Discovery of "Pronghorn" and "Lewis and Clark" Fields: Sweet-Spots within the Bakken Petroleum System Producing from the Sanish/Pronghorn Member NOT the Middle Bakken or Three Forks!*

Orion Skinner[1], Lyn Canter[1], Mark D. Sonnenfeld[1], and Mark Williams[1]

Search and Discovery Article #110176 (2015)**
Posted May 18, 2015

*Adapted from oral presentation at Forum: Discovery Thinking, at AAPG Annual Convention and Exhibition, Long Beach, California, USA, April 22-25, 2012

[1]Whiting Petroleum Corporation, Denver, CO (orions@whiting.com)

Abstract

Discovery of Bakken Petroleum System sweet-spots over the last 10 years has advanced by application of preceding paradigms to new areas. By contrast, each new sweet-spot represents a distinct combination of multiple play factors. Remaining open-minded to a variety of sweet-spot factors is fundamental to tight oil resource play exploration. Whiting's position in North Dakota's Sanish Field was based on regional mapping with a focus on the "B facies" of the middle Bakken juxtaposed to a thermally mature, lower Bakken Shale depocenter. Sanish and adjacent Parshall fields of Mountrail County, ND each represent giant oil fields producing from both the middle Bakken and Three Forks.

Our emphasis on core-based sedimentology and stratigraphy led us to refine our understanding of middle Bakken facies and recognize the significance of the 2nd-order regional angular unconformity separating the Three Forks and the lower Bakken Shale. Low-accommodation conditions succeeding this unconformity controlled depositional patterns of the entire lowstand (Pronghorn Member of Bakken) to transgressive (lower, middle, and upper Bakken) systems tracts, up to an MFS at the overlying Scallion Member of the Lodgepole. Regional, core-calibrated correlation in both the Pronghorn and the middle Bakken demonstrate that regional variations in siliciclastic and detrital dolomitic sediment supply and in carbonate productivity during this low accommodation LST-TST period critically impacted matrix reservoir quality.

Across the northern Williston Basin, the basal transgressive Pronghorn Member veneer (type-section being Antelope Field) has a northeastern-derived, siliciclastic provenance. By contrast, the southern Williston Basin was the locus of detrital dolomites derived from the Cedar Creek paleostructure. The Pronghorn Member extends well south of any preserved lower, middle, and upper Bakken deposits and is composed of a transgressive succession of restricted marine detrital dolomites capped by a locally preserved, burrowed limestone that represents open marine conditions prior to the restricted to anoxic episode marking lower Bakken deposition. Core-based definition of the Pronghorn Member's varying provenance, coupled with core- and cuttings-calibrated resistivity mapping to confirm oil saturation, recently led to discovery of

significant new sweet-spots at Whiting's "Pronghorn" and "Lewis and Clark" prospects in Stark, Billings, and southernmost McKenzie counties, ND.

References Cited

Johnson, J.G., G. Klapper and C.A. Sandberg, 1985, Devonian eustatic fluctuations in Euramerica: GSA Bulletin, v. 96/5, p. 567-587.

Lefever, J.A., R.D. LeFever, and S.H. Nordeng, 2011, Revised Nomenclature for the Bakken Formation (Mississippian-Devonian), North Dakota: Chapter 1: RMAG, The Bakken-Three Forks Petroleum System in the Williston Basin, p. 11-26.

Meijer Drees, N.C., and D.I. Johnston, 1996, Famennian and Tournaisian biostratigraphy of the Big Valley, Exshaw and Bakken formations, southeastern Alberta and southwestern Saskatchewan: Bulletin of Canadian Petroleum Geology, v. 44, p. 683-694.

Meissner, F.F., 1991, Petroleum geology of the Bakken Formation Williston Basin, North Dakota and Montana, *in* Hansen, W.B., ed., Geology and horizontal drilling of the Bakken Formation: Montana Geological Society, 1991 Guidebook, p. 19–42.

Oglesby, C. A., 1988, Deposition and dissolution of the Middle Devonian Prairie Formation, Williston Basin, North Dakota and Montana: Master's Thesis, Colorado School of Mines, Golden, Colorado, 79 p.

Originally presented at AAPG 2012 ACE Discovery Thinking Forum
Long Beach, CA
April 23, 2012

Discovery of "Pronghorn" and "Lewis and Clark" Fields:

Sweet-Spots within the Bakken Petroleum System Producing from the Sanish/Pronghorn Member *NOT* the Middle Bakken or Three Forks!

Orion Skinner, Lyn Canter, Mark Sonnenfeld, Mark Williams

Whiting Petroleum Corporation
Denver, Colorado USA

WHITING

Forward-Looking Statements

This presentation includes forward-looking statements that Whiting Petroleum Corporation (the “Company”) believes to be forward-looking statements within the meaning of the Private Securities Litigation Reform Act of 1995. All statements other than statements of historical fact included in this presentation are forward-looking statements. These forward looking statements are subject to risks, uncertainties, assumptions and other factors, many of which are beyond the control of the Company. Important factors that could cause actual results to differ materially from those expressed or implied by the forward-looking statements include the Company’s business strategy, financial strategy, oil and natural gas prices, production, reserves and resources, impacts from the global recession and tight credit markets, the impacts of state and federal laws, the impacts of hedging on our results of operations, level of success in exploitation, exploration, development and production activities, uncertainty regarding the Company’s future operating results and plans, objectives, expectations and intentions and other factors described in the Company’s Annual Report on Form 10-K for the year ended December 31, 2011. Whiting’s production forecasts and expectations for future periods are dependent upon many assumptions, including estimates of production decline rates from existing wells and the undertaking and outcome of future drilling activity, which may be affected by significant commodity price declines or drilling cost increases.

Acknowledgements

We thank Whiting management for permission to present this work, and of course all our Whiting colleagues of multiple disciplines who contributed immensely to turning the concepts described here into economic reality.

We are appreciative of the vast, unmatched core collection afforded by the North Dakota Geological Survey and to Julie LeFever and Kent Hollands of the ND Core Lab, in particular, for their support during our biannual "core trips" to Grand Forks, ND.

General Outline

1. Pre-discovery thinking
2. Play inception: correlating cores to subsurface
3. Sweetspot prediction and discovery
4. Regional stratigraphy and continued exploration implications
   - Mechanism for preservation within the Bakken Petroleum system of the Williston Basin
5. Conclusions

Summary

Remaining open-minded to a variety of sweet-spot factors is fundamental to tight oil exploration. Bakken Petroleum System sweet-spots:

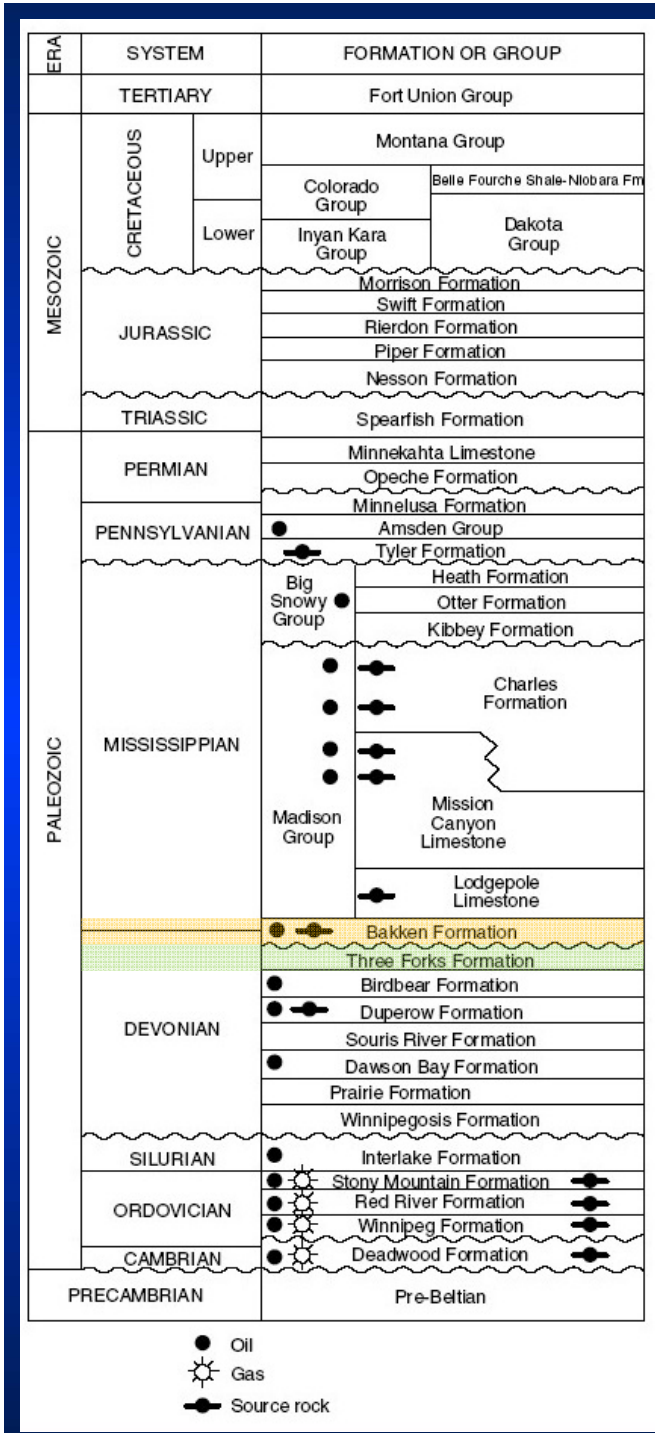
- ✓ *source rock quality & maturity*
- ✓ *reservoir matrix quality & saturation*
- ✓ *fractures, pressures, etc.*

Low-accommodation setting following the 2nd-order angular unconformity (top Three Forks) controlled depositional and preservational patterns throughout the lowstand (Pronghorn Member of Bakken) to transgressive systems tracts of the lower, middle, and upper Bakken.

Regional log correlations, calibrated to core, are needed to adequately identify key surfaces and help demonstrate important provenance variation:

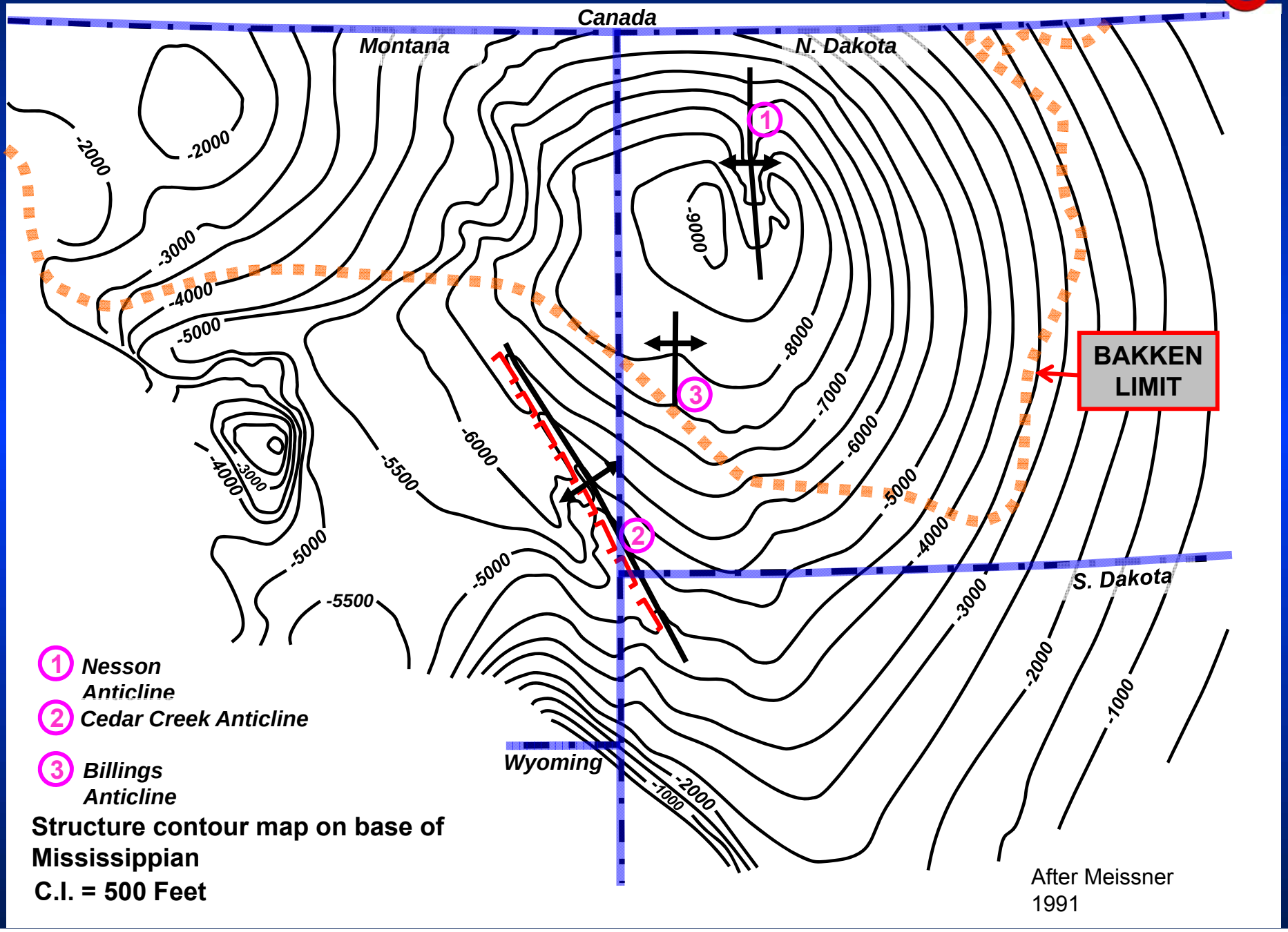
- *Northern Williston Basin, the basal transgressive Pronghorn member veneer has a northeastern-derived, siliciclastic provenance.*
- *Southern Williston was the locus of detrital dolomite derived from the Cedar Creek paleostructure. Subtidal, detrital dolomites form the main reservoir across Whiting's "Pronghorn" and "Lewis and Clark" Prospects.*

New productive zone identified between Bakken and Three Forks

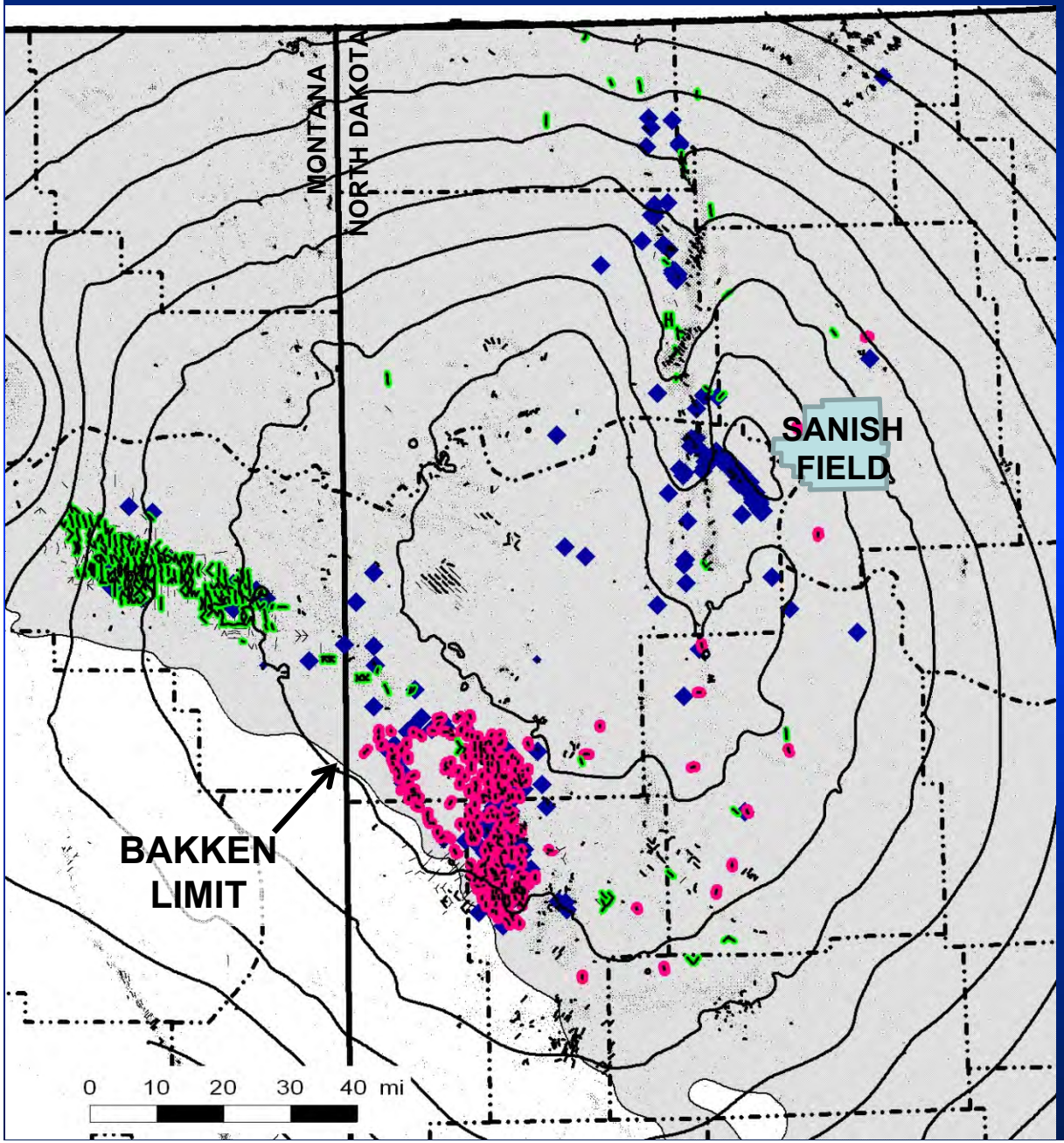


FOCUS ZONES FOR TALK

Williston Basin – simple structure/complex stratigraphy



Bakken production at end of 2004



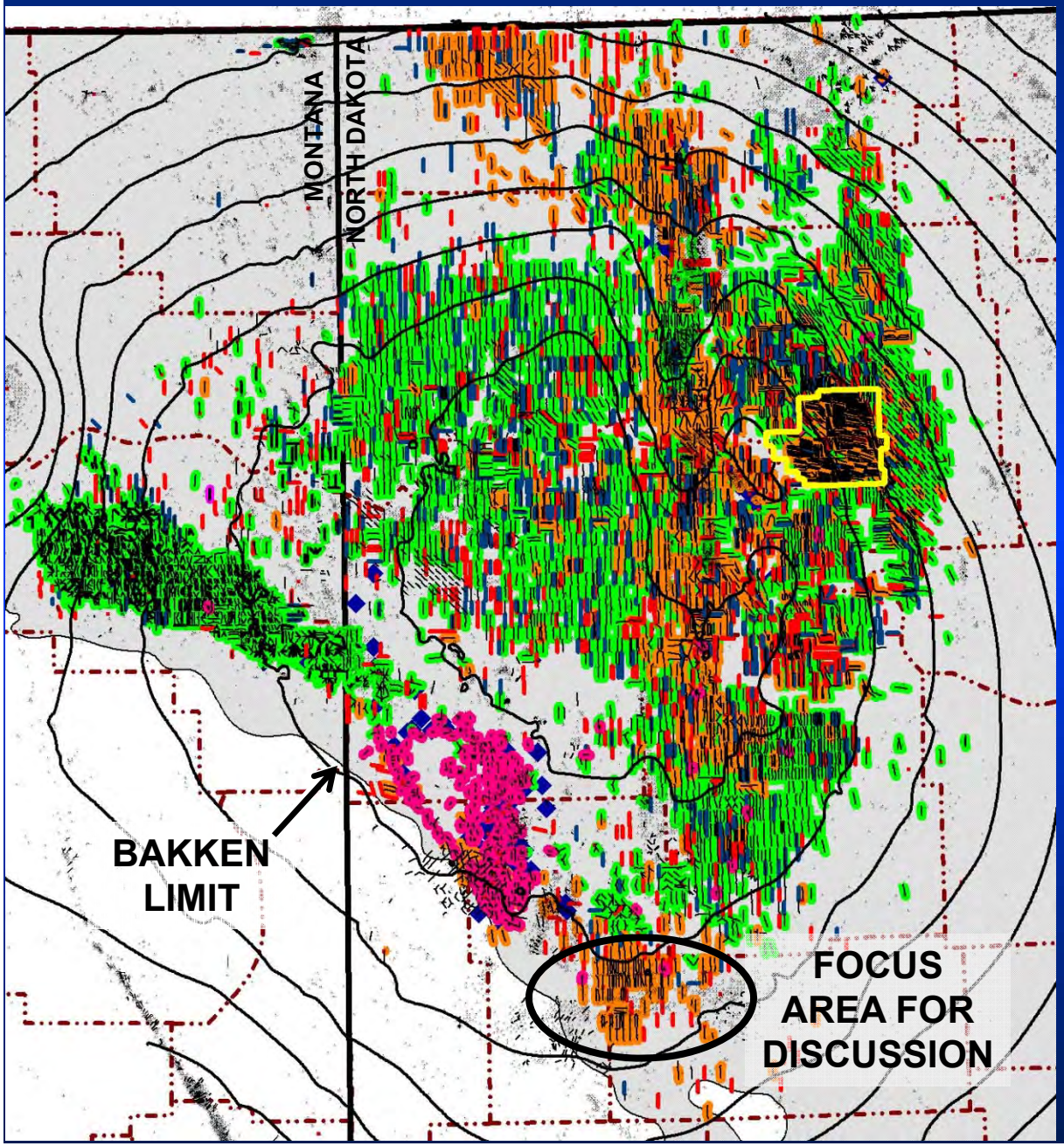
- 80's (unstimulated) horizontal play – *upper Bakken shale only*
- Early tests in ND Middle Bakken primarily tried to extend Elm Coulee trend and along the Nesson Anticline
- Mixed economic results with completion practices and limitations of the time

