OIL & GAS ACTIVITY UPDATE

Midwestern Association of State Departments of Agriculture

Medora, ND– June 21, 2013

NORTH DAKOTA
D M R
Department of Mineral Resources

North Dakota Development

- Regulation
- Resource Play
- Uniform Spacing—orderly development
- Multi-well locations—small footprint
- Corridors—industry and residents
- Water Needs—surface waters
- Bakken Results
- Other ND Resources

Bruce E. Hicks
Assistant Director
NDIC-DMR-OGD
Bismarck, ND

North Dakota Department of Mineral Resources

NDGS
Research Arm

OGD
Regulatory Arm

https://www.dmr.nd.gov/oilgas/   ***https://www.dmr.nd.gov/ndgs/***

600 East Boulevard Ave. - Dept 405
Bismarck, ND 58505-0840
(701) 328-8020   (701) 328-8000

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NORTH DAKOTA OIL AND GAS DIVISION

Welcome to the North Dakota Industrial Commission, Department Mineral Resources, Oil and Gas Division, home page.

Director's Cut - 04/16/2013 and Recent Presentations

The Director's Cut is an update on current activity in the North Dakota oil patch from the Director of Department of Mineral Resources. (View past Director's Cuts)

View the latest press releases from the Oil and Gas Division

Rules approved for Geologic Storage of Carbon Dioxide.
See the signed order.

Bakken and Three Forks Information!

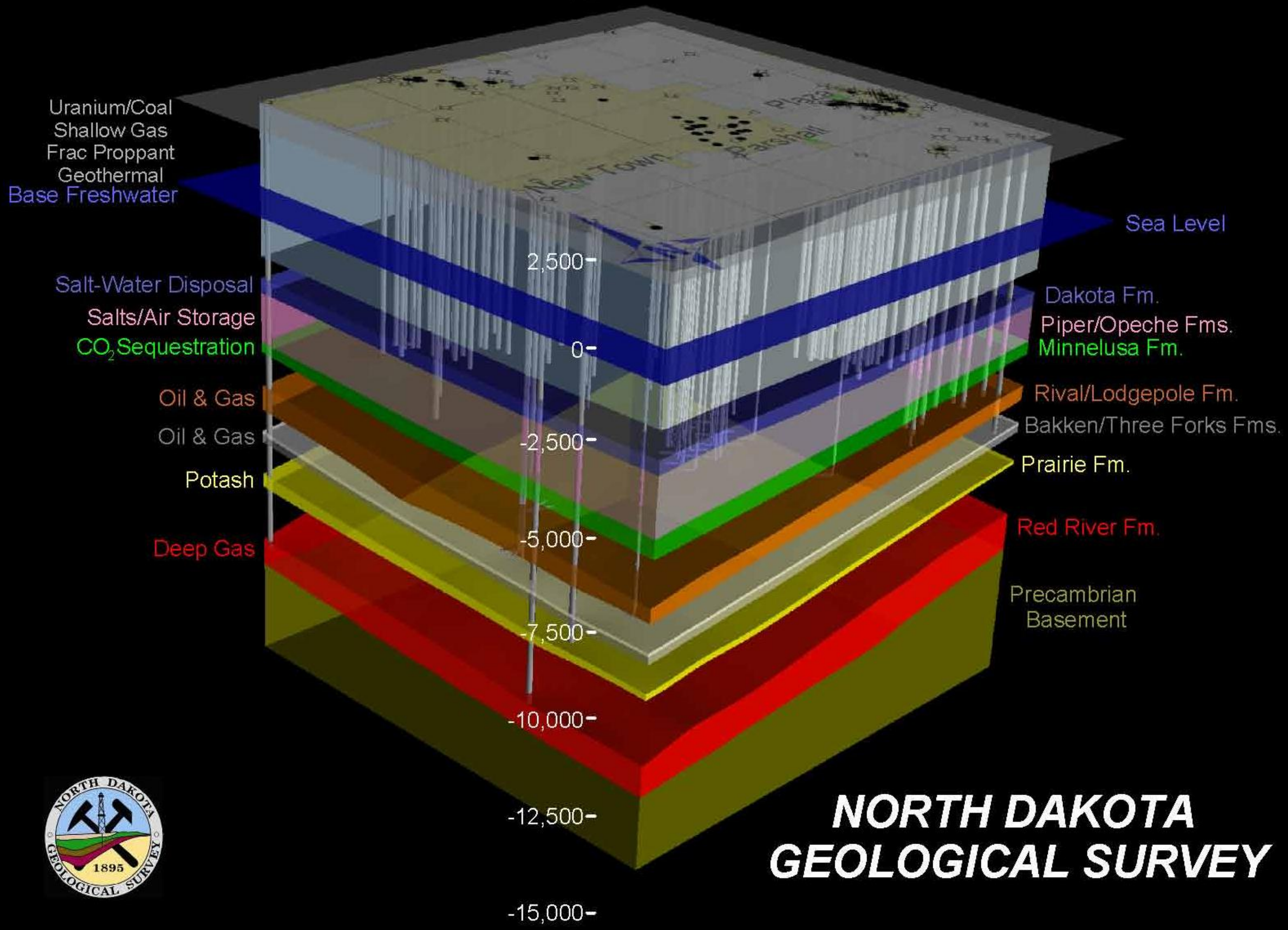
There are currently **2** job openings available for an Engineering Technician IV and Engineering Technician IV located in the Williston Field Office and one job opening available for an Engineering Technician IV located in the Dickinson Field Office.

Available on the ND Petroleum Council web site are the Surface Owner Information Center, the Royalty Owner Information Center and the PowerPoint presentations that were used at the 2012 Williston Basin Petroleum Conference.

The Oil and Gas Division regulates the drilling and production of oil and gas in North Dakota. Our mission is to encourage and promote the development

Phone: (701) 328-8020
Fax: (701) 328-8022

Three-Dimensional Geologic Model of the Parshall Area

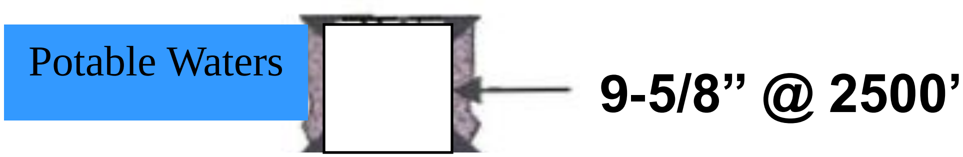


NORTH DAKOTA GEOLOGICAL SURVEY

North Dakota Development

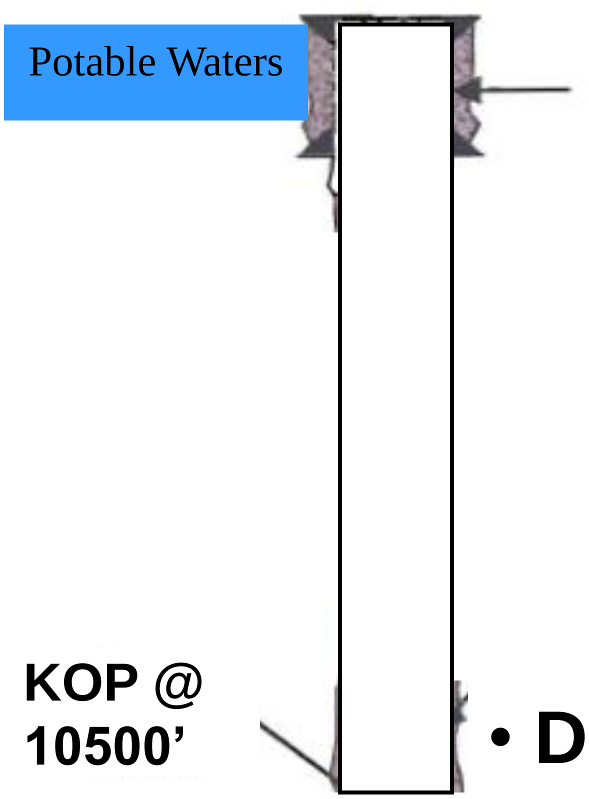
- **Regulation**
- **Resource Play**
- **Uniform Spacing—orderly development**
- **Multi-well locations—small footprint**
- **Corridors—industry and residents**
- **Water Needs—surface waters**
- **Bakken Results**
- **Other North Dakota Resources**

TYPICAL HORIZONTAL OIL WELL



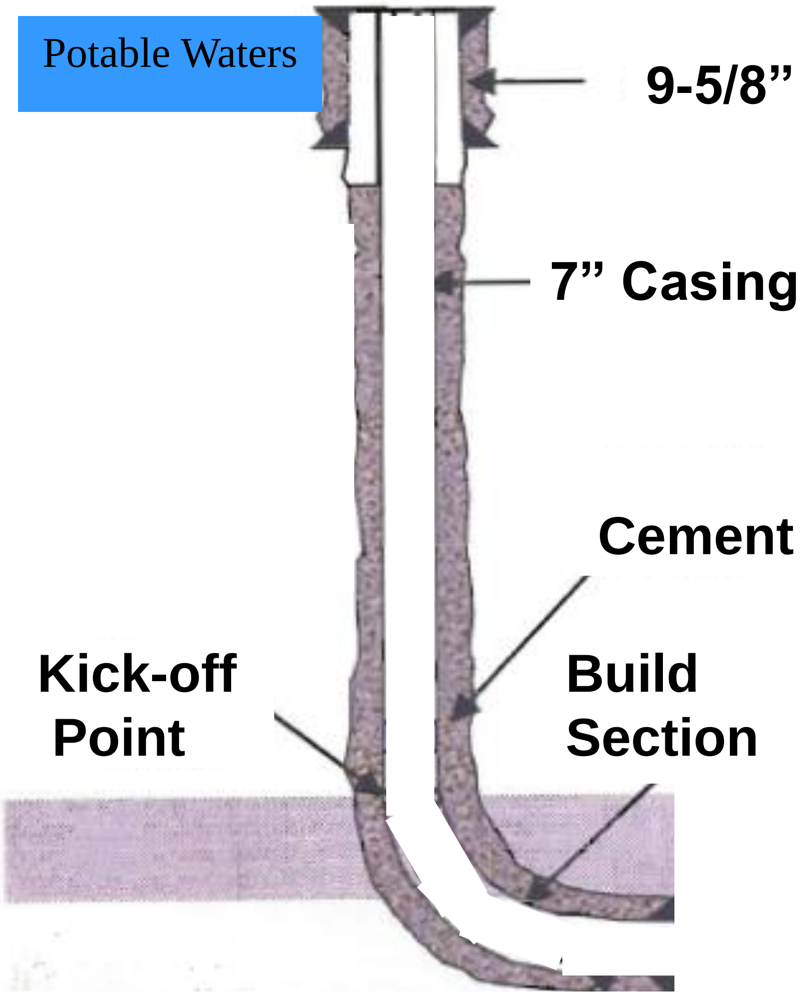
- Drill with fresh water
- Total depth below lowest potable water
- Run in hole with surface casing
- Cement casing back to surface of ground
- 1st layer of surface water protection

TYPICAL HORIZONTAL OIL WELL



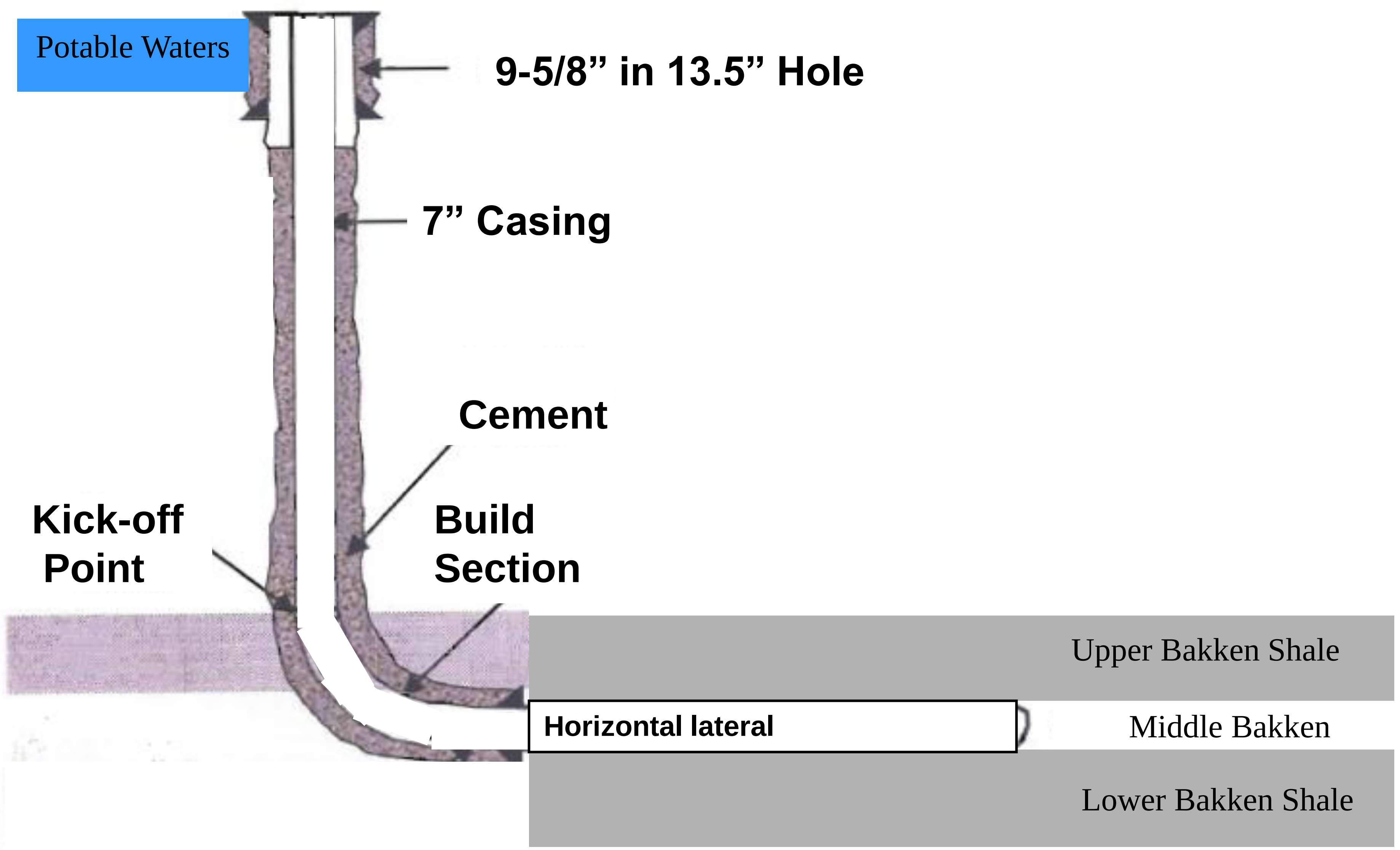
- **Drill vertically to kick-off point**
- **Run in hole with bent assembly**
- **Downhole mud motor**

TYPICAL HORIZONTAL OIL WELL



- Drill 8-3/4" hole to pay
- Run in hole with 7" casing
- Cement 7" casing
- 2nd layer of protection

TYPICAL HORIZONTAL OIL WELL



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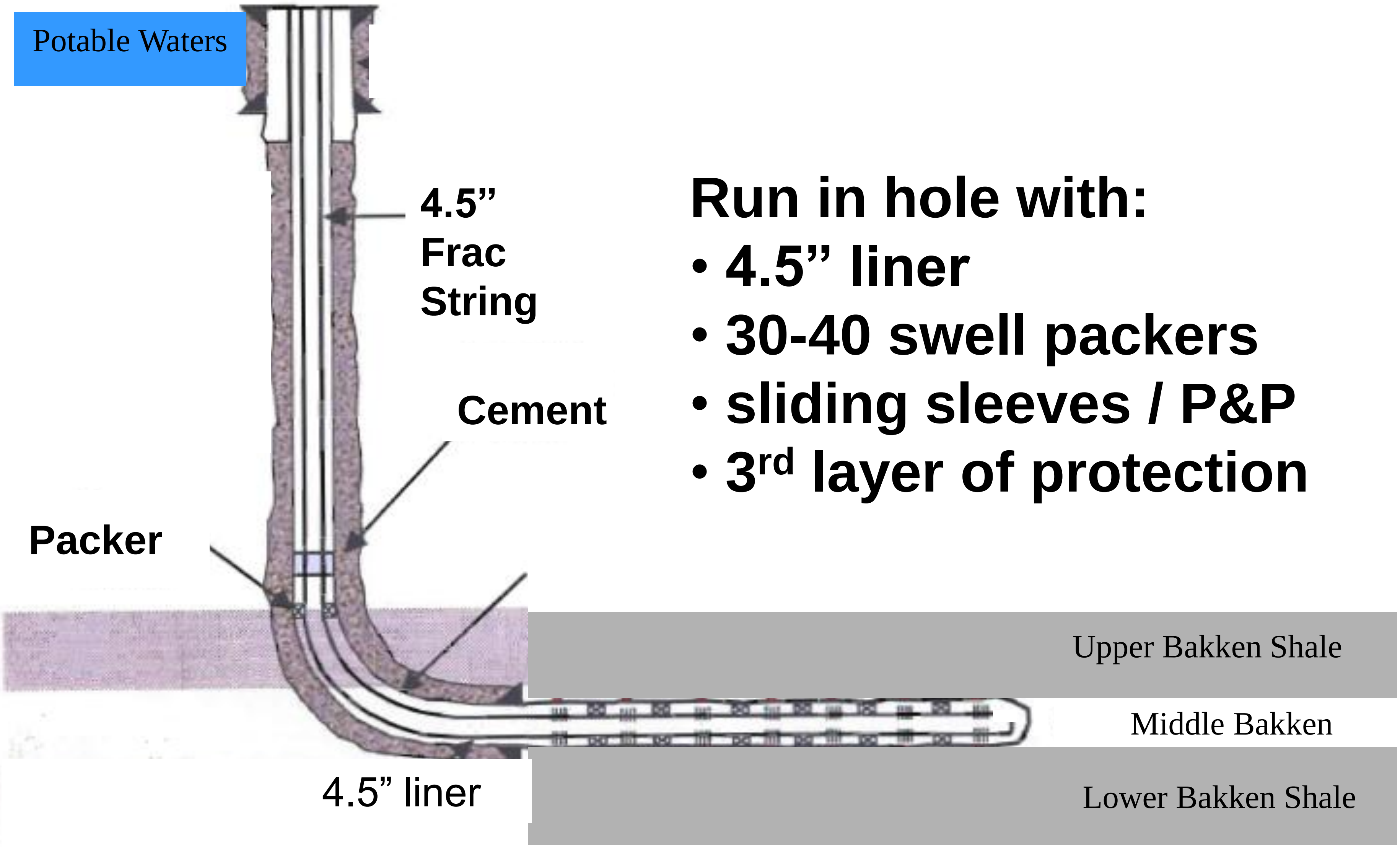
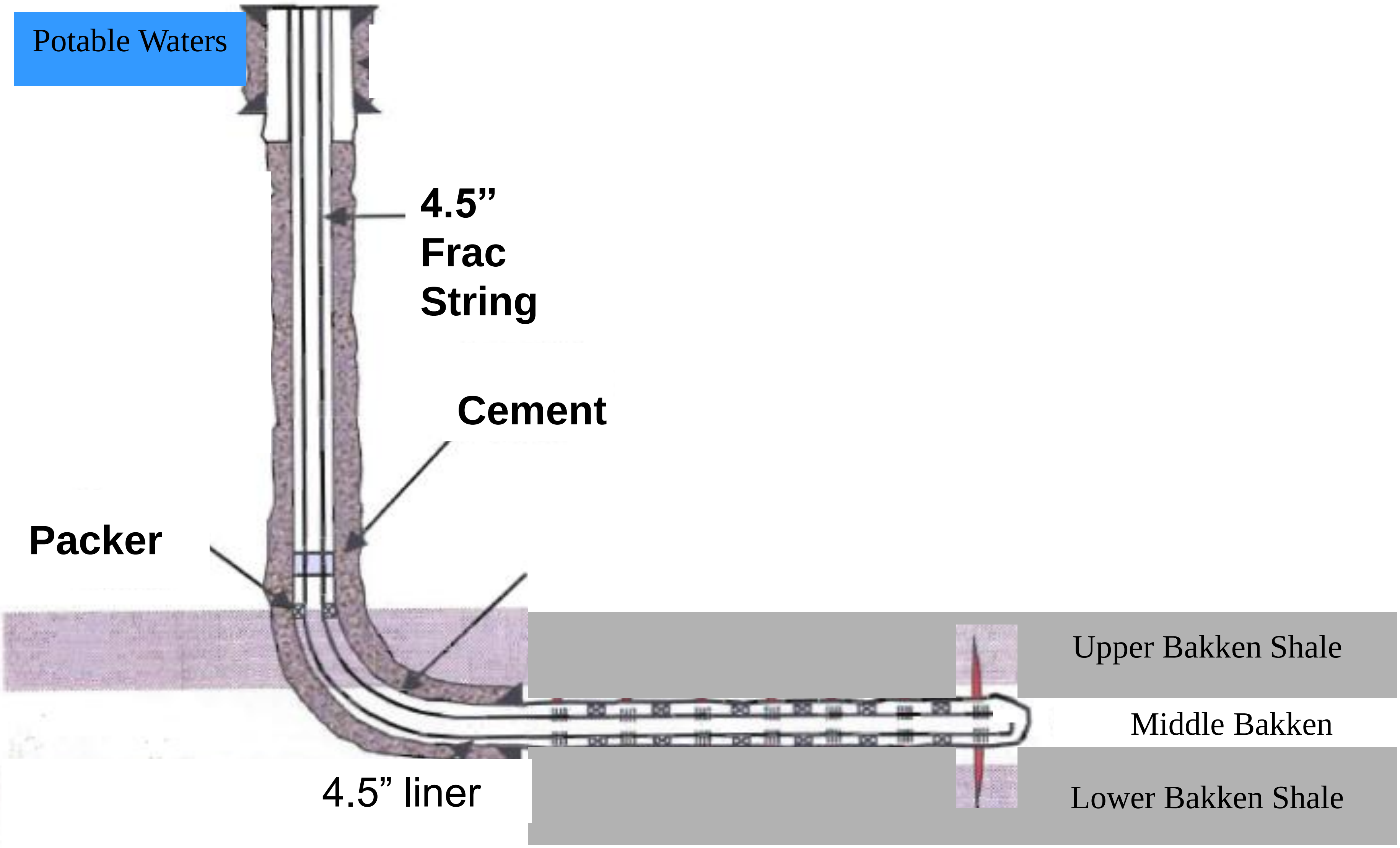


Run in hole with:

- **4.5" liner**
- **30-40 swell packers**
- **sliding sleeves / P&P**
- **3rd layer of protection**

TYPICAL HORIZONTAL OIL WELL



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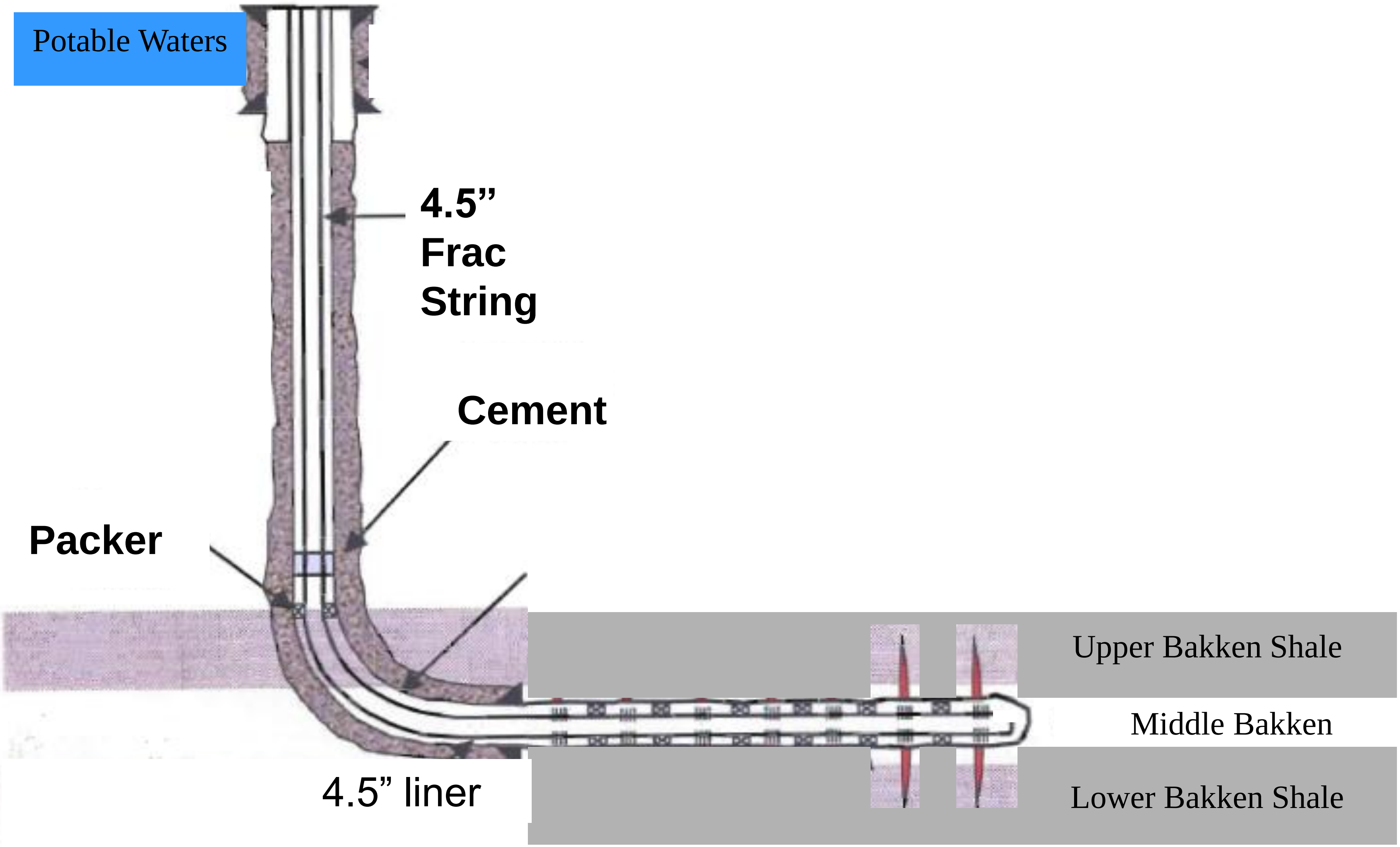

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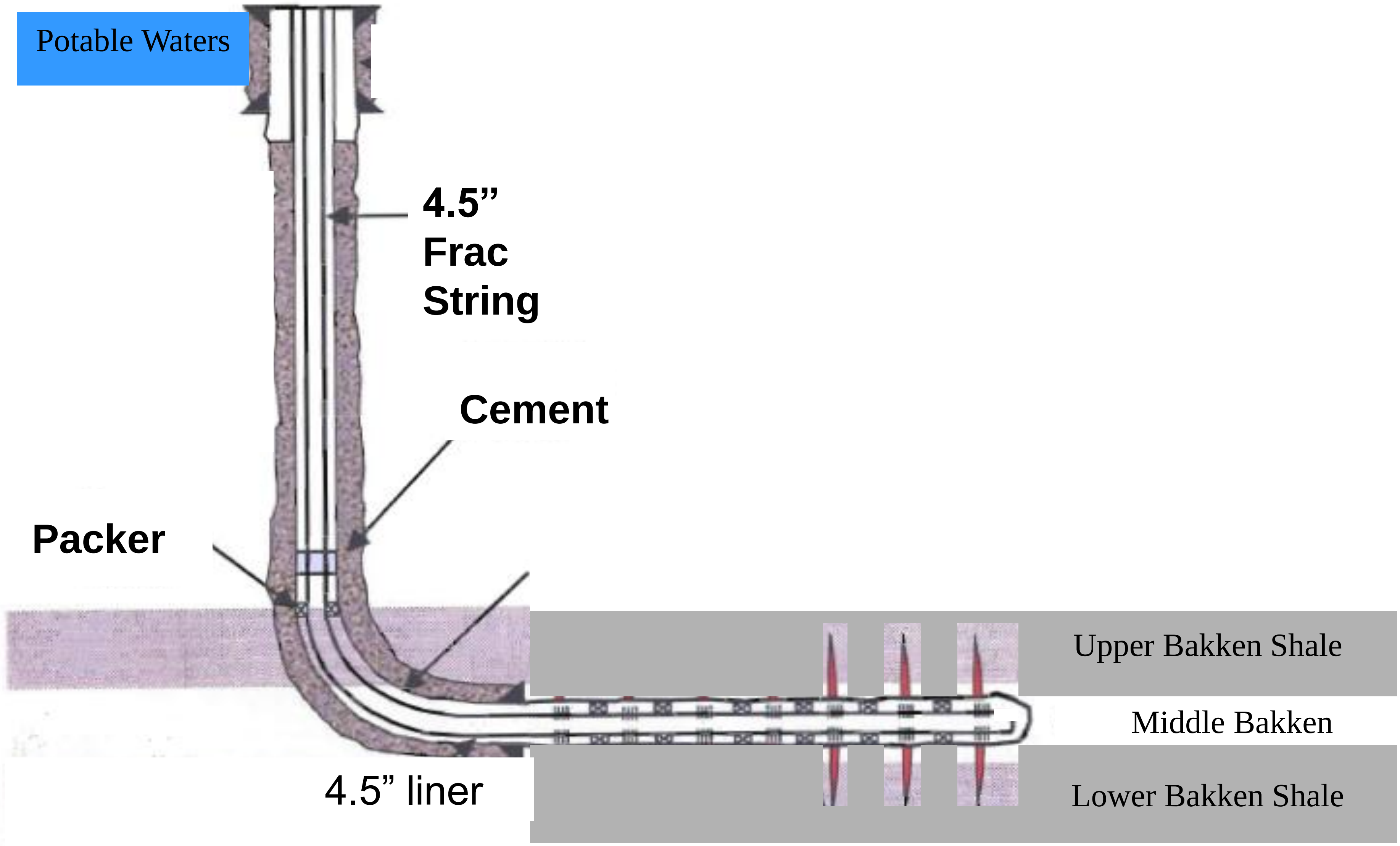

