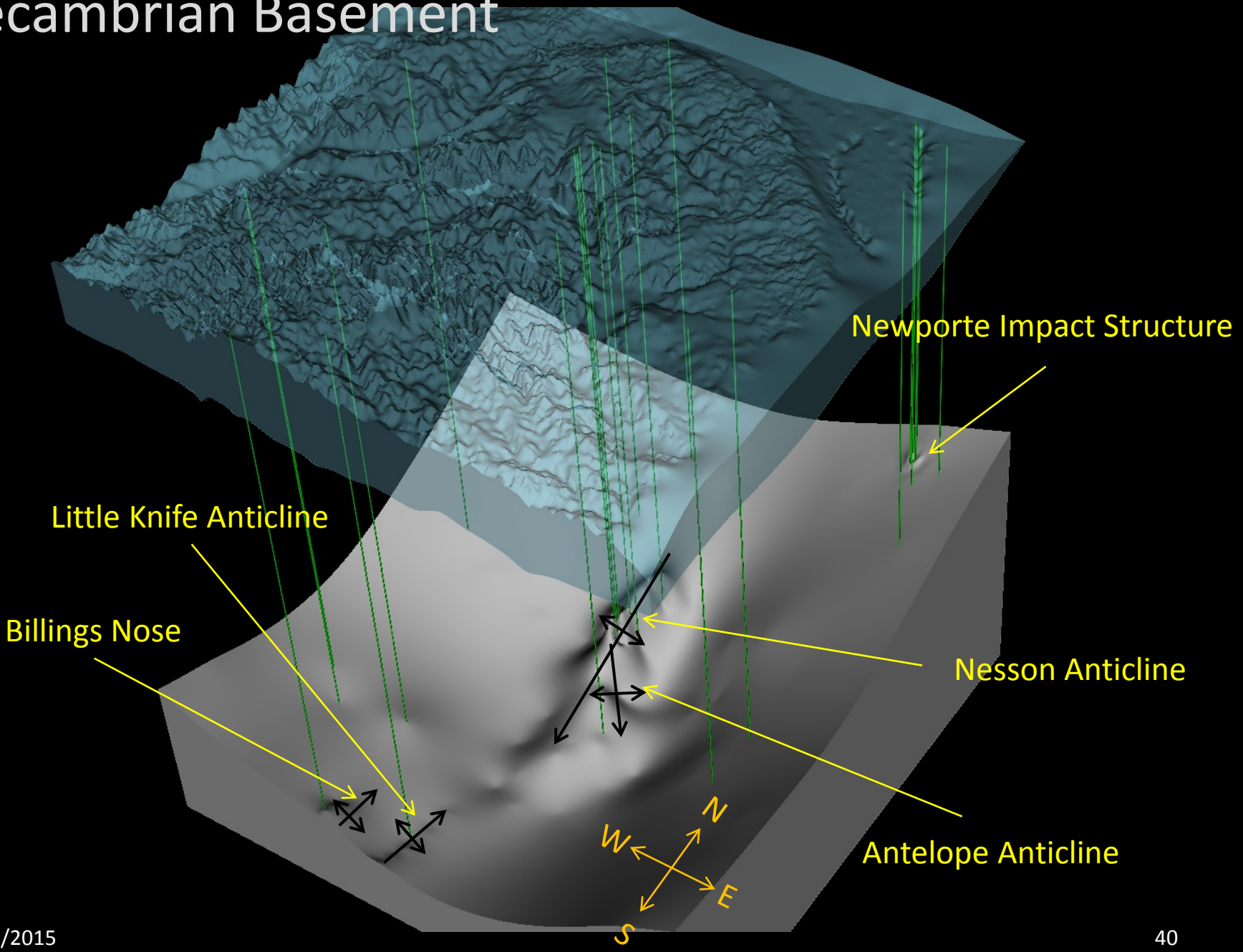


Gamma Ray cannot "see" organic carbon

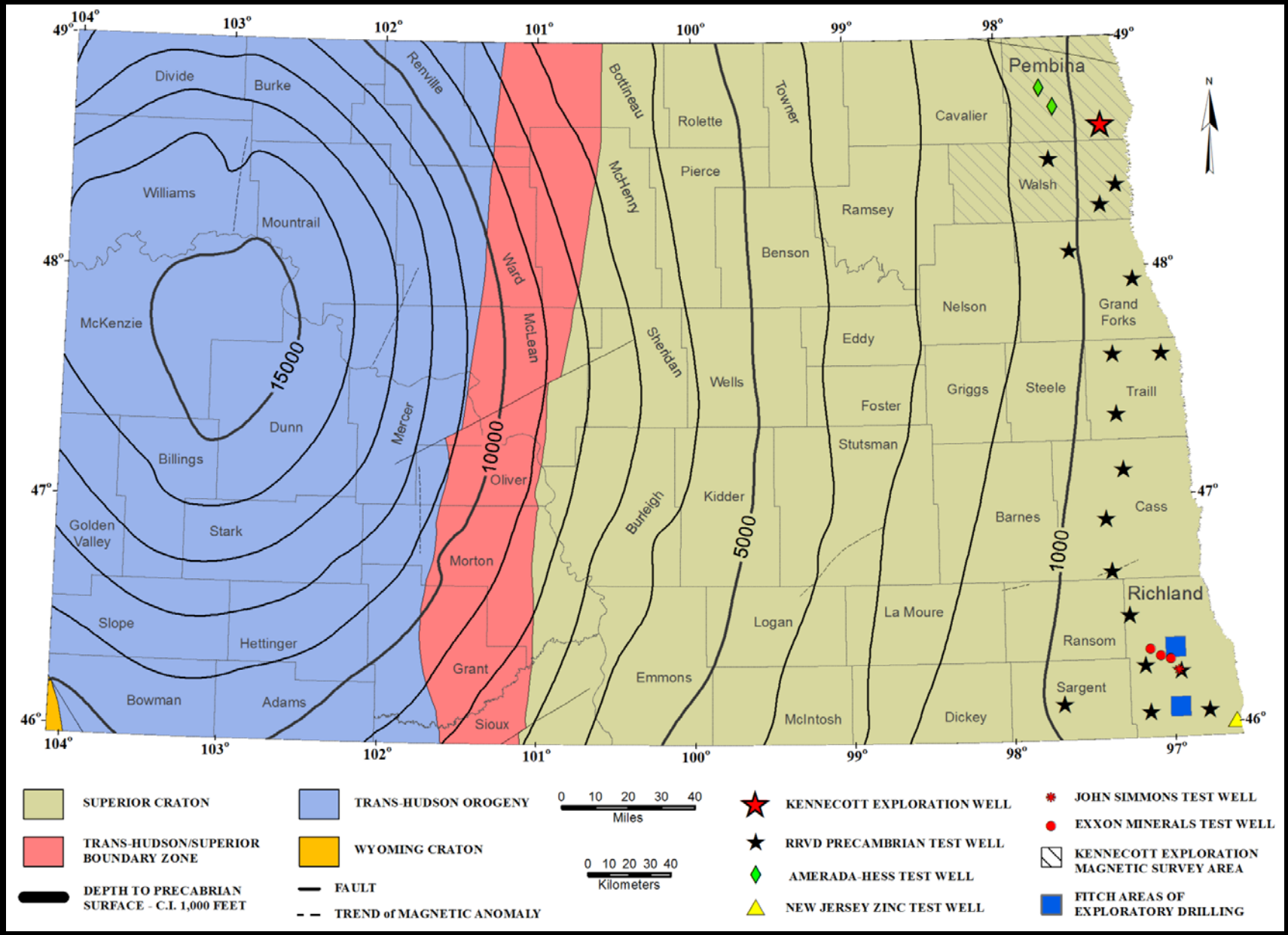
Finding the mass of reacting kerogen


104°
103°
102°
101°
100°
99°
98°
97°
49°
48°
47°
46°
N
Anticline
Nesson
Cedar Creek Anticline
EROSIONAL LIMIT OF INTERLAKE FORMATION
EROSIONAL LIMIT OF STONEWALL FORMATION
Miles
0 10 20 30 40
Kilometers
0 10 20 30 40
- Anticline
- Fault
- Stonewall Producer
- Sampled Stonewall Formation Core