Vertical Bakken Production

U. Bakken Shale Hz Production

M.Bakken Hz Production

Bakken Activity as of 10/1/12



- In 7+ years, play expanded to over 13,000 square miles
- Whiting currently at 20 rigs
- Whiting has operated 3.3 million linear feet of Bakken/Three Forks horizontal drilling and participated in another 1.9 million feet of non-op footage
- Whiting approaching 5 million linear feet of operated hz drilling by end of 2012

Vertical Bakken Production

Upper Bakken Shale Hz Production

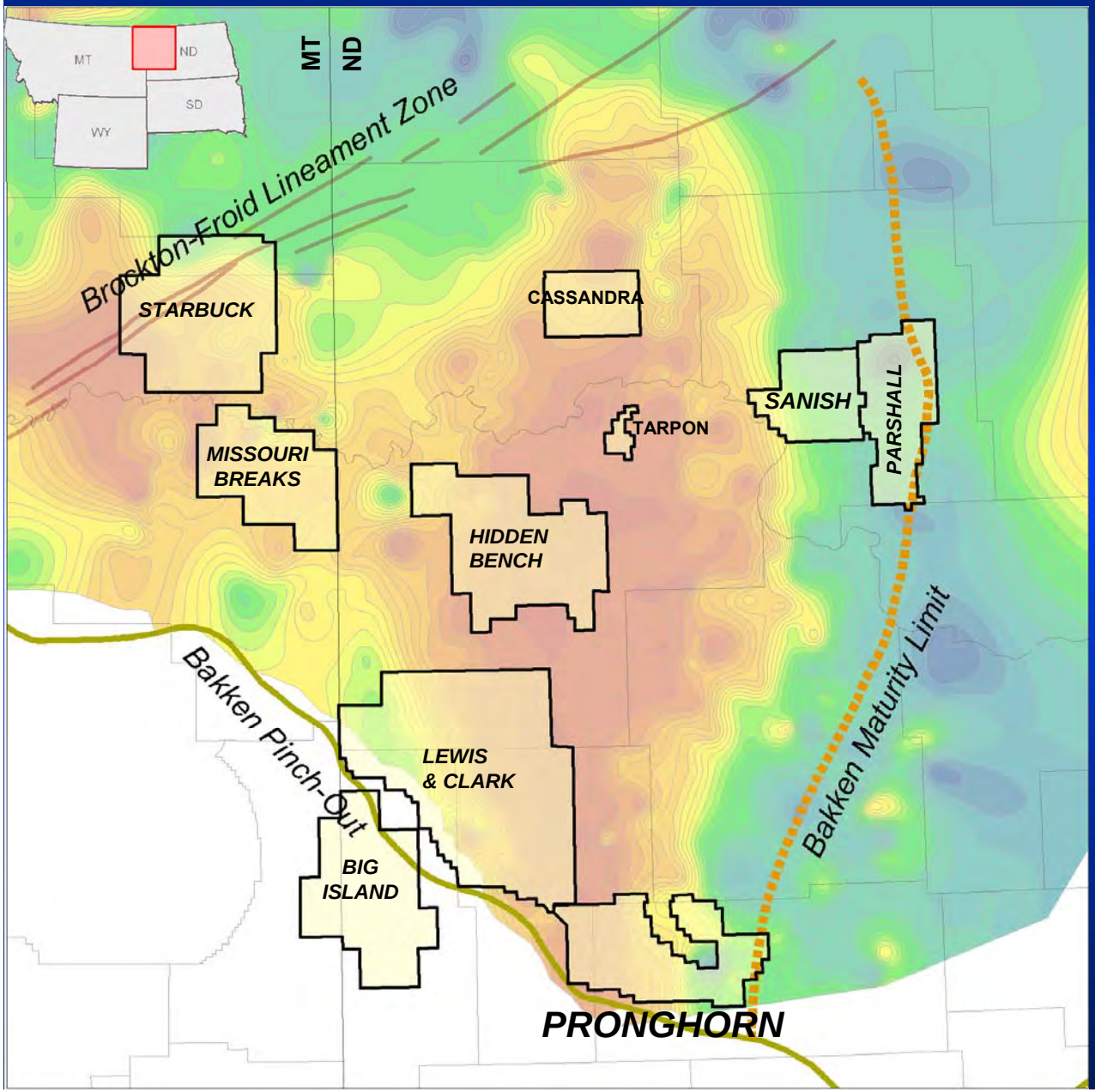
Middle Bakken Hz Production

Three Forks Hz Production

Bakken/Three Forks Hz Well Permit

Bakken/Three Forks Spud/Drilling Under Confidential status

Whiting Lease Areas within Williston Basin Plays (as of December 31, 2011)

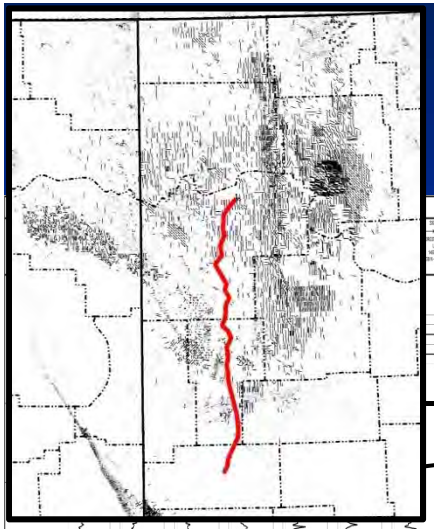


Whiting currently has over 1 million gross and 680,000 net acres – the majority of which are within the producing area of the Bakken petroleum system

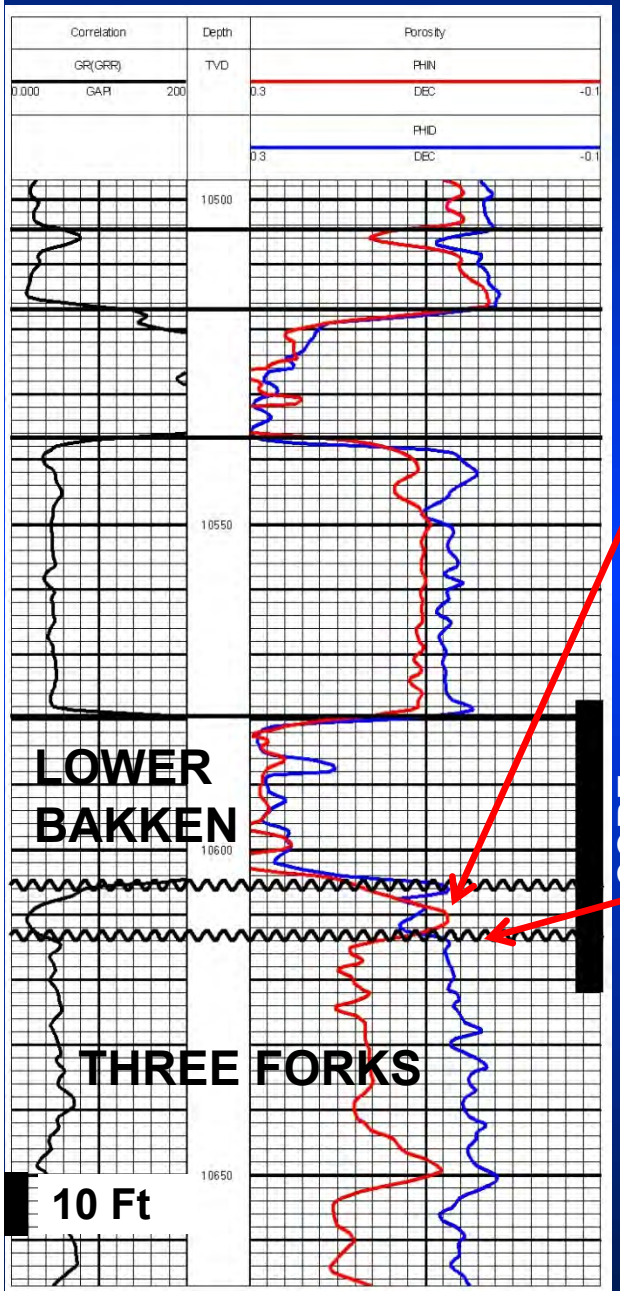
The colored map depicts the regional **Hydrogen Index** ("HI") of the upper Bakken Shale based on public domain data accessible from the USGS as compiled by the late Leigh Price, supplemented by in-house data.

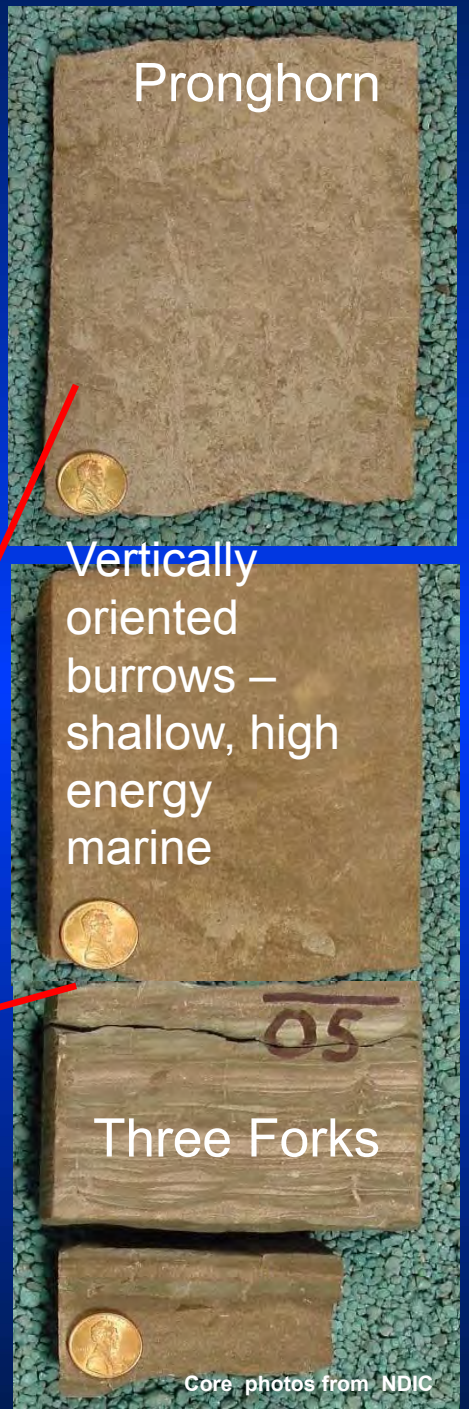
Hot colors are low HI values indicative of greater levels of thermal maturity; cooler colors are higher HI values indicative of lower thermal maturity.

Bakken petroleum system – the challenges of low accommodation…



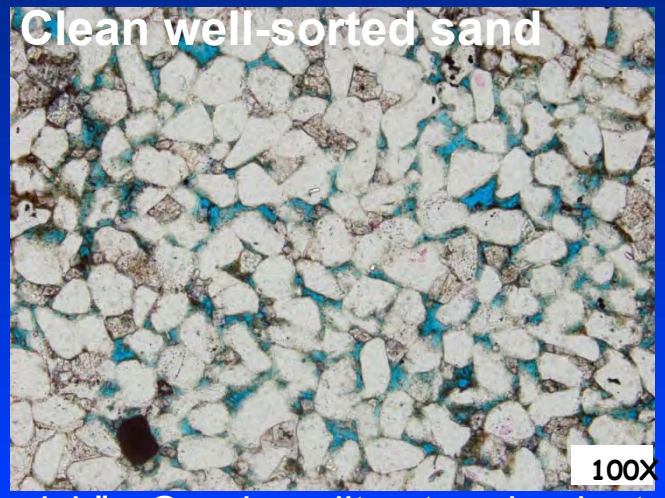
DUNCAN
Rose #1
33-T152N-R94W



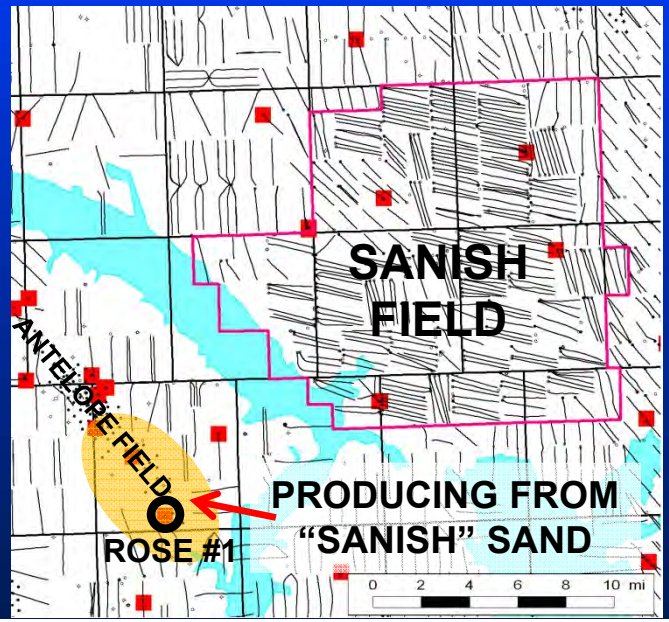


"Sanish" Sand
redefined as Pronghorn Mbr. by LeFever, 2011

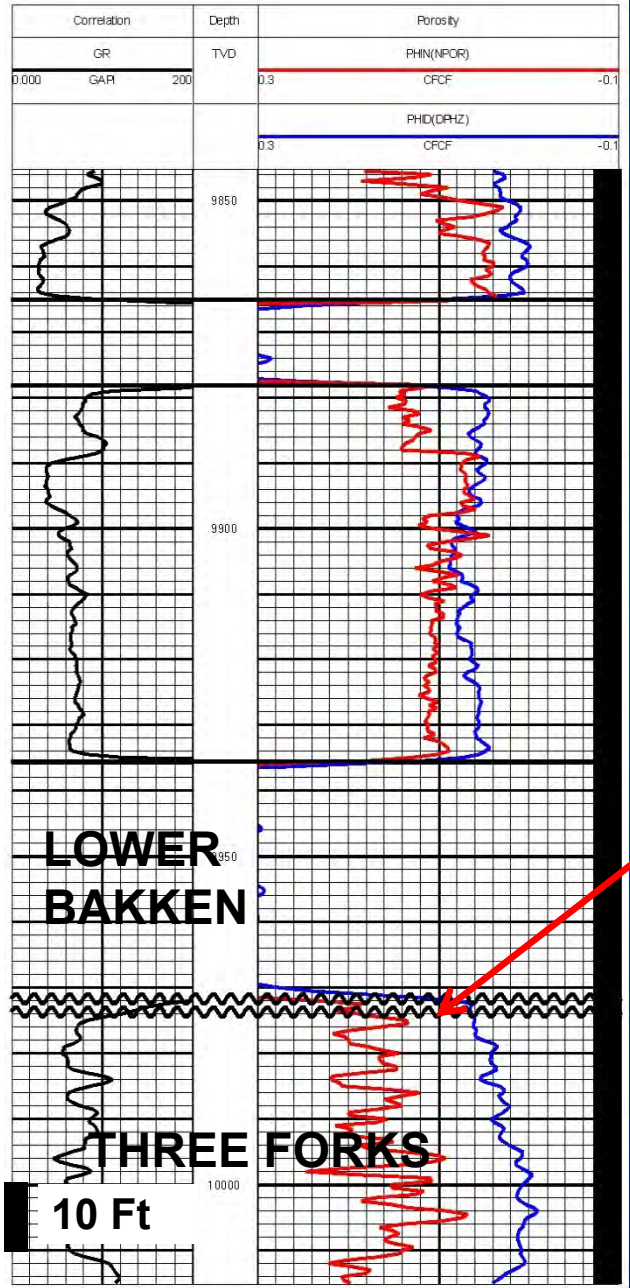
WHITING



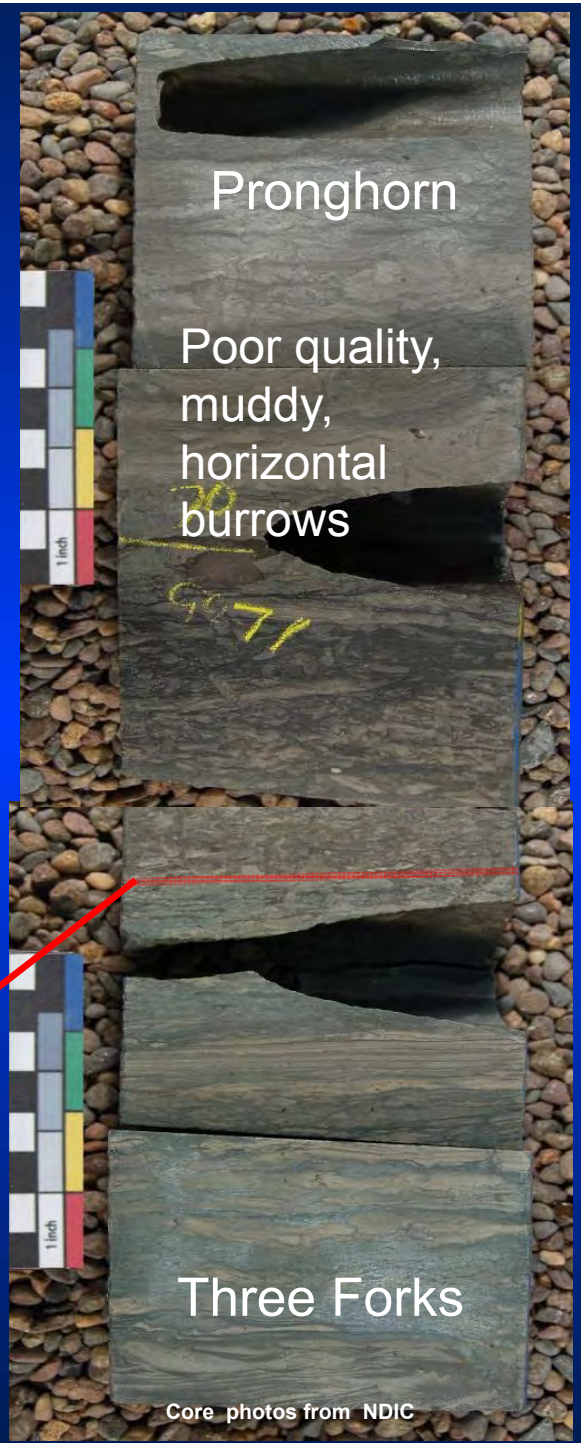
"Sanish" - Good quality qtz.- dominated reservoir – *but of limited extent!*



WHITING
Braaflat 11-11H
11-T153N-R91W

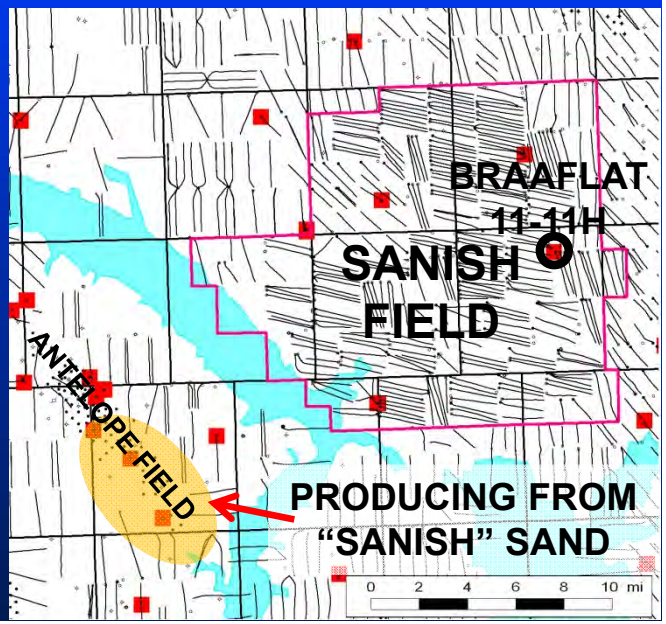


CORE

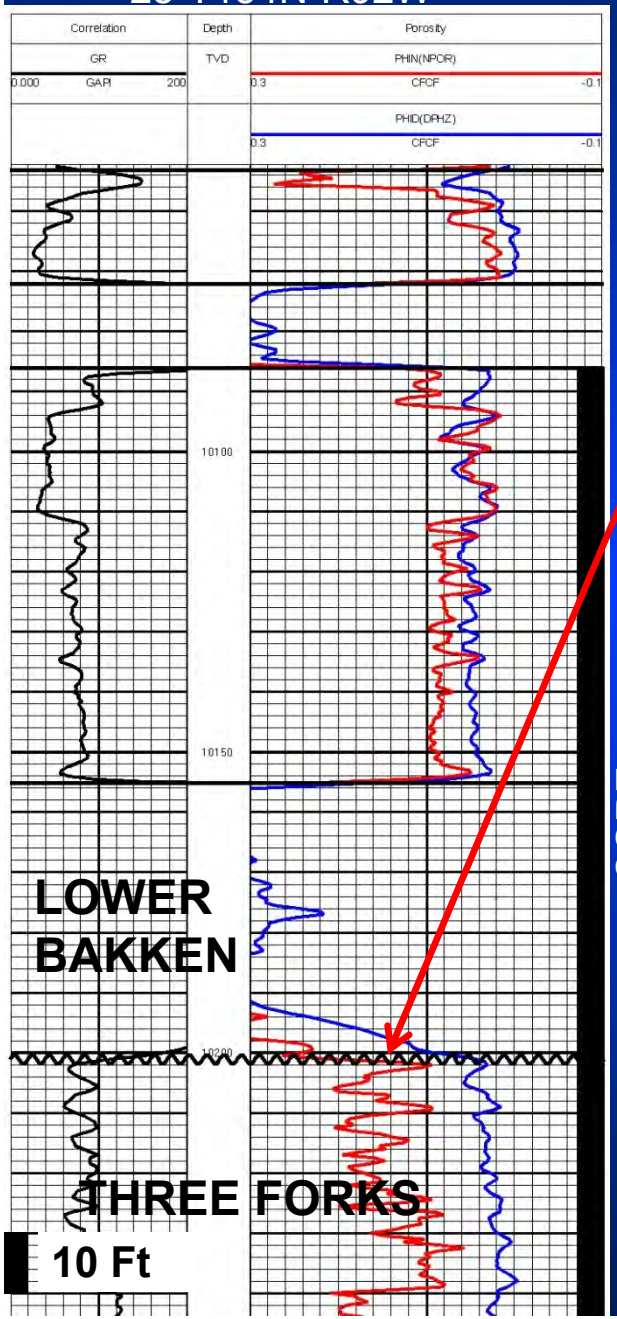


WHITING

Less than 1 foot of bioturbated Pronghorn Facies forms a patchy, thin veneer overlying the Three Forks at Sanish Field



