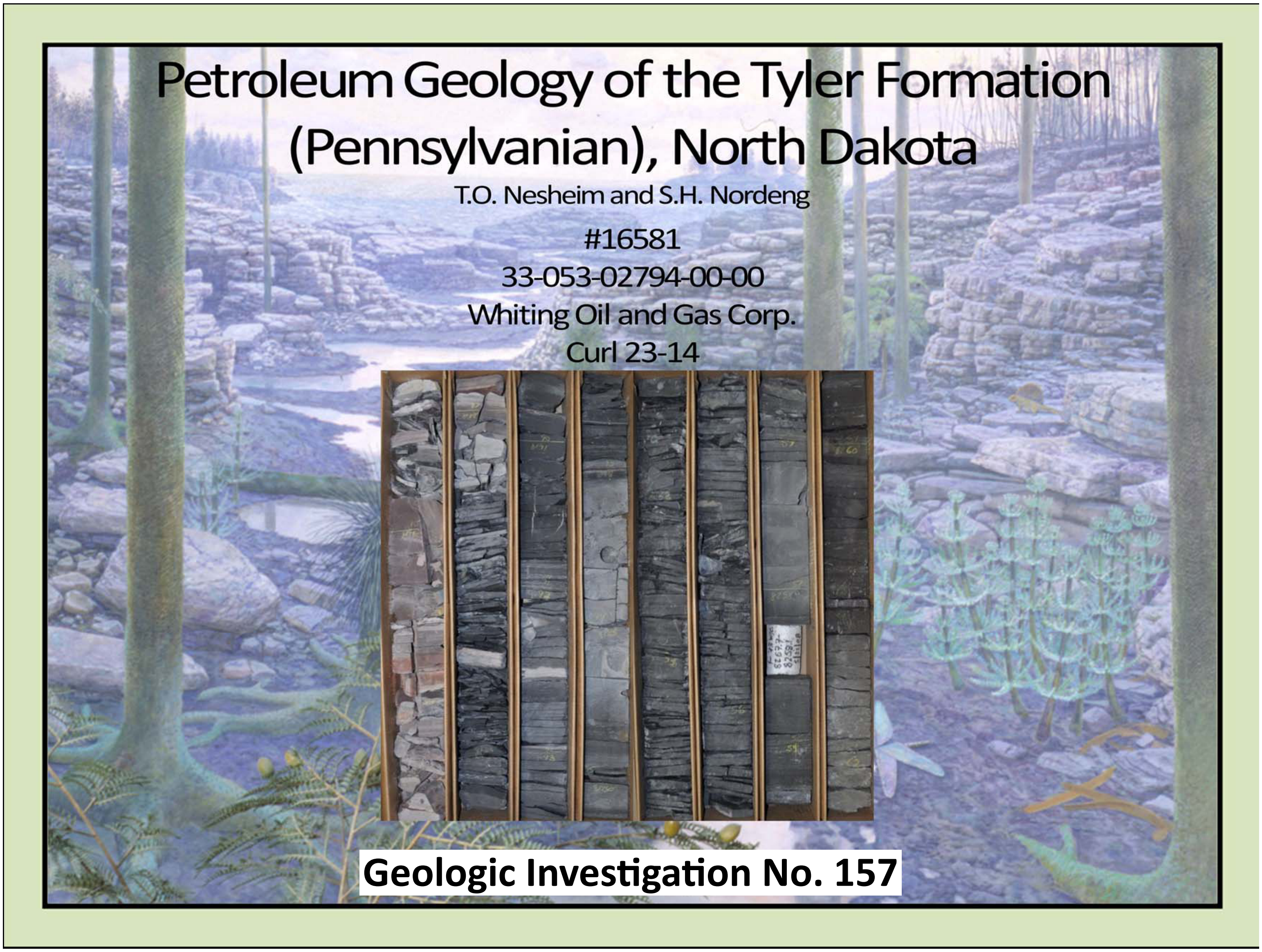
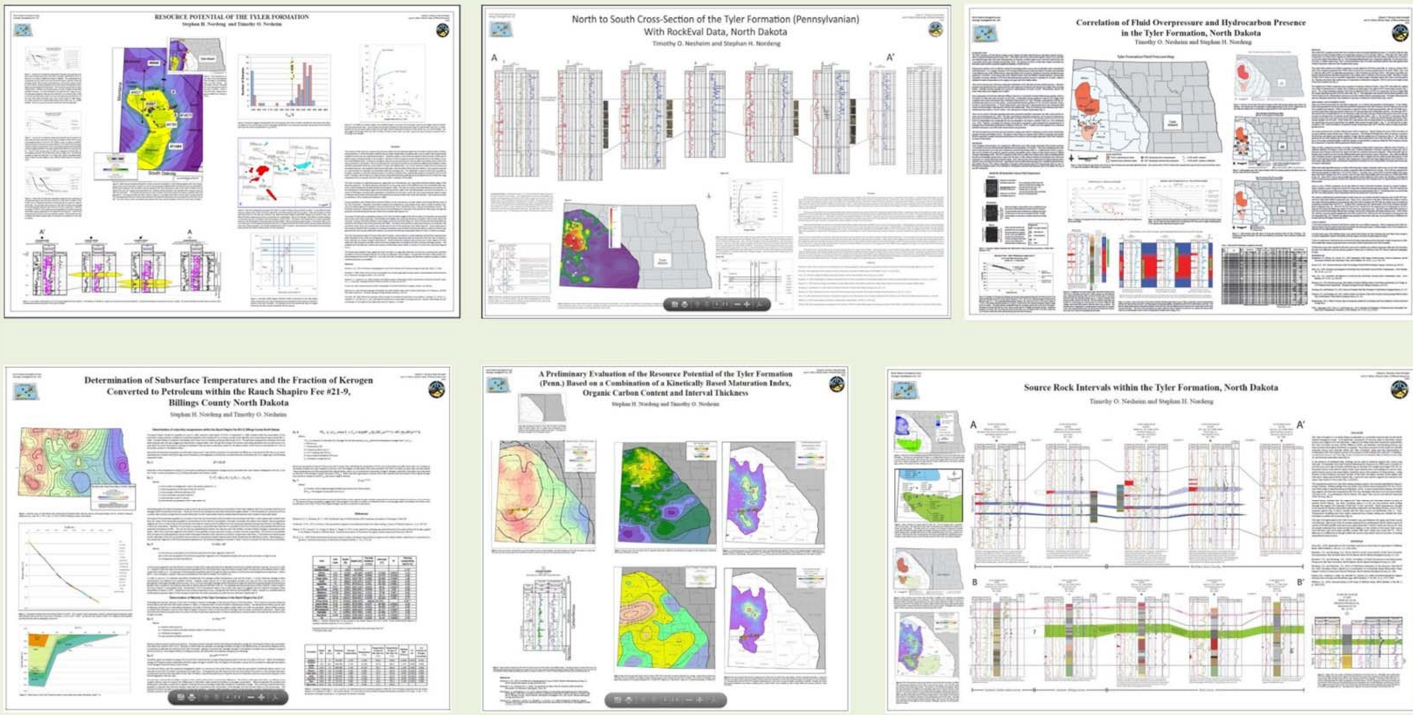


Good afternoon, the presentation that I am sharing with you today is an overview of the North Dakota Geological Survey's work on re-assessing the Tyler Formation as a potential Resource Play.

Our recent work on the Tyler Formation initially started after Stephen Nordeng, co-author for this talk, came across a Tyler core that appeared to contain intervals of organic-rich looking black shale, similar to the upper and lower Bakken shales. Dr. Nordeng had the thought that if the Tyler contains its own organic-rich shale, that it could be a resource play similar to that of the Bakken Formation. It is also of note that Whiting cut this Tyler core in central McKenzie County fairly recently, a location far removed from areas of Tyler production to date.

NDGS Tyler Publications within the Past Two Years:

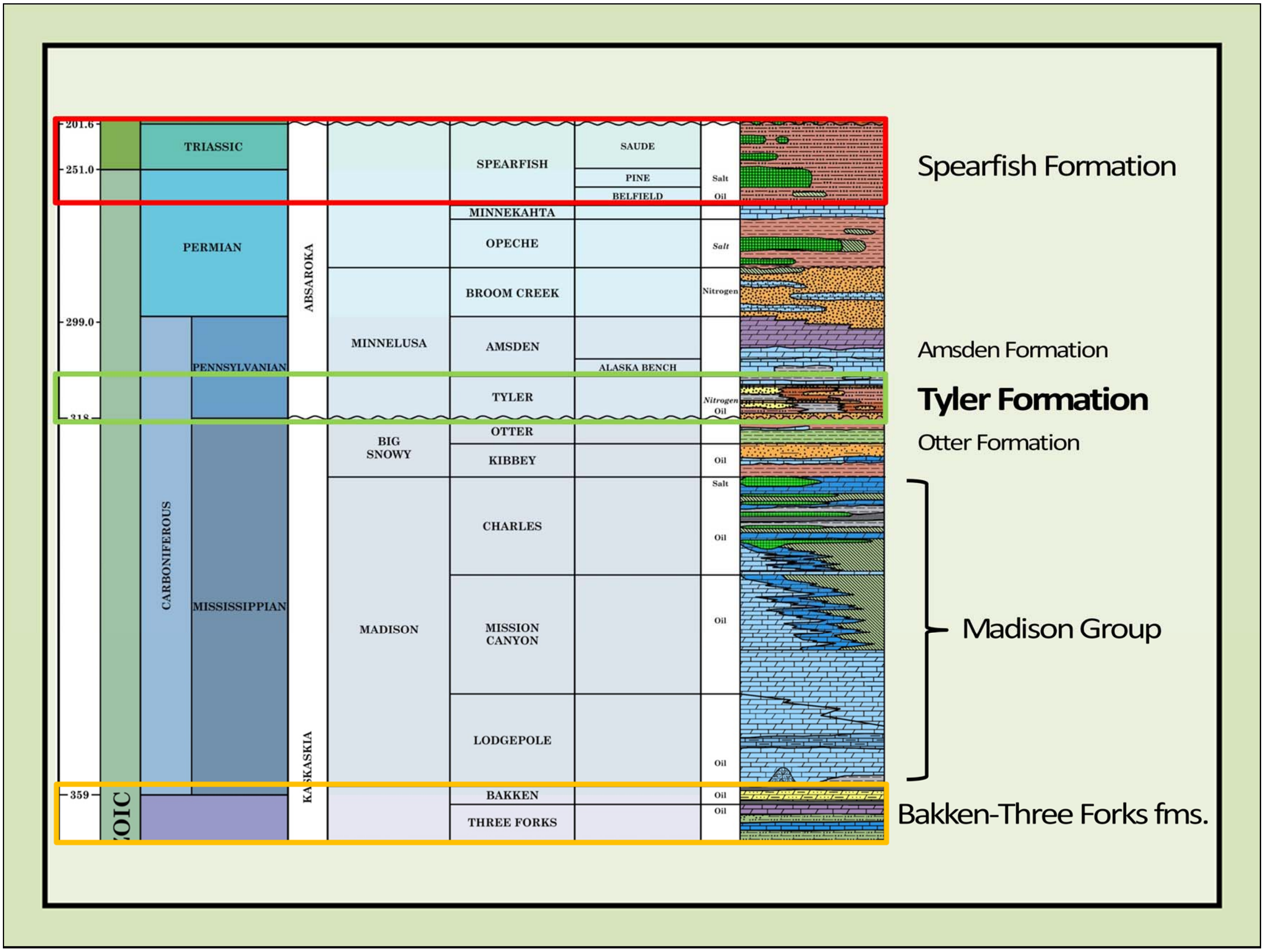
GI-127, GI-132, GI-144, GI-146, GI-148, GI-151, RI-111



*Core Workshops at AAPG-RMS 2011 and WBPC 2012

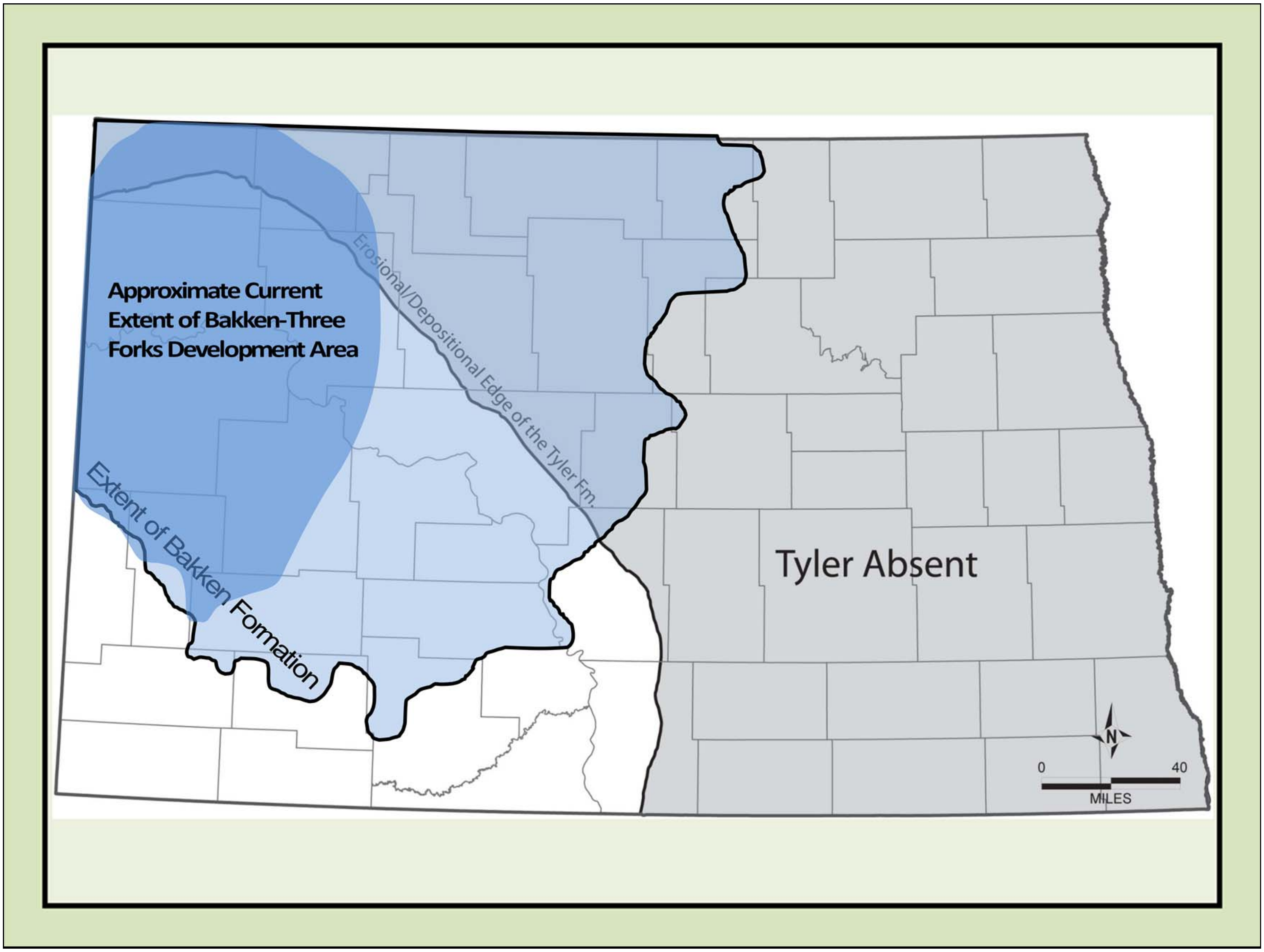
Over the past two years, the ND Survey has spent a significant amount of time and resources examining the Tyler Formation, putting out six poster publications to date along with now couple core workshops.

