[AV]Petroleum Potential of the Upper Three Forks Formation, Williston Basin, USA*

Stephen A. Sonnenberg[1], Alan Gantyno[1,2], and Rick Sarg[1]

Search and Discovery Article #110153 (2011)
Posted June 13, 2011

*Adapted from oral presentation at Session, U.S. Active and Emerging Plays--Paleozoic Basins and Cretaceous of Rockies, AAPG Annual Convention and Exhibition, Houston, Texas, USA, April 10-13, 2011

[1]Colorado School of Mines, Golden, CO (sasonnenbg@aol.com)
[2]Exxon, Indonesia

Abstract

The upper Three Forks is evolving into a significant resource play in the Williston Basin. Although Three Forks production was established in Antelope Field in 1953, the play has re-emerged because of the horizontal drilling and multi-stage fracturing technologies. The upper Three Forks can be subdivided into three main facies: a) massive to chaotic bedded dolostone; b) interbedded dolostone with green mudstones; c) bioturbated dolostone to sandstone. The bioturbated sandstone and dolostone is referred to as the Sanish. The units represent an overall transgressive sequence ranging from upper intertidal/supratidal to subtidal.

The upper Three Forks has poor reservoir quality with low porosities (generally less than 8%) and low permeabilities (less than 0.1 md). The reservoirs require fracture stimulation to produce economically. Sweet-spot areas are related to favorable facies development, natural fractures, and mature Bakken source rocks. The main source rock for the Three Forks is the lower Bakken shale. Where the lower and middle Bakken members thin in the southern part of the Williston basin, the primary source rock becomes the upper Bakken shale. The Three Forks is overpressured and overpressuring is related to hydrocarbon generation.

The upper Three Forks does not appear to be in communication with the overlying middle Bakken reservoirs where the lower Bakken shales are sufficiently thick to form a barrier between the producing units. The Three Forks resource potential is estimated to be 2 billion barrels of recoverable oil.

Selected References

Baars, D.L., 1972, compiler, Devonian System, *in* W.W. Mallory et al., editors, Geologic Atlas of the Rocky Mountain Region, United States of America: Rocky Mountain Association of Geologists, Denver, Colorado, 331 p.

Berwick, B., 2009, Depositional Environment, Mineralogy, and Sequence Stratigraphy of the Late Devonian Sanish Member (Upper Three Forks Formation), Williston Basin, North Dakota: Thesis (M.S. in Geology), Colorado School of Mines, 263 p.

Folsom, C. B., Jr., Carlson, C. G., and Anderson, S. B., 1959, Preliminary report on the Antelope-Madison and Antelope-Sanish pools: North Dakota Geological Survey Report, Investigation No. 32, 38 p.

Gantyno, A., 2010, Sequence Stratigraphy and Microfacies Analysis of the Late Devonian Upper Three Forks Formation, Williston Basin, North Dakota and Montana, USA: M.S. Thesis, Colorado School of Mines, Golden, Colorado, 201 p.

LeFever, J., 2005, Oil production from the Bakken Formation: A short history: North Dakota Geological Survey Newsletter, v. 32/1, p. 5-10.

Meissner, F.F., 1978, Petroleum Geology of the Bakken Formation, Williston basin, North Dakota and Montana, *in* D. Rehig., (ed.), The economic geology of the Williston basin: Proceedings of the Montana Geological Society, 24th Annual Conference, p. 207-227.

Rocky Mountain Association of Geologists (RMAG), 1972, Geologic atlas of the Rocky Mountain region, United States of America: RMAG, Denver, Colorado, 331 p.

Sandberg, C.A., 1962, Correlation of Devonian and lowermost Mississippian rocks between outcrops in western and central Montana and the Williston Basin in eastern Montana, *in* Three Forks-Belt Mountains area, and symposium – The Devonian system of Montana and adjacent areas: Billings Geological Society, 13th Annual Field Conference, p. 33-34.

Webster, R.L., 1984, Petroleum source rocks and stratigraphy of the Bakken Formation in North Dakota, *in* J. Woodward, F.F. Meissner, and J.L. Clayton, (eds.), Hydrocarbon source rocks of the Greater Rocky Mountain region: Rocky Mountain Association of Geologists, Denver, Colorado, p. 57-81.

Zoback, M. L., and M.D. Zoback, 1980, State of stress in the conterminous United States: Journal of Geophysical Research, v. 85/B11, p. 6113-6156.

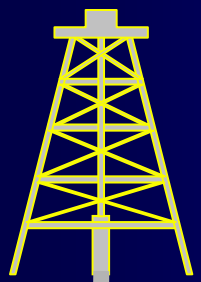
Website

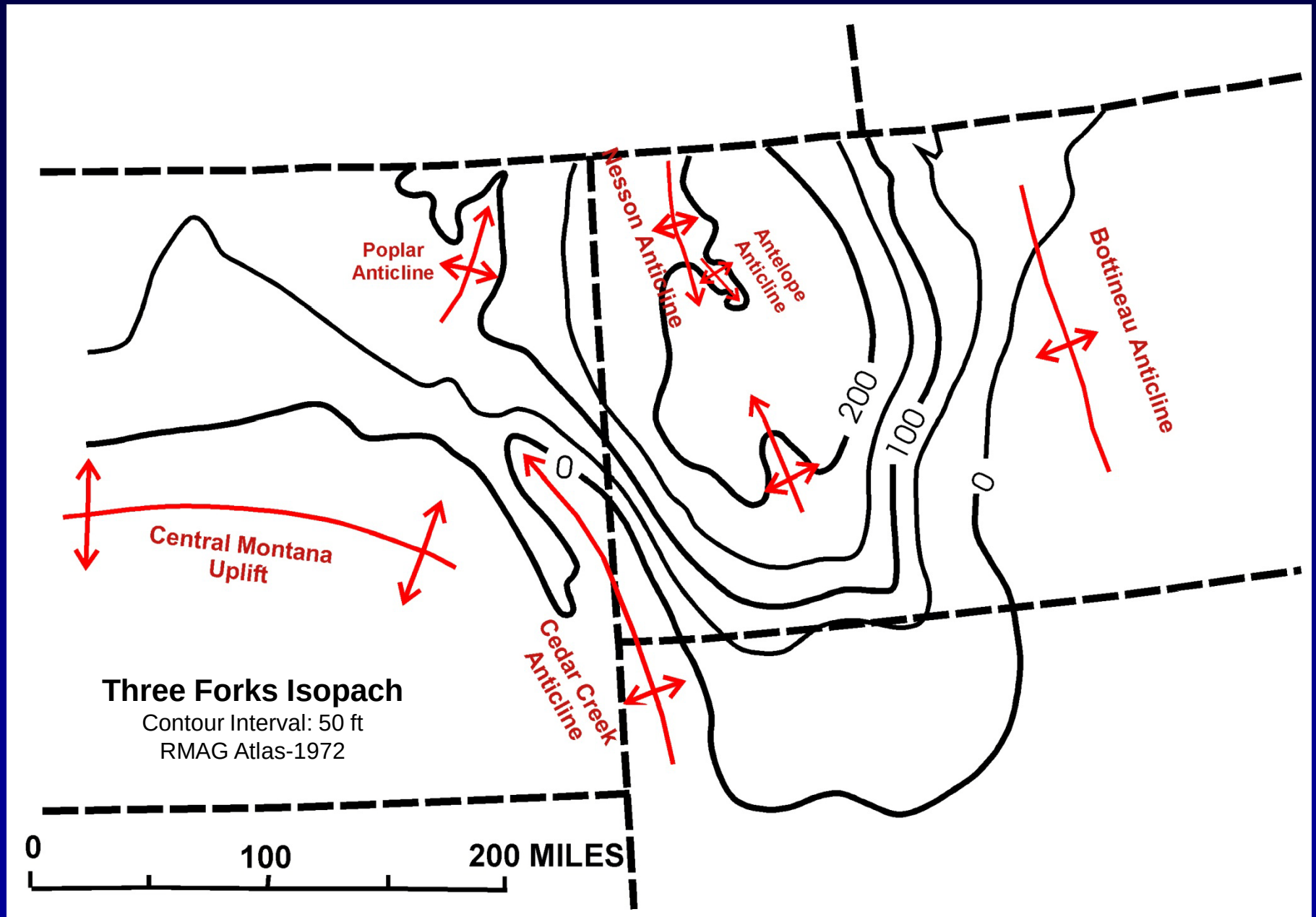
Blakey, Ron, 2011, North American Paleogeographic Maps: Late Devonian (360 Ma): Web accessed 30 May 2011, http://www2.nau.edu/rcb7/namD360.jpg

Petroleum Potential of the Upper Three Forks Formation, Williston Basin, USA

Stephen A. Sonnenberg[1]
Alan Gantyno [1,2]
Rick Sarg[1]