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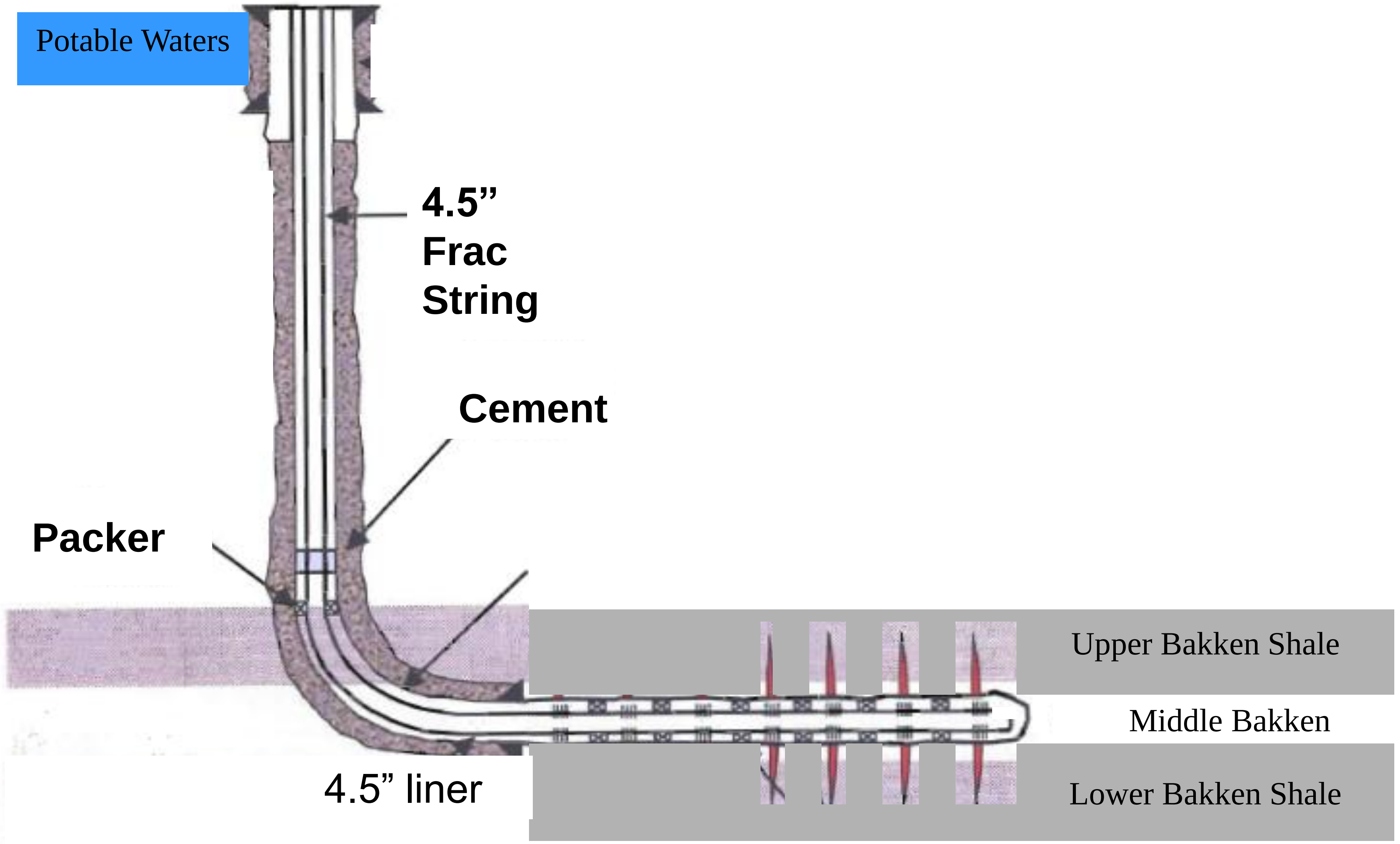

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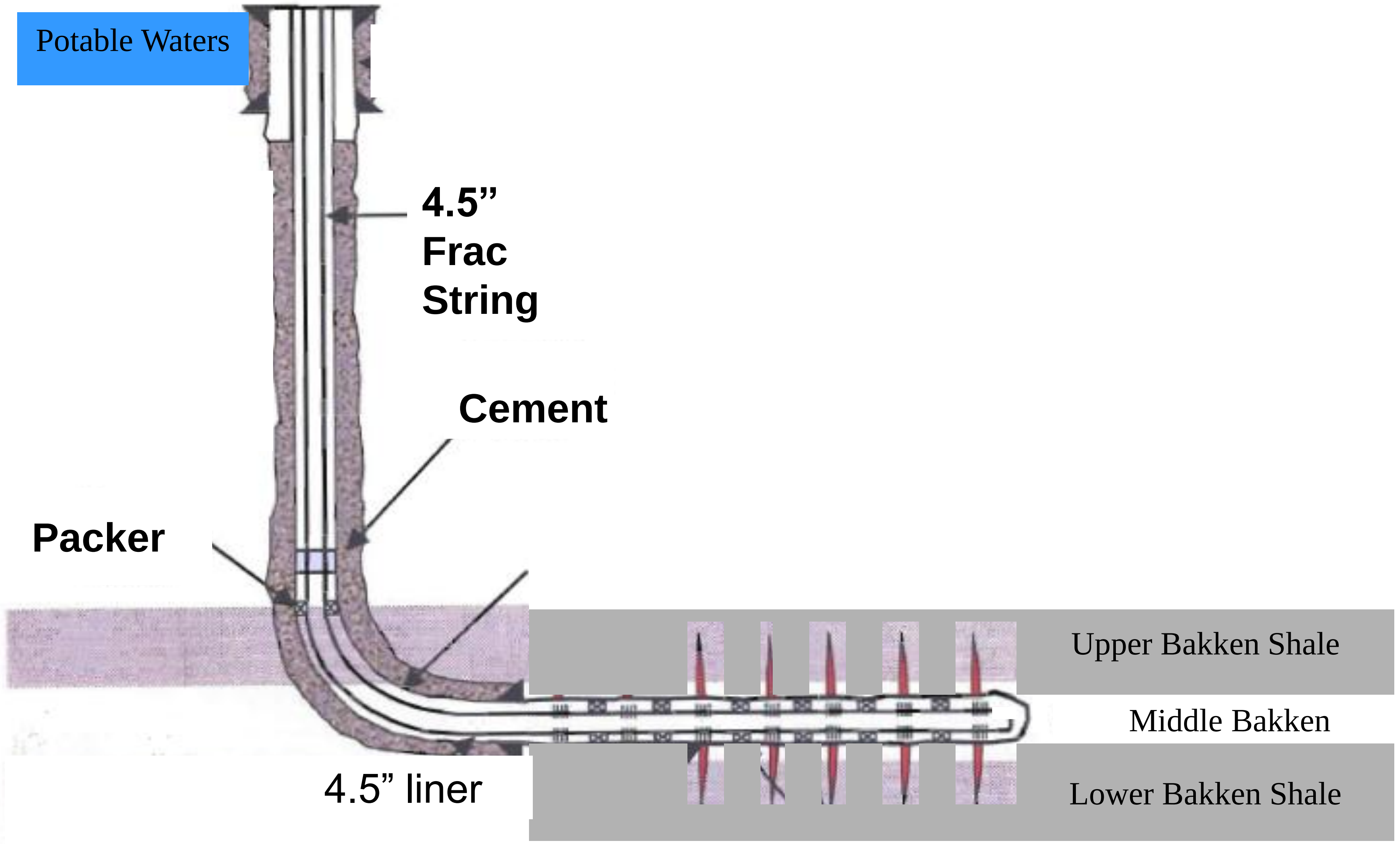

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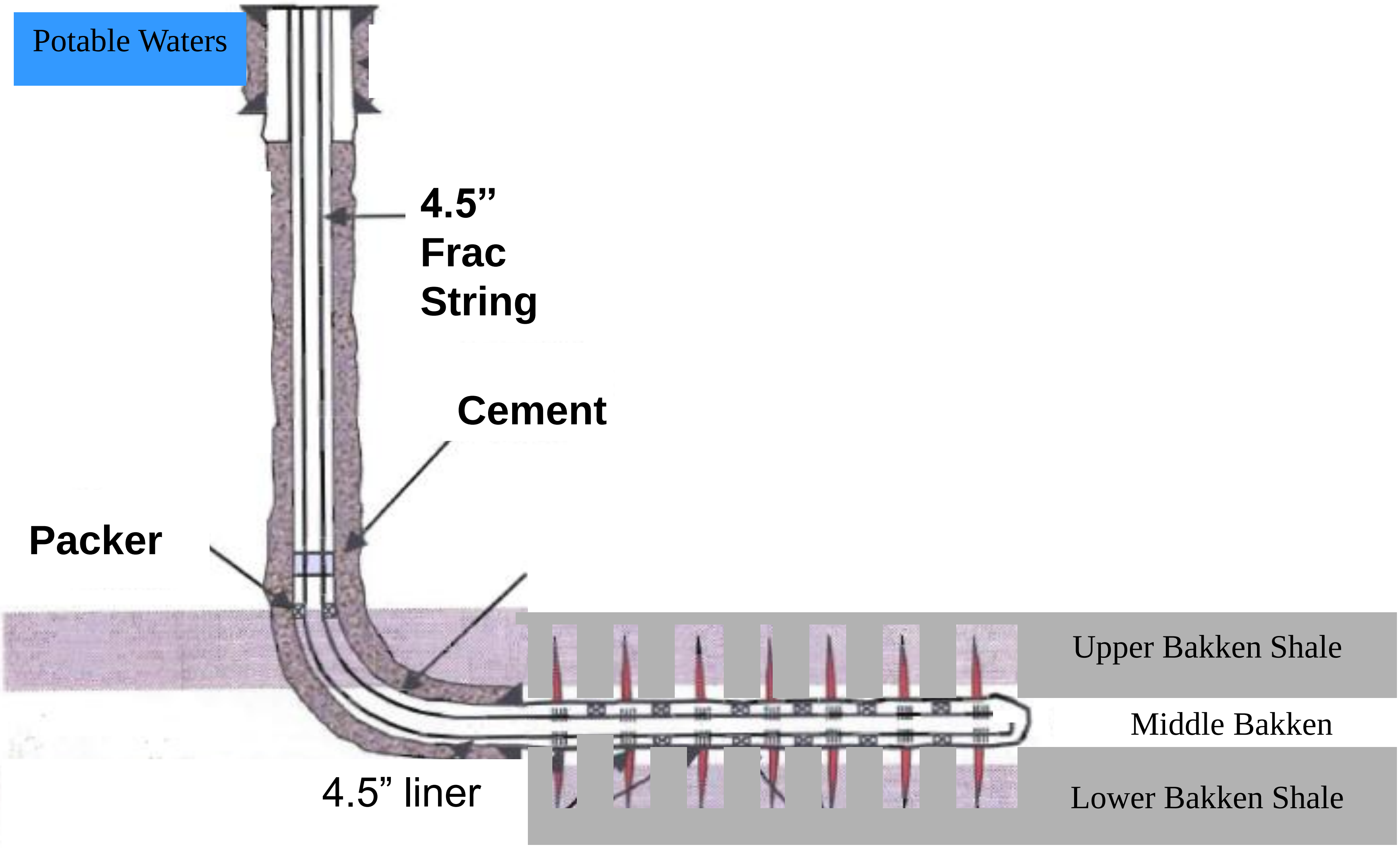
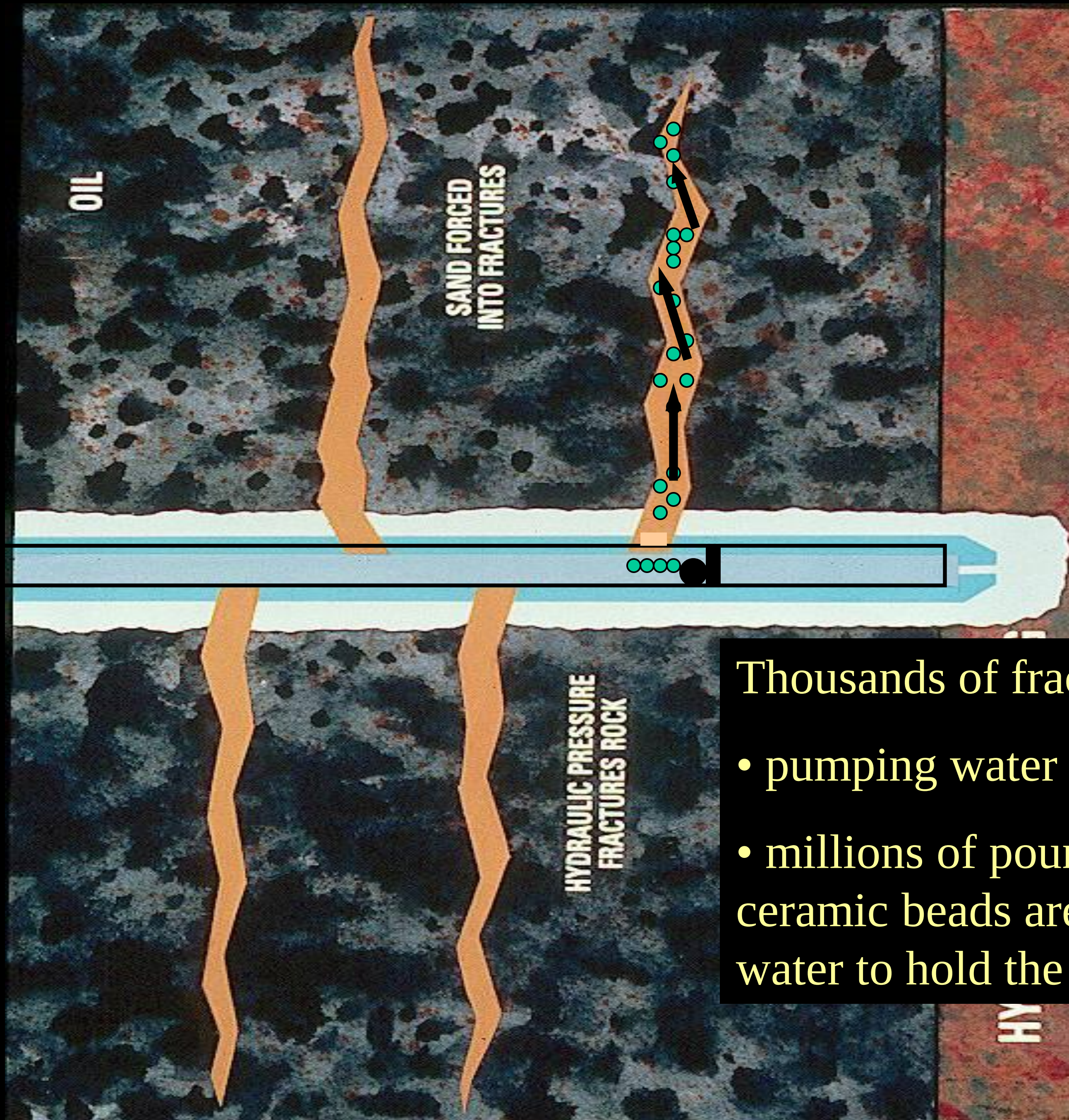
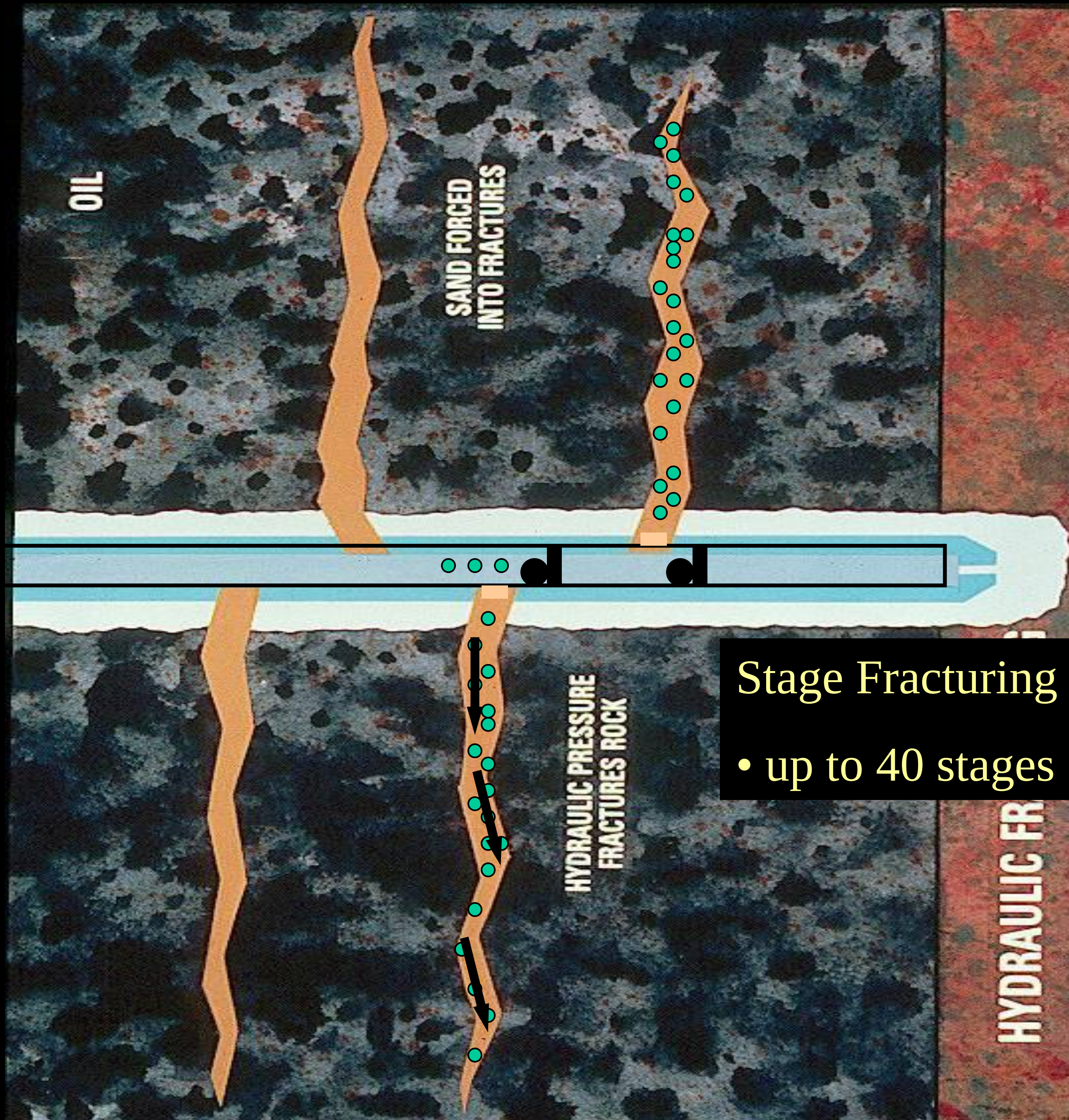




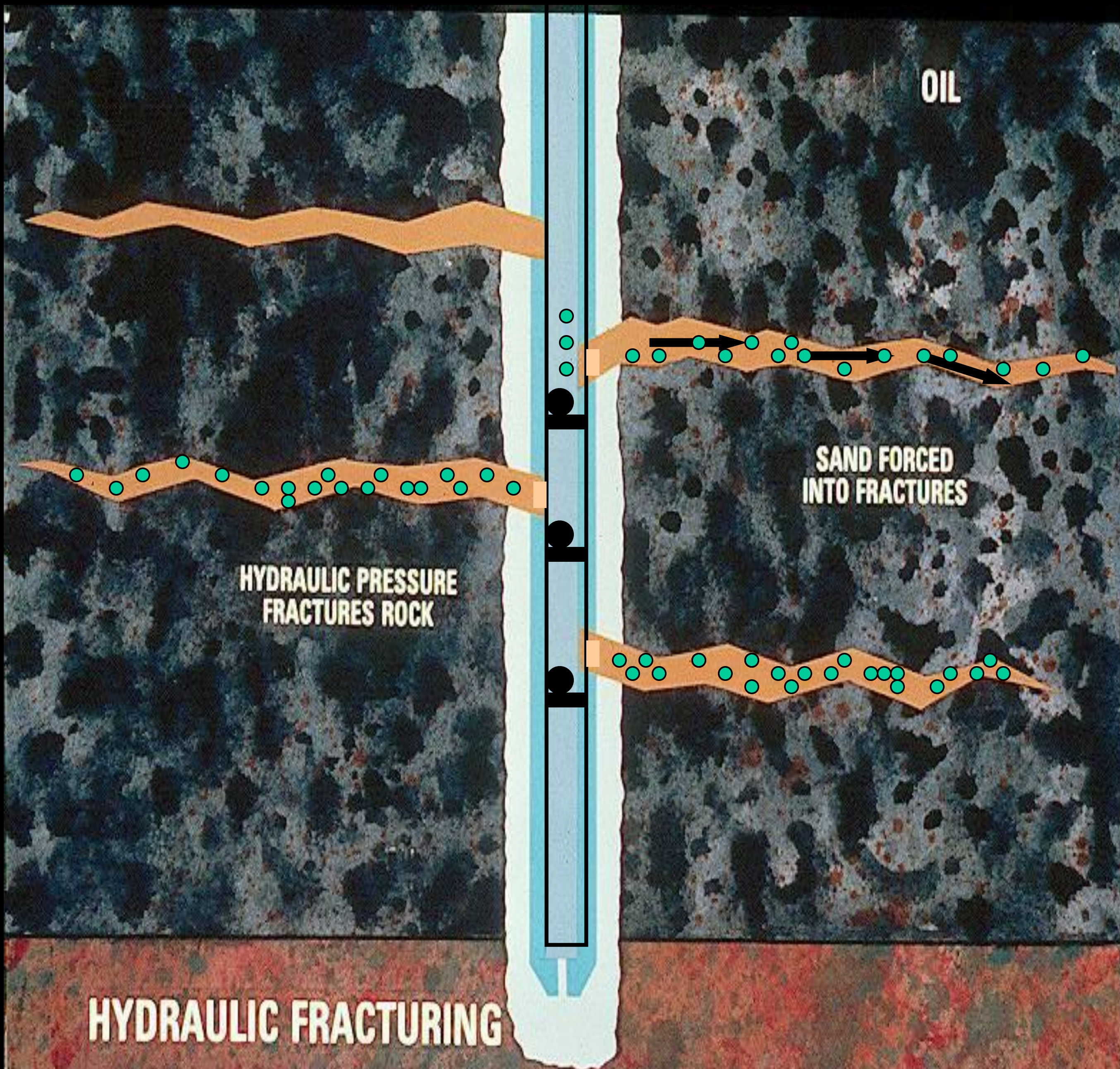
Thousands of fractures are created

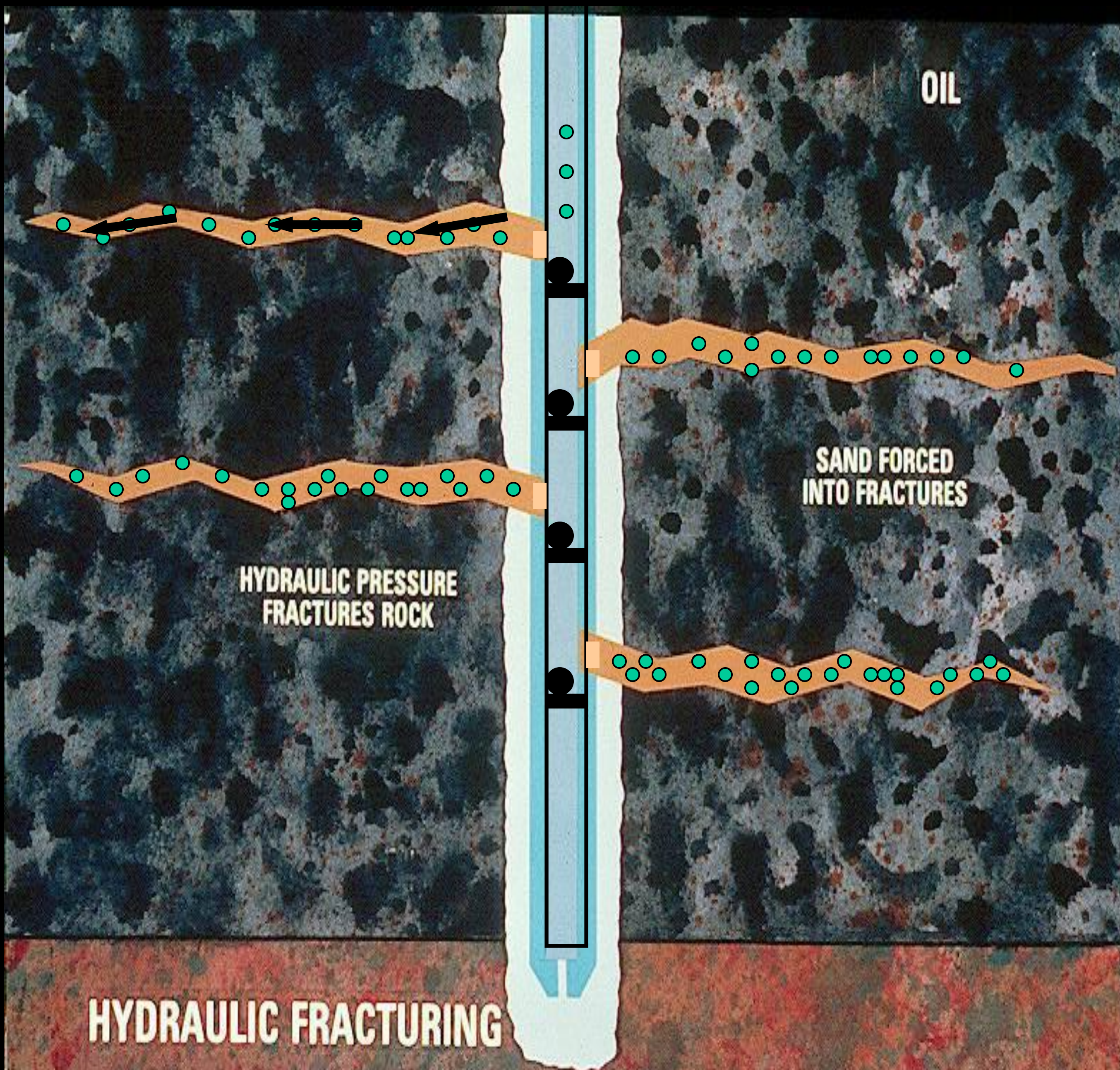
- pumping water at 6,000-9,000 psi
- millions of pounds of sand and ceramic beads are pumped with the water to hold the fractures open.



Stage Fracturing

- up to 40 stages


OIL
SAND FORCED INTO FRACTURES
HYDRAULIC PRESSURE FRACTURES ROCK
HYDRAULIC FRACTURING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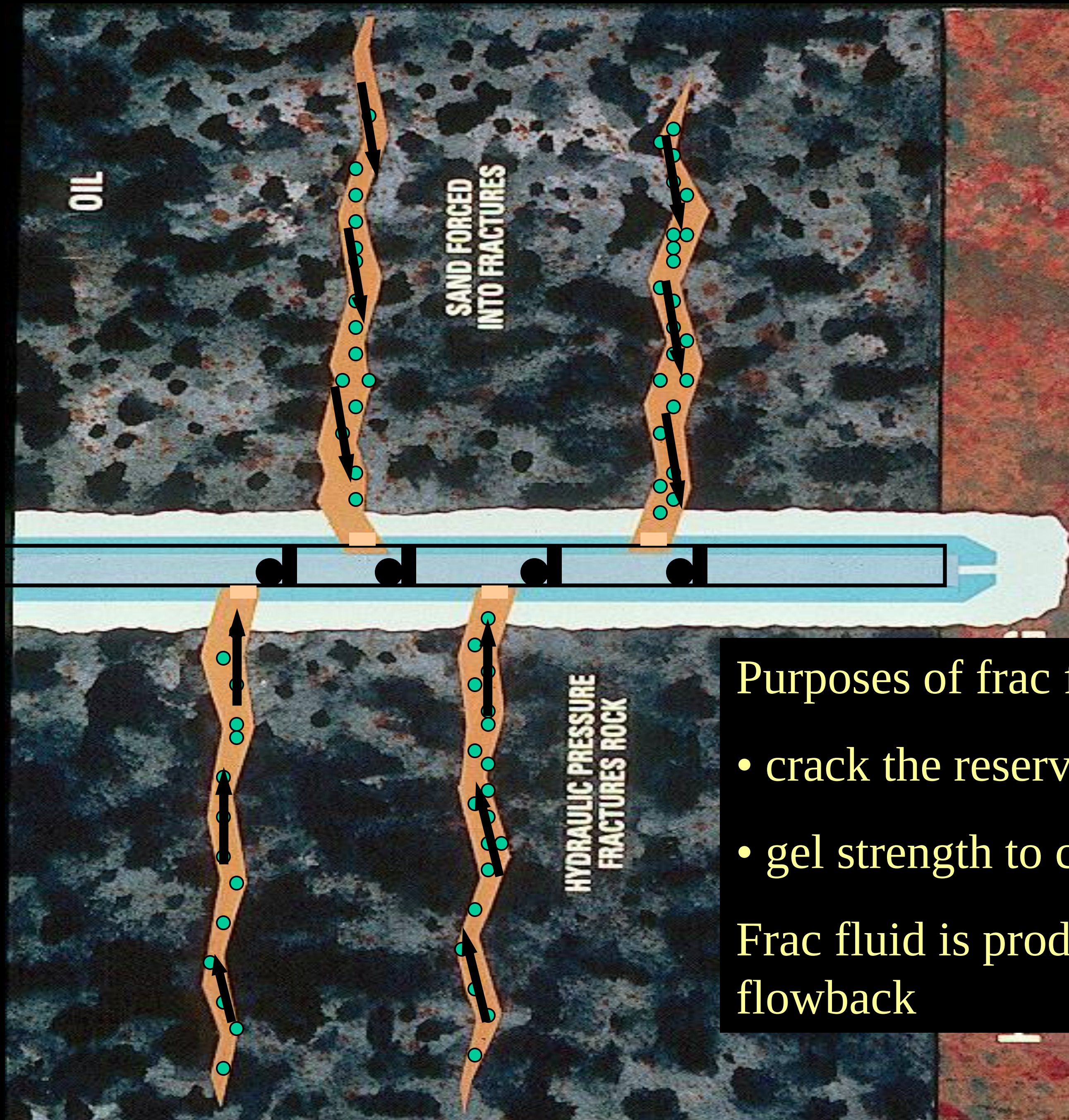
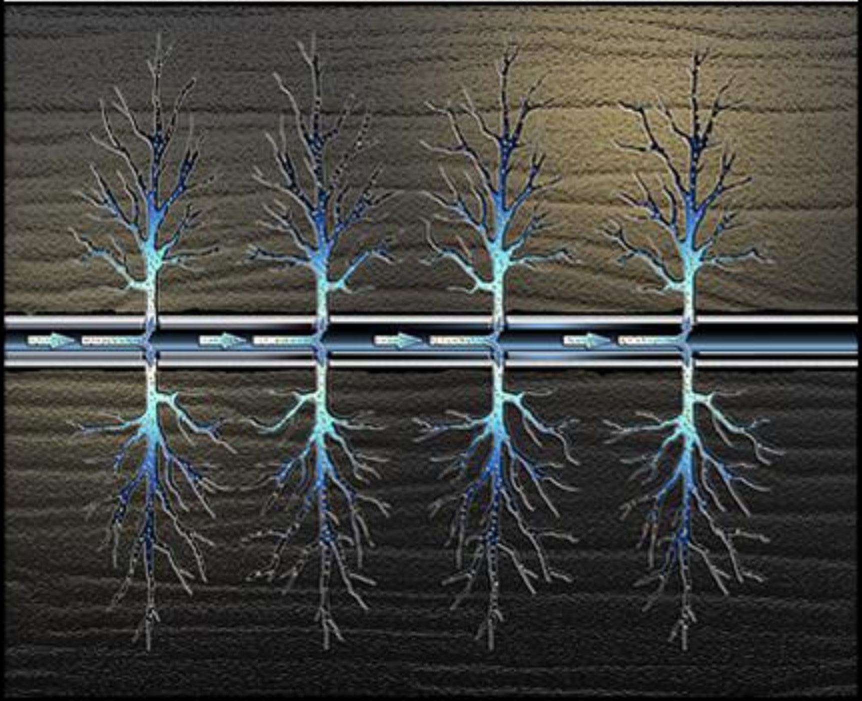


