Unconventional “Shale Plays” in MT

A Look at the Geology & Development of the Bakken and Heath Formations

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Montana Bureau of Mines and Geology

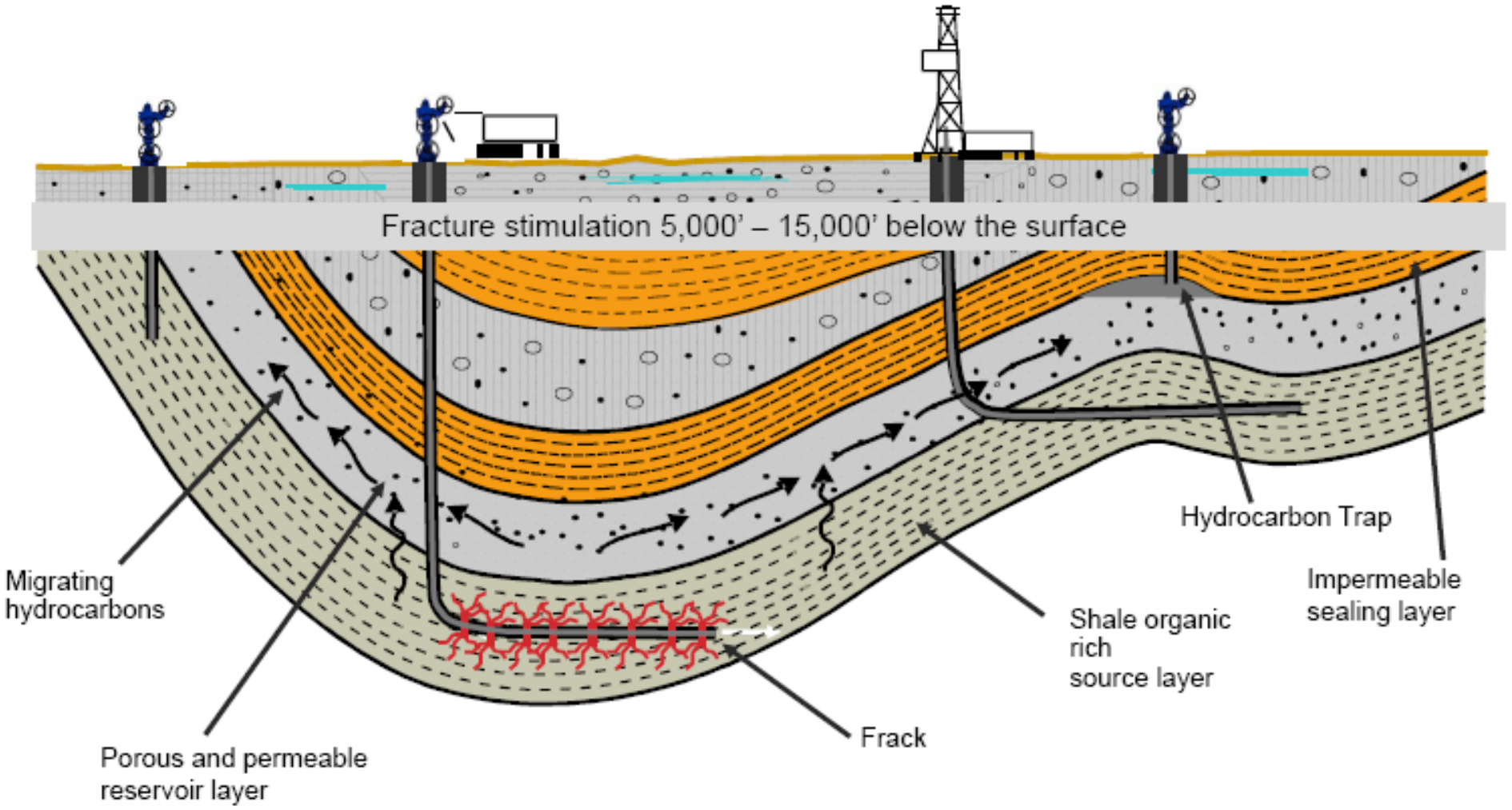
Why Shales?

- Traditional “Source Rocks”
  - Mostly clays - often high organic content
  - Little available pore space and virtually no matrix permeability
- Kerogens are baked into oil & gas; migrate out of the shale and into conventional traps
- New technology has turned these traditional source rocks into reservoir targets

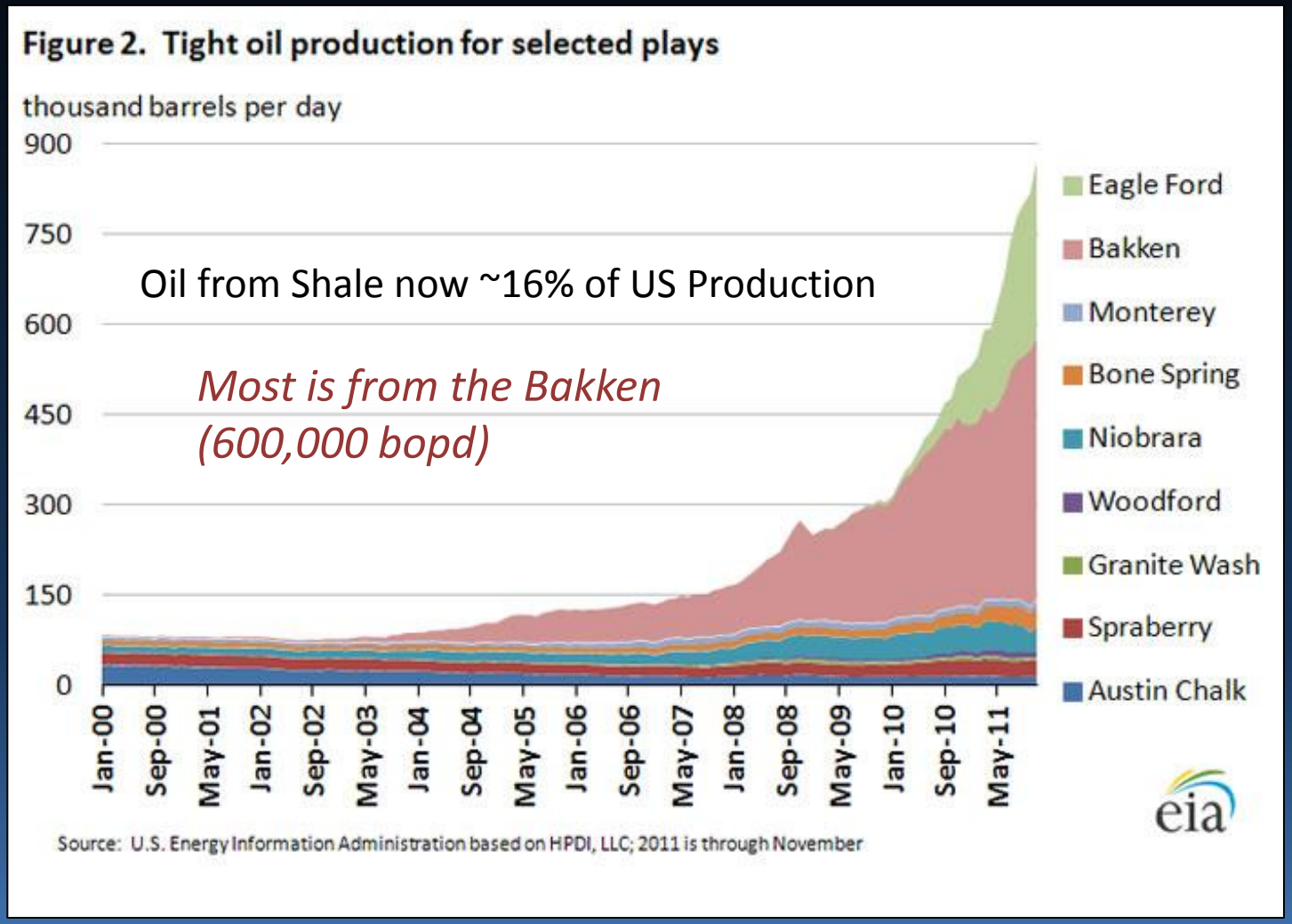
Horizontal Drilling & Frac'ing

Technology's Role

Why the revolution?



Bakken has been the "Proving Ground"

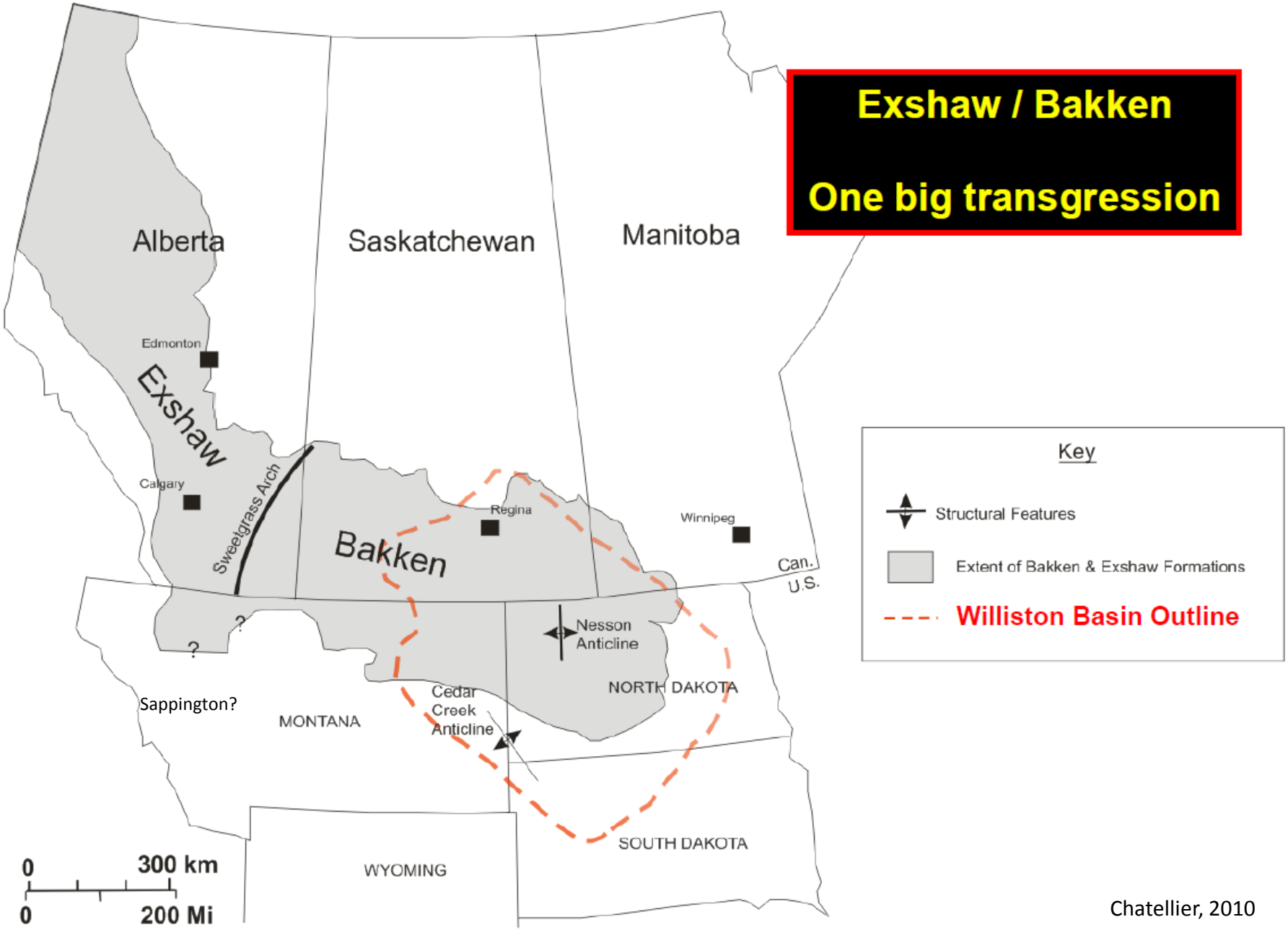


Current estimates of recoverable oil from the Bakken/ThreeForks range from 3-24 Billion bbls