FIDELITY
DCR 43-28H
28-T154N-R92W



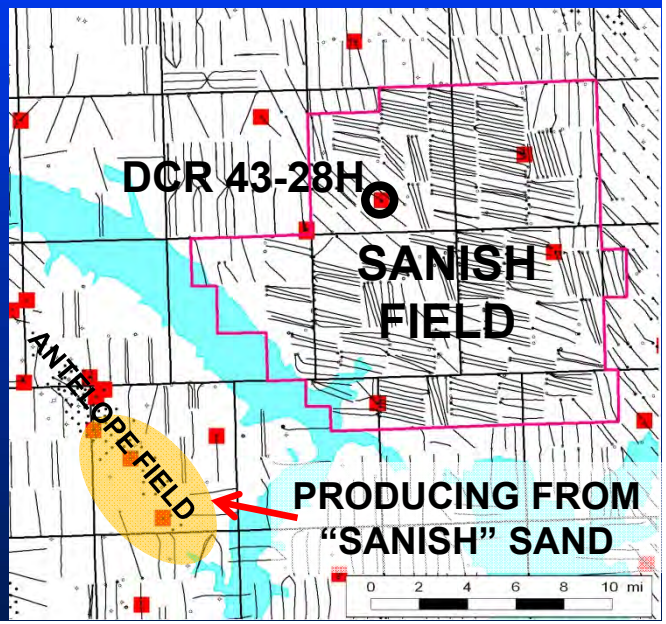
CORE

No Pronghorn beds present –

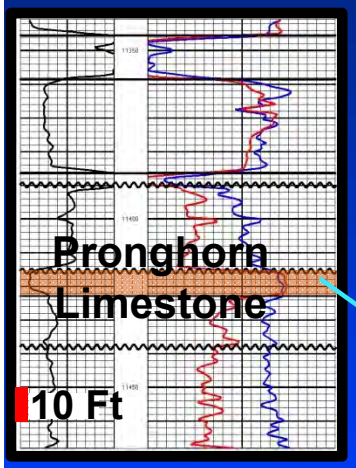
WHITING

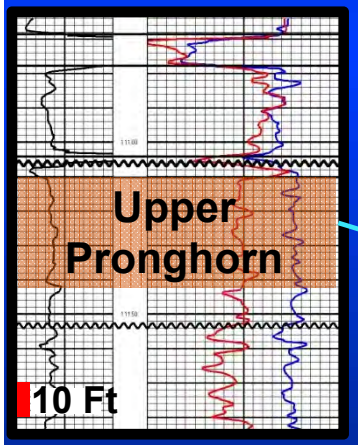
just rip-up clasts at Lower Bakken Shale/ Three Forks contact

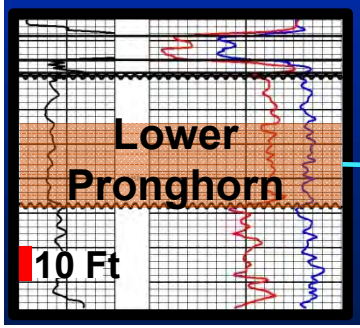
120 ft. of cumulative thickness found elsewhere in the basin is missing at this contact

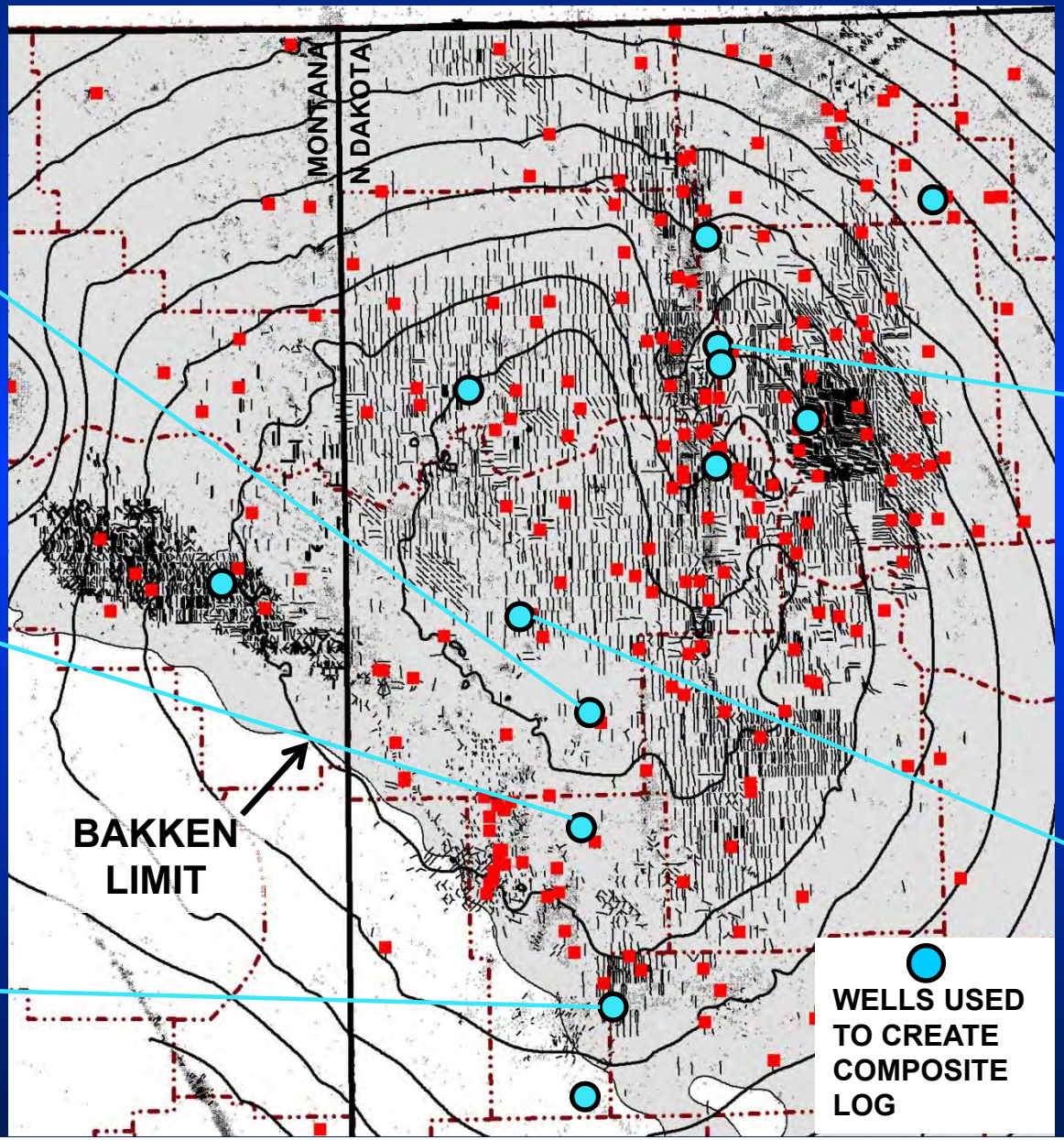


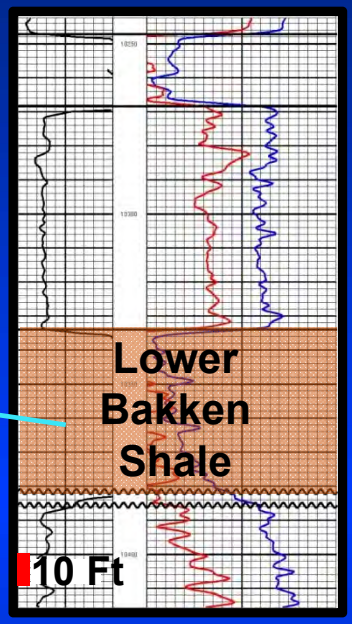
Bakken/Three Forks Core Control and the Challenges of Creating a Type Log

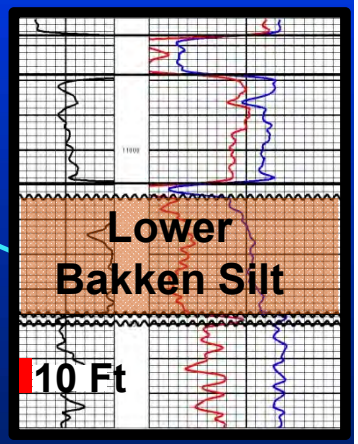








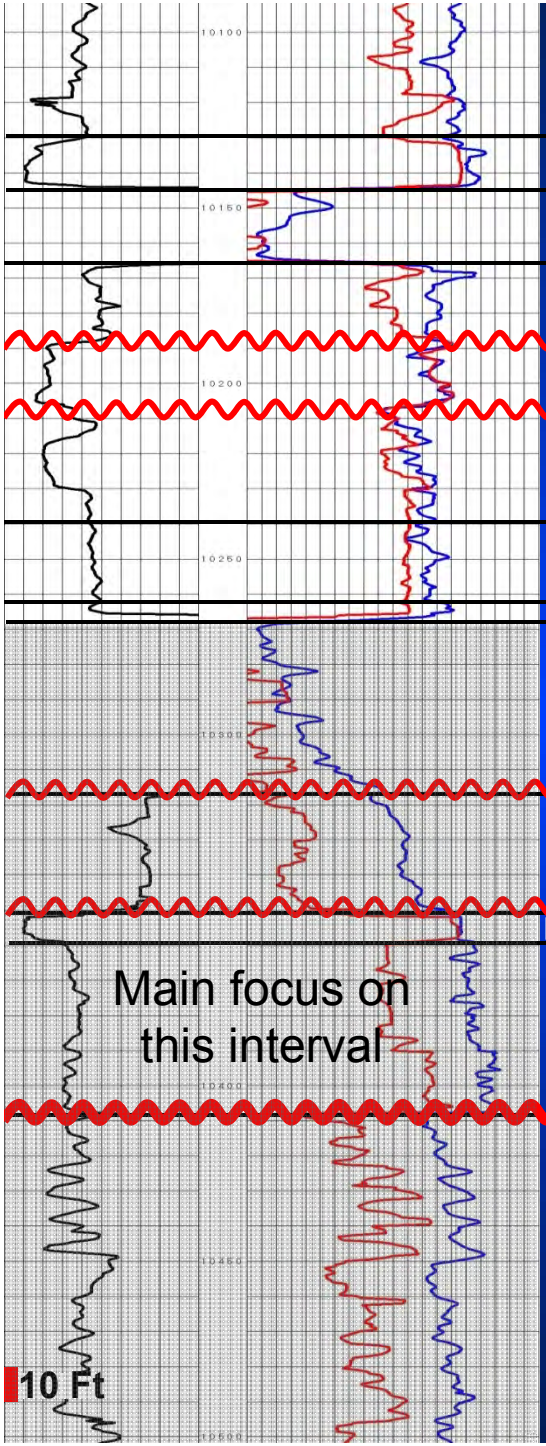




All logs shown extend 5 feet above Upper Bakken and 30 feet below the Three Forks top

Composite Type Log

Lag deposits define key surfaces



False Bakken

Scallion

Upper Bakken Shale

Middle Bakken "A" Facies

Middle Bakken "B" Facies

Middle Bakken "C" Facies

Middle Bakken "D" Facies

Middle Bakken "E" Facies

Lower Bakken Anoxic Shale

Lower Bakken Silt

Pronghorn Limestone

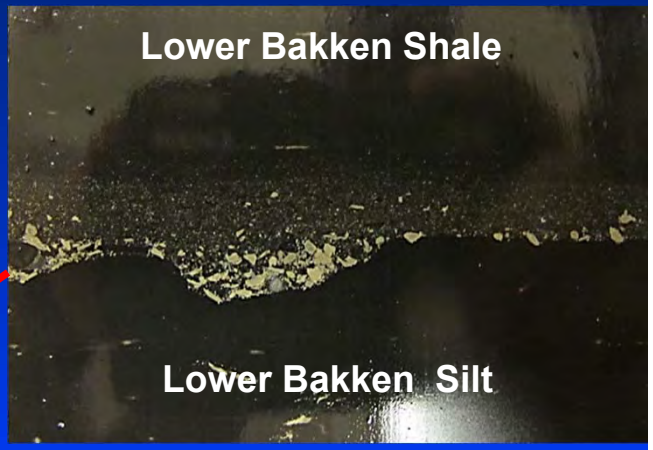
Main focus on this interval

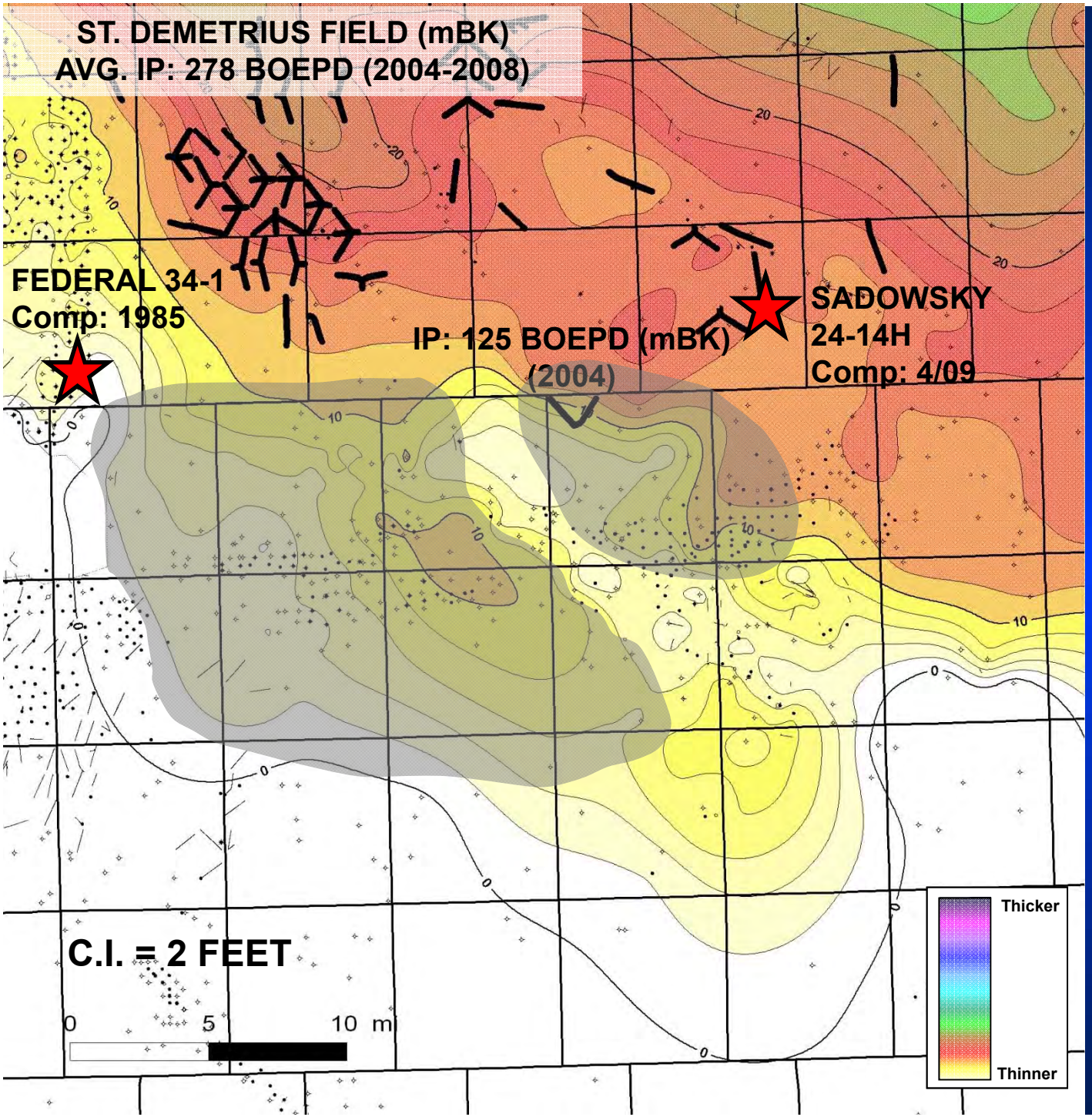
Pronghorn Member

Three Forks Cycle 1

Three Forks Cycle 2

10 Ft

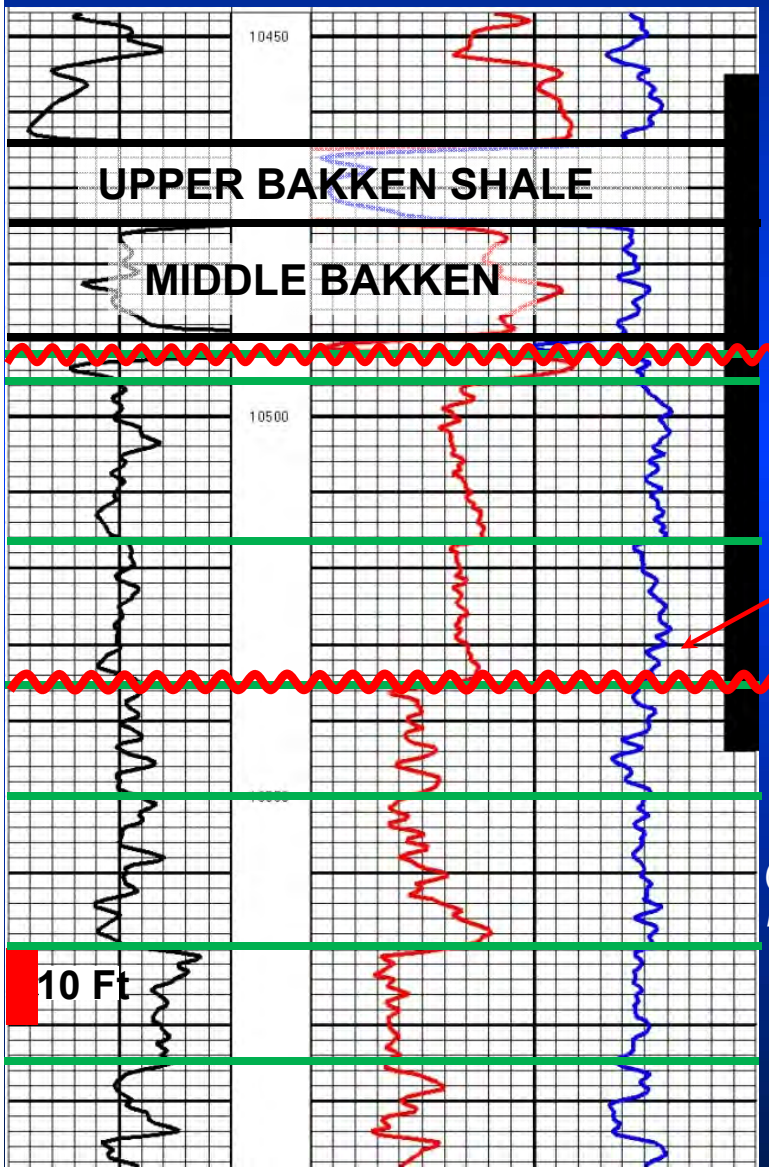




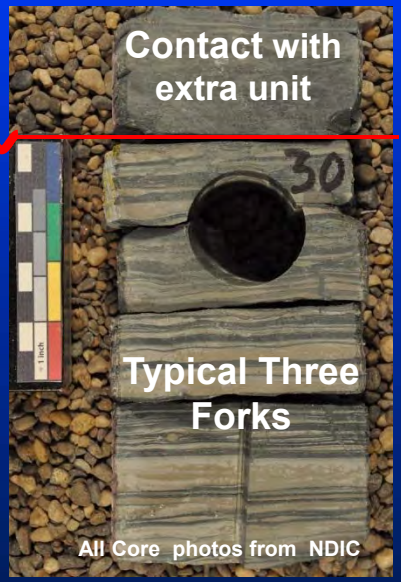
Middle Bakken Isopach with Bakken Hz. Wells Drilled prior to 2009

- Primary focus was for Middle Bakken
- Moderate to poor results and Middle Bakken only thinned to south – no additional industry interest for 4-5 years
- Several key cores were game changers
- Provided a new concept that ultimately ended up in a new focus area beyond where the Bakken was too thin and production was weak