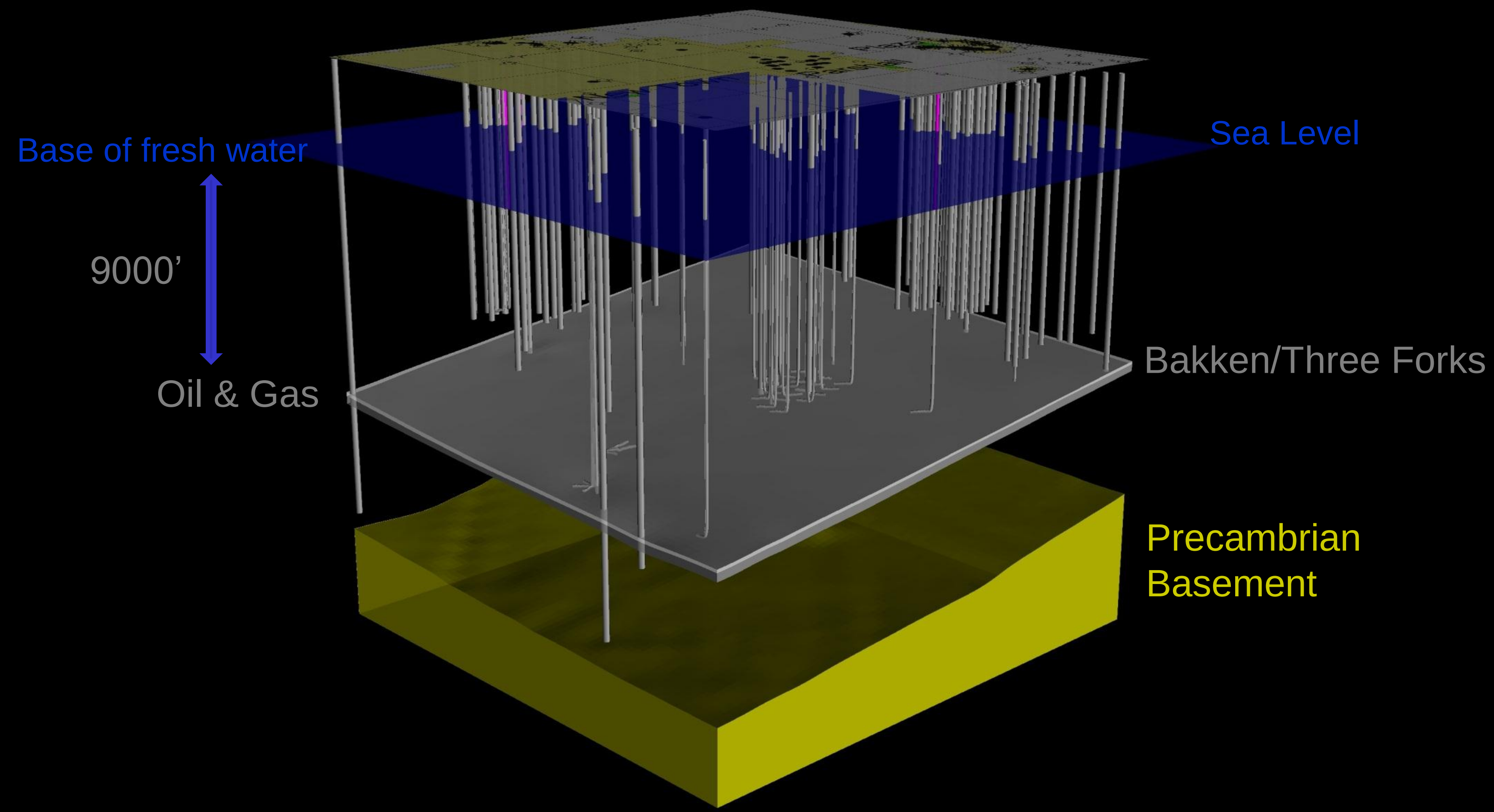
Purposes of frac fluid

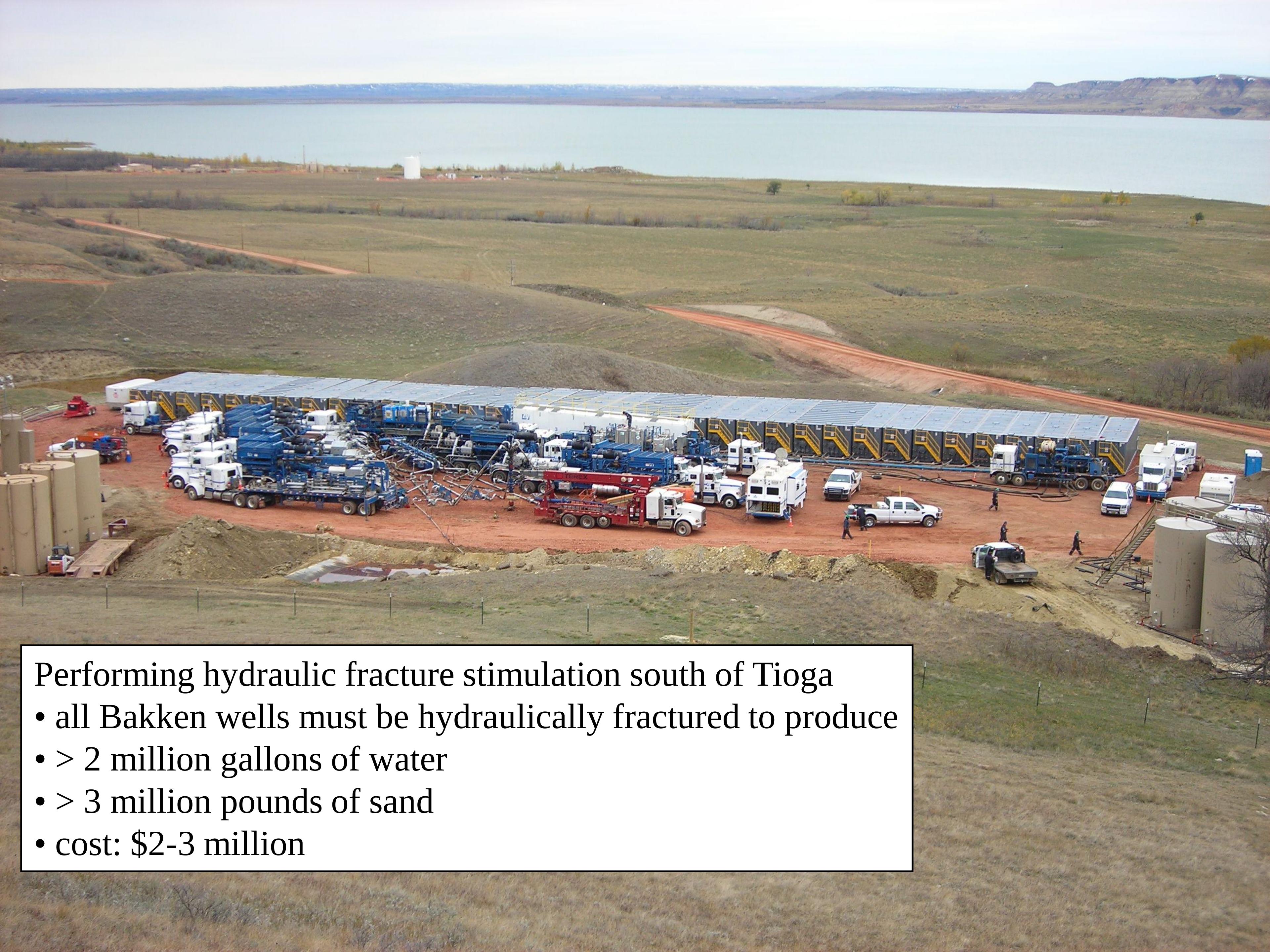
- crack the reservoir
- gel strength to carry sand

Frac fluid is produced back as flowback

Hydraulic Fracturing: Mixture of water, sand and chemicals pressurized and pumped into the well to form microscopic fractures in shale.




Base of fresh water
Sea Level
9000'
Oil & Gas
Bakken/Three Forks
Precambrian
Basement



Performing hydraulic fracture stimulation south of Tioga

- all Bakken wells must be hydraulically fractured to produce
- > 2 million gallons of water
- > 3 million pounds of sand
- cost: $2-3 million

WHY FRAC THE ROCK?

- already developed easy oil
  - oil flows easily without fracking

- Unconventional Reserves
  - reservoirs are tight
  - look at sample
  - uneconomic to produce w/o fracing
  - must create a path for oil to flow

Oil and Gas Resources—Statute

<u>NDCC Section 38-08-01</u>

- **Foster, encourage, & promote our natural resources**
- **Protect correlative rights**
- **Protect environment**

Industrial Commission Regulation

- Hydraulic fracturing regulation
  - NDAC Section 43-02-03-27.1
    - https://www.dmr.nd.gov/oilgas/
  - sur csg open + diversion line to pit/vessel
  - relief valve on treating lines w/ck valves
  - remote operated frac valve on treat lines
  - if sur csg press > 350 psi notify NDIC
  - 60 days post FracFocus chem registry

- **Frac down 4-1/2” frac string**
  - **sting into liner or set pkr below Kd**
  - **press and monitor 4-1/2” X 7” ann**
  - **press relief valve on treating lines**
    - **set </= 85% of yield press**
  - **press relief valve on 4-1/2” X 7” ann**
    - **set </= 85% of weakest 7” yield**
    - **diversion line run to pit or vessel**

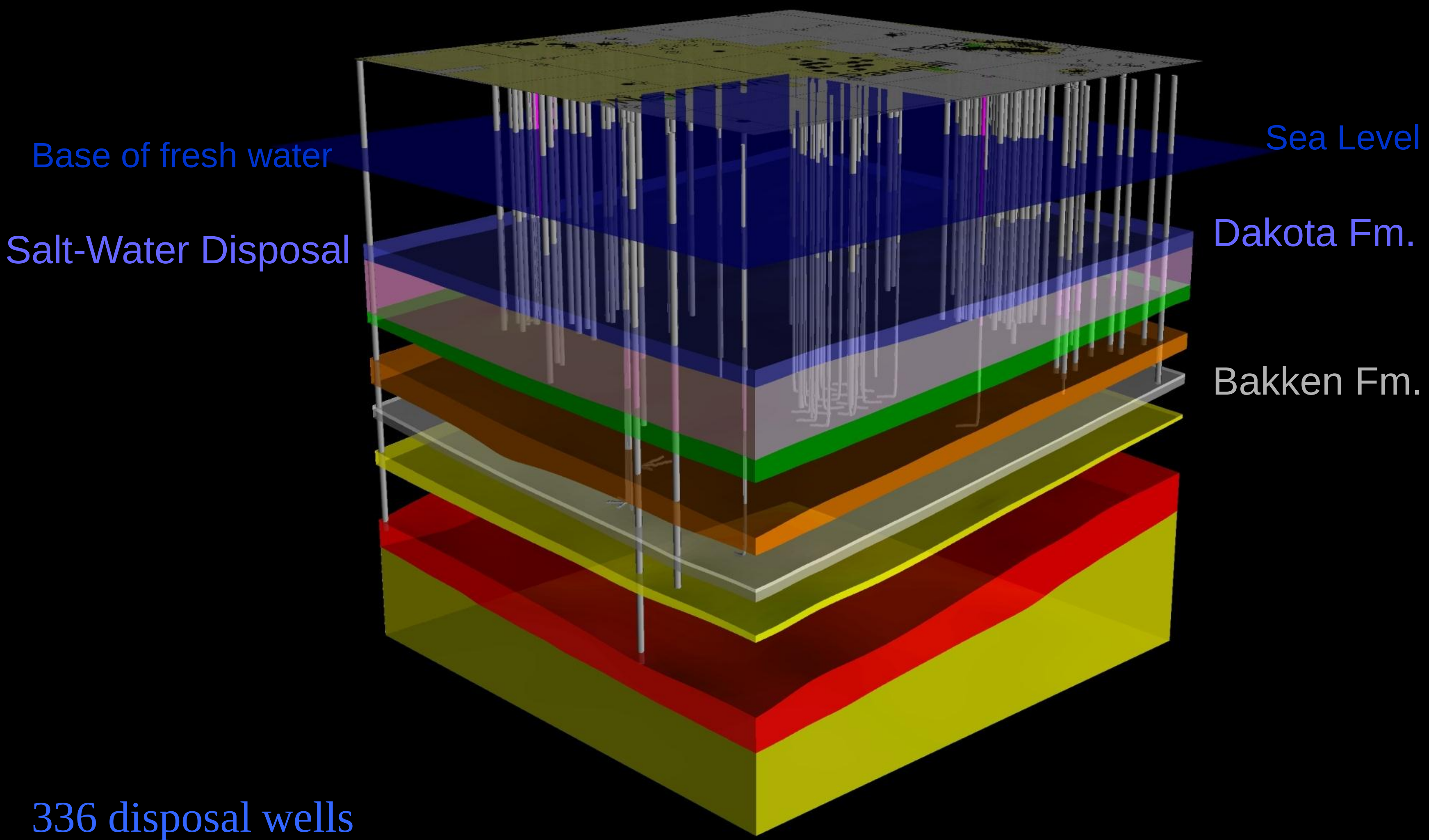
- Frac down 7” csg string
  - max treating press 85% of csg rating
  - csg eval tool to verify wall thickness
  - inspect + photo of top 7” csg jt
    - reduce treating press if warranted
  - cmt eval tool to confirm cmt
    - run frac string if defective cmt
  - press test 7” and wellhead
  - if wellhead press rating < frac design
    - use wellhead protection system

Hydraulic Fracturing Stimulation is Safe

- IOGCC survey—no contamination
- GWPC study verifies State's regs
- GWPC National Registry f/chemicals

States have been regulating the full life cycle of hydraulic fracturing for decades

- Water Appropriation Regulation
- Oil & Gas Regulation
- Health Department Regulation
- Geologic setting in each basin different



336 disposal wells

720,000 barrels per day

Rules and Legislation

- prohibit most reserve pits
- implement strong HF rules
- 63rd Legislative Session—☺
  - HB 2014—DMR budget: 21 new FTEs
  - HB 1348—safety f/SO w/in 1000’
  - HB 1333—create GIS pipeline database
- Rulemaking—hearing in Oct 2013

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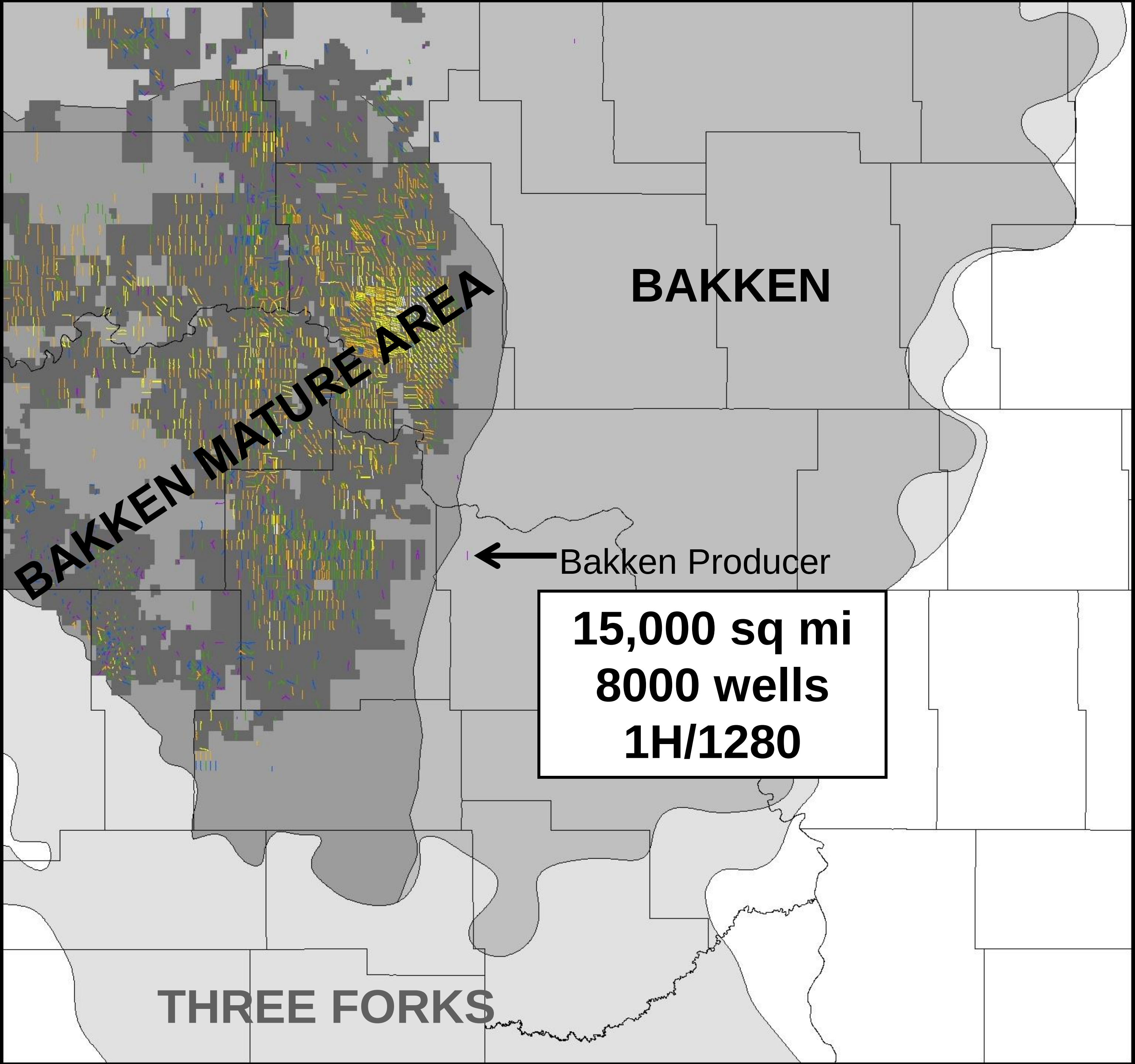
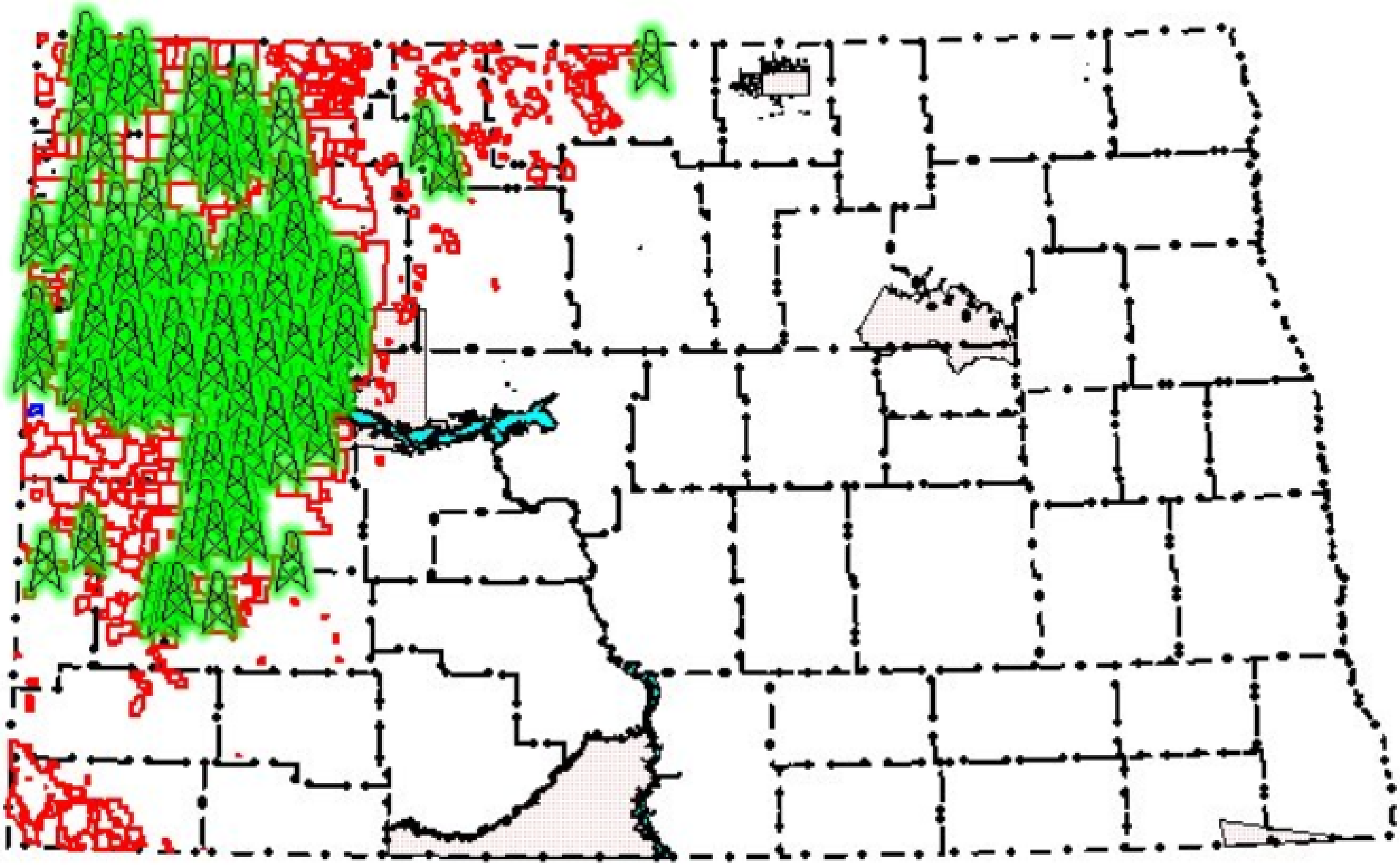

BAKKEN
BAKKEN MATURE AREA
Bakken Producer
15,000 sq mi
8000 wells
1H/1280
THREE FORKS

NORTH DAKOTA – 186 DRILLING RIGS – June 2013

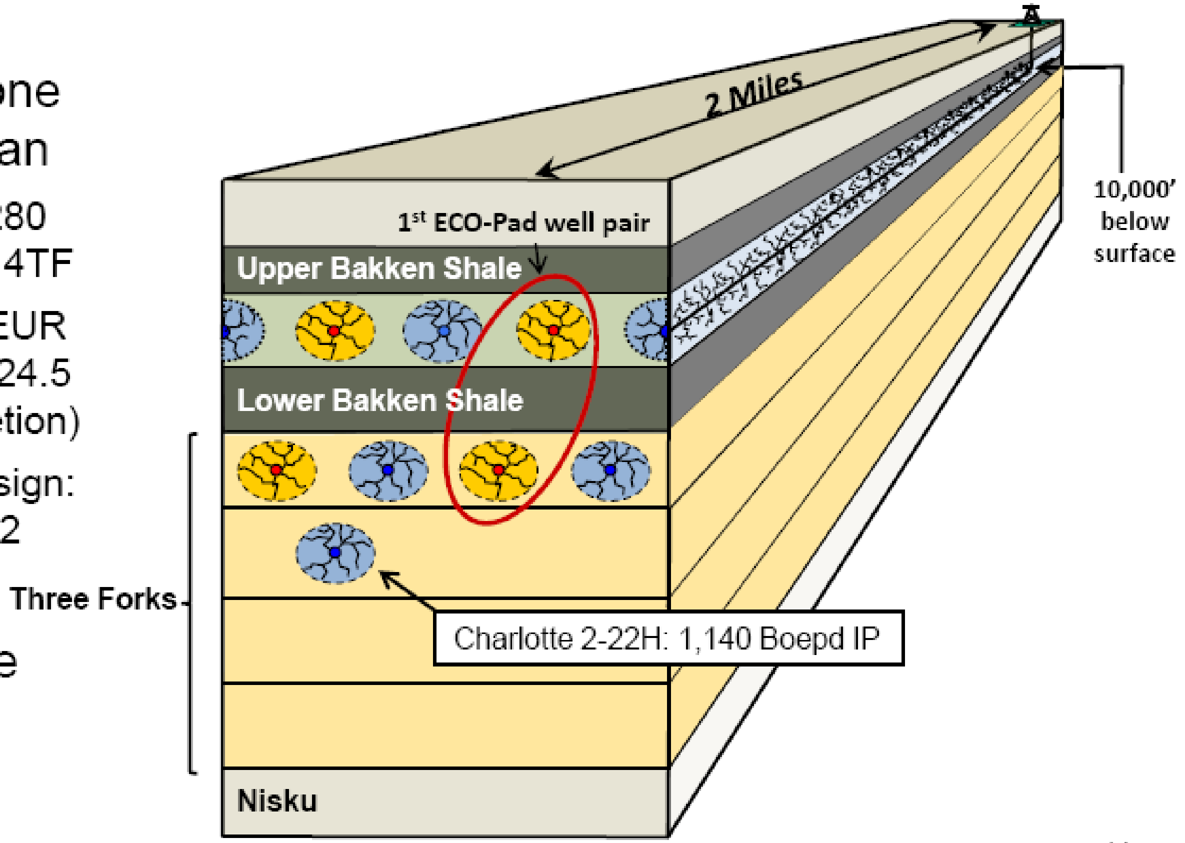


Current drilling activity is focused

in Mountrail, Dunn, McKenzie, and Williams Counties.

Bakken Development Plan

- Original dual-zone development plan
  - 8 wells per 1,280 acres – 4 MB, 4TF
  - 603,000 Boe EUR per well (avg. 24.5 stages/completion)
  - ECO-Pad® design: 2 wells south, 2 wells north
- Additional Three Forks potential



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ArcIMS Viewer

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: ArcIMS Viewer

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1280 Acre

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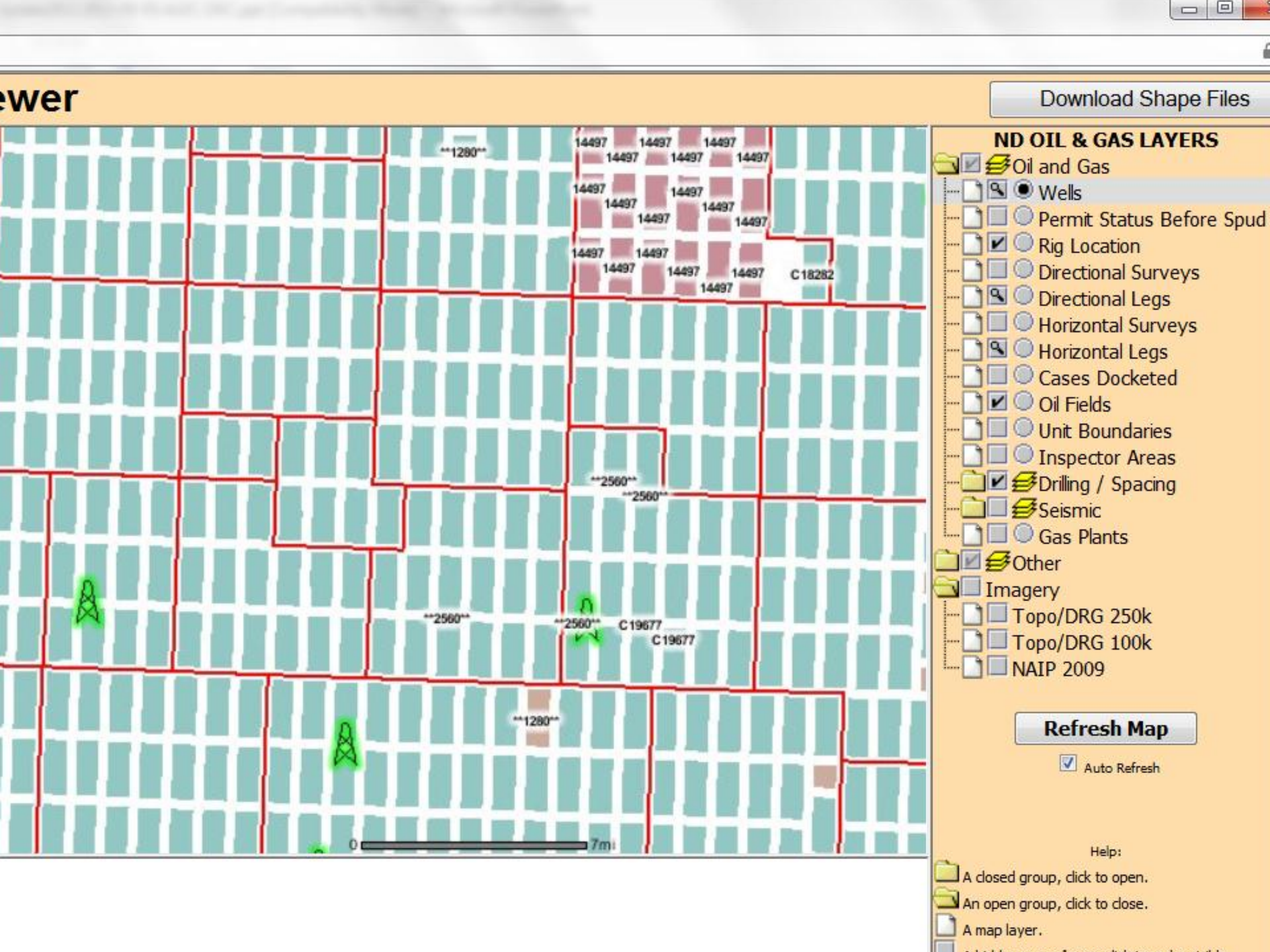
Bakken	1280	SPC		Thu, 5 Jun 2008 00:00:00	Mon, 8 Dec 2008 00:00:00			1280SPC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ND OIL & GAS LAYERS
Oil and Gas
Wells
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Rig Location
Directional Surveys
Directional Legs
Horizontal Surveys
Horizontal Legs
Cases Docketed
Oil Fields
Unit Boundaries
Inspector Areas
Drilling / Spacing
Seismic
Gas Plants
Other
Imagery
Topo/DRG 250k
Topo/DRG 100k
NAIP 2009
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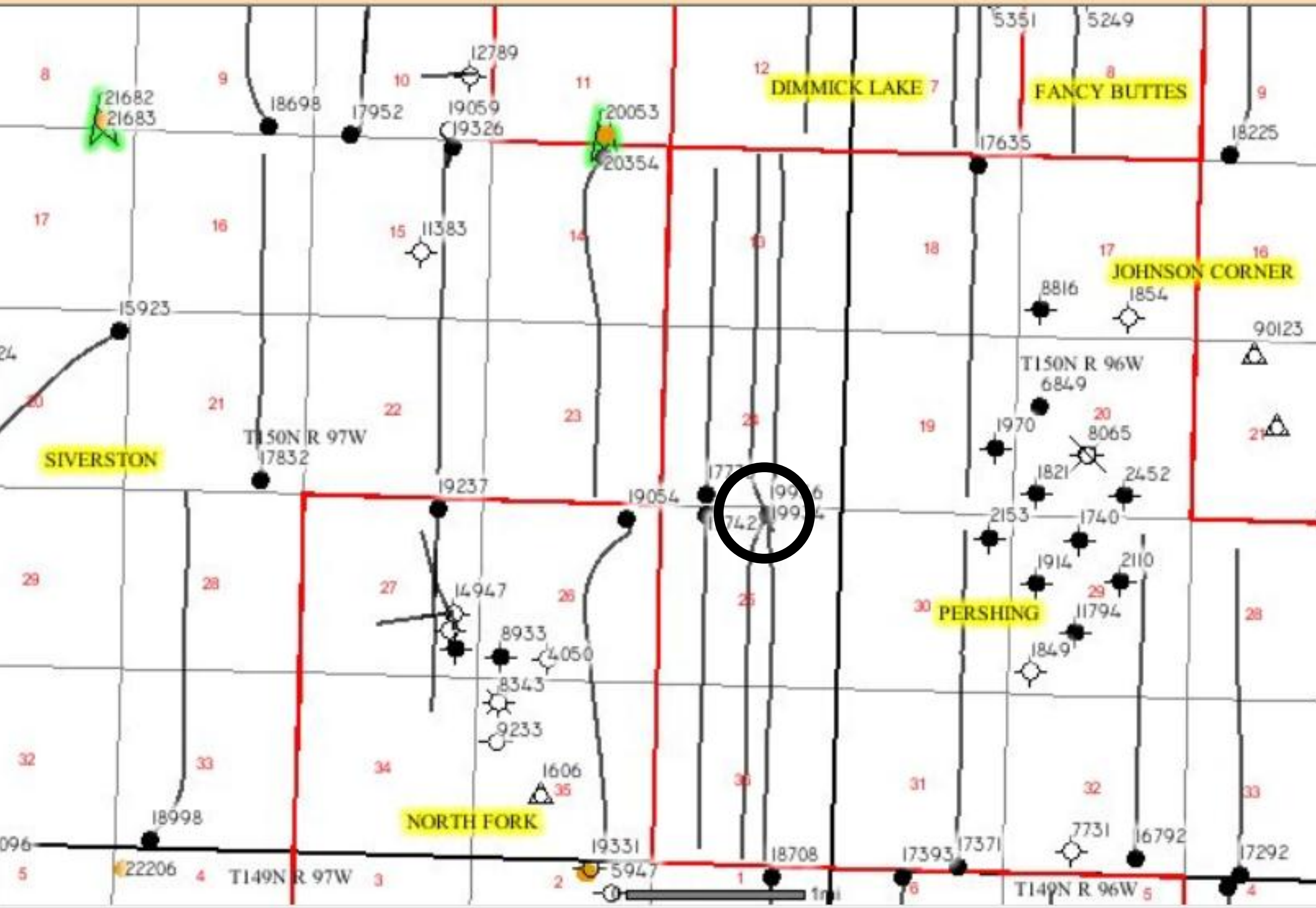