Source: U.S. Energy Information Administration based on data from various published studies. Canada and Mexico plays from ARI.
Updated: May 9, 2011

Requirements for Shale Resource Plays

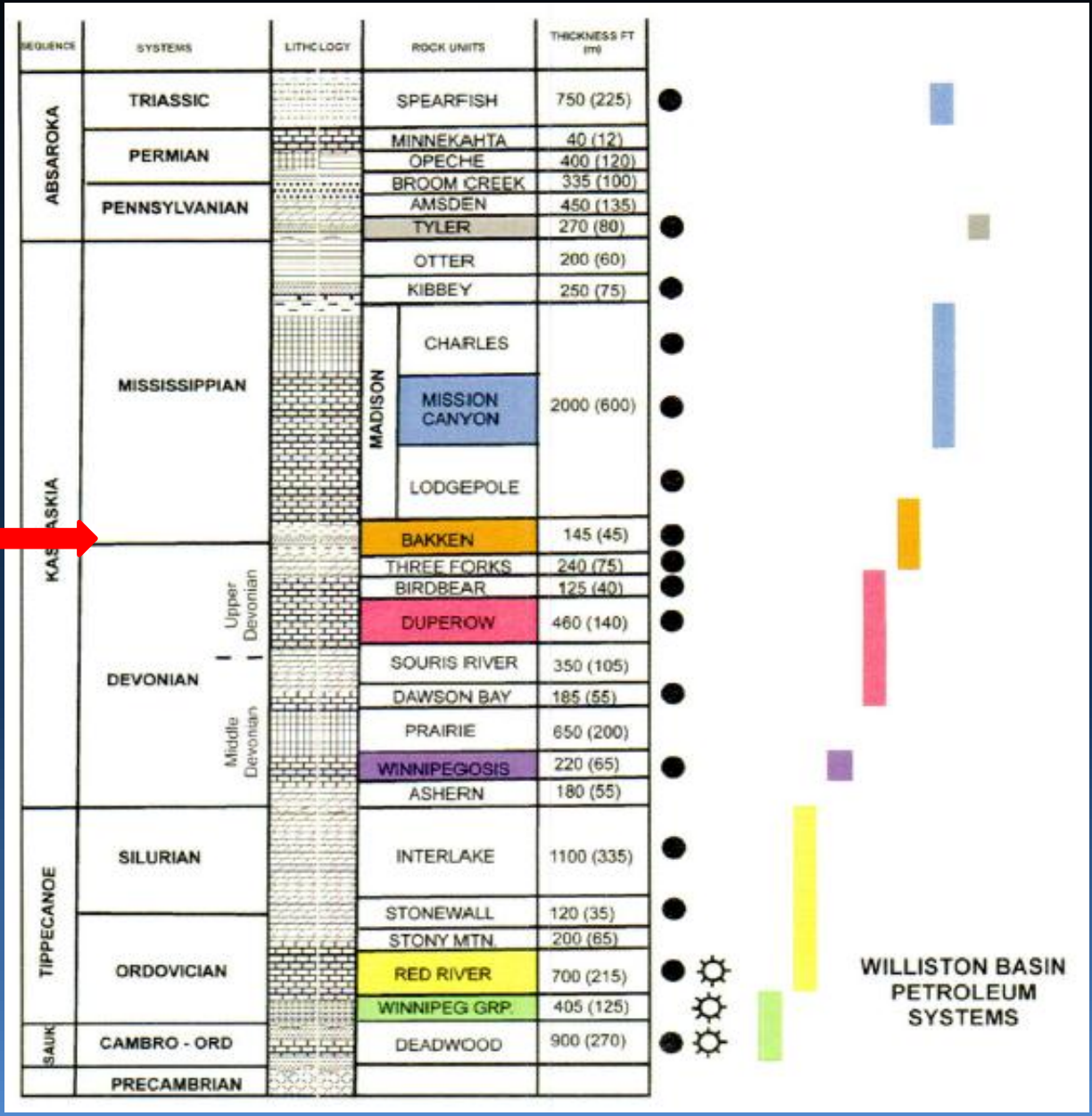
- **Large area** of organic-rich source rock
- **Heat**, pressure, and time to mature
- **Expulsion** of HC from source rocks into adjacent rocks
- **Trapping** of HC in overlying and underlying reservoirs that are porous, but low permeability
- **Technology** to extract HC using natural or artificial fractures



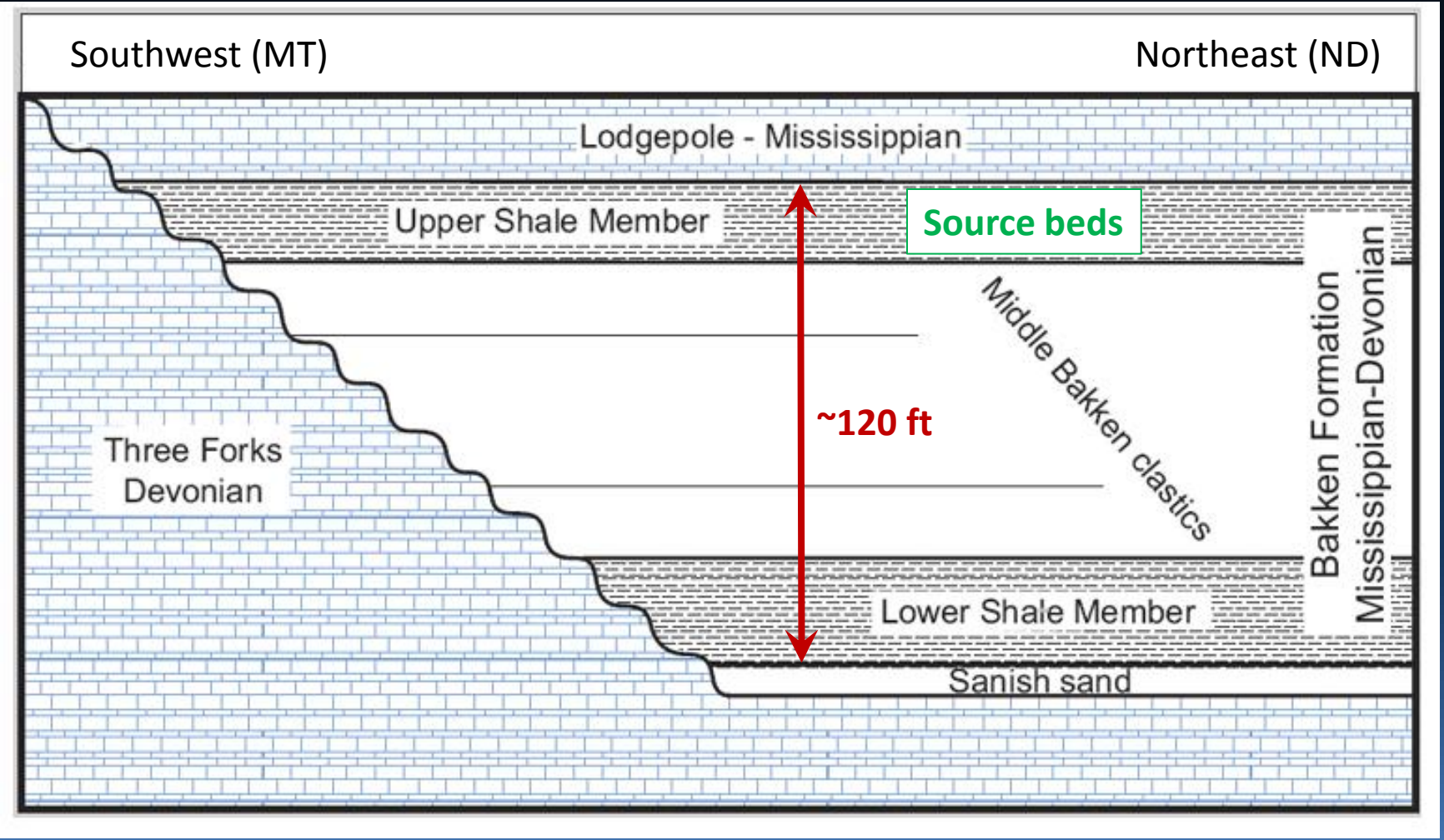
Chatellier, 2010

Williston Basin Stratigraphy

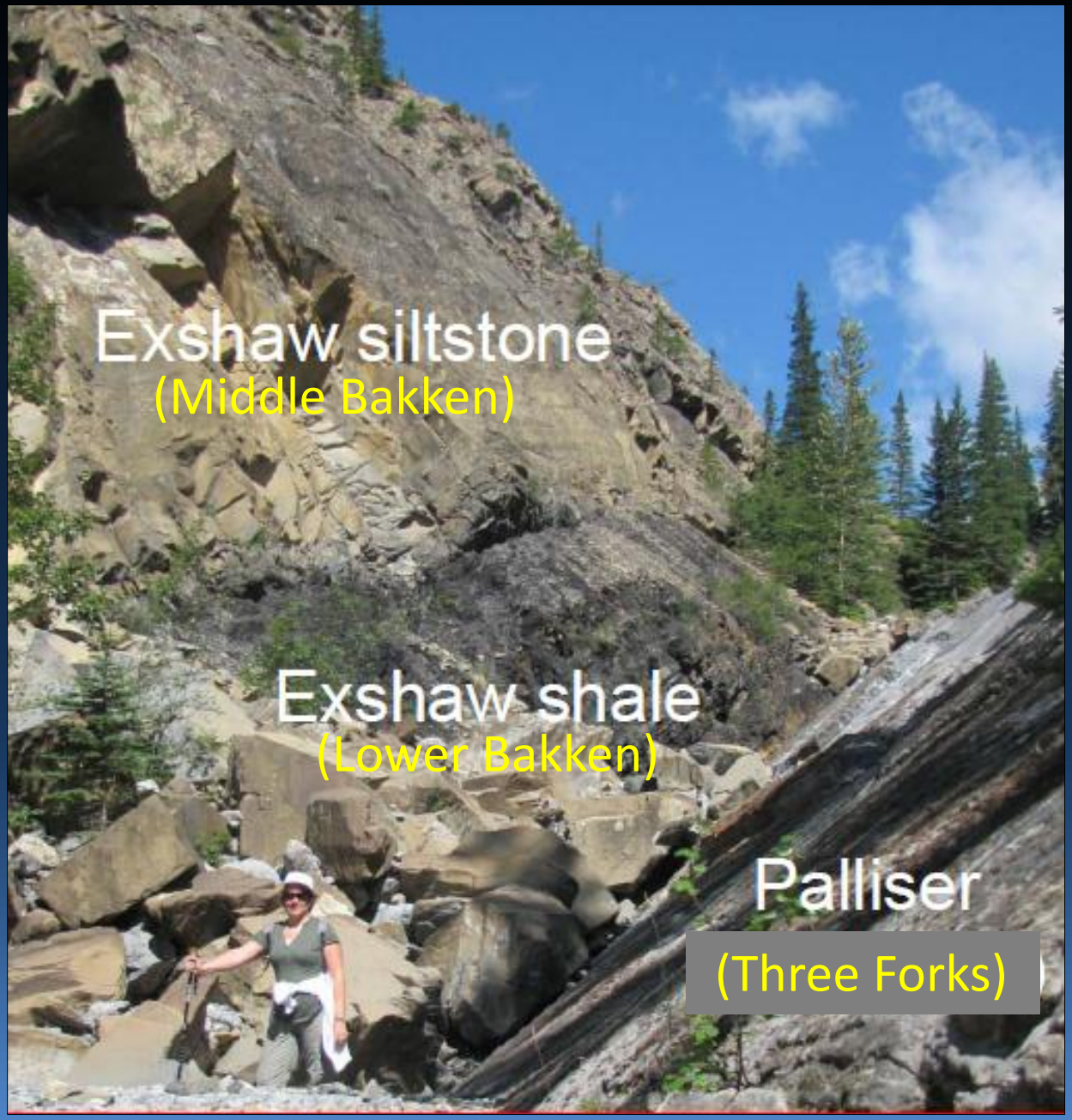
Bakken
Three Forks



The Bakken "Petroleum System"