Most recently, we have nearly finished RI-111, which combines all of our previously reported information along with new material into one comprehensive report. This presentation gives an overview for part of RI-111.



The Tyler Formation was deposited during the late Carboniferous, early Pennslyvanian. This places the Tyler stratigraphically above the Bakken-Three Forks formations and Madison group, and below the Spearfish Formation. Many of the Bakken and Three Forks horizontal wells that will be drilled in the coming years will be passing through the Tyler section. Our hope is that some of these Bakken-Three Forks wells will cut Tyler cores along the way to aid in future studies.

The Pennslyvanian was a geologic period in which glacial advances and retreats caused numerous sea level fluctuations. These sea level fluctuations left behind some very lithologically complex sedimentary sections, including the Tyler Formation.



The Tyler Formation extends throughout west-central, southwest, and south-central North Dakota, which is both beyond the area of current Bakken-Three Forks development and the total extent of the Bakken Formation.

Basin Centered Petroleum System
(Resource Play)

- 1) Regionally extensive organic-rich source rock
  - -Kerogen Type (Oil vs. Gas)
- 2) Maturation of the source-rock (oil generation)
- 3) Expulsion of generated oil from source rock
- 4) Accumulation of expelled oil in adjacent rock
- 5) Extraction of oil from the reservoir rock

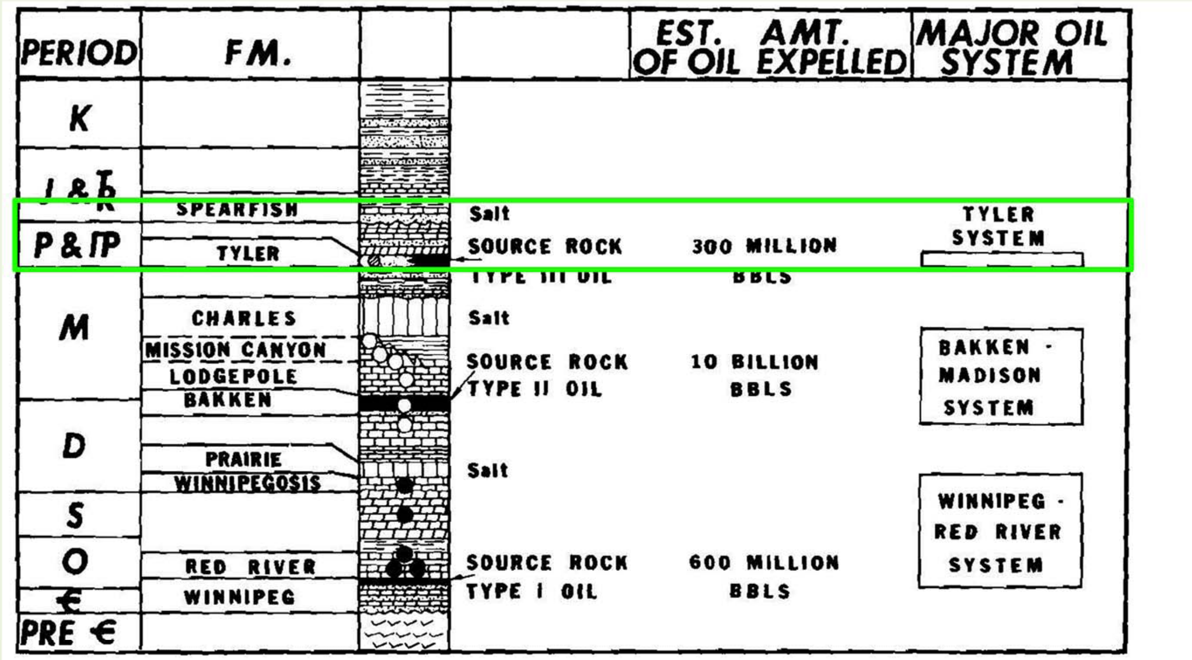
There are five key components necessary to have a Resource Play (Basin Centered Petroleum System). In addition to those five components, examining the kerogen type of the organic-rich source rock is important for understanding whether the potential play will yield gas and/or oil. The maturation history is also important for understanding the hydrocarbon type as well.

Basin Centered Petroleum System
(Resource Play)

- **1) Regionally extensive organic-rich source rock**
  - **-Kerogen Type (Oil vs. Gas)**
- **2) Maturation of the source-rock (oil generation)**
- **3) Expulsion of generated oil from source rock**
- **4) Accumulation of expelled oil in adjacent rock**
- *5) Extraction of oil from the reservoir rock*

For this talk, I will be discussing the first four of the Resource Play components leaving the Extraction component for the engineers and future talks.

Williston Basin Source Rocks (Dow, 1974)



2—Schematic columnar section showing stratigraphic terminology, vertical distribution of source rocks, reservoirs, and evaporite seals, and estimated amount of oil expelled. Not drawn to scale.

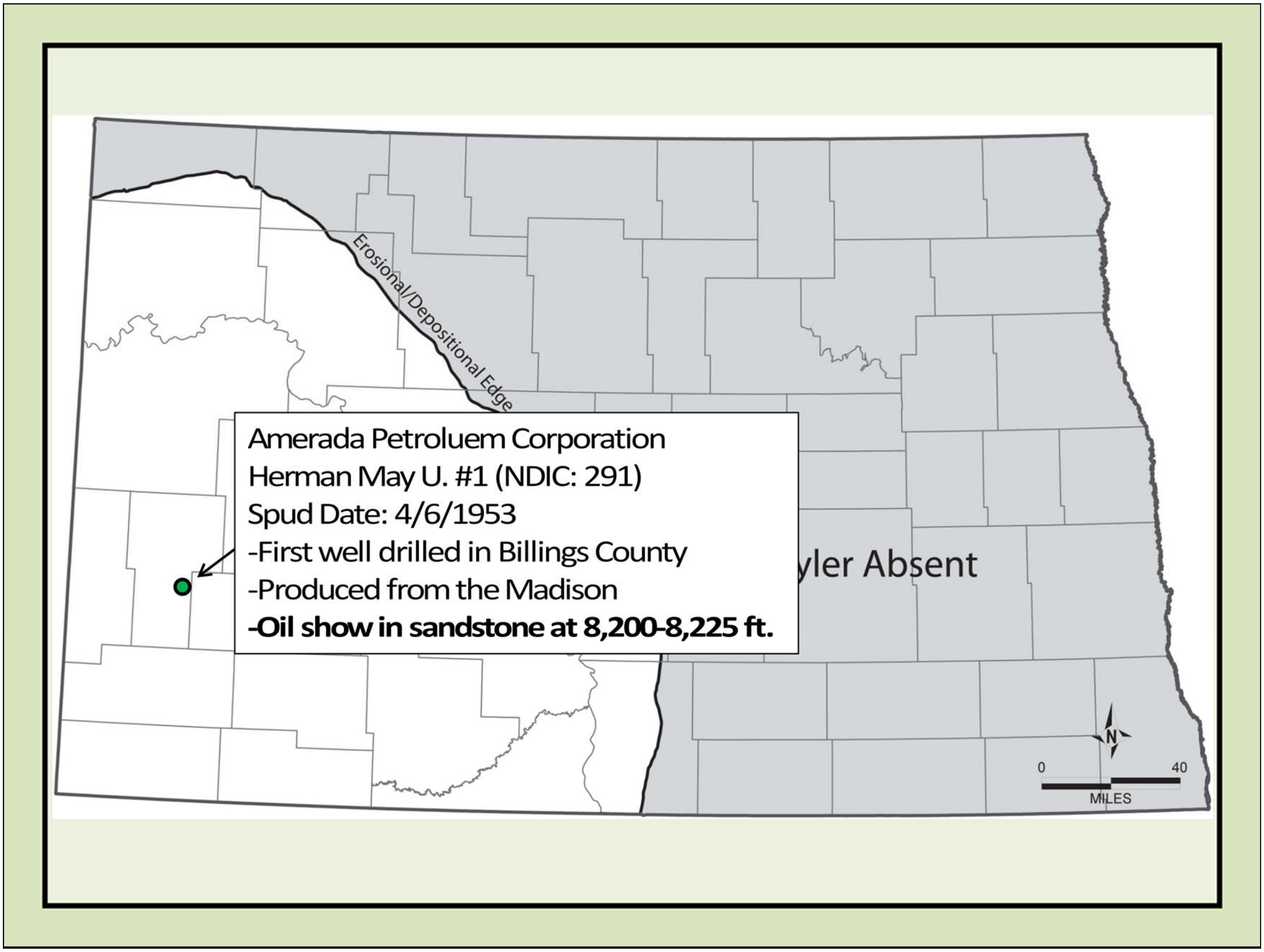
Publications:

Dow, W.G., 1974, Application of Oil-Correlation and Source-Rock Data to Exploration in Williston Basin: AAPG Bulletin, v. 58, no. 7, p. 1253-1262.

Williams, J.A., 1974, Characterization of oil types in Williston Basin: American Association of Petroleum Geologists Bulletin, v. 58, no. 7, p. 1243-1252.

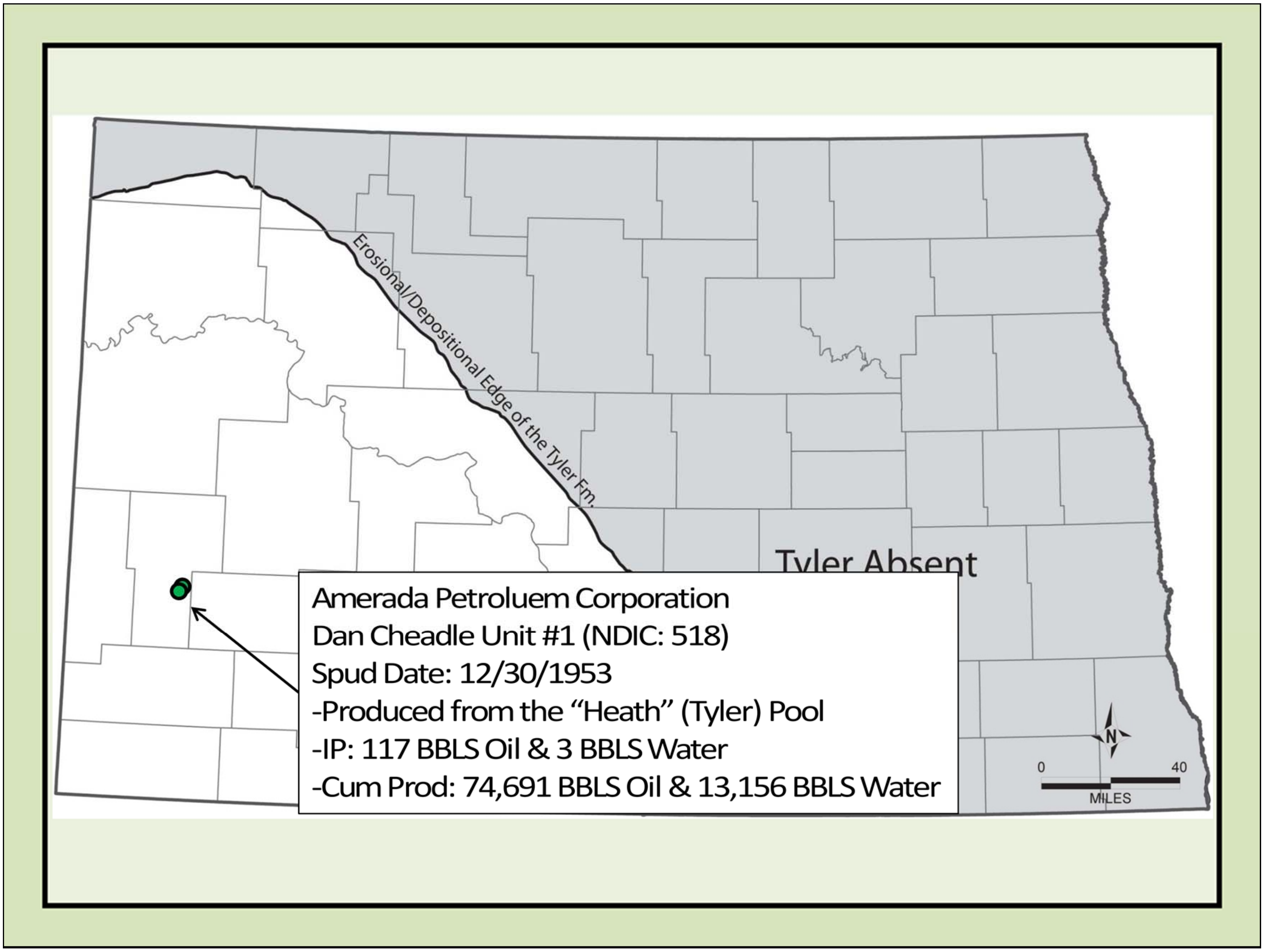
The Tyler Formation has been previously documented in the literature as an oil generating source rock. In a pair of study's conducted together, Dow and Williams examined oil types from Williston Basin oil wells and traced produced oils back to three primary source rock intervals: the Winnipeg or Icebox shale, the Bakken Formation, and the Tyler Formation.

Dow believed that the Tyler was a self sourcing and self producing interval, meaning that oil produced in the Tyler stayed in the Tyler until being produced. Dow and Williams interpretation of the Tyler indicates it has the necessary components to be a resource play. The question we will look at today, however, is where oil has likely been generated and accumulated within the Tyler section.



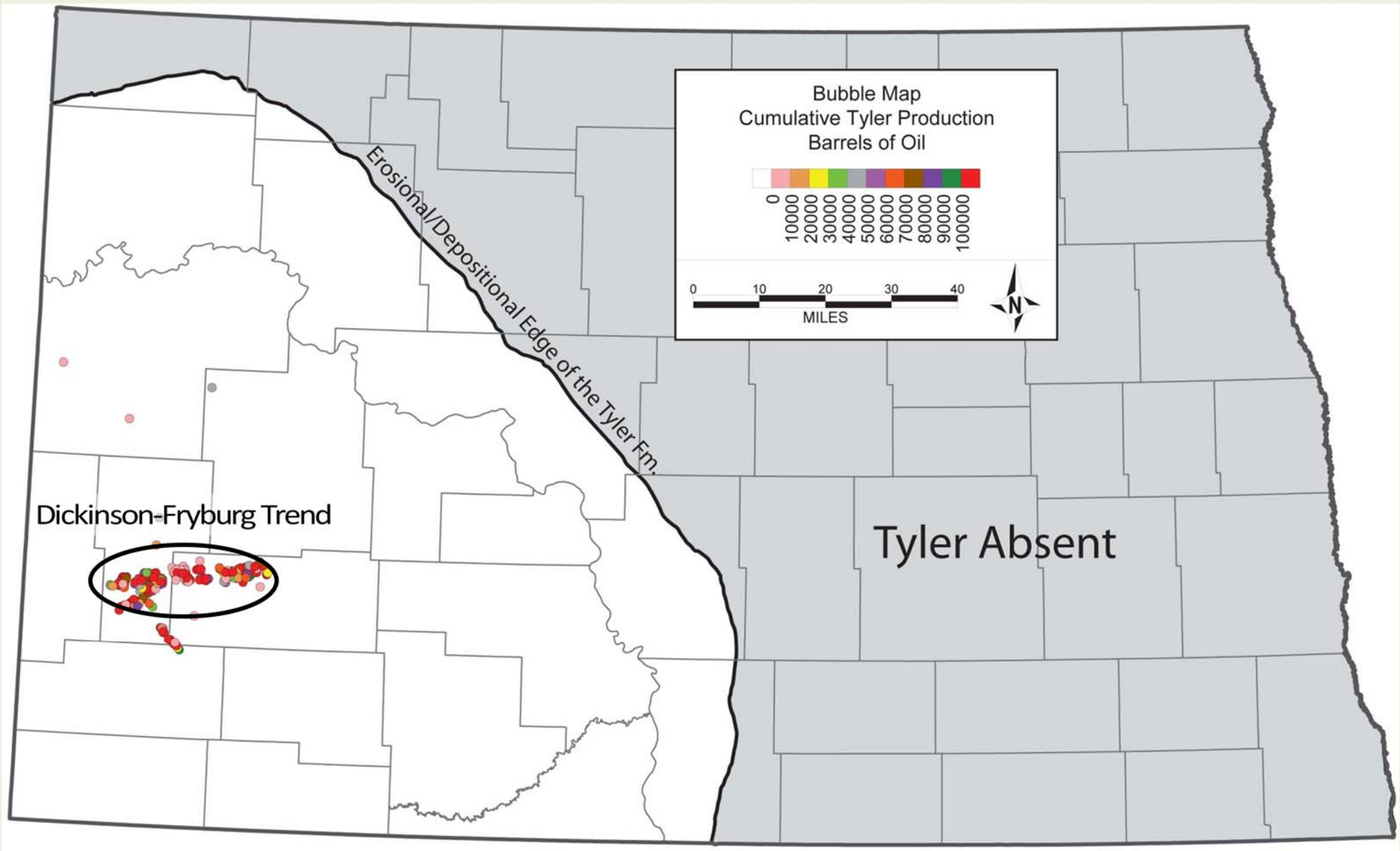
But before we look forward at where the Tyler might go as resource play/horizontal drilling target, I'd like to take a step back and look at where the Tyler has been for the past six decades.