[1]Colorado School of Mines
[2]Exxon, Indonesia

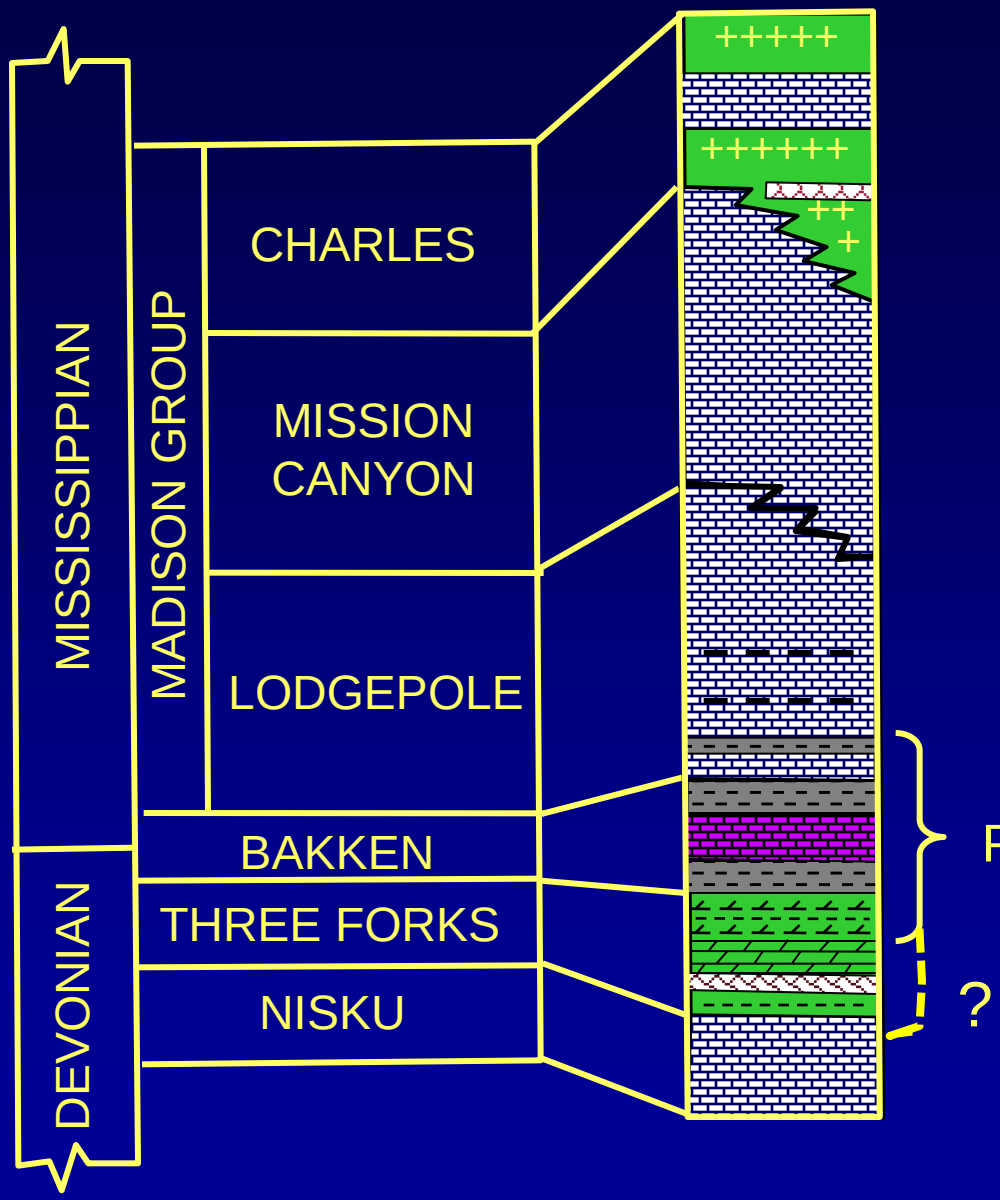




Three Forks Isopach

Contour Interval: 50 ft

RMAG Atlas-1972



Modified from Webster, 1984

NDIC (2010) estimated ultimate production
Bakken Petroleum System:

Bakken: 2.1 Billion barrels
Three Forks: 1.9 Billion barrels

USGS Estimate (2008)
Bakken Petroleum System:
3.6 Billion barrels

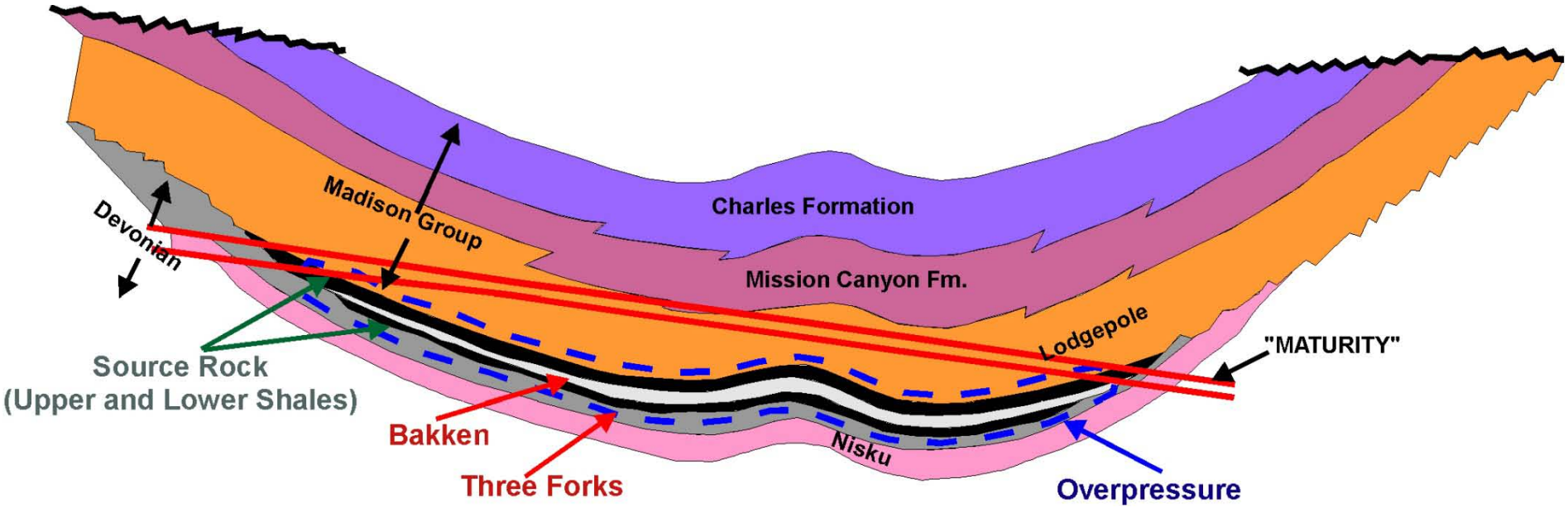
Modified from Blakey, 2005

Bakken Petroleum System Basics

- Upper & lower black shales
  - ‘World Class’ Source Rocks
    - Hard, siliceous, pyritic, fissile, organic rich
    - TOC’s as high as 40 wt% (average 11%)
    - High OM indicates anoxic conditions (amorphous-sapropelic OM)
    - HC Generation: 10 to 400 B bbl oil
- Middle member (target of horizontal drilling)
  - Dolomitic siltstone to a silty dolomite
  - Low porosity and permeability
- Upper Three Forks dolostones (target of horizontal drilling)
  - Low porosity and permeability
- Abnormal pressure and hydrocarbon generation (> 0.5 psi/ft)