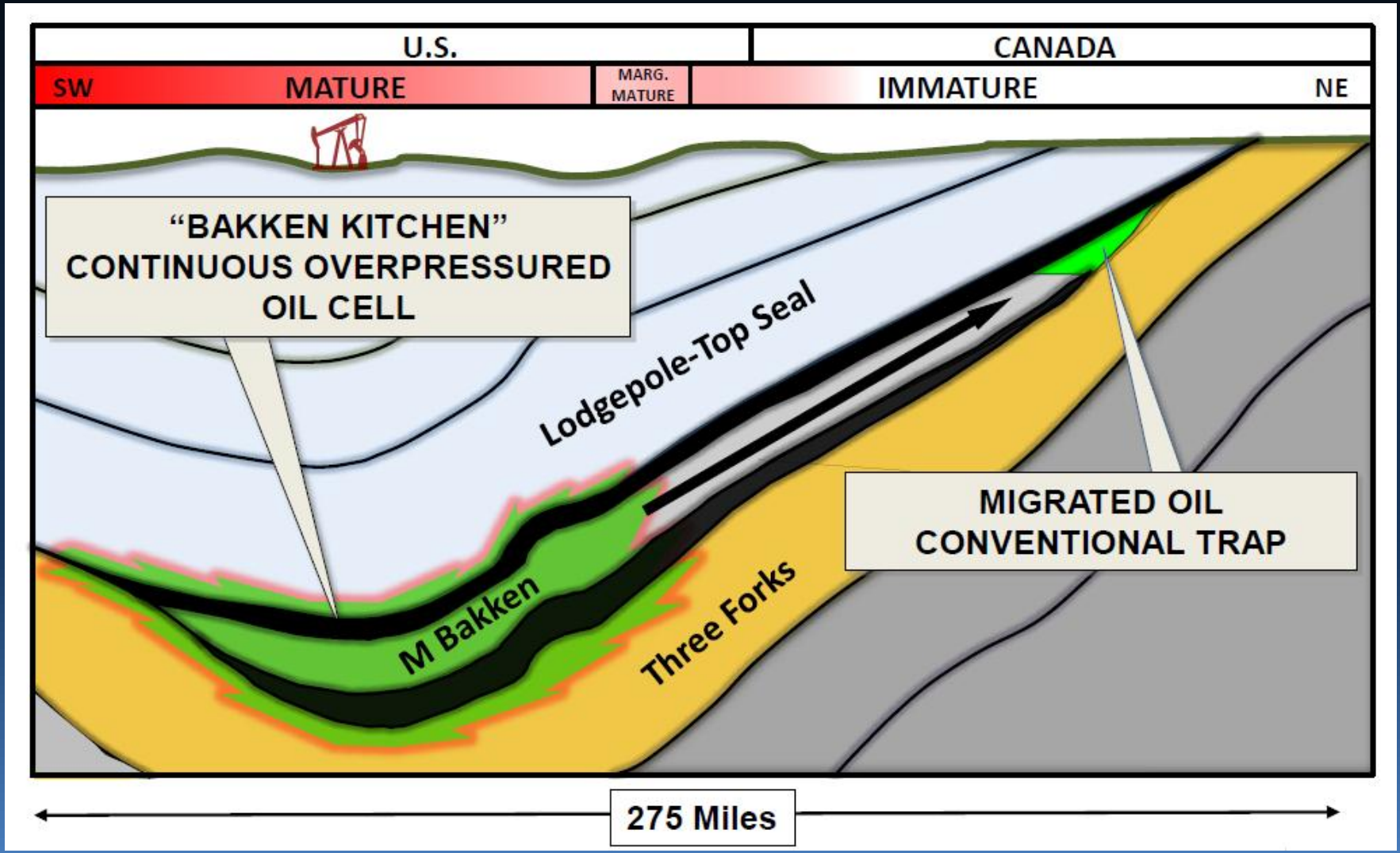


DEPTH: 9,000-11,000 feet

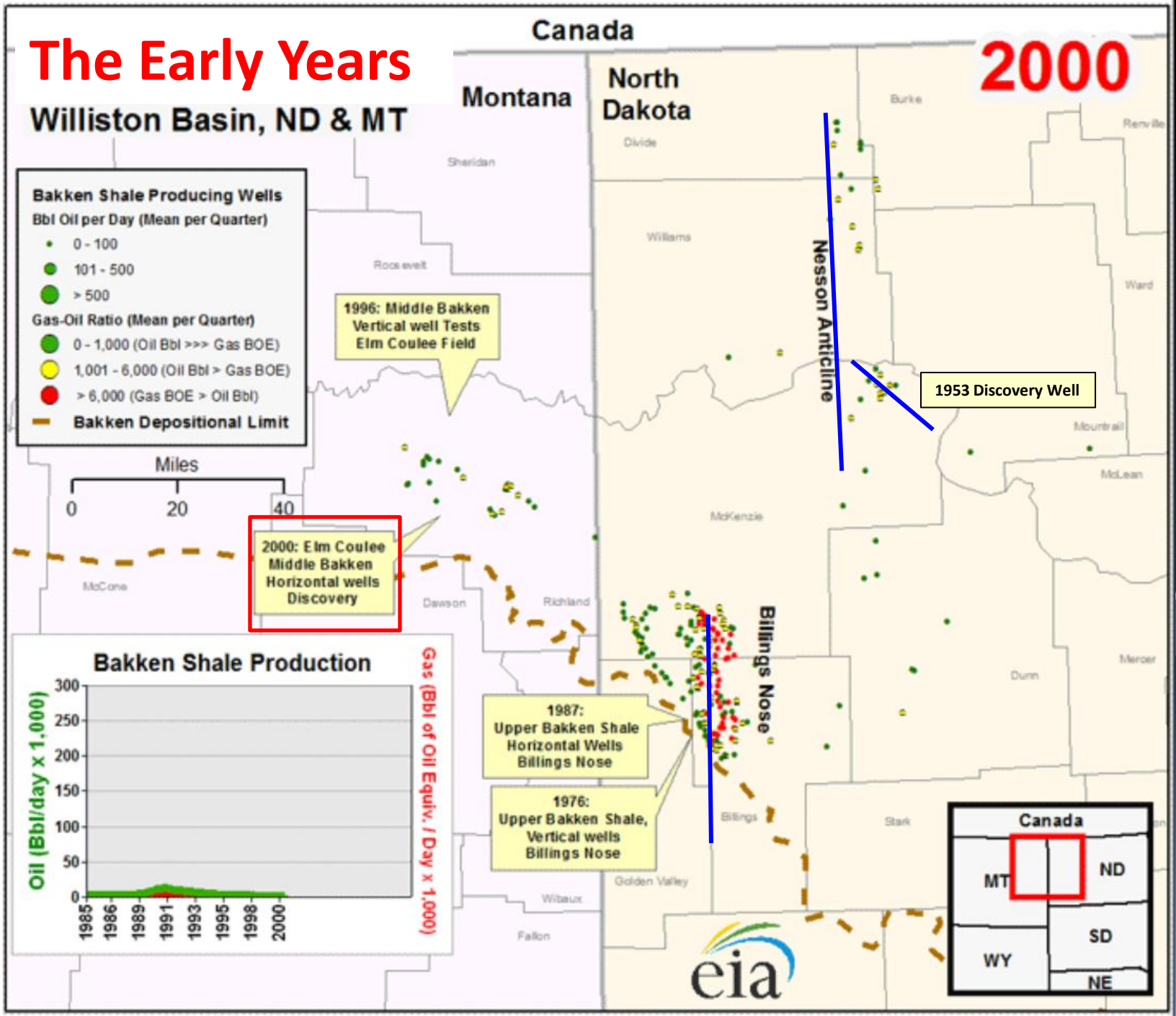


Chatellier, 2010

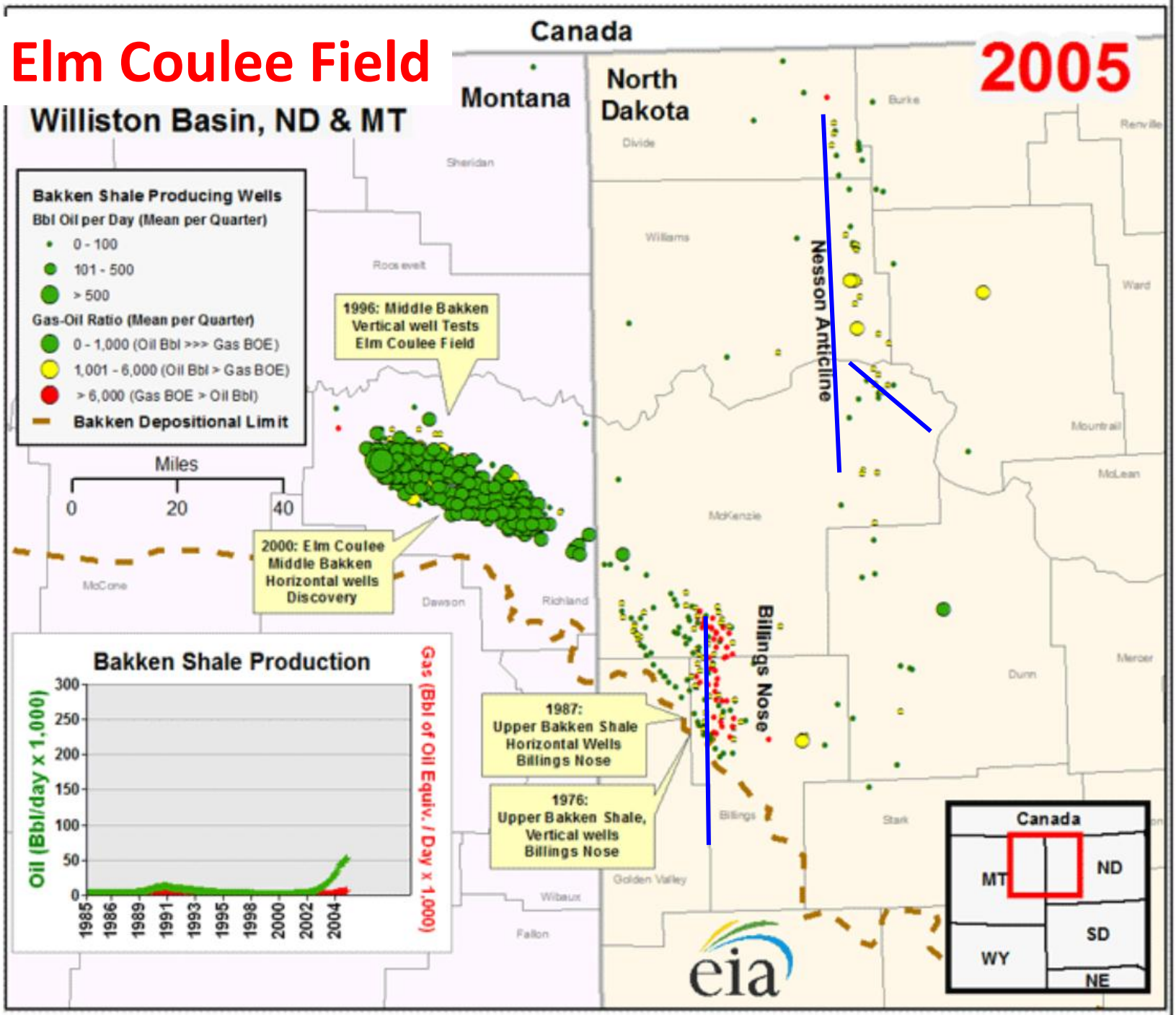
Burial & Oil Generation

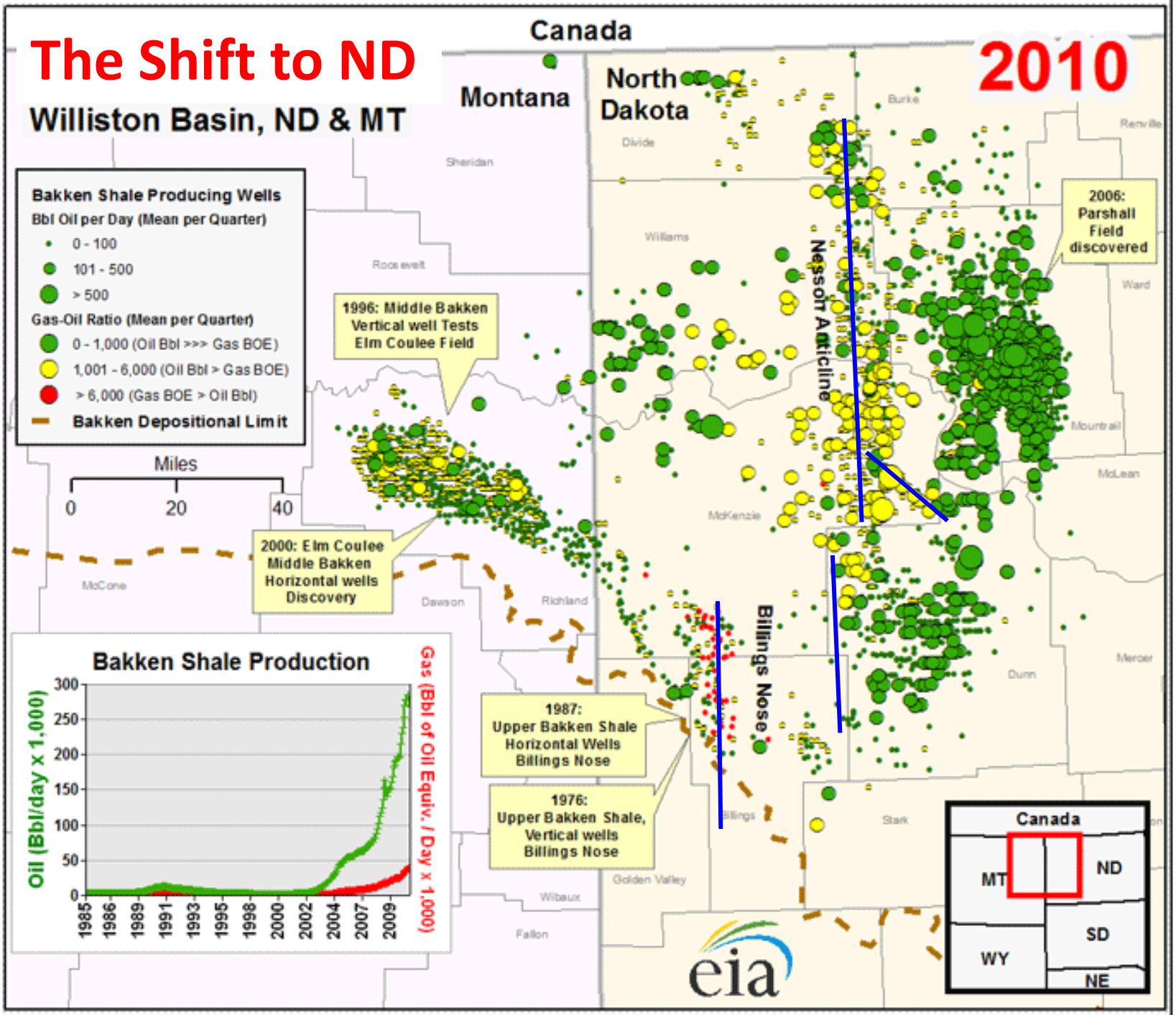


Source: Continental Resources


The Early Years
Williston Basin, ND & MT
2000
Canada
Montana
North Dakota
Bakken Shale Producing Wells
Bbl Oil per Day (Mean per Quarter)
0 - 100
101 - 500
> 500
Gas-Oil Ratio (Mean per Quarter)
0 - 1,000 (Oil Bbl >>> Gas BOE)
1,001 - 6,000 (Oil Bbl > Gas BOE)
> 6,000 (Gas BOE > Oil Bbl)
Bakken Depositional Limit
Miles
0
20
40
1996: Middle Bakken Vertical well Tests Elm Coulee Field
1953 Discovery Well
Nesson Anticline
2000: Elm Coulee Middle Bakken Horizontal wells Discovery
Billings Nose
1987: Upper Bakken Shale Horizontal Wells Billings Nose