The first recorded oil show in the Tyler, that I know of, was encountered in early 1953 during the drilling of Amerada's Herman May Unit number one, which was the first recorded oil well drilled in Billings County. While the Herman May went on to produce from the Madison, there was a notable oil show in a sand interval at 8,200 feet, several hundred feet above the Madison Group.



Later that year, Amerada spudded the Dan Cheadle Unit number one. While the Dan Cheadle drilled down and cored the Madison, the well completed uphole in the same sandstone interval noted in the Hermon May well. This oil productive sand was interpreted early on as the Heath Formation, but now as we better understand, it's actually the Tyler Formation. The difference being the Heath Formation is slightly older, upper Mississippian in age, while the is Tyler Pennslyvanian.

The Dan Cheadle had an IP of 117 barrels of oil and cumulatively produced over 74,000 barrels of oil and only around 13,000 barrels of water before being plugged and abandoned. The Dan Cheadle was completed just under four years after the Clarence Iverson #1 well came on production, which was the initial oil discovery well in North Dakota. So the Tyler has had a long production history in the Williston Basin.

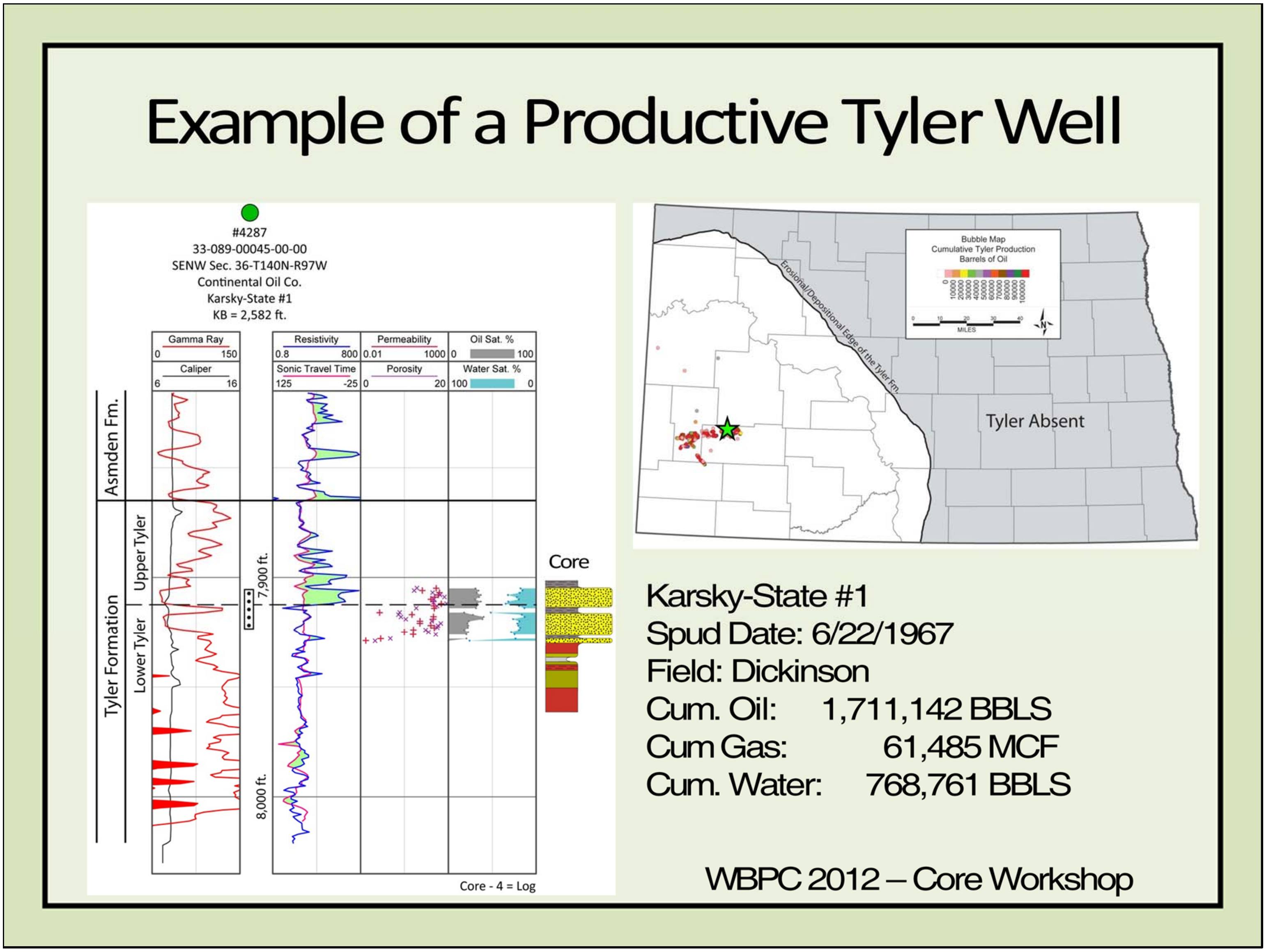


Cumulative Tyler Production

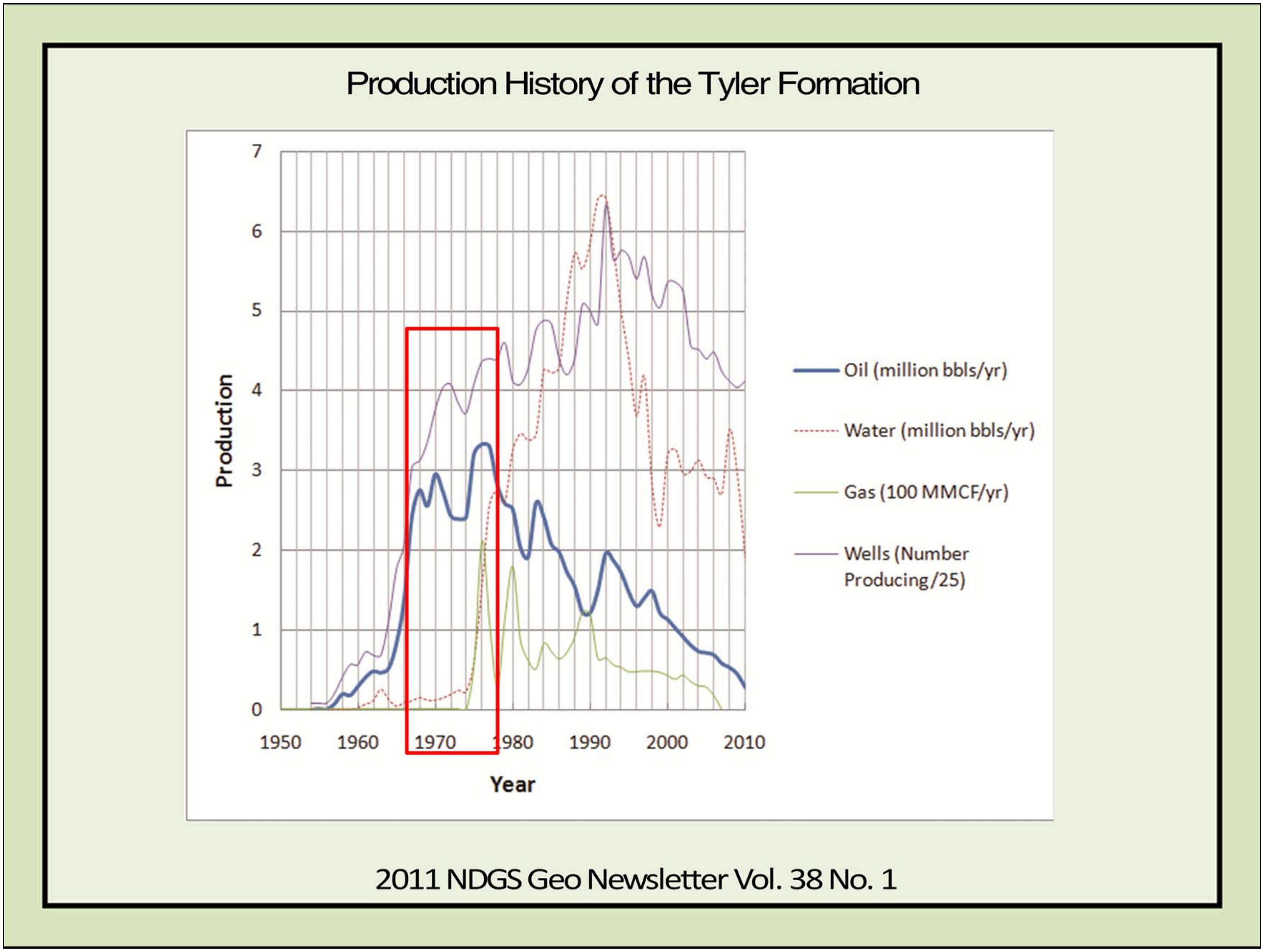
285 wells ⟶ >84 million bbls. Oil = >294,000 bbls. oil per well

From the Dan Cheadle discovery, Tyler productive spread eastward and westward along what is called the Dickinson-Fryburg trend. To date, over 84 million barrels of oil have been produced from the Tyler Formation from a total of 297 wells. So far the average Tyler well has produced over 280,000 barrels of oil, not including dry holes of cource (84 million barrels/297 wells).

There have been several horizontal wells drilled in the Tyler targeting the same sand intervals as the vertical wells. Most notably, Upton Resources completed two really nice Tyler horizontal producers in the early 2000's.

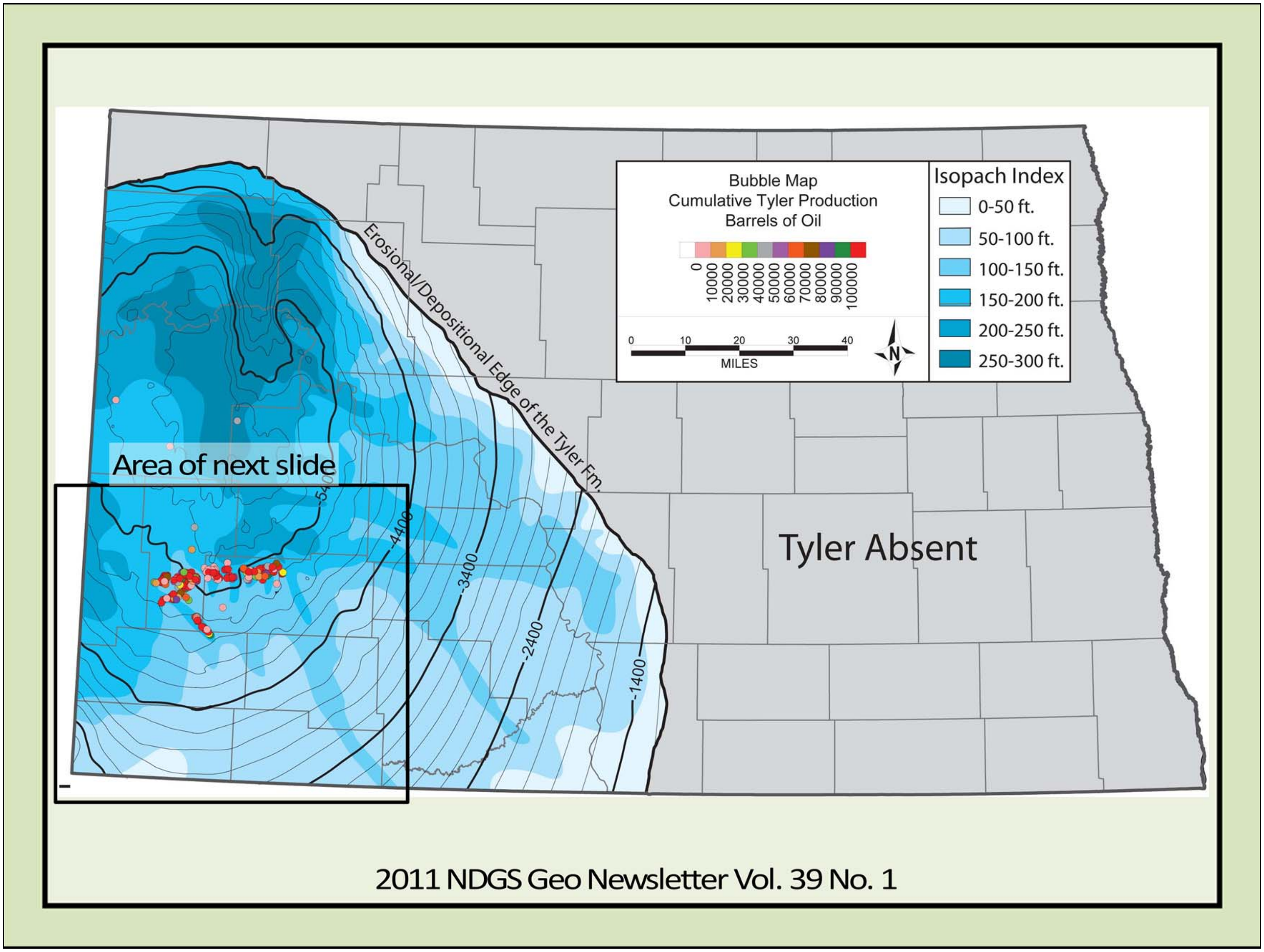


One of the better vertical Tyler wells was Continental Oil Company's Karsky-State #1. Spudded in 1967 in the Dickinson Field, Karsky-State produced over 1.7 million barrels of oil before being plugged and abandoned. As you can see in the illustrated core, the productive sand is typically located in the middle to upper portion of the Tyler section. In southwestern North Dakota the Tyler has been broken down by some into an upper and lower Tyler. The lower Tyler typically consisting of red to grey to vary colored shales and mudstone, and the upper Tyler consisting of interbedded grey to black shales and limestones. The productive sandstone is often described as being lenticular bar-type sand deposits.