Sadowsky 24-14H
14-T141N-R96W
Unexpected units identified in core …



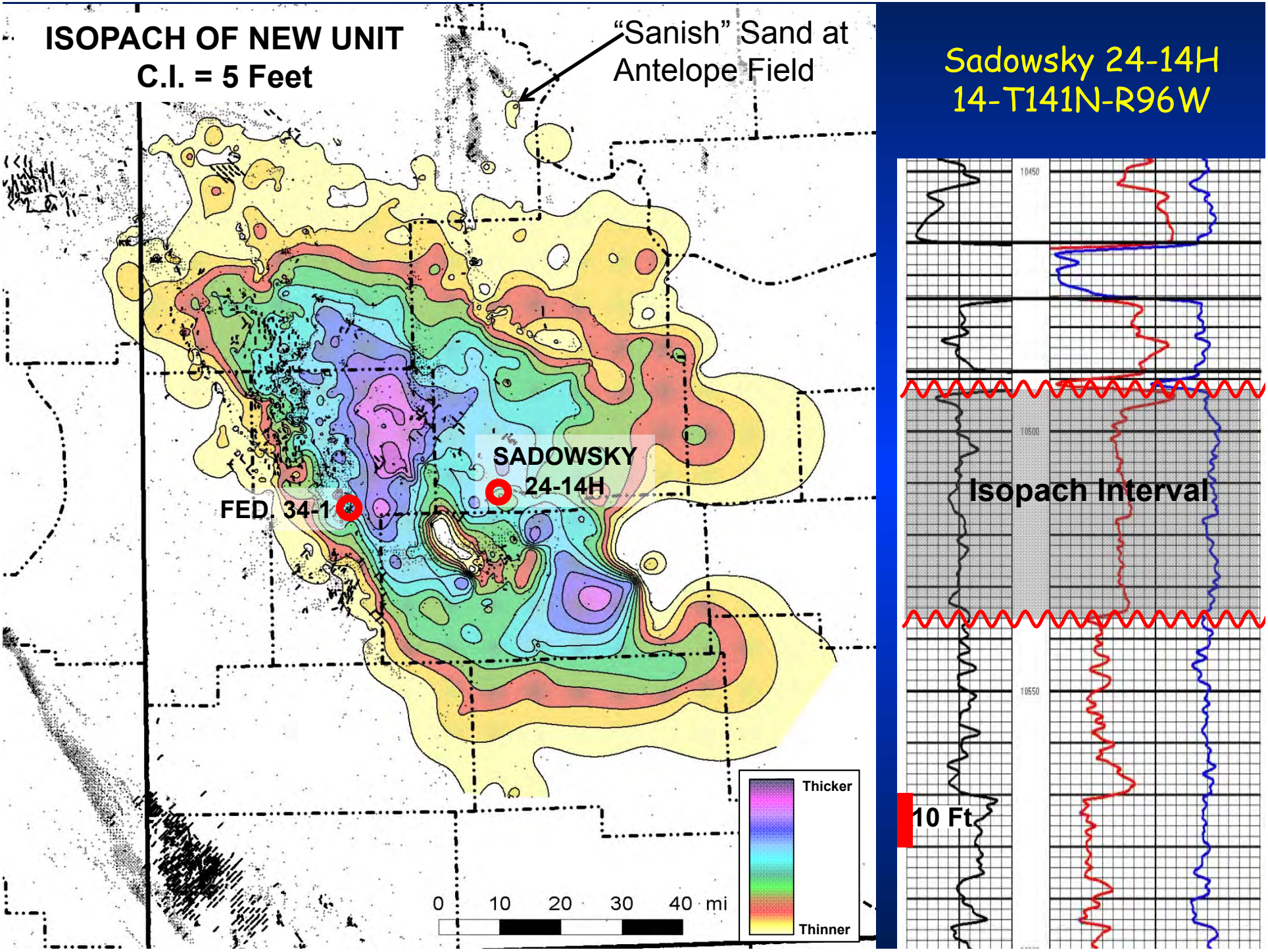
CORE

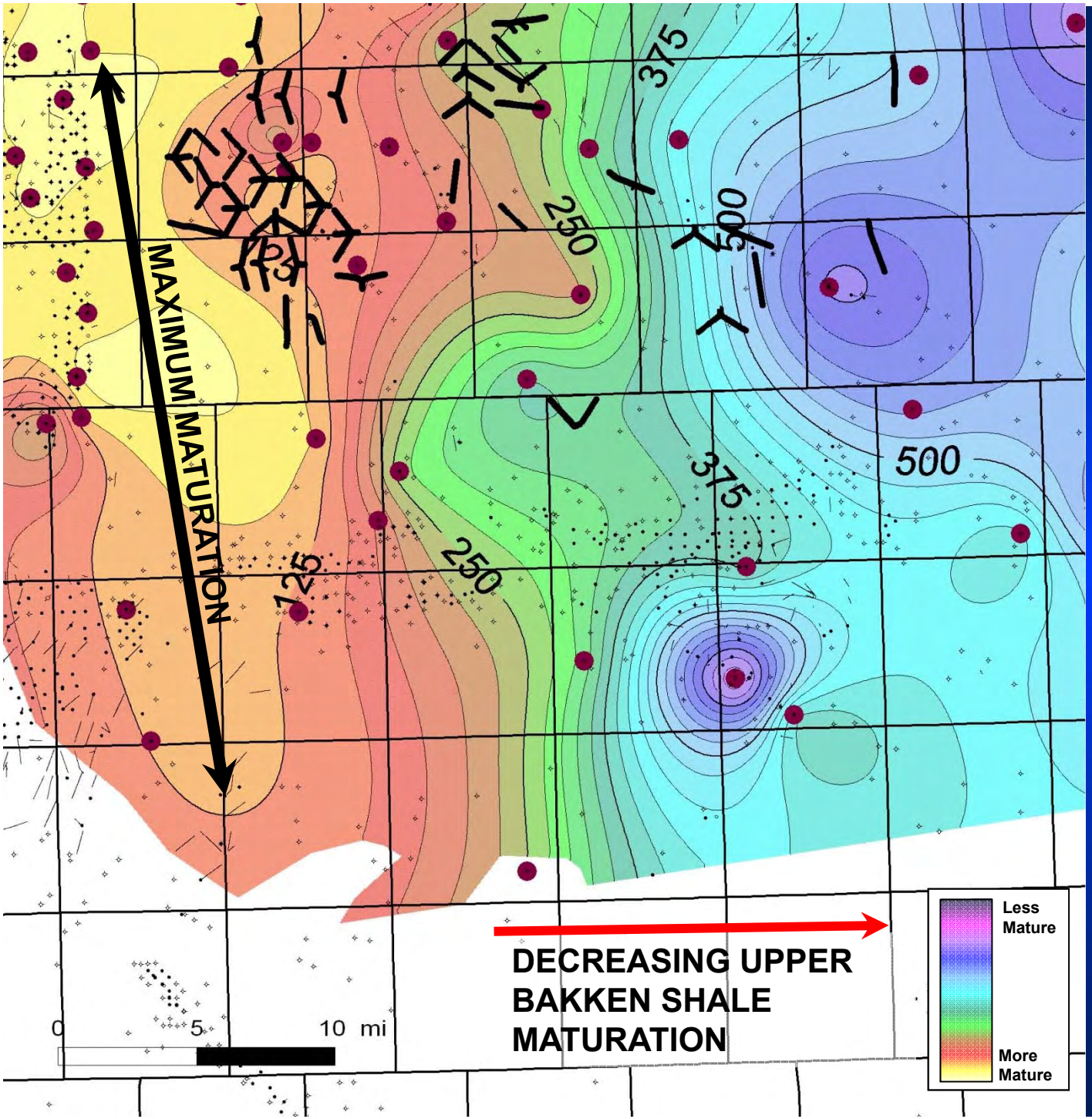


Three Forks markers (green) already picked through most of the basin before seeing this core

open marine limestone below the Lower Bakken Shale with lag deposit at contact

Below the limestone and above peritidal laminites of the Three Forks were diversely burrowed 1-3" storm beds– *definitely NOT Three Forks!*


ISOPACH OF NEW UNIT
C.I. = 5 Feet
"Sanish" Sand at
Antelope Field
SADOWSKY
24-14H
FED. 34-1
0 10 20 30 40 mi
Thicker
Thinner
Sadowsky 24-14H
14-T141N-R96W
10450
10500
10550
Isopach Interval
10 Ft



Upper Bakken Hydrogen Index (Data points from USGS)

Within this area the Upper Bakken Shale does not have any recognizable facies changes and originally had very high TOC values

The Hydrogen Index map can then be used as a proxy for maturation

Pronghorn Member Isopach with Key Pre-Drill Geologic Criteria Noted to Identify 2009 Leasing Areas

FED. 34-1

SADOWSKY 24-14H

PRESERVED THICK IN LOW BETWEEN STRUCTURES

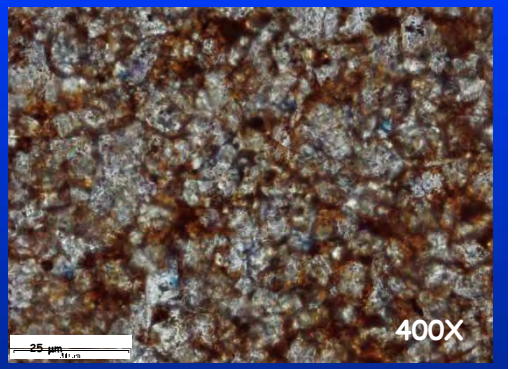
APPROX. LIMIT OF UPPER BAKKEN SHALE

PRONGHORN EROSIONAL LIMIT

DECREASING UPPER BAKKEN SHALE MATURATION

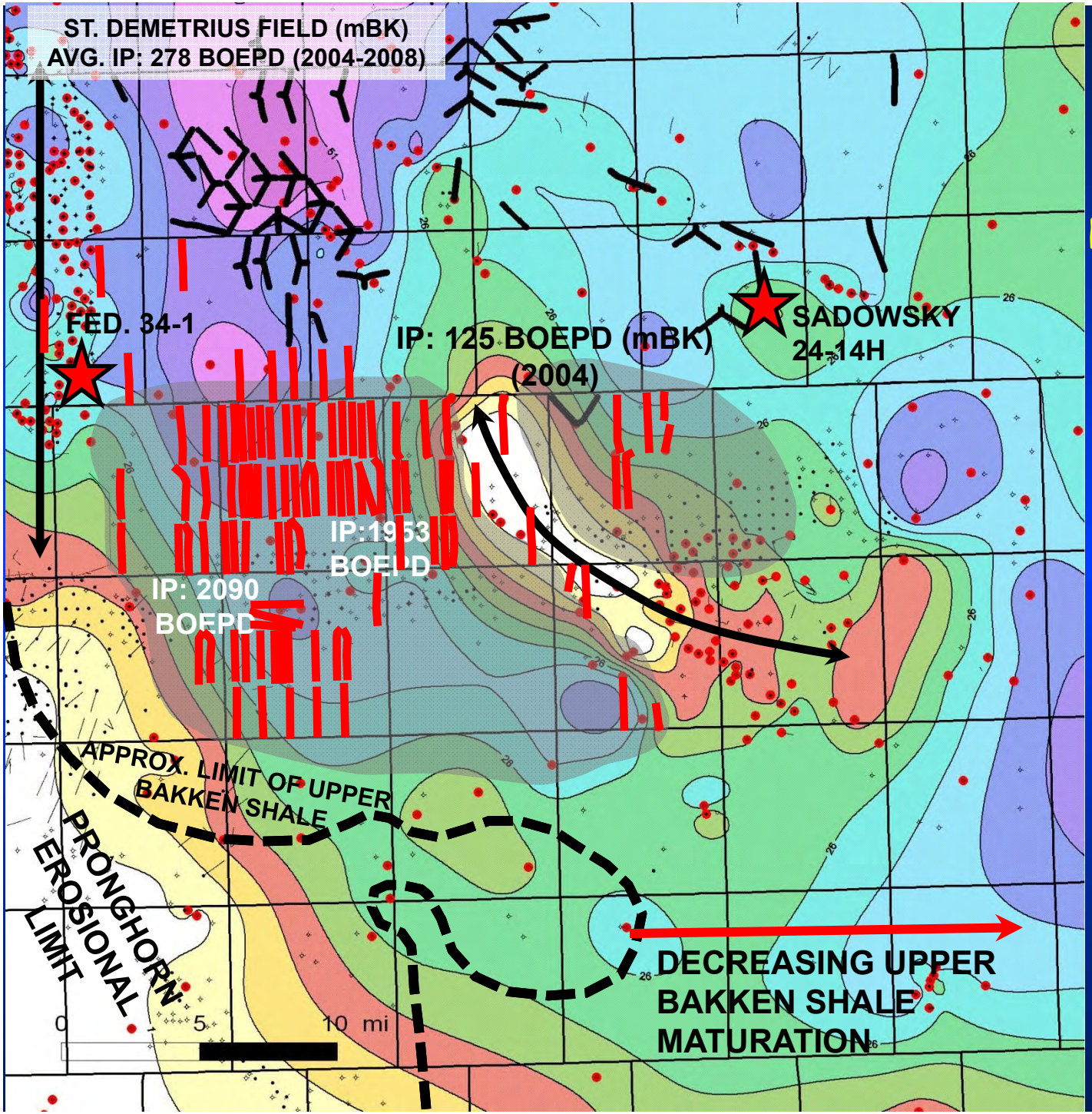
0 5 10 mi

Federal 34-1
Dolomite reservoir full of oil!



Thicker

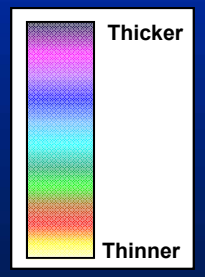
Thinner



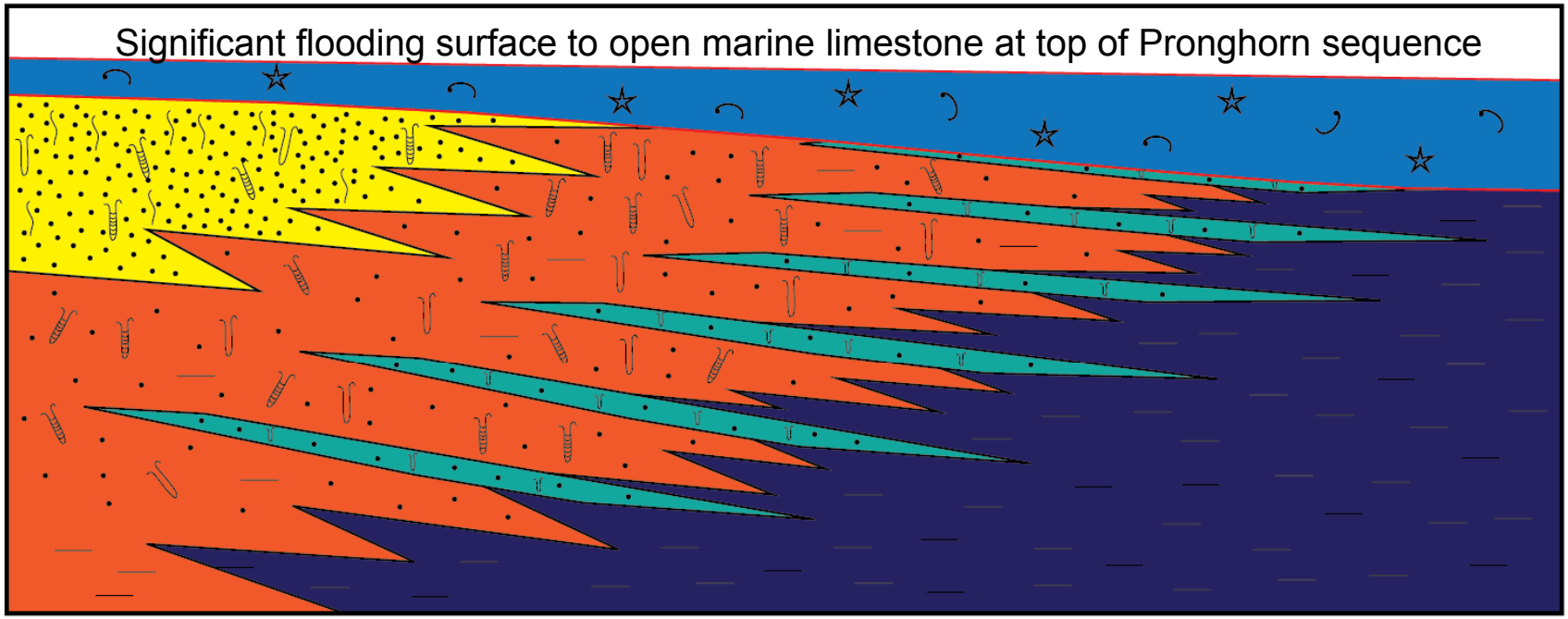
WHITING

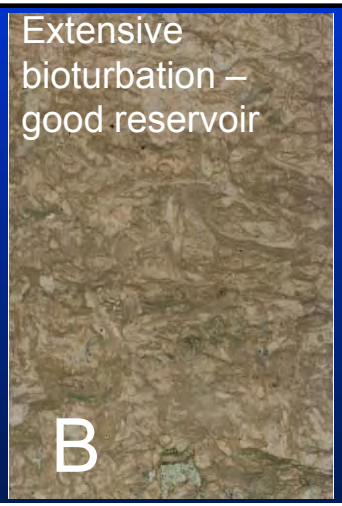
Pronghorn Member Isopach with Early Results and Current Drilling Activity

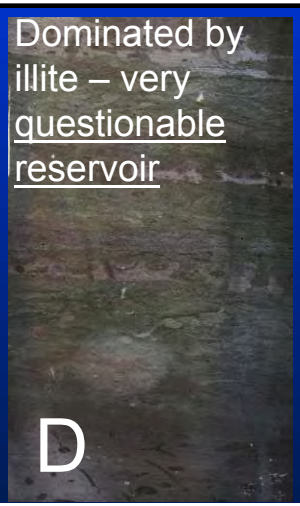
- Initial 2 wells avg. IP - 2021 BOEPD
- Whiting has drilled over 80 wells on this concept to date
- Whiting is the main operator in this area with 5 rigs
- IP's as high as 3611 BOEPD

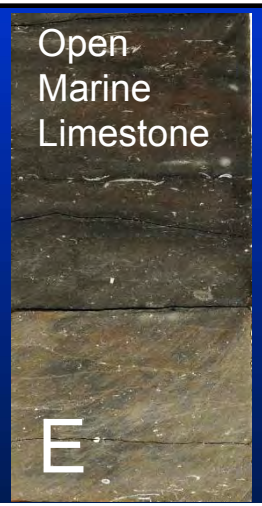


PRONGHORN FACIES

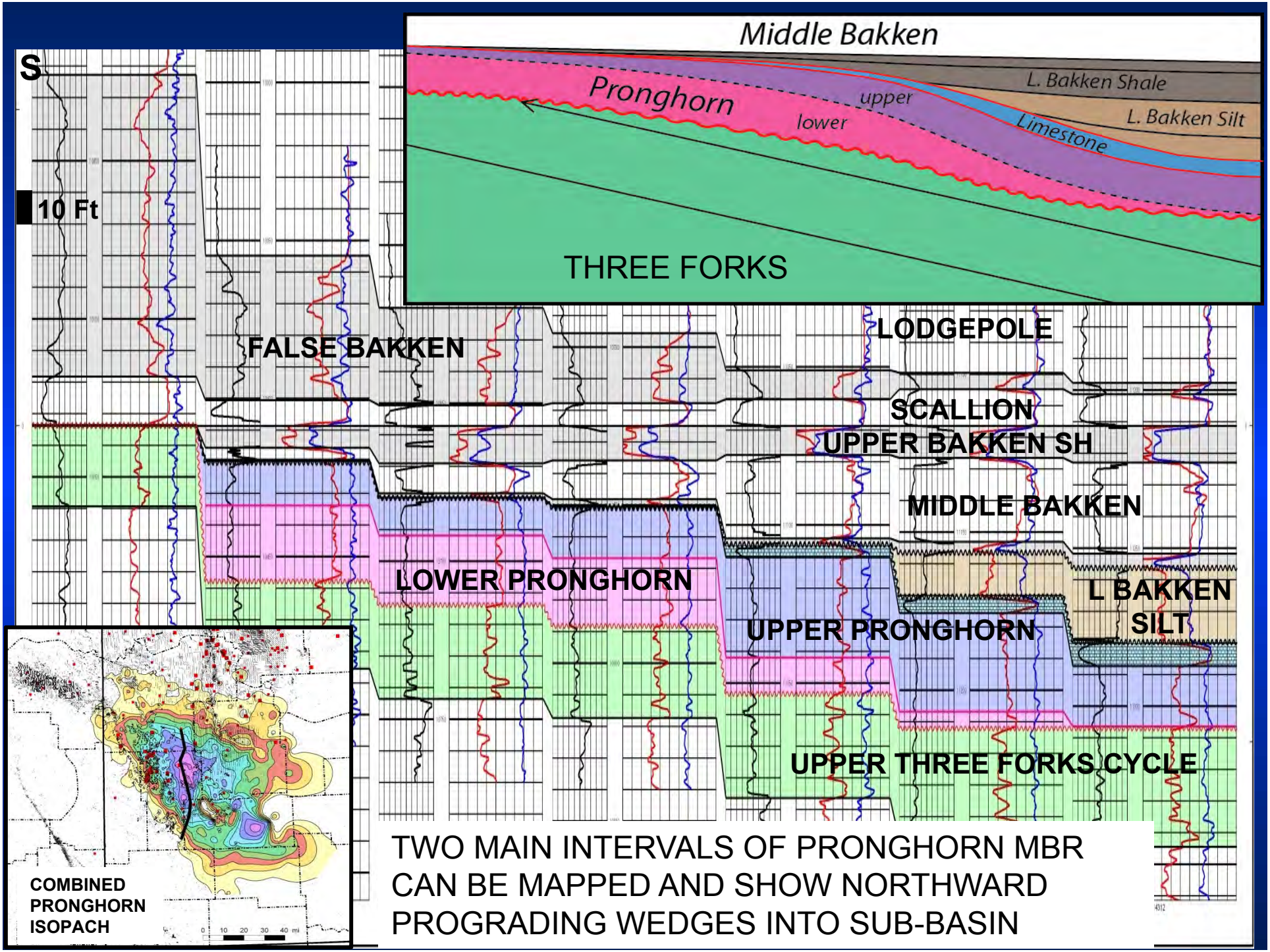






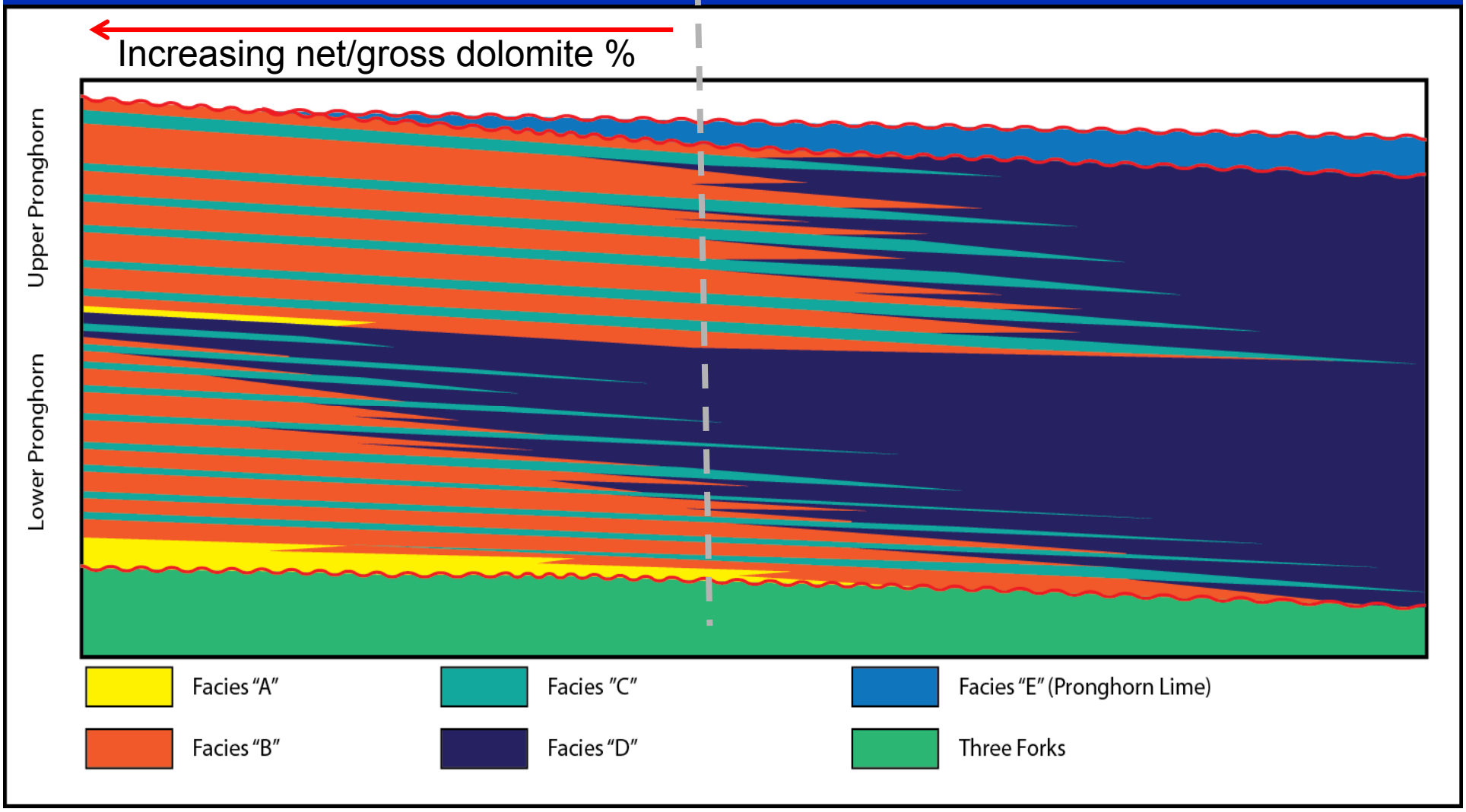


WHITING


S
10 Ft
Middle Bakken
Pronghorn
upper
lower
L. Bakken Shale
L. Bakken Silt
Limestone
THREE FORKS
FALSE BAKKEN
LODGEPOLE
SCALLION
UPPER BAKKEN SH
MIDDLE BAKKEN
LOWER PRONGHORN
L BAKKEN SILT
UPPER PRONGHORN
UPPER THREE FORKS CYCLE
COMBINED PRONGHORN ISOPACH
0 10 20 30 40 mi
TWO MAIN INTERVALS OF PRONGHORN MBR CAN BE MAPPED AND SHOW NORTHWARD PROGRADING WEDGES INTO SUB-BASIN

