Examination of the Tyler Formation's (Pennsylvanian) Exploration and Development History using Current Source Rock and Reservoir Maps*

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Search and Discovery Article #20265 (2014)**
Posted August 25, 2014

*Adapted from oral presentation given at AAPG Rocky Mountain Section Meeting, Denver, CO, July 20-22, 2014

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Abstract

The Tyler Formation contains two separate petroleum systems: a northern, basin-centered petroleum system that contains organic-rich marine shale within the Lower Tyler section, and a southern petroleum system containing organic-rich limestone beds in the Upper Tyler. The southern petroleum system has yielded >99% of Tyler production to date with a 60 year history of exploration and development along the southern margins of the Williston Basin (southwestern North Dakota). Exploratory drilling has recently been initiated to test the southern Tyler petroleum system's potential as a resource play. Reexamining the previous 60 years of Tyler activity with current geologic maps and information regarding source rocks and conventional reservoirs will provide insight into current and future exploration efforts.

Production began from the Tyler in 1954 with Amerada-Northern Pacific Railway's Dan Cheadle Unit #1 located in southern Billings County, southwestern North Dakota. Since the Dan Cheadle discovery, over 85 million barrels (BBLS) of oil have been produced from the Tyler Formation from 298 productive wells to date. Most of the productive Tyler wells have been vertical with a handful of horizontal completions. Based on productive wells drilled, the peak years of Tyler activity occurred during 1964-1975 when 117 successful Tyler wells were drilled (approximately one new productive well per month). Peak production occurred during the middle 1960's through the late 1970's when Tyler production totaled between 200 and 300 MBO per month. Water injection began in the early 1970's for enhance oil recovery and to date has injected ~228 million BBLS water into Tyler reservoirs versus 143 million BBLS of recovered water. Since the end of 1997, Tyler production has steadily decreased with only 20 additional productive wells being drilled and completed.

Most of the Tyler production to date has come from a series of bar-type sandstone bodies that trend approximately east-west and are collectively referred to as the Dickinson-Fryburg trend. Most of these sandstone bodies form isolated, oil-saturated porosity pods. Interpreted as either barrier and/or back-barrier sandstones deposited along shore, productive pay sandstone usually displays 10-20% porosity with permeability values of several hundred millidarcies. Organic-rich, argillaceous limestone beds overlay, as well as sometimes underlay, these

productive sandstone reservoir bodies and have locally sourced Tyler hydrocarbons. Changes in the quantity and quality of Tyler source rocks across the Dickinson-Fryburg trend controls the amount of hydrocarbon charge within these isolated sandstone reservoirs. In areas where there is high source rock to reservoir ratio, fluid overpressure (pre-production) is often present and production yields oil with low water cuts (prior to water injection).

References Cited

Barwis, J.H., 1990, Flood-Tidal Delta Reservoirs, Medora-Dickinson Trend, North Dakota, *in* J.H. Barwis and others, eds., Sandstone Petroleum Reservoirs: New York, Springer-Verlag, p. 389-412.

Maughan, E.K., 1984, Paleogeographic setting of Pennsylvanian Tyler Formation and relation to underlying Mississippian rocks in Montana and North Dakota: AAPG Bulletin, v. 68, p. 178-195.

Nesheim, T.O., and S.H. Nordeng, 2014, Core Based Examination of Upper Tyler Formation Source Rocks within Southwestern North Dakota: North Dakota Geological Survey, Geologic Investigation No. 173, 28 p.

Sturm, S.D., 1983, Depositional Environments and Sandstone Diagenesis in the Tyler Formation (Pennsylvanian), Southwestern North Dakota: North Dakota Geological Survey, Report of Investigation No. 76, 48 p.

Passey, Q.R., S. Creaney, J.B. Kulla, F.J. Moretti, and J.D. Stroud, 1990, A practical model for organic richness from porosity and resistivity logs: AAPG Bulletin, v. 74, p. 1777-1794.

Sturm, S.D., 1987, Depositional History and Cyclity in the Tyler Formation (Pennslyvanian), Southwestern North Dakota, M.W. Longman, ed.: Rocky Mountain Association of Geologists Symposium, Williston Basin Anatomy of a Cratonic Oil Province, p. 209-221.

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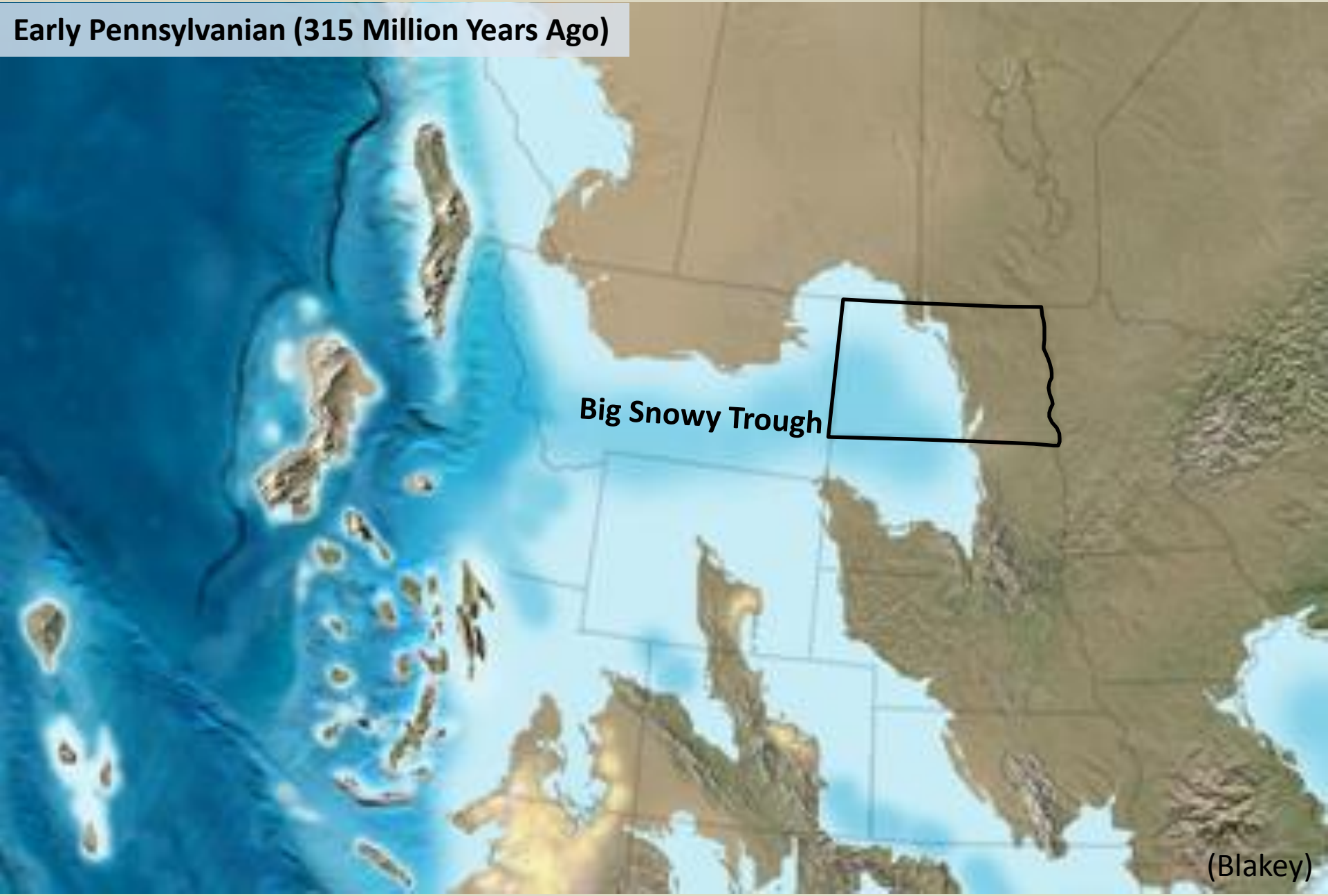
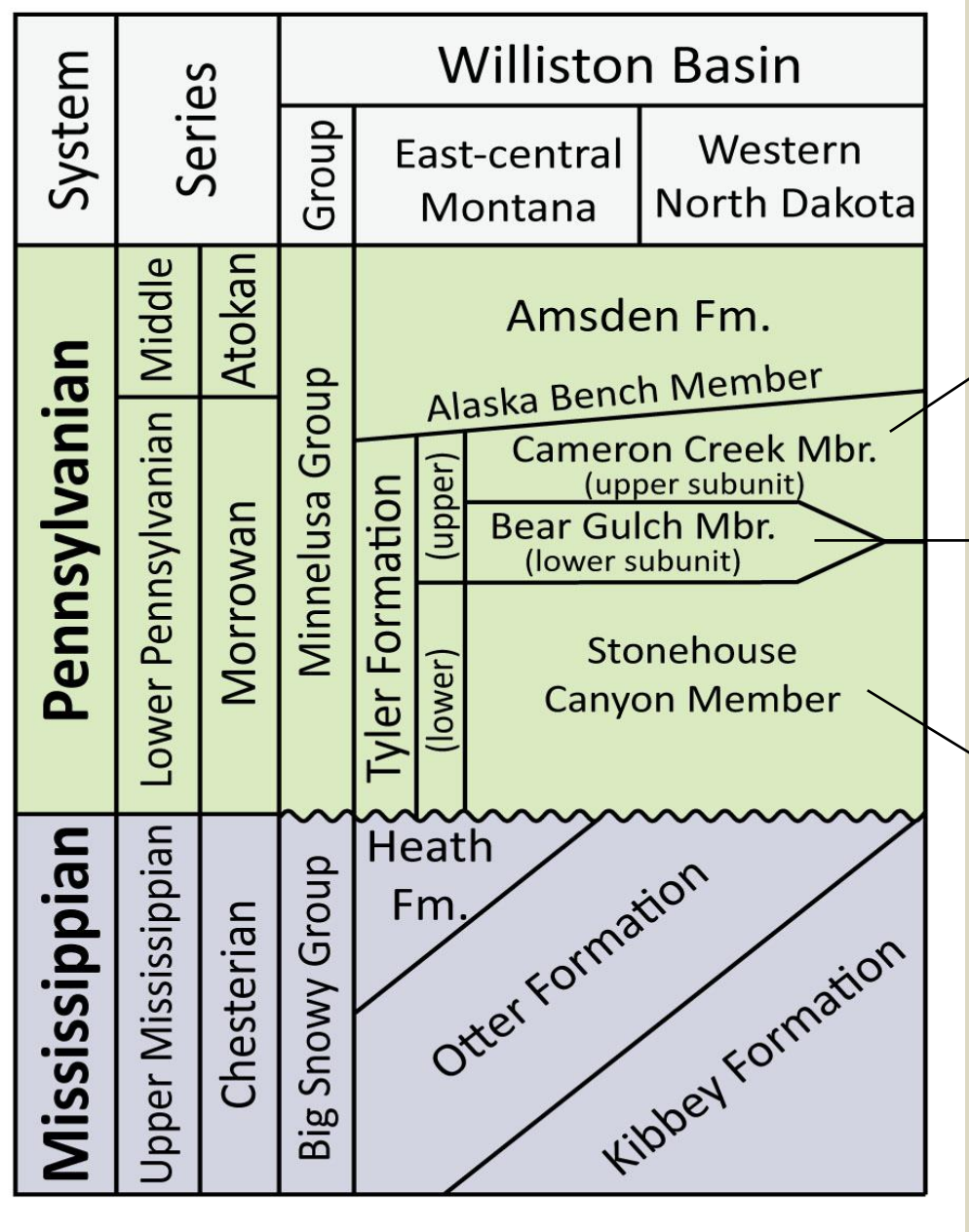
*North Dakota Geological Survey

Depositional Setting



Stratigraphy



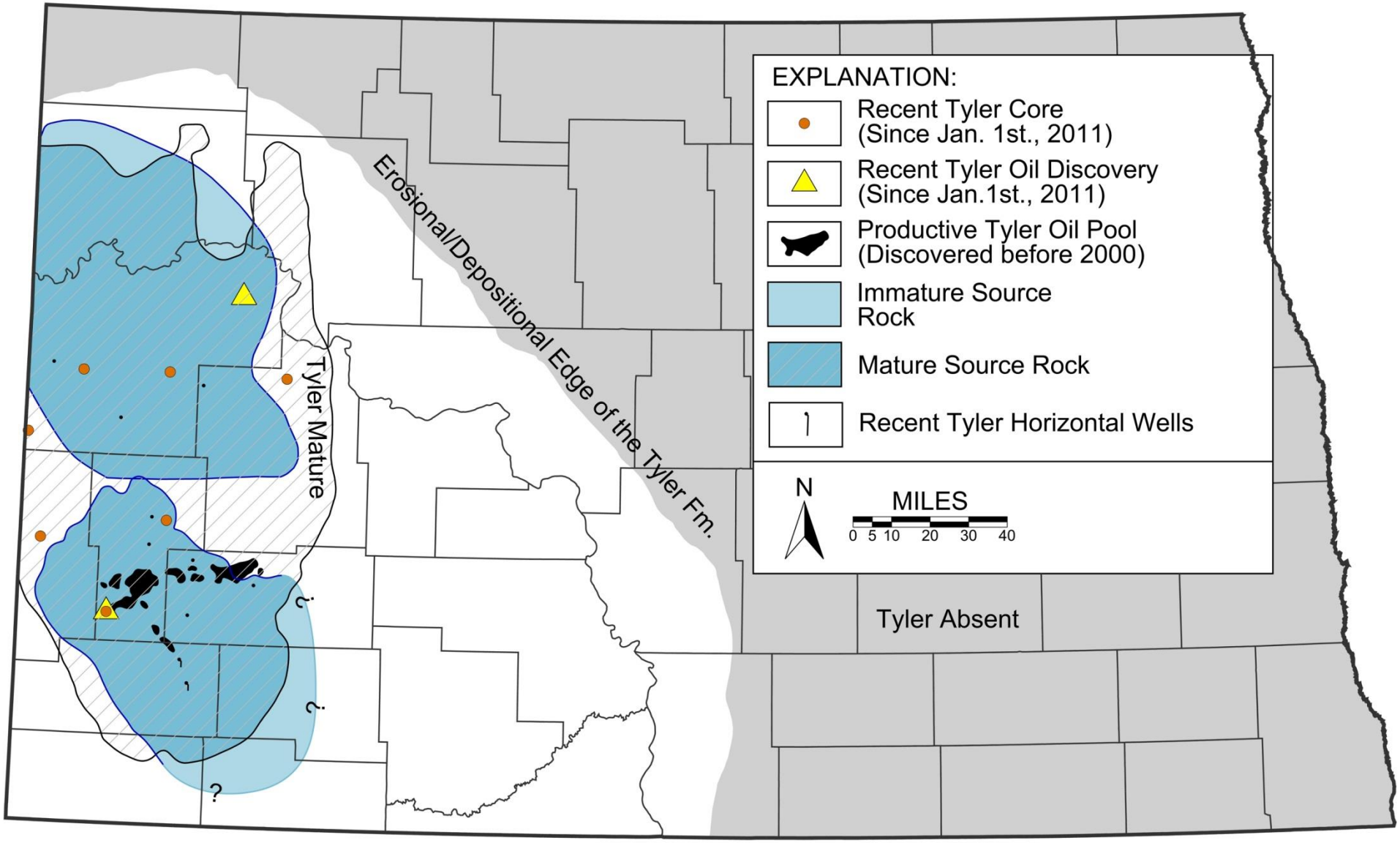
Cameron Creek Member:
Grey to red to varicolored carbonate and clay mudstone

Bear Gulch Member:
Interbedded grey to black shale and limestone, localized sandstone near base

Stonehouse Canyon Member:
Vari-colored to dark-grey shale/mudstone and yellowish gray to light grey sandstone, occasional carbonate beds

(Maughan, 1984; Sturm, 1983; 1987)

Source Beds

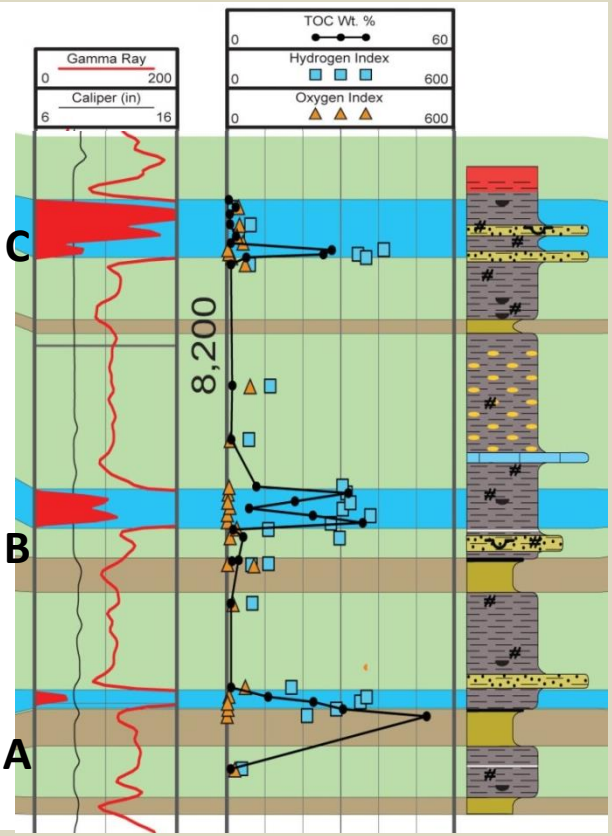


Two sets of source rock -> differentiated 1) spatially, 2) stratigraphically, 3) geochemically, and 4) lithologically

North vs. South Conclusions:

Log Signature

Northern Petroleum System

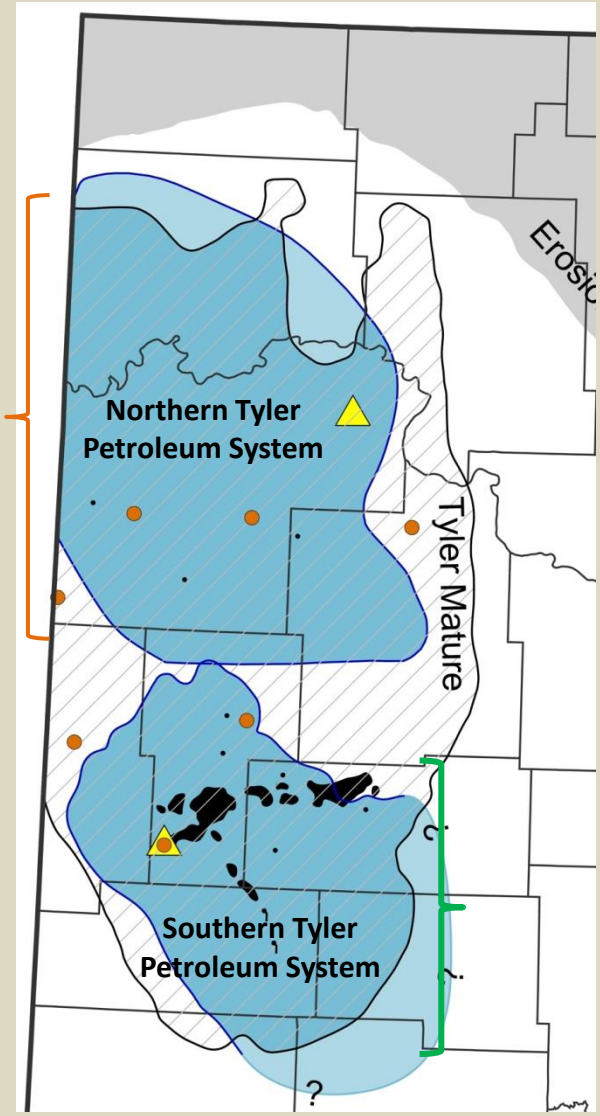


Organic-rich marine shale

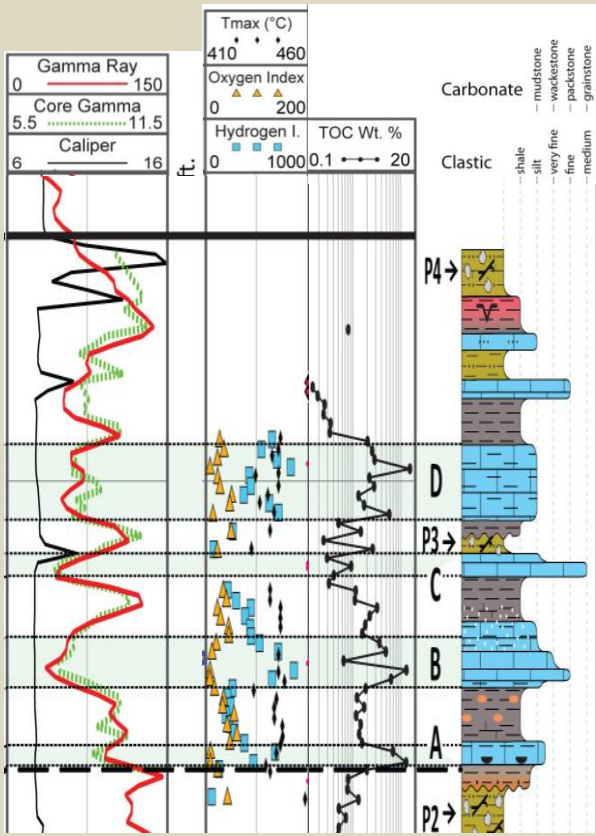
~20% TOC average w/ ~65 mg/g S2

High gamma ray signature

~10 ft. net thickness



Southern Petroleum System



Organic-rich limestone

~6% TOC average w/ ~38 mg/g S2

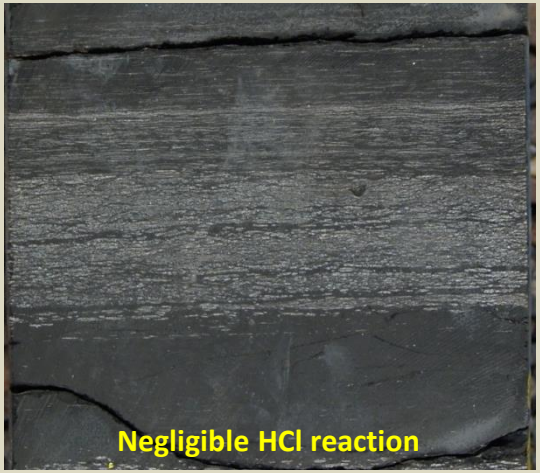
Very low gamma ray signature

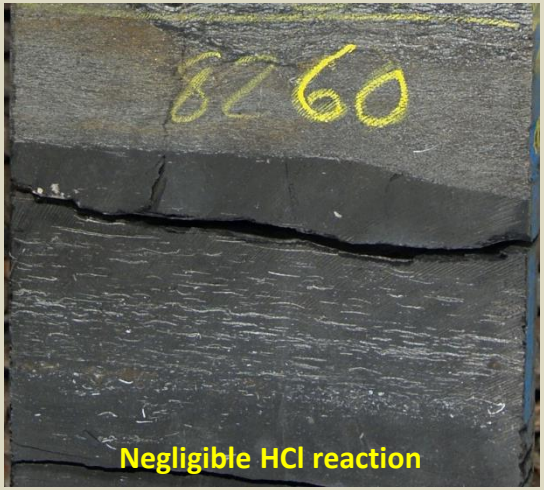
10-15 ft. net thickness

North vs. South Conclusions:

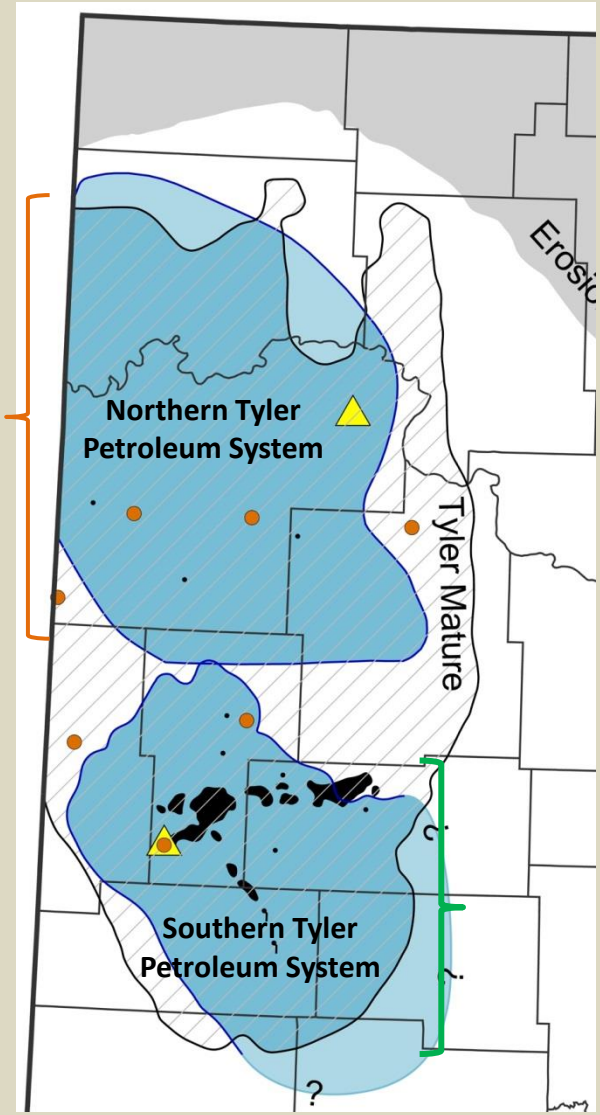
Primary Source Rock Lithology

Northern Petroleum System

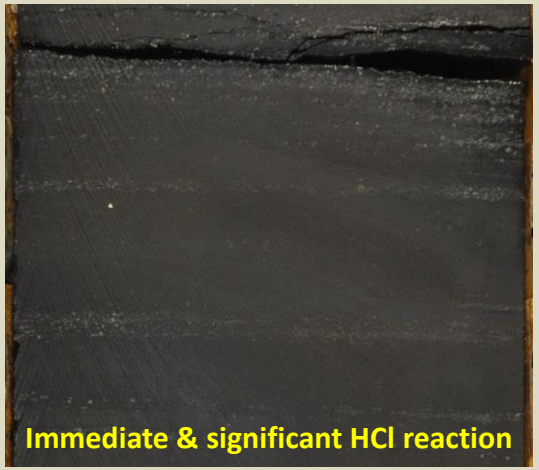




Organic-rich shale
(clay content?)



Southern Petroleum System



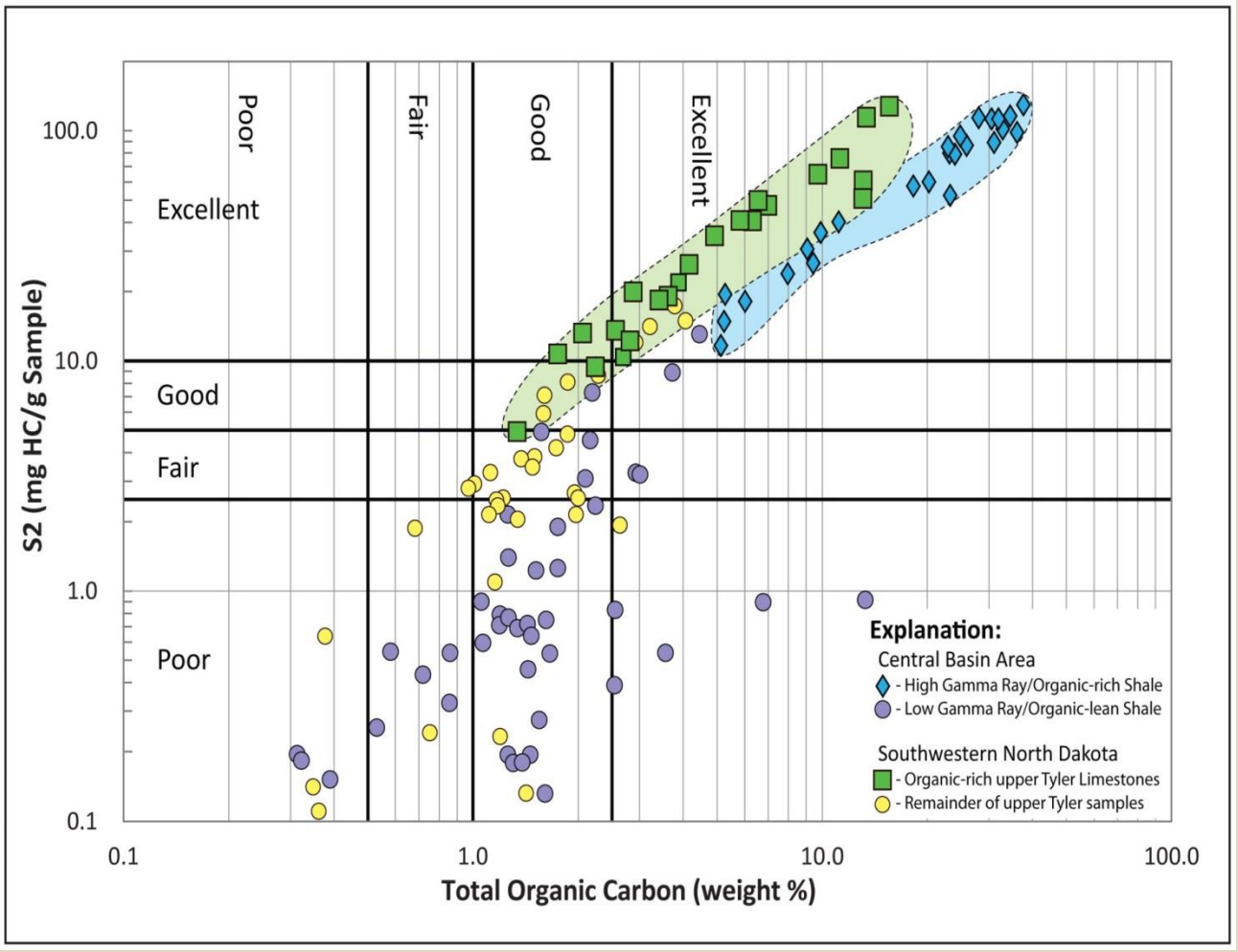
Organic-rich limestone
(abundant calcite content)

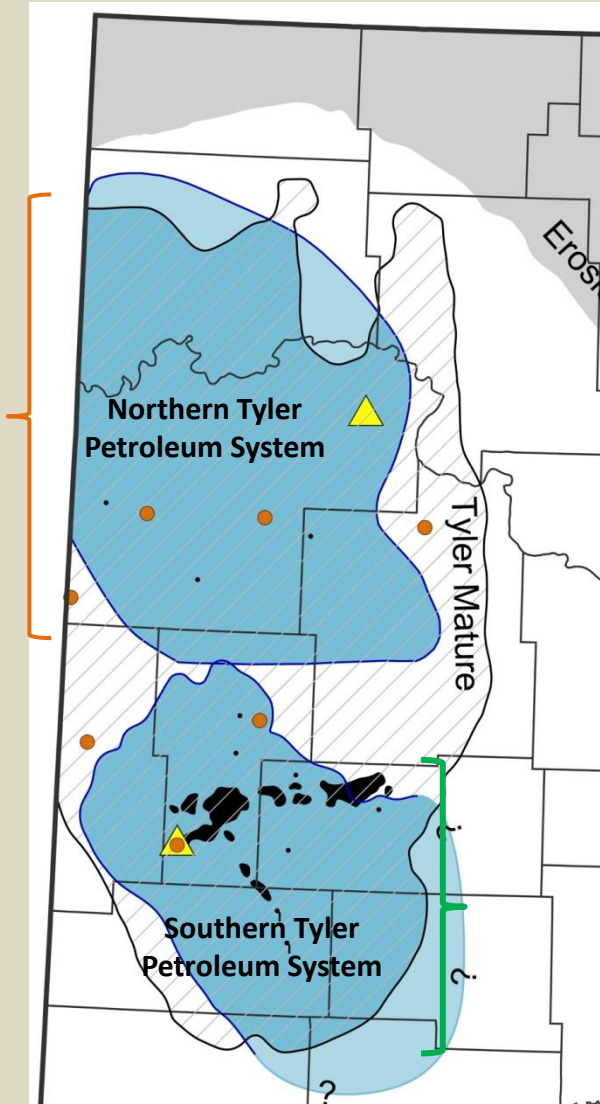
North vs. South Conclusions:

Primary Source Rock Organic-Richness

Northern Petroleum System
Avg: 20% TOC & 65 mg/g S2 (blue)

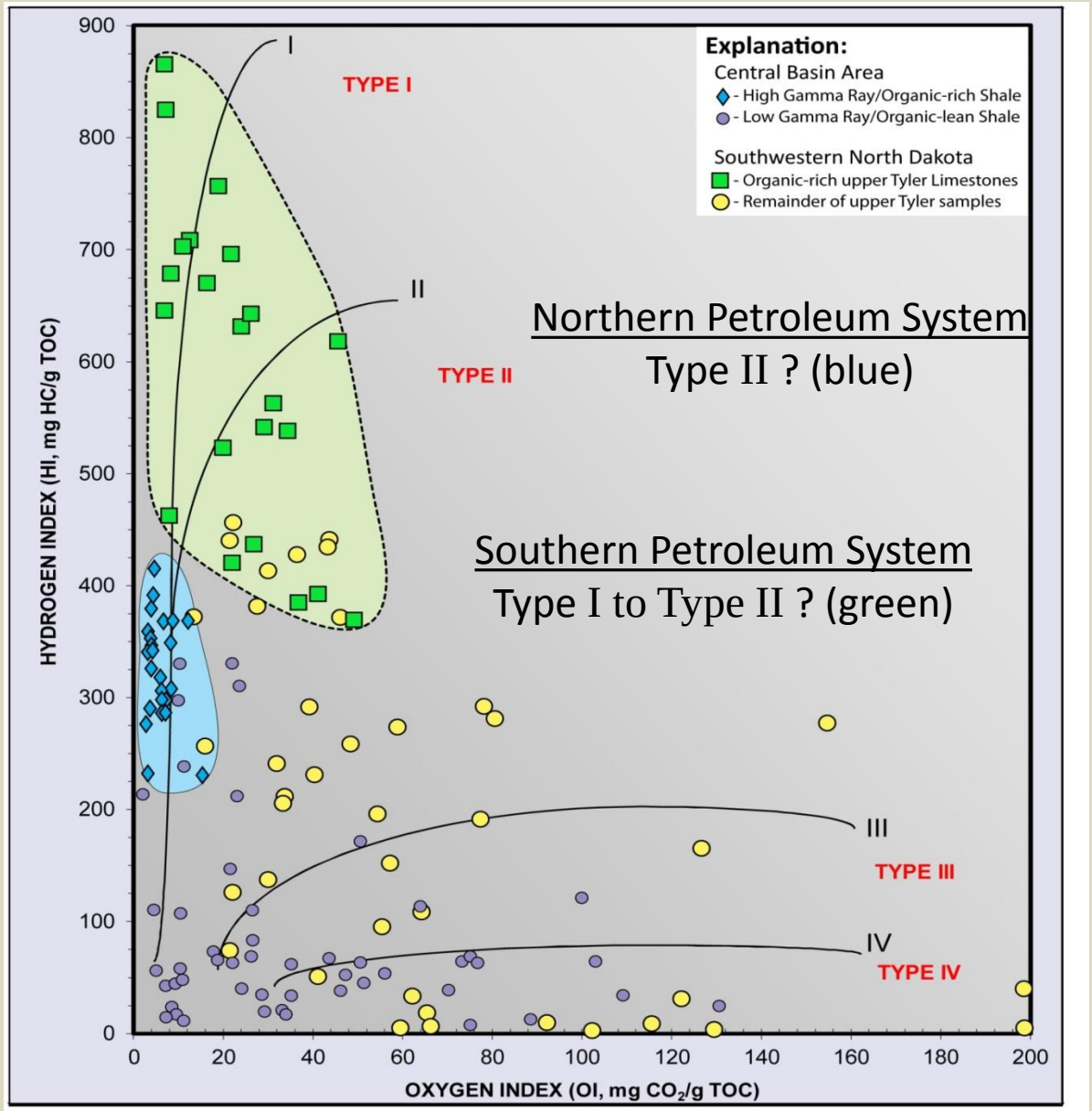
Southern Petroleum System
Avg: 6% TOC & 35 mg/g S2 (green)