Precambrian Basement

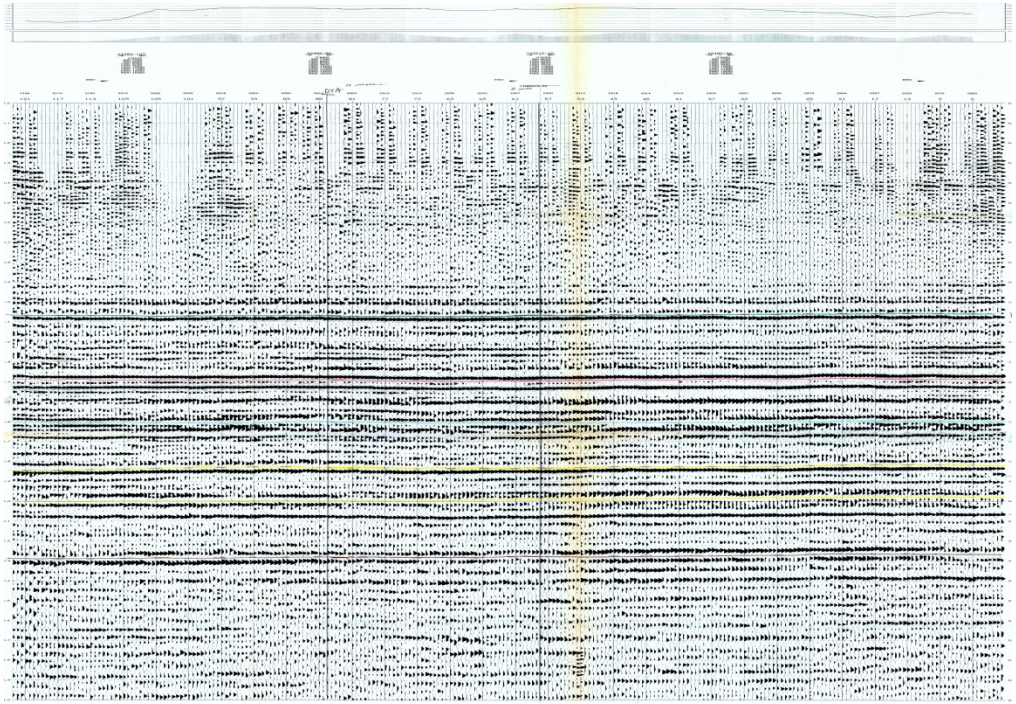


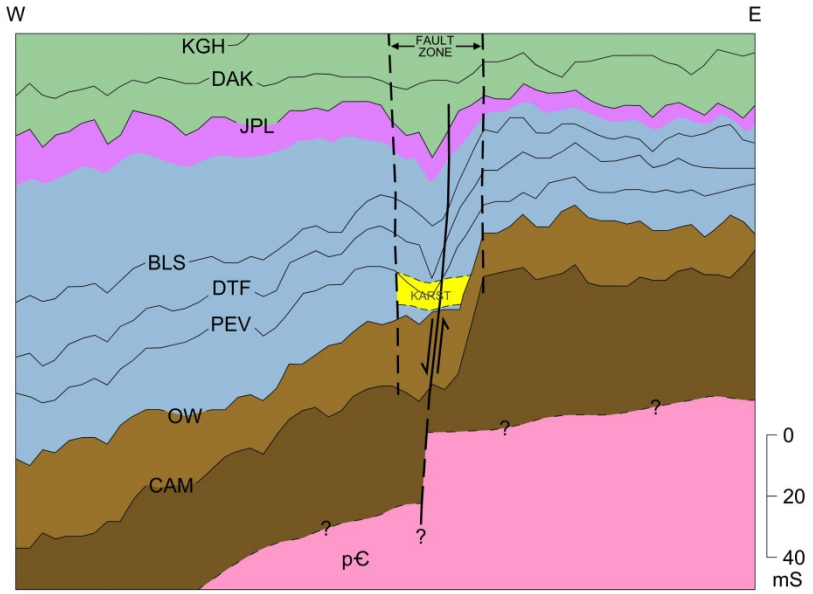
PRECAMBRIAN



DIGITAL CONVERSION OF 2D SEISMIC LINE GEOLOGICAL SURVEY (2015-2017)

Seismic profiles provide important insight into the rocks in the Williston Basin. Companies are not required to provide copies of seismic lines to the State of North Dakota. As a result, we seldom see seismic information. However, a number of years ago Chevron Oil donated fifty seismic lines that had been run in western and northwestern North Dakota. We digitally converted the data and hired a geophysicist to interpret the data. The remaining lines are to be converted to a digital format and interpreted by an independent contractor (geophysicist). This data will provide valuable insight into the character of the rock in these areas.





Left: One of the 2D seismic lines donated to the Geologic Survey. *Right:* A geophysicist's interpretation of one of the gifted seismic lines (KGH – Greenhorn Formation, DAK – Dakota Group, JPL – Piper Formation, BLS – Base of last salt, DTF – Three Forks Formation, PEV – Prairie Formation, OW – Winnipeg Group, CAM – Deadwood Formation, PC – Precambrian.