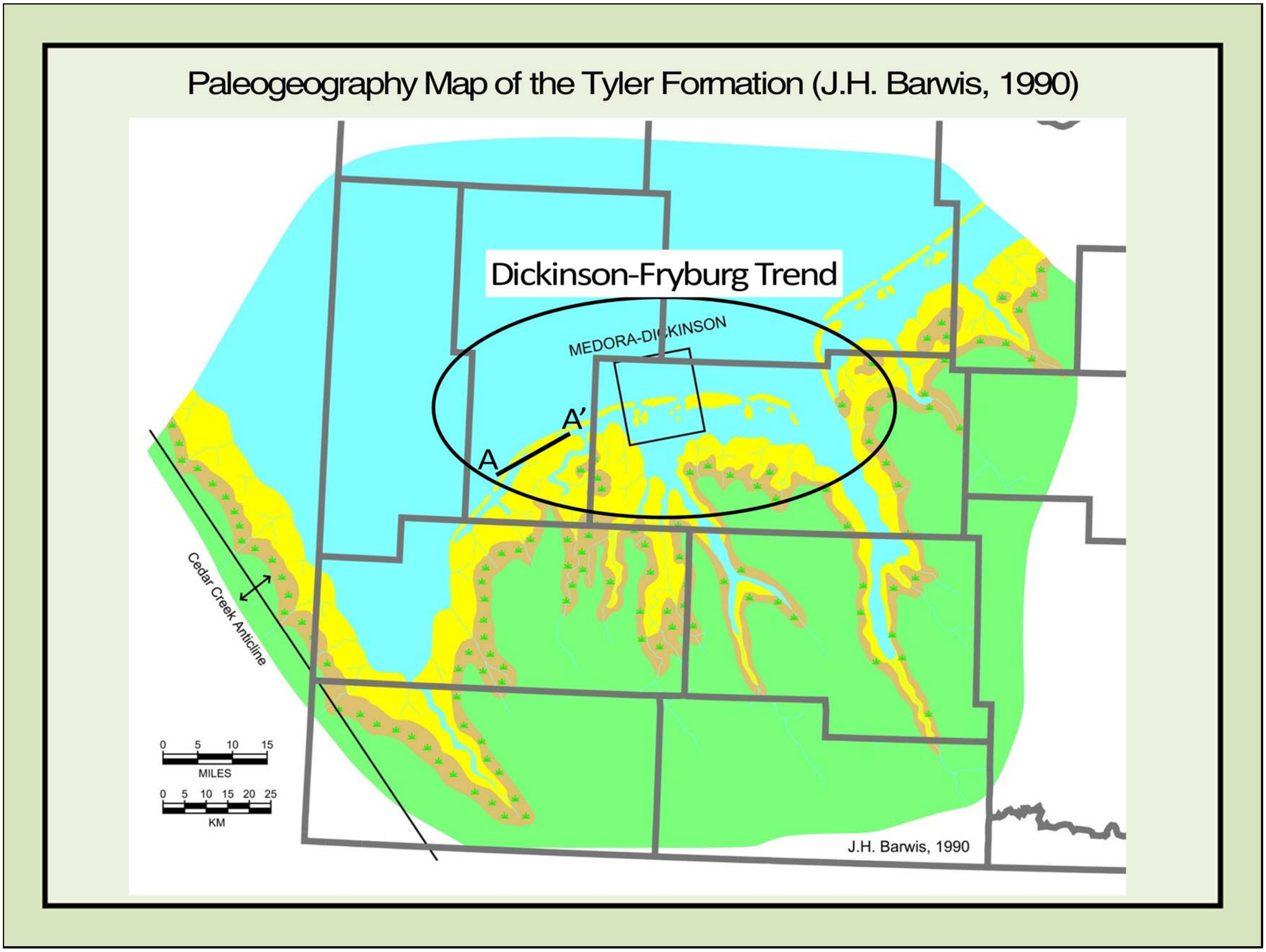
Looking at the yearly production history of the Tyler, peak production extended from the late 1960's to the late 1970's. Since then, Tyler production has been on an overall decline.

As a vertical target, the golden age of the Tyler has likely passed.



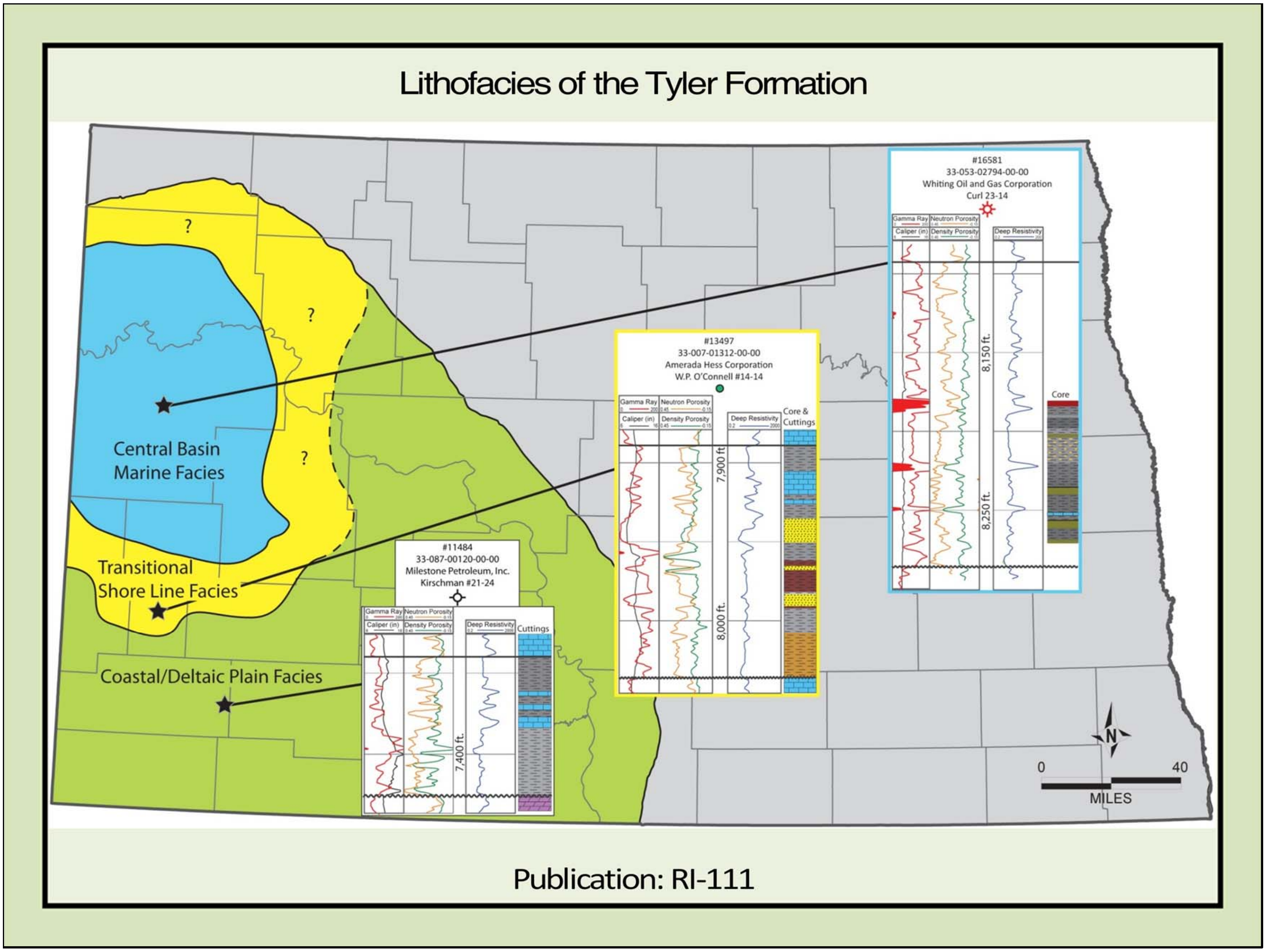
For this next map, Tyler structure contours are plotted overlying blue shaded isopach (thickness) intervals of the Tyler with the previously shown production bubbles. The thickness of the Tyler section varies from zero to around two hundred seventy feet thick in the deeper portions of the basin. The Dickinson Fryburg trend falls along where the Tyler is at its median thickness of around 150 to 170 ft. thick. Aside from that, there are a few oddball producers in the deeper part of the basin where the Tyler section thickens. These “oddball” producers out where the Tyler is thicker and deeper were one factor that indicates the Tyler petroleum system extends beyond the Dickinson-Fryburg trend.

So why has Tyler production been localized primarily to the Dickson-Fryburg trend so far? To answer that question, we will look at the geology of the Tyler starting with a paleogeographic map from the southwestern part of the state.



The Dickinson-Fryburg trend represents a southwest to northeast sand trend, where bar-type lenticular sand bodies have been preserved in the Tyler section which serve as the reservoir for most of the Tyler oil fields to date. North of this sand trend, the Tyler consists of more offshore marine deposits with limited sand. To the south, the Tyler contains primarily channel sand deposits, which aside from the Rocky Ridge Field, are often low permeability, low porosity sands or they are water productive.

So one reason for localized vertical Tyler production has been the localized distribution of the bar sand reservoir rock.



Somewhat expanding upon Barwis's paleogeography map, we are currently developing the idea that the Tyler can be separated into three broad, generalized facies.

In the deeper parts of the basin, the blue colored area, is the Central Basin Marine Facies is characterized by the presence of high-gamma ray, organic-rich, marine shales (marine based on some limited paleontological data (Grenda, 1977)).

Moving beyond the Central Marine Basin Facies, the high gamma ray intervals pinch out and discontinuous lenticular sand intervals become more common within the Tyler section. We are calling this sand-bearing area the Transitional Shoreline Facies.

Beyond the Transitional Shoreline Facies, sandstone becomes less common the in Tyler section and fresh water fossil assemblages become more common. We are referring to this third area in green as the Coastal/Deltaic Plain Facies.

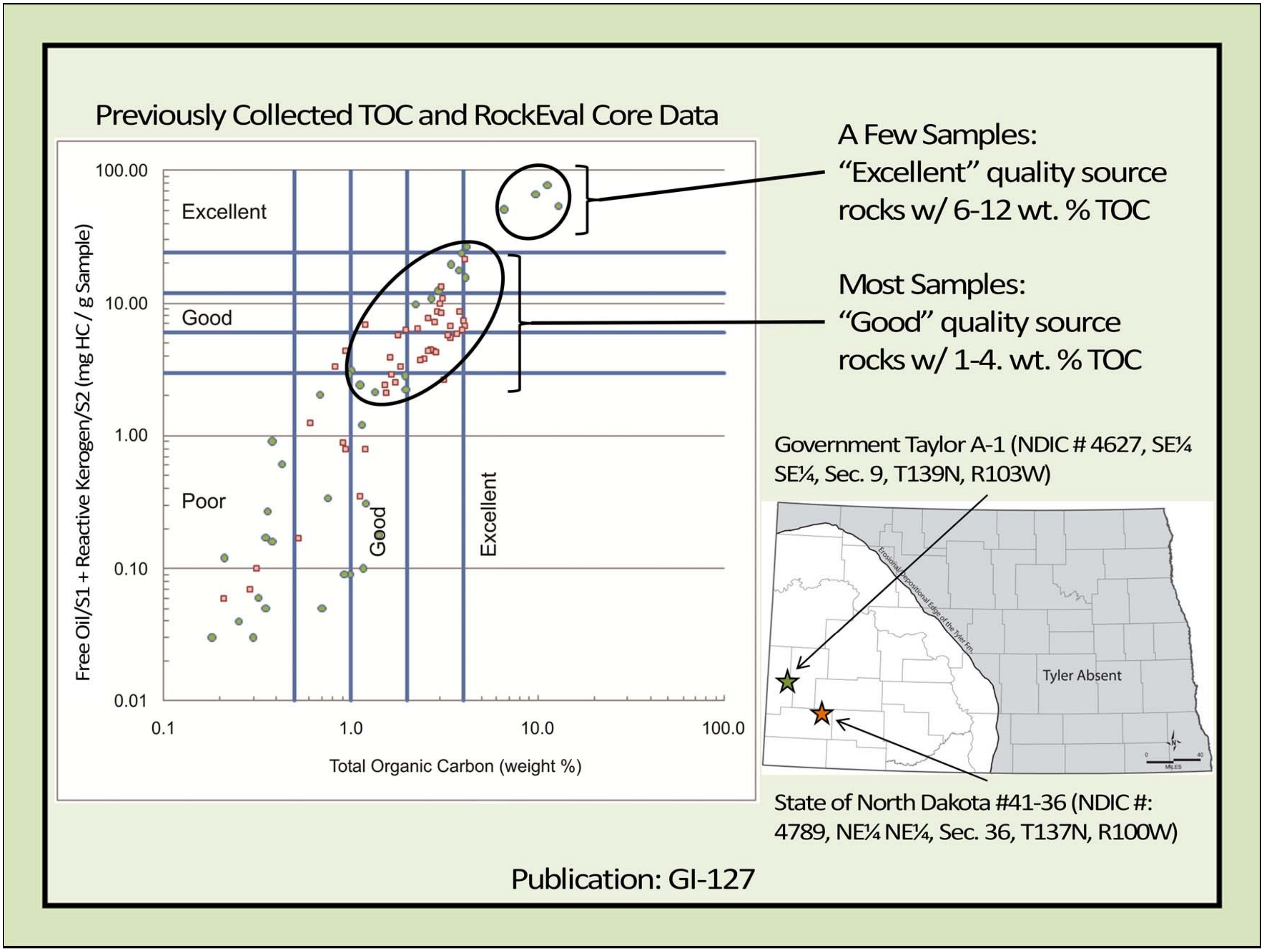
Hopefully to this point I've provided a sufficient summary of the geologic setting and the historical production for the Tyler Formation, and now we will take a look forward into what the Tyler might one day become.

Basin Centered Petroleum System

(Resource Play)

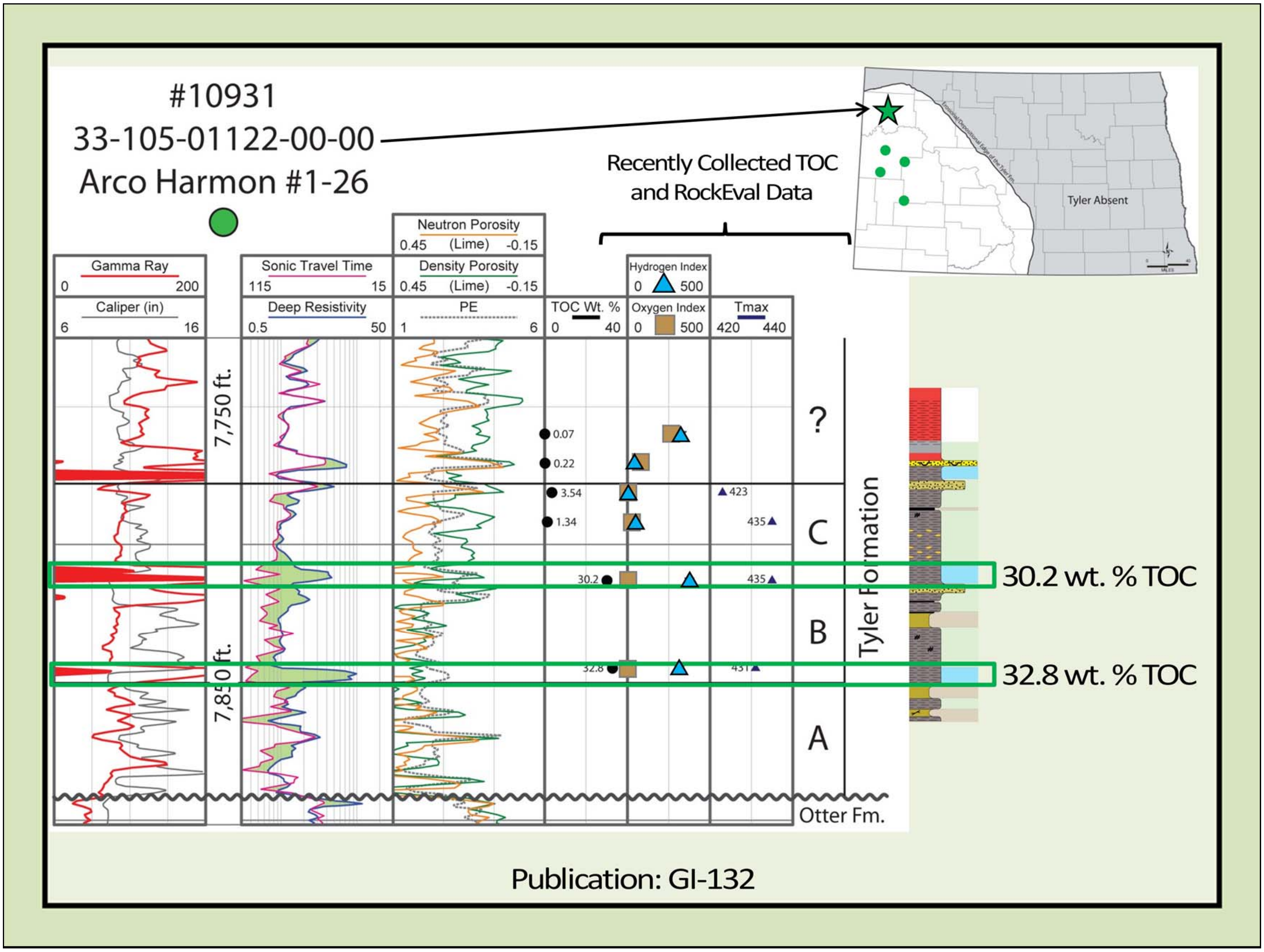
- **1) Regionally extensive organic-rich source rock**
  - -Kerogen Type (Oil vs. Gas)
- 2) Maturation of the source-rock (oil generation)
- 3) Expulsion of generated oil from source rock
- 4) Accumulation of expelled oil in adjacent rock
- *5) Extraction of oil from the reservoir rock*

The first essential component of a potential resource play we will review is the distribution of organic carbon within the Tyler.