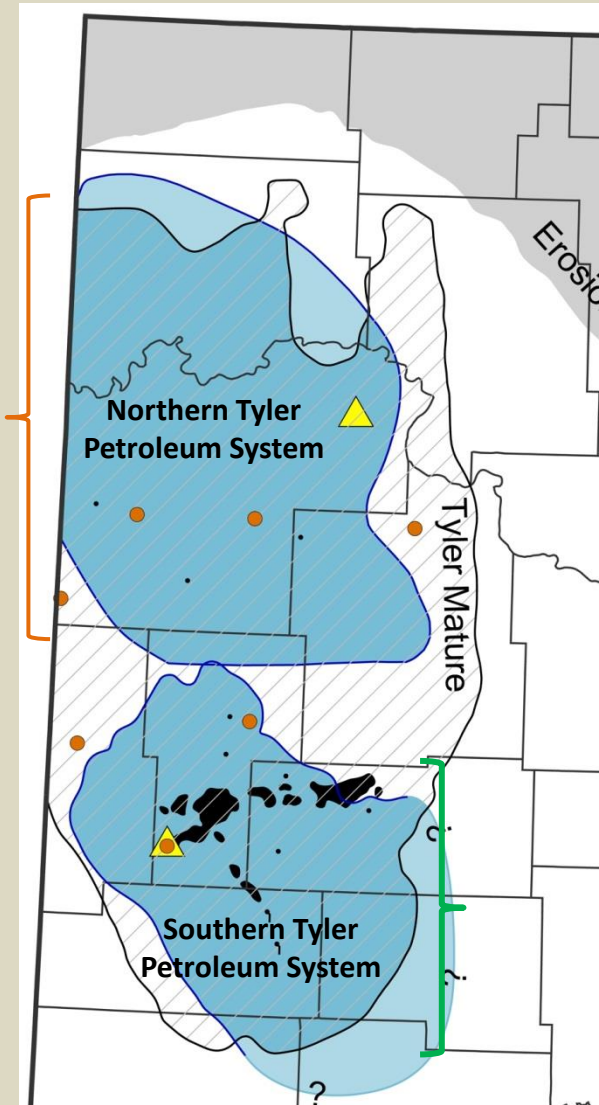




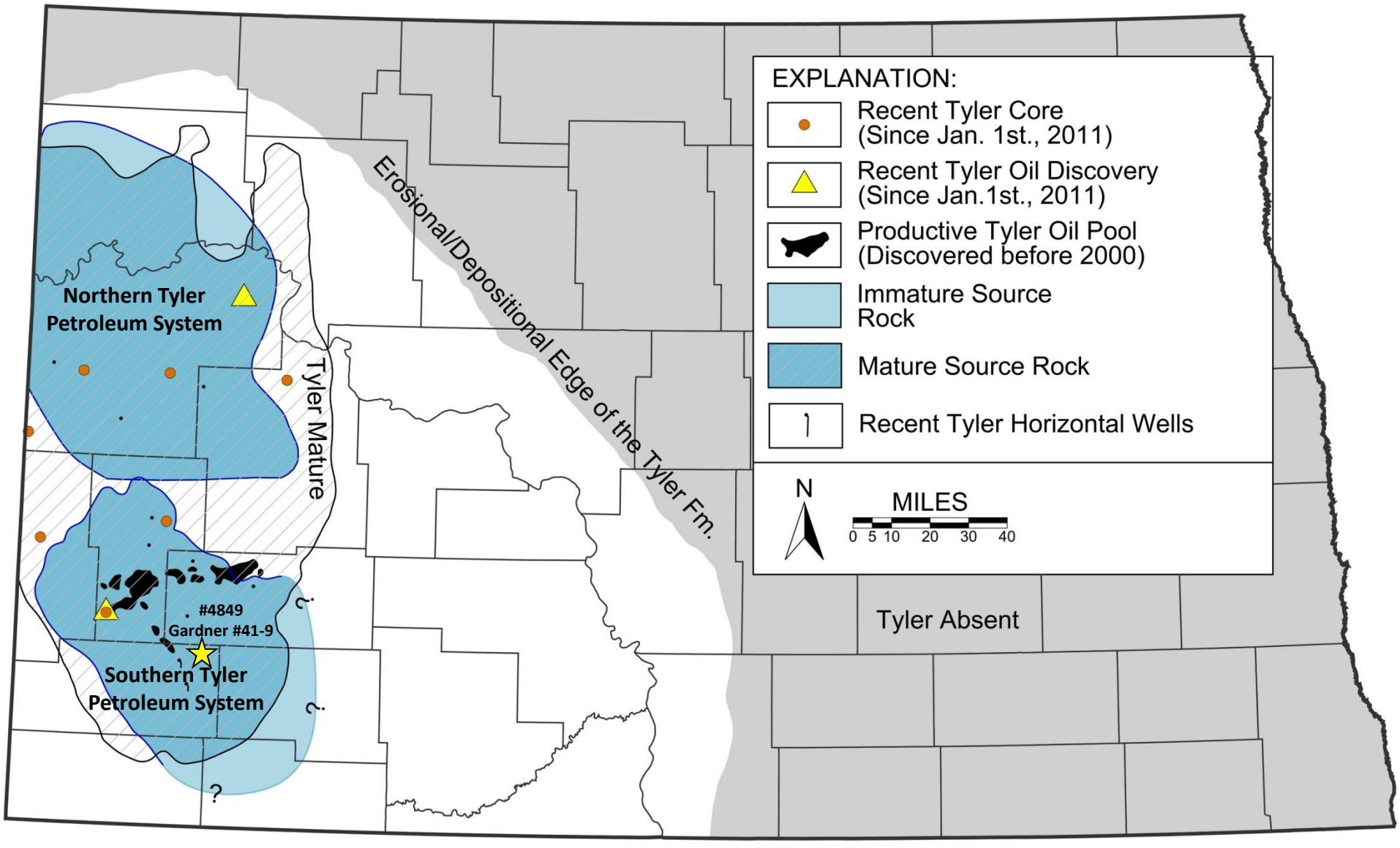
North vs. South Conclusions:

Primary Source Rock Kerogen Type

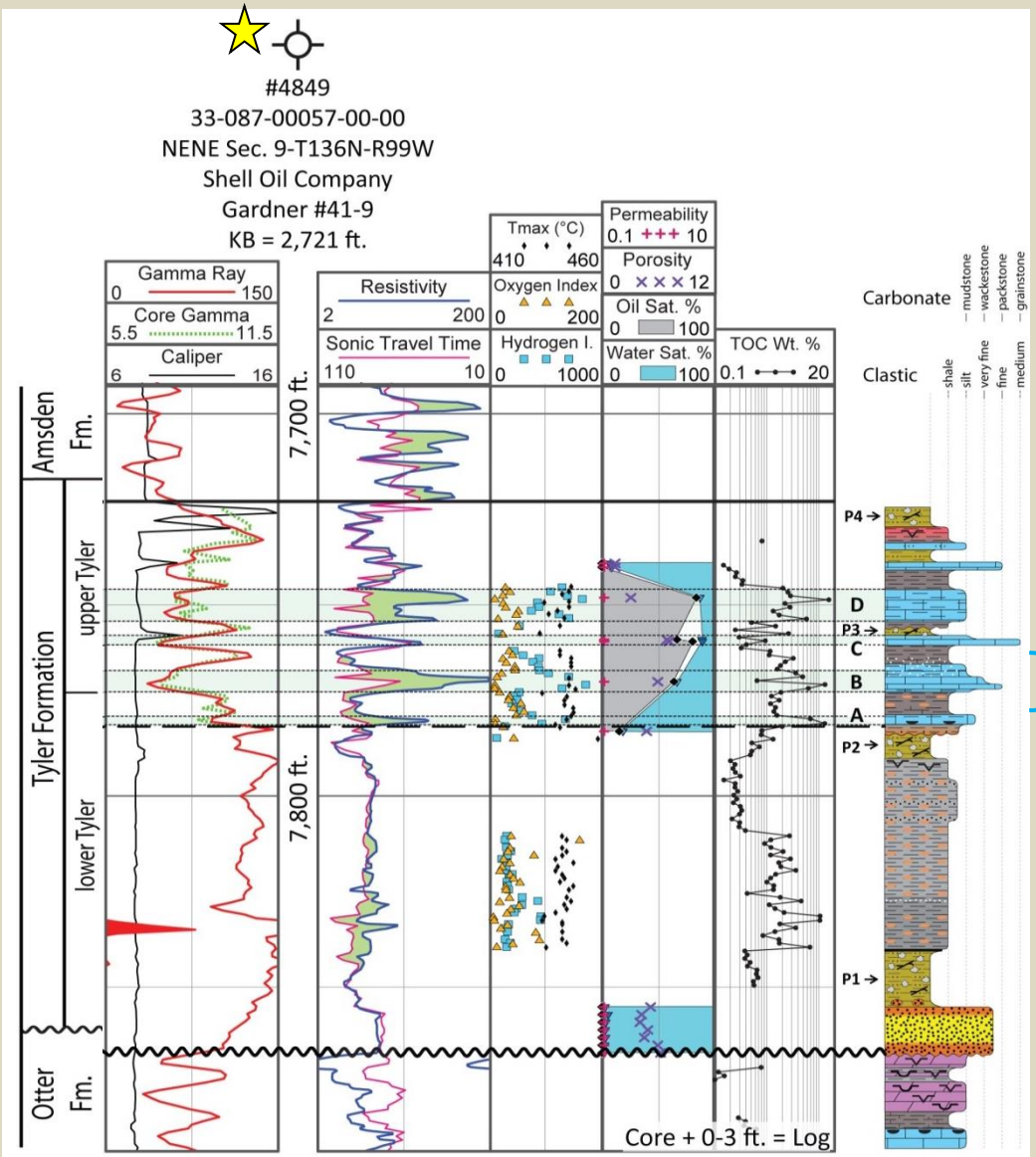




Source Beds

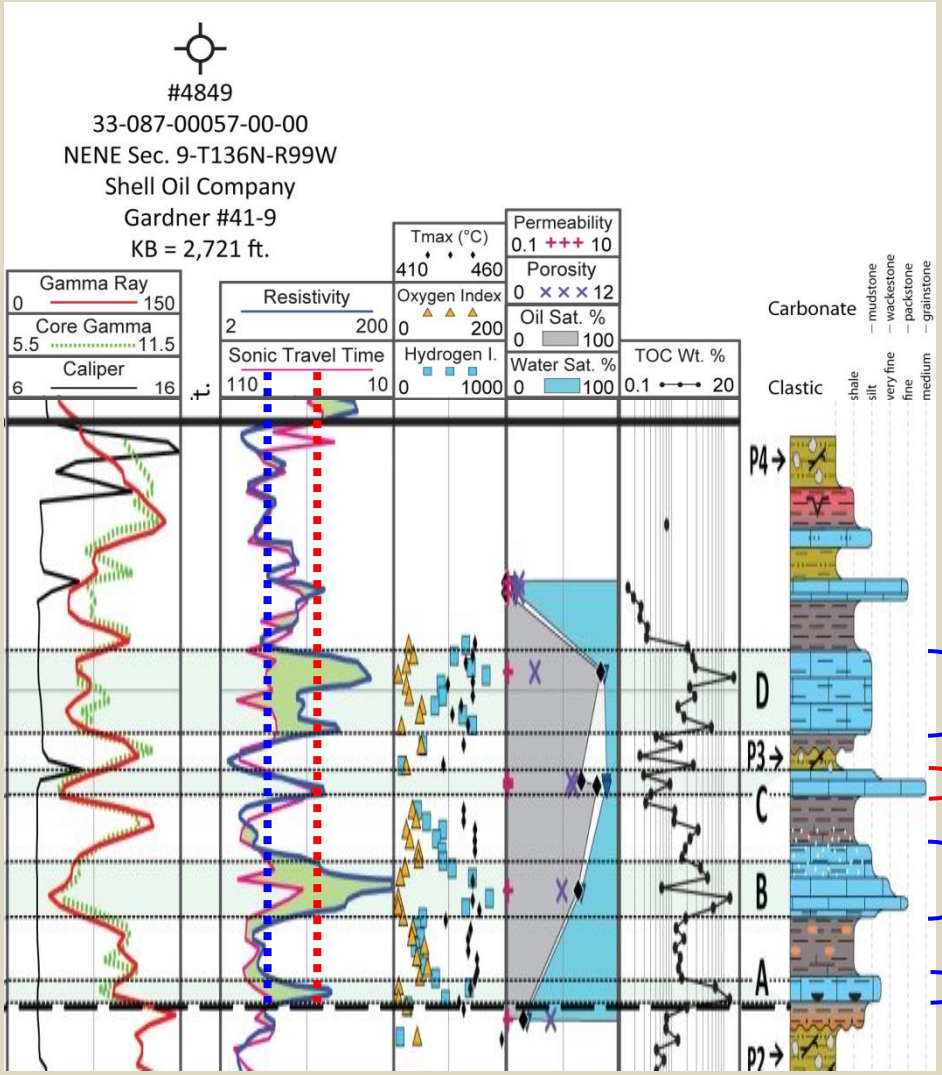

EXPLANATION:
Recent Tyler Core (Since Jan. 1st., 2011)
Recent Tyler Oil Discovery (Since Jan.1st., 2011)
Productive Tyler Oil Pool (Discovered before 2000)
Immature Source Rock
Mature Source Rock
Recent Tyler Horizontal Wells
N
MILES
0 5 10 20 30 40
Northern Tyler Petroleum System
Tyler Mature
Erosional/Depositional Edge of the Tyler Fm.
#4849 Gardner #41-9
Southern Tyler Petroleum System
Tyler Absent
?

Southern Tyler Petroleum System Source Beds



(Nesheim and Nordeng, 2014)

Southern Tyler Petroleum System Source Beds



Source Bed Summary
(Limestone Beds)
~16 ft. net thickness
TOC: 5.7 wt.%
S2: 38.1 mg/g
Tmax: 435-448°

*Interbedded shale is also moderately organic-rich in part (1-3% TOC, 3-10 mg/g S2)

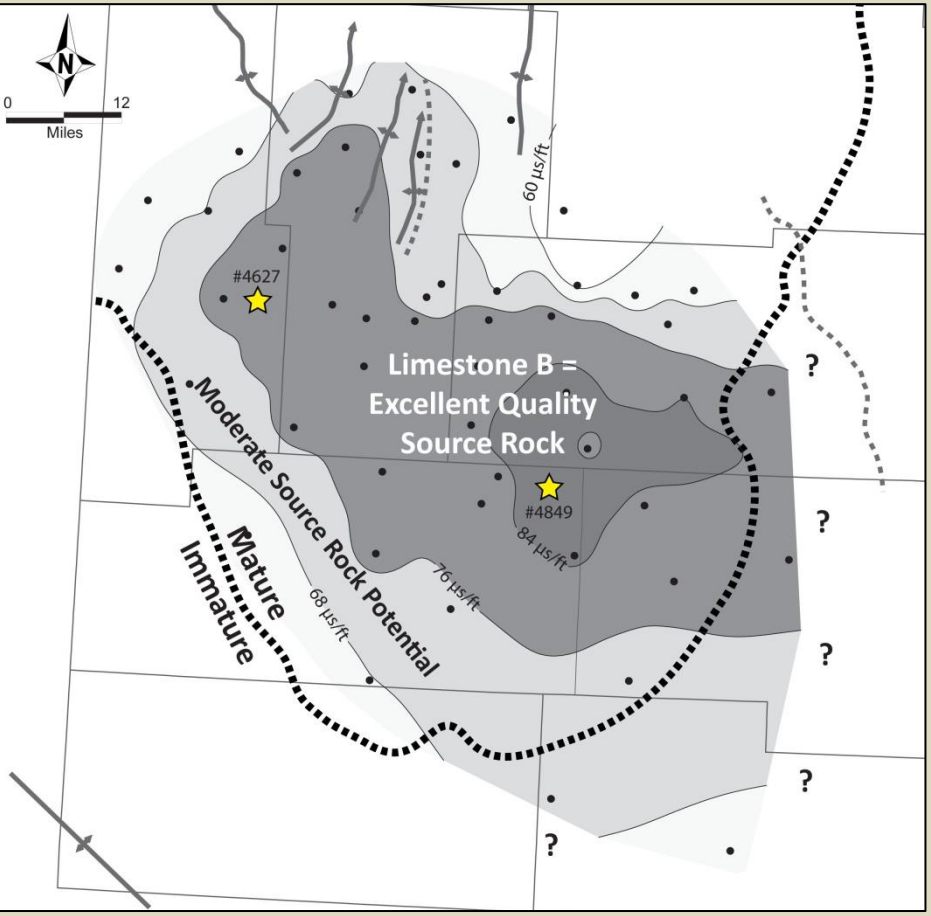
Sonic Travel Time ≈ Organic-Richness (Limestone)

≥75 µs/ft = excellent quality source bed
65-75 µs/ft = moderate quality source bed (?)
≤65 µs/ft = poor quality source bed

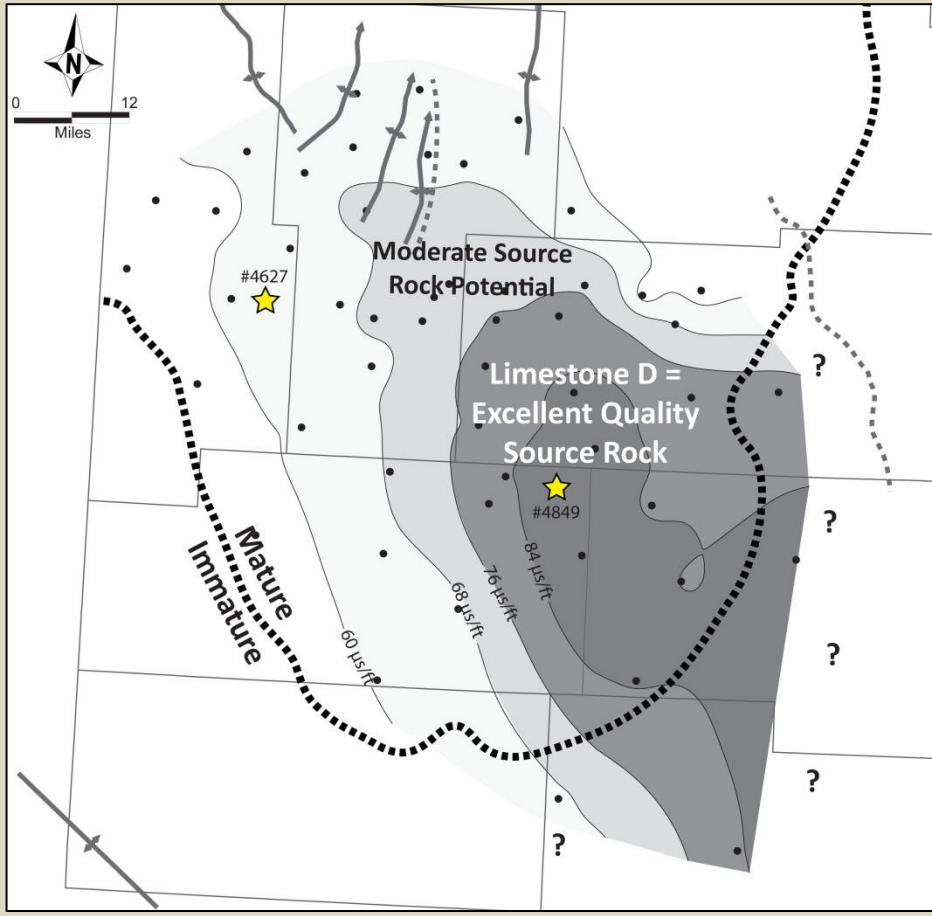
(Passey et al., 1990)