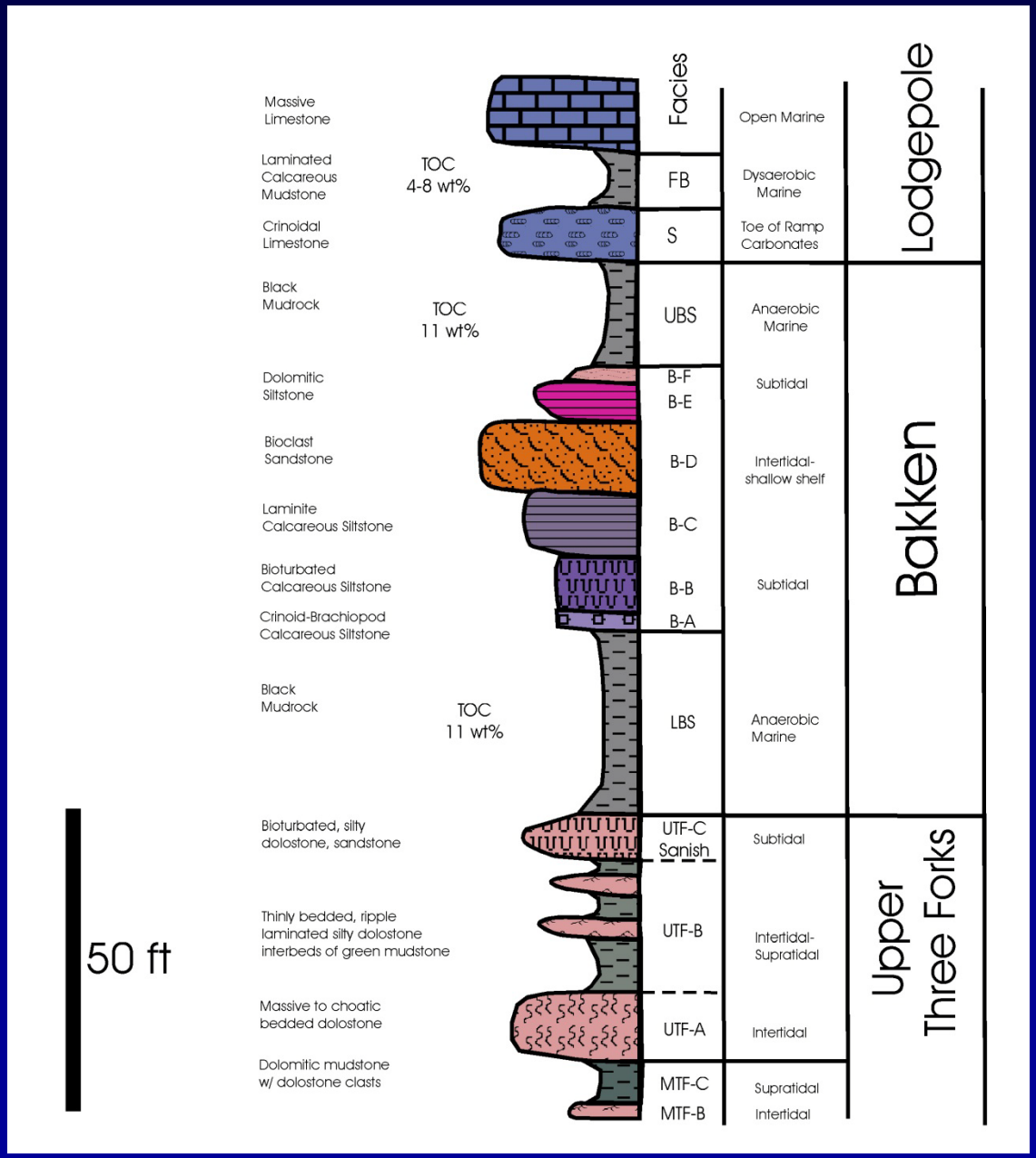
Modified from LeFever, 2005

Bakken Petroleum System



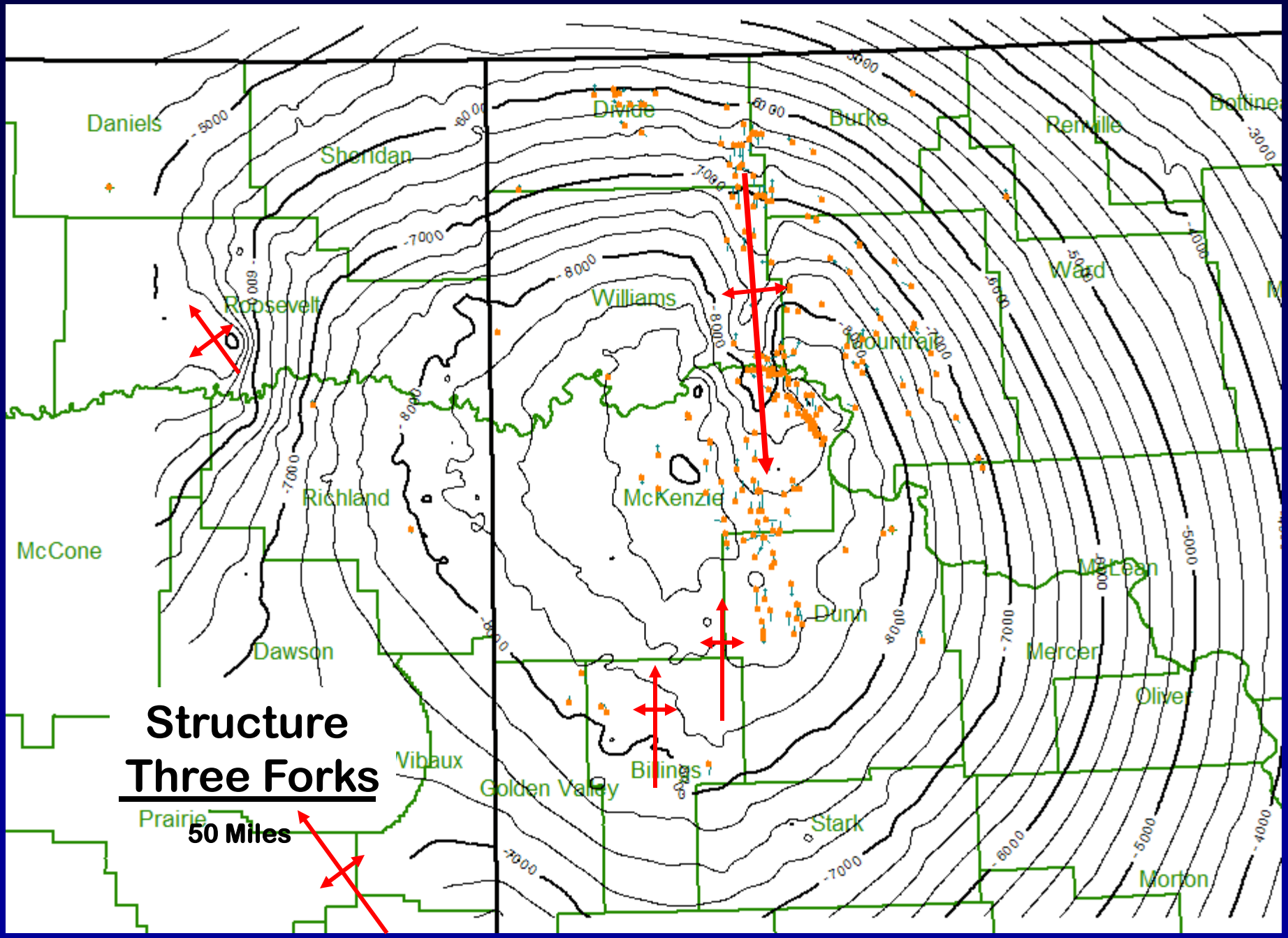
Reservoirs:
Middle Bakken & Three Forks

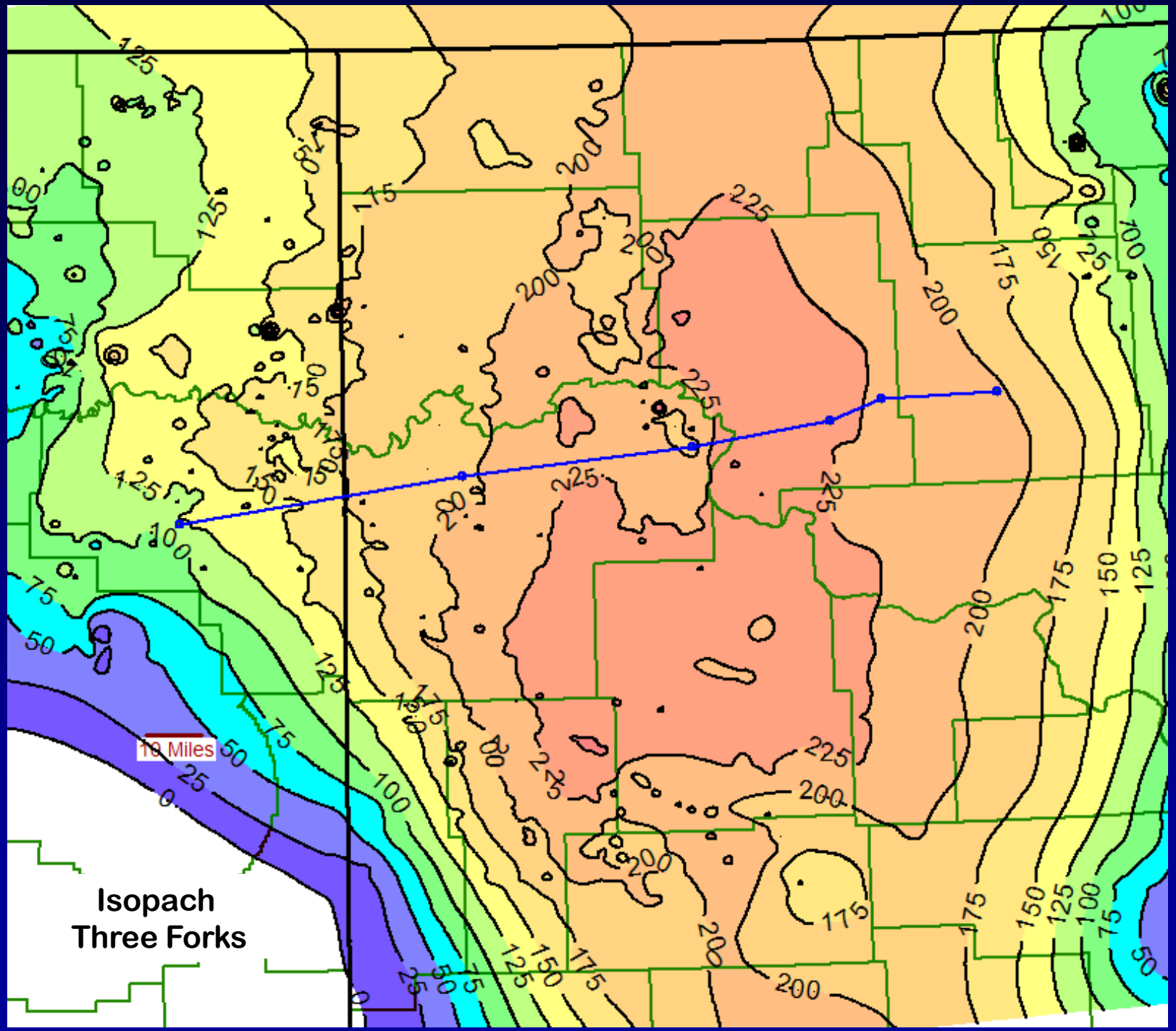
Source Beds:
Upper & Lower Bakken Shales