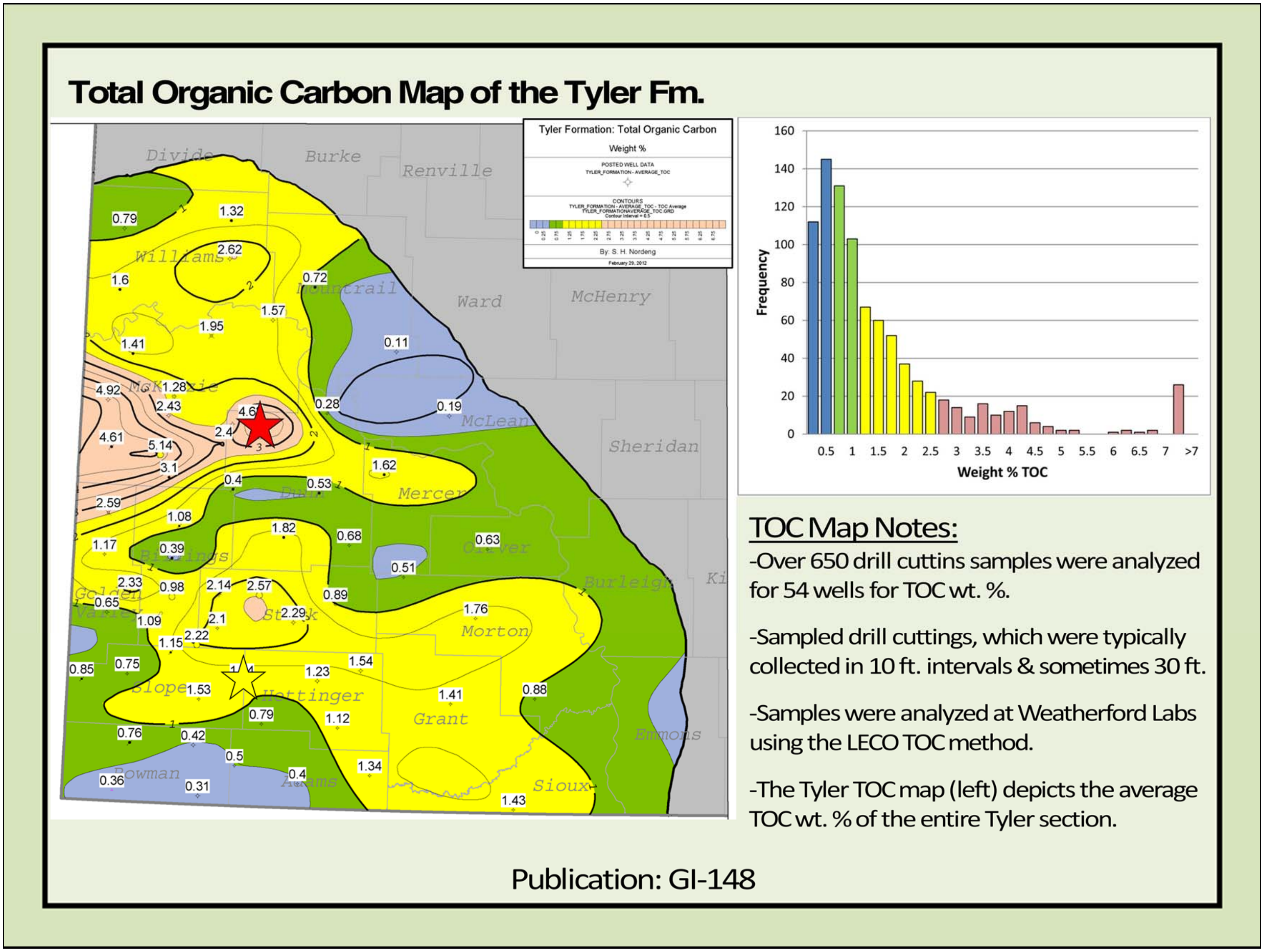
Two Tyler cores from southwestern North Dakota, the State of North Dakota #41-36 and Government Taylor A-1, were previously sampled and analyzed for TOC and RockEval data. As you can see on this organic-richness diagram that plots the S1, Free Oil, and S2, reactive kerogen, total versus Total Organic Carbon weight percentage, most of the samples from these two cores classified as "good" quality source rocks, with 1-4% TOC and a fair amount of S1 and S2. A few samples even classified as excellent quality source rock from the Government Tayler A-1.

Given some promise from these previously collect Tyler core data sets, we decided to do our own core sampling.



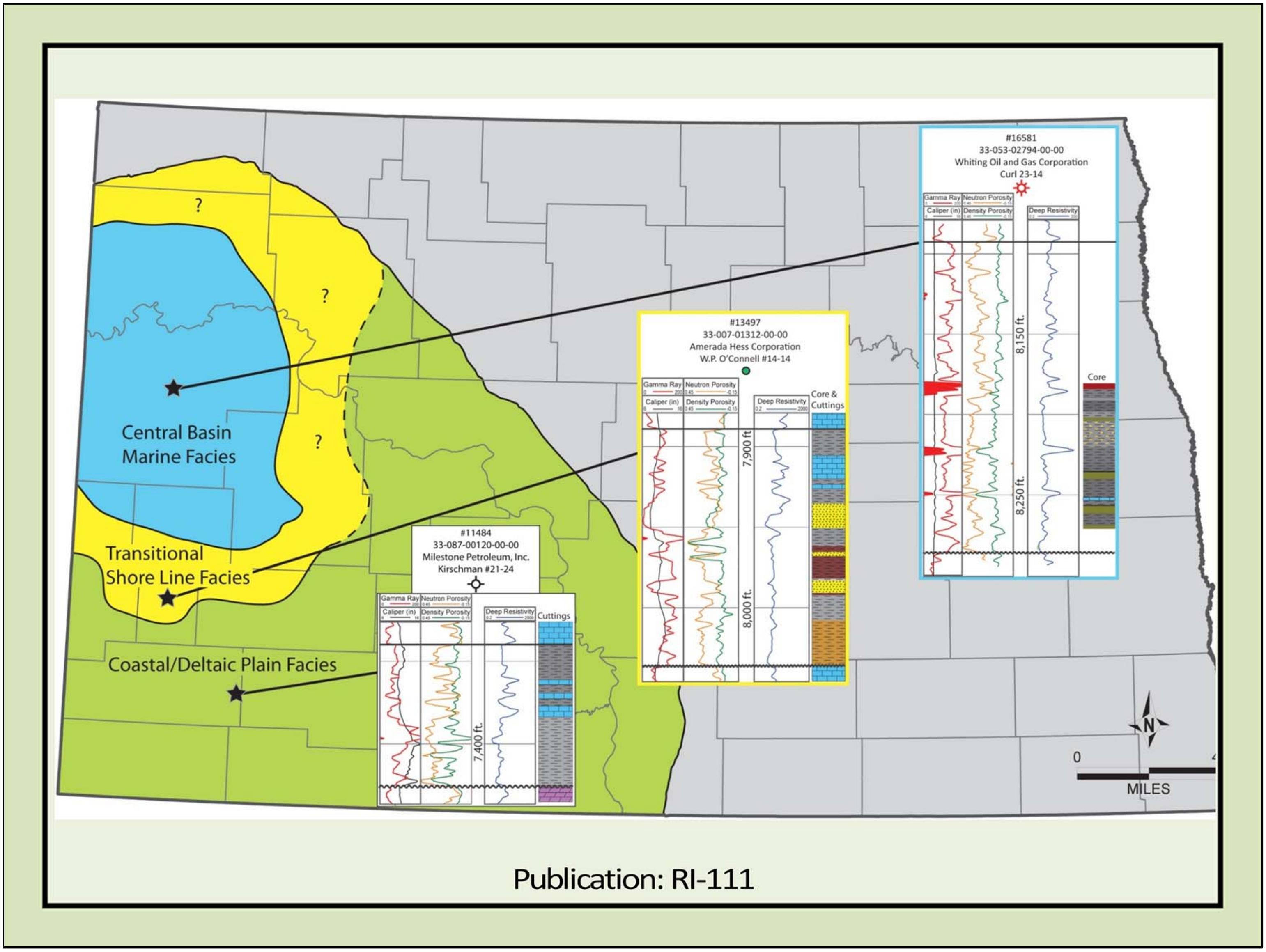
We collected samples from five different Tyler cores distributed across the basin for TOC and RockEval analysis. One of the more interesting data sets was from the Arco Harmon core from central Williams county. On the left hand side here is the gamma ray log for the Harmon well along with a cross-plot of deep resistivity and sonic travel time, which is based off of Passey's method that uses log analysis to determine organic-rich intervals. On the right is the RockEval data from the Harmon core.

Four samples from the upper portion of the core had around zero to three and a half weight percent TOC. Three and a half isn't to bad, but the low hydrogen index values, the blue triangles, indicate the kerogen in these samples is inert and incapable of generating any hydrocarbon. The lower two samples from the core though each had around 30% TOC, which being Pennslyvanian could be coal. However, high hydrogen index values of around three to four hundred, blue triangles, and extremely low oxygen index values, brown squares, indicate these samples are oil-prone source rock. Furthermore, these lower two samples correlate with gamma ray spikes and organic-rich intervals indicated by Passey's method.

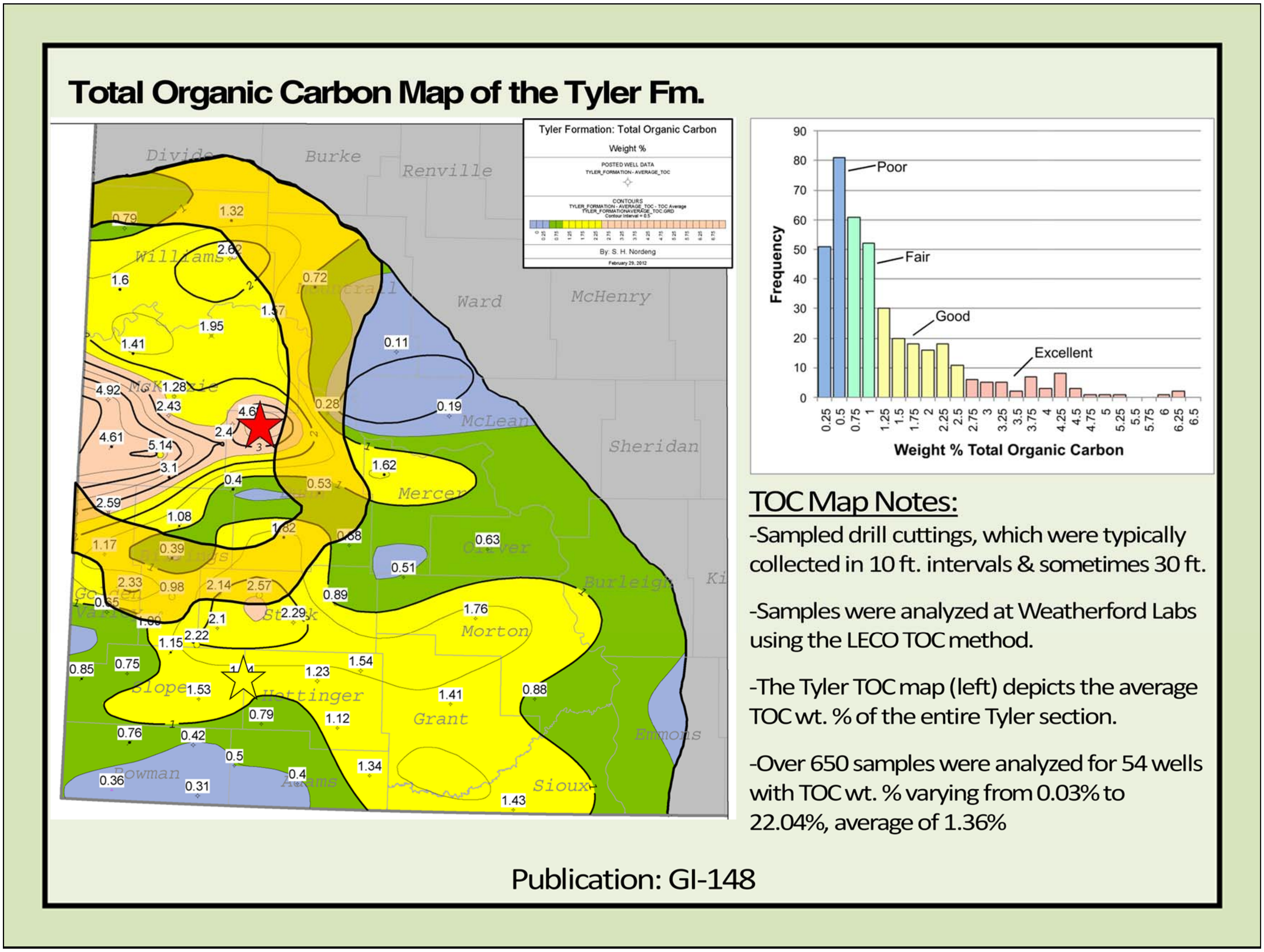


Our next step was to examine the distribution of total organic carbon within the Tyler Formation throughout the Williston basin of North Dakota. To complete this study, we had to sample drill cuttings. Through two rounds of sampling, we collected over 650 drill cuttings samples of the Tyler section from 54 wells. Each drill cutting sample was analyzed for its Total Organic Carbon weight percentage at Weatherford labs. For each well we sampled the entire Tyler section, the red beds along with the black shales and sandstones.