ND OIL & GA

Oil and Gas

Wells

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Vern Whitten Photography

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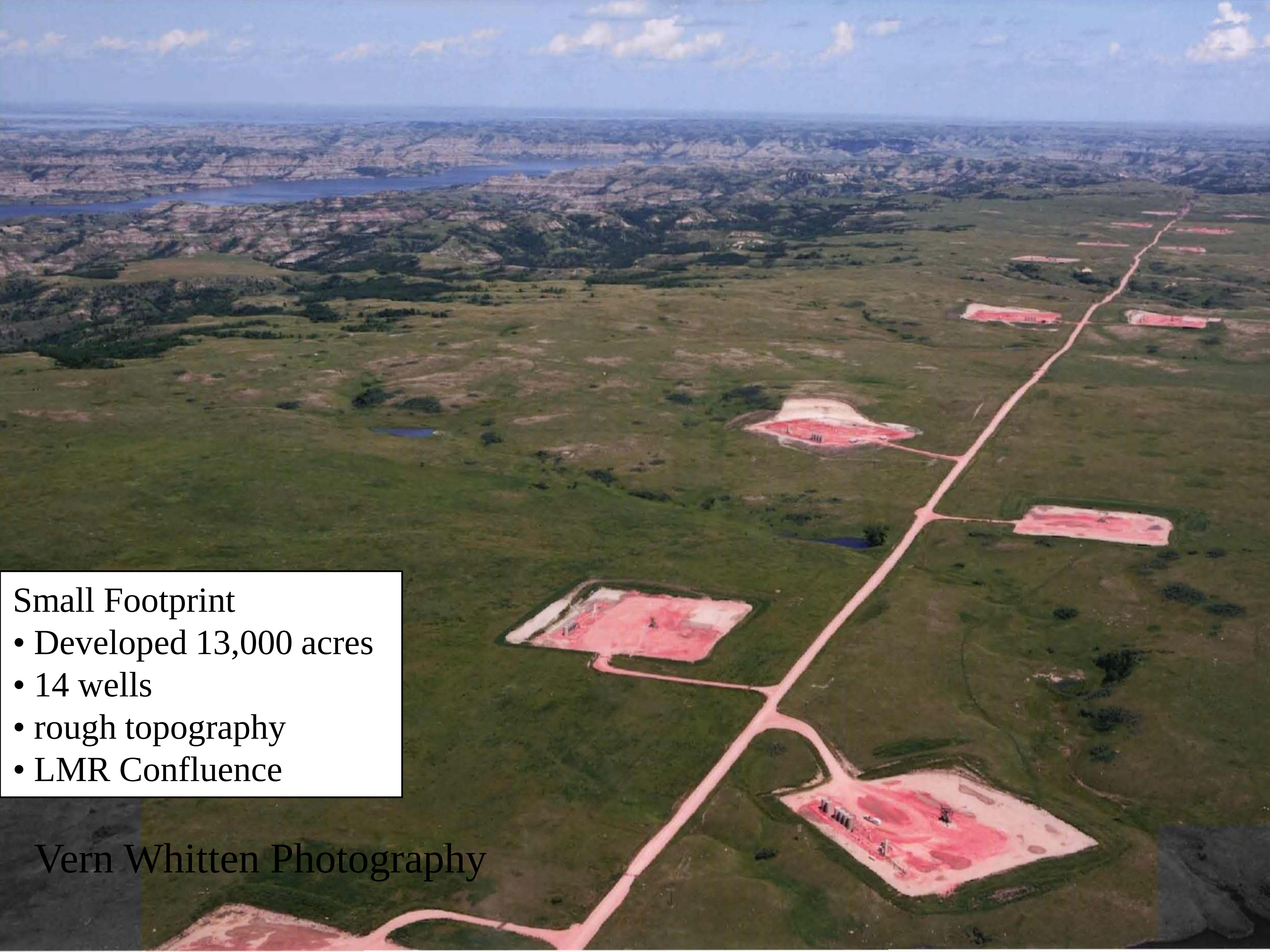
Small Footprint
• Developed 13,000 acres
• 14 wells
• rough topography
• LMR Confluence
Vern Whitten Photography

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Zoom In
Zoom Out
Pan
Rect Identify
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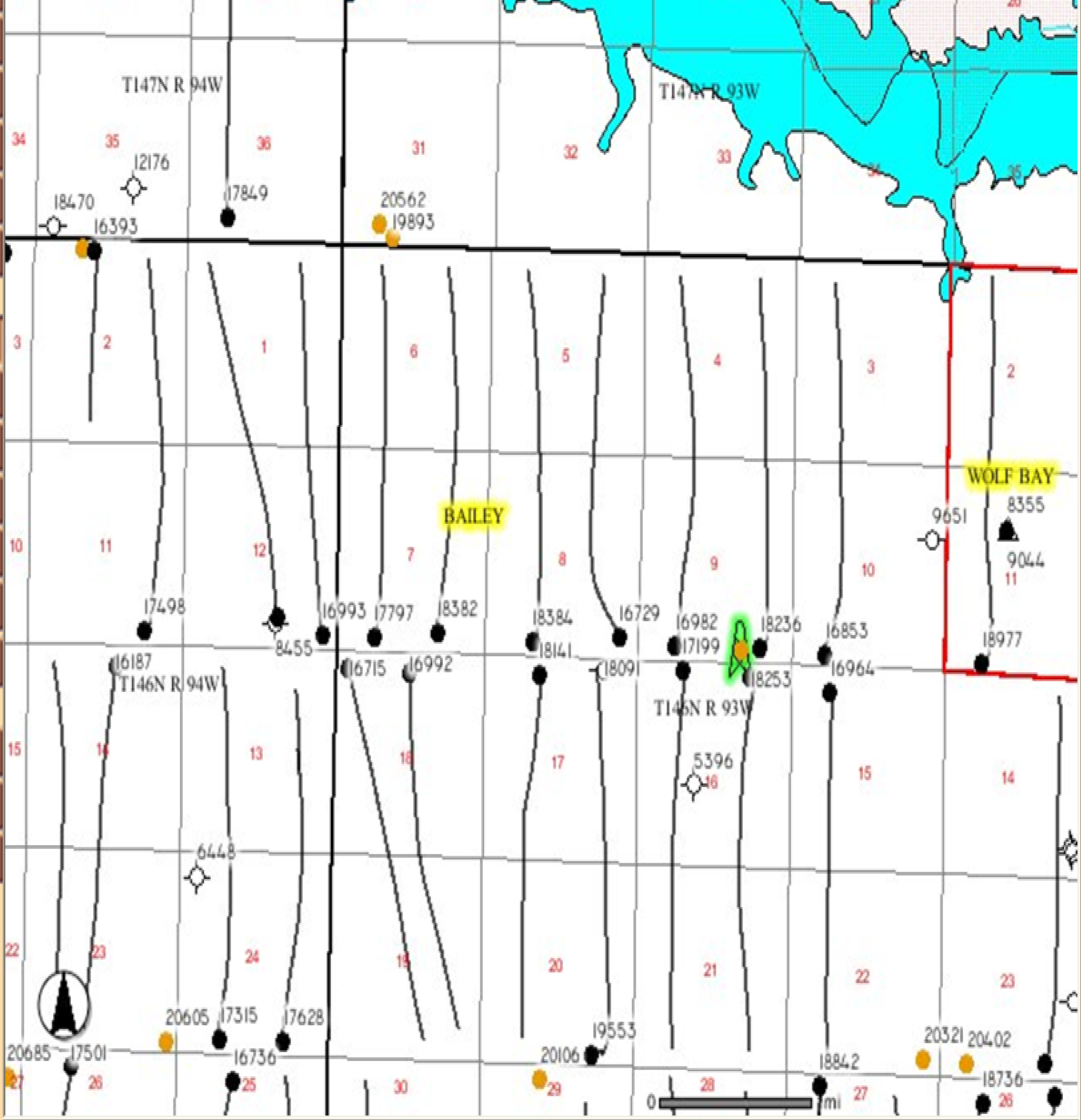
Distance

Find Well
nd Field/Unit
Find Section



Major Rivers
Selection cleared.

Wells
Rig Location
Directional Surveys
Directional Legs
Horizontal Surveys
Horizontal Legs
Cases Docketed
Oil Fields
Unit Boundaries
Inspector Areas
Drilling / Spacing
Seismic
Gas Plants
Other
Reservations
Corporate Boundaries
Rivers and Roads
County Roads
Major Roads
Major Rivers
Missouri River
Land Ownership
Imagery
Topo/DRG 250k
Topo/DRG 100k
NAIP 2009

Refresh Map

Auto Refresh

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Overview Map
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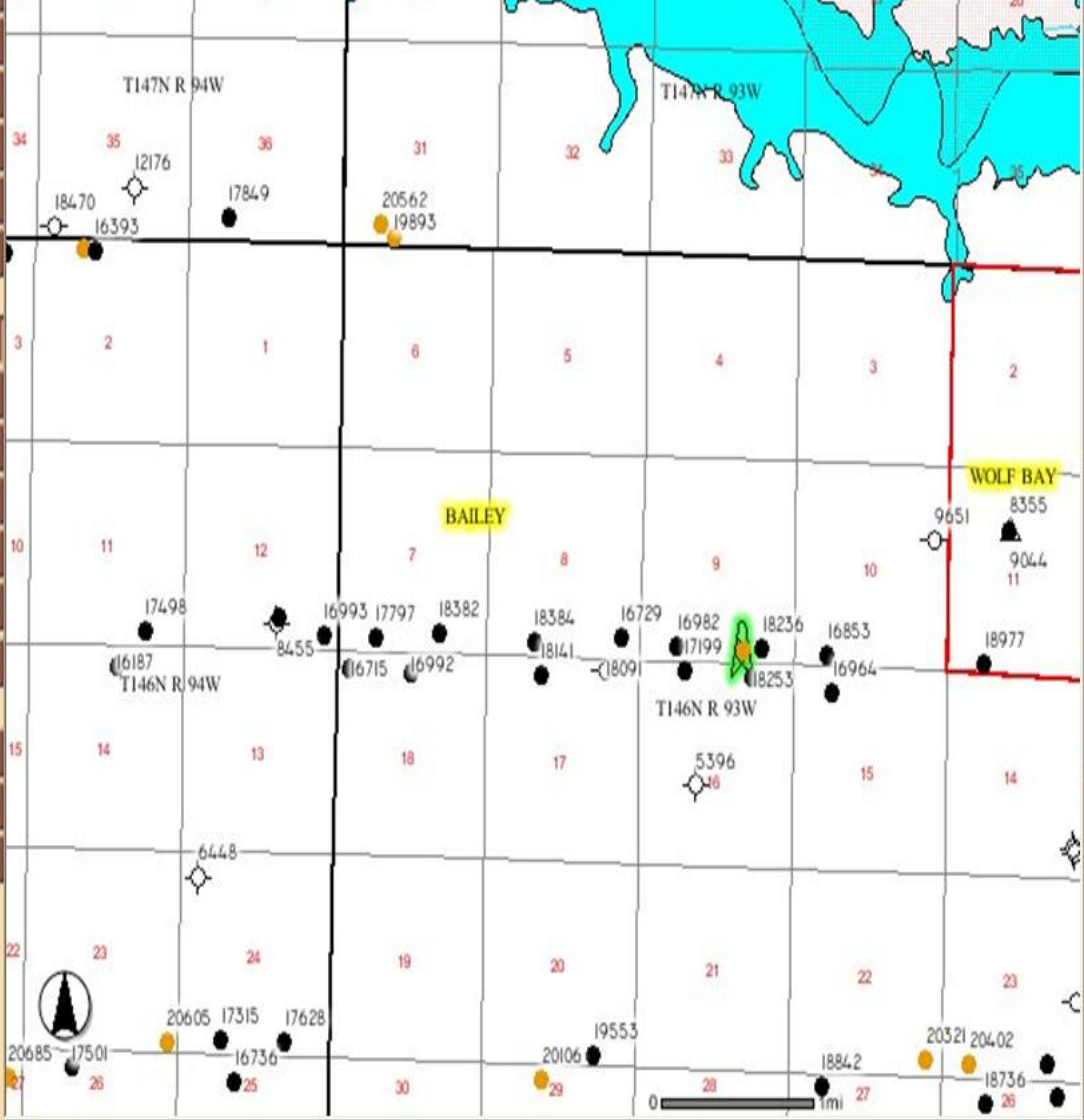
Find Well
nd Field/Unit
Find Section



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Thirsty Horizontal Wells

- 2,000 wells / year
- 15-25 years duration
- 20 million gallons water / day

Commission supports surface water use

- Lake Sakakawea best water resource
  - one inch contains 10 billion gal water
    - 5000 wells @ 2mil gal wtr/well
    - 2-year supply

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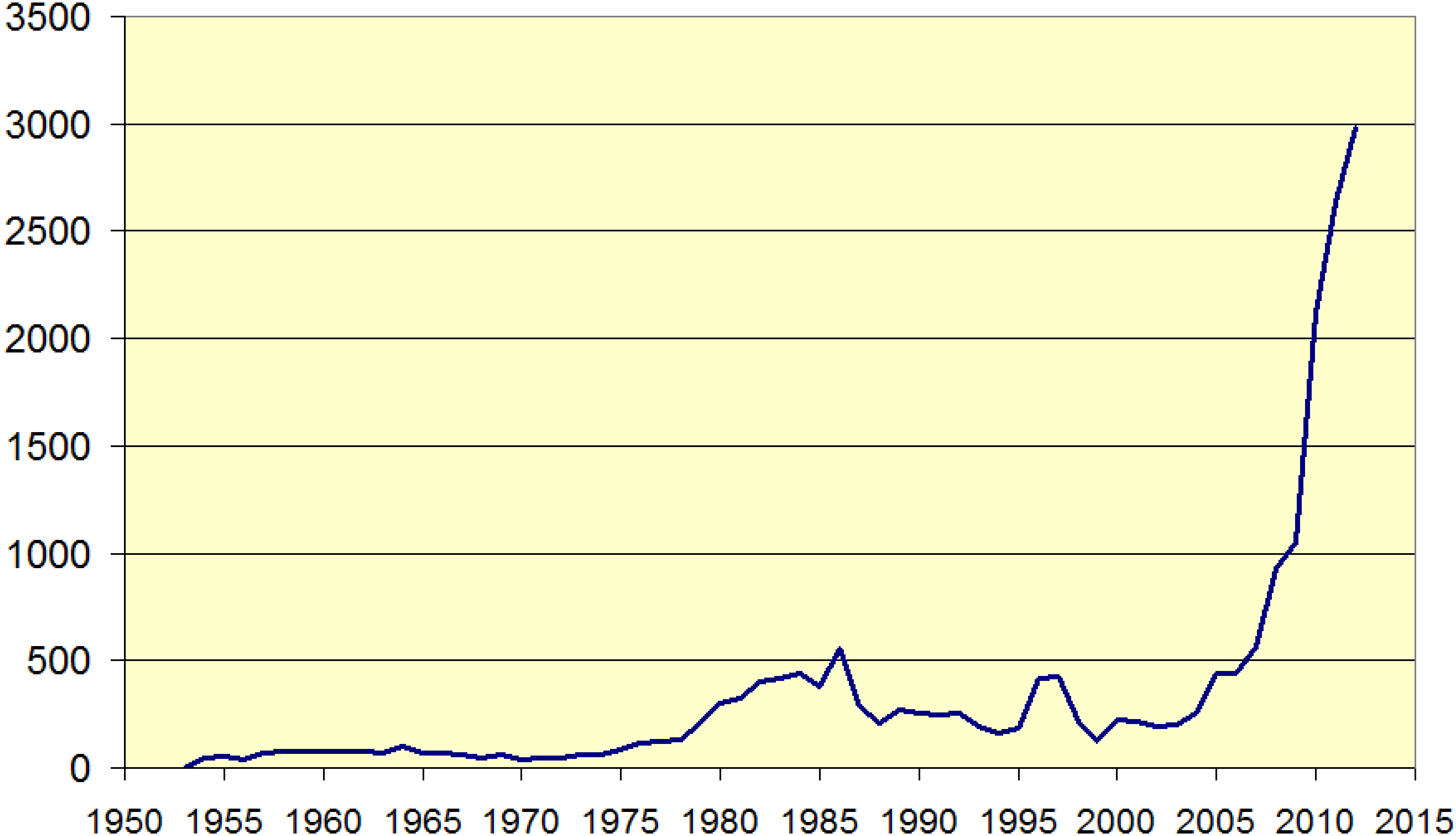
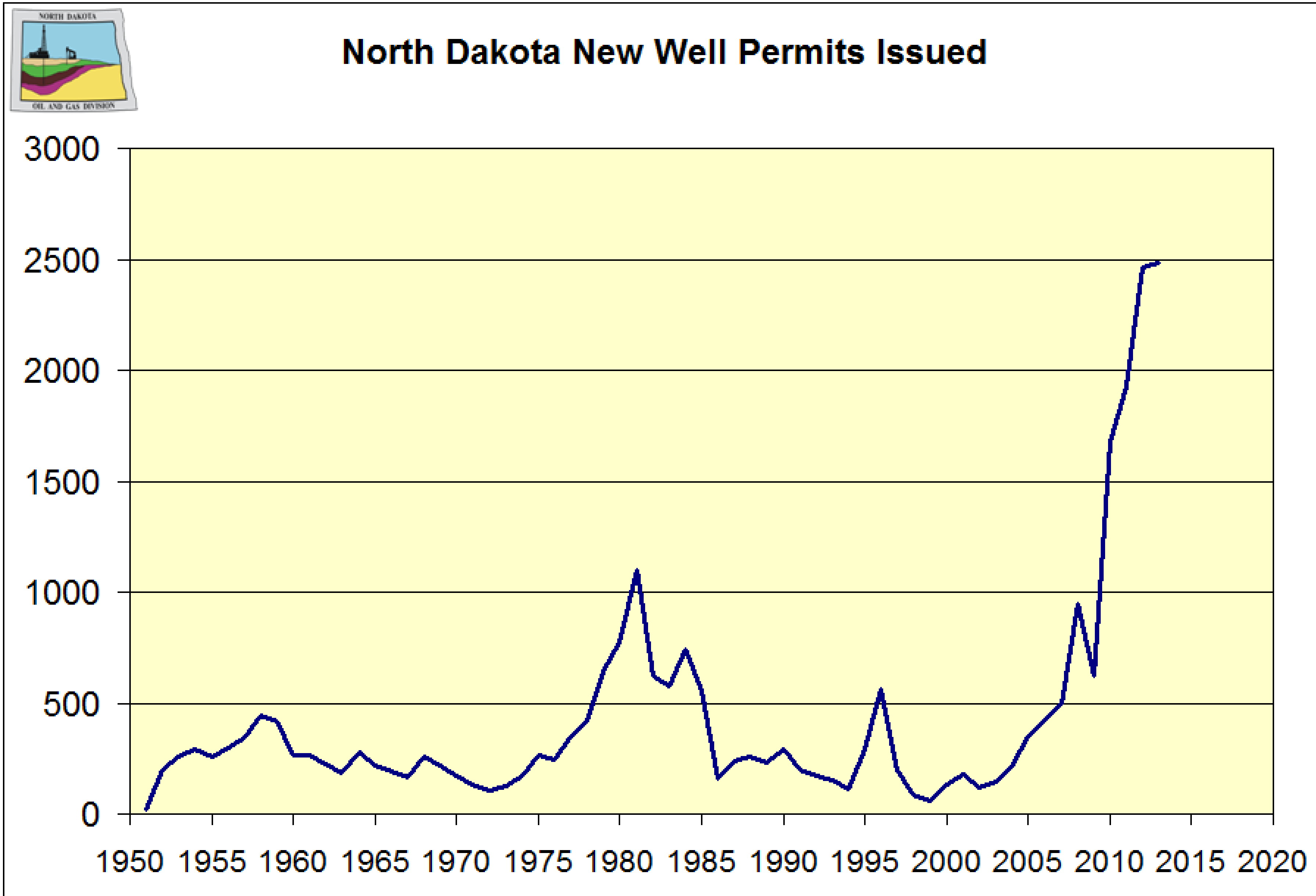
NORTH DAKOTA
OIL AND GAS DIVISION

North Dakota Industrial Commission Cases Heard




NORTH DAKOTA
OIL AND GAS DIVISION
North Dakota New Well Permits Issued
3000
2500
2000
1500
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500
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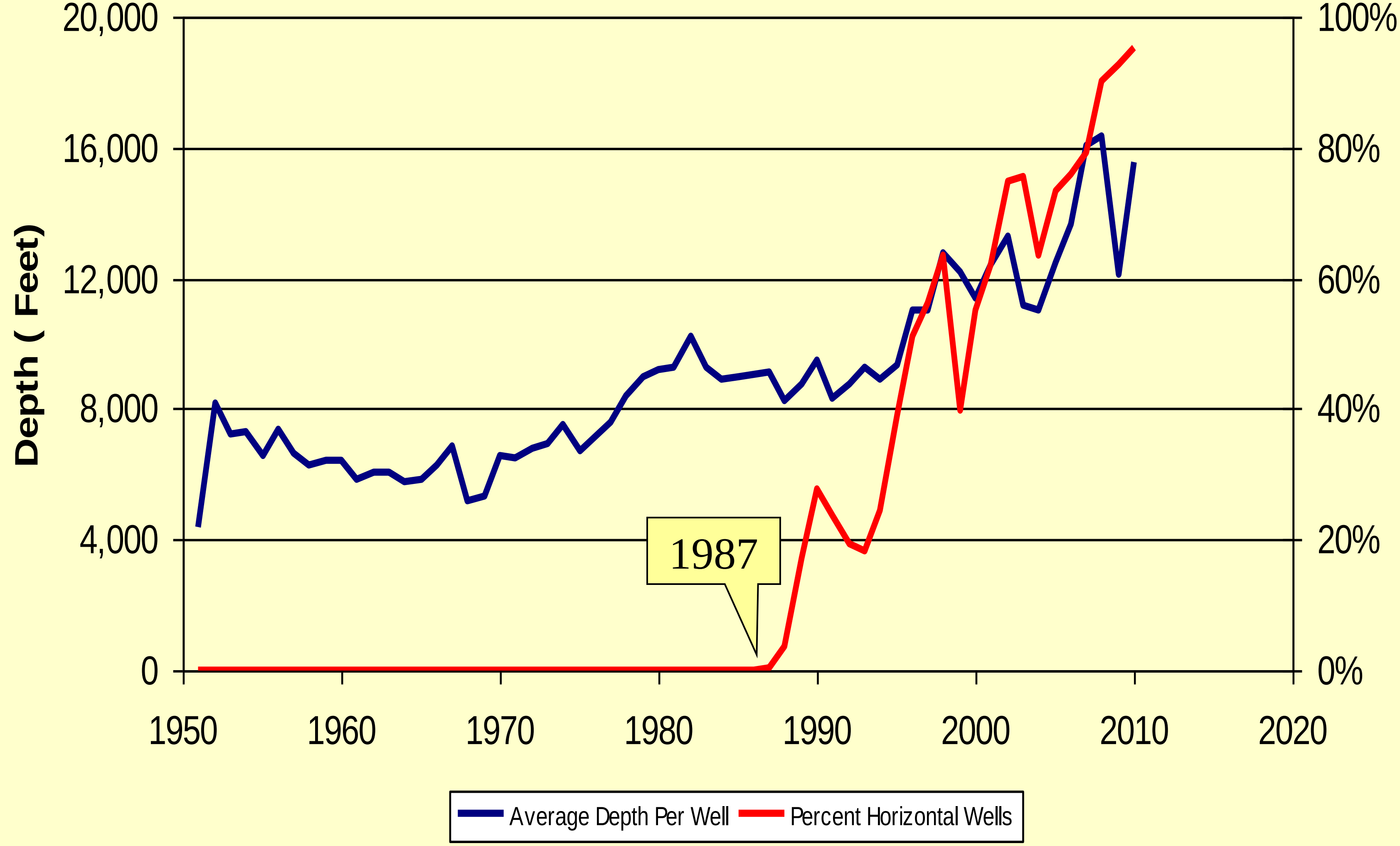
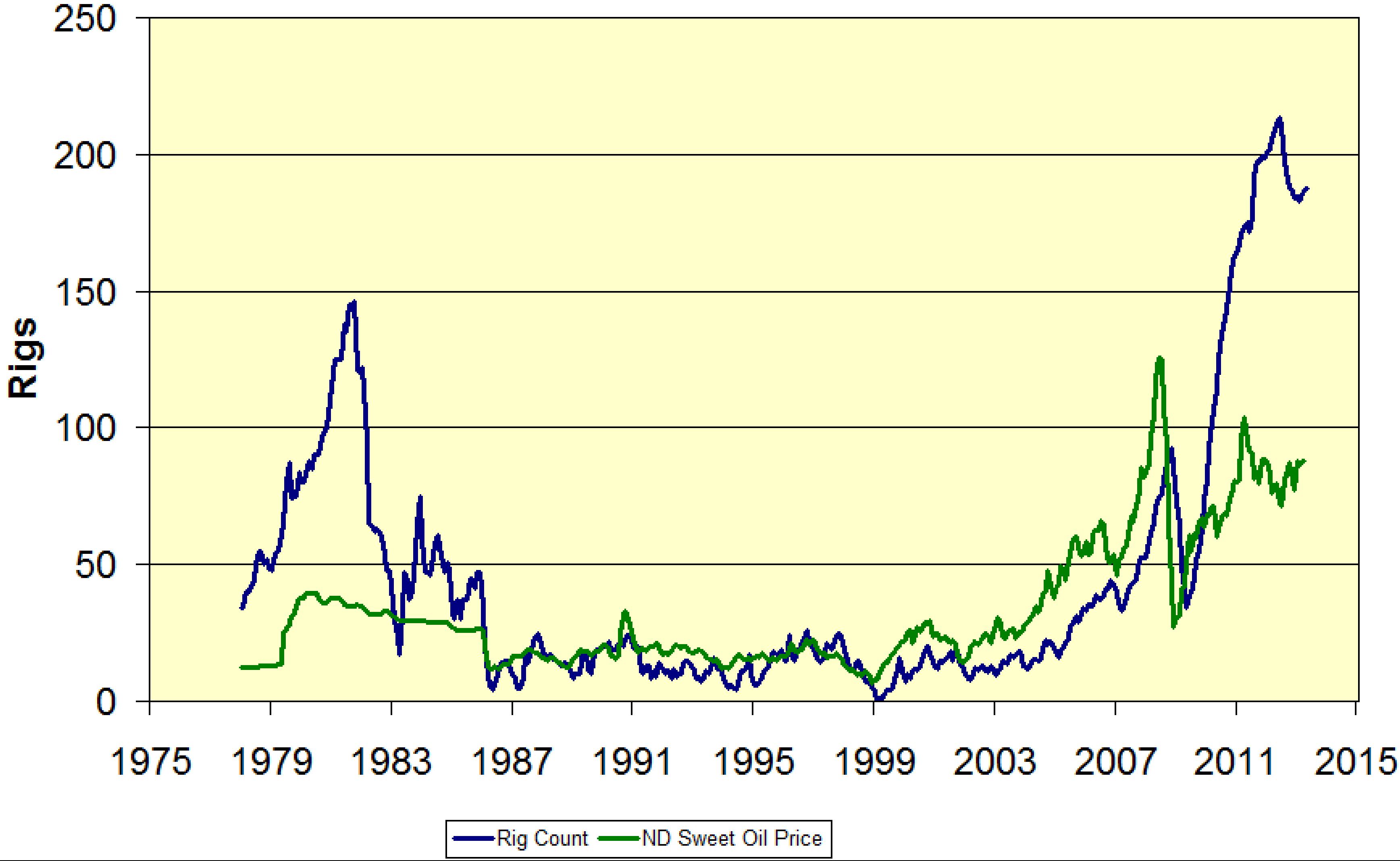
1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020