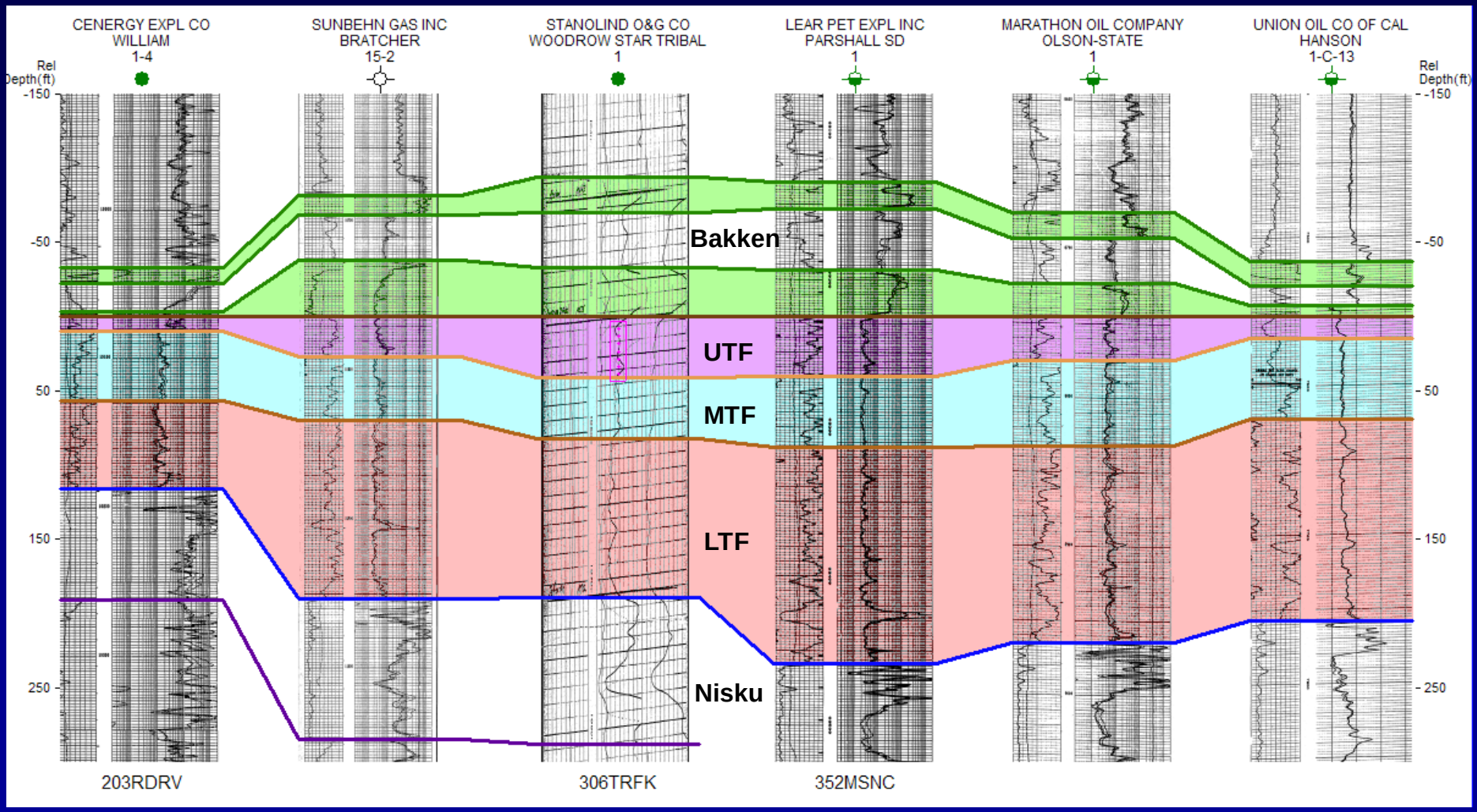


6-10% Porosity
< 0.1 md Permeability

6-10% Porosity
< 0.1 md Permeability

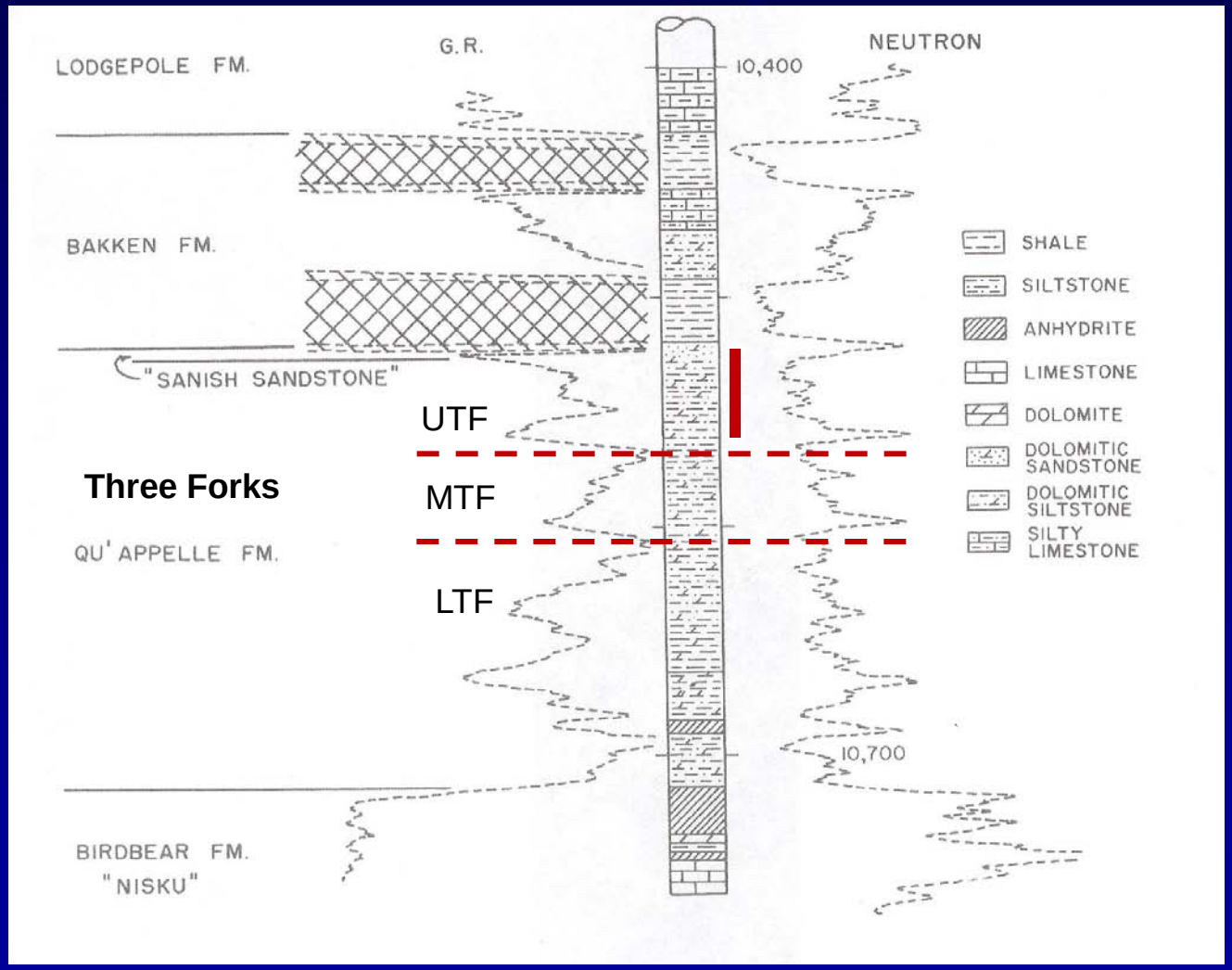

Structure
Three Forks
50 Miles
Daniels
Sheridan
Divide
Burke
Renville
Bottineau
Roosevelt
Williams
Ward
Mountrail
McKenzie
Richland
McCone
McLean
Dunn
Dawson
Mercer
Oliver
Billings
Golden Valley
Vibaux
Prairie
Stark
Morton


10 Miles
Isopach
Three Forks


CENERGY EXPL CO
WILLIAM
1-4
SUNBEHN GAS INC
BRATCHER
15-2
STANOLIND O&G CO
WOODROW STAR TRIBAL
1
LEAR PET EXPL INC
PARSHALL SD
1
MARATHON OIL COMPANY
OLSON-STATE
1
UNION OIL CO OF CAL
HANSON
1-C-13
Rel Depth(ft)
-150
-50
50
150
250
Bakken
UTF
MTF
LTF
Nisku
203RDRV
306TRFK
352MSNC

Pan American Pet. W. Starr No. 1

SwSe Sec. 21-T152N-R94W
KB 2145 TD 12460

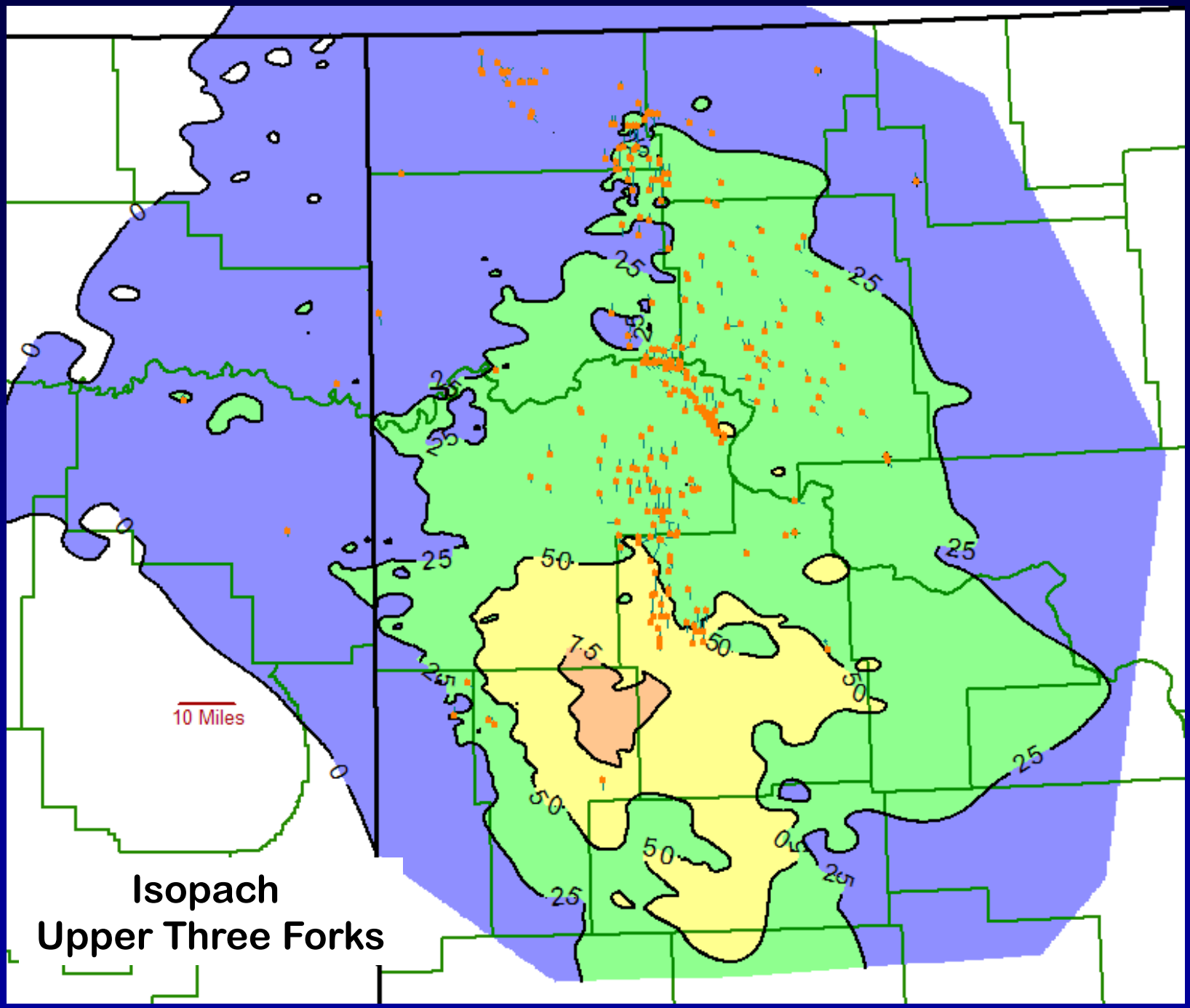


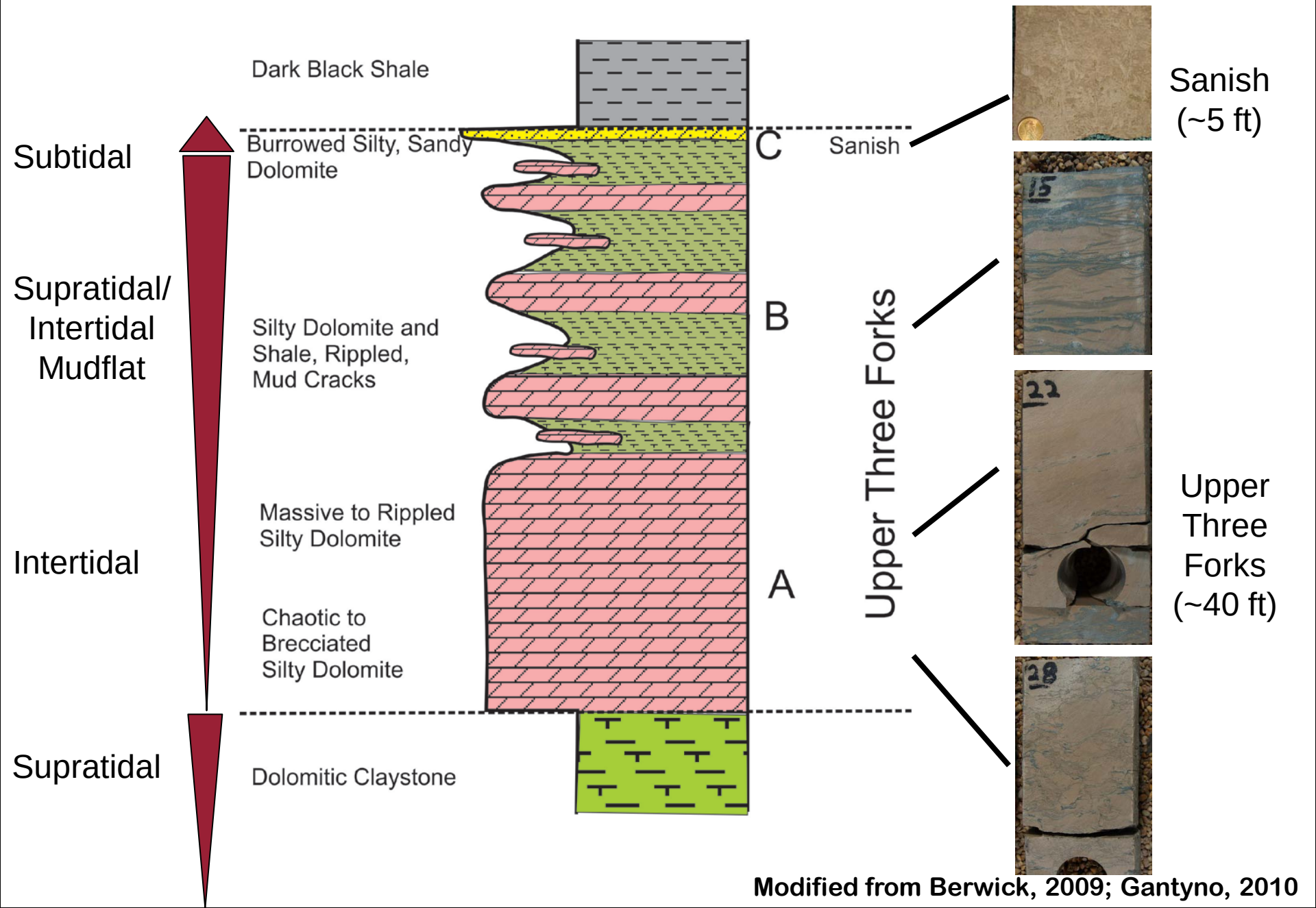
Pfs: 10528-10556; well swabbed in; sand-oil squeeze; break down pressure 4900 psi;