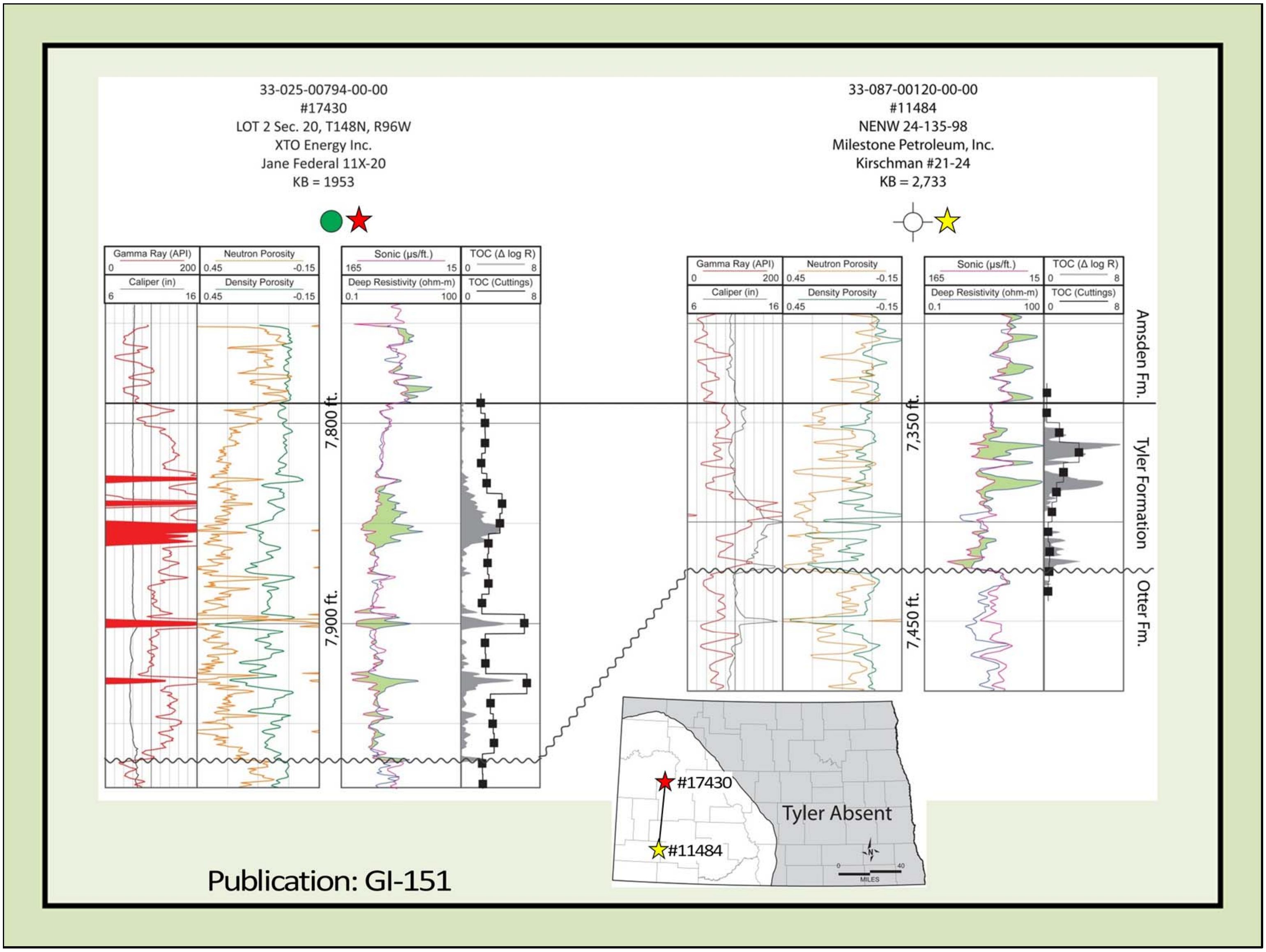
The "Total Organic Carbon Map of the Tyler Formation" as displayed was contoured using the average TOC wt. % from each well. Again, we averaged the red beds along with the black shale samples. As you can see, the area with the highest TOC concentration, the red shaded area, is in McKenzie and northwestern Dunn counties, where the Tyler averages as an excellent quality source rock, greater than 2.5% TOC. Throughout the yellow area the Tyler also has significant TOC content which extends throughout a large area.



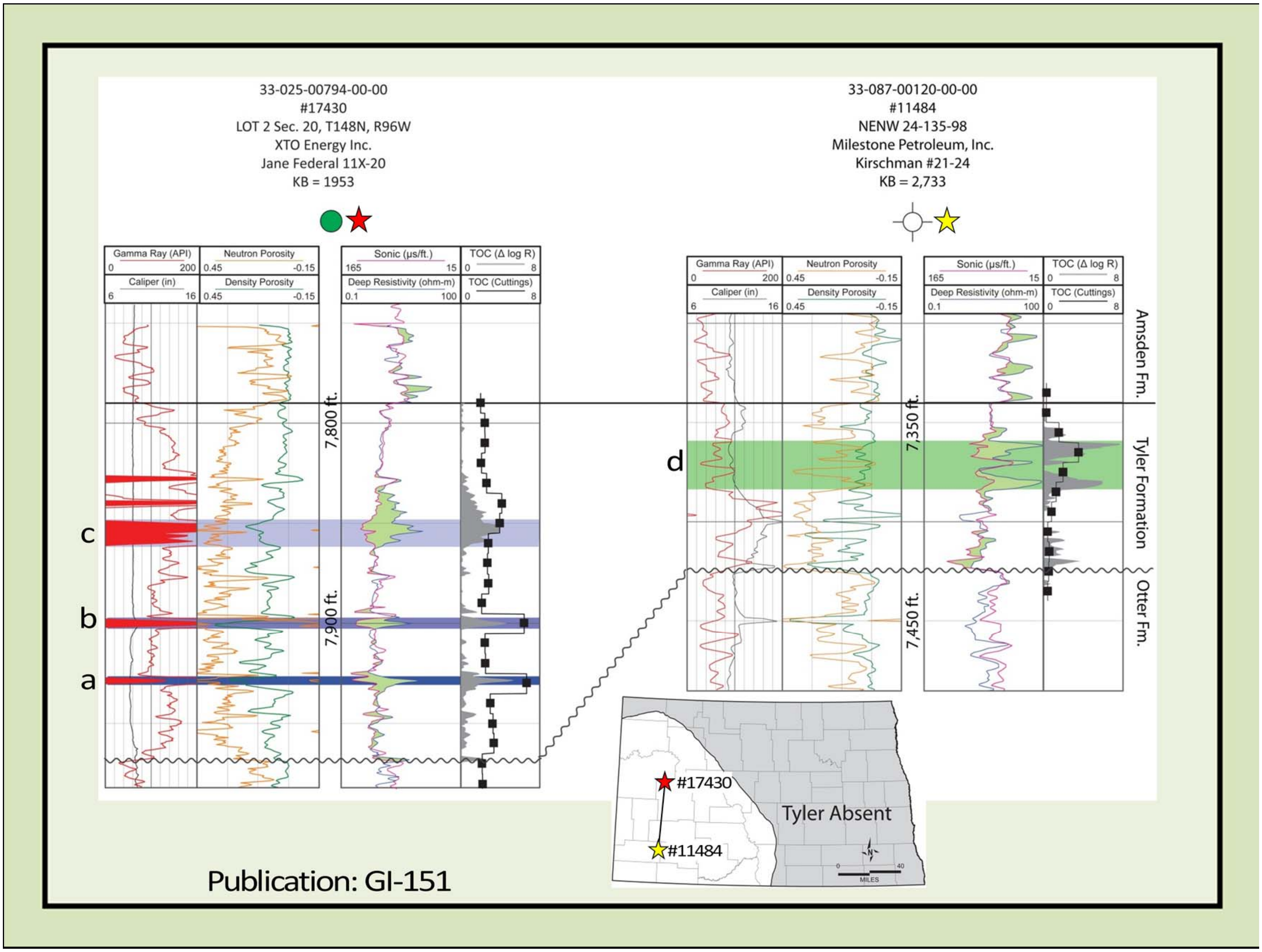
Going back to the generalized facies map, and tracing the Transitional Shore Line Facies . . .



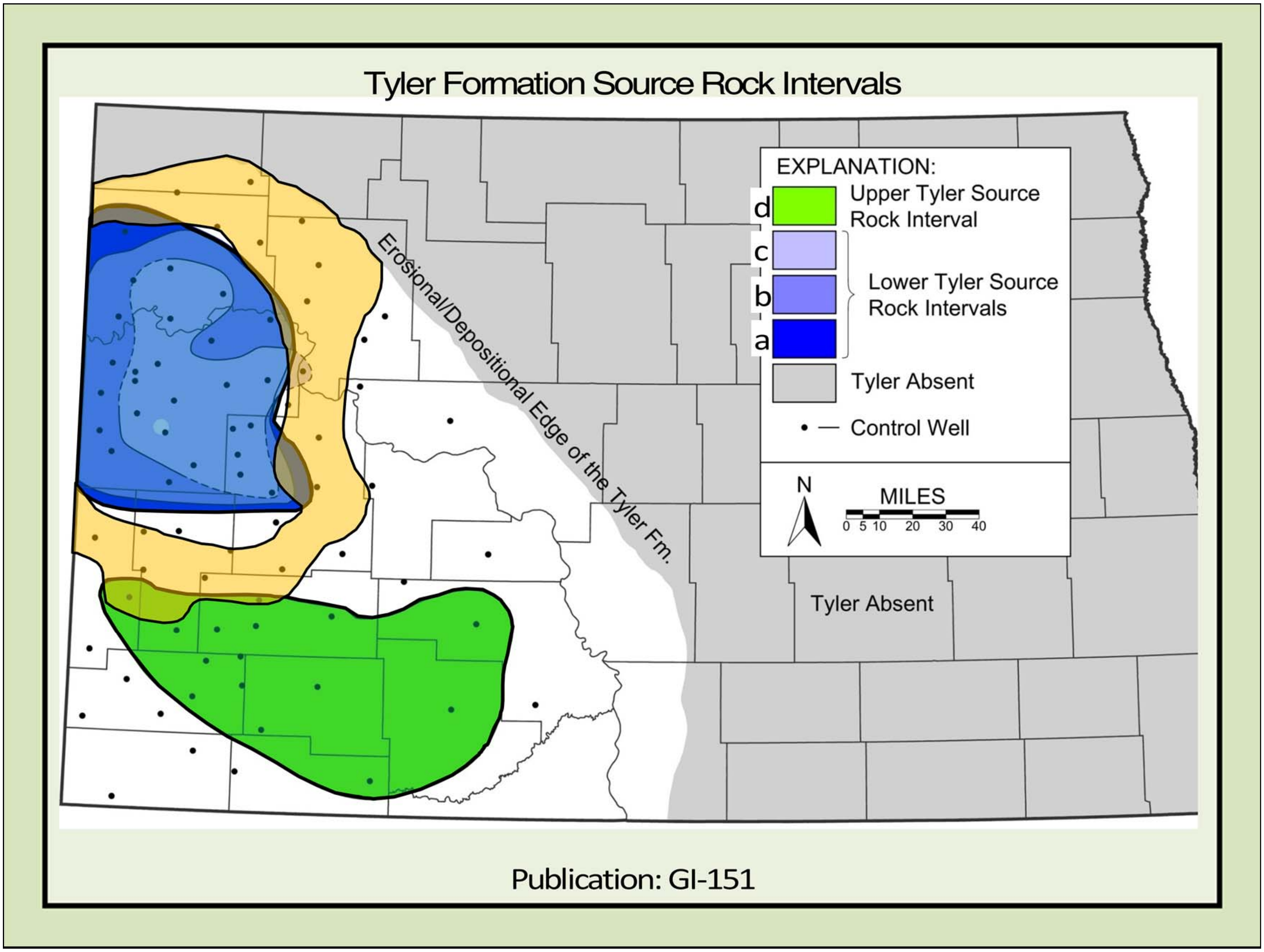
. . . And dropping the Shore Line Facies on the TOC map, it looks like the transition from high to low TOC content in parts of the basin occurs along the Transitional Shore Line Facies area. The organic-rich area in west-central North Dakota occurs within the Central Marine Basin Facies. And a second organic-rich trend occurs beyond the sandy Shore Line Facies along a northwest-southeast trend in the Coastal/Deltaic Plan Facies. The Dickinson-Fryburg trend is located where the Shore Line Facies overlaps the southern organic-rich area.



Here are wire line logs and TOC data for two wells. The Jane Federal from northwestern Dunn County has three intervals with high TOC content. All three of these intervals correlate with gamma ray spikes and can be identified using Passey's Delta Log R technique, which calculates Total Organic Carbon using a porosity log in combination with deep resistivity. The Kirschman well, from eastern Slope county in the southwest, has one organic-rich interval in the upper Tyler which averages 3-5 wt. % TOC while it is organic-lean in the lower section. The gamma ray signature of this interval is very low, however, Passey's method can be used to identify this interval quit nicely.

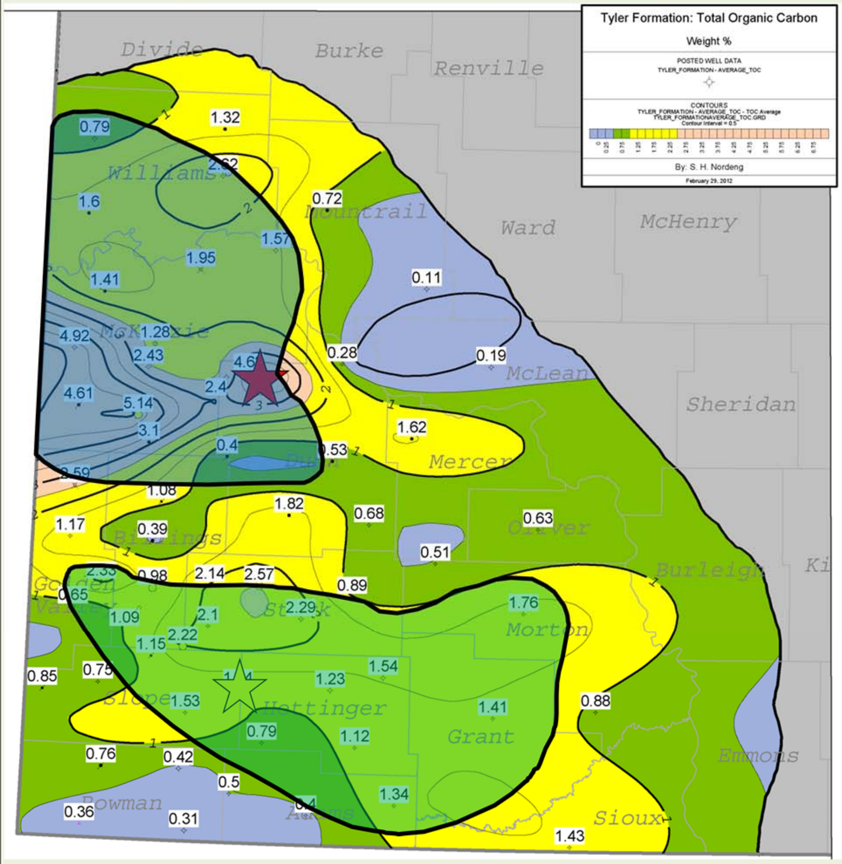


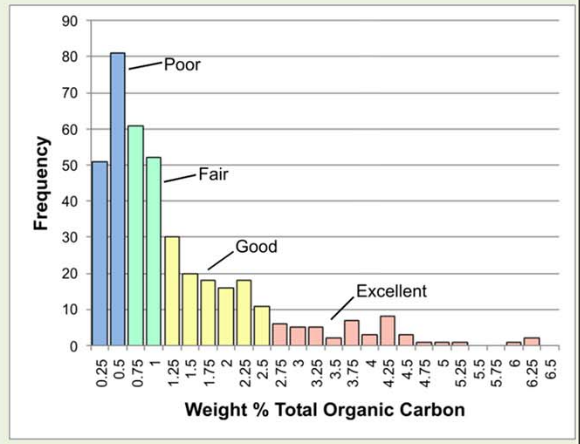
So while the Tyler averages around 1.3 wt. % TOC, it contains intervals that may average upwards of 10 to 20% TOC in west central North Dakota and an interval of 3-6% TOC in the southwest.