1976: Upper Bakken Shale, Vertical wells Billings Nose
Bakken Shale Production
Oil (Bbl/day x 1,000)
Gas (Bbl of Oil Equiv. / Day x 1,000)
300
250
200
150
100
50
0
1985
1986
1989
1991
1993
1995
1998
2000
Canada
MT
ND
SD
WY
NE
eia

Elm Coulee Field




The Shift to ND
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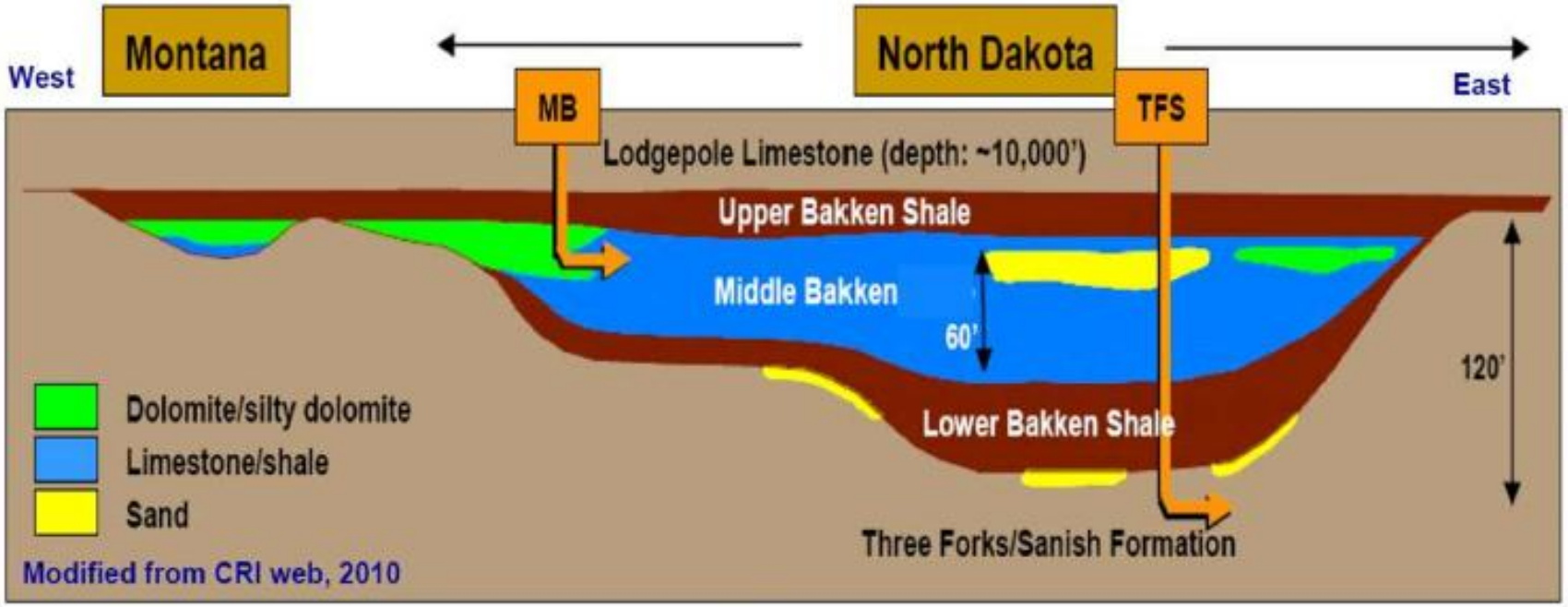
Bakken Shale Production
Oil (Bbl/day x 1,000)
Gas (Bbl of Oil Equiv. / Day x 1,000)
300
250
200
150
100
50
0
1985
1986
1989
1991
1993
1995
1998
2000
2002
2004
2007
2009
Sheridan
Roosevelt
Divide
Burke
Renville
Williams
Ward
Mountrail
McLean
McKenzie
McCone
Dawson
Richland
Dunn
Mercer
Billings
Stark
Golden Valley
Wibaux
Fallon
Canada
MT
ND
SD
WY
NE
eia

Geology dictates where the rigs go

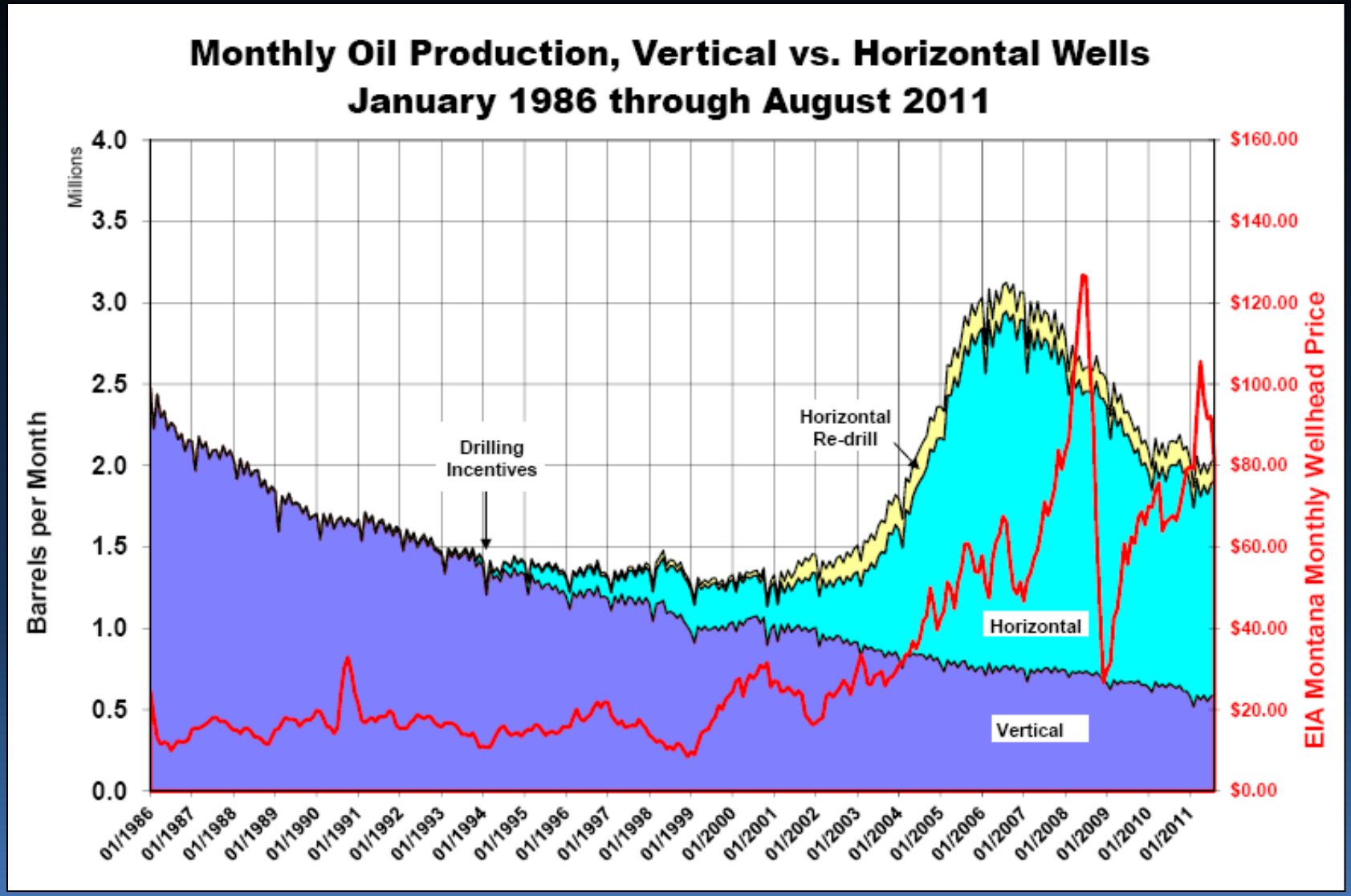
Middle Bakken / Three Forks Pay Variation