North Dakota Well Depth and % Horizontal



North Dakota Average Monthly Rig Count



RIGS

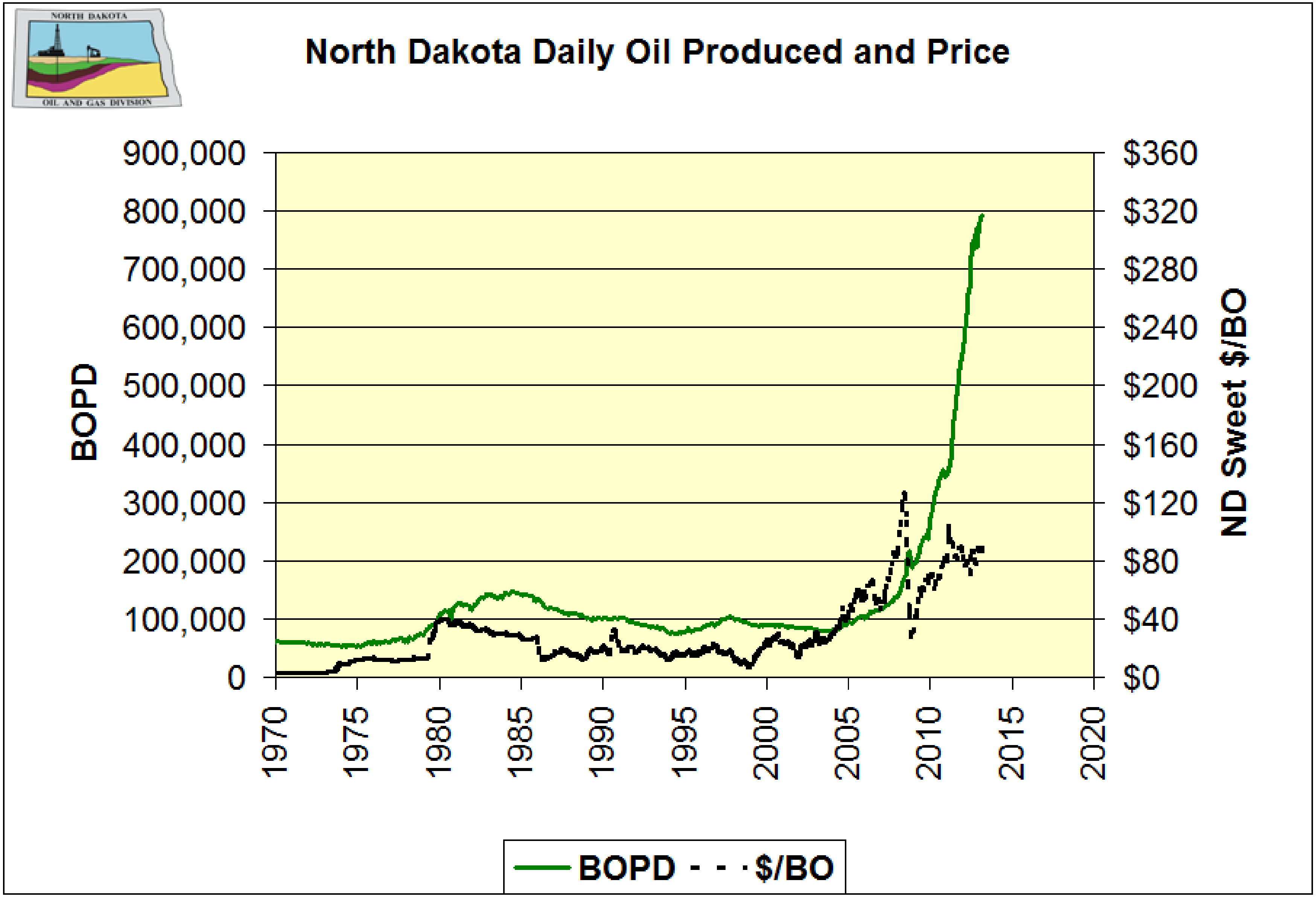
- 186 rigs currently
- 225 rigs - 2 years to secure leases
- 225 rigs – another 16 years f/5H/SU
- Declining rig count?
  - walking rigs replace inefficiencies
  - drilling more wells w/less rigs

WELLS

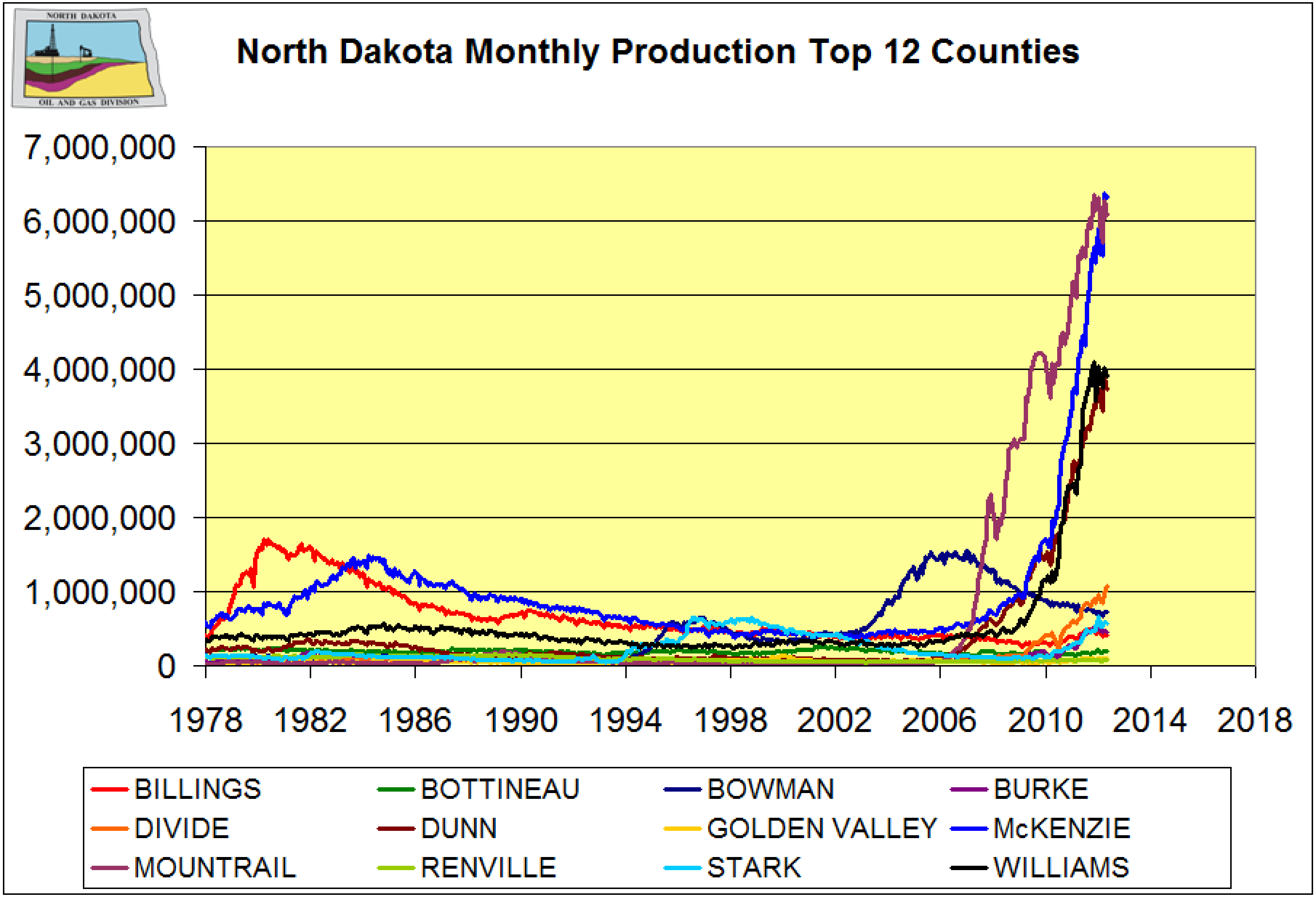
- 8,755 wells currently producing
  - 5,462 Bakken
  - 3,500 more to secure leases
- 40,000 additional development wells
  - 225 rigs – another 16 years
  - 100 rigs – another 30 years
- Bakken Pool – 4 targets

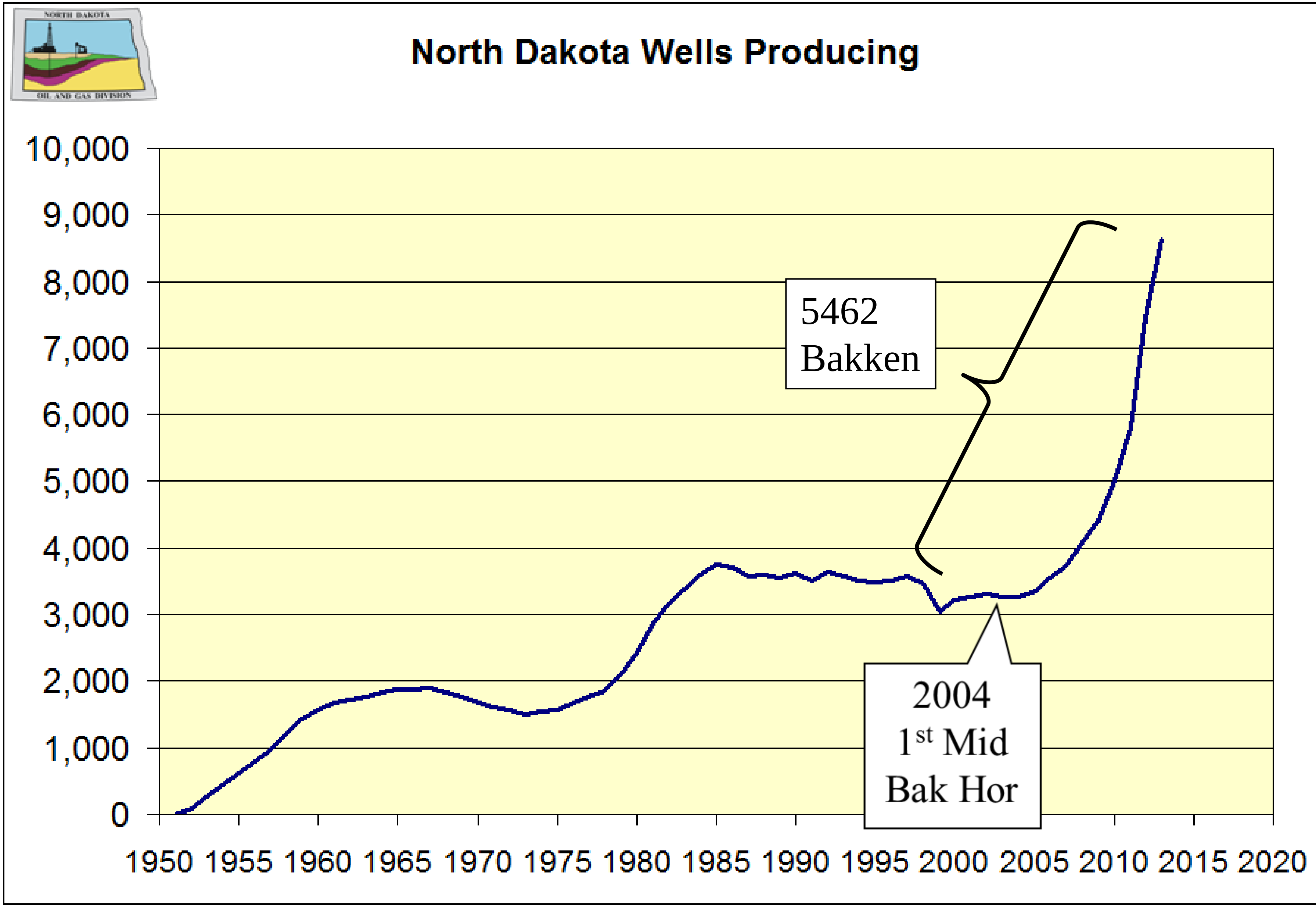
Typical 2012 Bakken well

- **45-year well life**
- **615,000 barrels of oil**
- **$9 million to drill and complete**
- **$20 million net profit**
- **$4 million in taxes**
- **$7 million in royalties**
- **$2 million in wages**
- **$2 million in operating expenses**

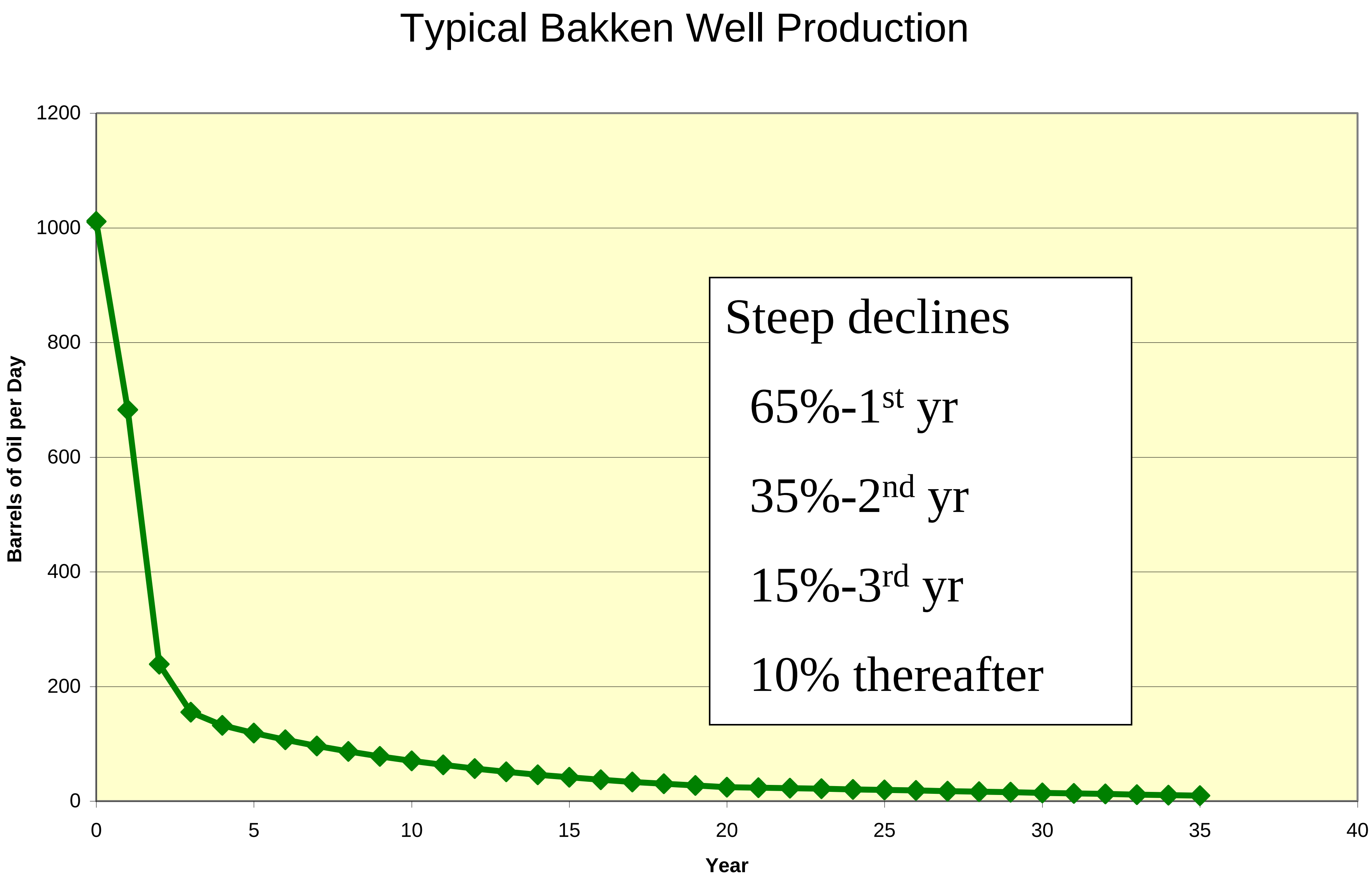


Production 793,216 bopd (appr 719,050 from Bakken—91%)


NORTH DAKOTA
OIL AND GAS DIVISION
North Dakota Monthly Production Top 12 Counties
7,000,000
6,000,000
5,000,000
4,000,000
3,000,000
2,000,000
1,000,000
0
1978
1982
1986
1990
1994
1998
2002
2006
2010
2014
2018
BILLINGS
BOTTINEAU
BOWMAN
BURKE
DIVIDE
DUNN
GOLDEN VALLEY
McKENZIE
MOUNTRAIL
RENVILLE
STARK
WILLIAMS

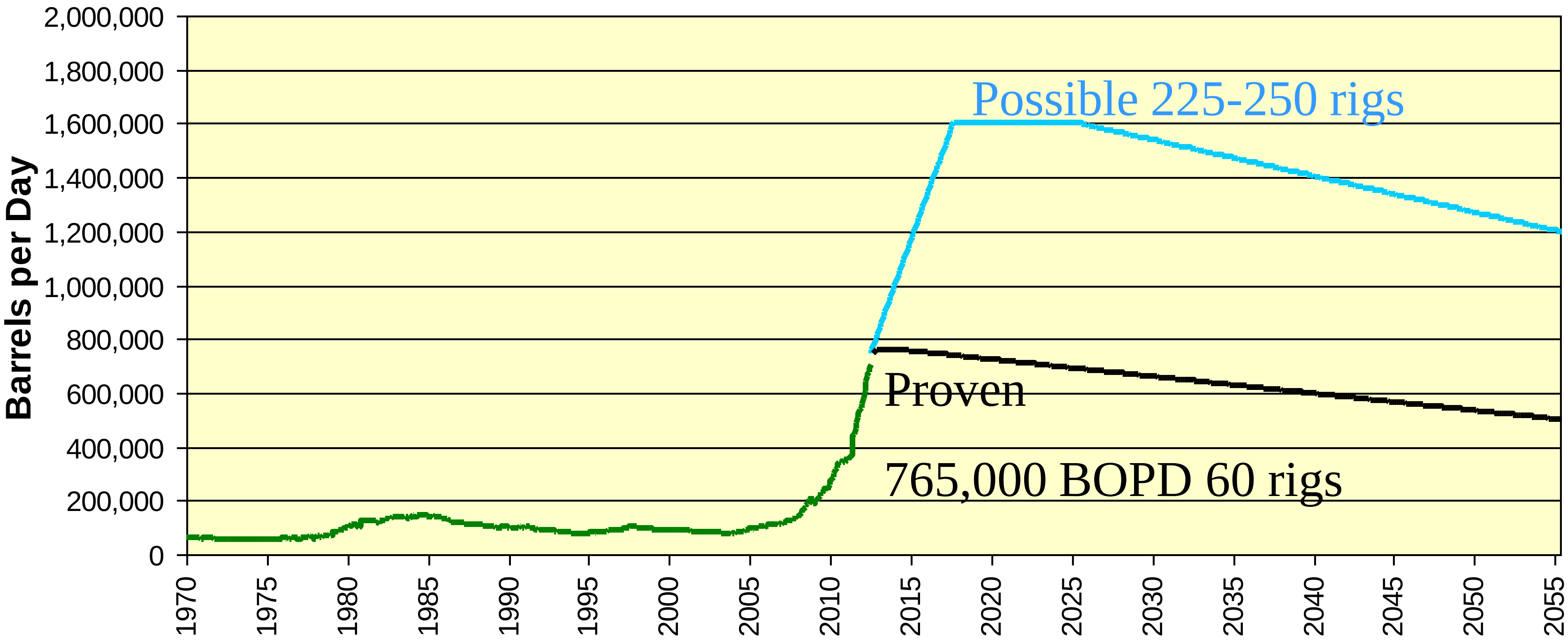


8755 total wells – 5462 Bakken horizontal (62.4%)



Typical Bakken Well Production
1200
1000
800
600
400
200
0
Barrels of Oil per Day
0
5
10
15
20
25
30
35
40
Year
Steep declines
65%-1st yr
35%-2nd yr
15%-3rd yr
10% thereafter

North Dakota Oil Production



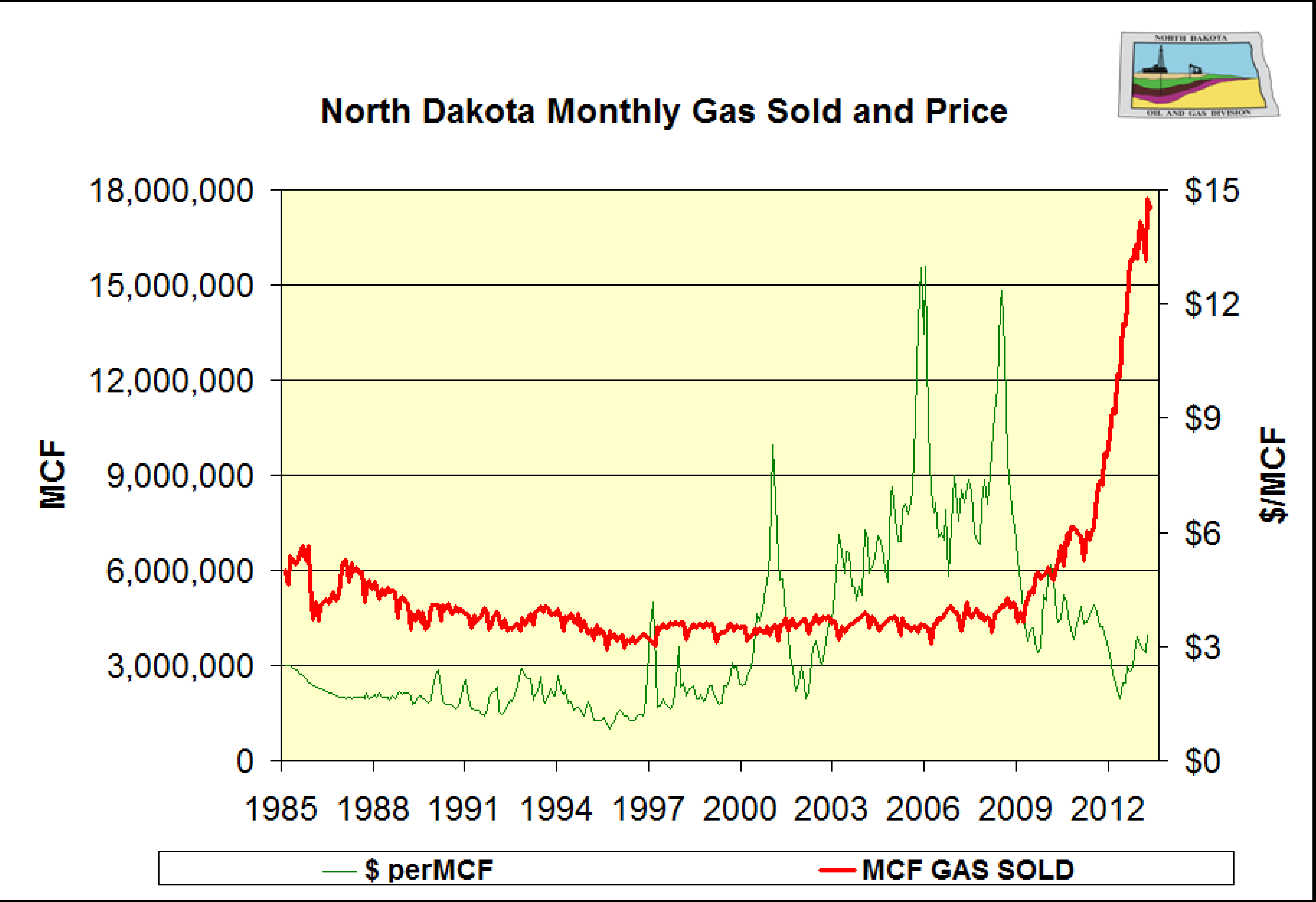
5,462 Bakken and Three Forks wells drilled and completed

35,000 - 40,000 more new wells possible in thermal mature area

History — Bakken - Three Forks P10 — Bakken - Three Forks P90

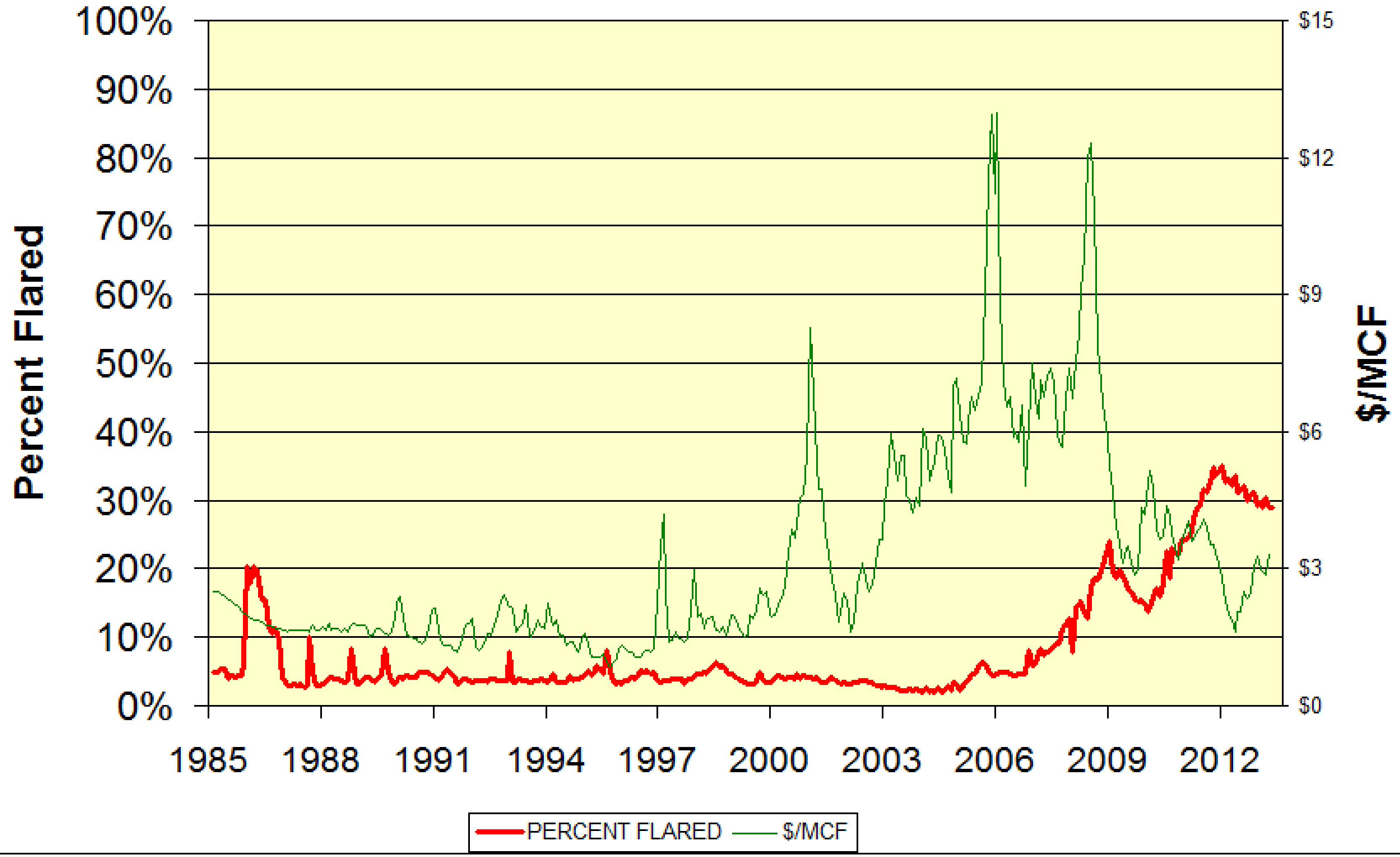
ASSOCIATED GAS

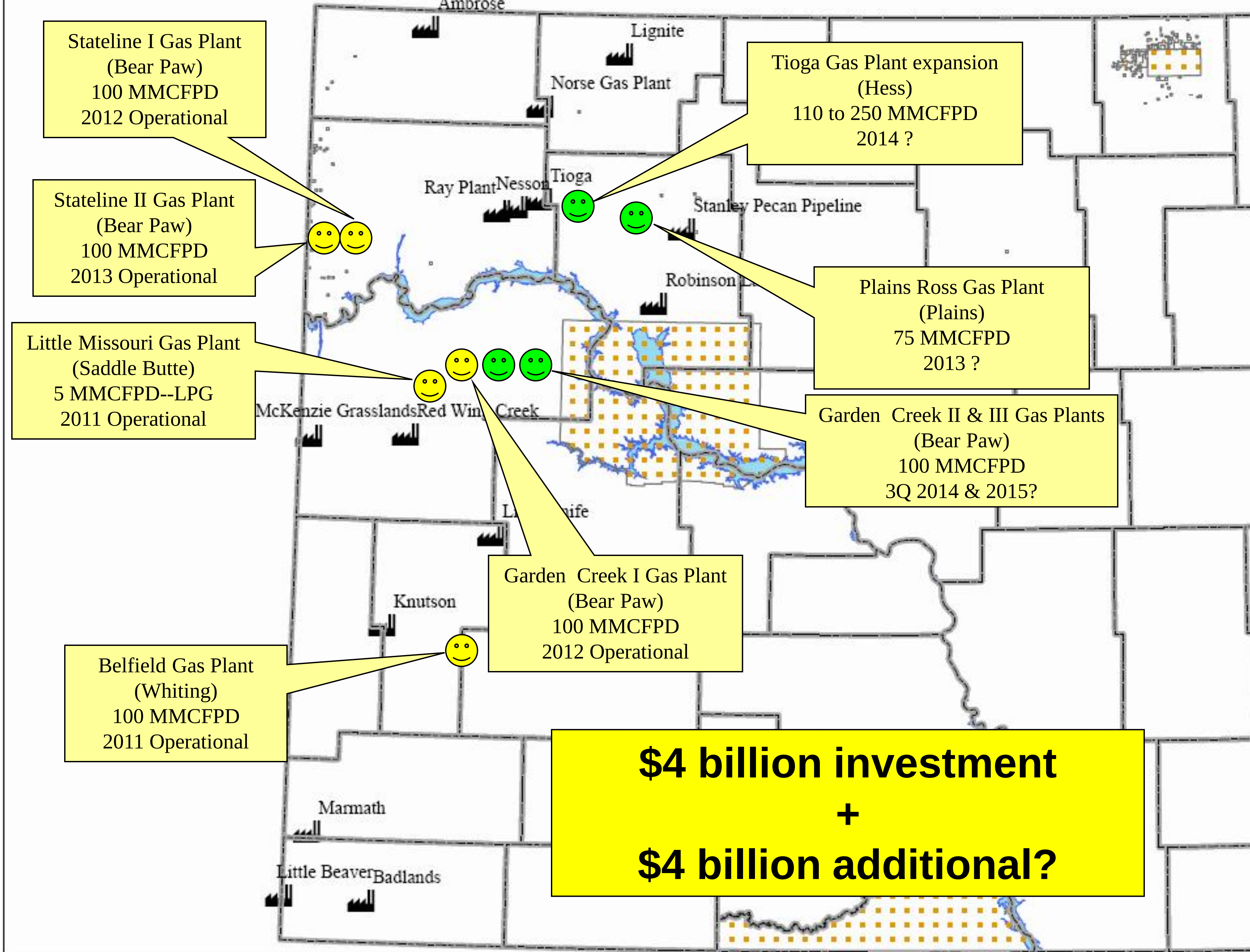
- Current gas plant cap exceeds prod
  - no infrastructure
  - infrastructure bottlenecks
- $4 billion investment in gas
  - must justify expendatures
  - 4 new plants recently online
  - 4 new + one expansion planned
  - compressor upgrades