North Dakota Challenges
&
Opportunities

Current Situation:

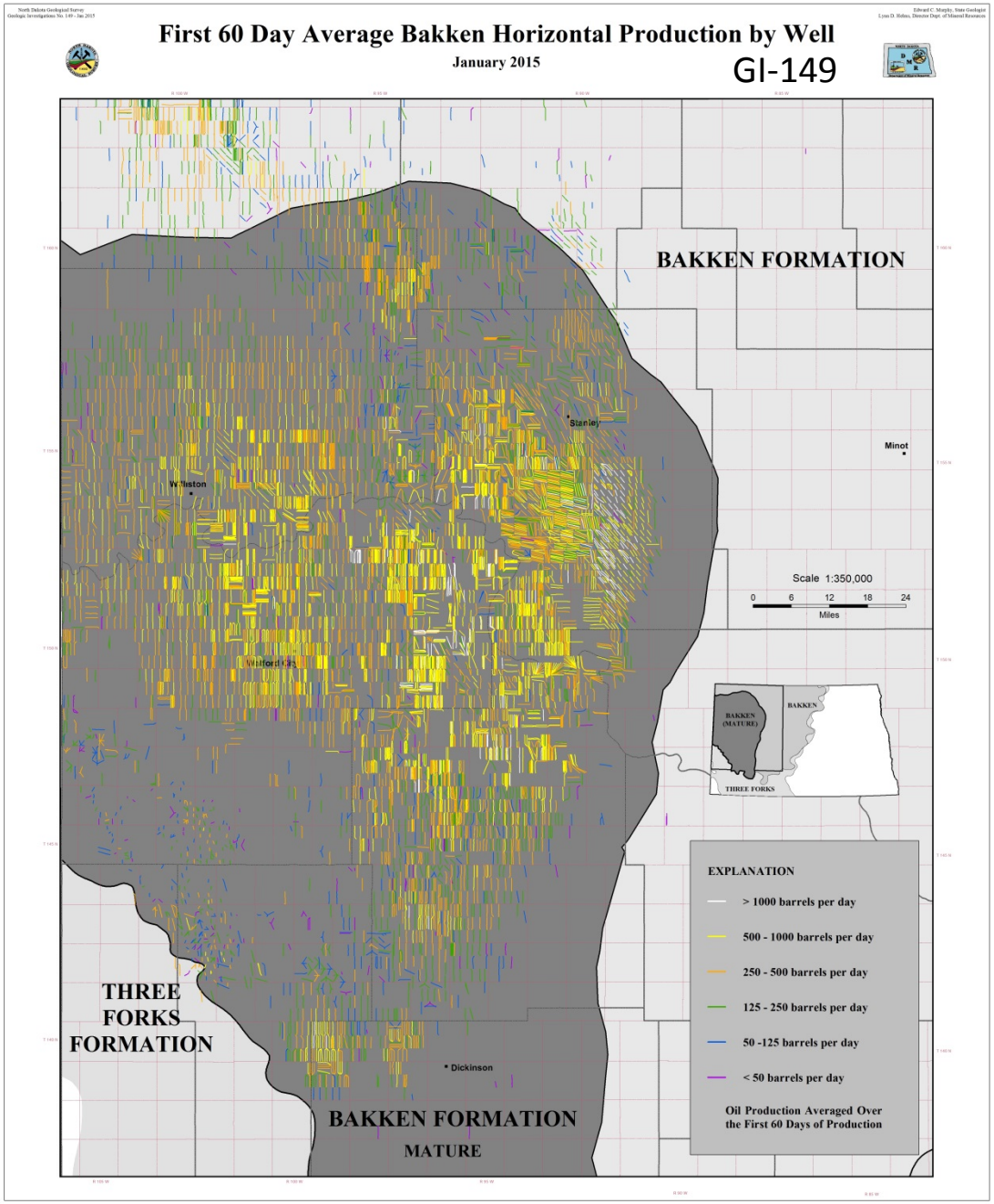
Oil Price: $48.83/WTI
$32.25/FHR
Avg. Price: $40.54