IP: 541 BOPD; GOR 770 cu ft / bbl; 44° API

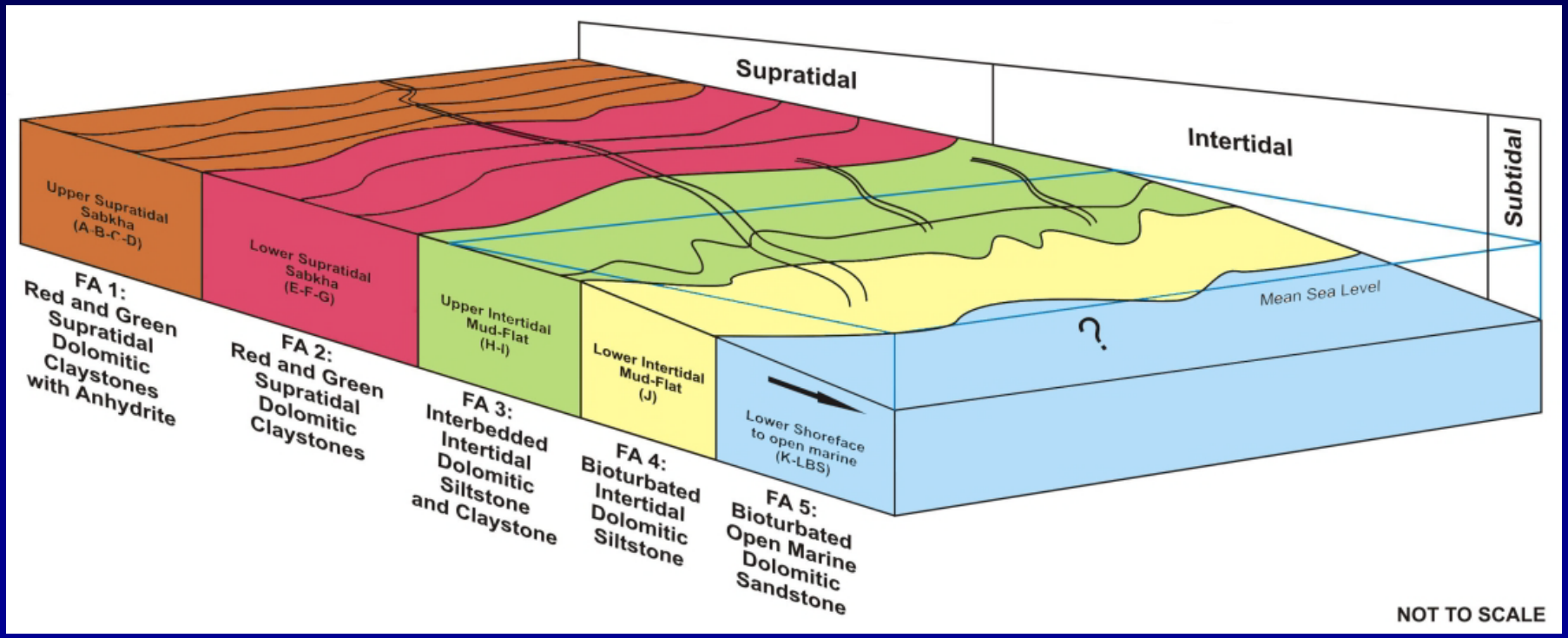
Completed: Dec. 6, 1953

Carlson and Anderson, 1959


0
25
50
75
10 Miles
Isopach
Upper Three Forks

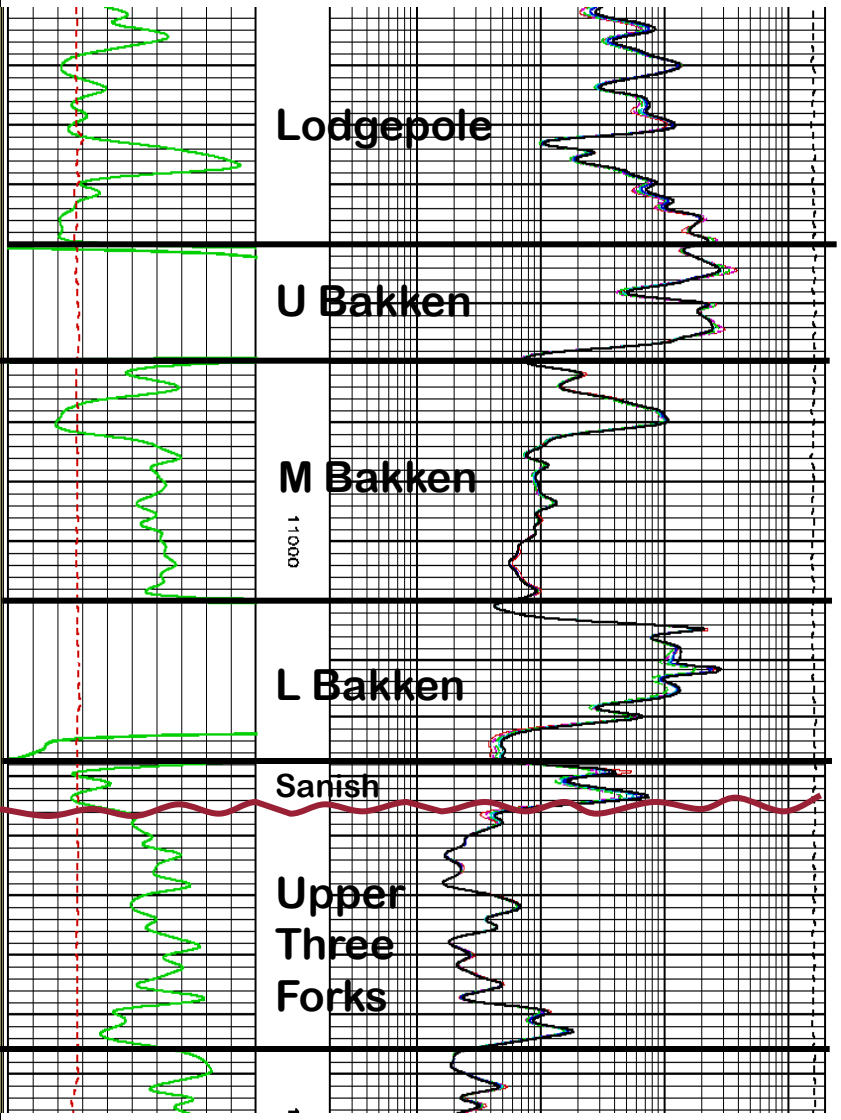


Modified from Berwick, 2009; Gantyno, 2010

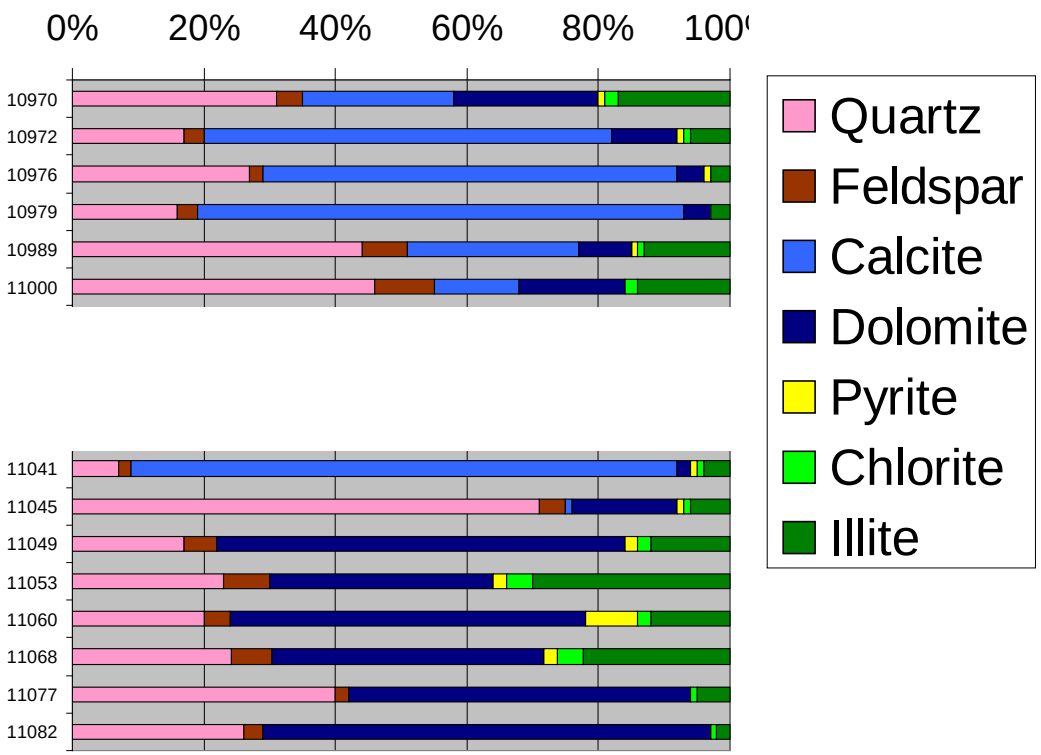


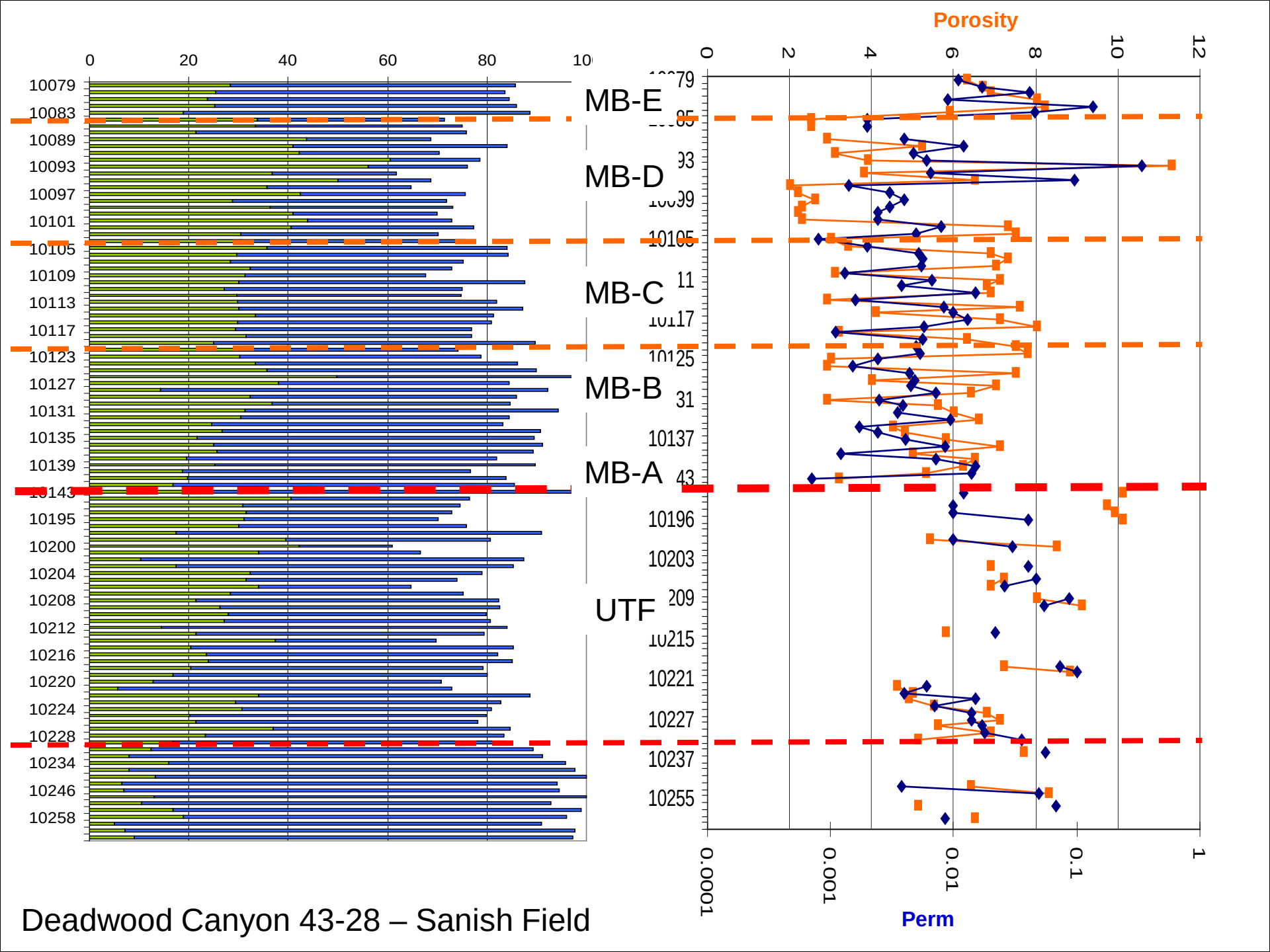