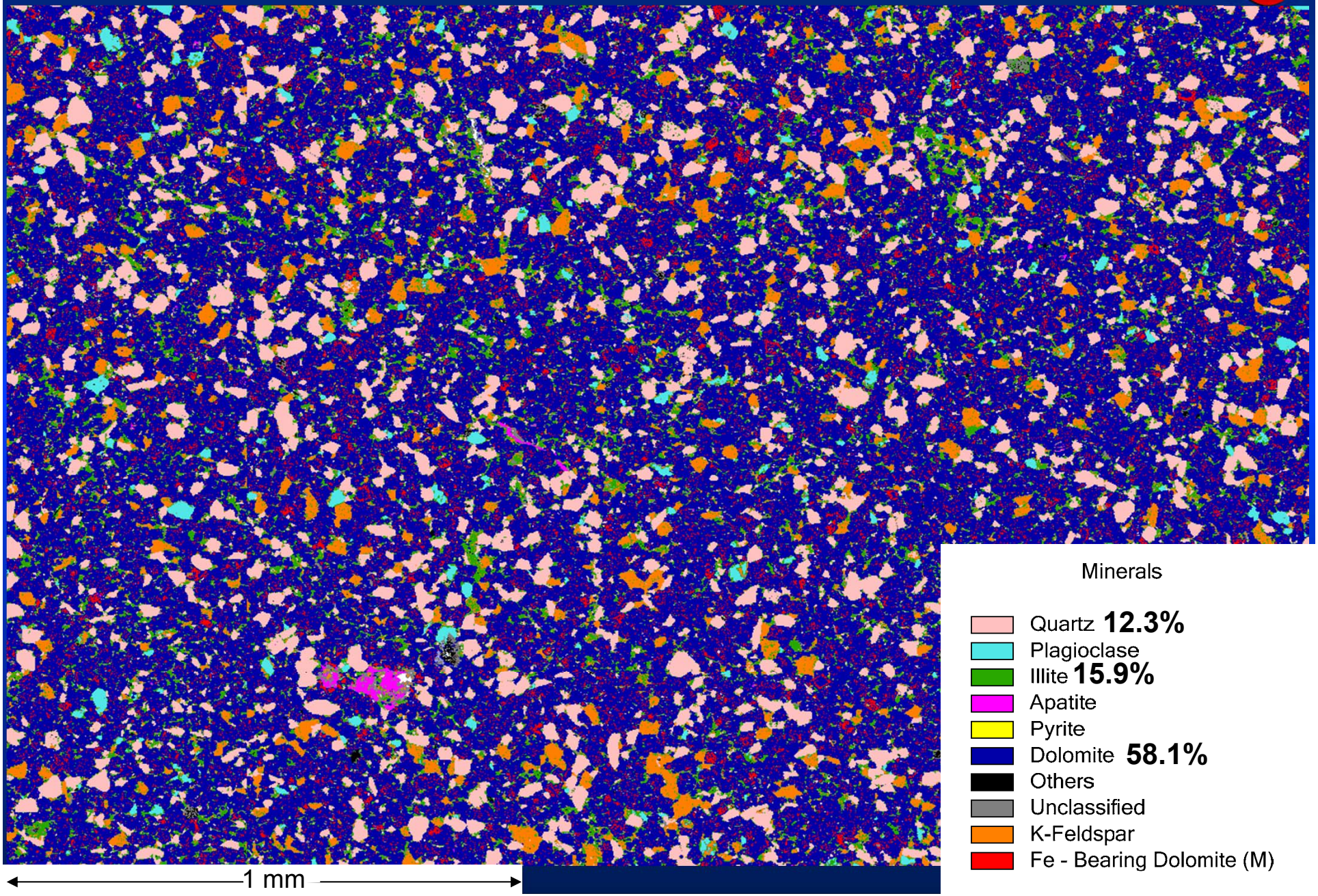
Whiting focused leasing efforts in the thicker net/gross dolomite areas within the upper and lower Pronghorn intervals

Proximal to distal facies changes within each of the two mapped Pronghorn intervals



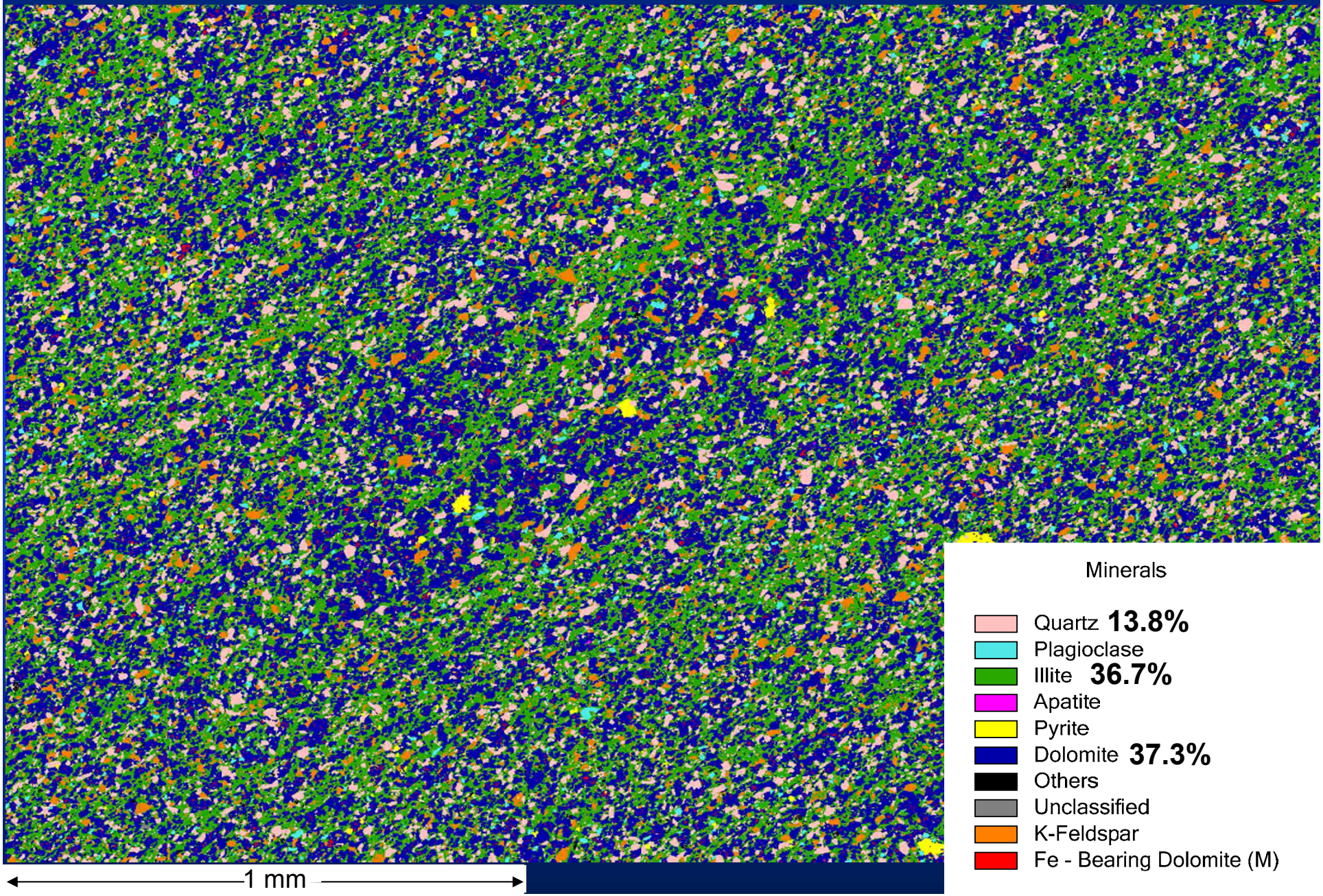
Qemscan Mineral Map – Pronghorn B Facies

Detrital dolomite reservoir with quartz and illite

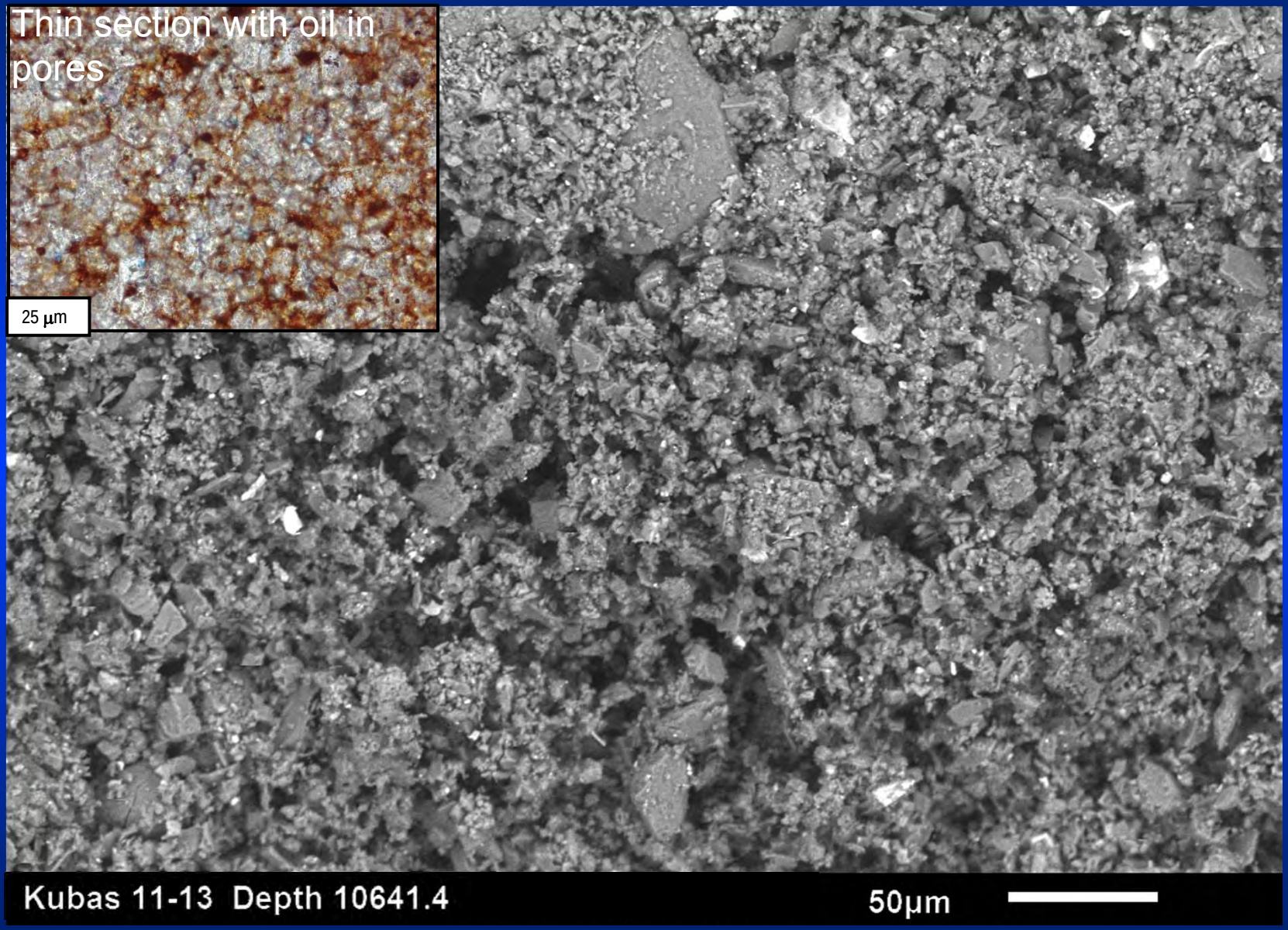


Qemscan Mineral Map - Pronghorn D Facies

Muddy Dolomite/Dolomitic Mudstone w/ significantly poorer reservoir quality



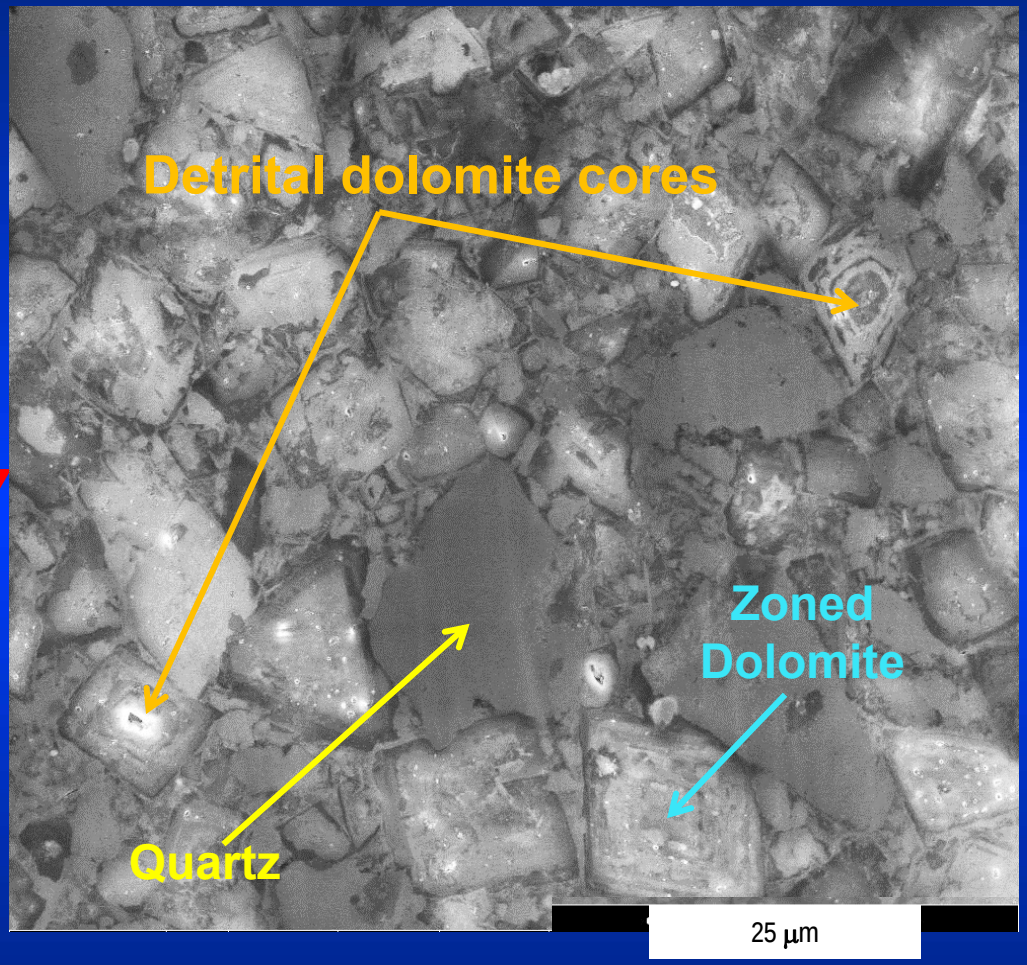
Pronghorn B Facies



Thin section and SEM image at same scale – bi-modal dolo with intercrystalline pores

a)

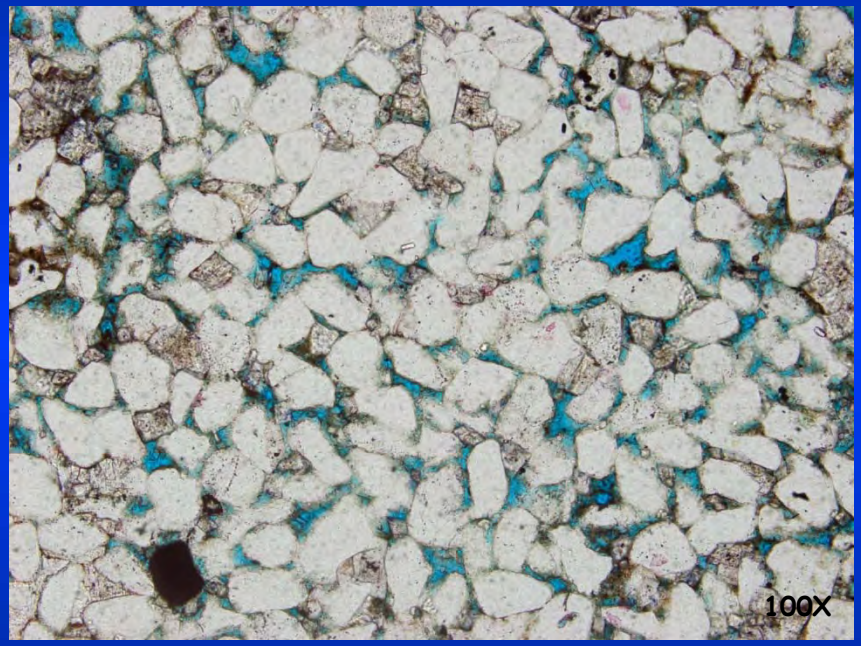
b)



Pronghorn facies are detrital in origin

Cedar Creek high is likely source

Changes in Source Area "Provenance"



Manitoba / E. North Dakota

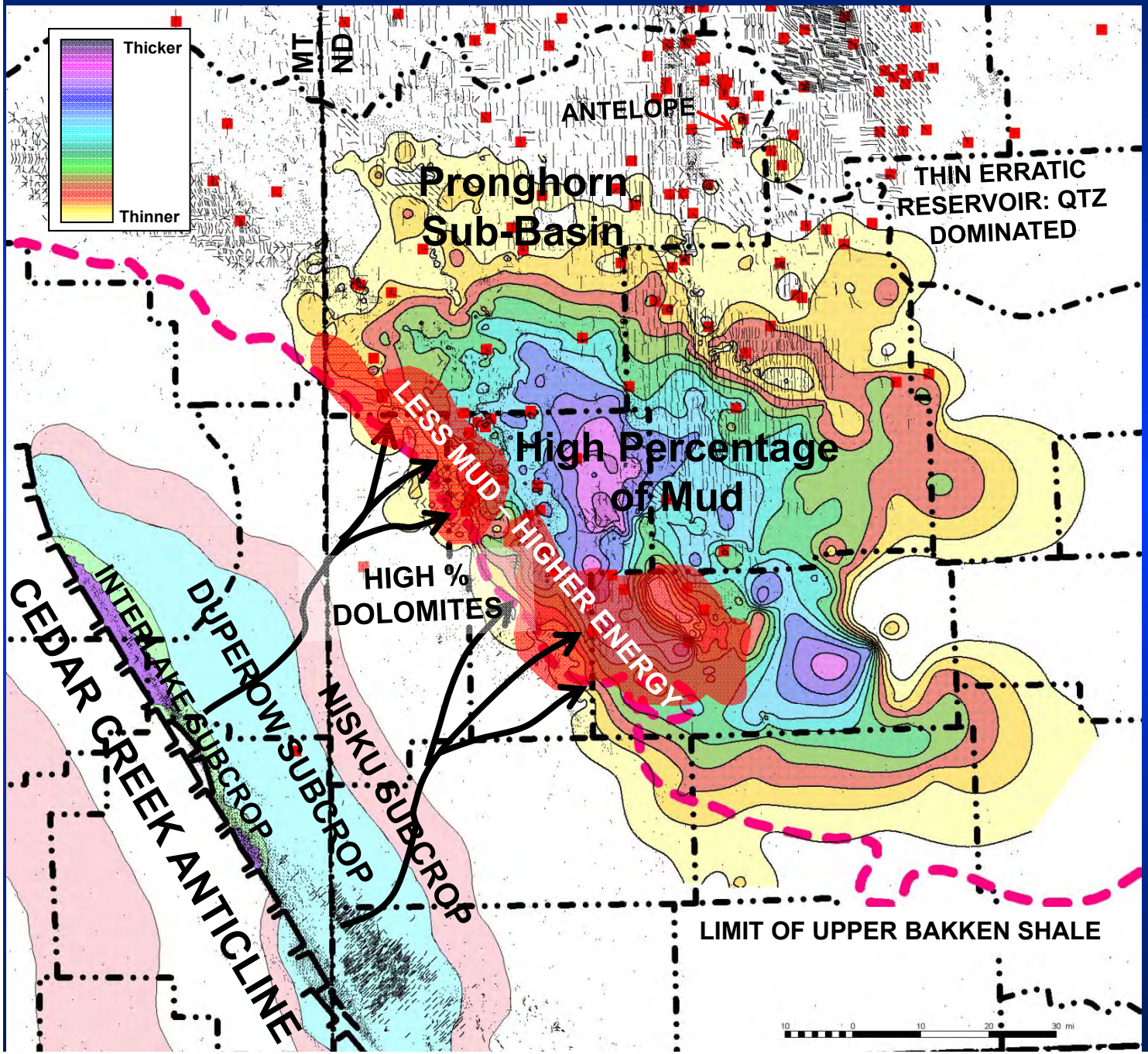
Quartz source area

Antelope Field

vs. Cedar Creek Anticline

Dolomite source area

Pronghorn Reservoir
in Stark/Billings Co.