- Middle Bakken pay not a shale lithology
  - Complex, laterally varying lithology & play types
  - Stratigraphic / diagenetic trap drivers
- Underlying Three Forks 'non-shale' play potential established 2008
  - Also sourced by Bakken shale
  - Dual zone development underway

from ConocoPhillips

MT Oil Production

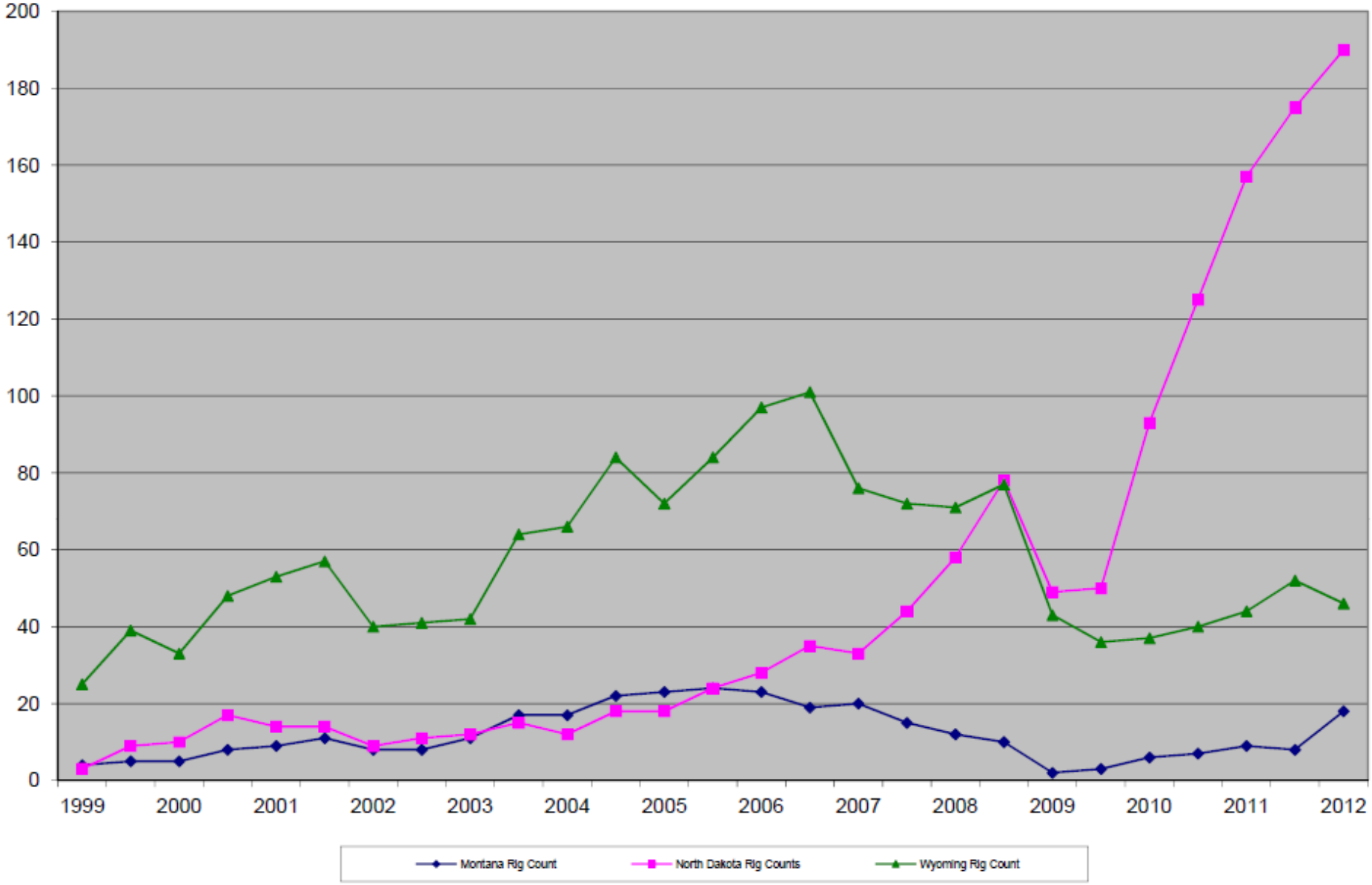


In MT, the "Boom" has Passed?

Rig Count as of 7/20/12
Montana 20
North Dakota 198
Wyoming 47

Total Rig Count

Source: Montana Petroleum Assoc.

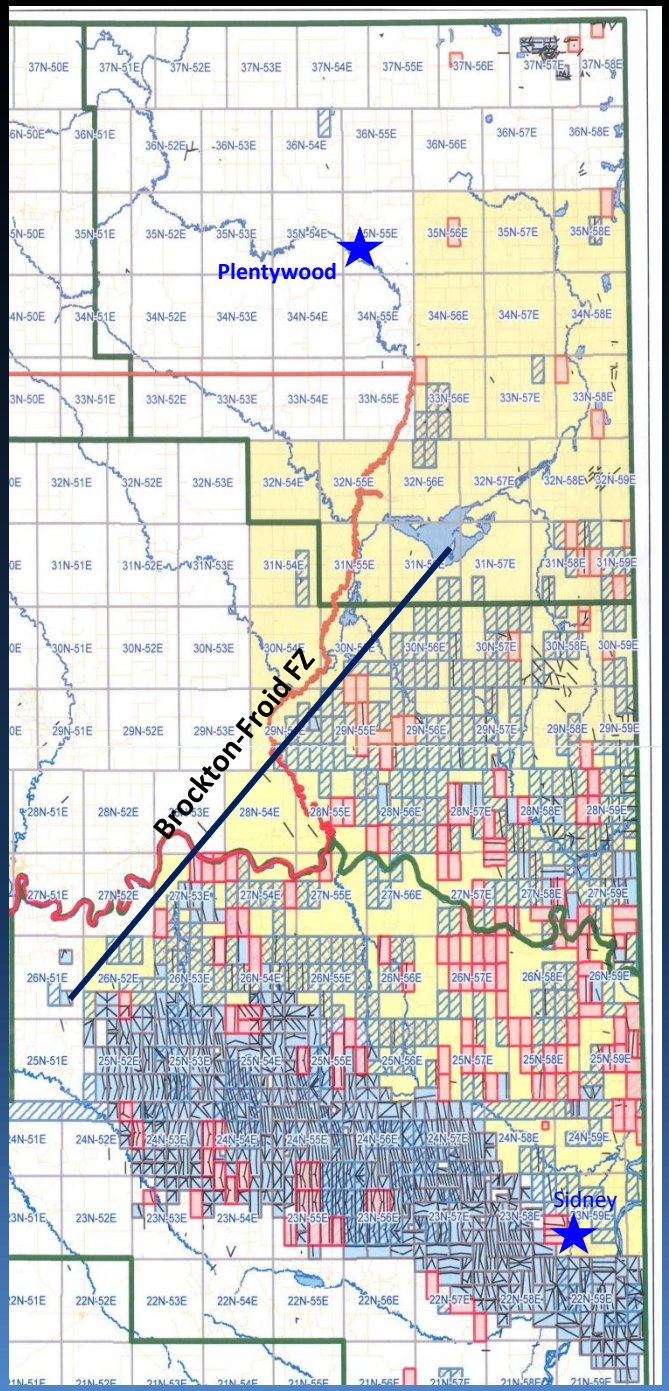


Current Activity

- Rigs are trickling back into MT
  - 10-15 rigs to drill & hold leases for Bakken/Three Forks targets

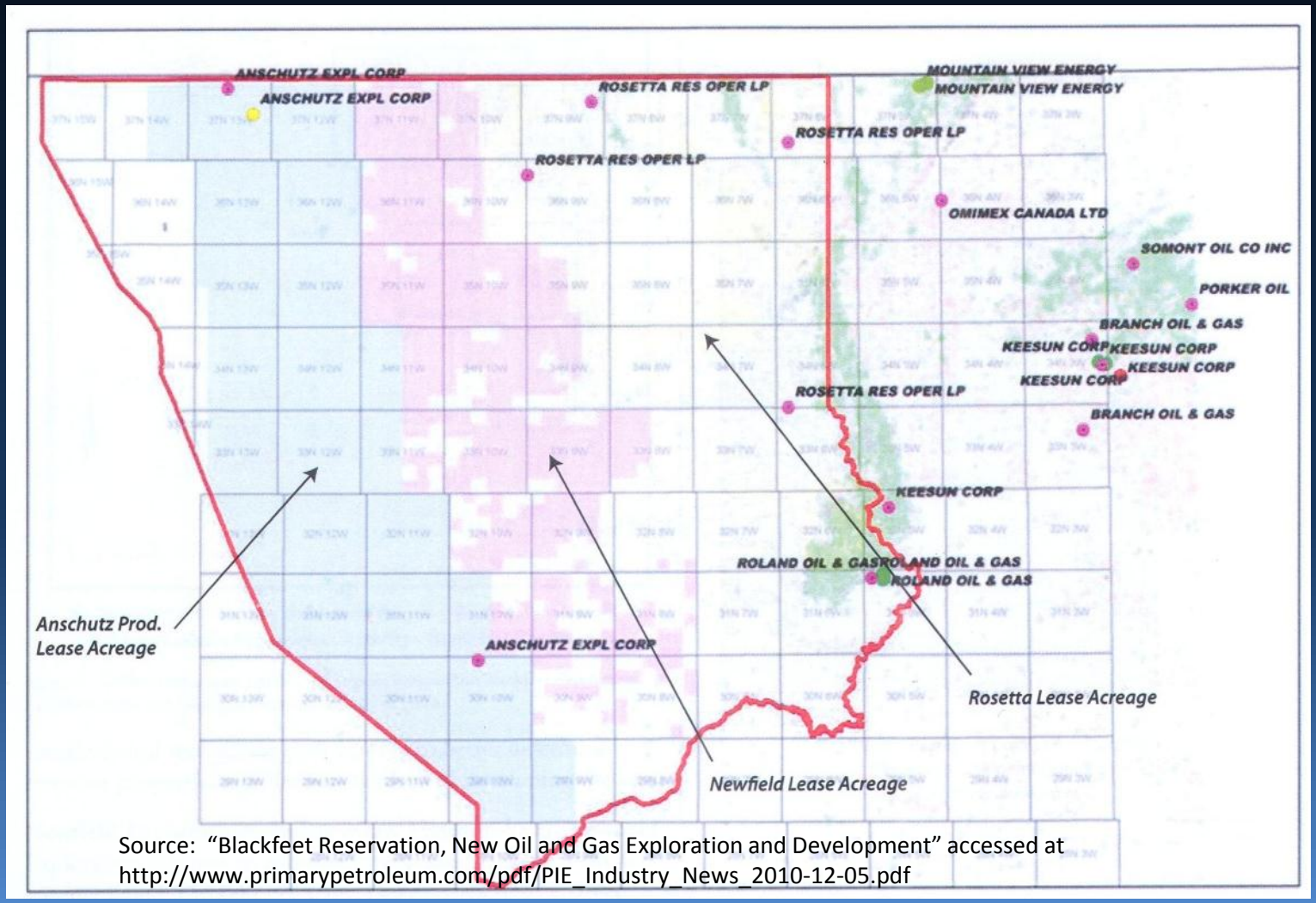
- Still some Elm Coulee infill wells
- Geopressured area along MT-ND border
- South edge Elm Coulee - upper shale

- Marginal production to the north
- No economic production NW of Brockton-Froid fault zone yet



Glacier Co., MT

- Maybe a dozen wells in last 3 years
- < 50 bopd max
- no pressure?