Southern Tyler Petroleum System Source Beds

Limestone B: Average Sonic Velocity



Limestone D: Average Sonic Velocity

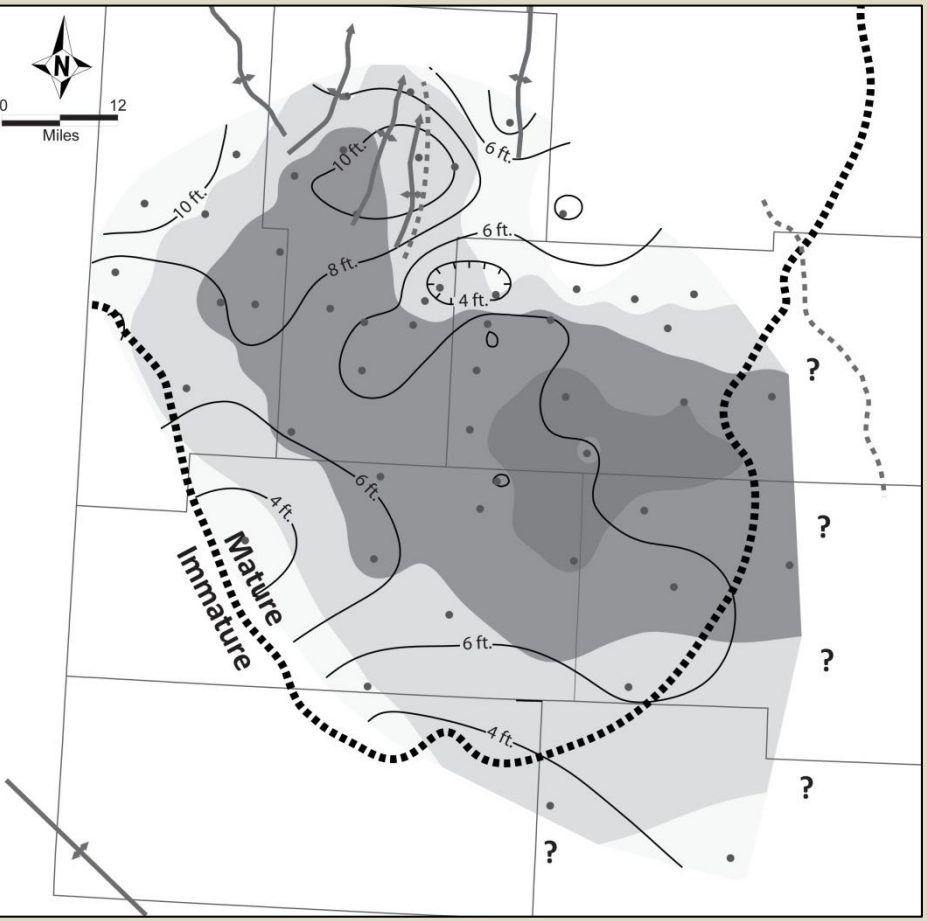


*Black dots represent control wells for sonic travel time mapping, yellow stars represent core control wells.

Limestone beds B and D transition from excellent quality, organic-rich source beds to organic-lean non-source beds moving laterally across the study area based on their average sonic travel time.

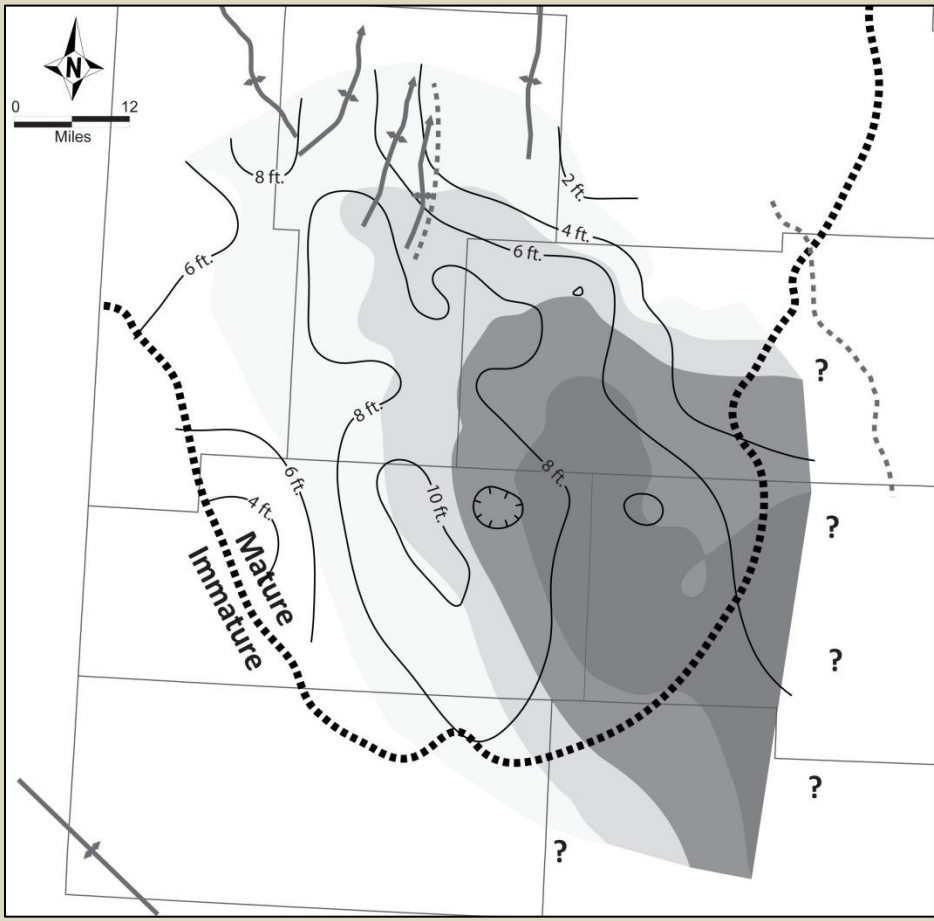
Southern Tyler Petroleum System Source Beds

Limestone B: Isopach Contours



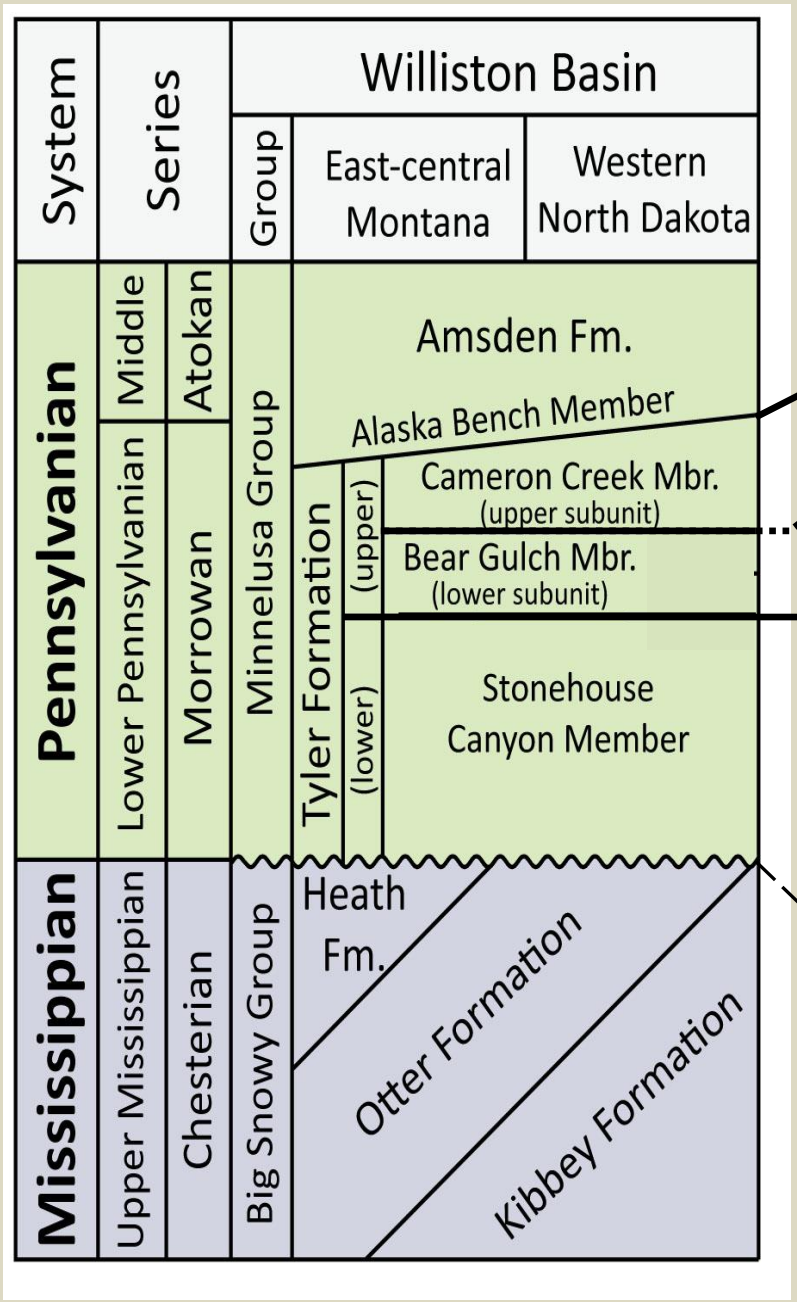
<4-10 ft. thick

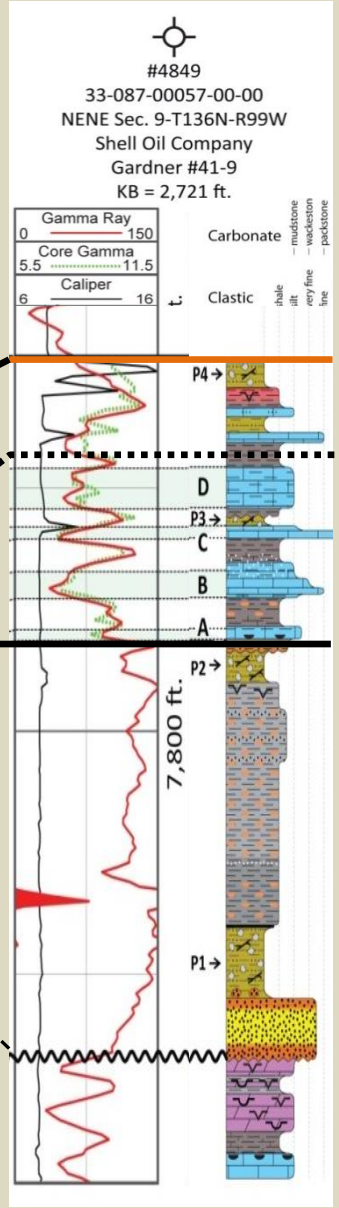
Limestone D: Isopach Contours



<2-10+ ft. thick

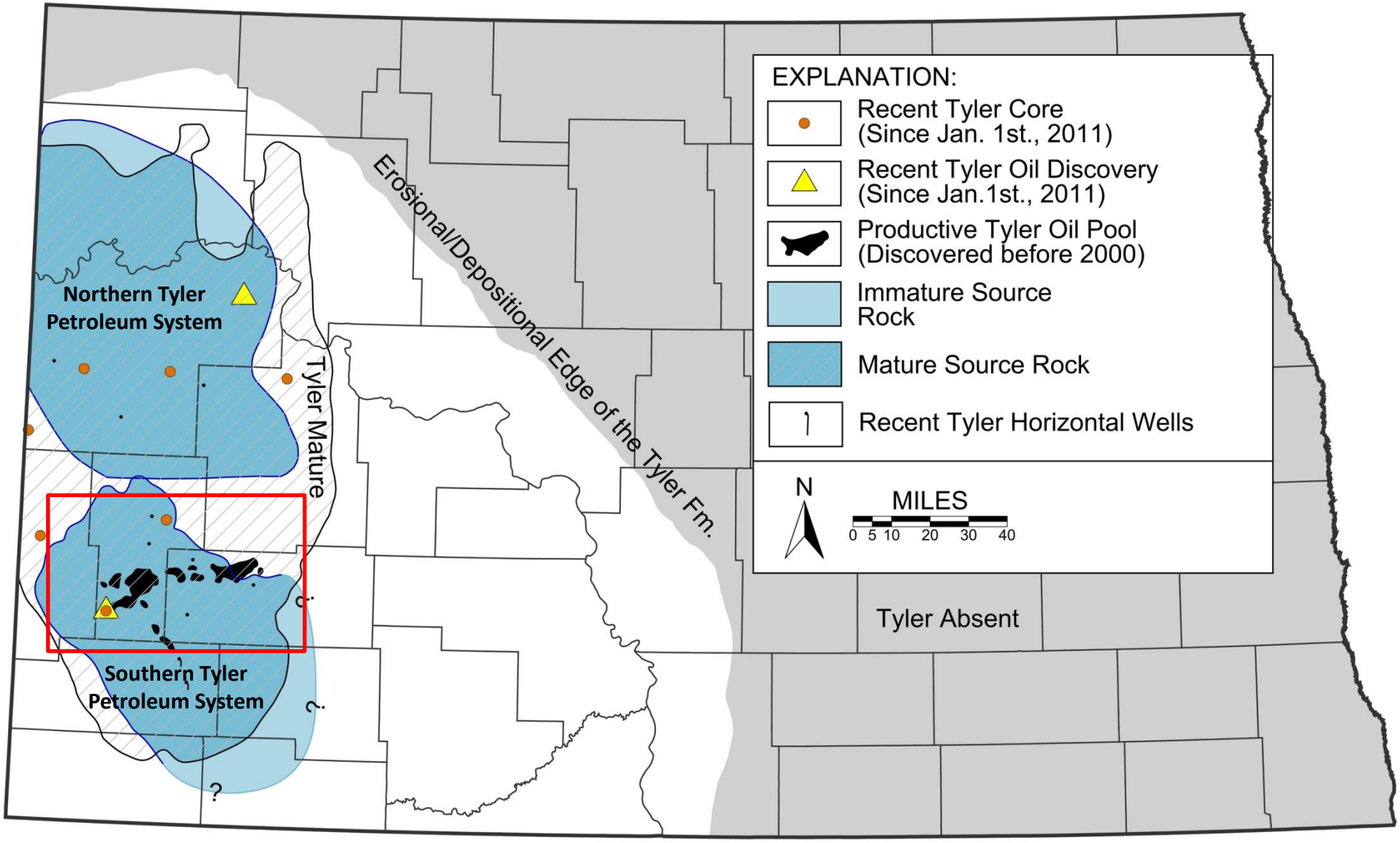
Limestone beds B and D are typically 6-8 ft. thick where they are organic-rich and thermally mature.





upper Tyler source beds located within the Bear Gulch Member.

Source Beds

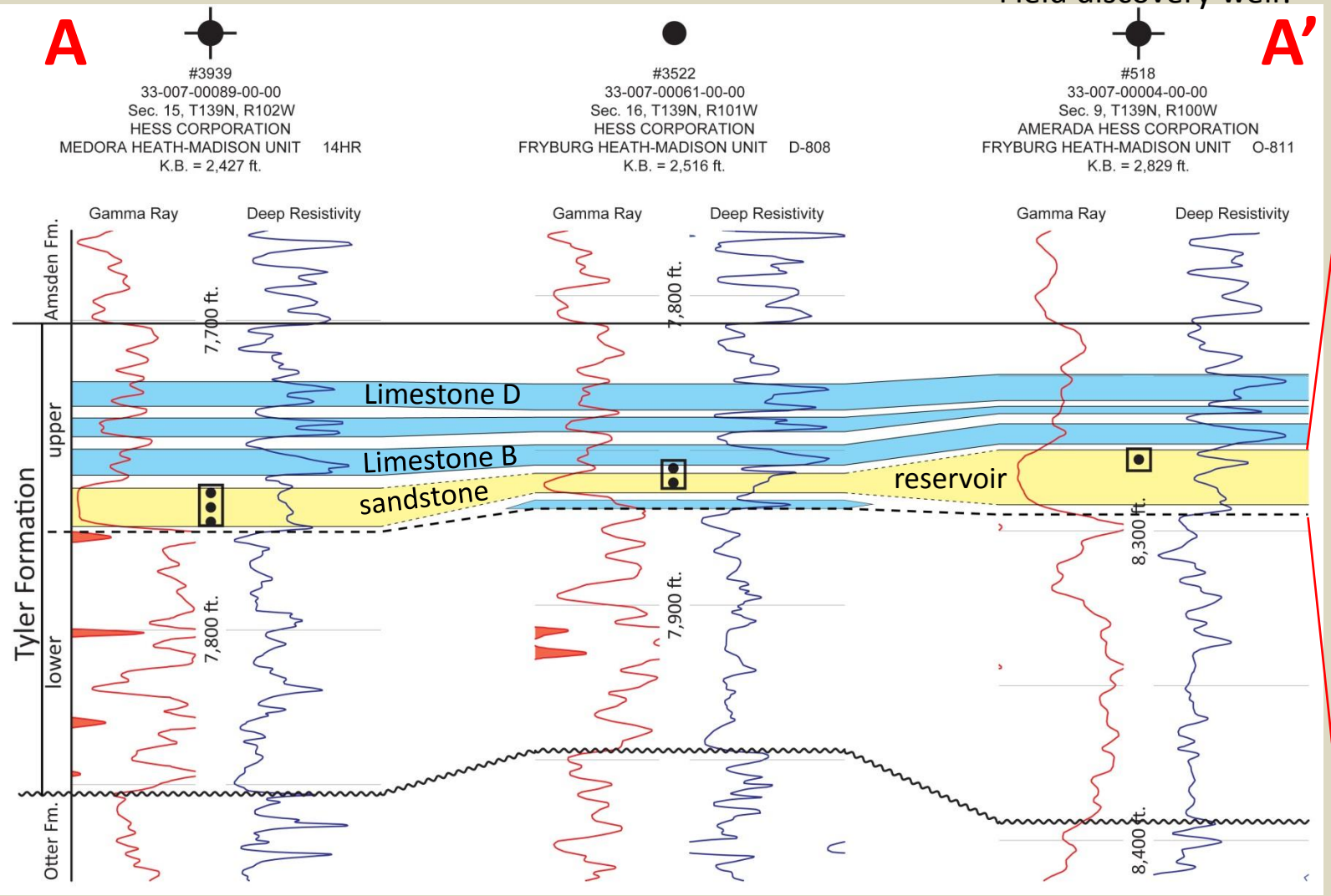


The remainder of this presentation will focus on the southern Tyler Petroleum System. All of the following maps will depict the red outlined area.