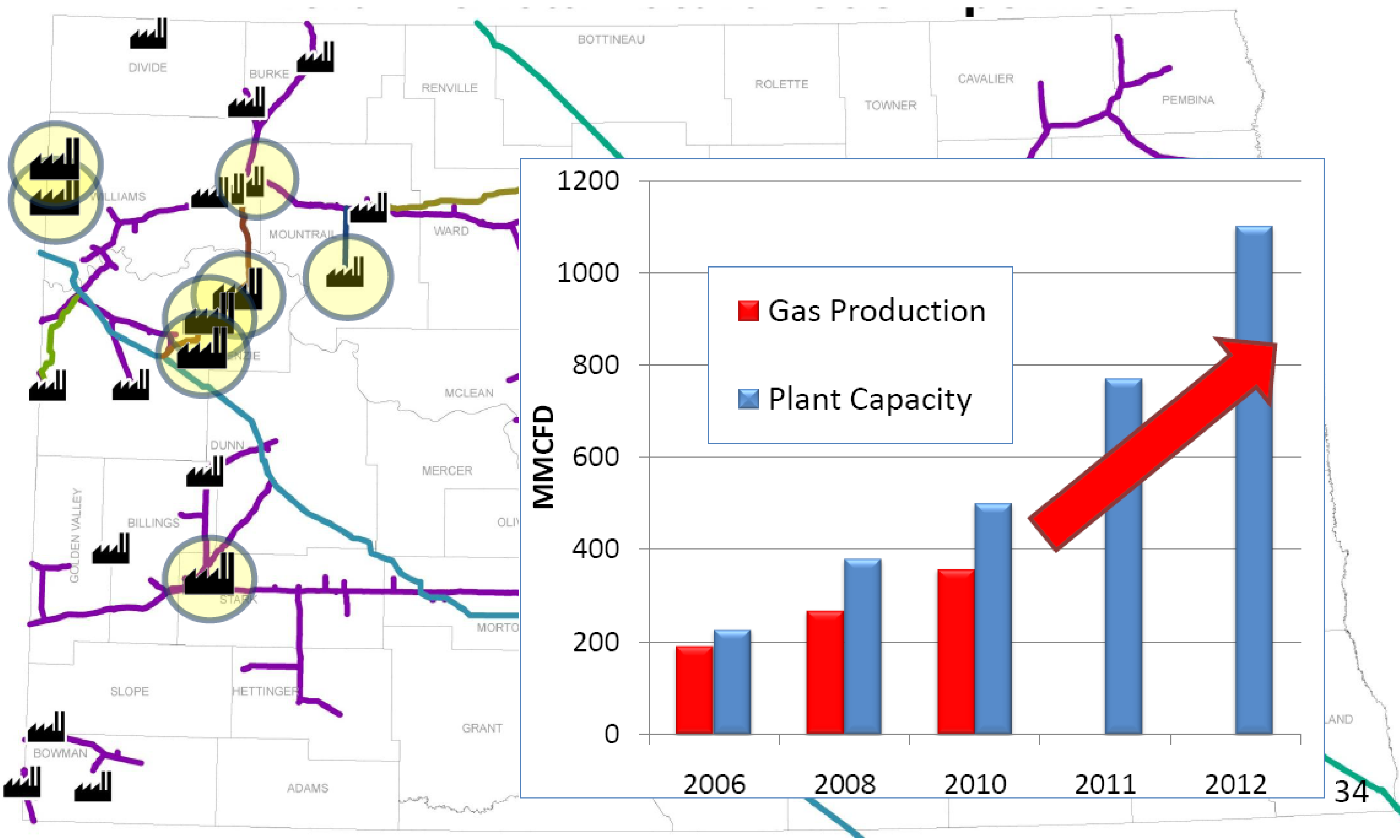
North Dakota Monthly Gas Sold and Price
NORTH DAKOTA
OIL AND GAS DIVISION
18,000,000
15,000,000
12,000,000
9,000,000
6,000,000
3,000,000
0
MCF
$15
$12
$9
$6
$3
$0
$/MCF
1985
1988
1991
1994
1997
2000
2003
2006
2009
2012
$ perMCF
MCF GAS SOLD

North Dakota Monthly Gas Flared

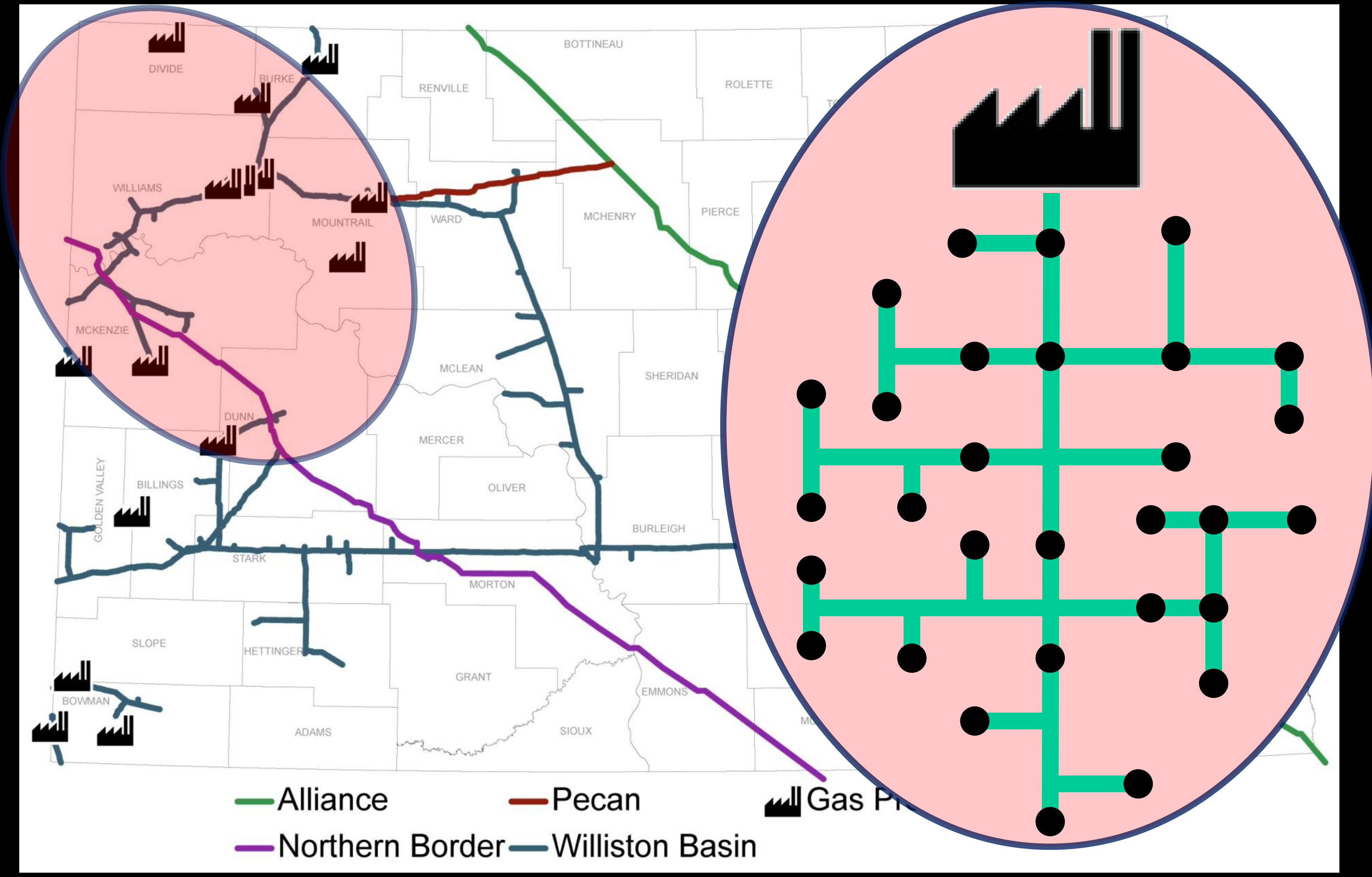


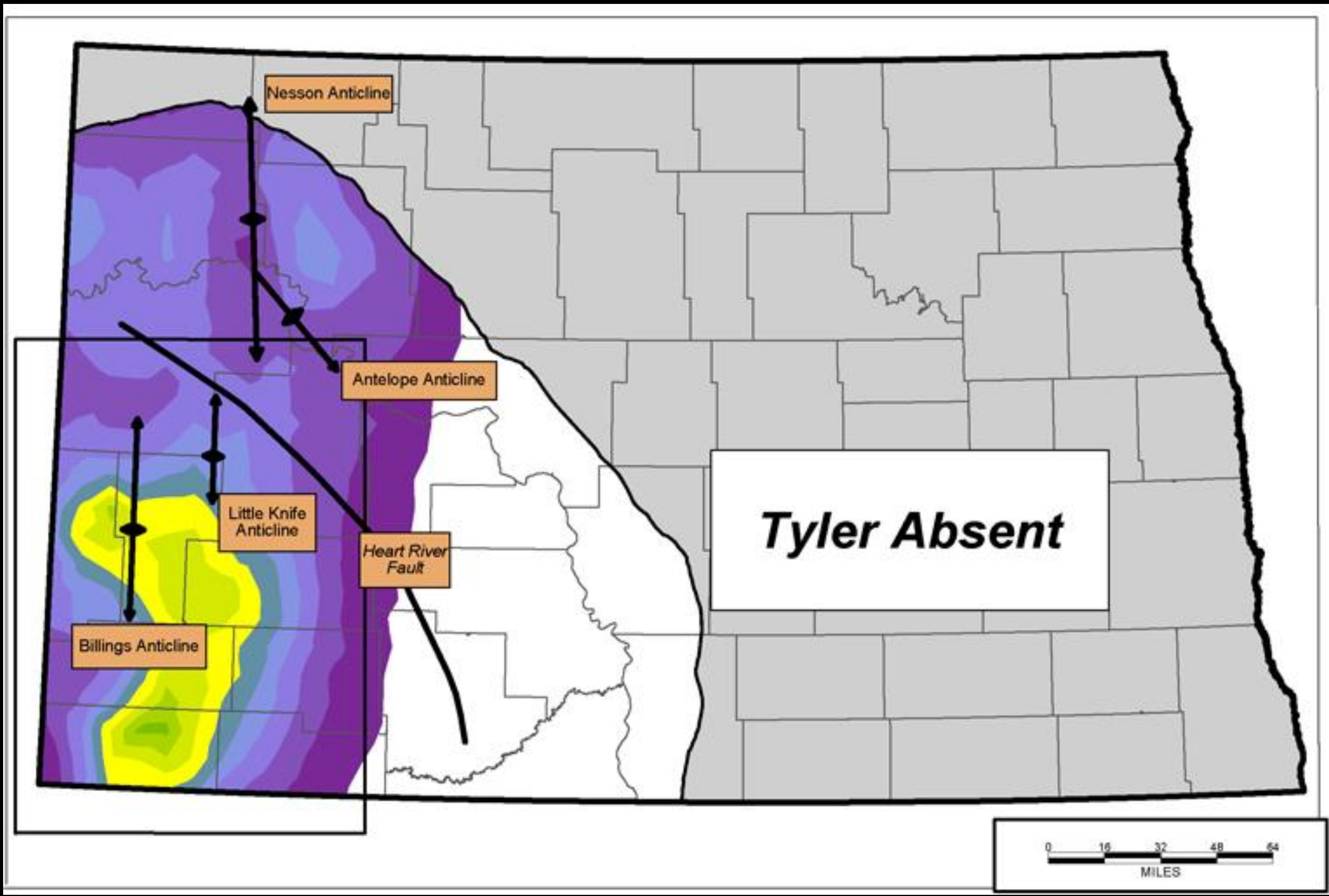

Stateline I Gas Plant
(Bear Paw)
100 MMCFPD
2012 Operational
Stateline II Gas Plant
(Bear Paw)
100 MMCFPD
2013 Operational
Little Missouri Gas Plant
(Saddle Butte)
5 MMCFPD--LPG
2011 Operational
Belfield Gas Plant
(Whiting)
100 MMCFPD
2011 Operational
Garden Creek I Gas Plant
(Bear Paw)
100 MMCFPD
2012 Operational
Tioga Gas Plant expansion
(Hess)
110 to 250 MMCFPD
2014 ?
Plains Ross Gas Plant
(Plains)
75 MMCFPD
2013 ?
Garden Creek II & III Gas Plants
(Bear Paw)
100 MMCFPD
3Q 2014 & 2015?
Lignite
Norse Gas Plant
Ray Plant
Tioga
Stanley Pecan Pipeline
Robinson
McKenzie Grasslands
Knutson
Marmath
Little Beaver
Badlands
$4 billion investment
+
$4 billion additional?

New or Expanding Gas Plants



Natural Gas Challenges





Nesson Anticline
Antelope Anticline
Little Knife Anticline
Heart River Fault
Billings Anticline
Tyler Absent
0
16
32
48
64
MILES

North Dakota Geological Survey
Geologic Investigations No. 127

RESOURCE POTENTIAL OF THE TYLER FORMATION

Stephan H. Nordeng and Timothy O. Nesheim

Edward C. Murphy, State Geologist
Lynn D. Helms, Director Dept. of Mineral Resources
2010

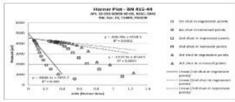


Figure 1. Horner plot of pressures measured during the shut-in periods of an open hole drill stem test (DST) of the Tyler Formation (8180-8282 ft. M.D.) in Pennzoil Co. & Depco's BN#15-44 (Figure 5, #6848). The extrapolated shut in pressures (Horner, 1951) from the 2nd and 3rd shut in periods of the DST indicate that the Tyler formation fluid pressure is ~4525 psi at a depth of 8230 ft., which yields a pressure gradient (0.55 psi/ft.) above the expected hydrostatic pressure range (0.43-0.46 psi/ft.). The 1st shut-in period did not reach "steady-state" conditions and therefore does not yield a reliable extrapolated formation pressure. The fluid recovered in this test was 354' of gas cut mud. This well was spudded on February 2nd, 1979 (DST run on March 18th, 1979) in the Flat Top Butte field, where only one well produced just 446 bbls of oil from the Tyler-Heath Formation over a four month period in 1960 (Texaco Inc.'s Mary Pace #1; API: 33-053-00461-00-00; NDIC: 2667; Sec. 14, T146W, R101W). There is no record of injection within the Flat Top Butte field.

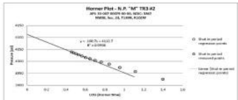


Figure 2. Horner plot of pressures measured during the shut-in period of an open hole drill stem test (DST) of the Tyler Formation (7743-7776 ft. M.D.) in Amerada Petroleum Corp.'s N.P. "M" TR# #2, shown on Figure 5 by #3867. Both the maximum pressure recorded (4039 psi = 0.52 psi/ft.) and the extrapolated formation pressure (4112.7 psi = 0.53 psi/ft.) are above the hydrostatic pressure range expected for the depth tested (3300-3560 psi = 0.43-0.46 psi/ft.). The DST fluid recovery was 2.5 BBLS oil, reversed out 69.54 BBLS oil. Cumulative production for this well was 1,440,113 BBLS of oil. This well was spudded on May 2nd, 1965 (DST run on May 15th, 1965) in the Medora field, where initial production began in June, 1964 and initial injection in February, 1970.

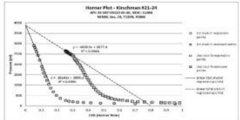
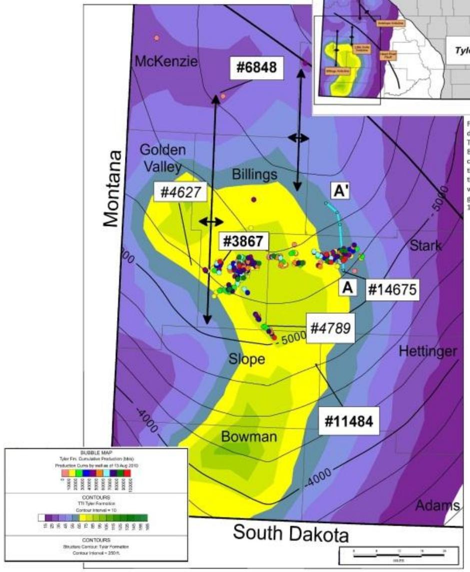


Figure 3. Horner plot of pressures measured during the shut in periods of a conventional bottom hole drill stem test (DST) on the Tyler Formation (7540-7556 ft. M.D.) in Milestone Petroleum's Kirschman #21-24, shown on Figure 5 by #11484. The calculated fluid pressure of the Tyler formation (the average of the extrapolated pressures from the two DST shut in periods) is ~3883 psi at a depth of 7545 ft., which yields a pressure gradient (0.51 psi/ft.) above the hydrostatic pressure expected for this depth (0.43-0.46 psi/ft.). The DST fluid recovered was 0.03 bbls of oil and 0.48 bbls of water. Kirschman #21-24 was a wildcat well drilled outside areas of production and injection for the Tyler Formation.



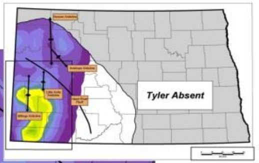


Figure 6. Time-Temperature Index map of the Pennsylvanian Tyler Formation in the Williston Basin of North Dakota. The color-filled contours represent the Time Temperature Index of the Tyler Formation. Areas in which the Tyler is absent are in gray (modified from Anderson, 1974).

Figure 5. Detail map showing the distribution of Tyler production (Total Bbls) in North Dakota together with Time-Temperature contours and the location of wells from which pressure gradients (#6848, #3867, #11484) and Rock Eval data (#4627, #4789) were obtained. The color-filled contours represent the Time-Temperature Index of the Tyler Formation and are keyed to the color bar located in the lower left corner. Shades of yellow and green (>65) represent the TTIs that correspond with the oil window. TTIs less than 65 and above 15 are in shades of blue and purple and represent conditions that could generate oil. This map lies within the black outline on Figure 6. Cumulative production from the Tyler Formation (barrels oil) is represented by the color of the circles centered on the wells that have and/or are producing oil from the Tyler Formation. The solid contour lines on the detail map represent the mean sea level elevation of the top of the Tyler Formation.

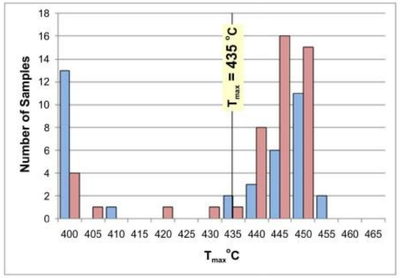


Figure 7. A frequency diagram showing that most of the samples of the Tyler Formation collected from the Government Taylor A-1 (#4627) in red, and the State of North Dakota #41-36 (#4789) in blue, have been thermally matured beyond the threshold that marks the onset of oil generation (Tmax ~435oC).

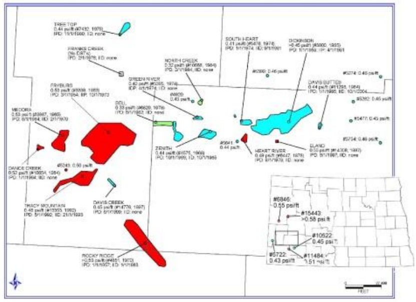


Figure 8. Field map showing the producing Tyler Fields in southern Billings, Slope, and Stark counties. For each field the Initial Pressure Gradient (IPG), Initial Production Date (IPD), and Initial Injection Date (IID) are given. Fields with evidence of initial fluid overpressure in the Tyler are colored in red, fields that were initially at hydrostatic pressure are colored in blue, and fields that were underpressured prior to production are colored green. Most of the western Tyler fields all contain evidence of overpressuring prior to injection with the exception of Davis Creek. The eastern Tyler fields were at or below hydrostatic pressure, with the exception of the Heart River and Eland fields. Field boundaries are approximate. In the bottom right corner is an index map of North Dakota showing the Tyler DST's of interest with their NDIC well numbers that are located outside the main area of Tyler production. DST results indicate that the Tyler Formation is over-pressured in three wells and at hydrostatic pressure within two wells outside the area of main production.

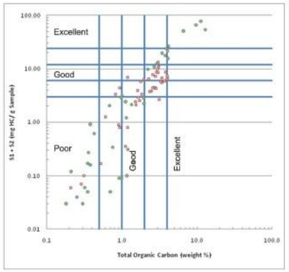


Figure 9. A kerogen quality diagram (Dembicki, 2009) constructed from the Total Organic Carbon (TOC) versus the mass of existing (S1) and potential (S2) hydrocarbons contained in samples of the Tyler Formation. The samples are from the Government Taylor A-1 (green circles) and the State of North Dakota #41-36 (red squares).

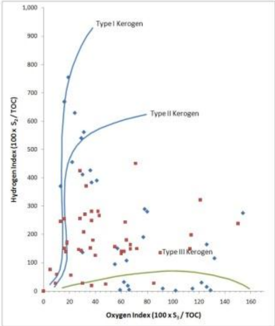


Figure 10. A modified van Krevelen diagram that classifies kerogen on the basis of the Hydrogen Index (HI) and Oxygen index (OI) derived from Rock Eval pyrolysis data. The blue diamonds represent the data from the Government Taylor A-1 (NDIC # 4627, SESE, Sec. 9, T139N, R103W) and the red squares refer to data from the State of North Dakota #41-36 (NDIC #: 4789, NE NE, Sec. 36, T137N, R100W). The data suggest that kerogen within the Tyler Formation includes oil prone Type I and Type II, gas prone Type III as well as mixtures of both oil and gas prone kerogen.

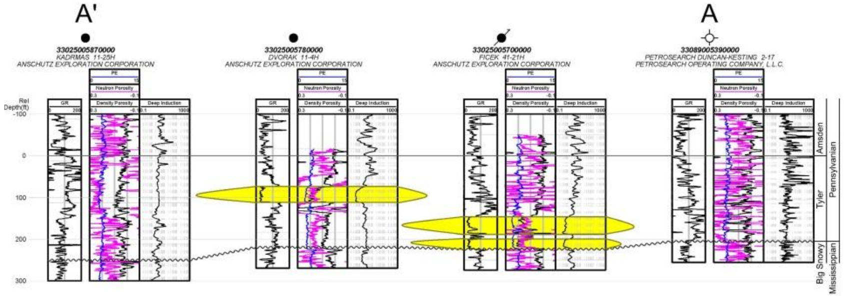


Figure 4. Cross-section extending from A to A' along the light blue line in Figure 5. The Kesting 2-17 (#14675 on Figure 5) corresponds to the point labeled A. Conventional sandstone reservoirs are shown in yellow. The section illustrates the discontinuous nature of the conventional sandstone reservoirs of the Tyler Formation.

Discussion

The purpose of this study is to examine the pressures within the Pennsylvanian aged Tyler Formation with the intent of determining whether or not the formation exhibits pressure-depth relationships consistent with a source system that is hydraulically isolated from the over and underlying formations. Hydraulic isolation is one of the key elements that Schmoker (1996) used to define a basin-centered petroleum accumulation. Meissner (1978) recognized several of these elements in the Bakken Formation in the Williston basin. In these accumulations, the source rock and reservoir rock are either one and the same or lie in very close proximity to one another. This occurs because the rocks that encase the source beds lack sufficient permeability to allow petroleum generated within the source beds to escape and migrate away. As a result, pressures within the source beds and associated reservoir rocks typically exhibit abnormally high or low formation fluid pressures relative to the pressure expected in a reservoir that is in hydraulic communication with the overlying rocks. The "expected" pressure in this study assumes hydrostatic conditions so that the expected pressure would be consistent with a hydrostatic gradient of between 0.43 and 0.49 psi/ft. Therefore, abnormally low or high pressure would yield hydraulic gradients (pressure/depth) that lie outside the range of gradients that correspond with fresh water (0.43 psi/ft) or saltwater (0.49 psi/ft).

The Tyler Formation is a regionally extensive, organically-rich, Pennsylvanian unit deposited during the earliest stages of the Absaroka Sequence. Terrestrial sediments derived from source areas south of the Williston basin are interbedded with near-shore, marine limestone and shale (Gerhard and Anderson, 1988). The Tyler Formation is bounded below by an erosional surface developed on Mississippian aged rocks formed during tectonic uplift in the Late Mississippian and Early Pennsylvanian. A variety of lithologies consistent with progradation of sediments into the basin overly the Tyler except along the eastern margin of the basin where these rocks have been truncated by the erosional surface that marks the Absaroka – Zuni sequence boundary (Anderson, 1972; Gerhard and Anderson, 1988).

Pressure gradients were obtained from pressure build up curves and pressure recorder depths used during drill stem tests of the Tyler Formation. Estimates of formation pressures are obtained by constructing Horner plots in which formation pressures are plotted against the logarithm of Horner time (Horner Time = [total Flow Time + ΔShut-in time]/ΔShut-in time). The formation pressure is determined from the Horner plot by finding the y-intercept of the best-fit line that passes through the pressures recorded during the last part of the shut-in periods (See Figures 1-3).

The range of initial pressure gradients present in the Tyler Formation suggest that the formation is frequently over-pressured and in a few cases under-pressured. Several fields were initially over-pressured and prior to injection: Dance Creek, Eland, Flat Top Butte, Fryburg, Heart River, Medora, Rocky Ridge, and Round Top Butte (Figure 8). Most of these over-pressured fields are located on the western side of the producing Tyler fields. Two fields may have been under-pressured prior to production, Bell and North Creek, which are located in the central area of most of the producing Tyler Fields (Figure 8). These results lead to the conclusion that the Tyler Formation is not always in hydraulic communication with the units above or below it and thus suggests that the Tyler may be sufficiently isolated so as prevent the petroleum generated within the Tyler Formation to escape.

The Time-Temperature Index (TTI) map of the Tyler Formation, constructed from modern geothermal heat flow measurements (SMU Geothermal Lab, 2010) and stratigraphic interval thickness data shows that oil production from the Tyler Formation is from rocks that are mature enough to generate oil. RockEval data also indicates that at least some of the organic-rich rocks within the Tyler are good to excellent source rocks even though there is probably more than one type of kerogen present. The available Rock Eval data also confirms the presence of thermally mature shales in vicinity of current Tyler production (Figures 5 & 7).

The limited data available today suggest the Tyler Formation is a regionally extensive unit that may contain good to excellent quantities of oil prone kerogen (Figures 9 & 10) that is sufficiently mature (Figure 7) to generate oil within a hydraulically compartmentalized environment (Figure 8). If so, then the Tyler Formation possesses the elements needed to qualify as a basin centered petroleum accumulation.

References

Anderson, S. B., 1974, Pre-Mesozoic paleogeographic map of North Dakota, North Dakota Geological Survey, Misc. Map 17, 1 Plate.

Dembicki, H., 2009, Three common source rock evaluation errors made by geologists during prospect or play appraisals, American Association of Petroleum Geologists Bulletin, v. 93, p 341-356

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Meissner, F.F., 1978, Petroleum geology of the Bakken Formation Williston Basin, North Dakota and Montana, in D. Rehig, ed., 1978 Williston Basin Symposium: Montana Geological Society, Billings, Montana, p. 207-227.

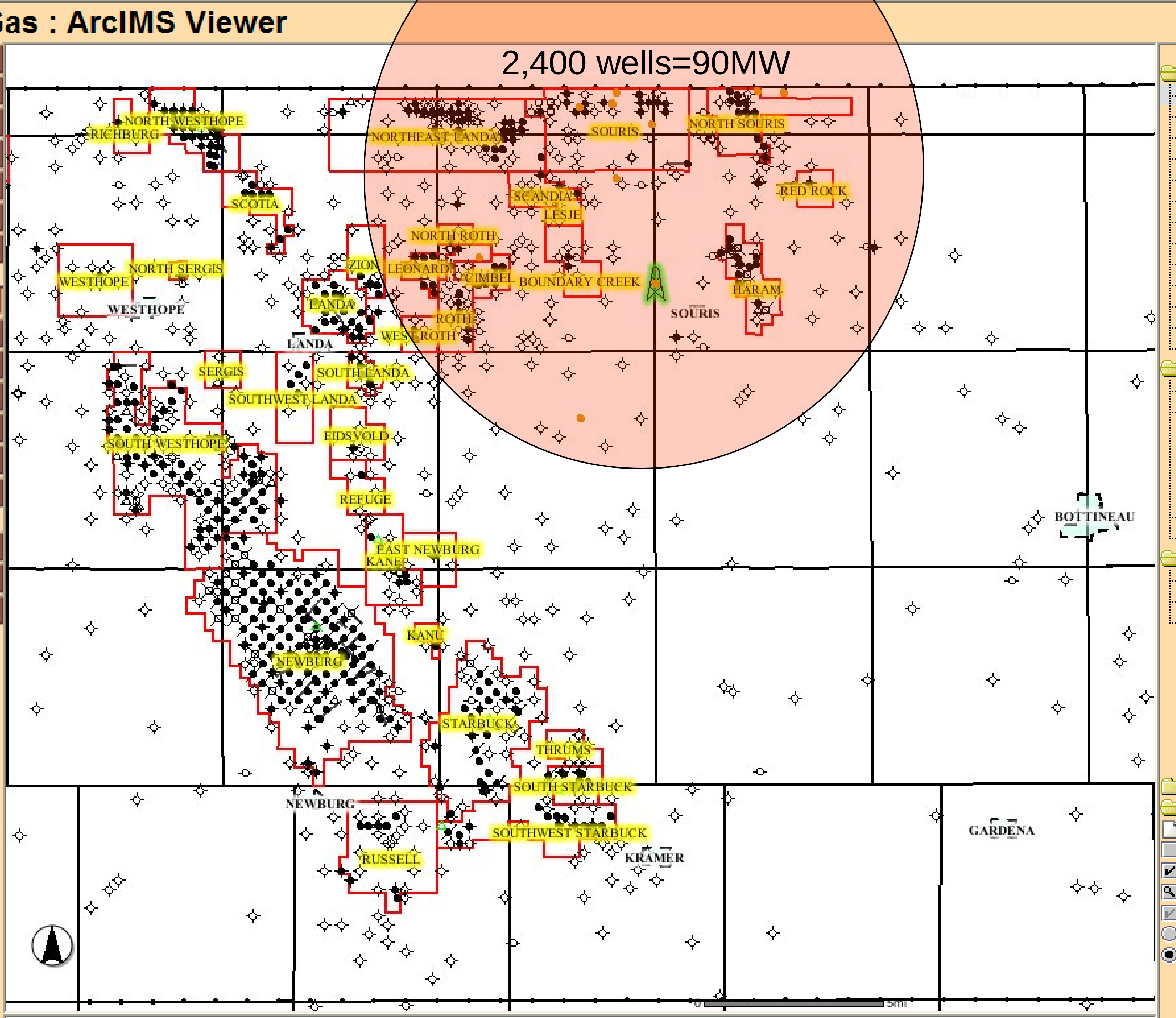
Schmoker, J.W., 1996, Method for assessing continuous-type (unconventional) hydrocarbon accumulations, in Gautier, D.L., Dolton, G.L., Takahashi, K.I., and Varnes, K.L., eds., 1995 National assessment of United States oil and gas resources—Results, methodology, and supporting data: U.S. Geological Survey Digital Data Series 30, release 2, 1 CD-ROM.