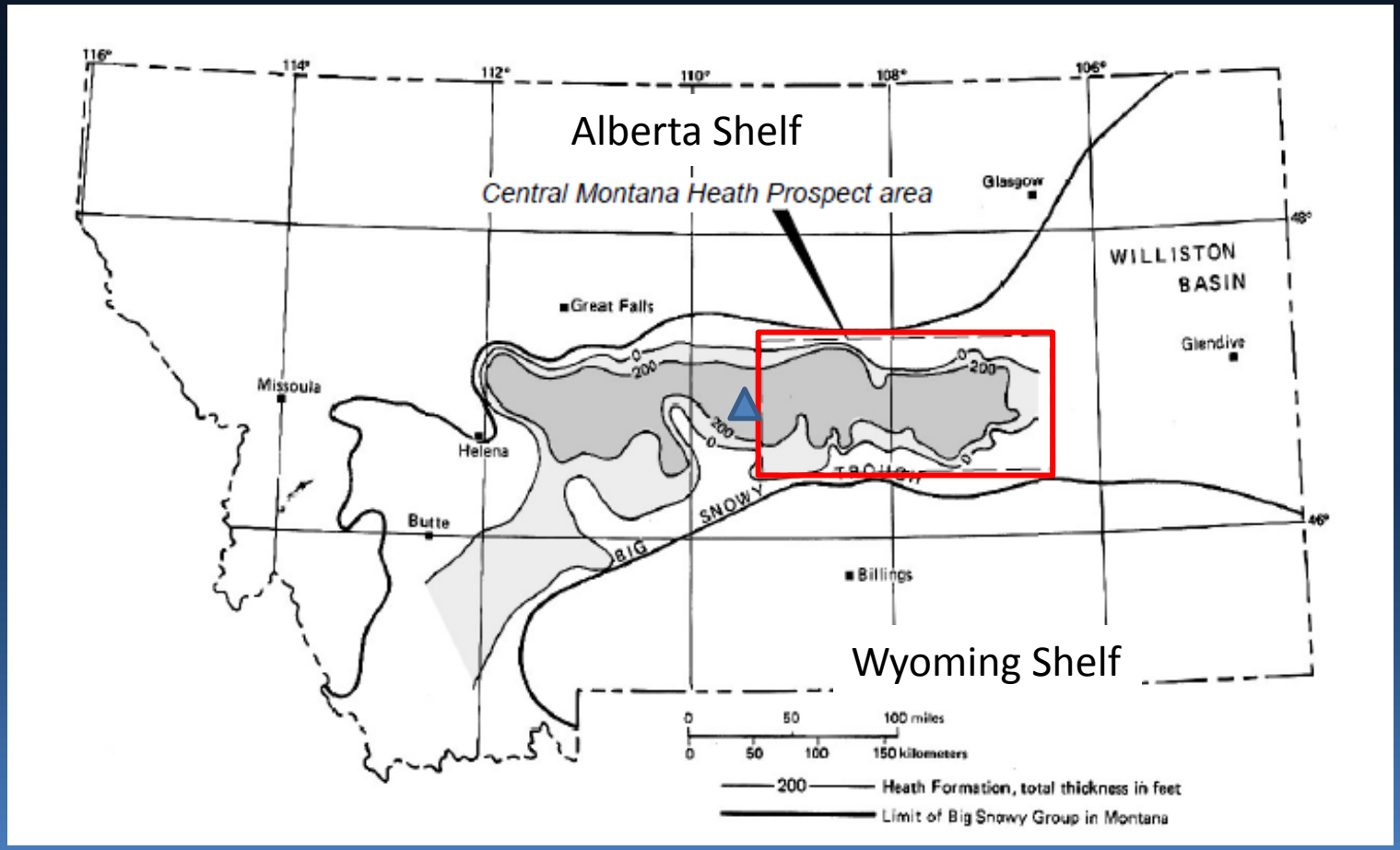


Source: "Blackfeet Reservation, New Oil and Gas Exploration and Development" accessed at http://www.primarypetroleum.com/pdf/PIE_Industry_News_2010-12-05.pdf

There will continue to be Bakken drilling in Elm Coulee and to the north (?), but probably not elsewhere in the State .....at least for now.

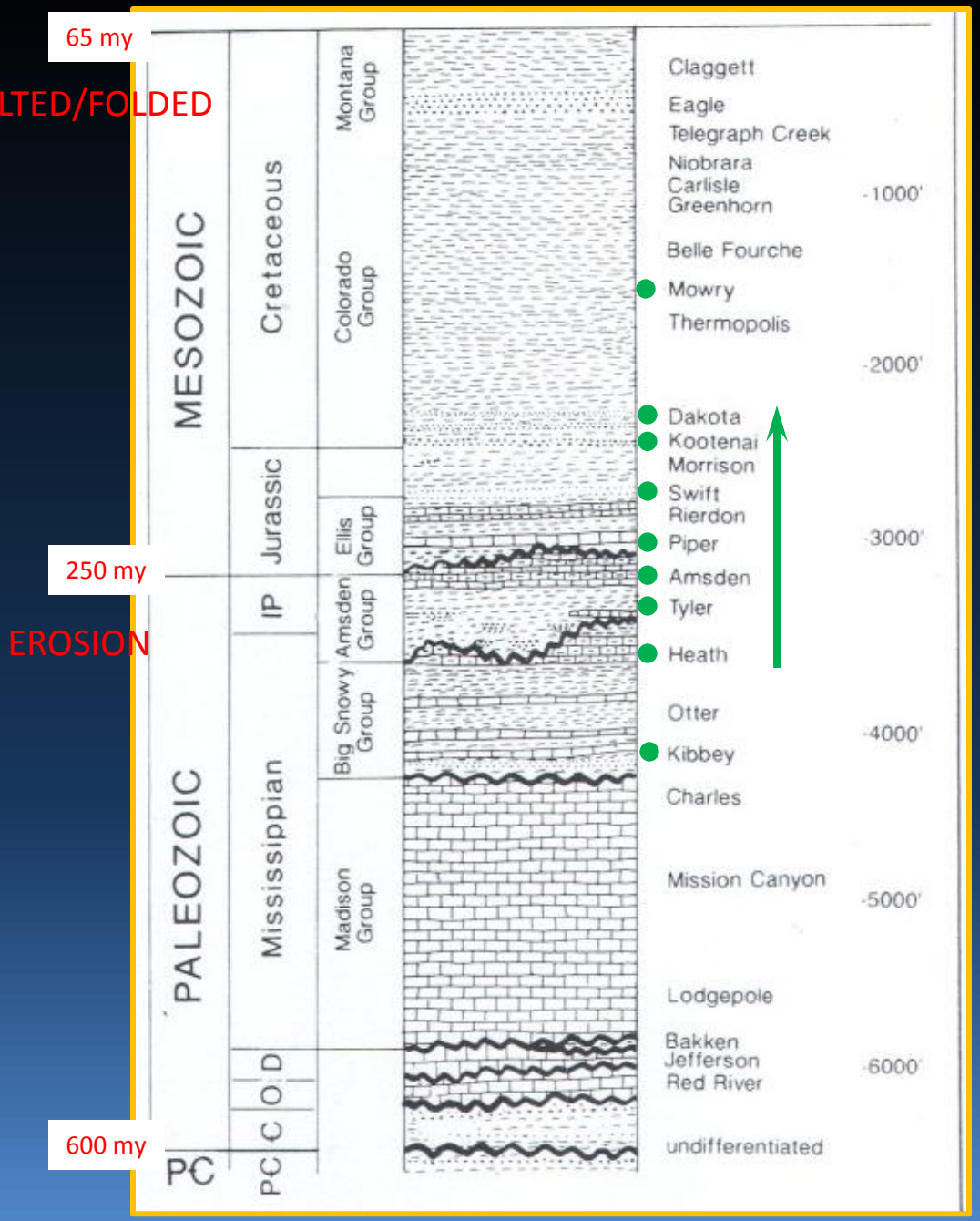
Heath Formation

Depth: 0 to 5000’
Some in Judith Basin



Central Montana Stratigraphy

Not simple layer-cake



Heath Formation – Complex Mix of Lithologies

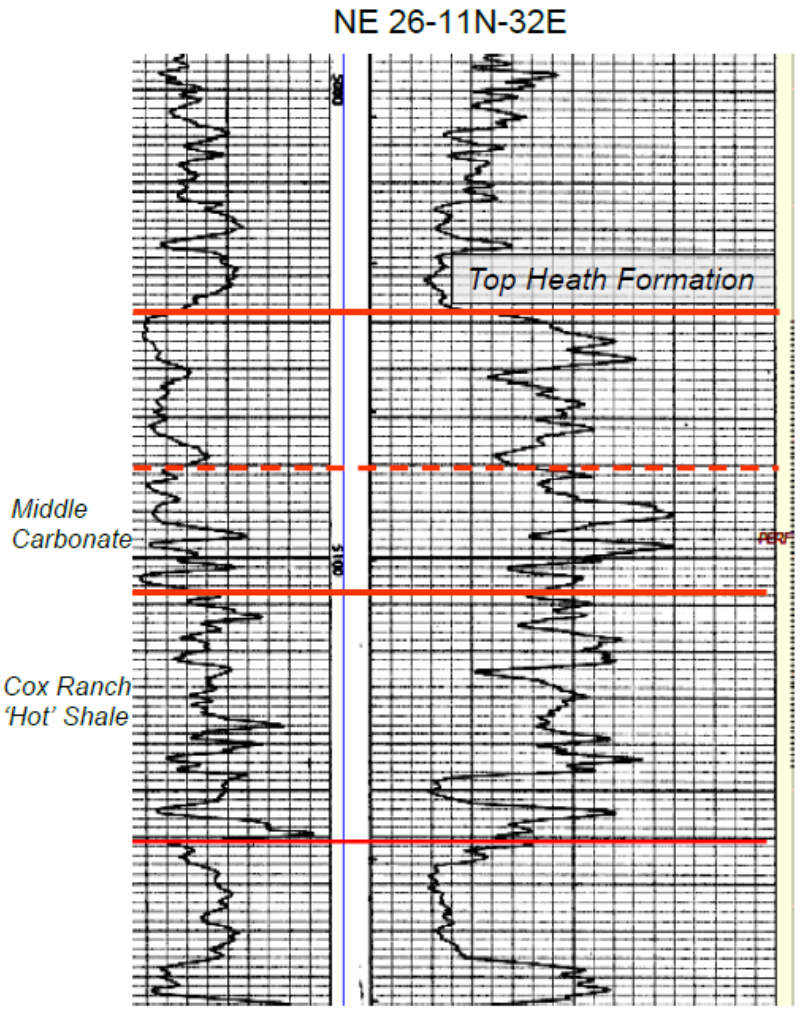
Key components:

- Middle Carbonate Member (up to 40' thick)
  - Thin limestones and dolomites
  - Porosity developed in places (up to13%, 5% avg)
  - Possible 'carrier' beds; tested oil

  Brittle, fractures – especially on structure

- Cox Ranch Member ("Hot" Shale)
  - 10 to 60 feet thick (4 – 20% porosity, 11% avg)
  - High organic content
  - Thermally mature to volatile oil window
  - Tested 30 – 35.5 API gravity oil