Southern Tyler Petroleum System Field Map

Southern Tyler Petroleum System: Reservoir
Medora-Fryburg Field Area

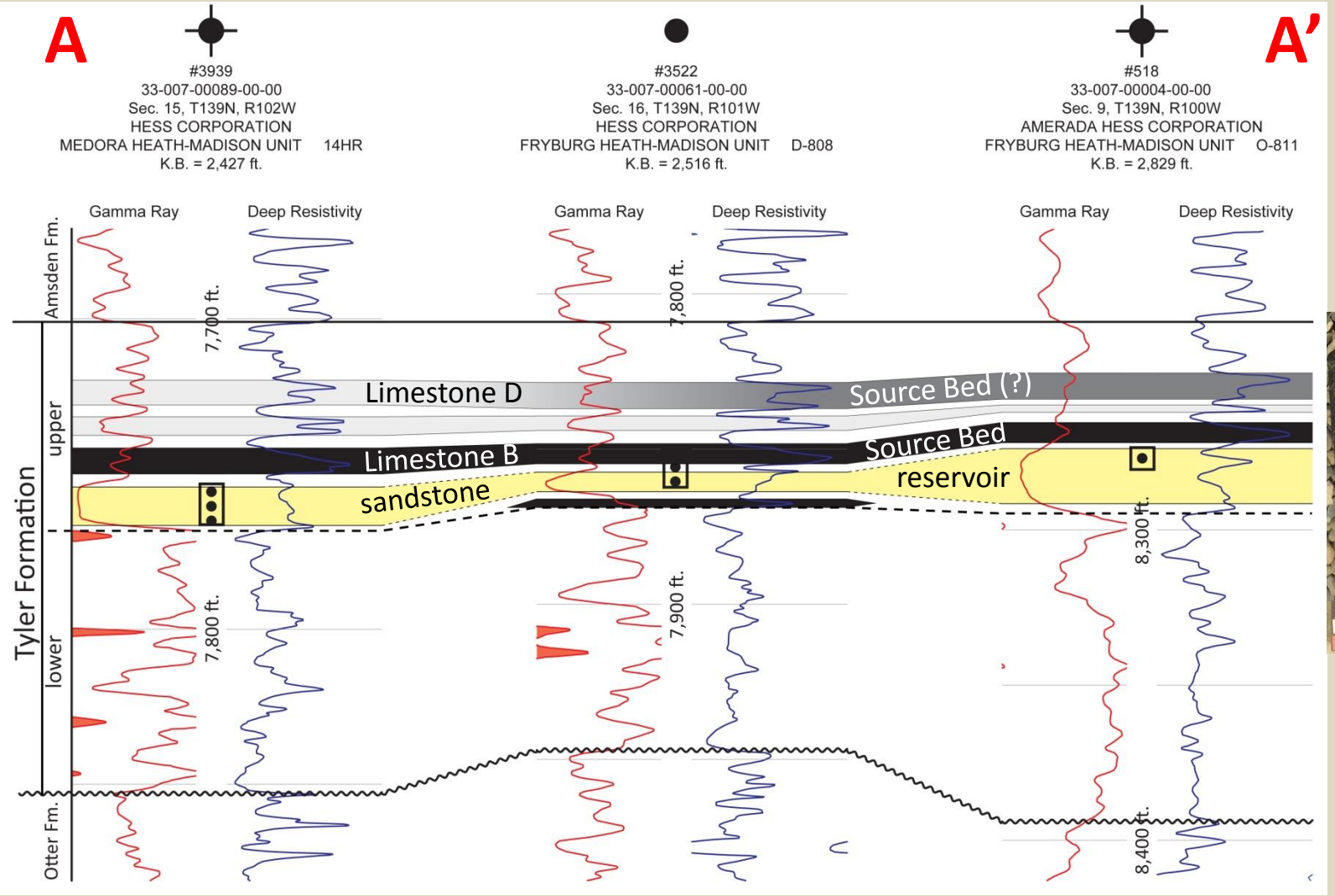
*Field discovery well!



pay sand - #3939

The Tyler Formation contains one oil productive sandstone interval within the Medora-Fryburg-Tracy Mountain Field area, which is stratigraphically located between Limestone A and B.

Southern Tyler Petroleum System: Reservoir
Medora-Fryburg Field Area



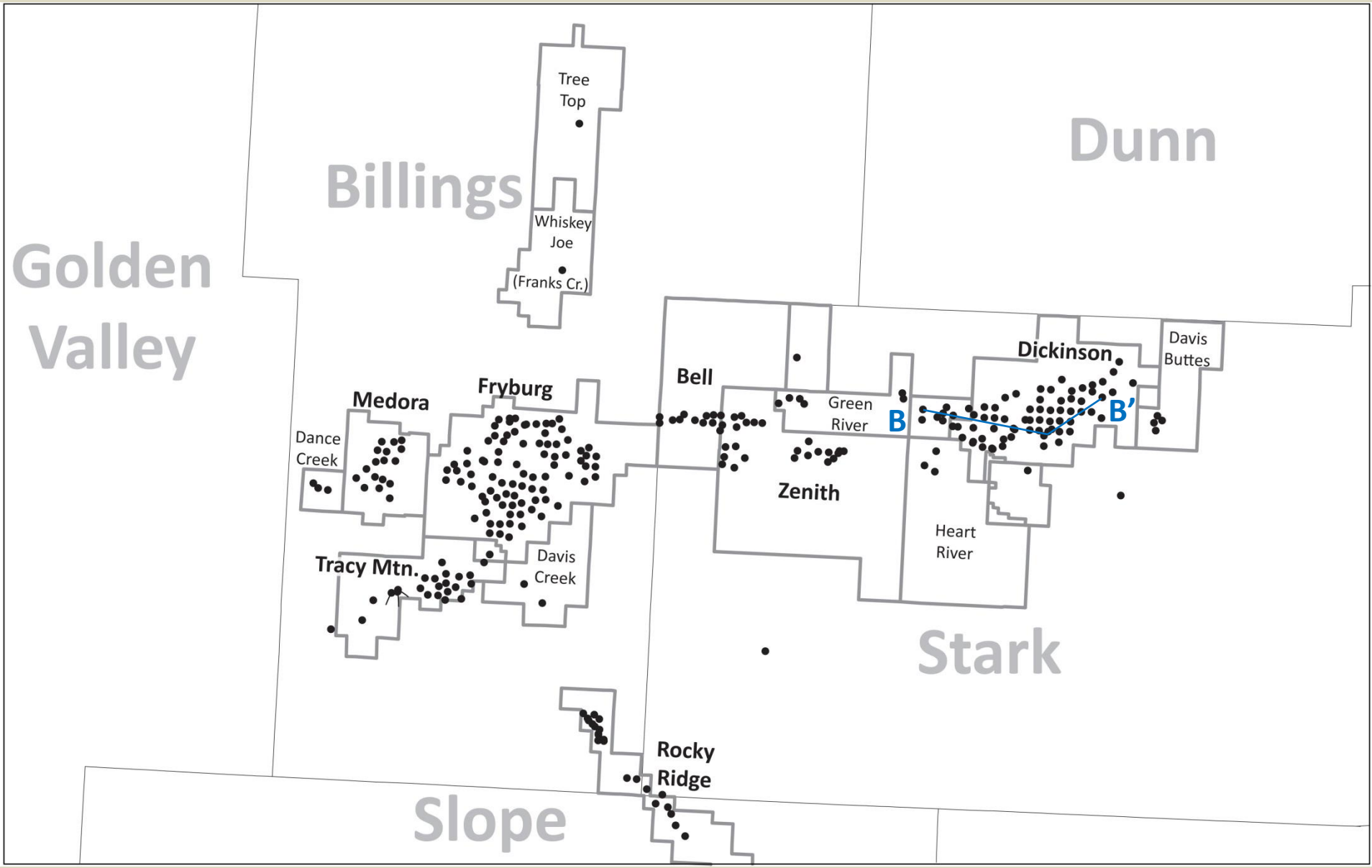
Limestone B - #3939

Source Rock Quality

- low
- moderate
- high

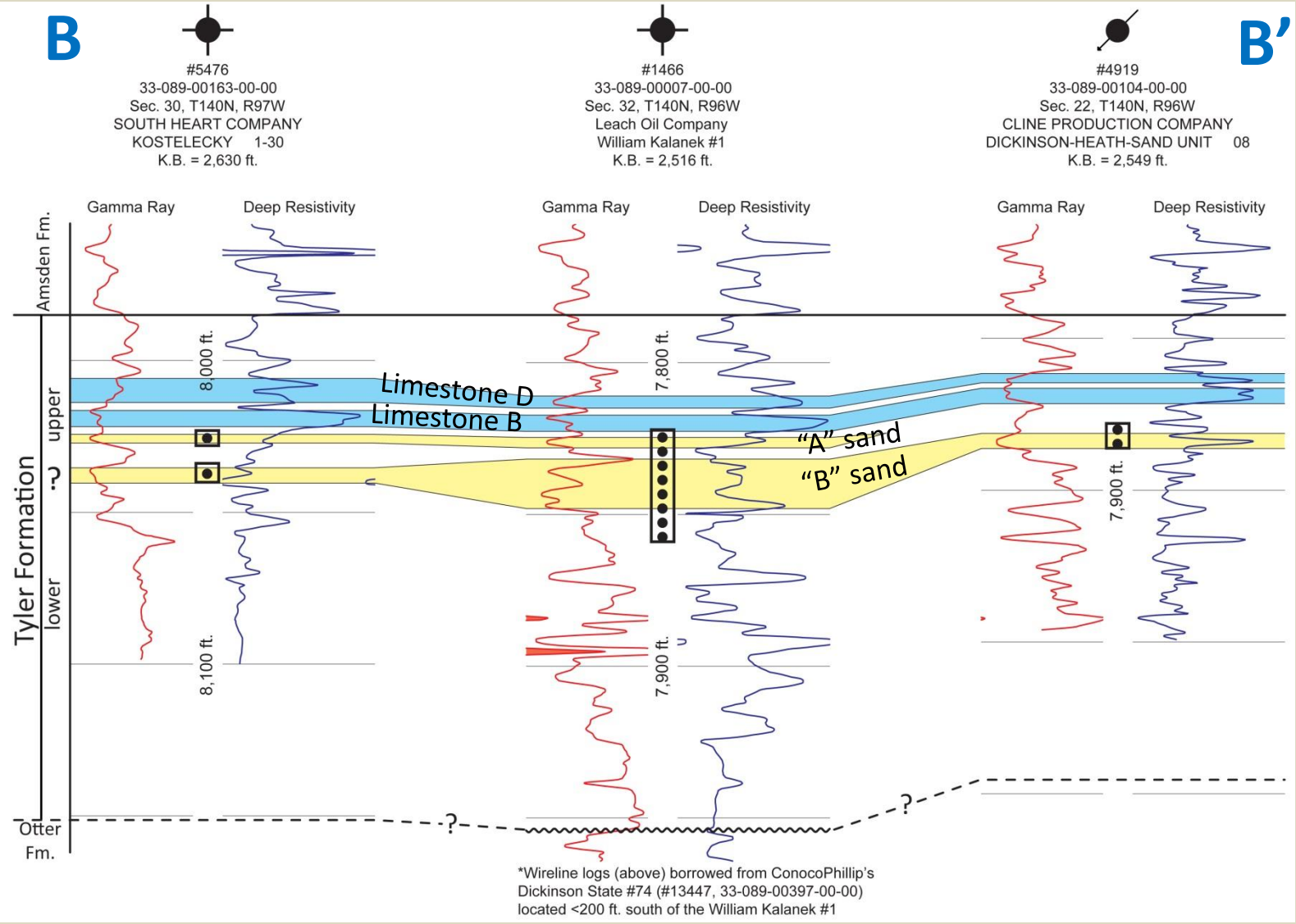
Limestone B, and A when present, appear to average as excellent quality source rock within the Medora-Fryburg Field area. Limestone D may transition from a moderate quality source rock in the east to a non-source rock in the west.

Southern Tyler Petroleum System: Reservoir



Southern Tyler Petroleum System: Reservoir

*Field discovery well!

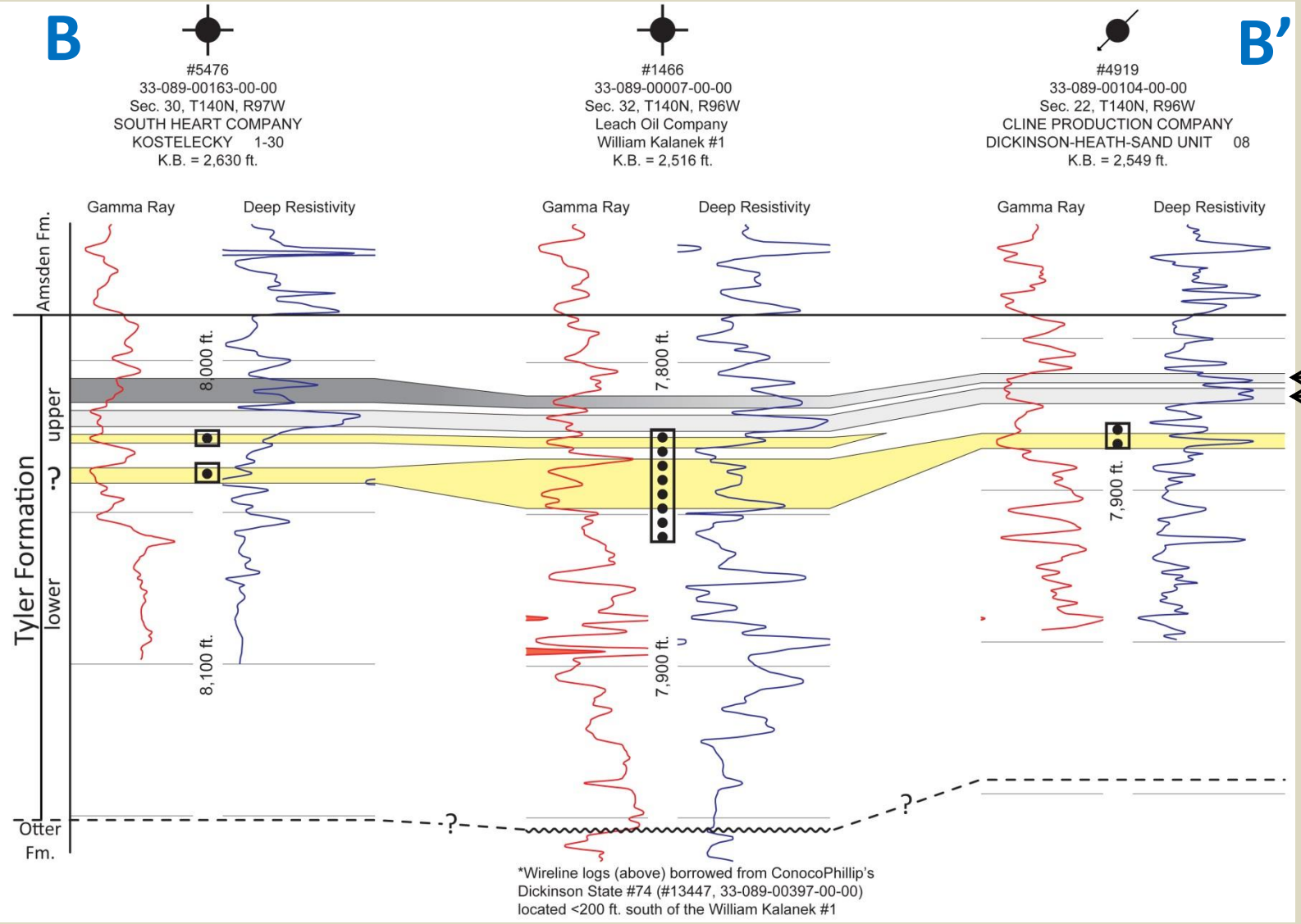


"A" Sand - #5476

"B" Sand - #5476

Within the Dickinson Field area, the Tyler Formation contains two sandstone intervals that are hydrocarbon (oil) productive.

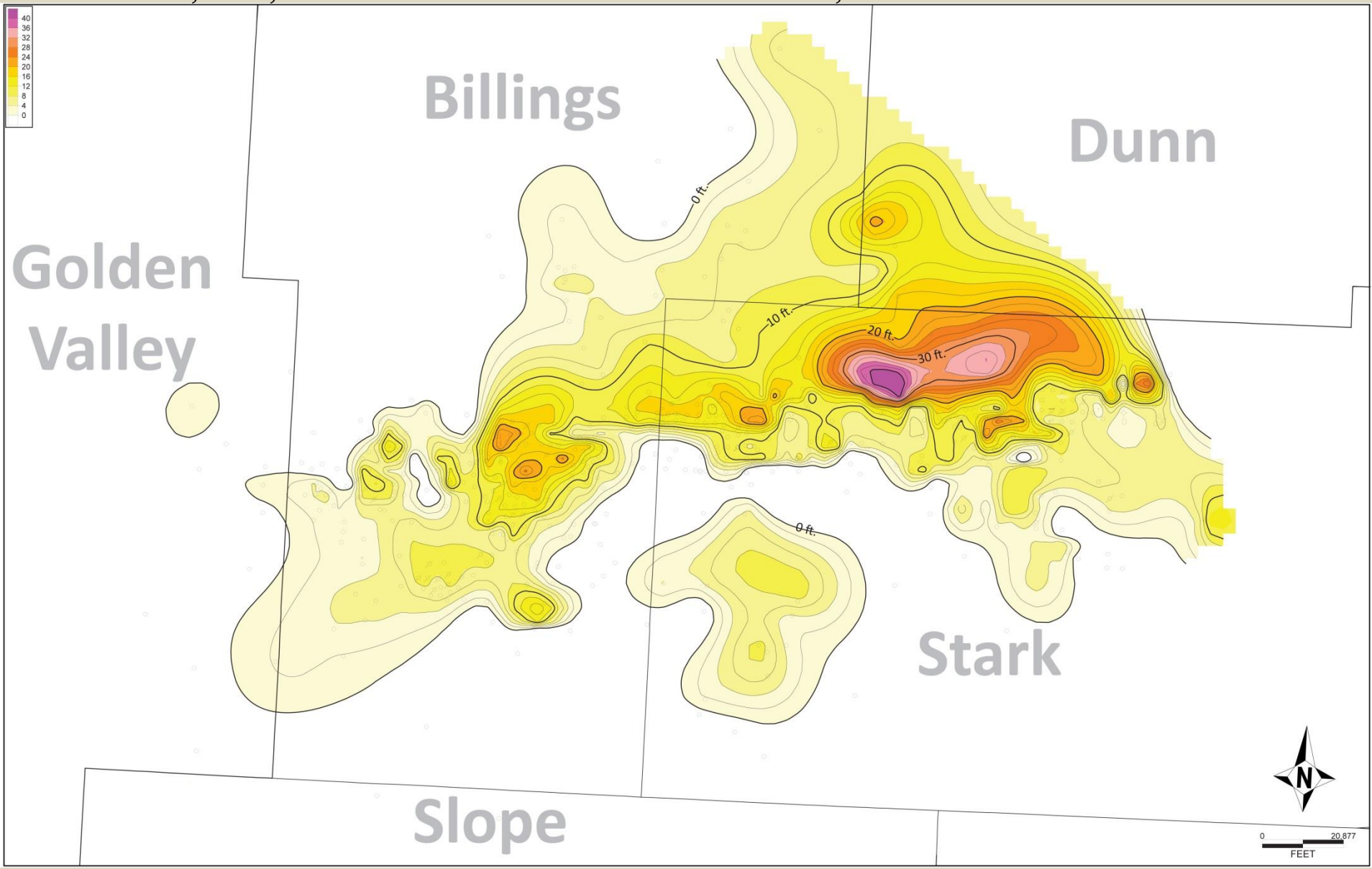
Southern Tyler Petroleum System: Reservoir



The organic-richness (based on log analysis and core observation) of Limestone B and D diminishes within the Dickinson Field Area, where there is an oil-water contact within the reservoir.