Gantyno, 2010

Jorgenson 1-15H
Sec. 15-T148N-R96W



XRD



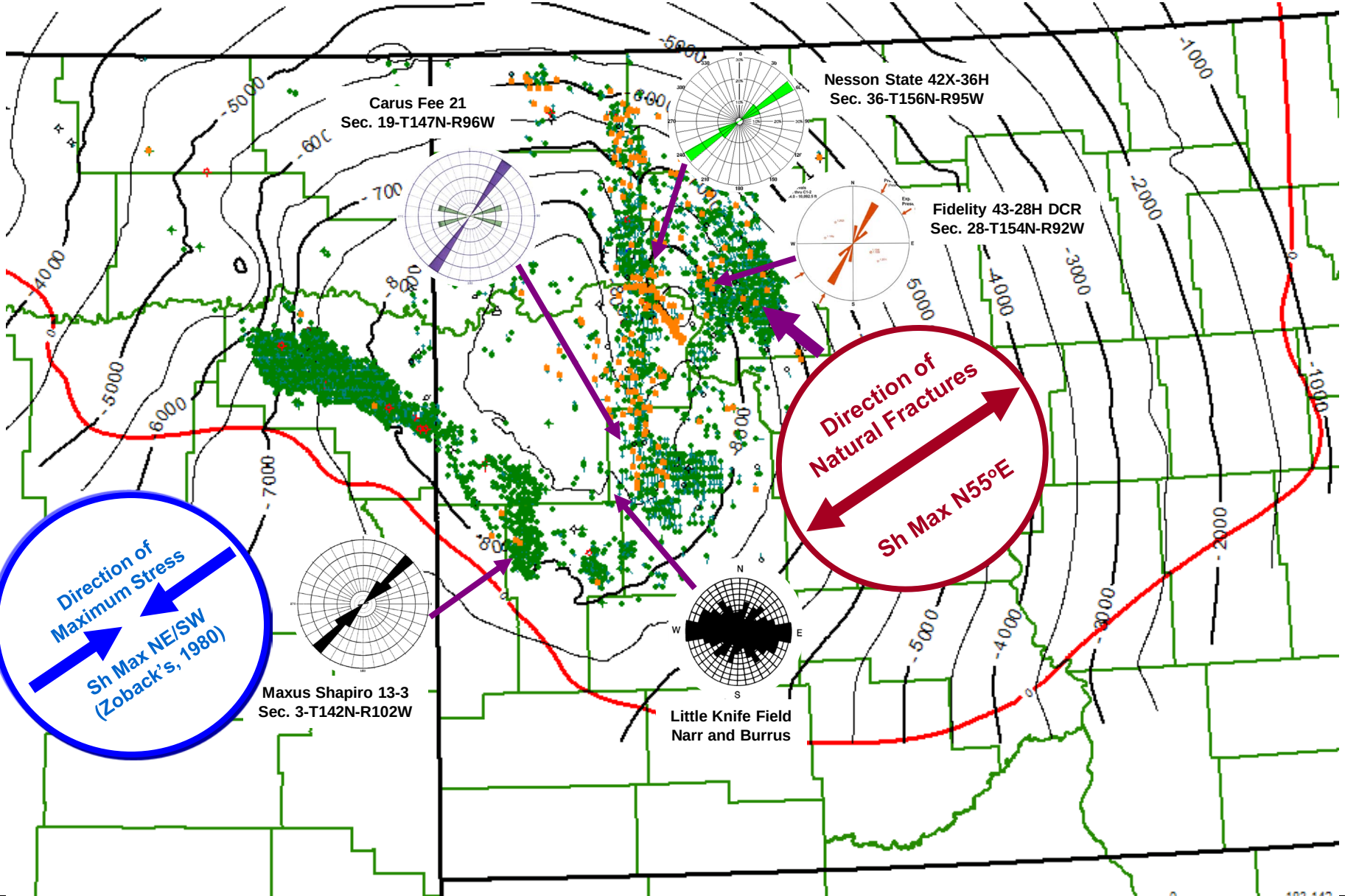


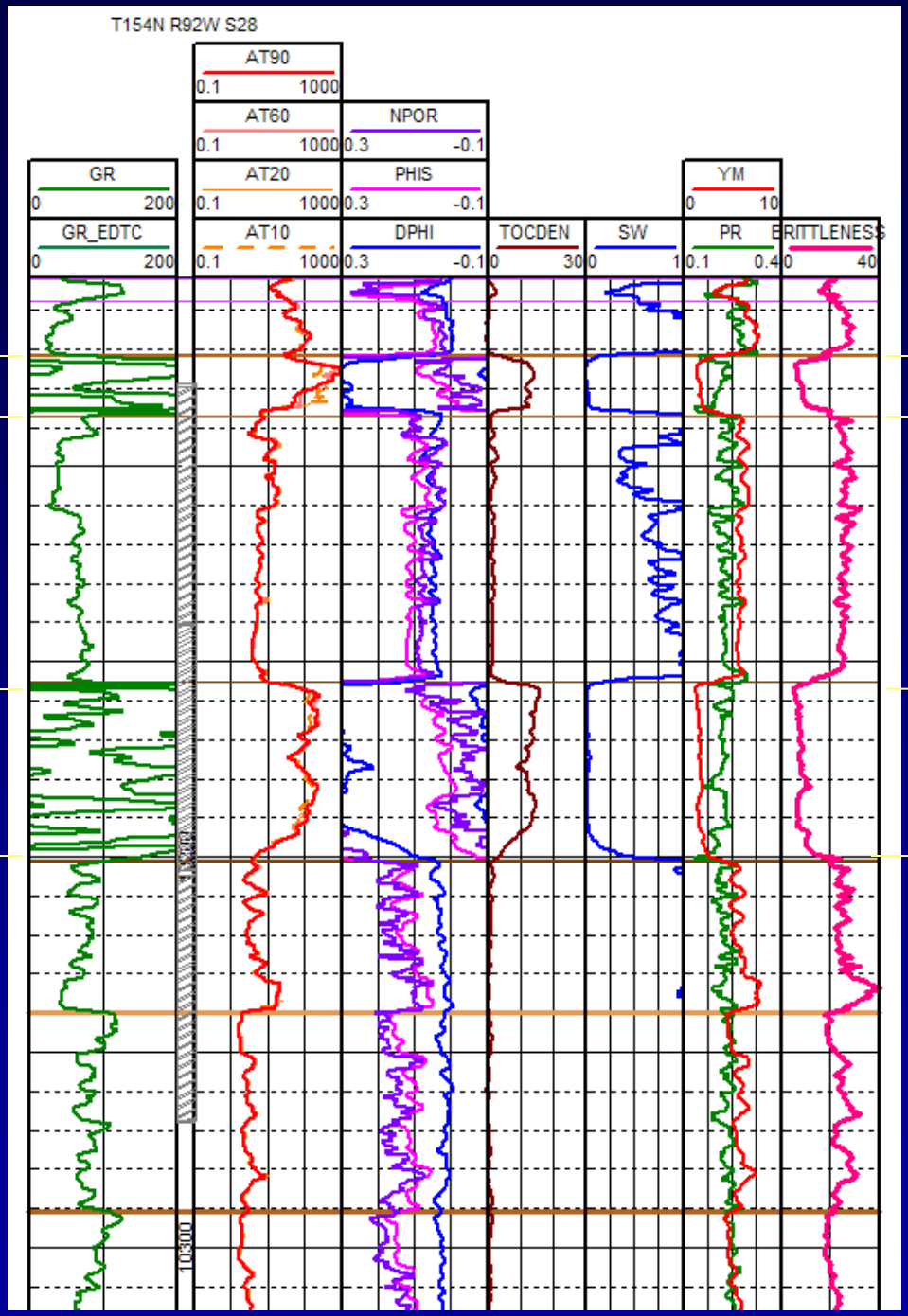
Deadwood Canyon 43-28 – Sanish Field

Bakken / Three Forks Fractures

- Tectonic\structural
- Regional Fractures
- Hydrocarbon generation

Regional Fractures





Scallion

U Bakken shale

Middle Bakken Facies