Mapping out the extent of these organic-rich, source rock intervals using the TOC data in combination with the wire log Passey method, these source rocks are quit extensive throughout the state. The green area represents where the upper Tyler contains that 20-30 ft. interval of 2-6% TOC. The blue-purple areas are where the lower Tyler contains 2-3 intervals, 4 to 20 ft. in thickness, with 3-20 Wt. % TOC.

Total Organic Carbon Map of the Tyler Fm.





TOC Map Notes:

-Sampled drill cuttings, which were typically collected in 10 ft. intervals & sometimes 30 ft.

-Samples were analyzed at Weatherford Labs using the LECO TOC method.

-The Tyler TOC map (left) depicts the average TOC wt. % of the entire Tyler section.

-Over 650 samples were analyzed for 54 wells with TOC wt. % varying from 0.03% to 22.04%, average of 1.36%

Publication: GI-148

Taking the mapped source rocks back to the TOC map, the source rocks overlap with where the entire Tyler section averages greater than 1 wt. % TOC.

Basin Centered Petroleum System

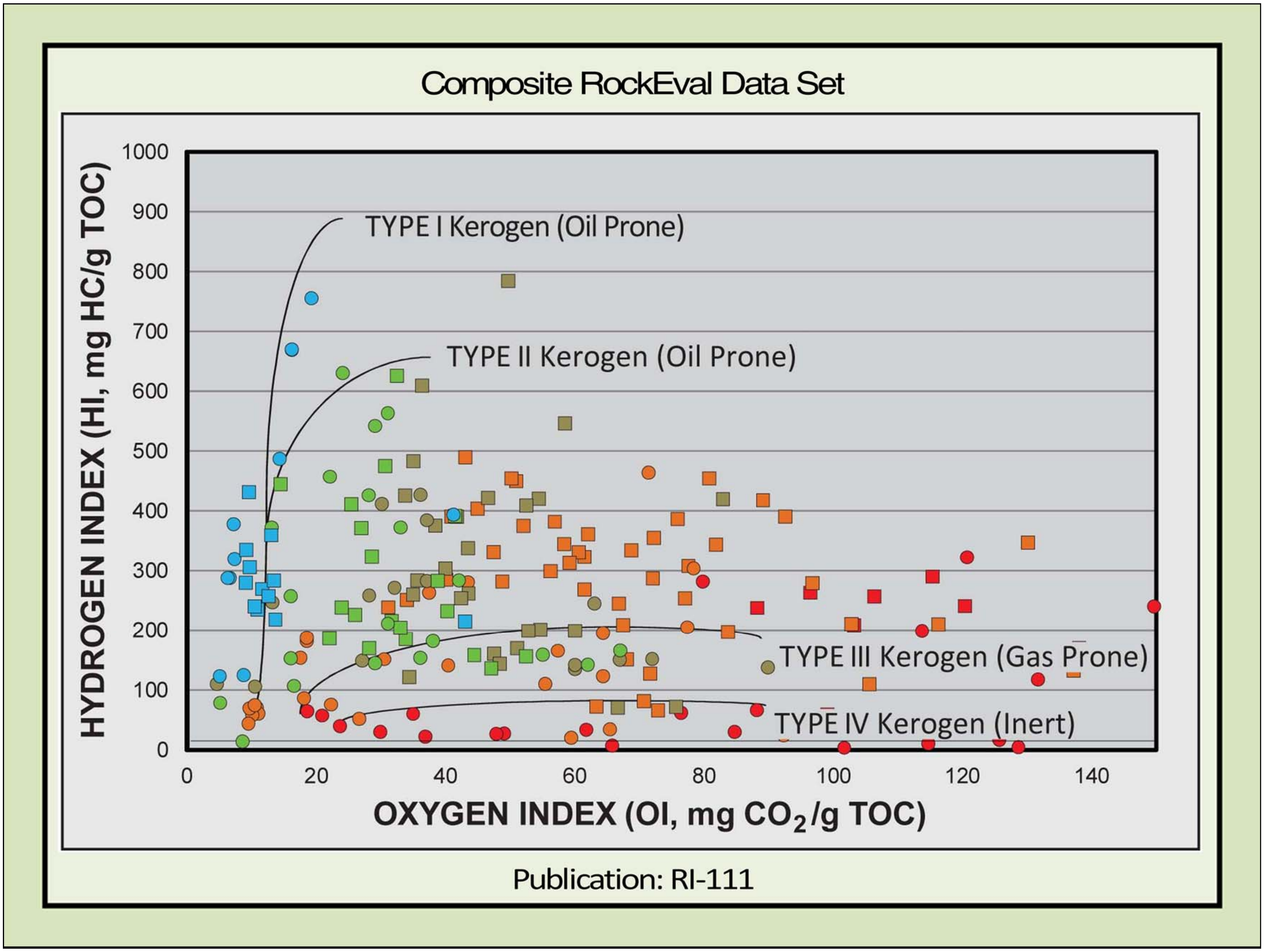
(Resource Play)

- 1) Regionally extensive organic-rich source rock ✓

    -Kerogen Type (Oil vs. Gas)

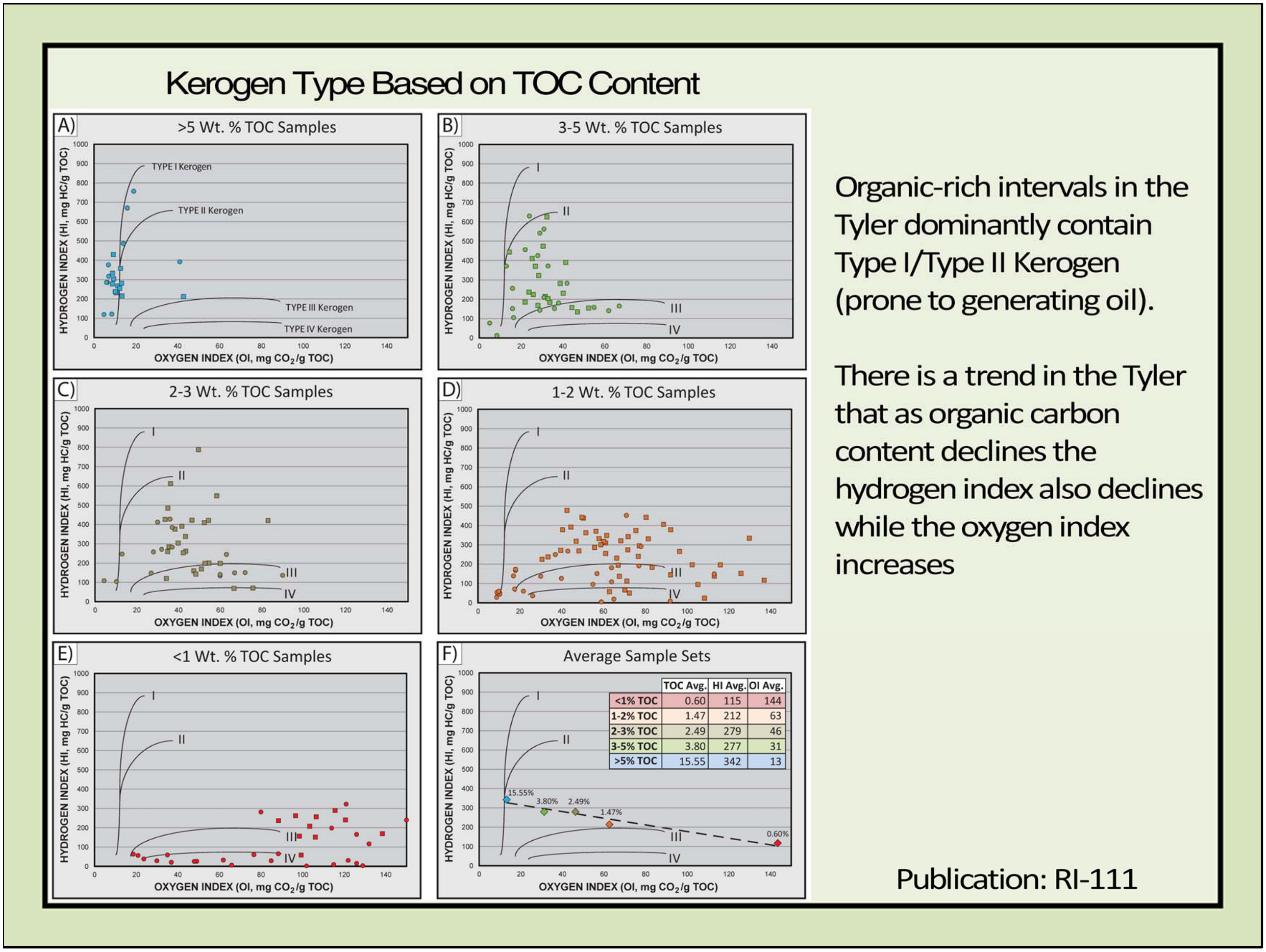
- 2) Maturation of the source-rock (oil generation)
- 3) Expulsion of generated oil from source rock
- 4) Accumulation of expelled oil in adjacent rock
- *5) Extraction of oil from the reservoir rock*

Now that we’ve established that the Tyler contain regionally extensive, organic-rich intervals, we will take a look at the kerogen type.



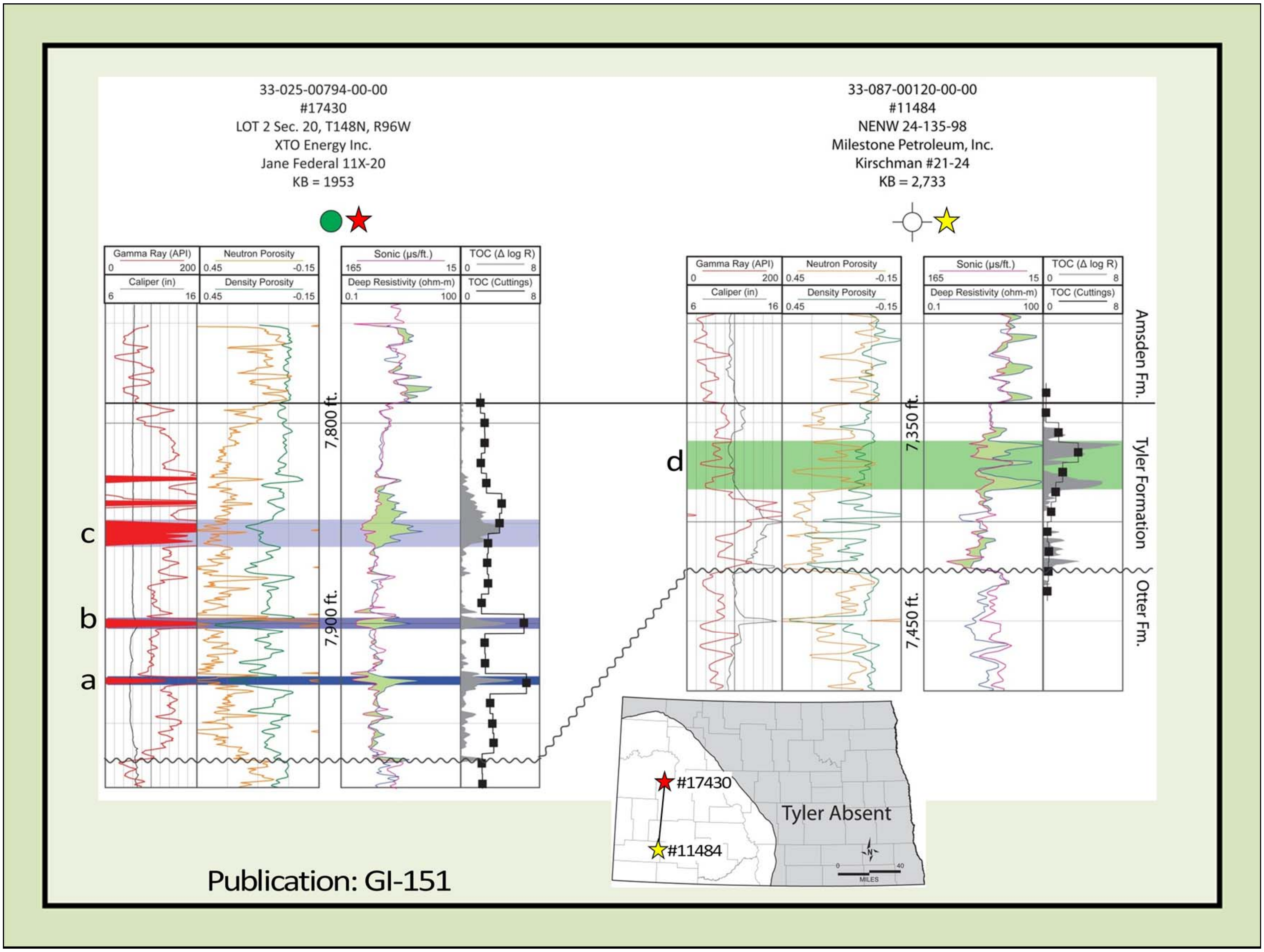
This next diagram is a modified Van Krevelan Diagram that plots the Hydrogen vs. Oxygen Index values from the RockEval data. Circles show core samples while the squares show drill cutting samples.

As you might notice, there is quite a spread in the data, with samples ranging from Type I/Type II oil prone kerogen to Type III Gas prone and Type IV inert kerogen. However, you may also notice a color scheme within the plotted data set.



Dividing the RockEval data based on TOC content, samples with greater than 5 wt. % TOC mostly fall along the Type I/Type II kerogen curve indicating that the more organic-rich intervals are prone to generating oil. As TOC content declines, the Kerogen type transitions from a Type II/Type III mix to a Type III/Type IV mix for samples with less than 1 wt. % TOC.

So while is a quit a bit of variation in kerogen types in the Tyler Formation, the more organic-rich intervals are prone to generating oil.