Rig Count: 166

Daily Production: 1.2 million bopd

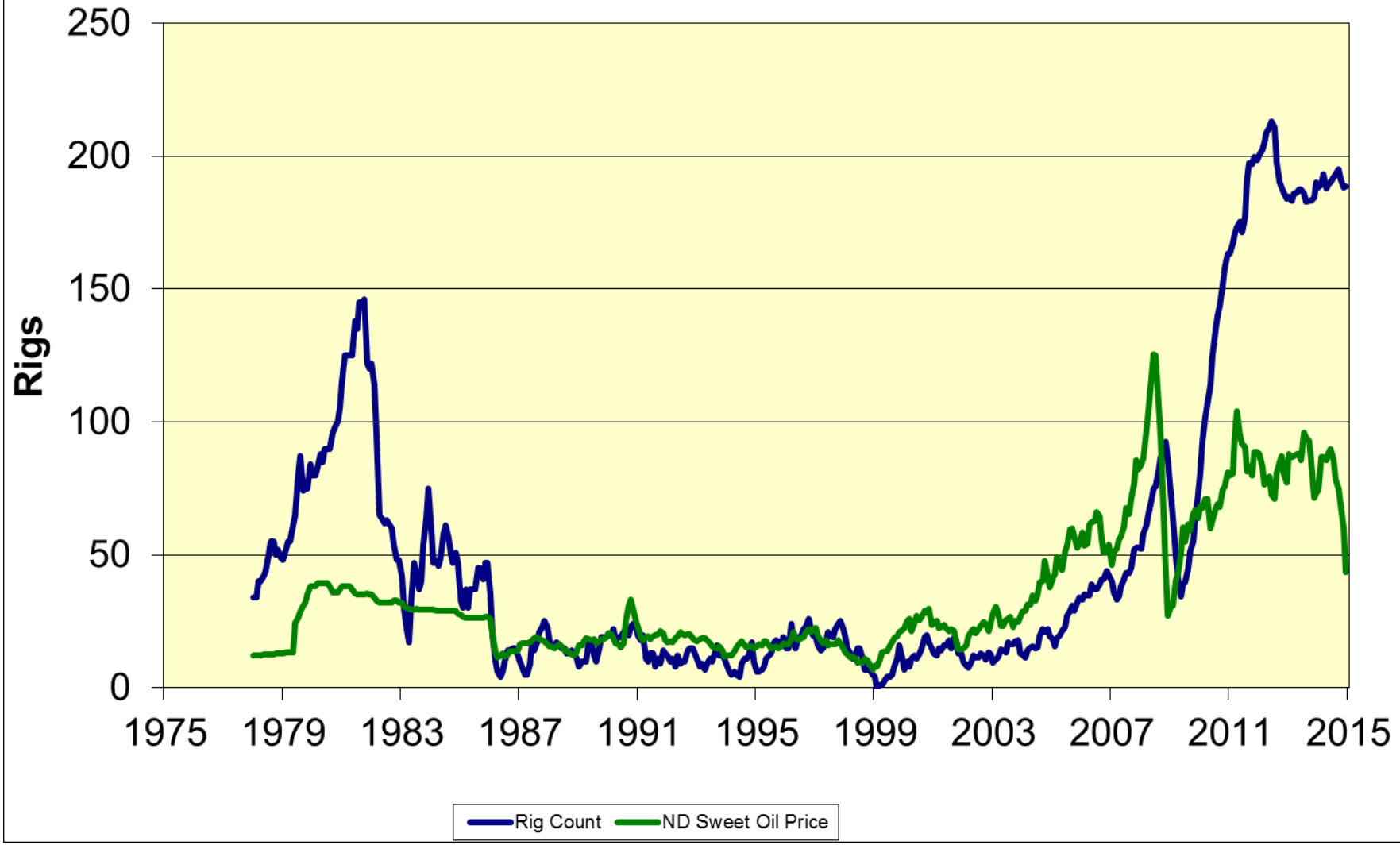
Well Count : 11,892
8,406 well are Bakken/TF
3,486 wells are legacy pools