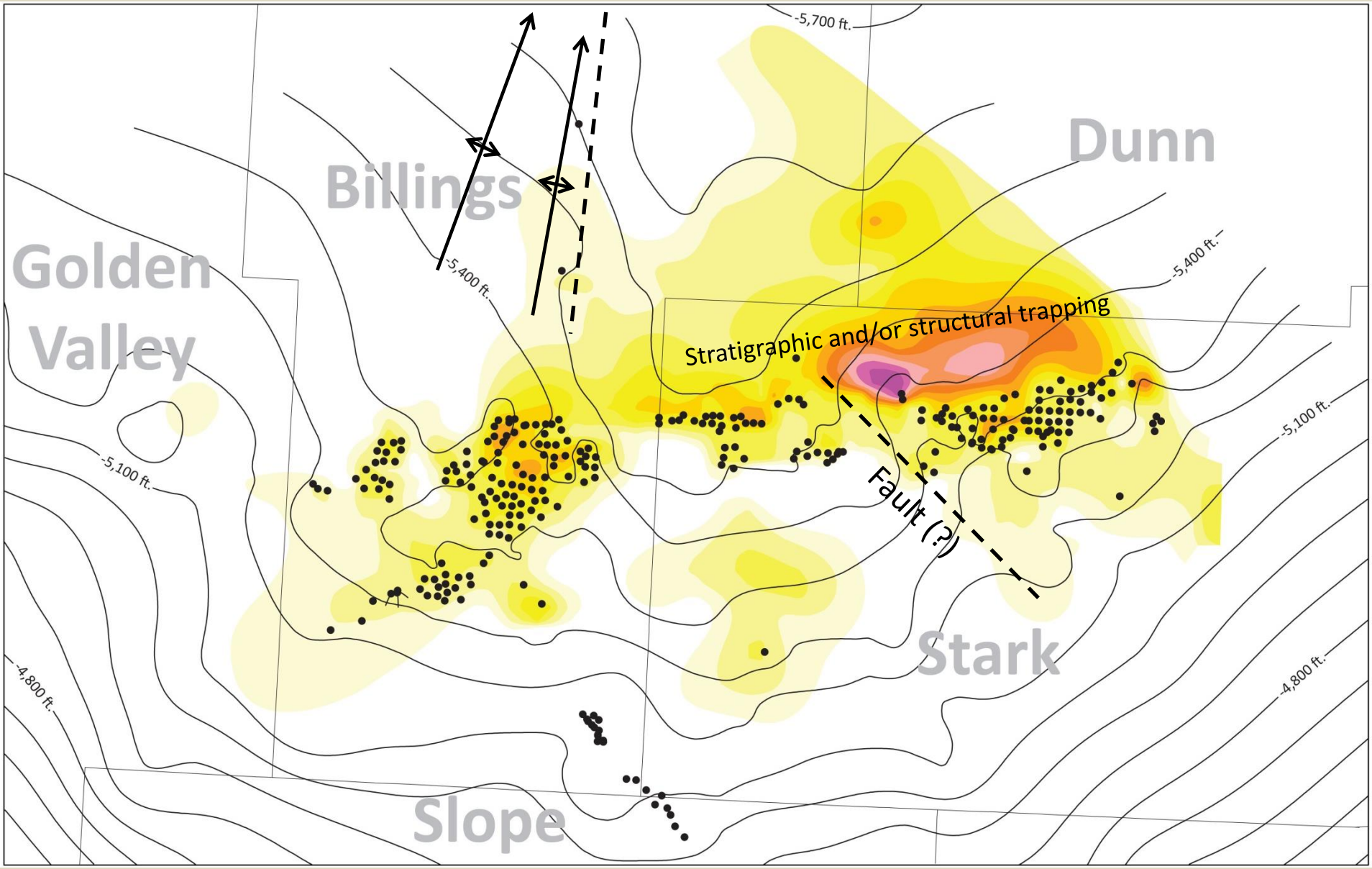
Southern Tyler Petroleum System: Reservoir

Sturm, 1983; 1987-> Barrier Island Sandstones vs. Barwis, 1990 -> back-barrier sandstones

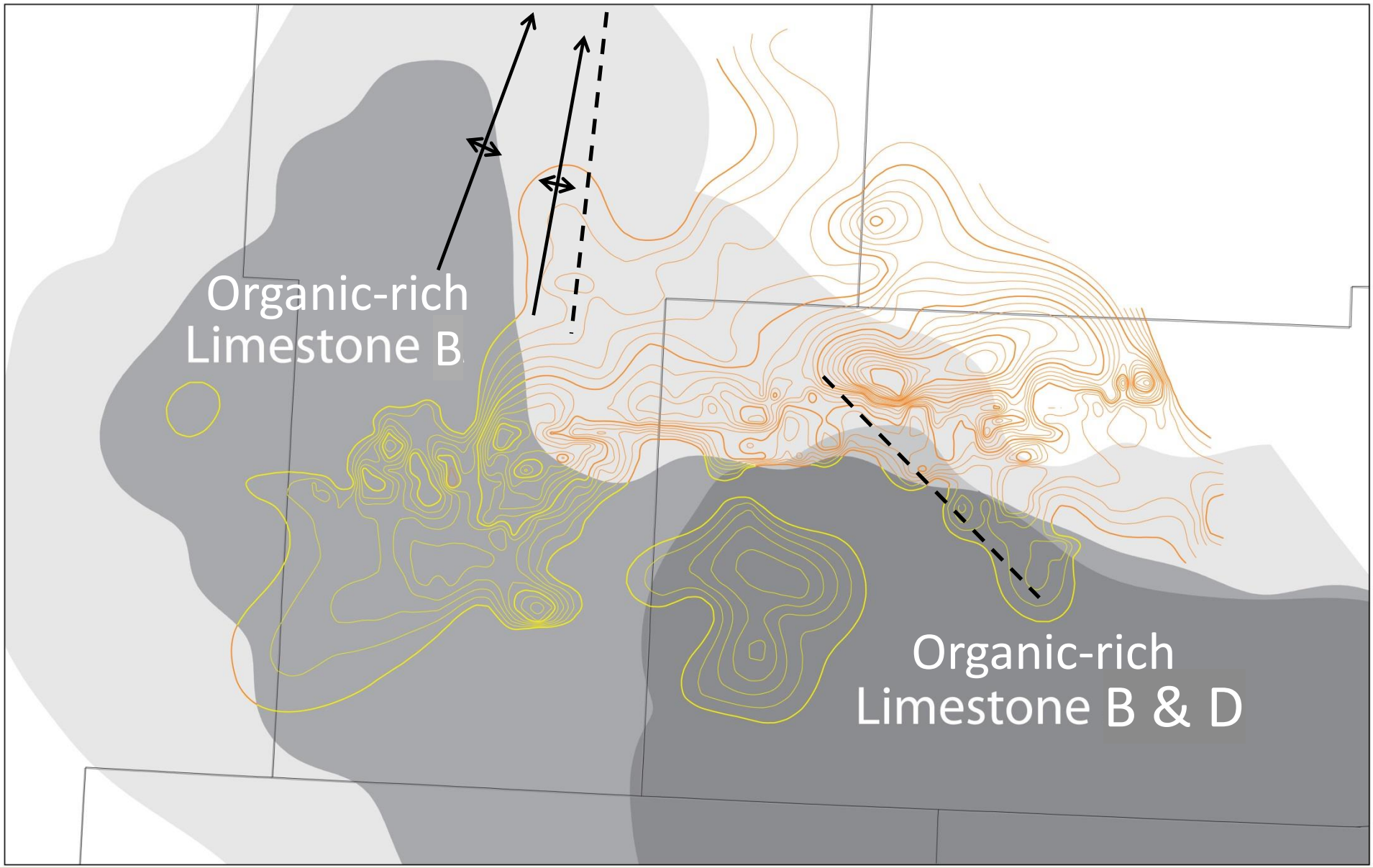


Isopach map of sandstone layer/s located at the approximate stratigraphic position of the reservoir sandstones along the Dickinson-Fryburg Trend. Reservoir quality & oil saturations vary within the displayed sandstone.

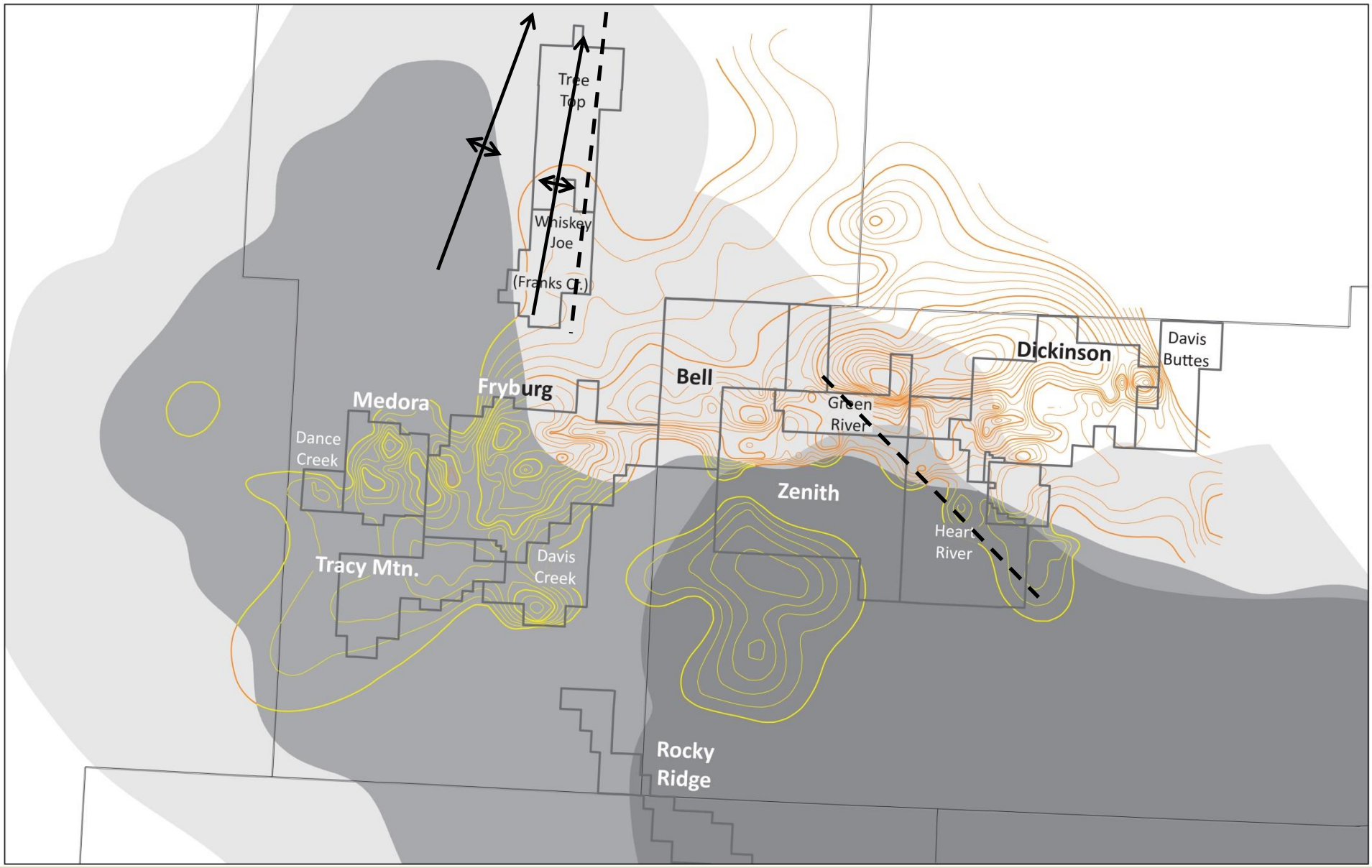
Southern Tyler Petroleum System: Reservoir + Structure Contours



Oil accumulations within northwestern Stark County are stratigraphic and/or structural, and have oil-water contacts. Oil accumulations in southern Billings County do not appear to have oil-water contacts.

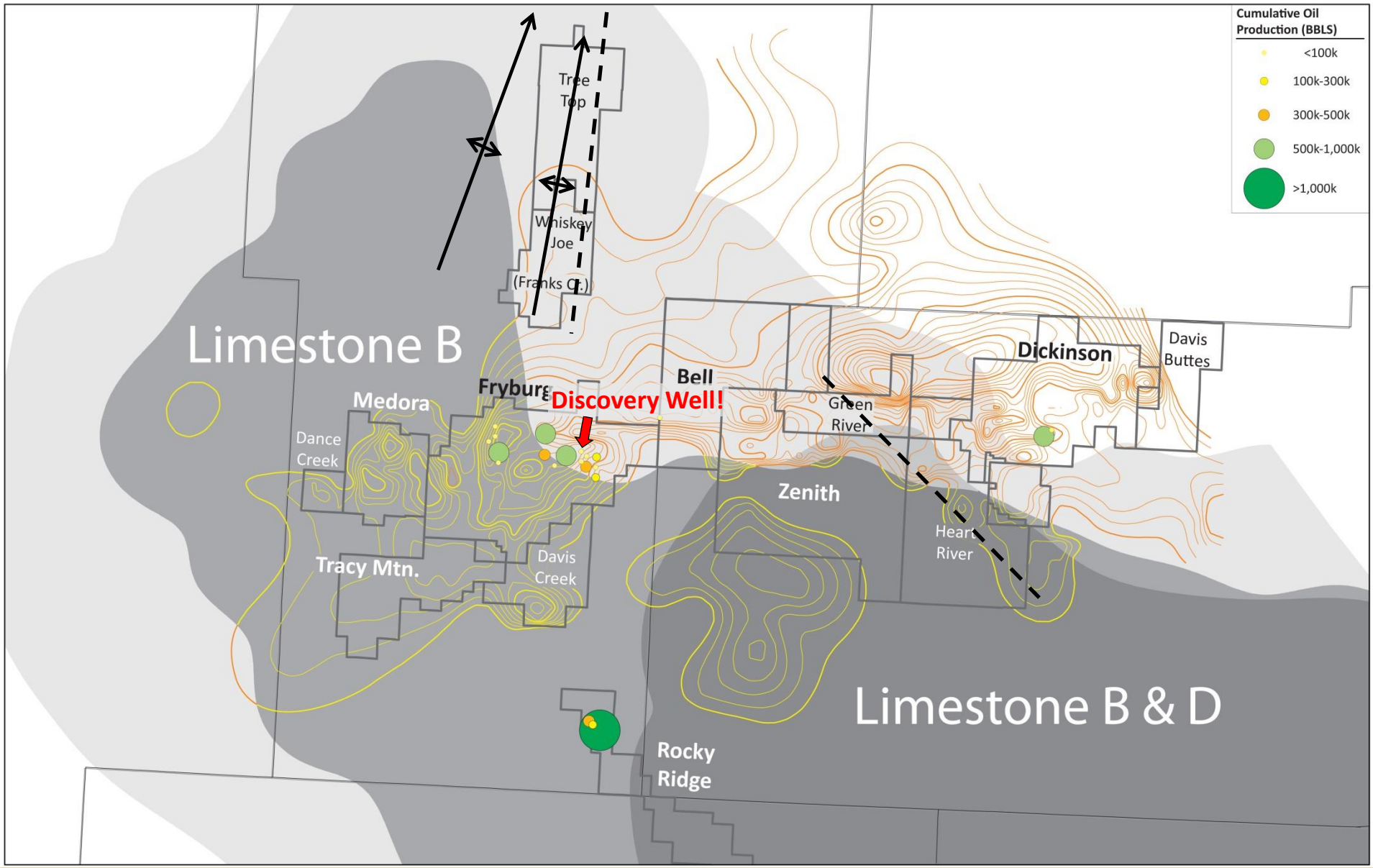


Comparison between the extents of the conventional sandstone reservoir/s and the organic-rich portions of Limestones B and D.