SHALE +/- Coal, gypsum, DM, LS



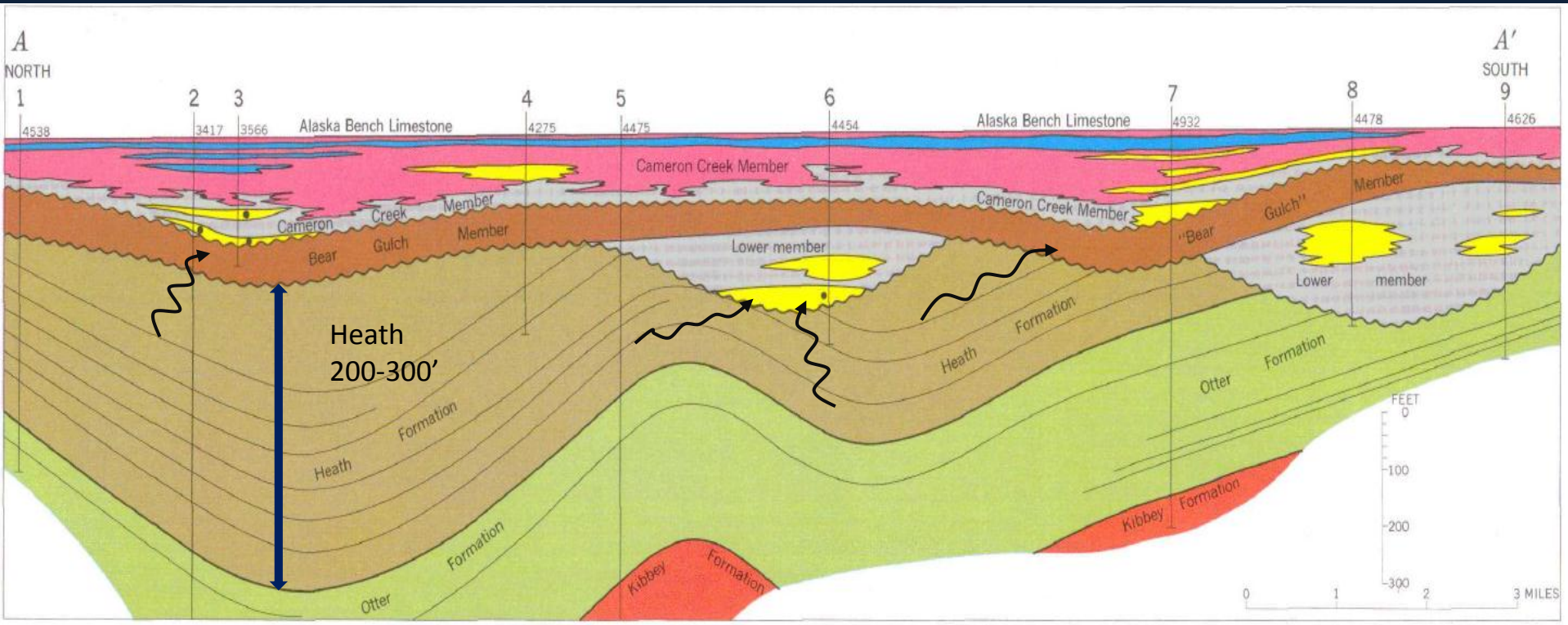
DST 1700' clean oil
IP 73 BOPD, 35.3 API

Source: Central Montana Heath Prospect Geological Report, 2009, Great Northern Gas Company

Complex Geology: folded & faulted

Oil Migrated into Permeable Rocks & Conventional Traps

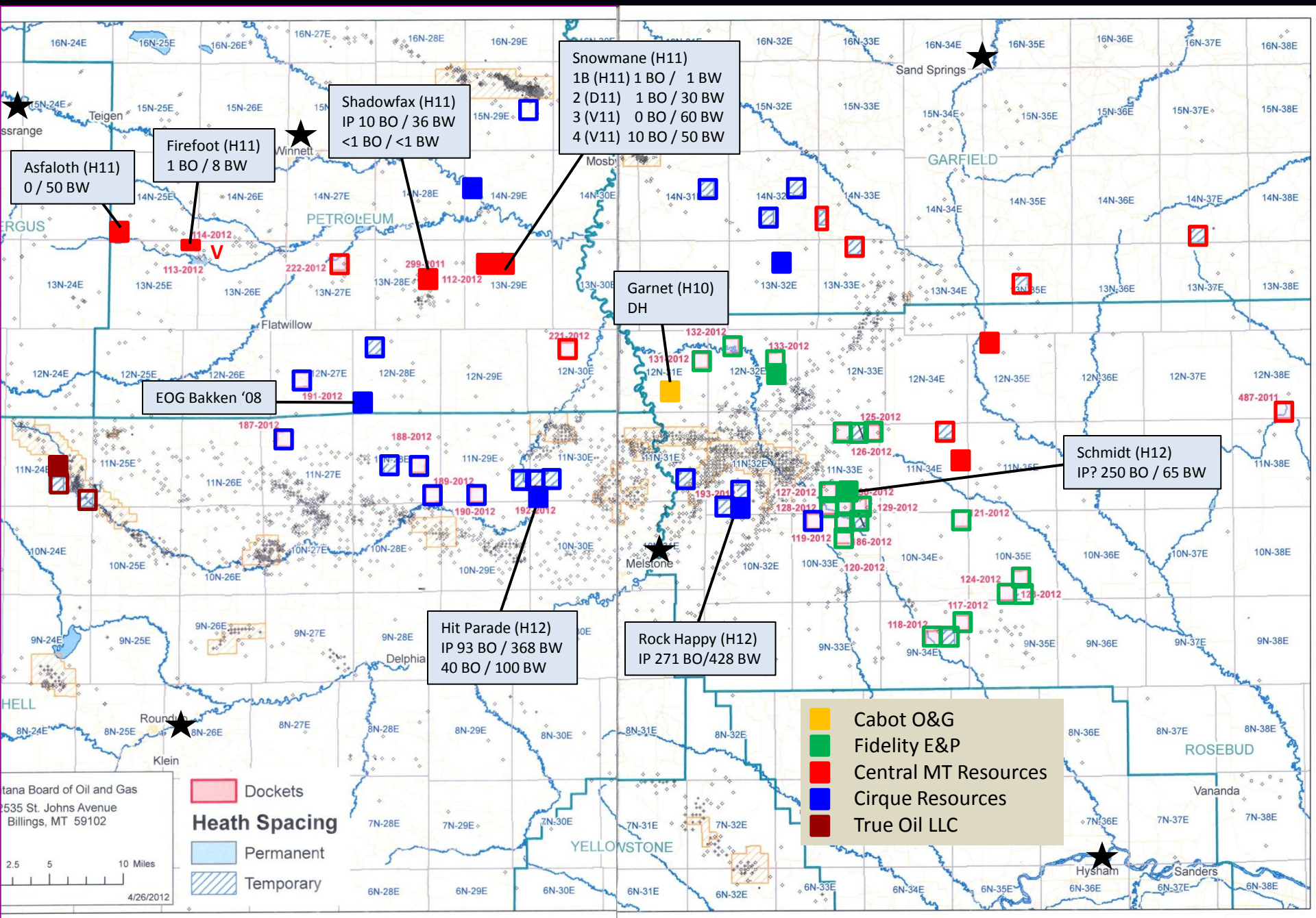
- Over 40 oil fields in Central MT
- Most are Amsden-Tyler
- Cumulative oil production 110-140 MMBO (sourced from Heath)



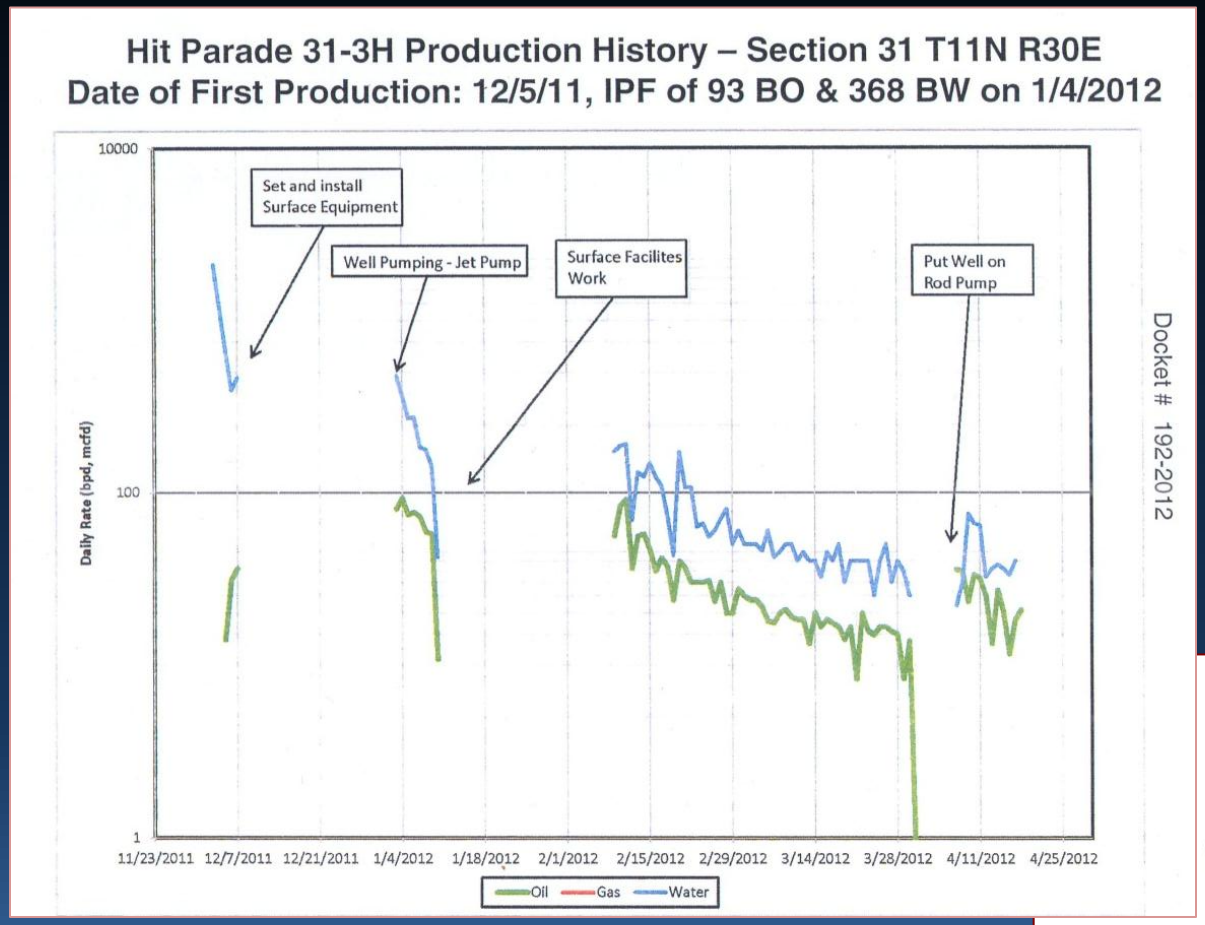
From AAPG-RMS 1972

Exploration Status?