Pronghorn Interval Depositional Model

Three Forks, Nisku, Duperow and Interlake exposed during Pronghorn/Bakken time – *Source for detrital dolomite*

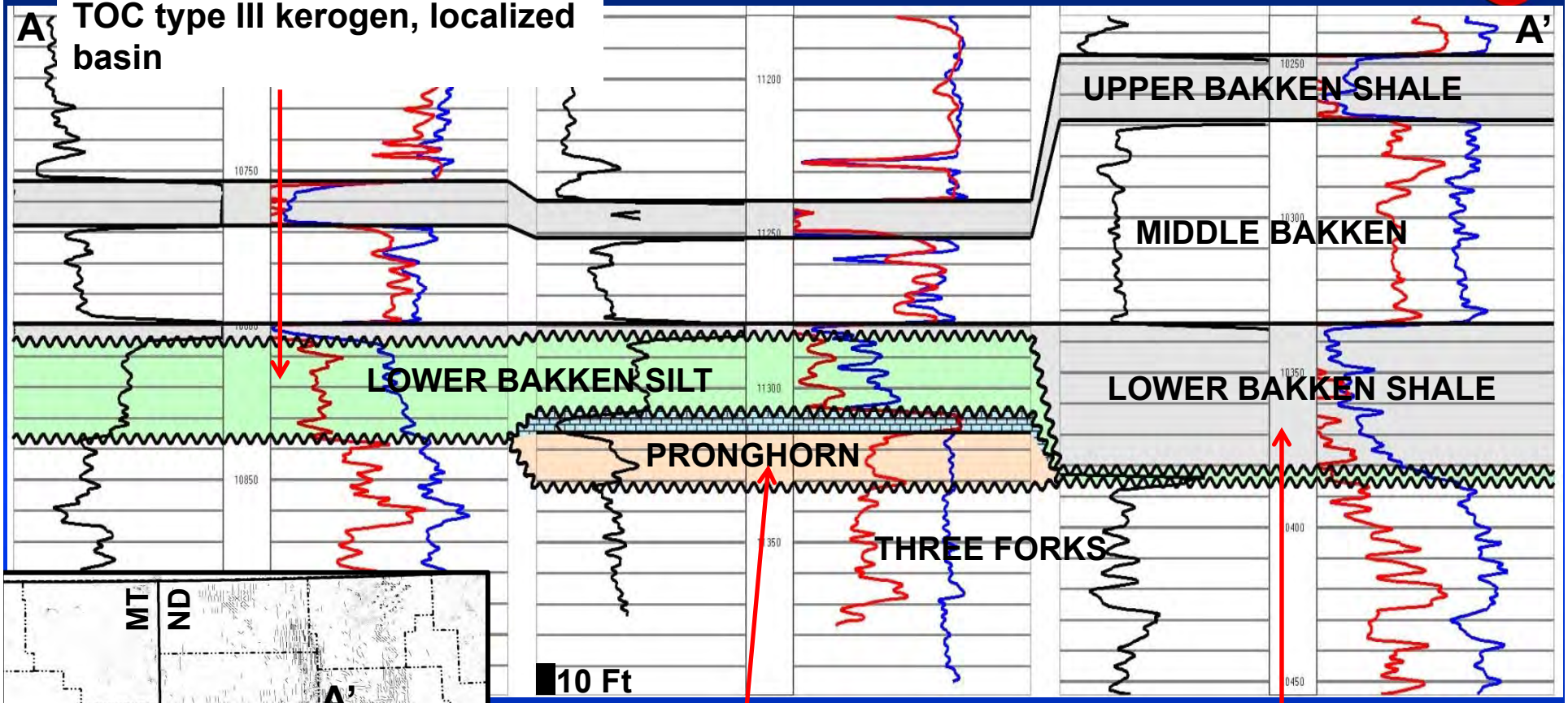
- **Core control: Bakken petroleum system**

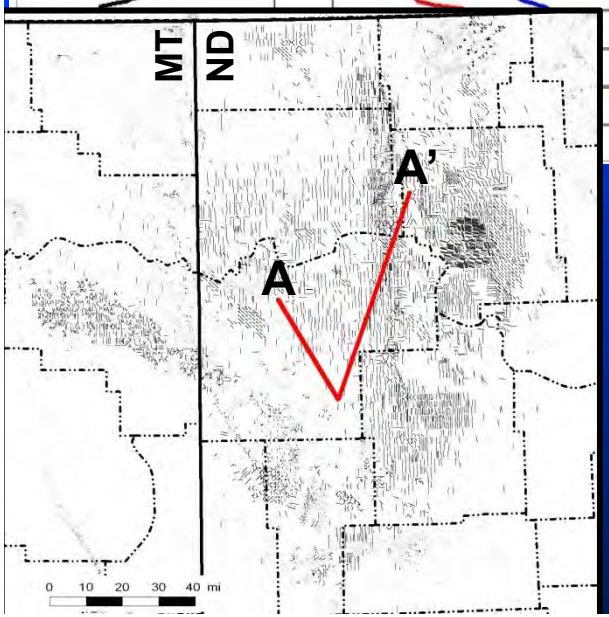
Regional Stratigraphic and Continued Exploration Implications

Low Accommodation Stratigraphic Mapping of the Greater Pronghorn Interval

Separating sequences correctly matters

LOWER BAKKEN SILT – Dark gray muddy siltstone, 1-5% TOC type III kerogen, localized basin

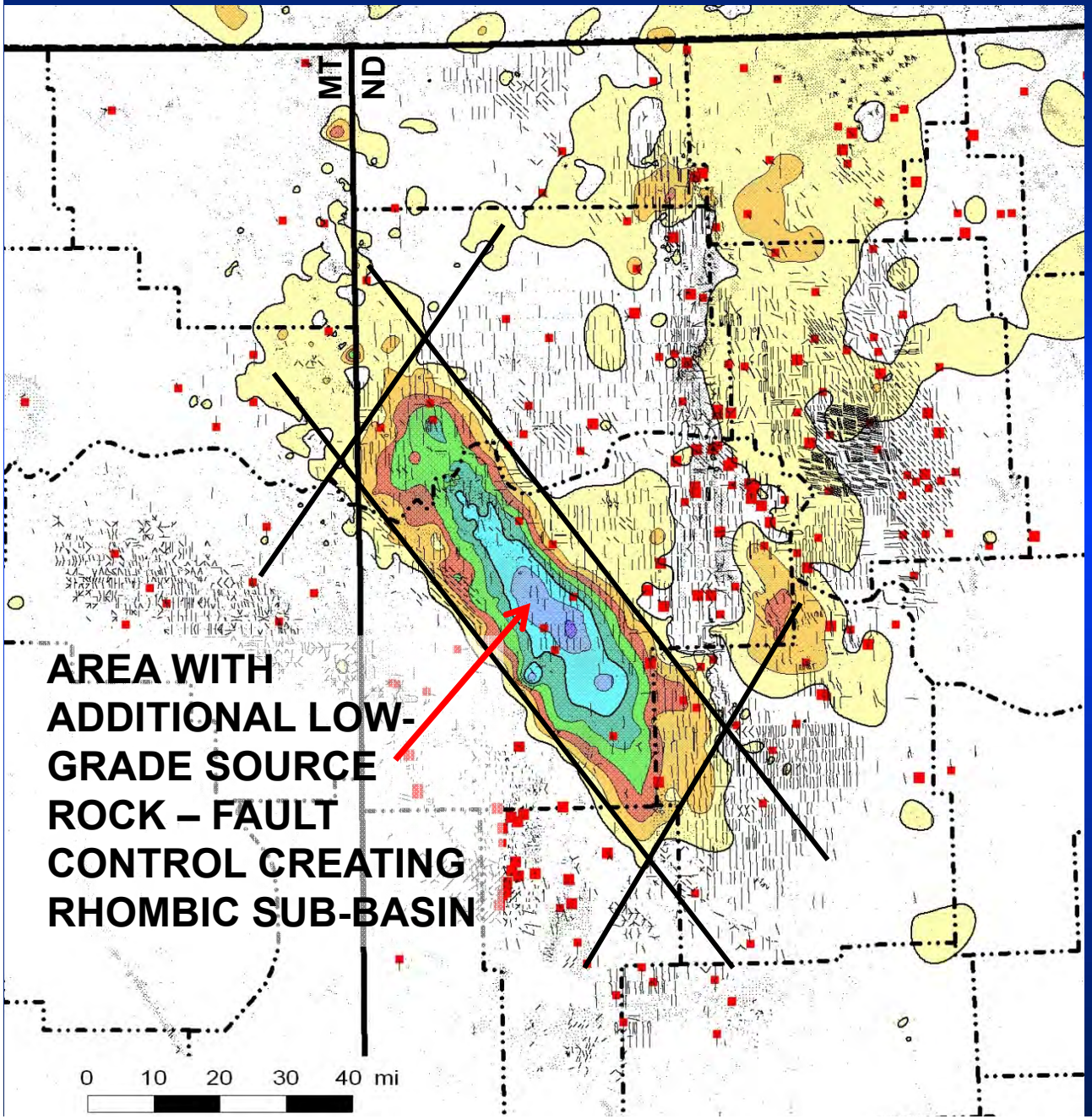




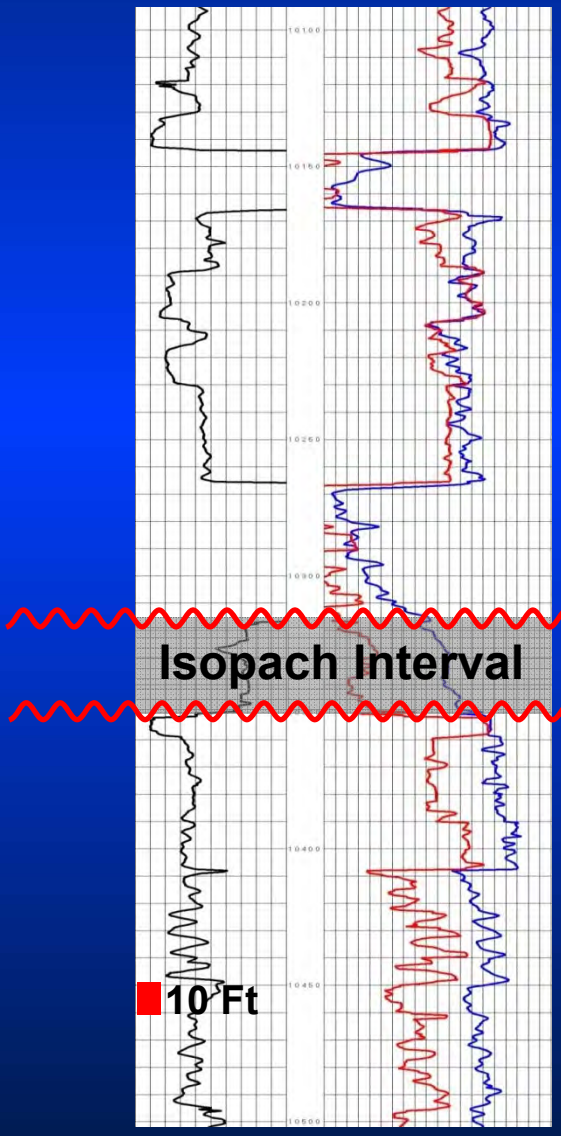
PRONGHORN – Clay rich over much of the area, local isolated qtz rich in places with extensive dolomite in SW depocenter, NO TOC

LOWER BAKKEN SHALE - Anoxic kerogenous mudstone, dark brown to black, type I and II kerogen, *TOC up to 20%*

Lower Bakken Silt C.I.= 5 Feet 0-37 Feet thick



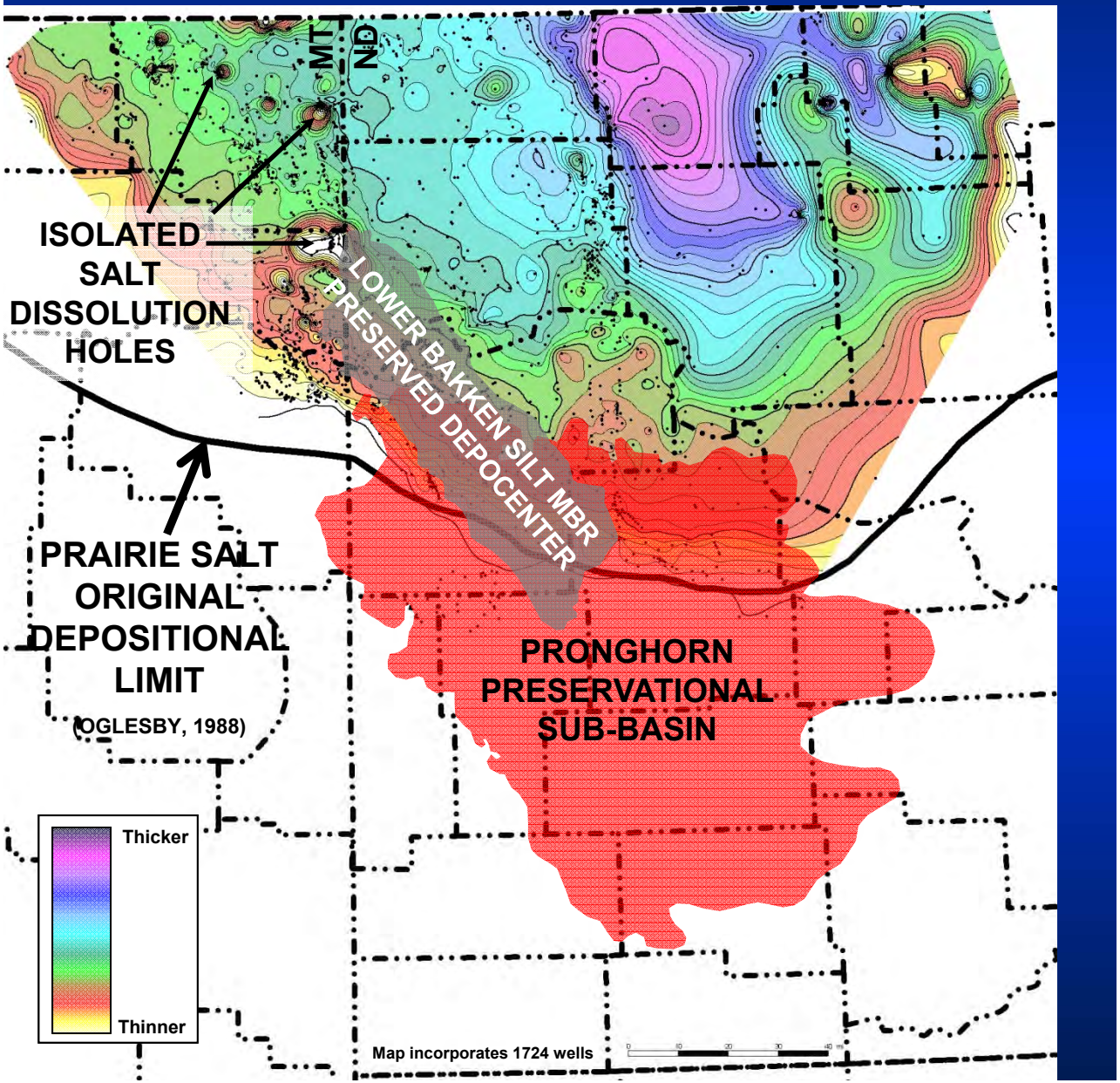
Composite Log

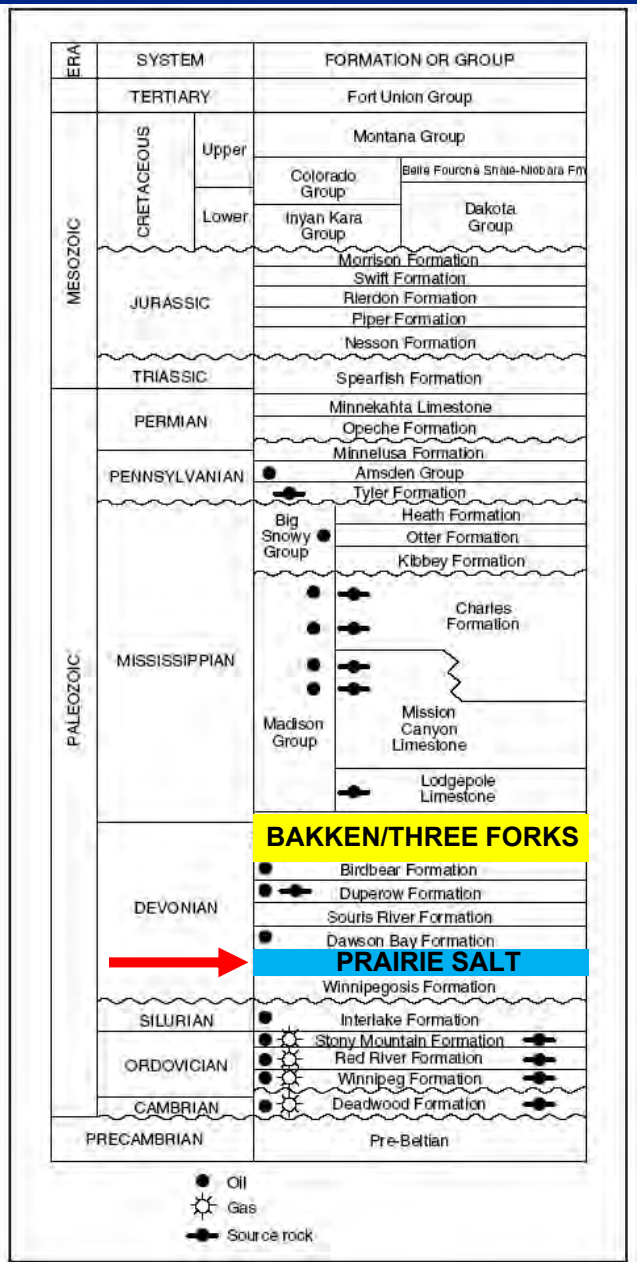


Mechanism for preservation within the Bakken Petroleum system of the Williston Basin:

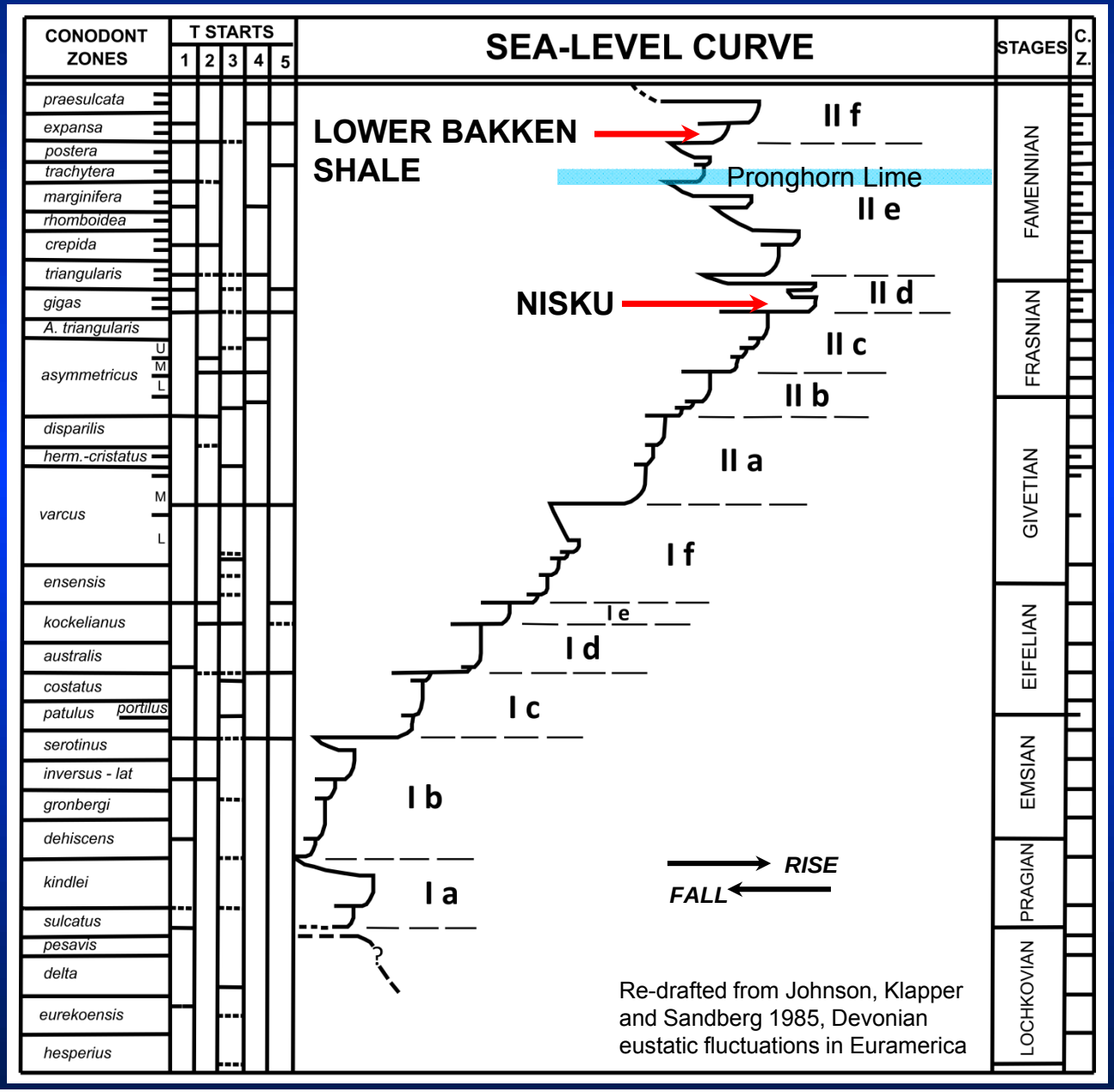
Tectonics or salt dissolution?