2014 Permitting: 3,030 (all-time high) ***issued permit #30000**

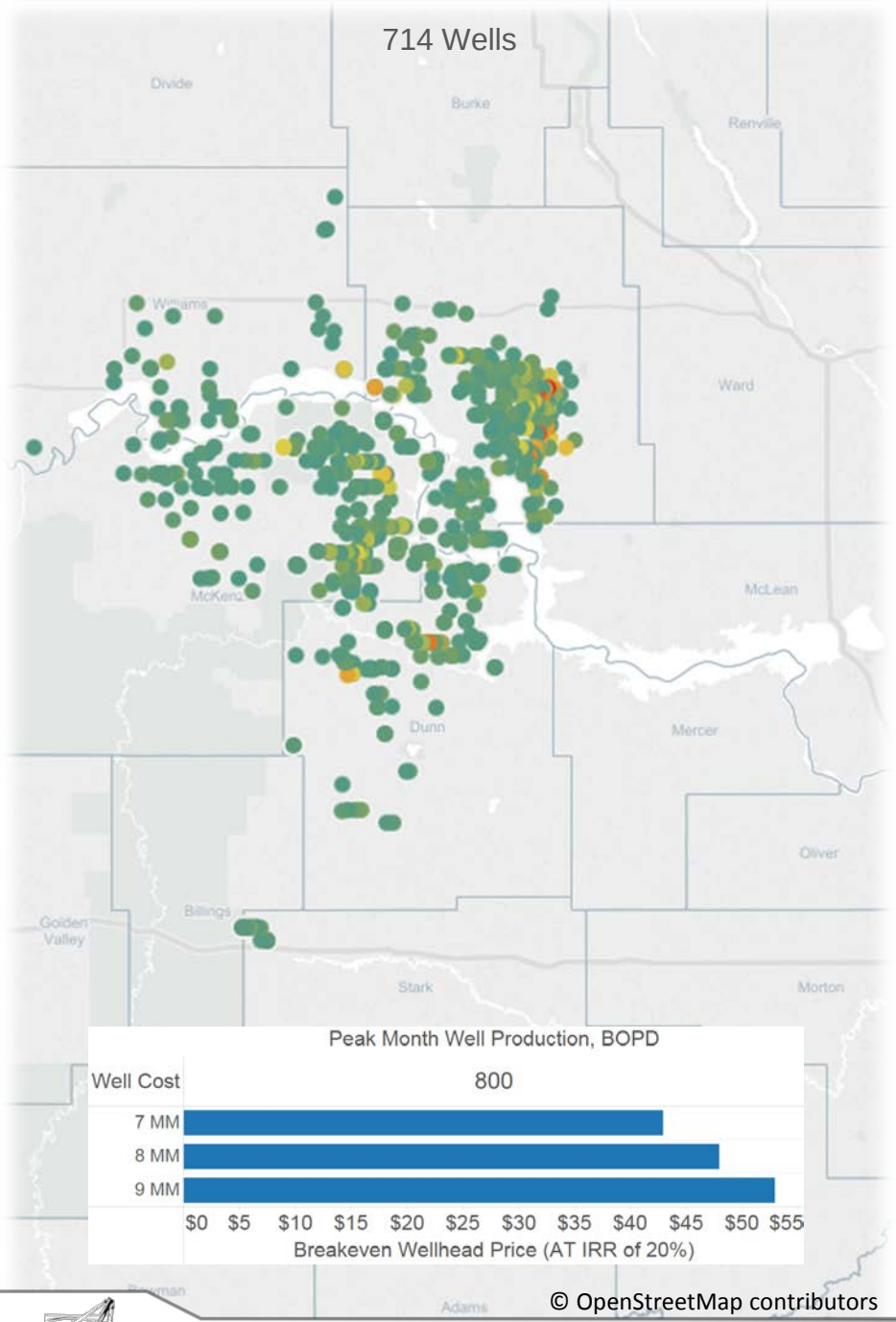


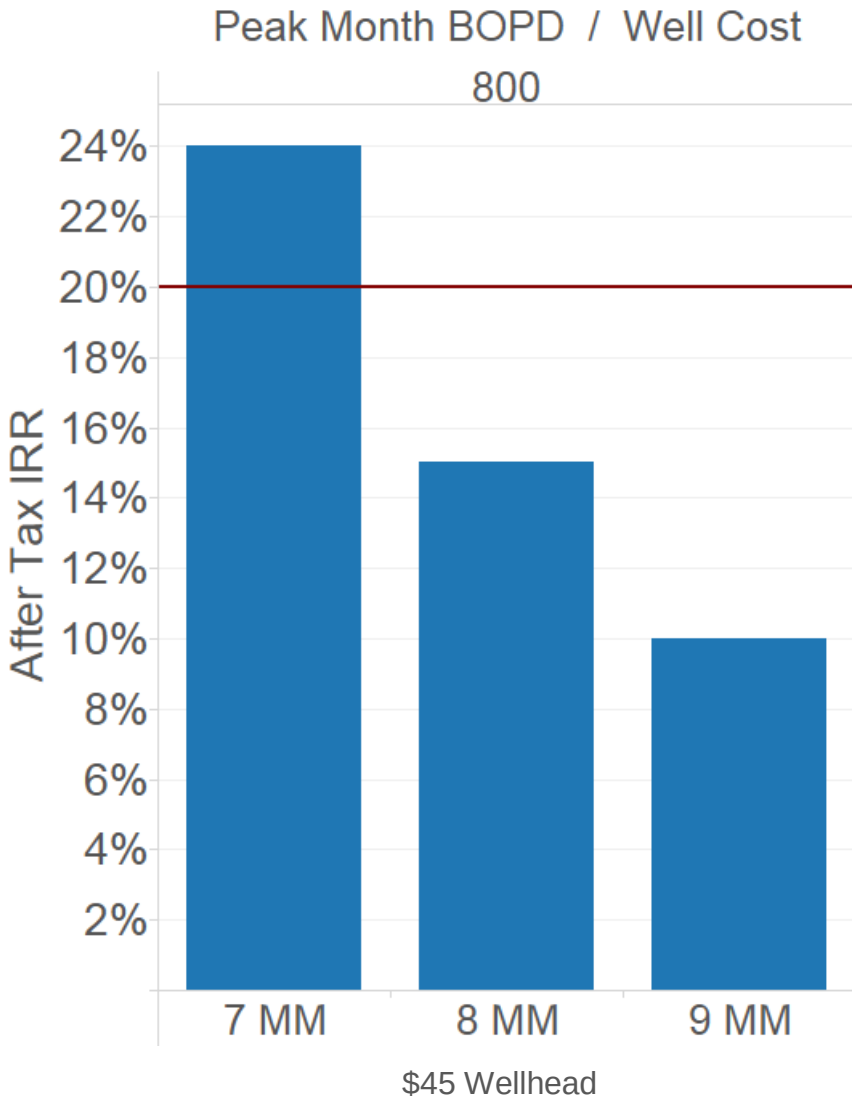
1/9/2015

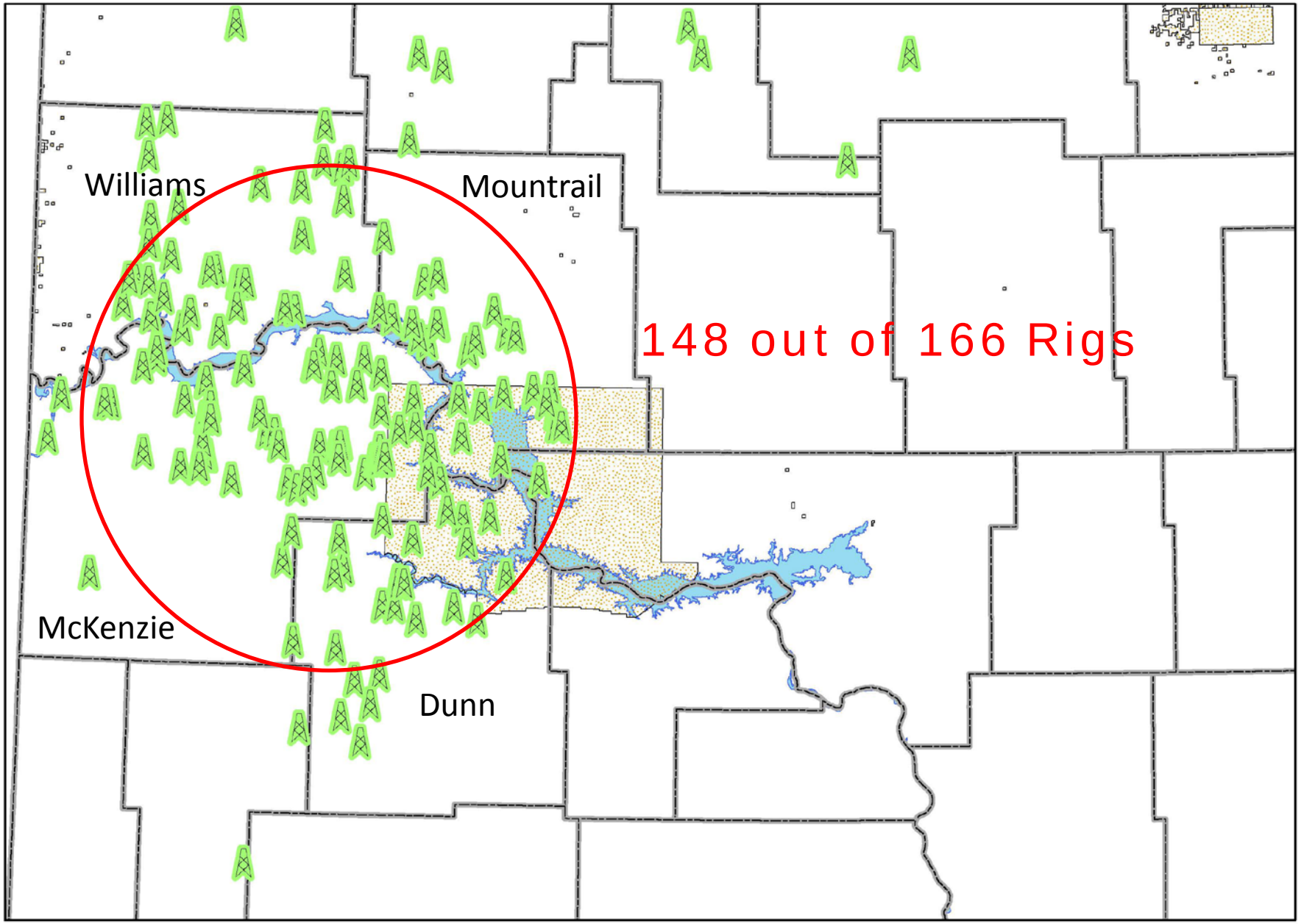
North Dakota Average Monthly Rig Count



Peak Month Minimum 800 BOPD







0 15 30 60 Miles

Prepared by N.D.I.C.
Oil and Gas Division

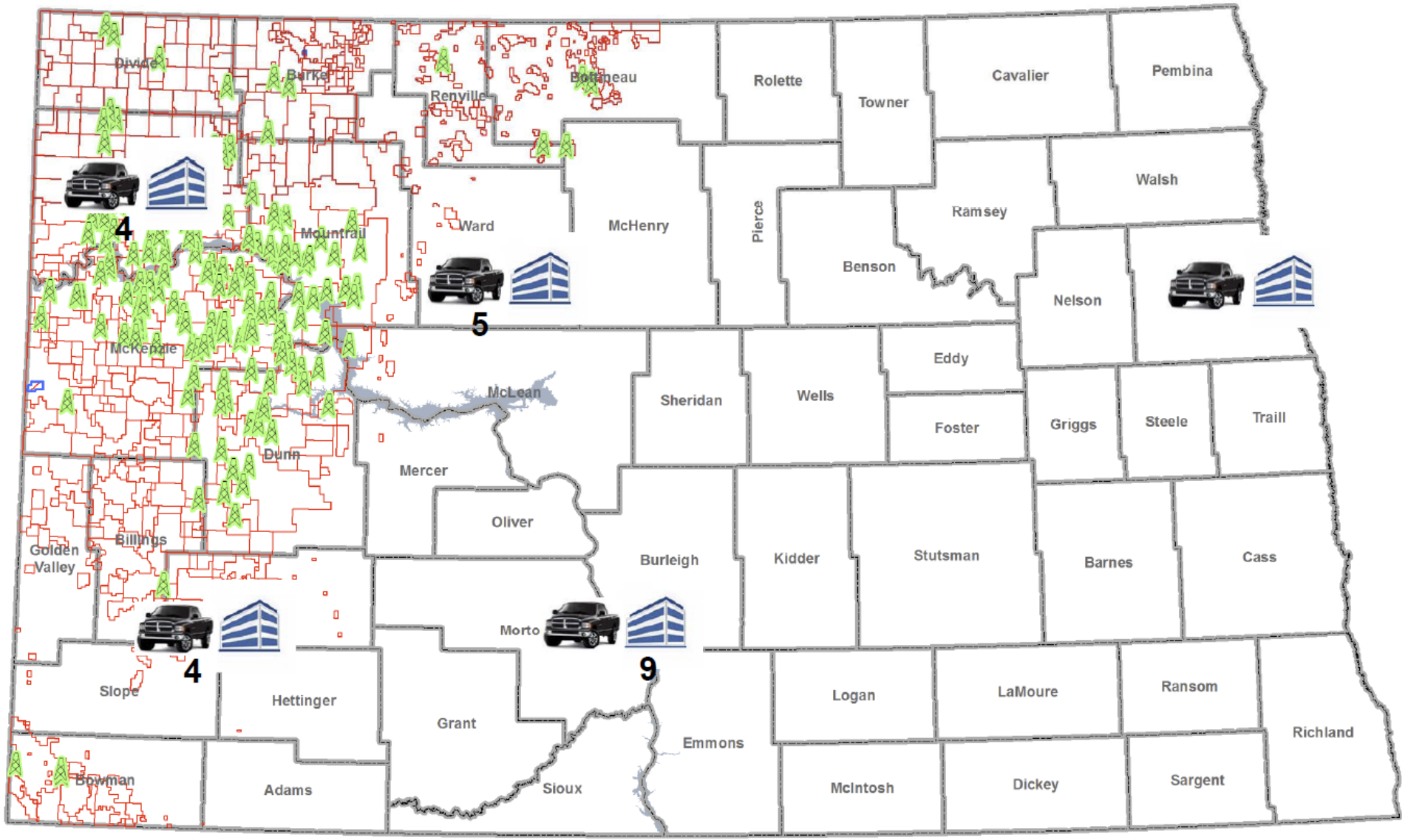
Production Projections

$/BO	Rigs	New Wells	BOPD 7/1/15	BOPD 7/1/16	BOPD 7/1/17
$25	40	1,100	1,000,000	800,000	700,000
$35	90	2,400	1,030,000	875,000	720,000
$45	120	3,200	1,100,000	1,050,000	975,000
$55	140	3,800	1,200,000	1,200,000	1,150,000
$65	155	4,200	1,200,000	1,225,000	1,250,000
$75	170	4,600	1,200,000	1,300,000	1,400,000
$85	190	5,000	1,250,000	1,400,000	1,550,000

Regulatory Policies

- Potential Federal Impacts:
  - BLM revised regulations for hydraulic fracturing on federal and Indian lands.
  - BLM venting and flaring regulations.
  - USFWS additional endangered species protections.
- Potential State Impacts:
  - Gas Capture targets:
    - Jan. 2015: 77%
    - Jan. 2016: 85%
    - Oct. 2020: 90-95%
  - Oil Conditioning practices.
    - Effective April 1, 2015.

DMR Budget Highlights
2015 - 2017



Additional Requests: Core Library Expansion, $16 million
Litigation Contingency Fund, $3 million