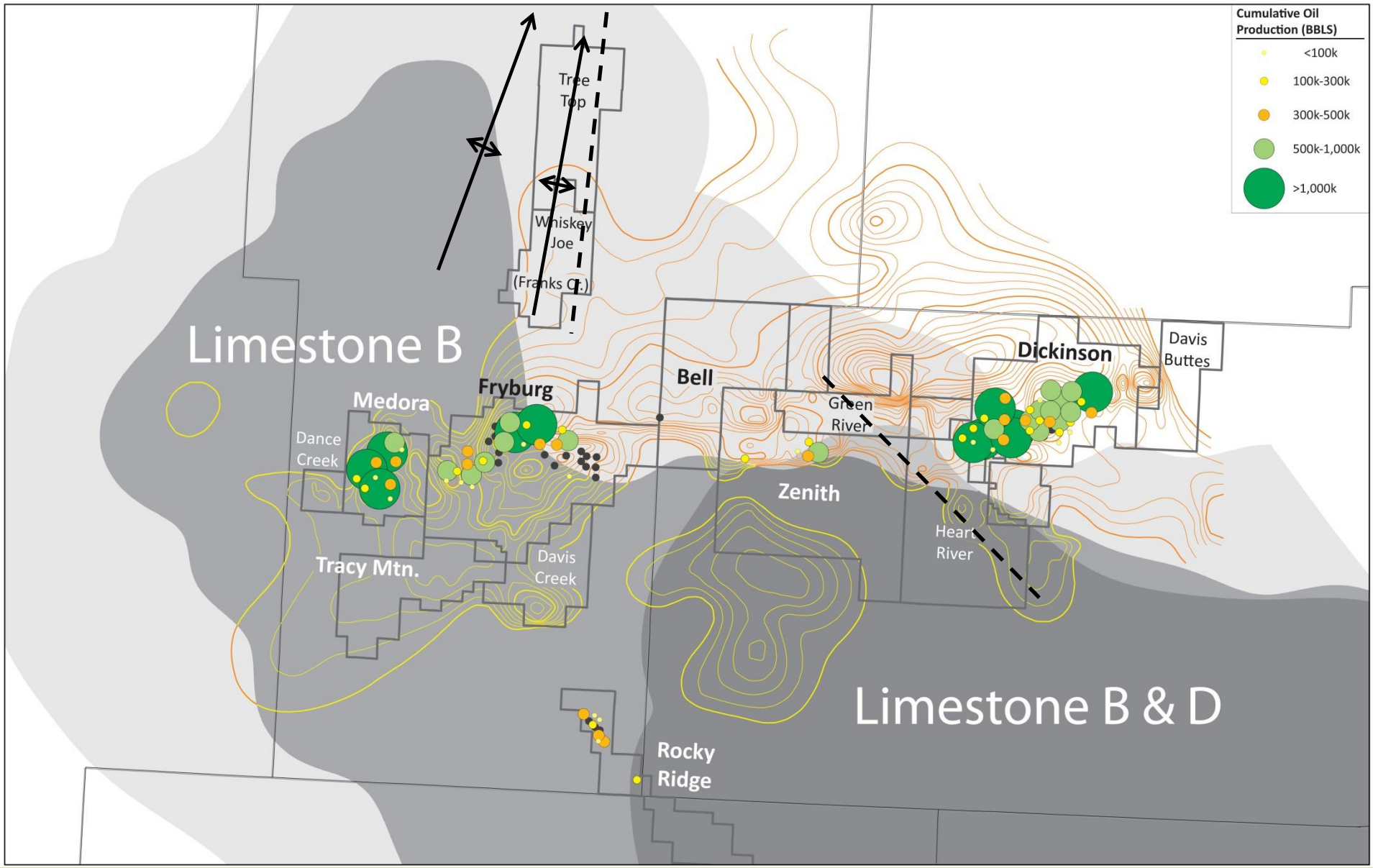
Excellent quality source rock (Limestone B) is in close stratigraphic proximity to the conventional sandstone reservoir within southern Billings County, where conventional fields initially displayed fluid overpressure.

Successful Tyler Wells through the 1950's



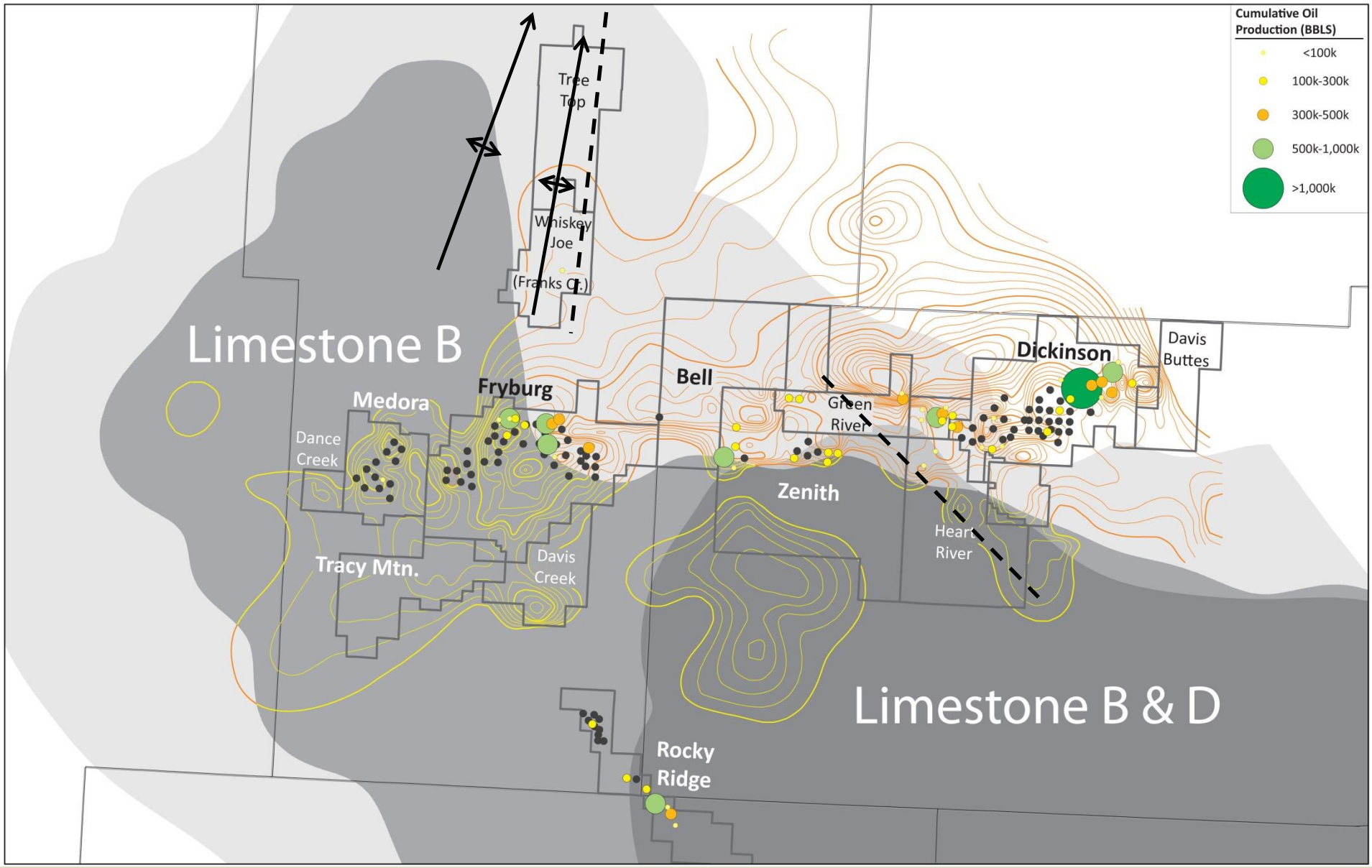
Discovery of the Fryburg, Rocky Ridge, and Dickinson Fields, development of the Fryburg Field.

Successful Tyler Wells through the 1960's

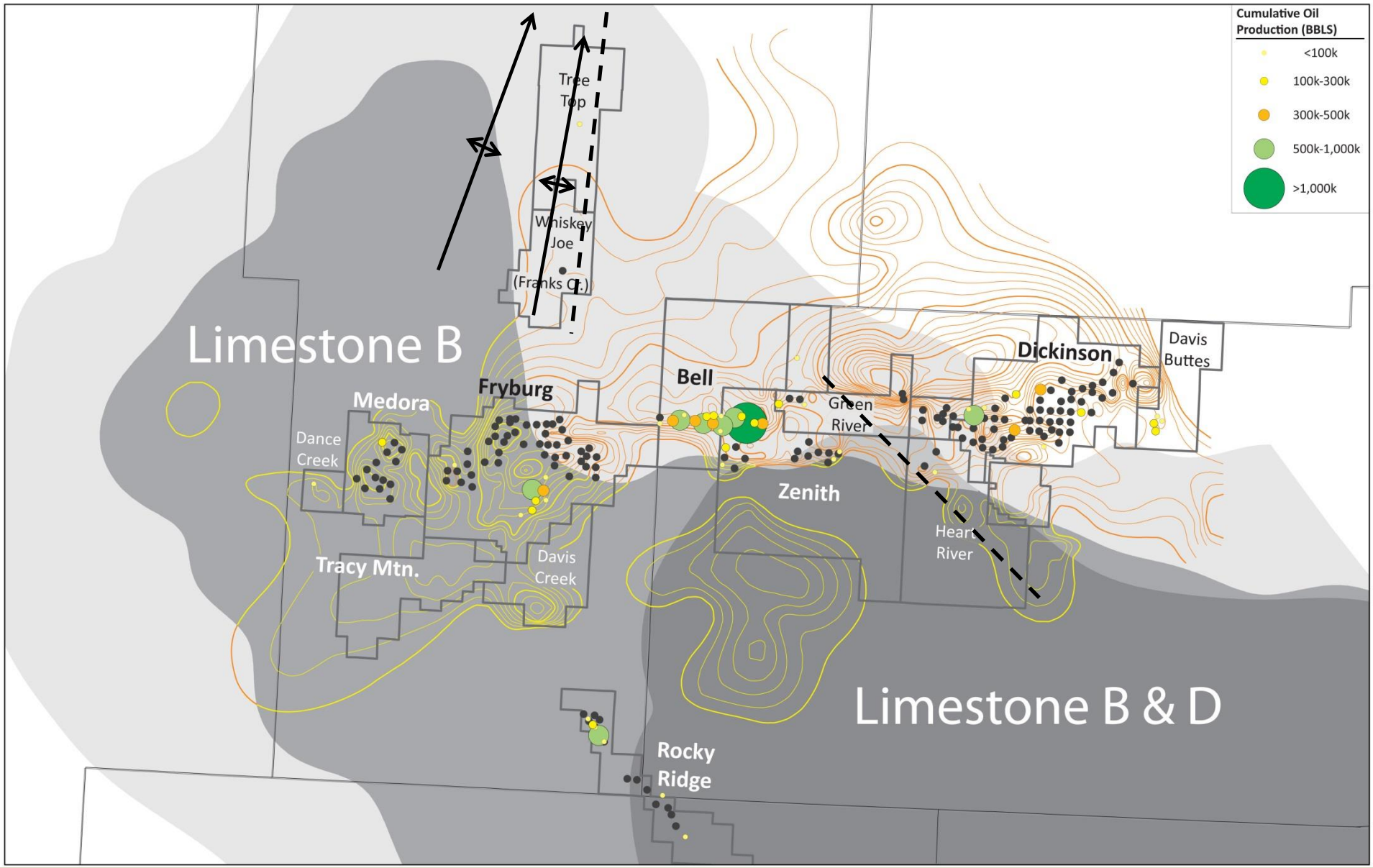


Discovery and development of the Medora Field, expansion/development of the Fryburg & Dickinson Fields.

Successful Tyler Wells through the 1970's

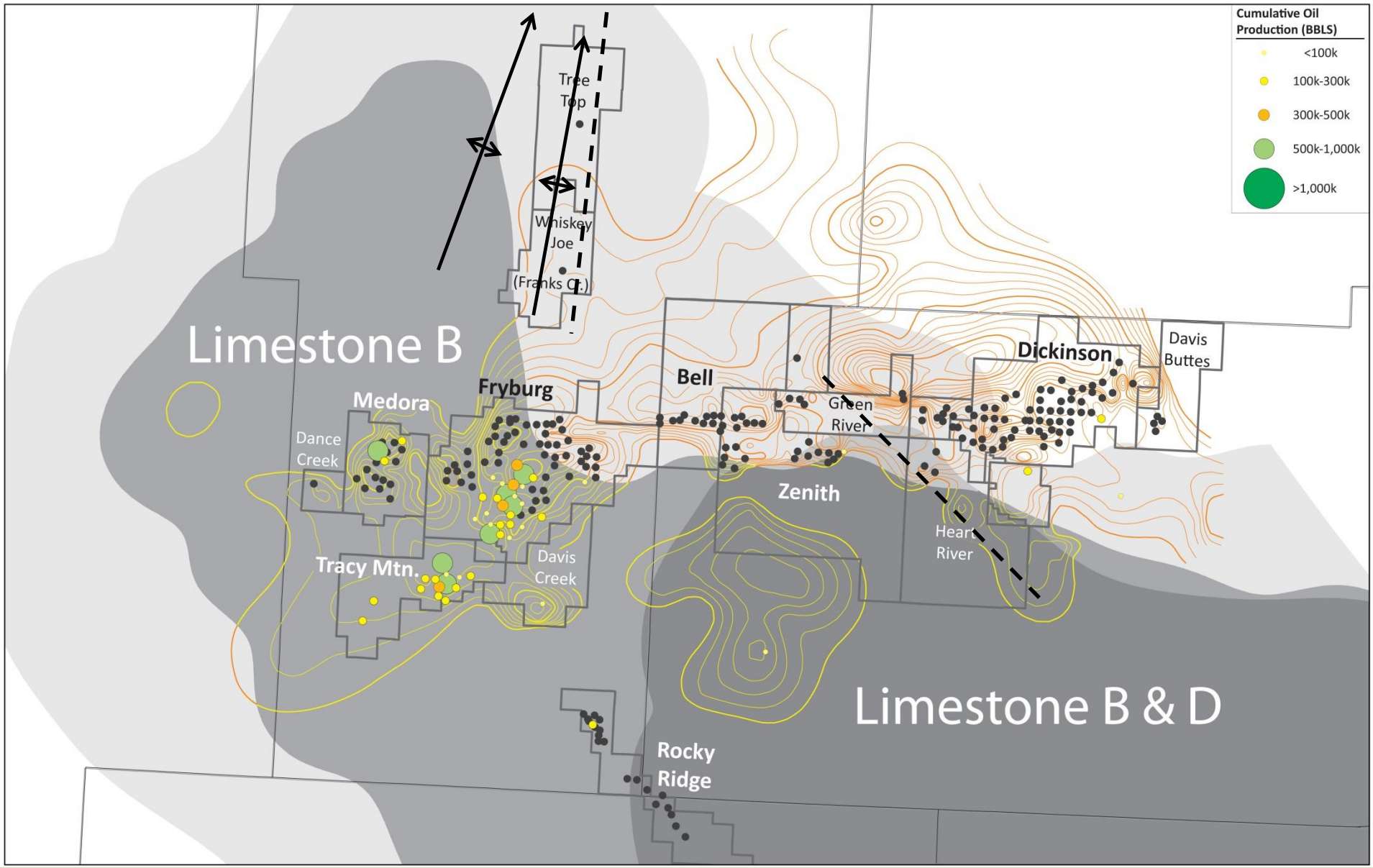


Successful Tyler Wells through the 1980's



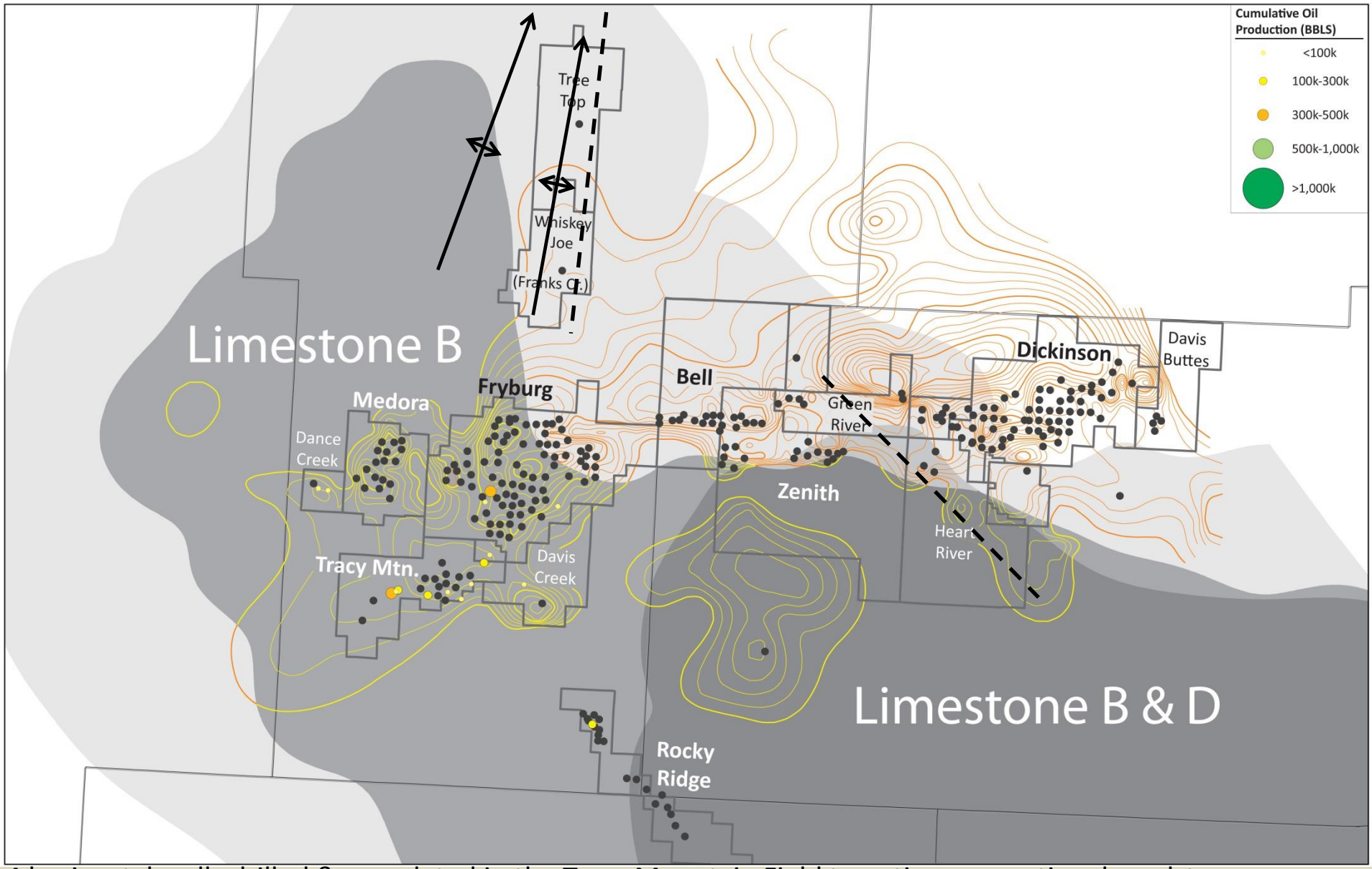
Development of the Bell-Zenith Field area, initial southward expansion of the Fryburg Field