E, F

D

C

B

A

L Bakken shale

Upper Three Forks Facies

B

A

Middle Three Forks

Scallion

U Bakken shale

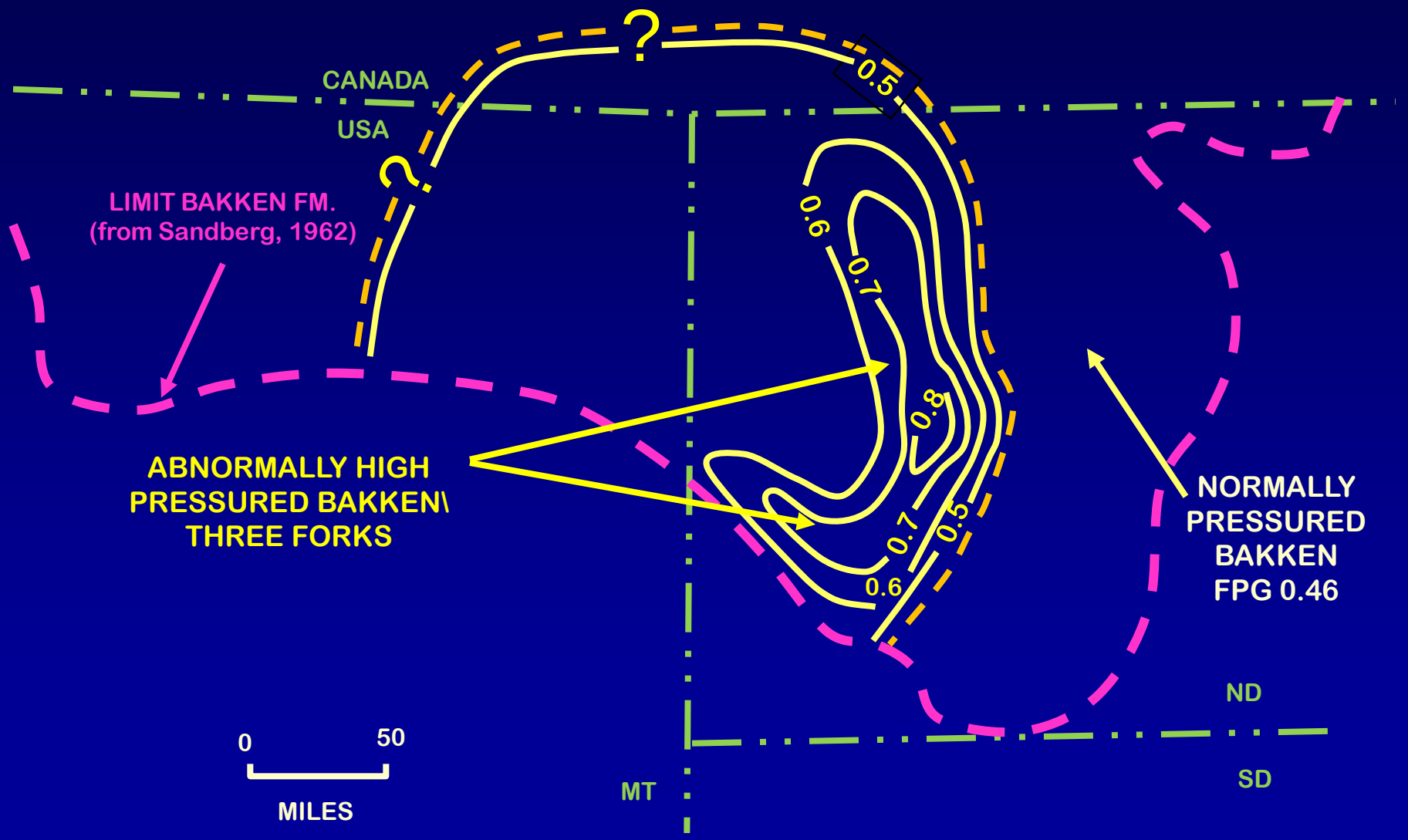
Middle Bakken

L Bakken shale

Upper Three Forks

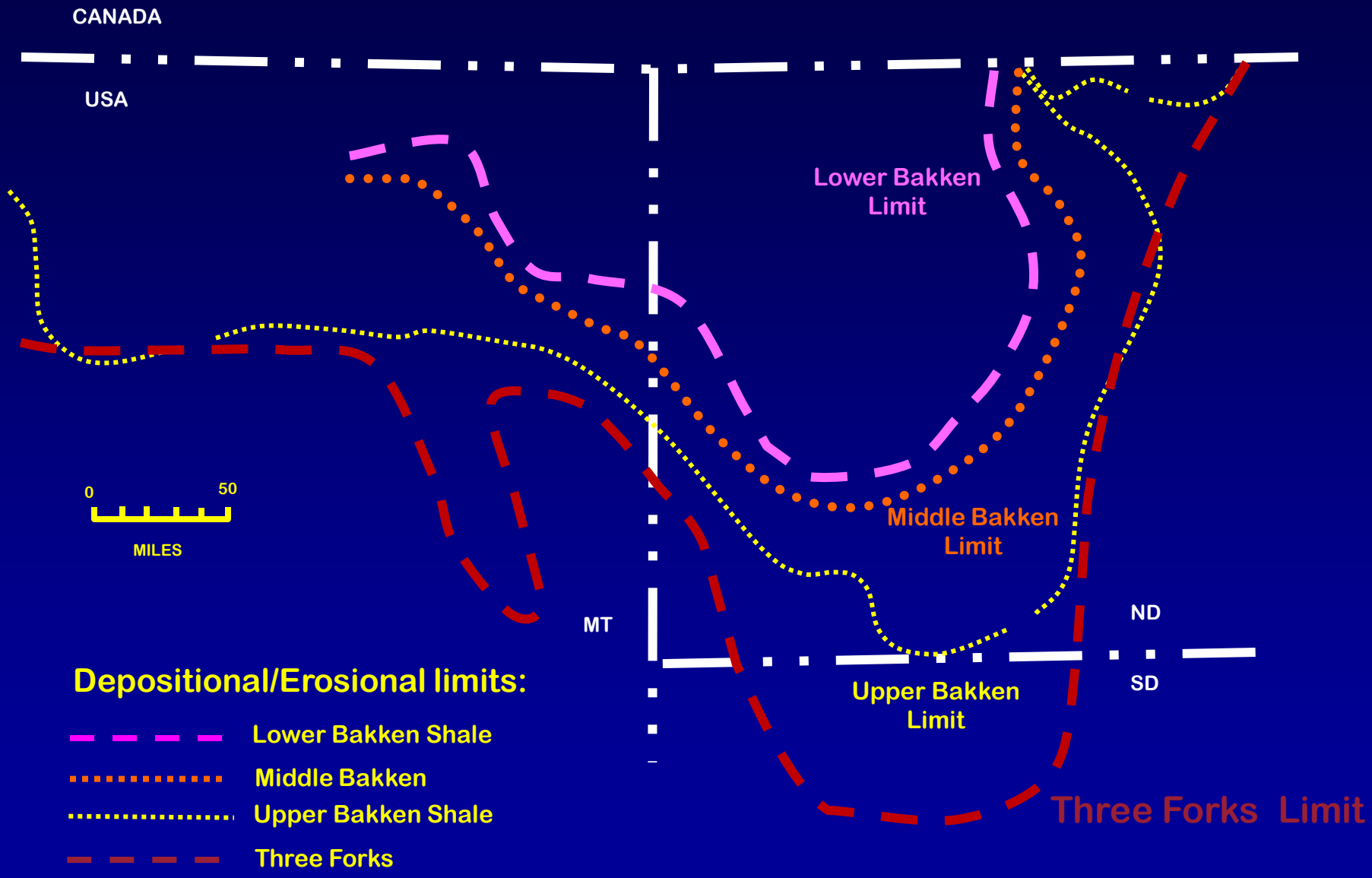
Middle Three Forks

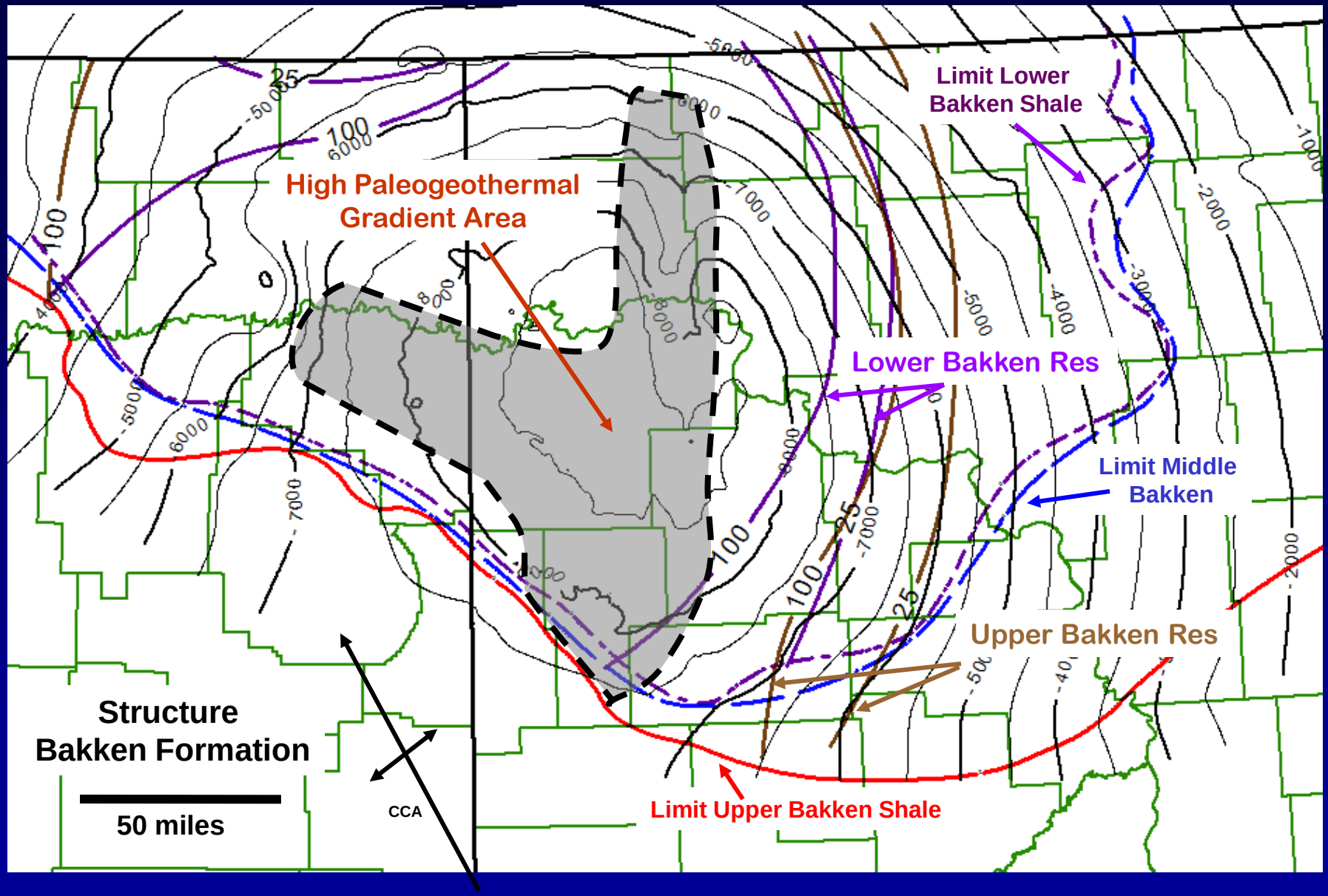
PORE FLUID GRADIENTS
BAKKEN PETROLEUM SYSTEM