- We just don't know that much yet; few wells drilled
- Since 2009
  - ~ 10 vertical wells drilled
    - Coring: oil shows, fractures, water/oil saturation, porosity, etc
  - ~15 horizontal wells drilled
    - Operators testing drilling and completion techniques
    - Only 2-3 on production
- 1 rig currently running


Asfaloth (H11)
0 / 50 BW
Firefoot (H11)
1 BO / 8 BW
Shadowfax (H11)
IP 10 BO / 36 BW
<1 BO / <1 BW
Snowmane (H11)
1B (H11) 1 BO / 1 BW
2 (D11) 1 BO / 30 BW
3 (V11) 0 BO / 60 BW
4 (V11) 10 BO / 50 BW
Garnet (H10)
DH
EOG Bakken '08
Schmidt (H12)
IP? 250 BO / 65 BW
Hit Parade (H12)
IP 93 BO / 368 BW
40 BO / 100 BW
Rock Happy (H12)
IP 271 BO/428 BW
Cabot O&G
Fidelity E&P
Central MT Resources
Cirque Resources
True Oil LLC
Dockets
Heath Spacing
Permanent
Temporary
Teigen
Winnett
Flatwillow
Melstone
Delphia
Klein
Sand Springs
GARFIELD
PETROLEUM
ROSEBUD
YELLOWSTONE
Vananda
Hysham
Sanders
10 Miles
4/26/2012

Example: Recent Heath Production Graph



Heath Volumetrics

Aerial Extent	640	acres
Pay Thickness	103	ft
Porosity	8.7	%
Water Saturation	42.1	%
Oil Gravity	35	degrees API @ 60 degrees F
GOR	215	scf/bbl
Gas Gravity	1.06	
Reservoir Temperature	147	degrees F
Oil Formation Volume Factor	1.15	STB/RB by correlation
OOIP	22,400,976	STB
Primary Recovery Factor (%)	0.1	%
Recoverable Oil	16,000	STB
Recoverable Gas	3,440	MCF

So, is it another Bakken?

We probably won't know for a while yet……."wait & see"

- The potential is certainly there: Both have
  - Organic rich black shales of similar age
  - Low porosity, low perm shales, high TOC
  - Both in oil window – thermally mature

Heath is a little more Complex

- Oil has migrated out of the system
  - Juxtaposition with conventional reservoirs
  - Faults may provide pathways
- Central MT is structurally complex: faulted / folded, erosional unconformities
- Testing different zones – which is the “Reservoir”?
- Reservoir Pressure – can production be sustained?

……remember, it took ~50 years for the Bakken to become what it is today

Hydrofracturing ("fracking")

- Hydrofracturing is also not new (late 1940's)
- Pressurize to exceed fracture gradient, crack the rocks & prop the cracks open
- Create pathways for fluid flow (permeability)
- Frac fluid is ~99% water and sand (or ceramics); 1% things to worry about.

  - Fracking has not caused any earthquakes
  - Water contamination can be mitigated; water conservation may be a bigger issue

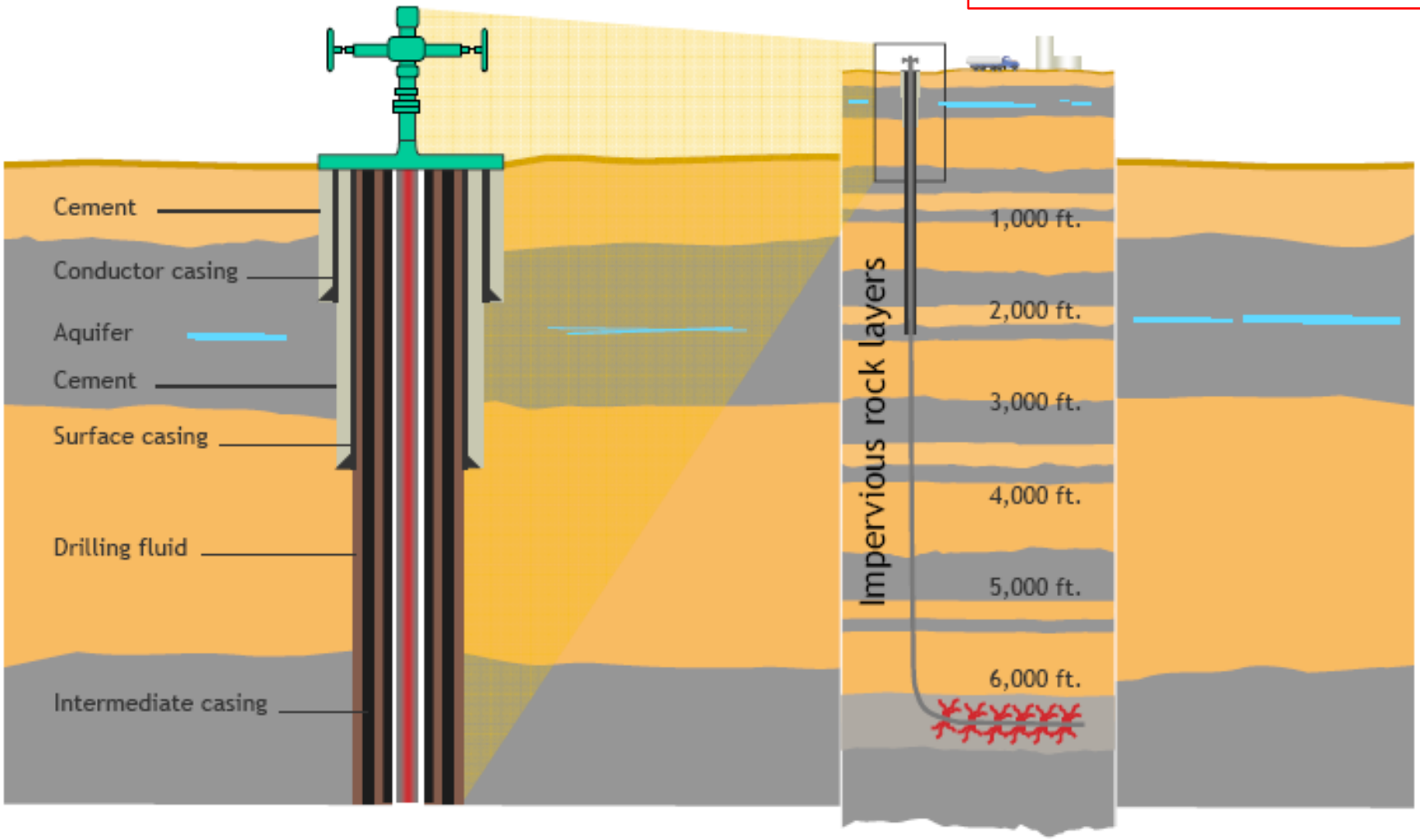
Potential Impacts on Groundwater?

- Potential for leakage of Frac fluid into groundwater aquifers
  - At depth due to frac'ing
  - Surface spills
  - Operators do not want to frac into water-bearing fms
    (they end up with an $8-10 million saltwater well)
- Water consumption
  - 2-mile lateral uses ~2 million gal of water for frac job.

Groundwater Protection

through proper well construction

Surface casing and cement are always required to isolate & protect aquifers

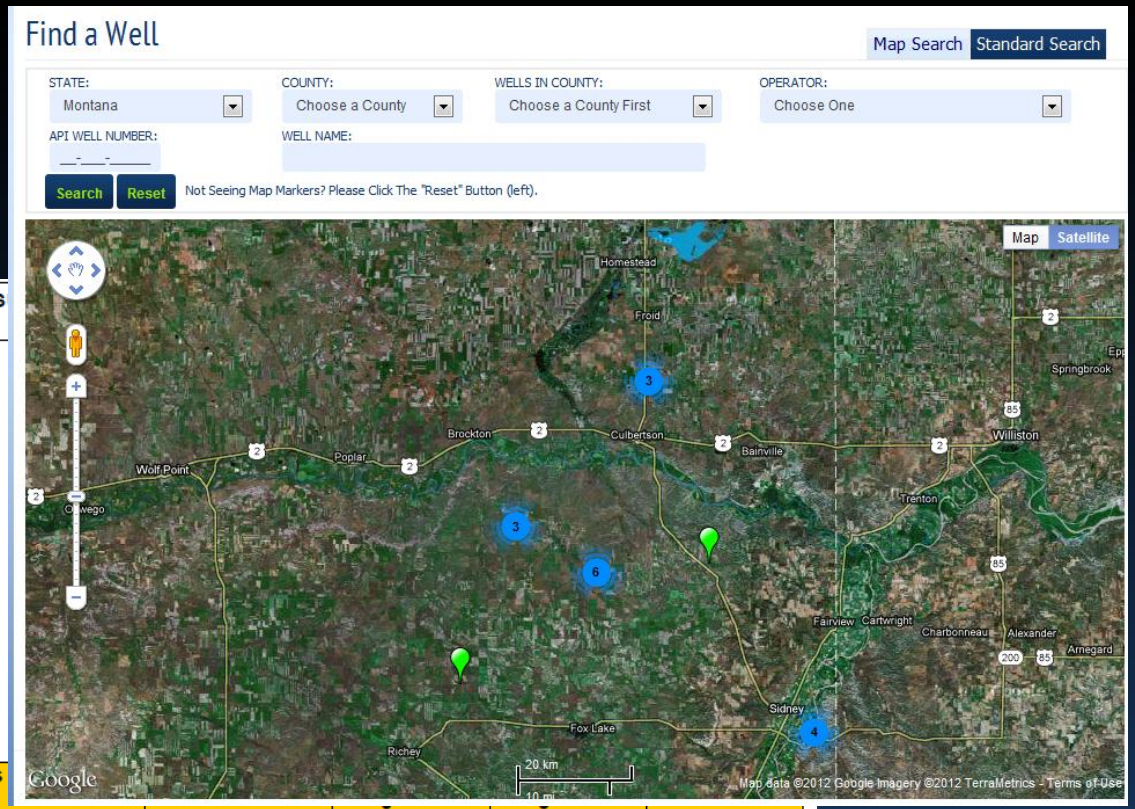


MBOG Frac'ing Rules Adopted 2011

http://www.bogc.dnrc.mt.gov/PDF/FinalFracRules.pdf

- Pressure test casing & equipment
- Must report composition of Frac fluid
  - Either public website (fracfocus.org) OR
  - File form in MBOG office – also public information
- Constituents deemed to be proprietary can remain protected unless health care emergency demands disclosure

www.fracfocus.org



Hydraulic Fracturing Fluid Product Component Information Disclos

Fracture Date	12/29/2011
State:	MT
County:	Richland
API Number:	25-083-22898
Operator Name:	Continental Resources
Well Name and Number:	Ripley 1-24H
Longitude:	-104.68829
Latitude:	47.98435
Long/Lat Projection:	NAD27
Production Type:	Oil
True Vertical Depth (TVD):	
Total Water Volume (gal)*:	2,092,092

Hydraulic Fracturing Fluid Composition:

Trade Name	Supplier	Purpose	Ingredients	(CAS #)	Concentration in Additive (% by mass)**	Concentration in HF Fluid (% by mass)**	
WF125, YF125FLEX	Schlumberger	Base Fluid, Bactericide, Breaker, Crosslinker, Gelling Agent, Non-Emulsifying Agent, Proppant, Sand, Stabilizer	Water (Including Mix Water Supplied by Client)	-	-	83.96459%	
			Crystalline silica	14808-60-7	59.44812%	9.53275%	
			Ceramic materials and wares, chemicals	66402-68-4	33.78111%	5.41694%	
			Distillates (petroleum), hydrotreated light	64742-47-8	2.14020%	0.34319%	
			Aliphatic polyol	Proprietary	0.56194%	0.09011%	
			Methanol	67-56-1	0.33083%	0.05305%	
			Tetramethylammonium chloride	75-57-0	0.32060%	0.05141%	
			Potassium hydroxide	1310-58-3	0.28094%	0.04505%	
			Decyl-dimethyl amine oxide	2605-79-0	0.08014%	0.01285%	
			Oxyalkylated alkyl alcohol (1)	Proprietary	0.04727%	0.00758%	
			Oxyalkylated alcohol (2)	Proprietary	0.04727%	0.00758%	
			Diammonium peroxidisulphate	7727-54-0	0.03143%	0.00504%	
			Heavy aromatic naphtha	64742-94-5	0.02364%	0.00379%	
			Quaternary ammonium compound	Proprietary	0.02364%	0.00379%	
			Oxyalkylated alcohol (1)	Proprietary	0.02364%	0.00379%	
			Tetrakis(hydroxymethyl)phosphonium sulfate	55566-30-8	0.01515%	0.00243%	
			Amorphous silicia	Proprietary	0.01515%	0.00243%	