Oil and Gas : ArcIMS Viewer

Legend / Layers
Overview Map
View Entire State
Previous View
Clear Selection
Search
Generate PDF

Zoom In
Zoom Out
Pan
Rect Identify
Select Object
Buffer
Distance

Find Well
Find Field/Unit
Find Section

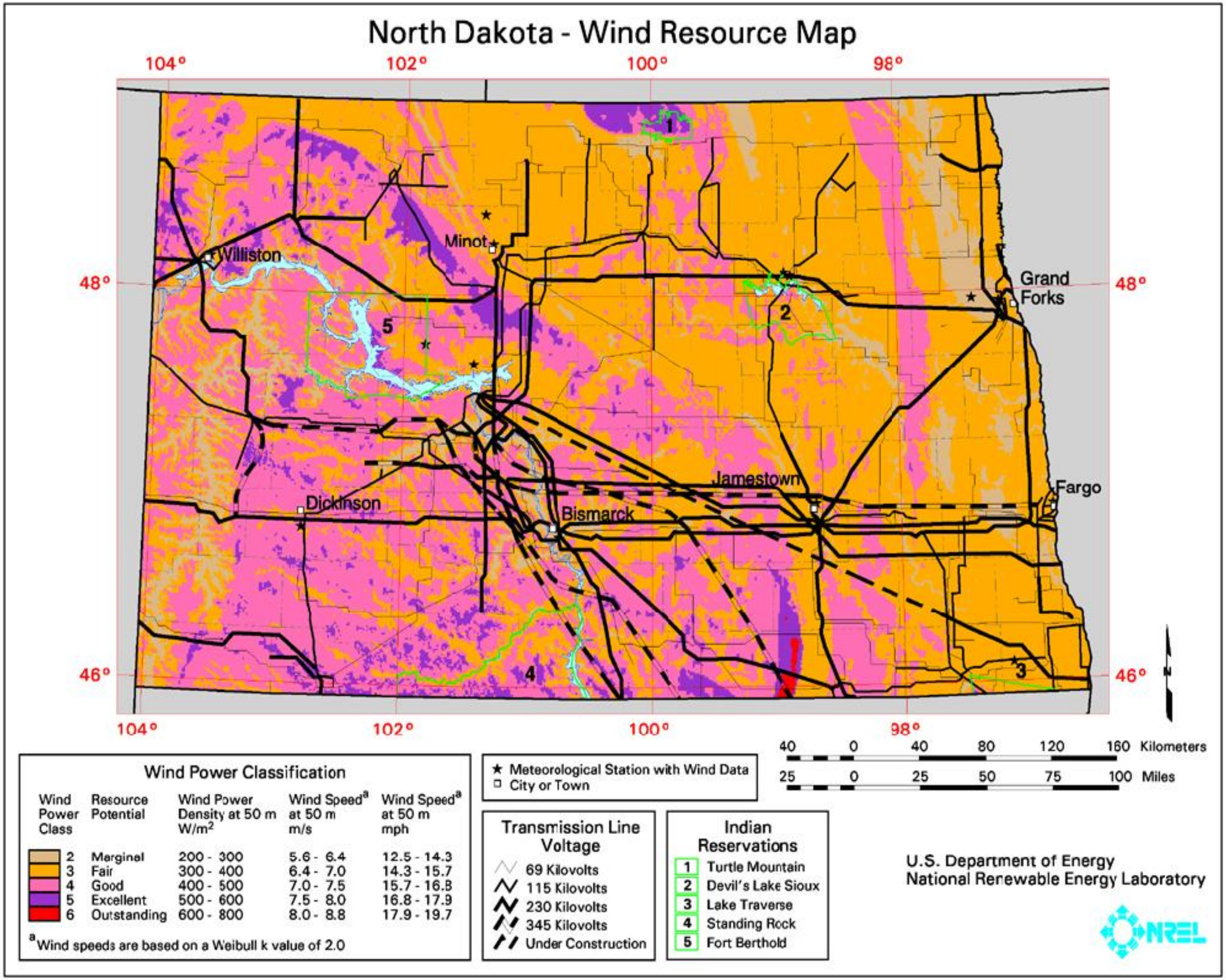


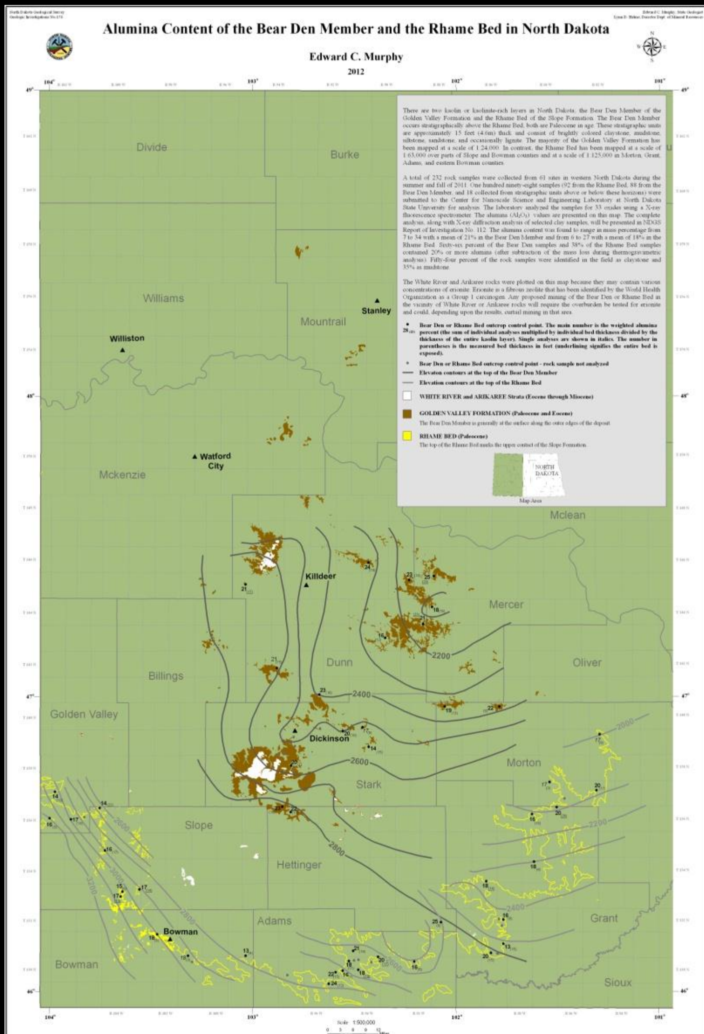

Reclaimed Location
File No. 15092
Armstrong #1-5 Hanson
Sec 5-T155N-R102W
Williams County, ND

North Dakota Development

- Regulation
- Resource Play
- Uniform Spacing—orderly development
- Multi-well locations—small footprint
- Corridors—industry and residents
- Water Needs—surface waters
- Bakken Results
- Other North Dakota Resources
- Other North Dakota Resources

Current installed capacity 1.6 Gigawatts – Estimated potential 6 Gigawatts





Over 4 million tons of sand and ceramic proppants are used every year in the Williston Basin, part of a multi-billion dollar industry. During the 2009-2011 biennium, the Geological Survey collected 125 sand samples throughout the state in our search for deposits that could be utilized for oil and gas proppants in the well fracing process. In the fall of 2011, we collected 232 clay samples from western North Dakota to determine their suitability for the manufacture of ceramic proppant.

The Nanoscale Science and Engineering Laboratory at North Dakota State University determined the alumina content using x-ray fluorescence and is currently determining the clay mineralogy using x-ray diffraction. The alumina content of the clay samples ranged from 7 to 34% with a mean of 21% in the Bear Den Member and 18% in the Rhame Bed. North Dakota deposits could contain over 1 billion tons of mineable clay with a value of over $50 billion.

Seventeen feet of brightly colored clay of the Bear Den Member (Golden Valley Formation) at the base of a butte in Dunn County.

1.3 Trillion Tons of Coal in North Dakota

25 Billion Tons of Mineable Lignite 800+ yr supply @ current withdrawl

THE LIGNITE RESOURCES OF NORTH DAKOTA

by

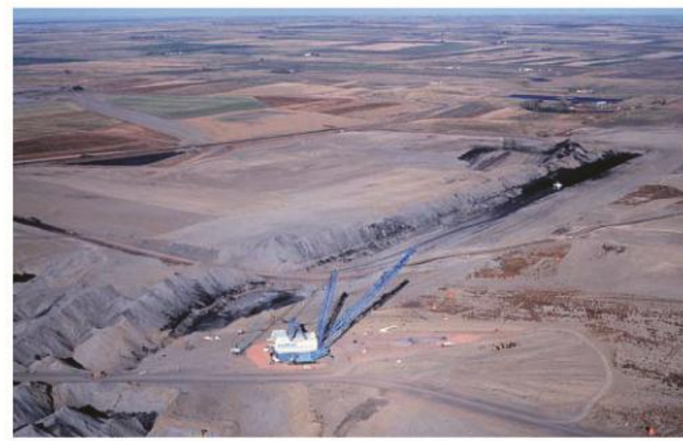
Edward C. Murphy, Ned W. Kruger, Gerard E. Goven,
Quentin L. Vandal, Kimberly C. Jacobs, and Michele L. Gutenkunst

REPORT OF INVESTIGATION NO. 105
North Dakota Geological Survey
Edward C. Murphy, State Geologist
Lynn D. Helms, Director Dept. of Mineral Resources
2006

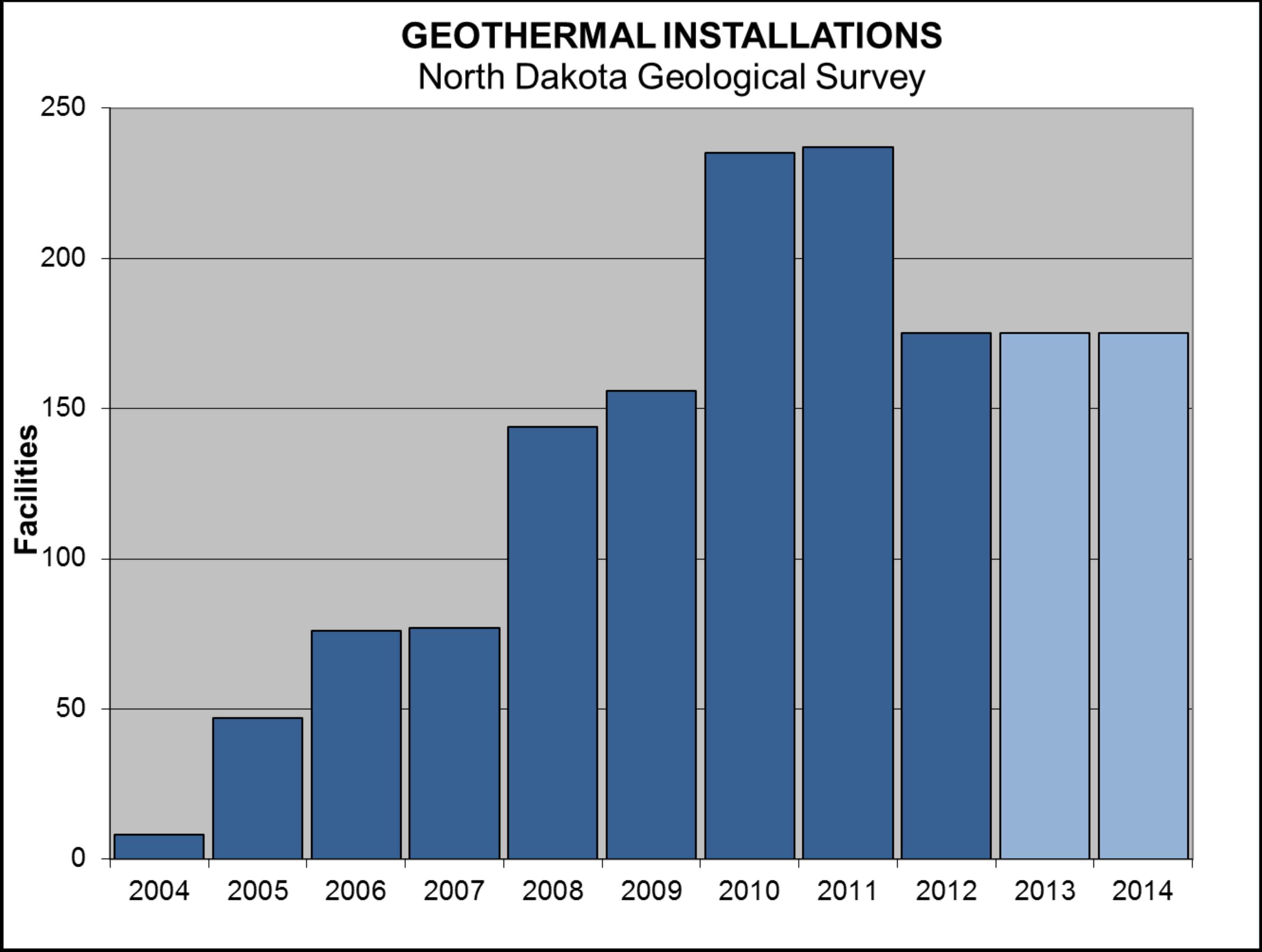
THE LIGNITE RESERVES OF NORTH DAKOTA

by

Edward C. Murphy



REPORT OF INVESTIGATION NO. 104
North Dakota Geological Survey
Edward C. Murphy, State Geologist
Lynn D. Helms, Director Dept. of Mineral Resources
2006

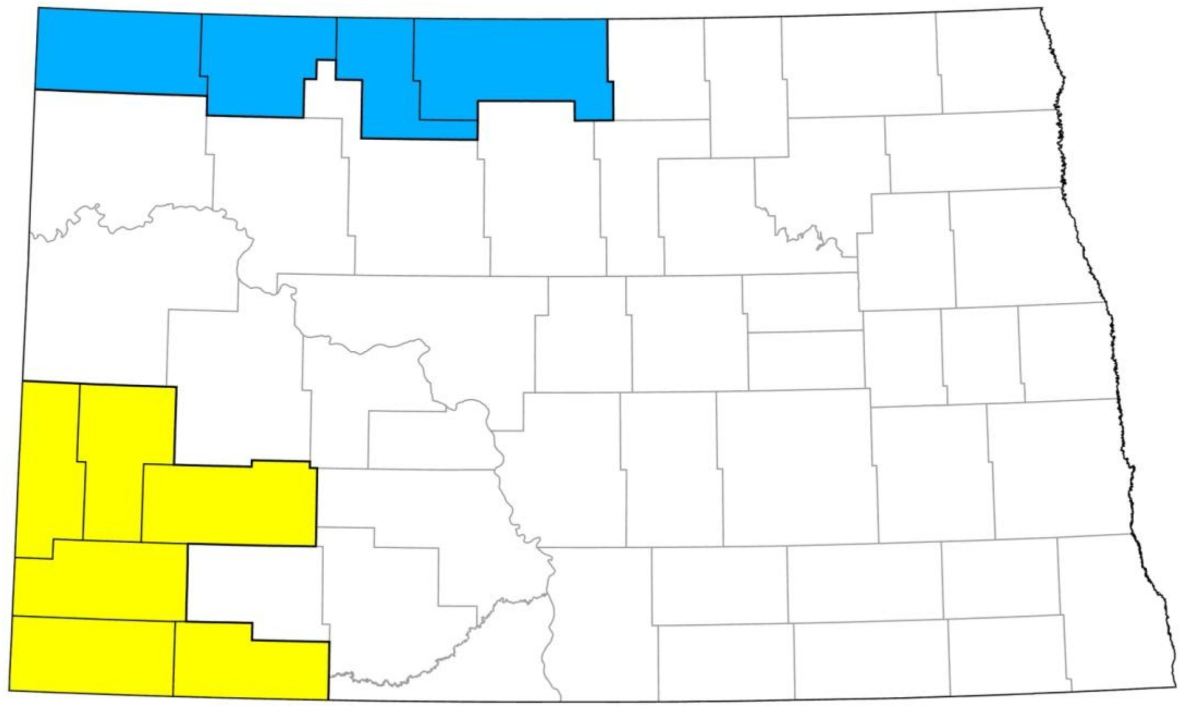

GEOTHERMAL INSTALLATIONS
North Dakota Geological Survey
Facilities
0
50
100
150
200
250
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014

Estimate 10-20 million pounds Mineable

worth $900 million – $2 billion

Uranium was mined in North Dakota in the 1960s. It was heavily explored for in the 1970s, but has been of little interest for the last 30 years until the price for uranium oxide reached an all time high in June of 2007. Companies have also expressed interest in associated elements molybdenum and germanium. We are aware of three companies that are contemplating mining uranium in southwestern North Dakota.

Formation Resources drilling for uranium, molybedenum, and germanium under a subsurface mineral permit in Billings County during the fall of 2008.



Counties that contain uranium deposits are in yellow.

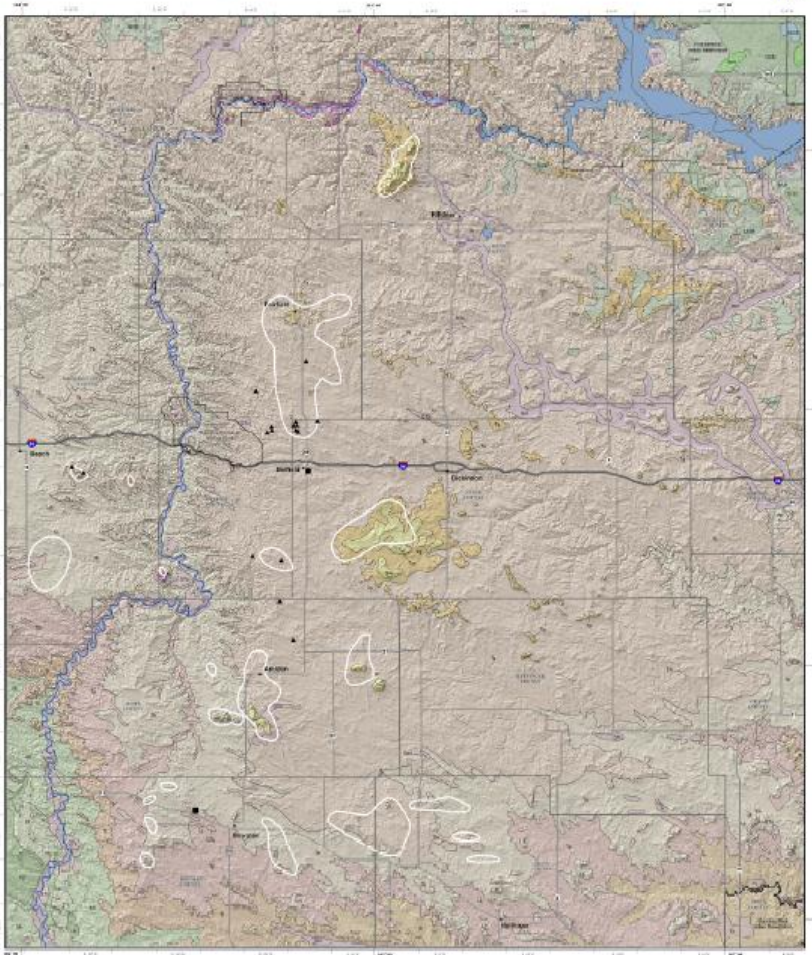
North Dakota Geological Survey
Geologic Investigations No. 40

Edward C. Murphy, State Geologist
Lynn D. Helms, Director Dept. of Natural Resources

Uranium Deposits in Southwestern North Dakota

Edward C. Murphy

2007



Introduction

Exploration and Mining in the 1950s and 1960s

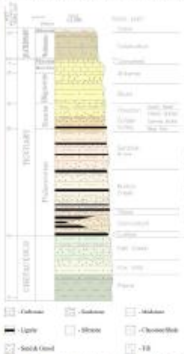


Figure 1.

Figure 2.

Exploration in the 1970s

Figure 3.

Potential Health Problems Associated with Uranium

Current Market for Uranium

References

Explanation

Explanation of Surface Geologic Units

Geologic and Mine Surface Symbols

Inbox ... Depar... Activit... https:...

12:00 PM
6/20/2013

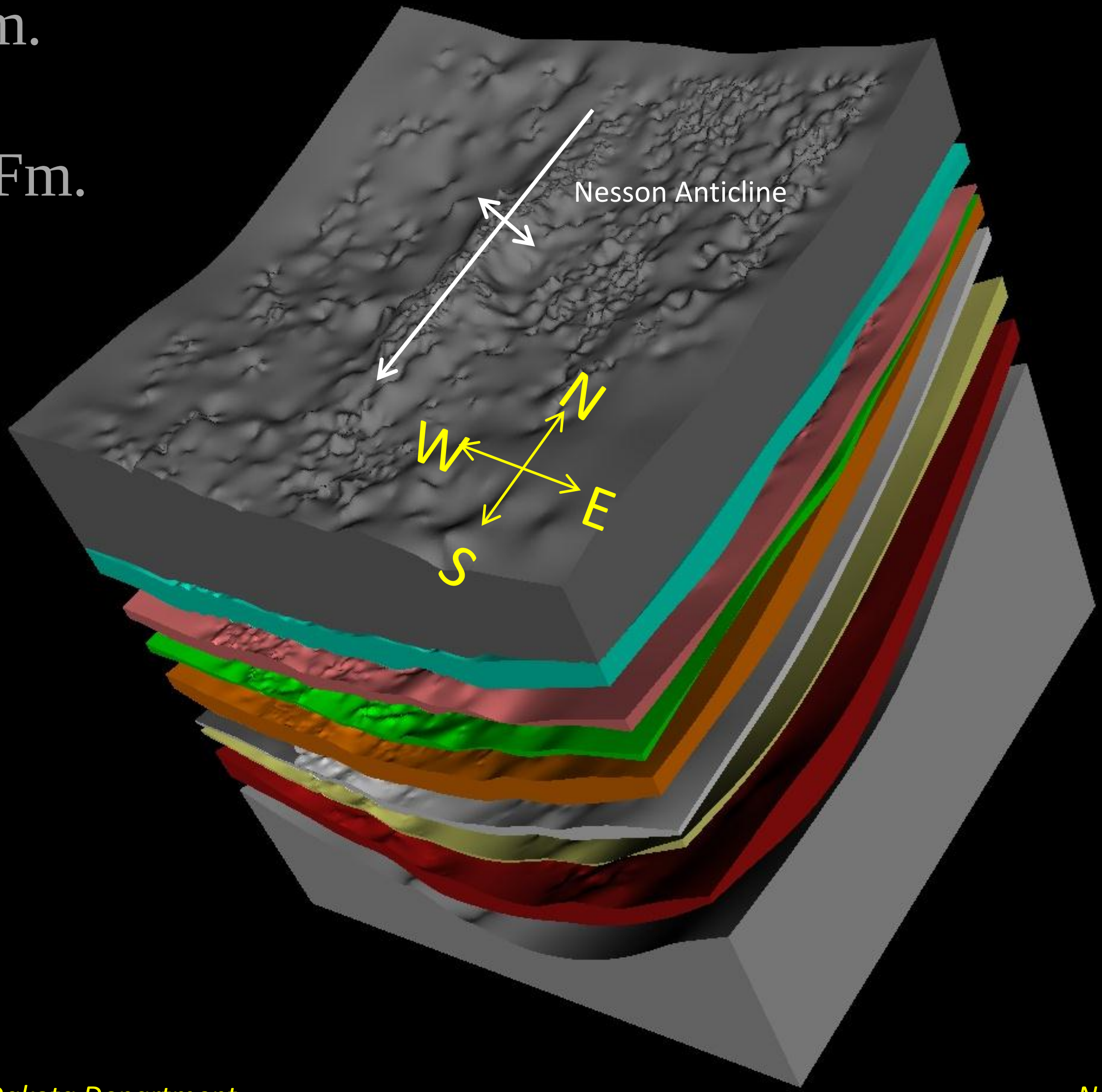
Shallow Gas Prospects

-Pierre Fm.

-Niobrara Fm.

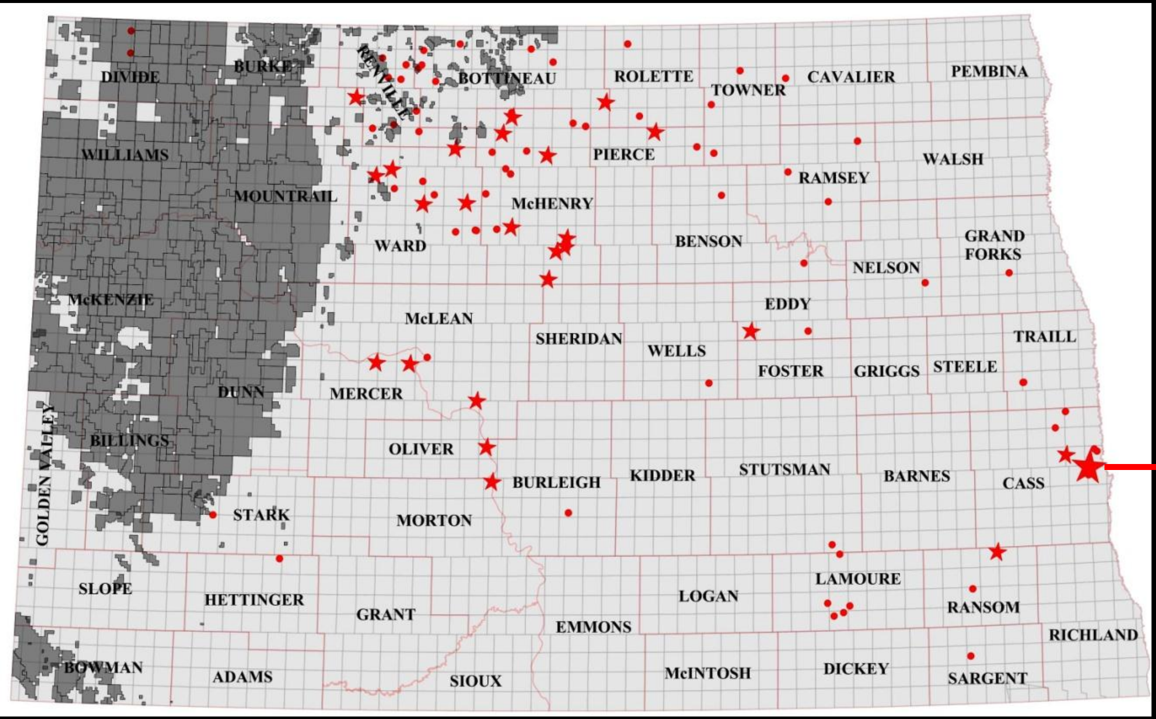
-Carlile Fm.

-Greenhorn Fm.



The Geological Survey recently completed phase II of a study of shallow natural gas in North Dakota. Having detected methane in 905 of the 4,325 ND State Water Commission monitoring wells tested, we turned our attention to private wells that had a history of gas. In the fall of 2012, we tested more than 100 private wells for methane and detected gas in 25.

We will be analyzing a dozen or so groundwater samples during the spring of 2013 for major ions and isotopes to enable us to determine the source of the gas and identify chemical groundwater signatures that might assist the oil and gas industry in natural gas exploration.

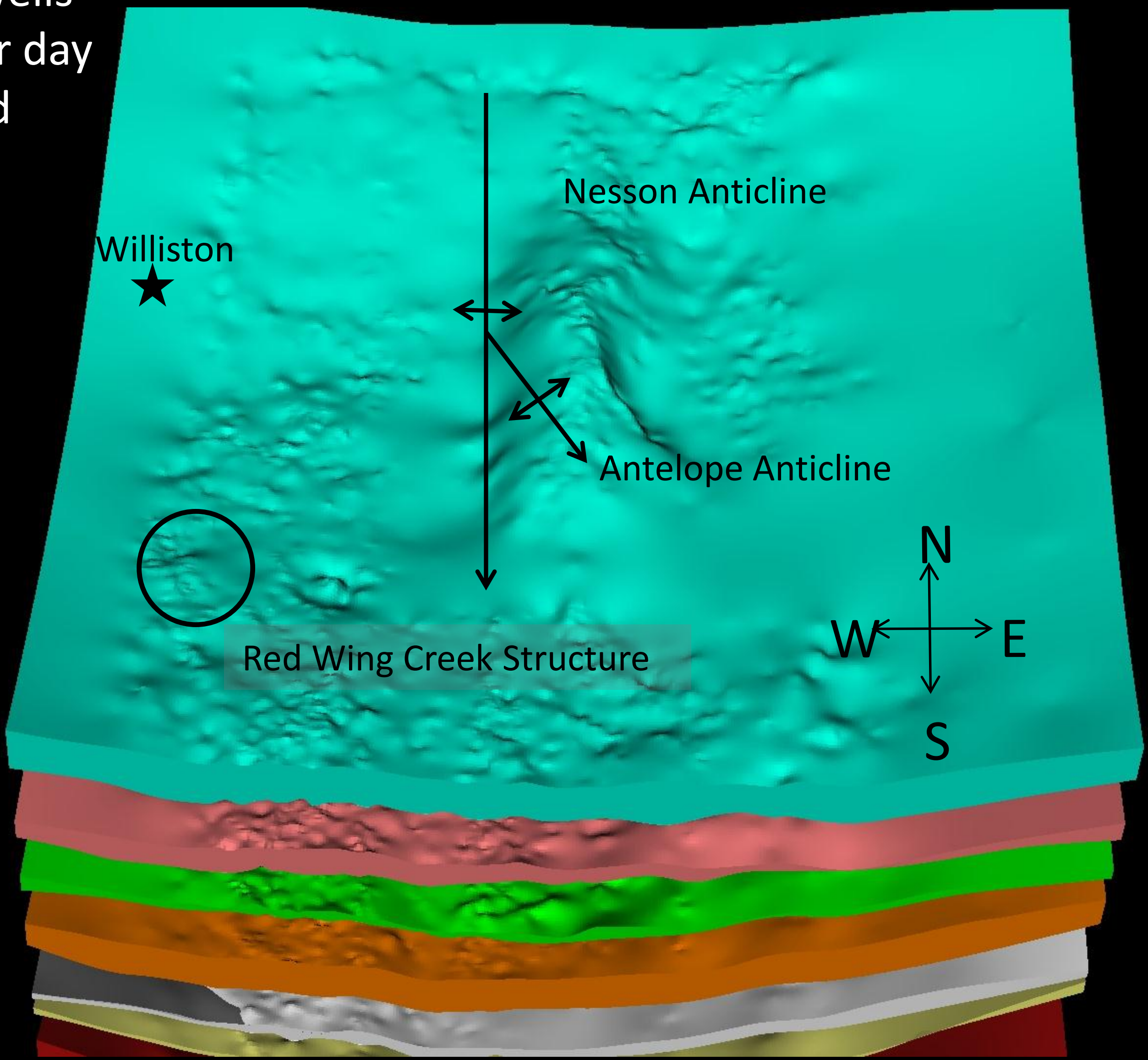


Private wells with reported shows of methane are indicated with a red dot and those we were able to confirm contain methane are indicated by a star. Oil fields are shown in gray.