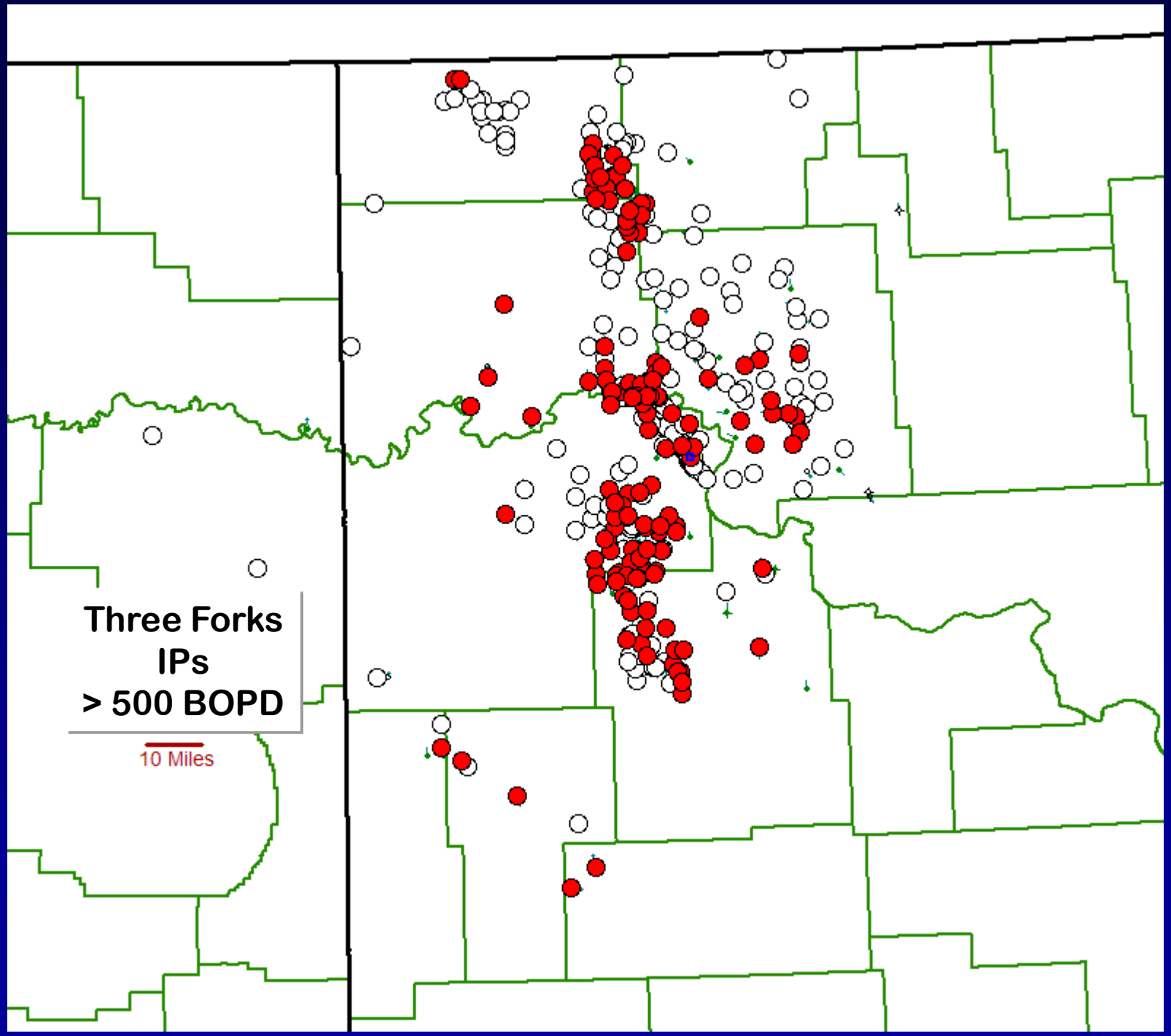
Modified from Meissner, 1978

Source Beds for Three Forks



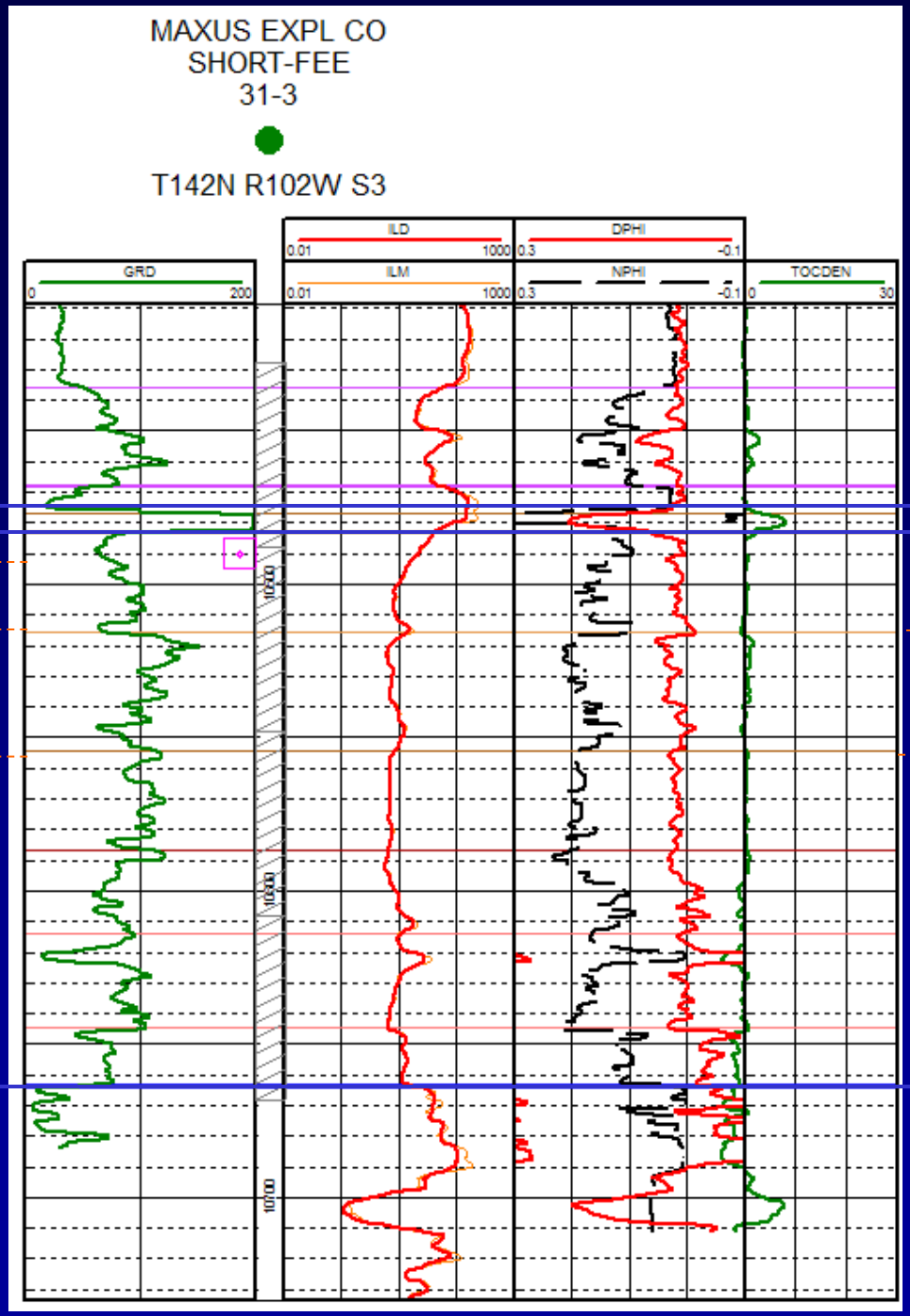


Resistivities Bakken Shales


Three Forks
IPs
> 500 BOPD
10 Miles

Deepening-upwards

Shallowing-upwards



Lodgepole

False Bakken

Scallion

Upper Bakken Shale

Upper

Middle

Lower

Three Forks

Nisku/Birdbear

Lower Intertidal

Intertidal

Intertidal

Supratidal

3rd Order Cycle

4th Order Cycles

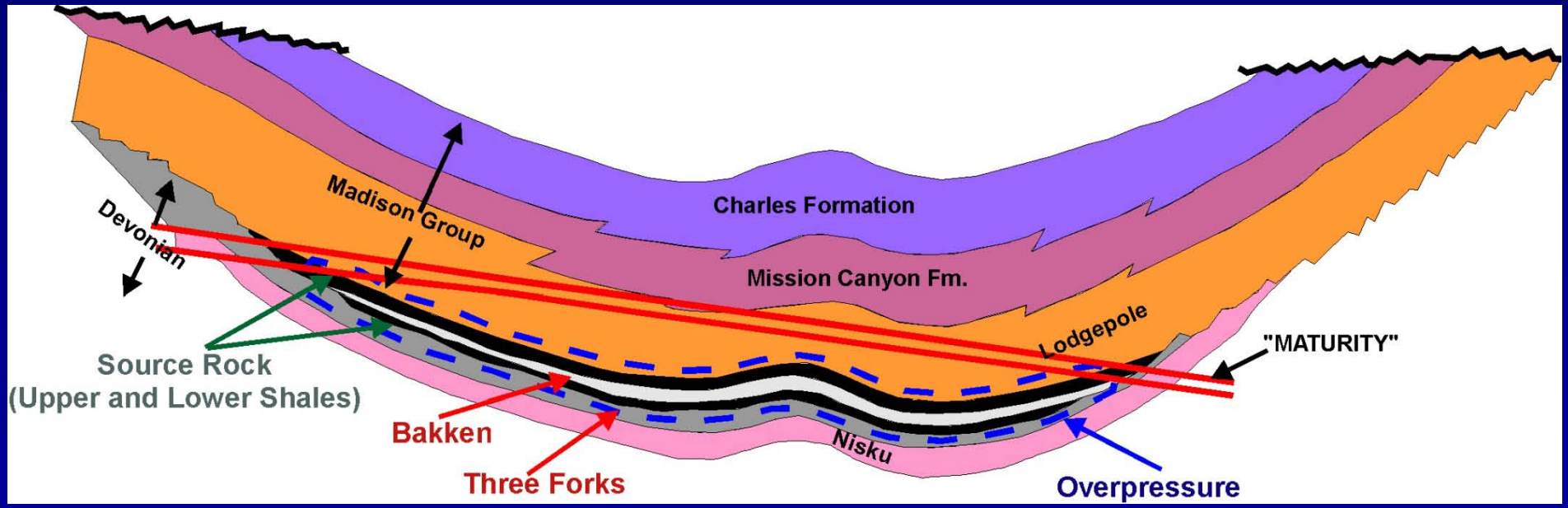
After Gantyno, 2010

Summary

- Unconventional tight oil resource plays are ‘changing the game’
- Three Forks potential is enormous
- It all starts with good to excellent source beds
- Source beds mature over large areal extent
- Natural fracturing enhances tight reservoirs
- Horizontal drilling and fracture stimulation technology important in tight oil plays

Bakken/Three Forks Tight Oil Resource Play

Bakken Research Consortium
Steve Sonnenberg
ssonnenb@mines. edu



Colorado School of Mines
Bakken Consortium

Mike Johnson

Consulting Geologist