Devonian Prairie Salt Isopach (0-650 Feet)
C.I. = 20 Feet





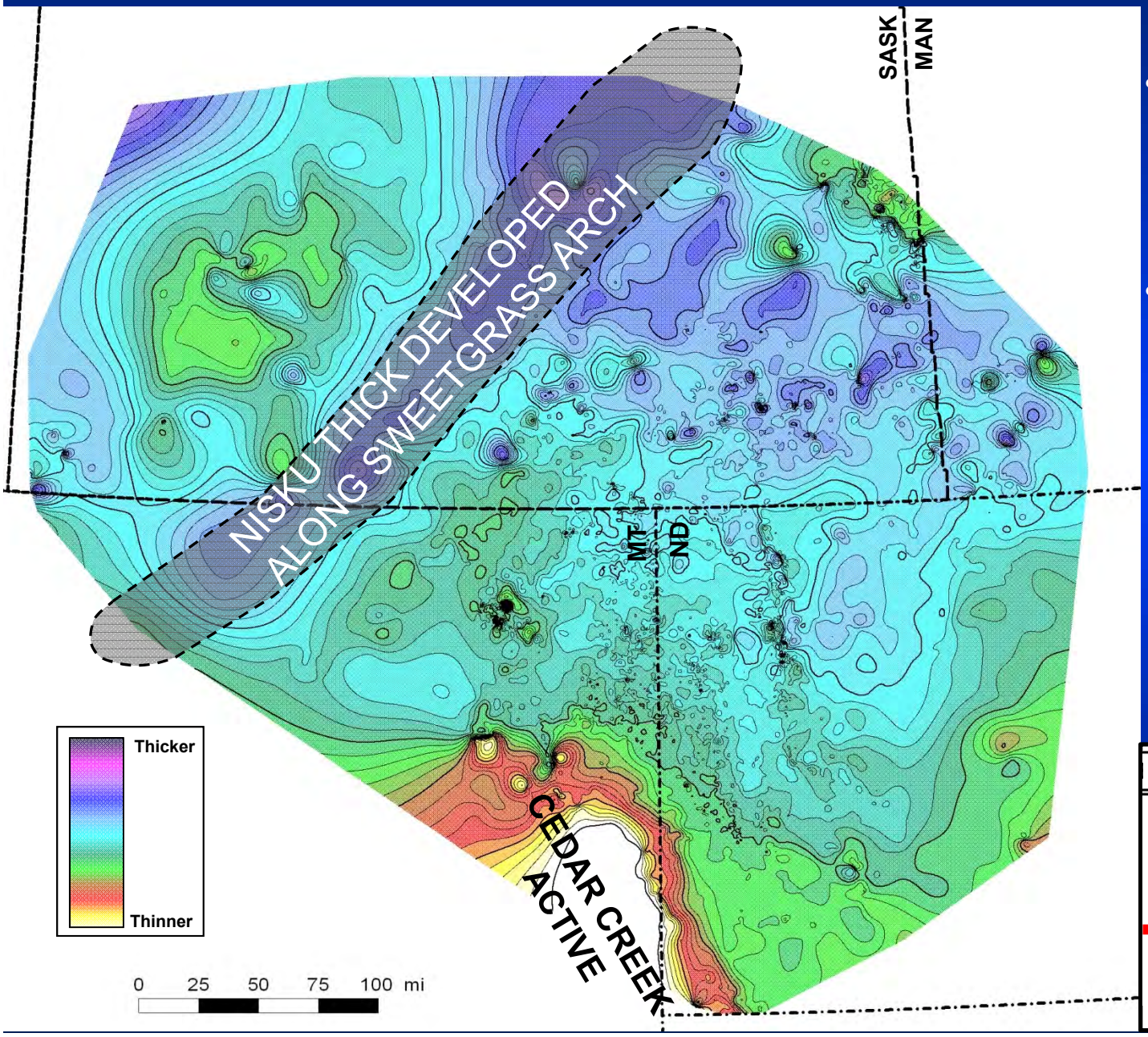
Qualitative eustatic sea-level curve for the Devonian and its relationship to Devonian conodont zones



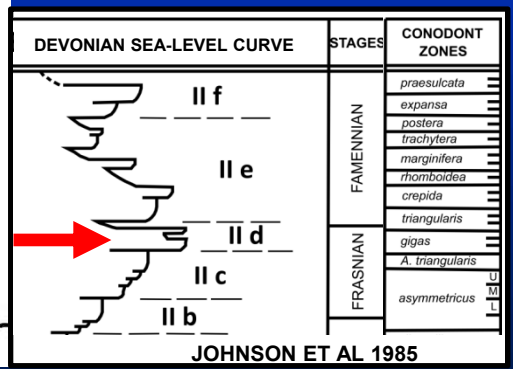
Multiple transgressive/ regressive pulses have been documented in the western U.S. based on geology combined with conodont age dating

These sea-level pulses can significantly impact deposition and preservation – especially in a low-accommodation setting like the Bakken petroleum system within the Williston Basin

Nisku Isopach C.I.= 5 Feet
0-183 Feet thick



- Broad open marine limestone with widespread preservation
- No obvious depo-center



Three Forks Isopach C.I.= 5 Feet
0-255 Feet thick

WHITING

SE OF SWEETGRASS ARCH -RESTRICTED ENVIRONMENT– INTERLAYERED SHALES & DOLOMITES – ANHYDRITE PRESENT

SWEETGRASS ARCH – ACTS AS SILL

SASK

MAN

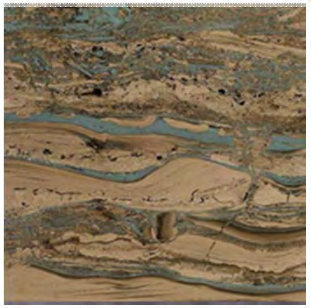
MT

ND

DEPOCENTER

CEDAR CREEK ACTIVE

TYPICAL THREE FORKS FROM CENTER OF BASIN

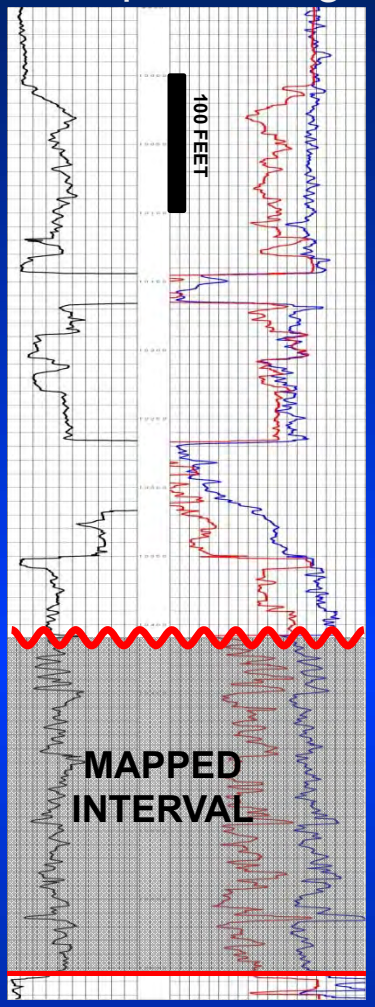


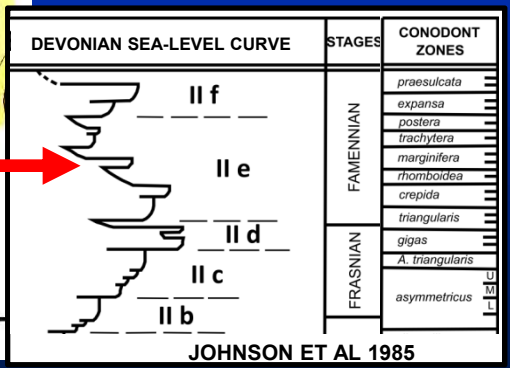
Thicker

Thinner

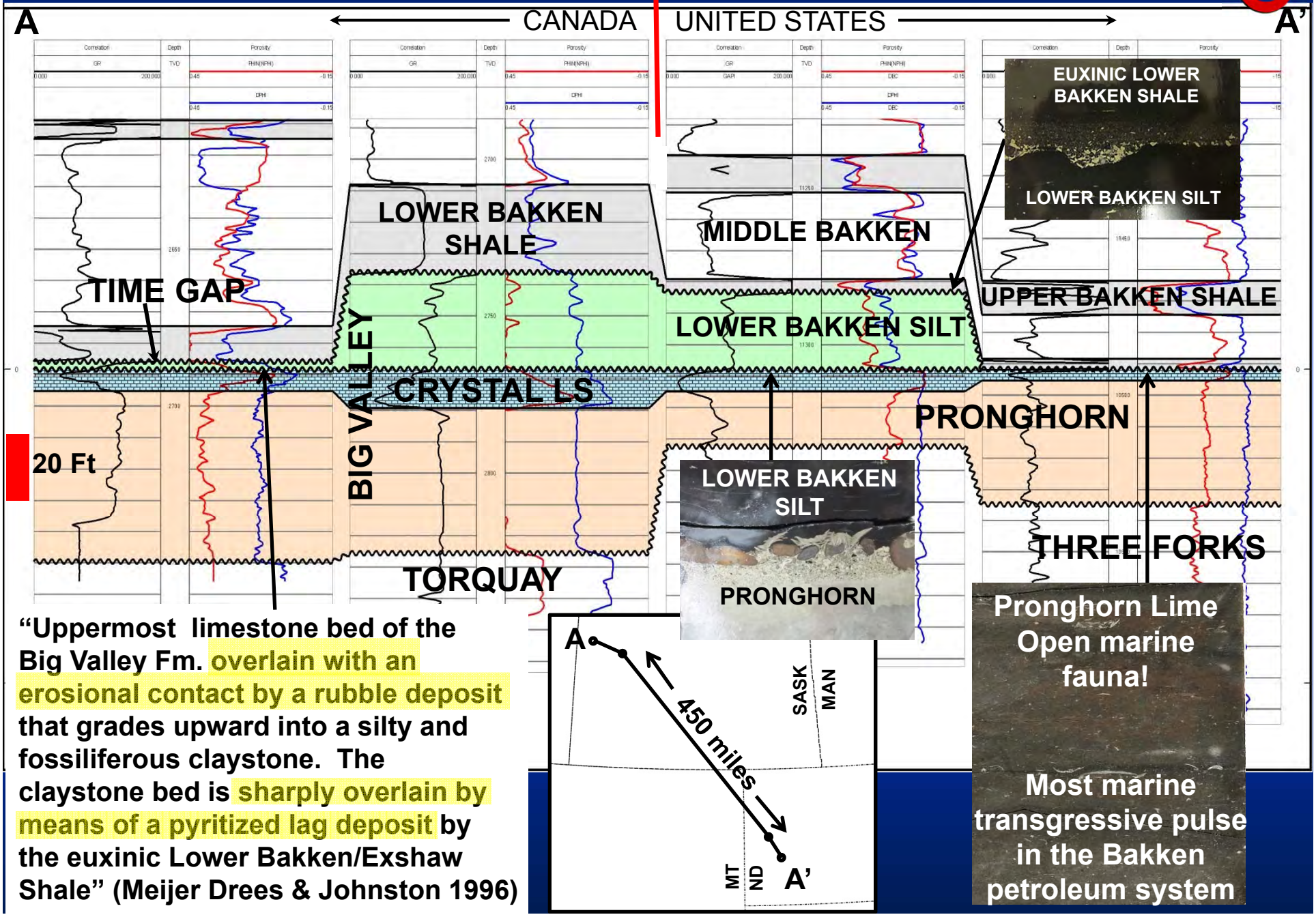
0 25 50 75 100 mi

Composite Log



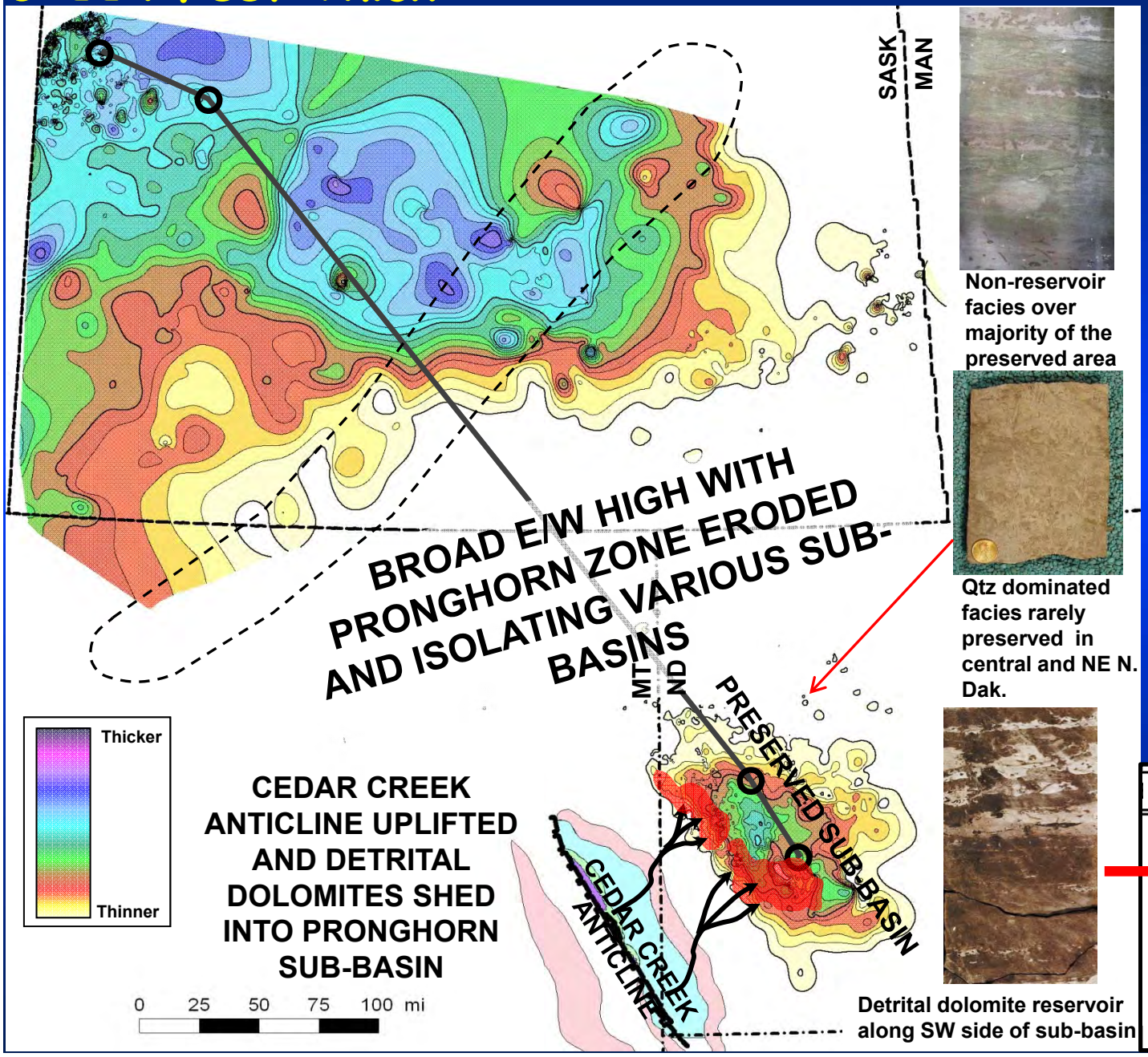


Understanding the regional correlations – The limestone is the key



"Uppermost limestone bed of the Big Valley Fm. overlain with an erosional contact by a rubble deposit that grades upward into a silty and fossiliferous claystone. The claystone bed is sharply overlain by means of a pyritized lag deposit by the euxinic Lower Bakken/Exshaw Shale" (Meijer Drees & Johnston 1996)

Pronghorn/Basal Big Valley Isopach C.I. = 5 Feet
0-114 Feet Thick

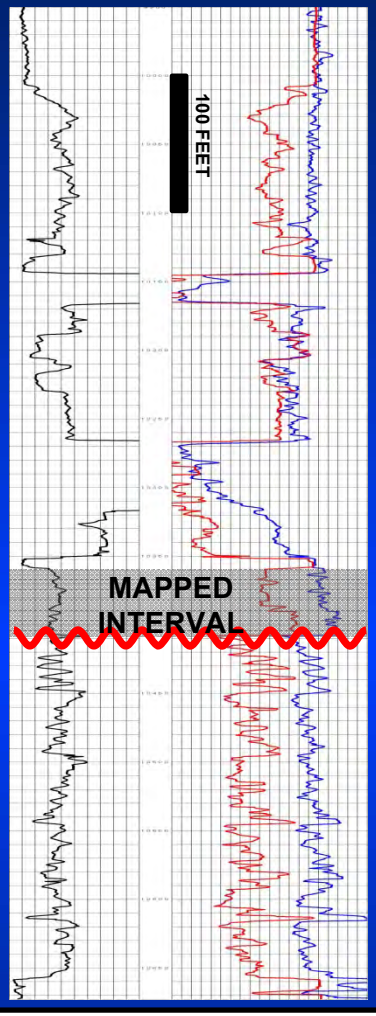


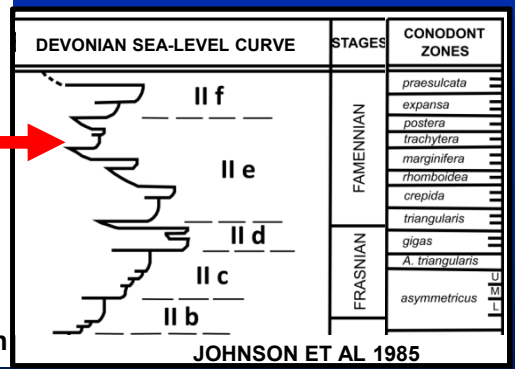
Non-reservoir facies over majority of the preserved area

Qtz dominated facies rarely preserved in central and NE N. Dak.