Methane bubbles in a groundwater sample recently obtained from a private well southwest of Harwood in Cass County (large star on map).

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

400 current SWD wells
950,000 barrels per day
400 + more needed

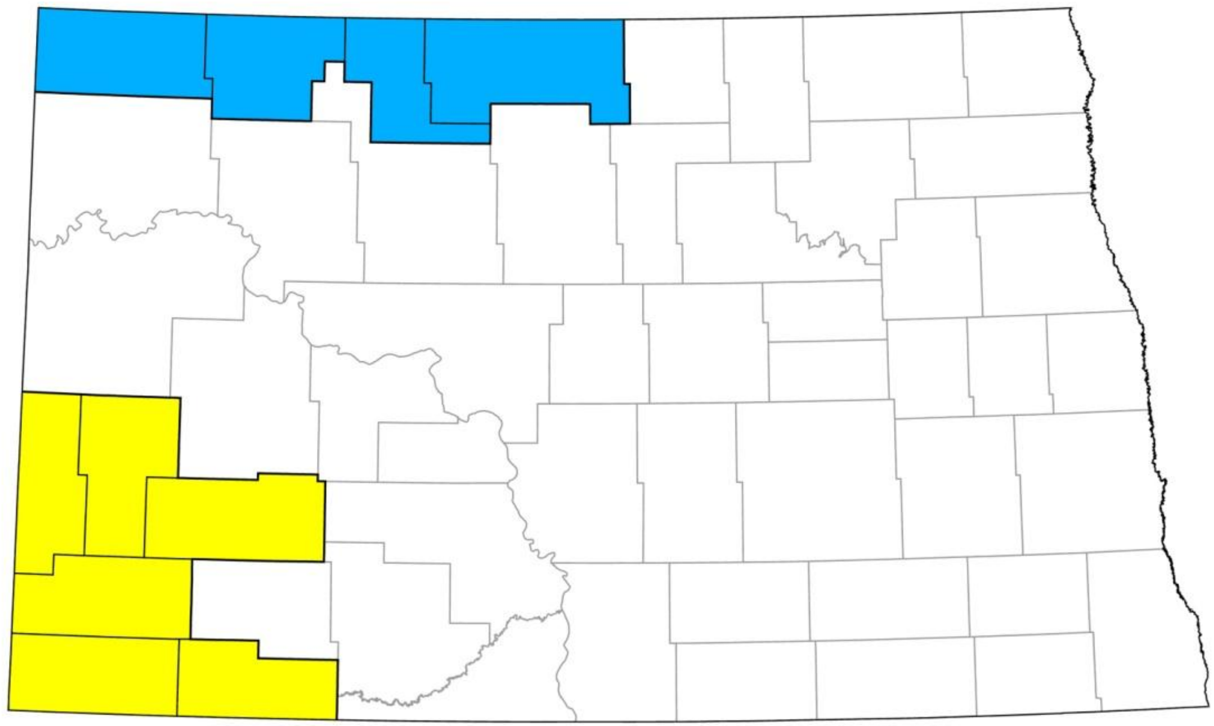


Estimate 20-50 billion tons of ND Mineable Reserves

Potash core from a depth of 9,000 feet in Burke County.

$6 trillion -15 trillion

Potash or potassium salts are primarily used in the production of fertilizer. Potash exploration took place in northwest North Dakota in the 1970s. Since the beginning of 2007, the price of potash has risen from $190 to $1,050 per ton based on a low supply and increasing demand. Due to the increased workload, we will need a geologist to oversee potash exploration and production if we receive a permit from either of the two companies that we know are actively pursuing potash exploitation.

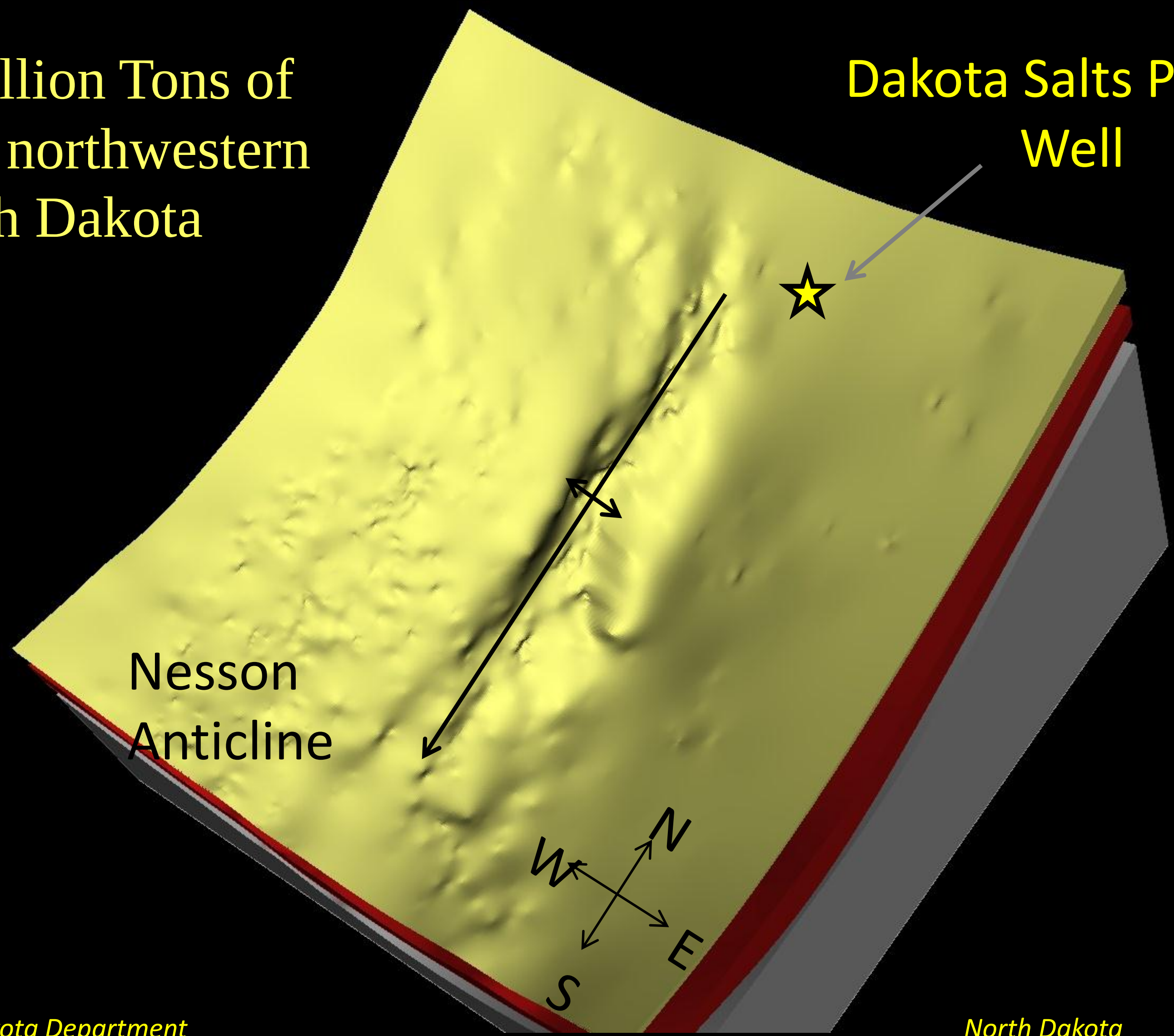


Counties that contain the shallowest potash deposits are in blue.

Prairie Formation

20-50 Billion Tons of Potash in northwestern North Dakota

Dakota Salts Potash Well



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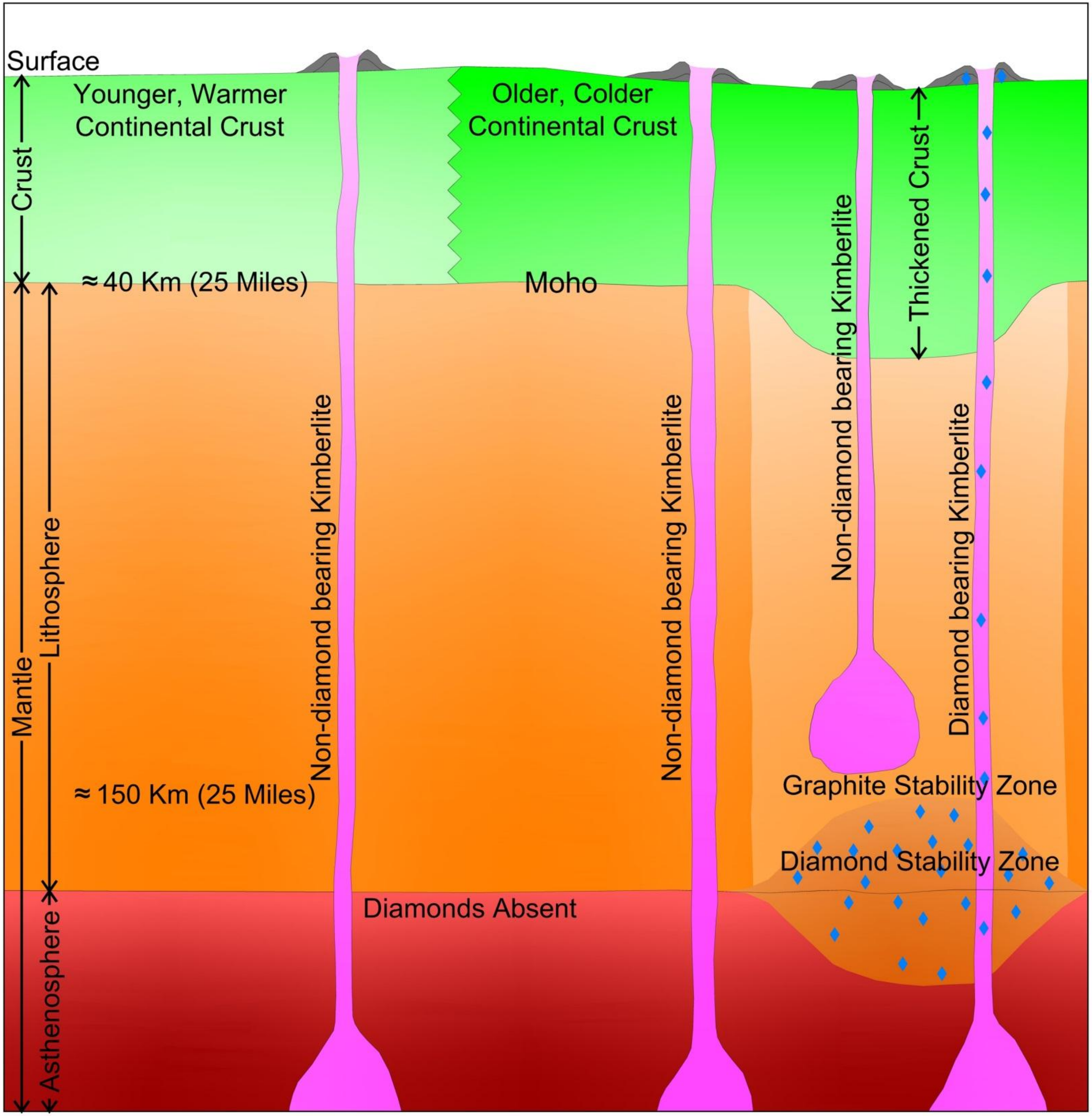
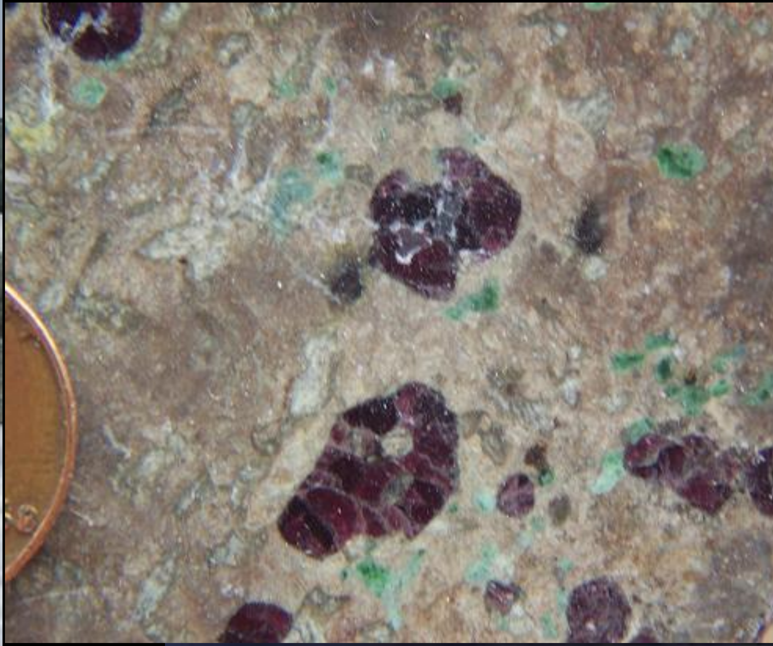
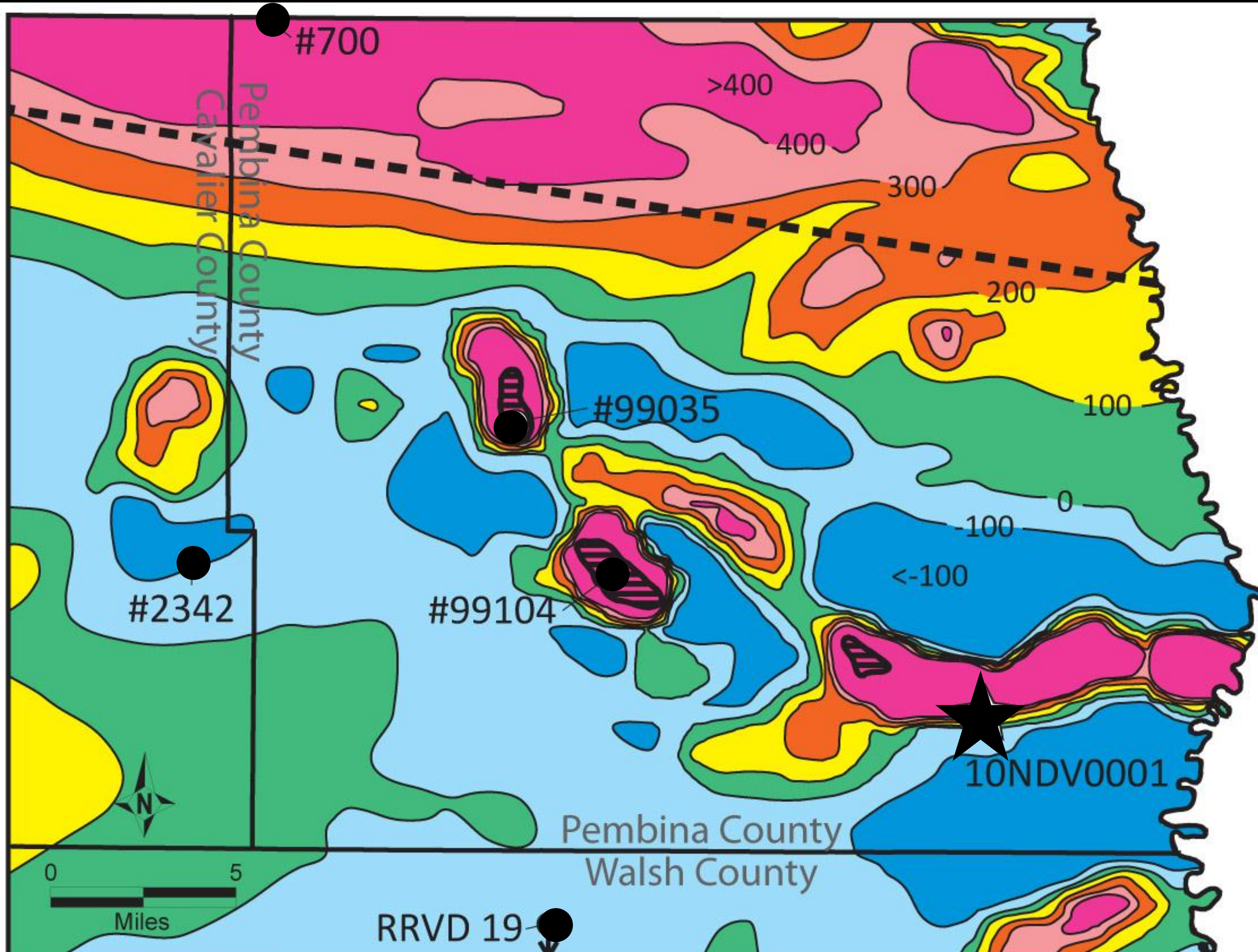


Surface
Younger, Warmer
Continental Crust
Older, Colder
Continental Crust
Crust
≈ 40 Km (25 Miles)
Moho
Thickened Crust
Mantle
Lithosphere
Non-diamond bearing Kimberlite
Non-diamond bearing Kimberlite
Non-diamond bearing Kimberlite
Diamond bearing Kimberlite
≈ 150 Km (25 Miles)
Graphite Stability Zone
Diamond Stability Zone
Diamonds Absent
Asthenosphere

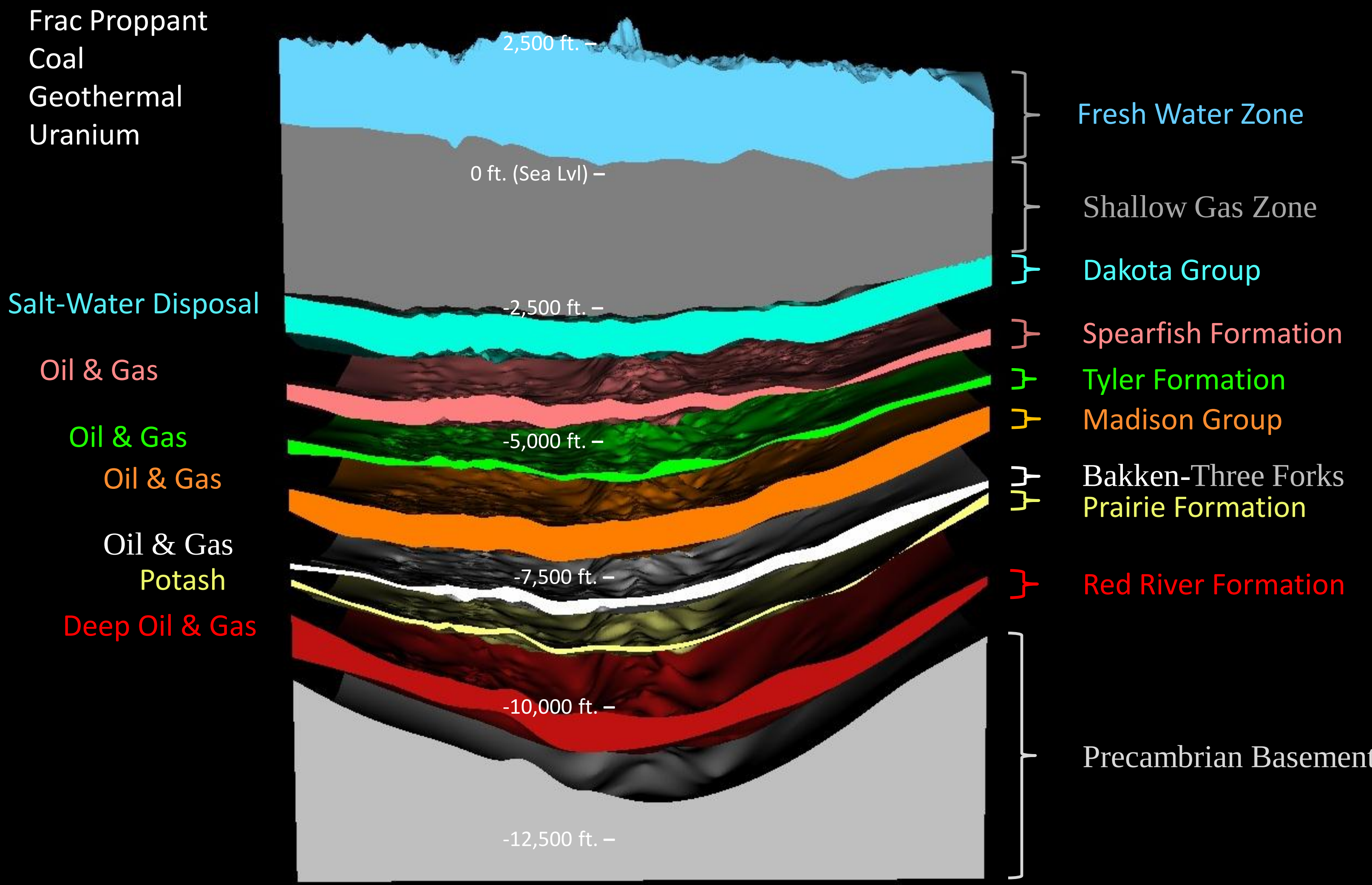
Kimberlite





#700
>400
400
300
200
100
0
-100
<-100
Pembina County
Cavalier County
#99035
#99104
#2342
10NDV0001
Pembina County
Walsh County
RRVD 19
N
0
5
Miles

Three-Dimensional Geologic Model of Northwestern North Dakota



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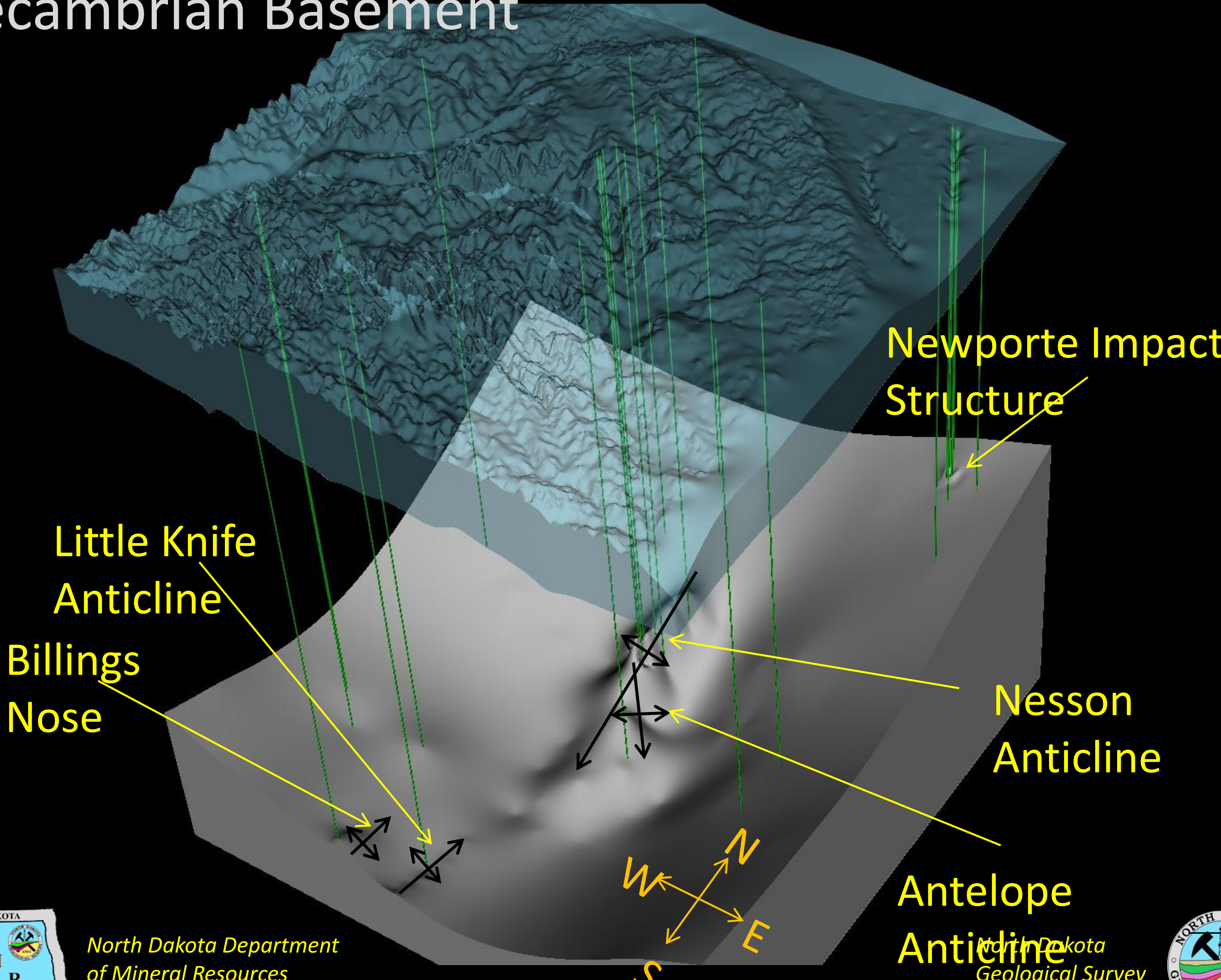
North Dakota Geological Survey

North Dakota Mineral Resources
Status and Outlook

Industrial Commission Regulation

- Water flowback after frac
  - Storage in open pits prohibited
  - Disposal wells permitted through Underground Injection Program
  - Disposal zone is 2,500 feet below potable waters

Precambrian Basement



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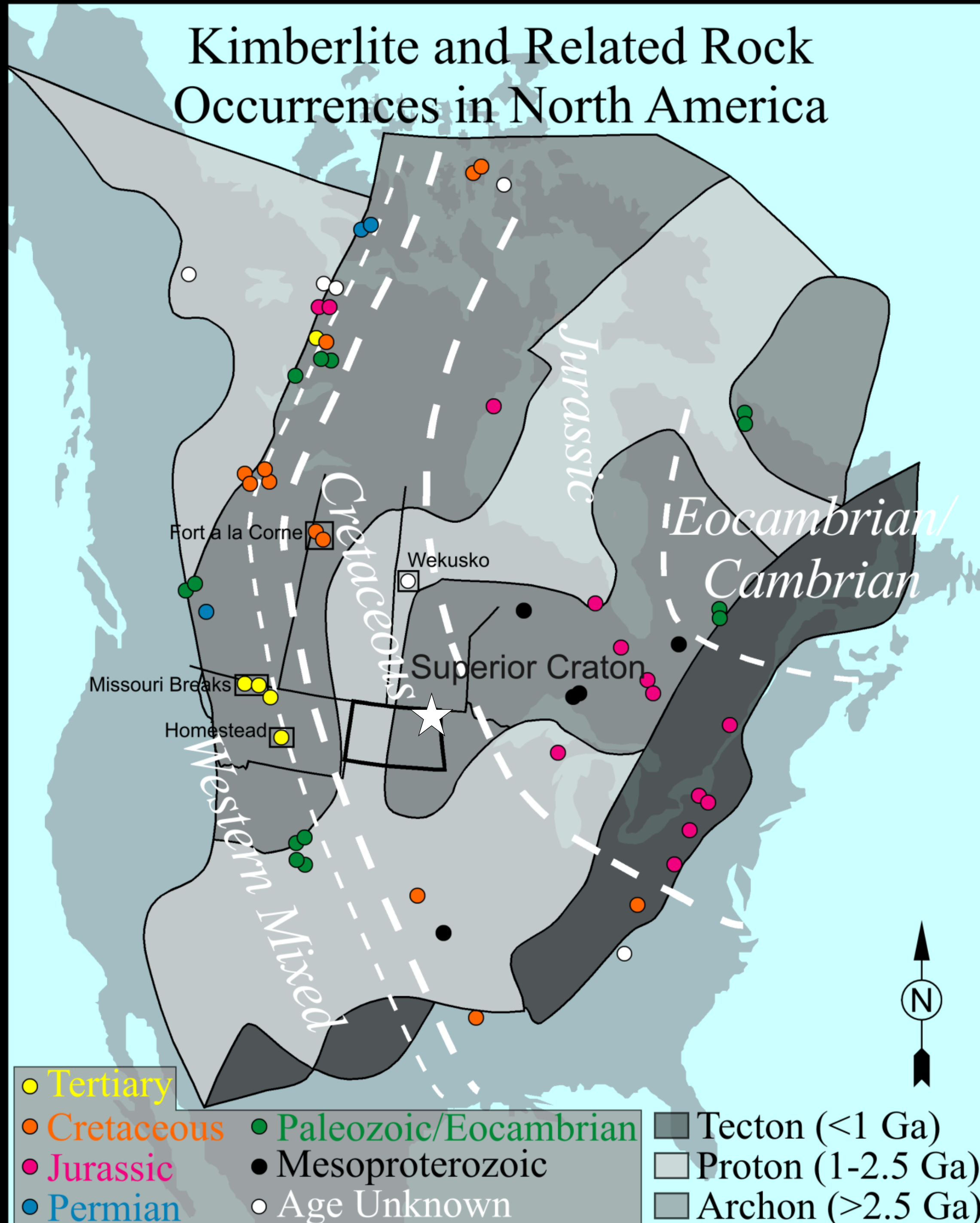

Kimberlite and Related Rock Occurrences in North America
Jurassic
Eocambrian/ Cambrian
Cretaceous
Fort a la Corne
Wekusko
Superior Craton
Missouri Breaks
Homestead
Western Mixed
N
Tertiary
Cretaceous
Jurassic
Permian
Paleozoic/Eocambrian
Mesoproterozoic
Age Unknown
Tecton (<1 Ga)
Proton (1-2.5 Ga)
Archon (>2.5 Ga)