Successful Tyler Wells through the 1990's



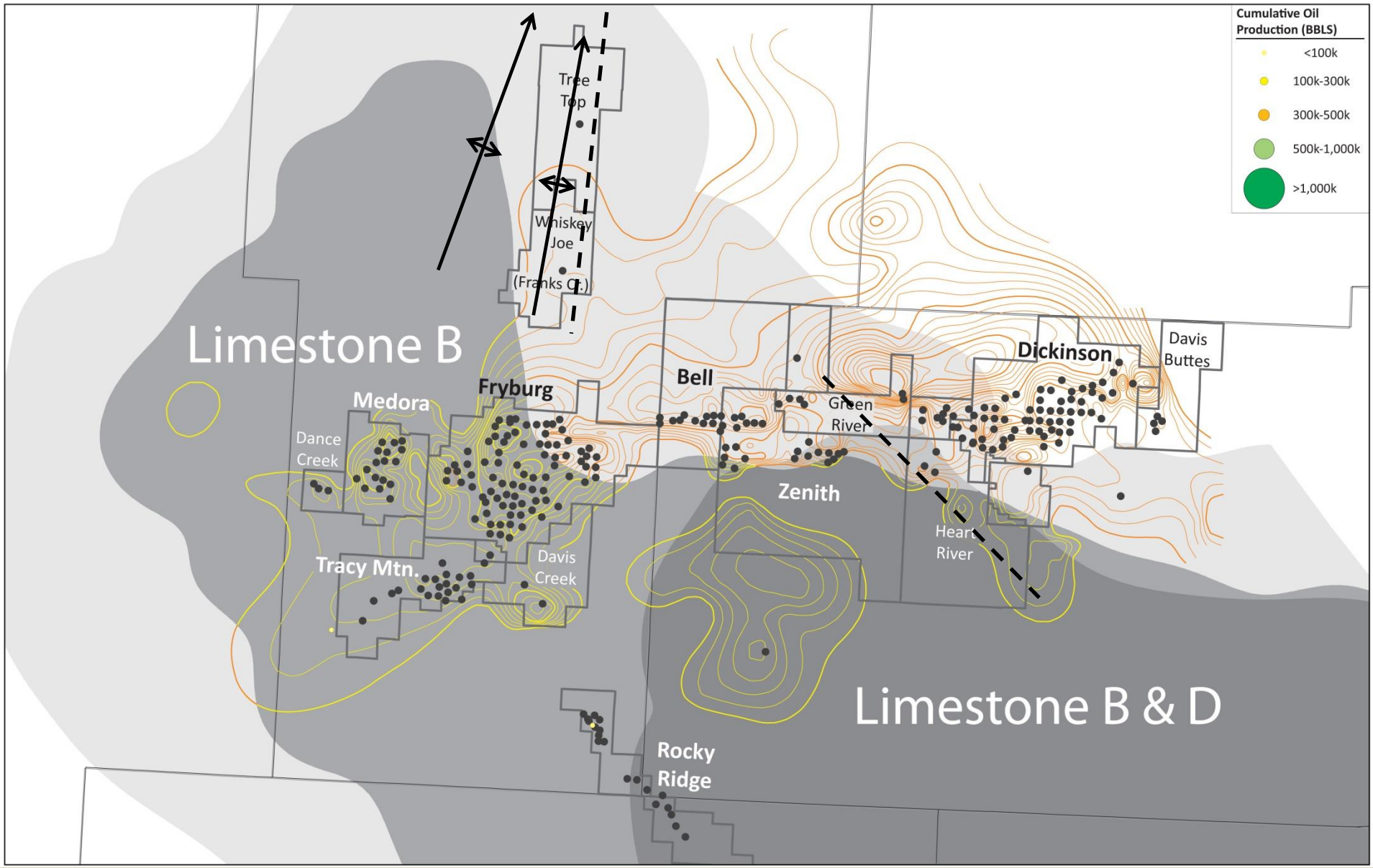
Discovery and development of the Tracy Mountain Field, development of south Fryburg.

Successful Tyler Wells through the 2000's

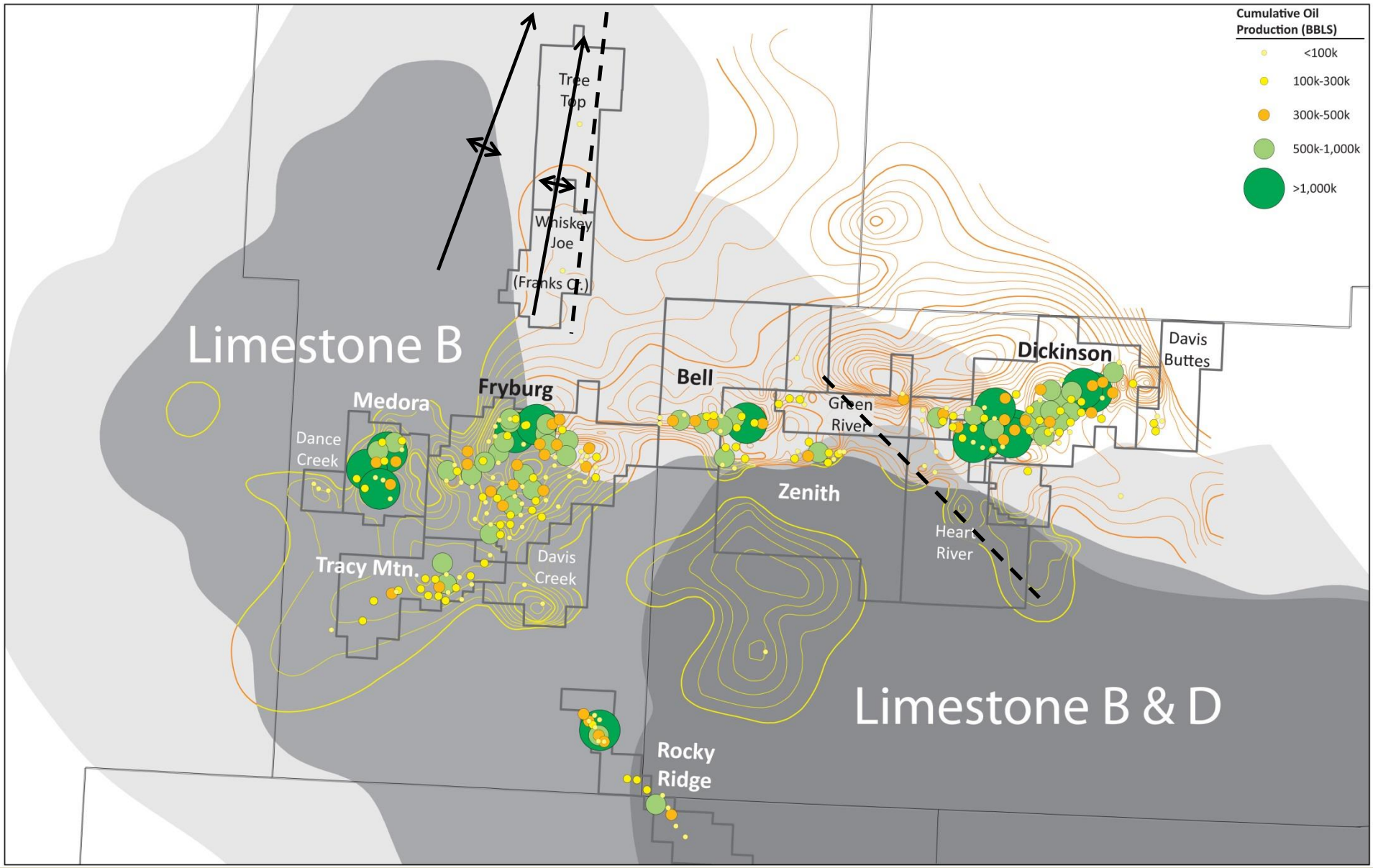


4 horizontal wells drilled & completed in the Tracy Mountain Field targeting conventional sandstone reservoir. The first two have been very successful, the 3rd has been marginal, and the 4th was unsuccessful.

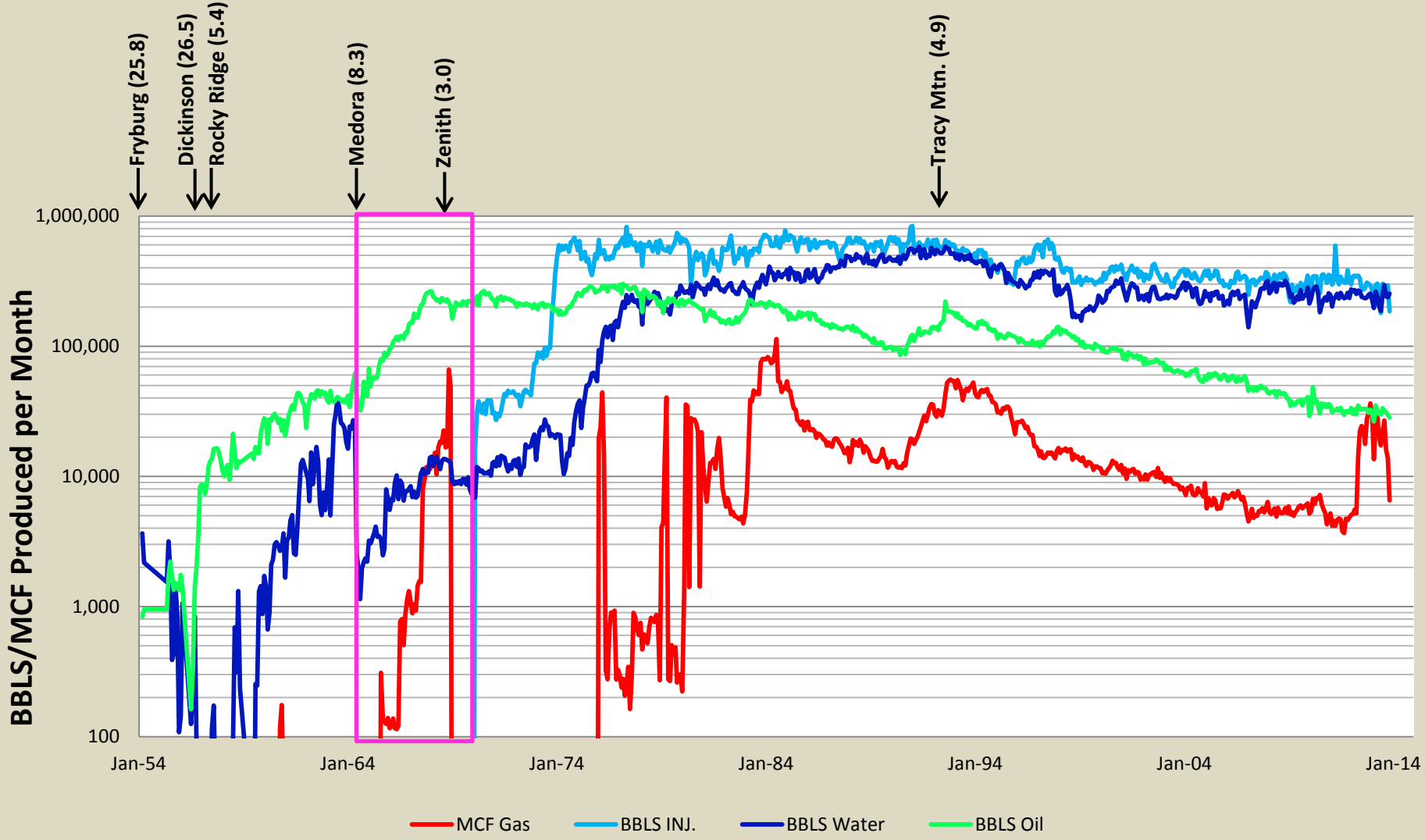
Successful Tyler Wells through the 2010's

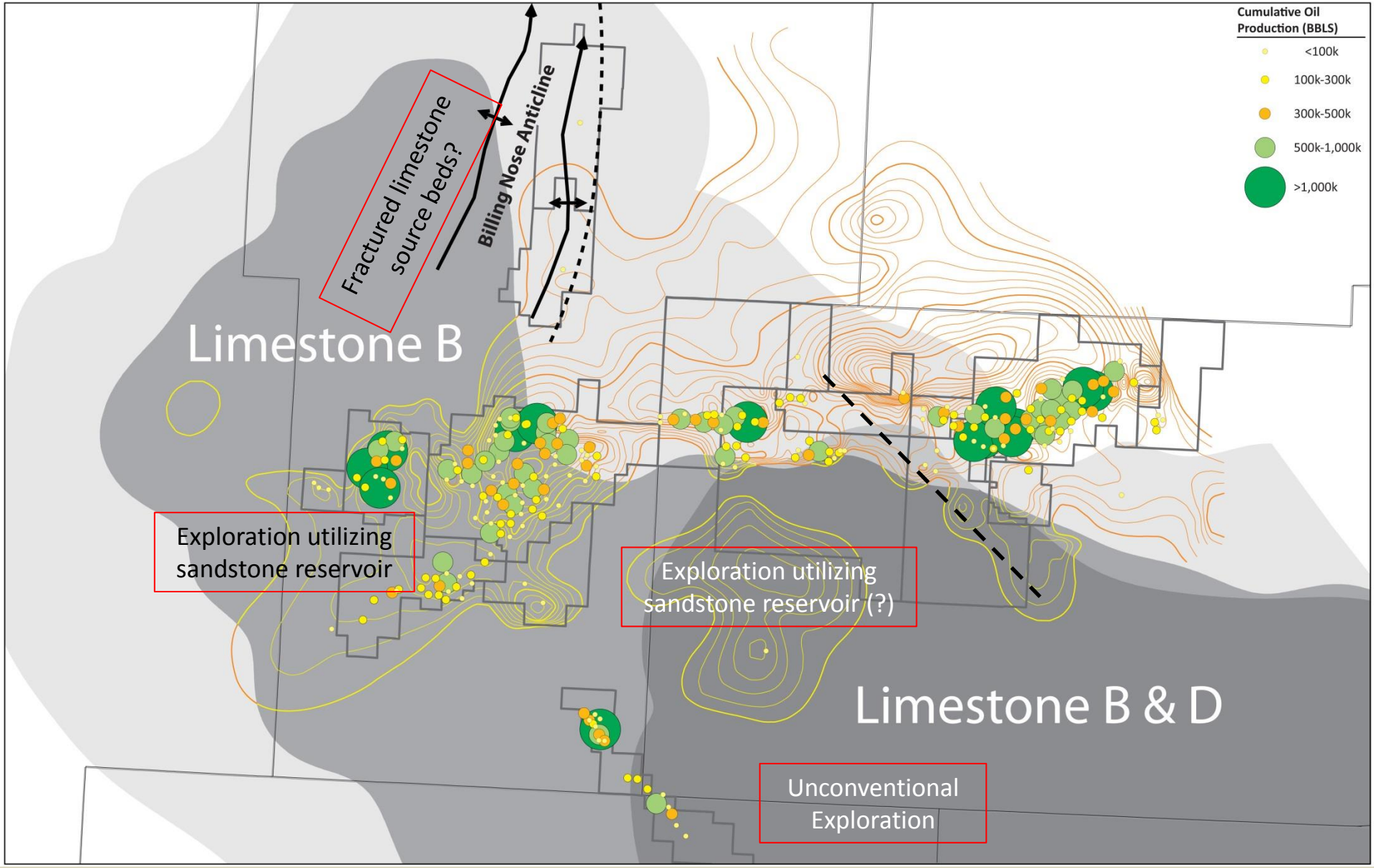


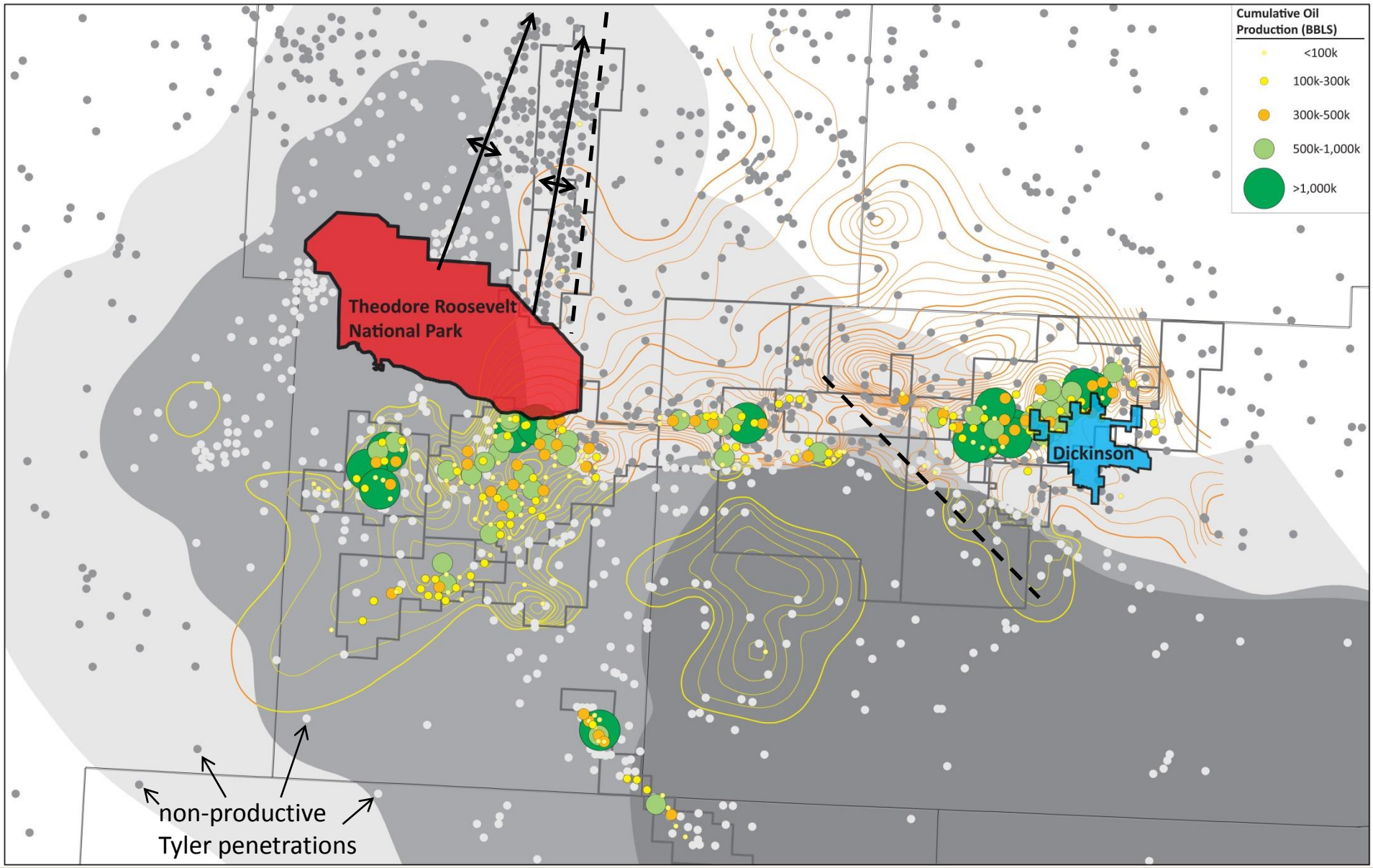
Cumulative Tyler Wells to date



Composite Tyler Production History




Cumulative Oil Production (BBLS)
<100k
100k-300k
300k-500k
500k-1,000k
>1,000k
Fractured limestone source beds?
Billing Nose Anticline
Limestone B
Exploration utilizing sandstone reservoir
Exploration utilizing sandstone reservoir (?)
Limestone B & D
Unconventional Exploration



Various grey circles are additional wells that have penetrated the Tyler Formation.