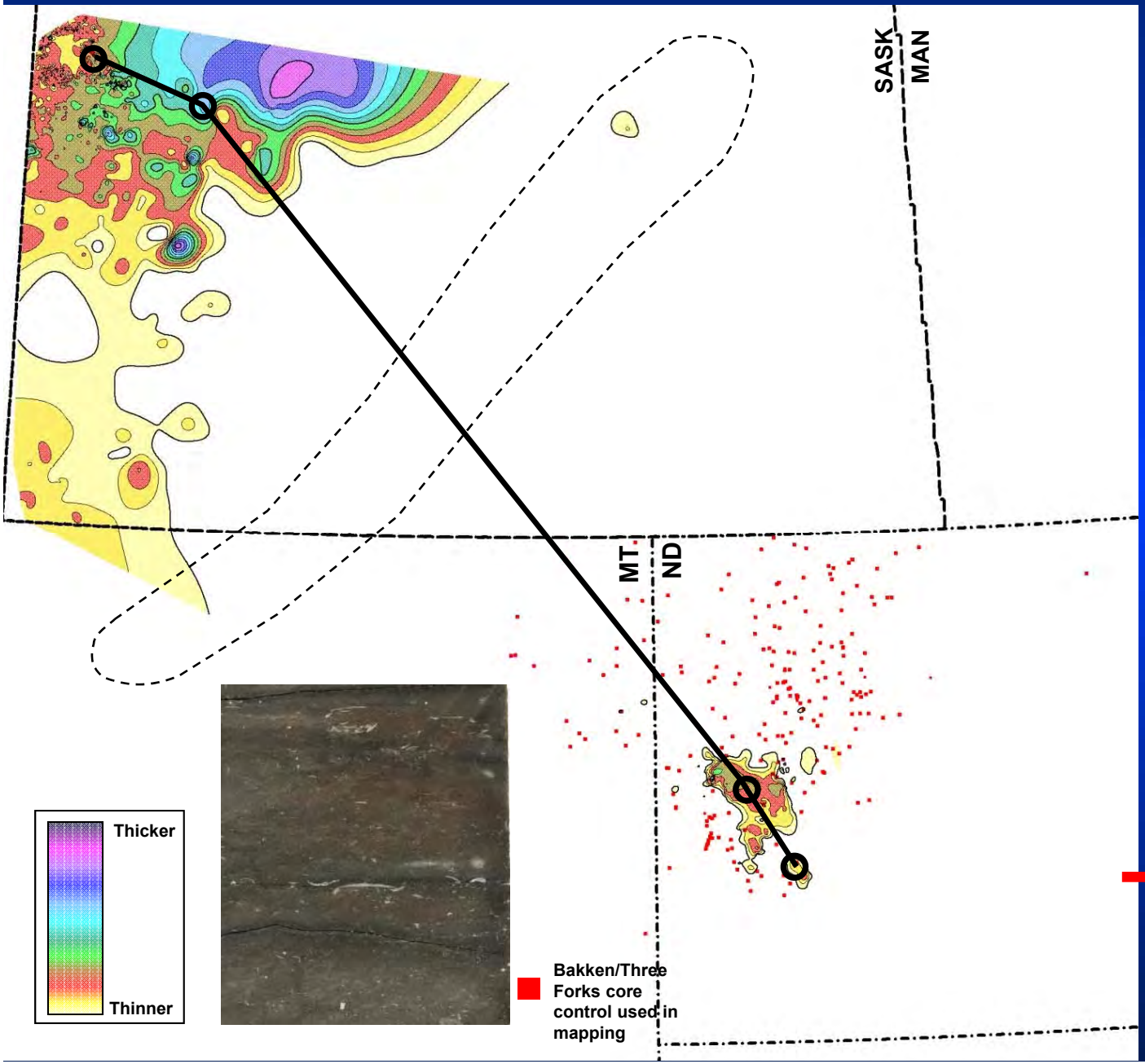
Detrital dolomite reservoir along SW side of sub-basin

Composite Log

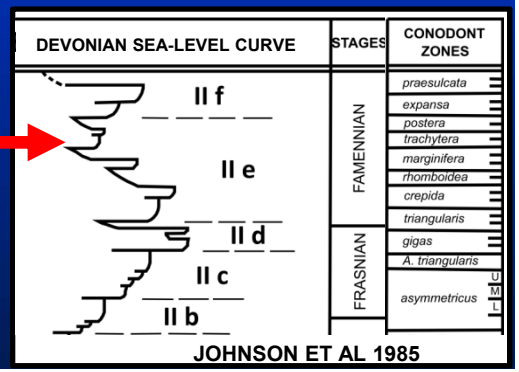




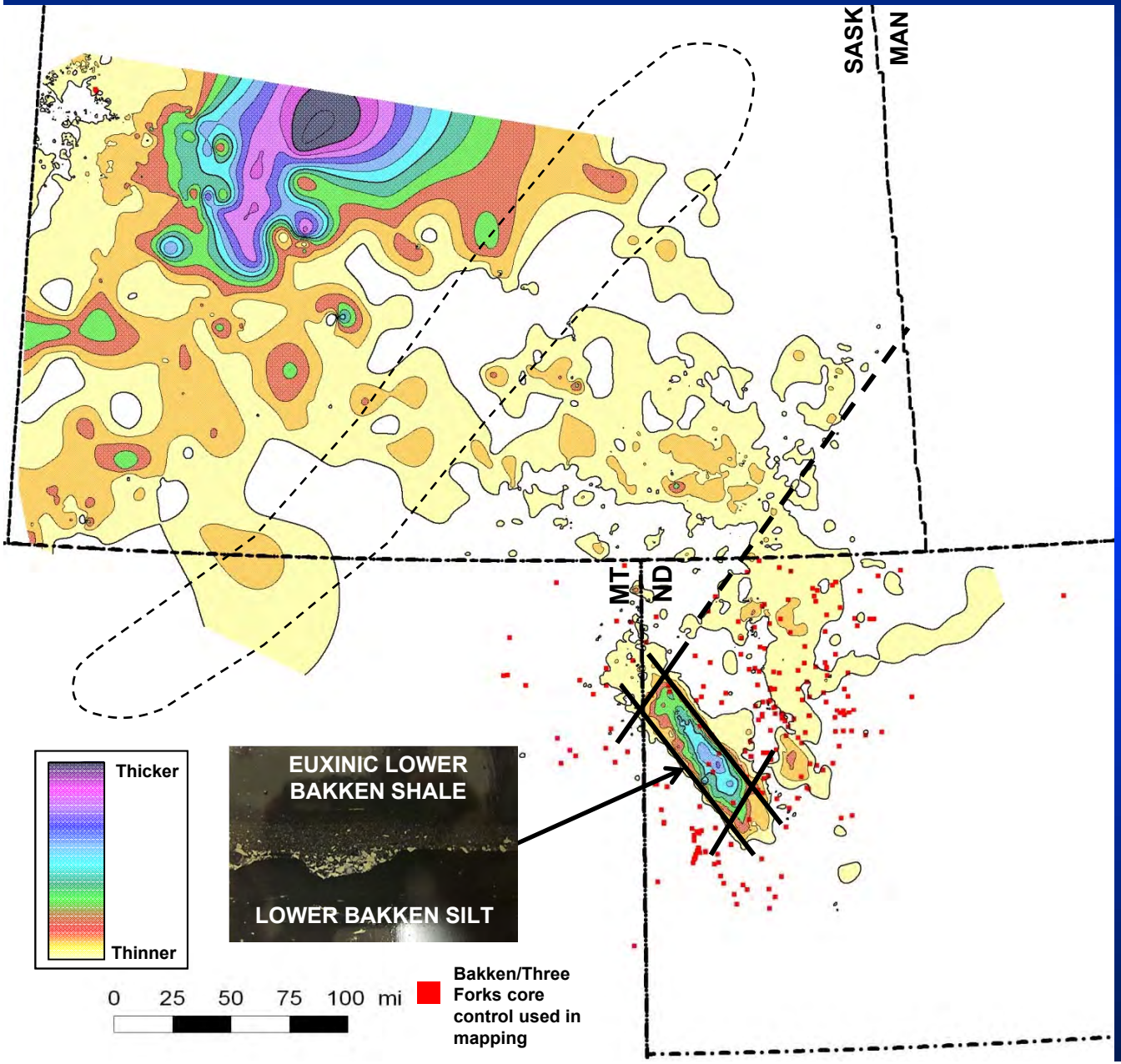
Pronghorn/Crystal Limestone Isopach C.I.= 2 Feet
0-22 Feet thick



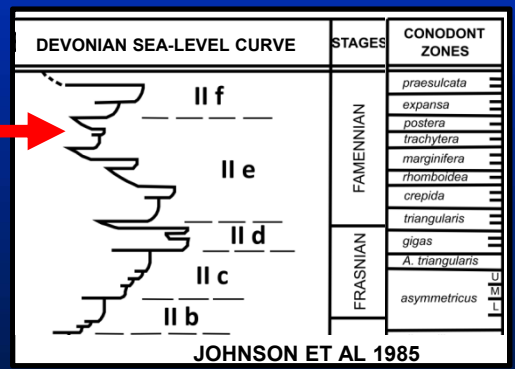
- Local preservational remnant
- Much greater inferred original depositional extent because the Pronghorn lime represents open marine deposition over a vast, low-relief region



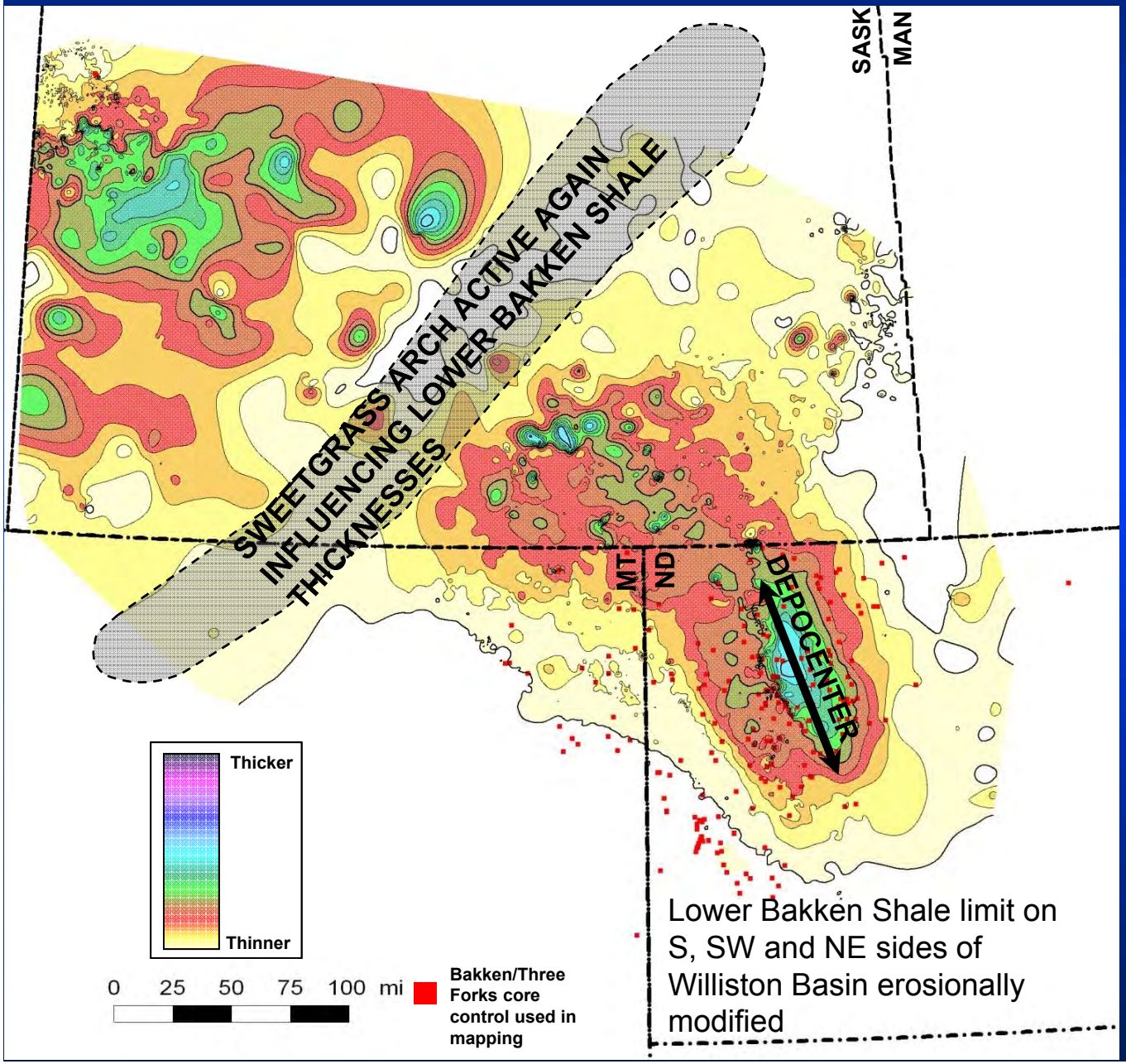
Lower Bakken Silt/Upper Big Valley Isopach
C.I.= 5 Feet 0-55 Feet thick



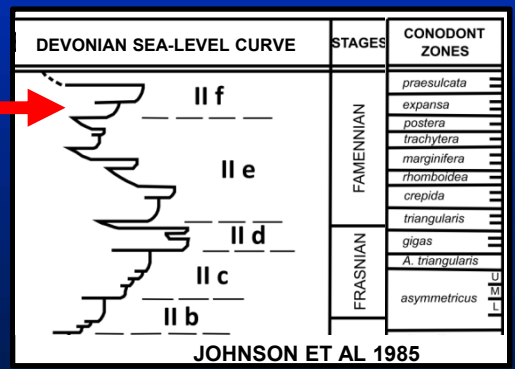
- Spotty preservation
- Downdropped graben/rhombochasm
- 1-5%TOC
- Muddy siltstone



Lower Bakken Shale Isopach C.I.= 5 Feet
0-87 Feet thick

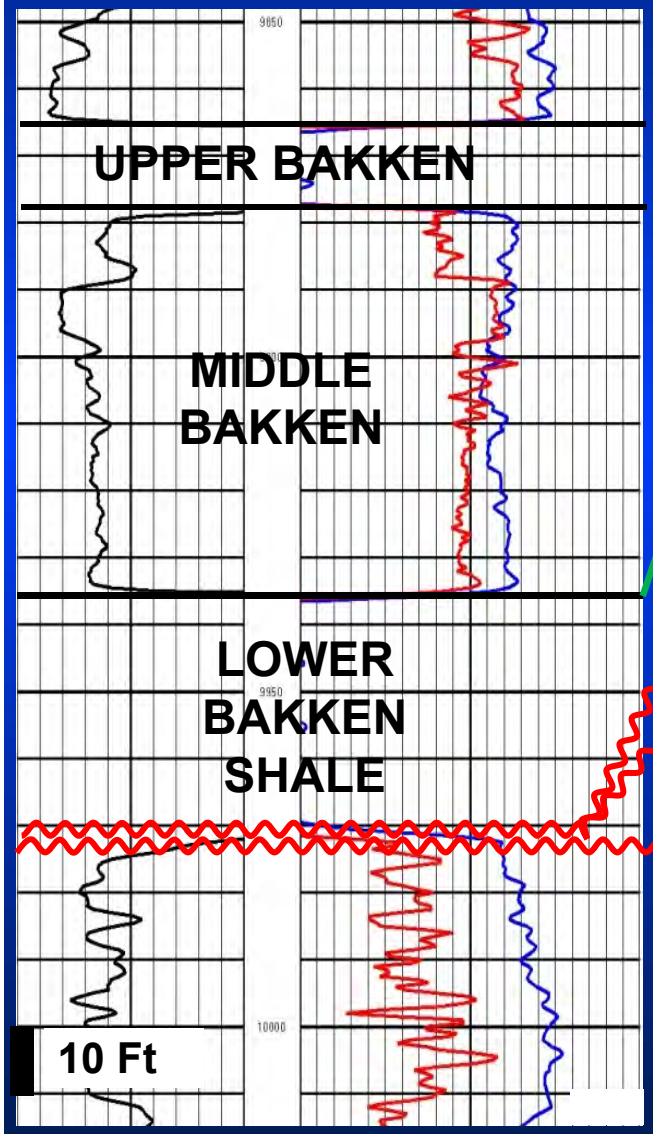


- Preserved depocenter during Lower Bakken Shale time shifts back to Mountrail County
- Sweetgrass Arch active during and/or after Lower Bakken time – preserved thicknesses likely erosionally modified
- Sets the stage for Middle Bakken deposition

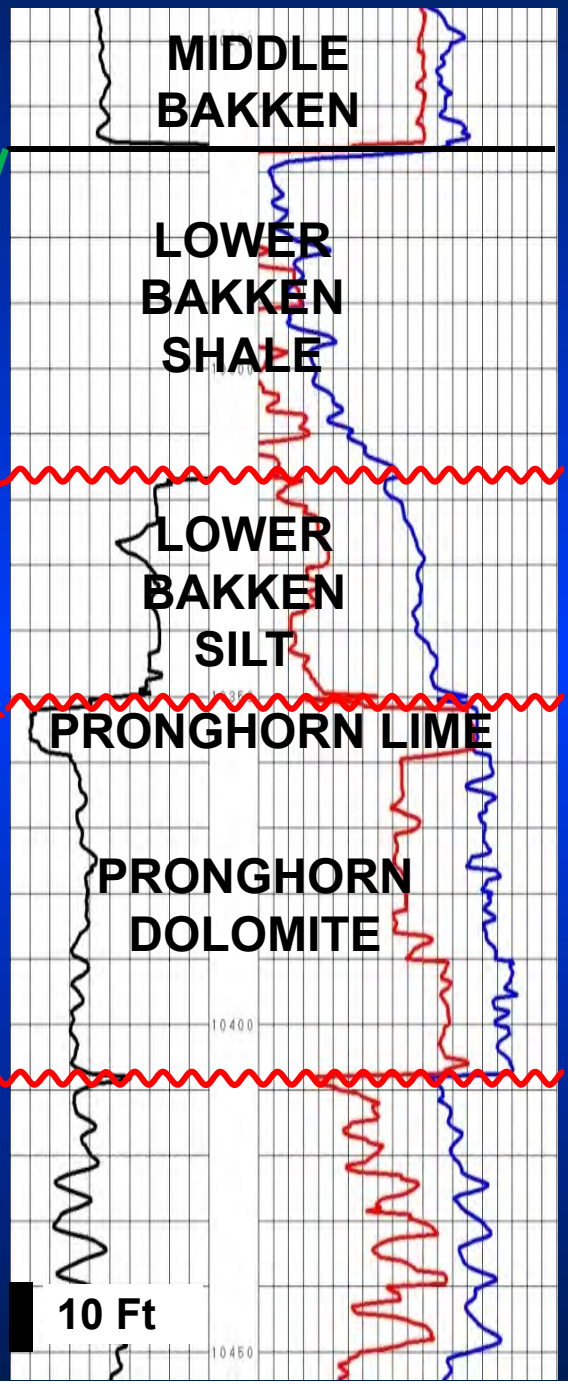


Conclusions

WHITING
Braaflat 11-11H
11-T153N-R91W



COMPOSITE LOG

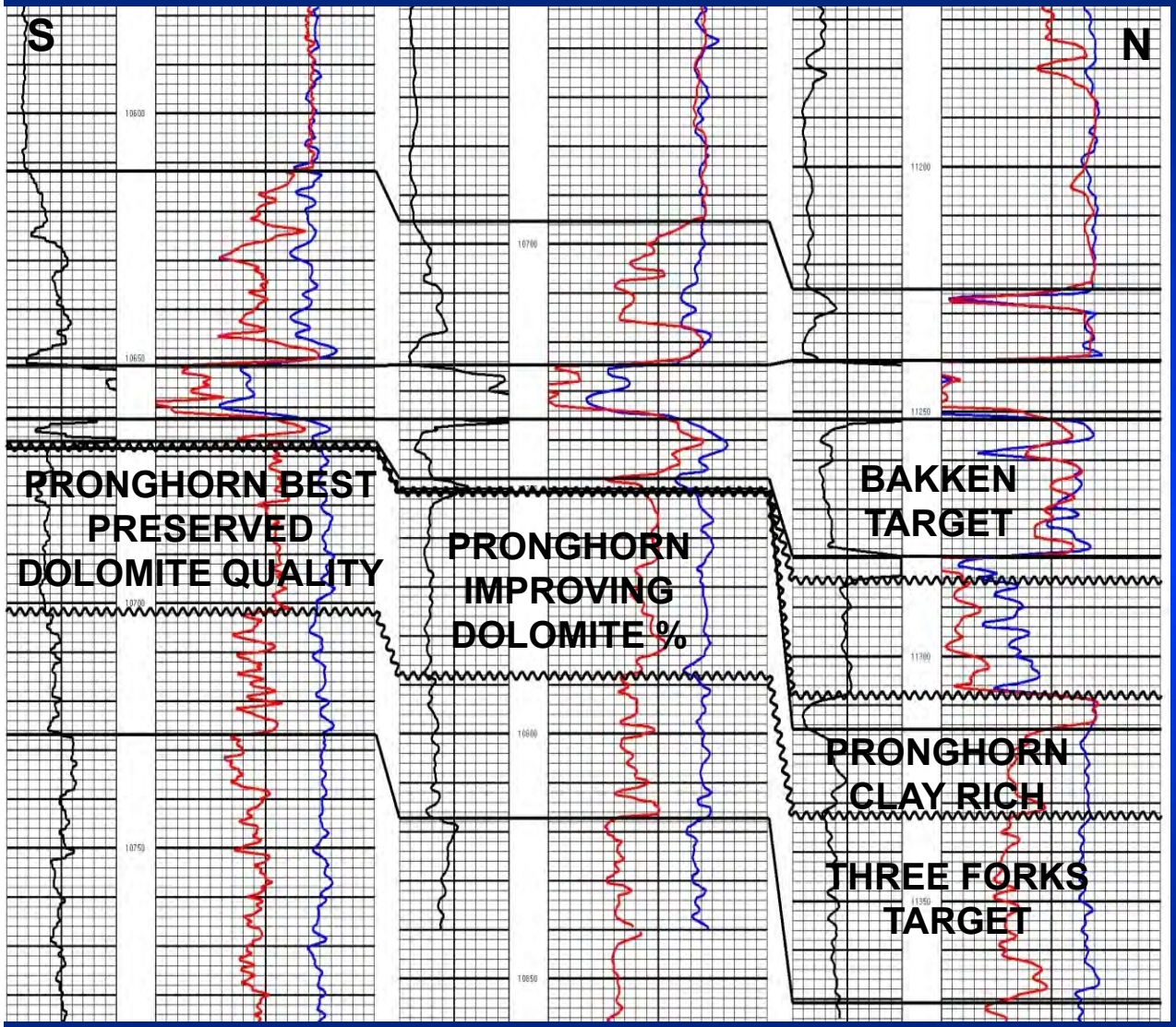


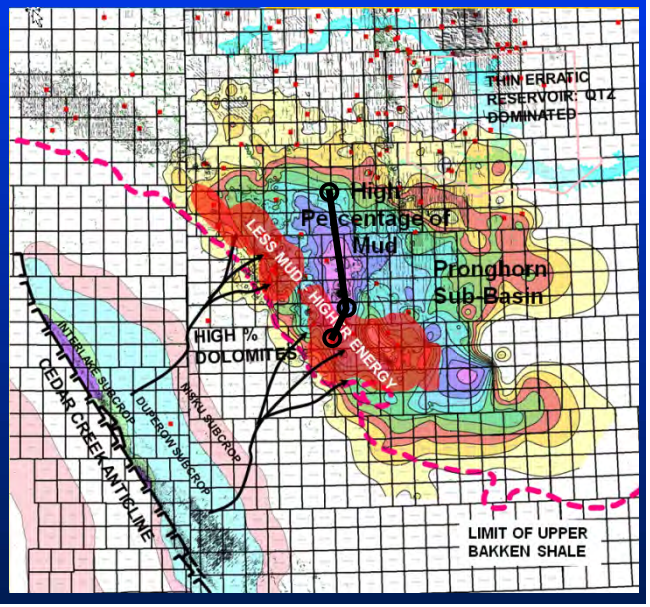
- What is typically thought of as a well behaved and simple correlation scheme between Three Forks and Middle Bakken is anything but!
- Regional mapping tied to core control is essential to recognizing what units should be expected
- In the case of the Pronghorn member, the intrigue of seeing an unexpected zone helped lay the bread crumbs leading to a new productive area

WHITING

DRS Federal 24-24TFH

GEOLOGY MATTERS!





IP: 2898 BOEPD

Other Operator Nearest Hz well IP: 276 BOEPD

THANK YOU!