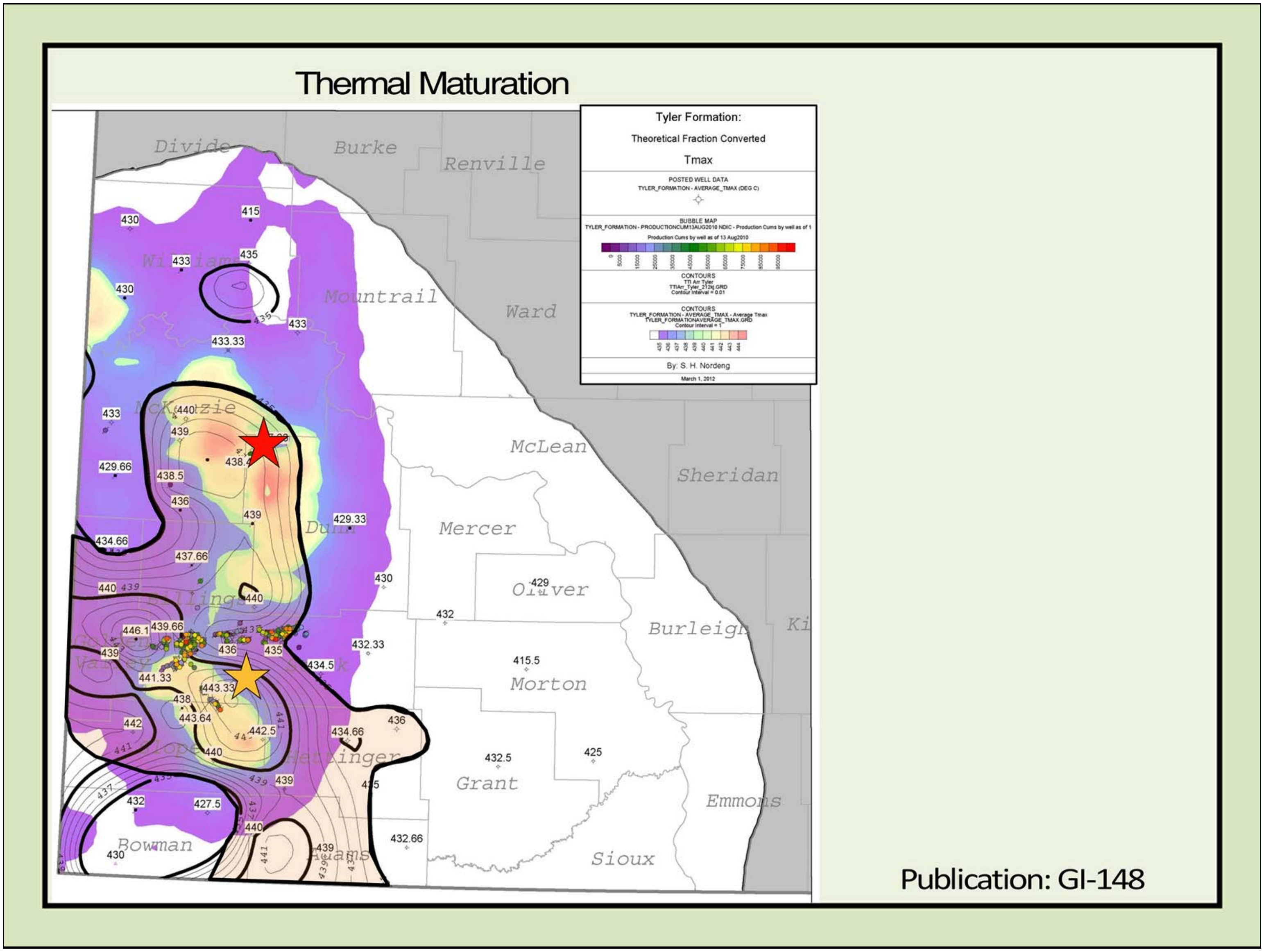
Therefore, the source rocks that were previously defined in this talk are likely prone to generating oil.

Basin Centered Petroleum System

(Resource Play)

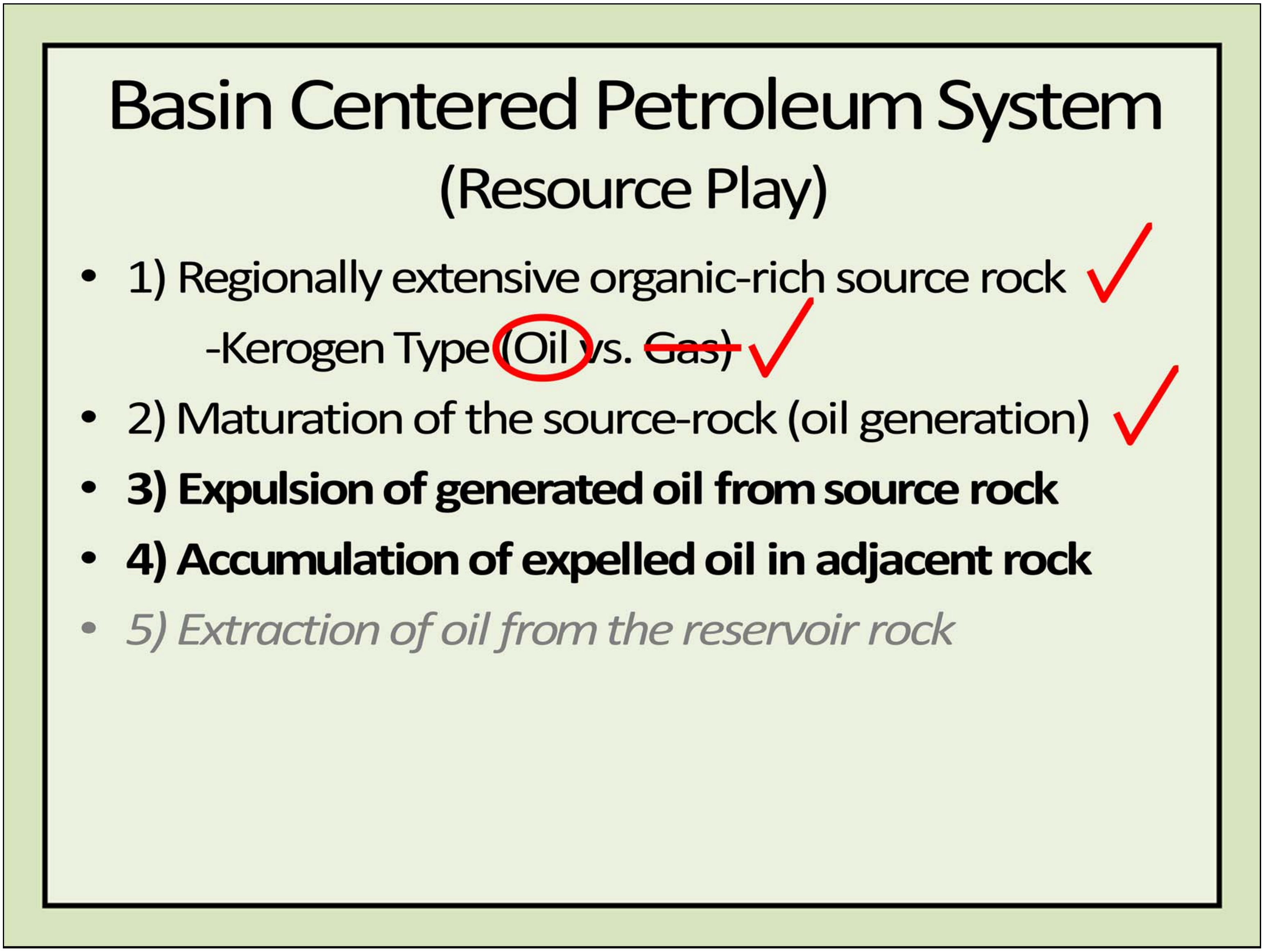
- 1) Regionally extensive organic-rich source rock ✓
  - -Kerogen Type (Oil vs. ~~Gas~~) ✓
- **2) Maturation of the source-rock (oil generation)**
- 3) Expulsion of generated oil from source rock
- 4) Accumulation of expelled oil in adjacent rock
- *5) Extraction of oil from the reservoir rock*

Next we'll look at where the Tyler may be thermally mature and has undergone intense oil generation.



To examine the Thermal Maturity of the Tyler, we've completed a few different studies, two of which are shown on the displayed map. Steve Nordeng, the co-author of this talk put quit a bit of work into modeling the thermal history of the Williston basin in part to generate a time-temperature index of the Tyler Formation which is displayed by the purple-green-yellow-red shaded areas. The purple regions are where the Tyler has begun to enter the oil window and the brightly colored yellow to red areas are where it has likely undergone the most intense oil generation based on the TTI Map. There are three of these brightly colored areas.

A second way we examined thermally maturity was plotting and contouring the Tmax values from the drill cutting and core samples RockEval data. Tmax values of 435 and above typically indicate a sample has undergone intense oil generation. Contouring the average Tmax from approximately 45 of the wells we sampled, and shading the area enclosed by the 435 Tmax contour, the Tmax "intense" oil generation window overlaps with the two of the brightly colored areas from the TTI modeling, indicating the area in southwestern Williams County may not be as thermally mature as the TTI map indicates. Also, while there is some indication by our maps that the Tyler is thermally mature in western Bowman County, down in the southwest corner of the state, this is likely an edge effect from our computer contouring program.



So now we've established that the Tyler likely contains organic-rich, oil-prone, thermally mature source rocks. The next question is, where has the generated oil gone? Has it been expelled from the source rock and accumulated in adjacent, low permeable rock intervals, waiting to be extracted? Or has most of the generated oil migrated out of the Tyler section?

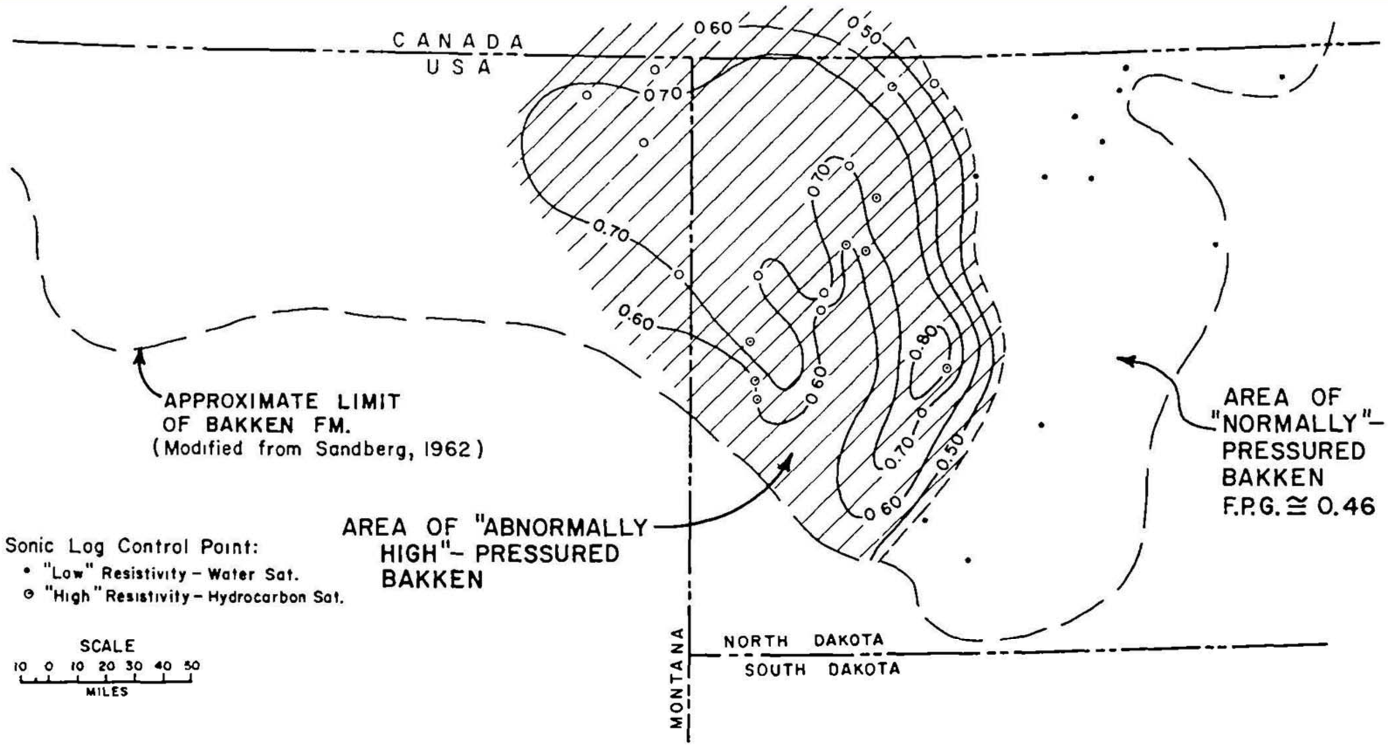


FIGURE 15

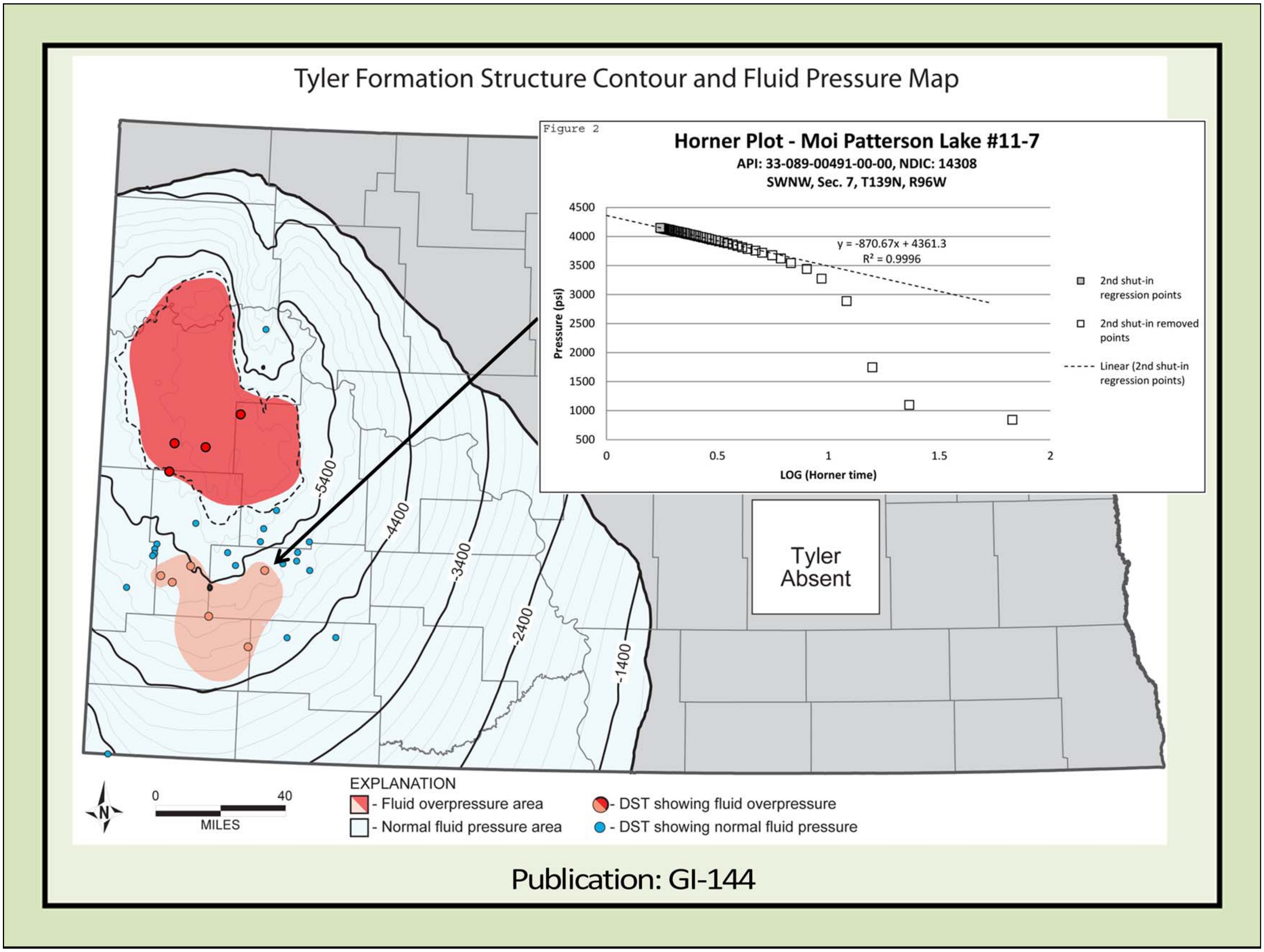
Aerial distribution of pore-fluid gradients in the Bakken Formation and areas of "normal" and "abnormally-high" pressure. Note coincidence of "low" electrical resistivity with "normal" pressure and "high" resistivity with "abnormally-high" pressure. Compare area of abnormally-high pressure with area of interpreted source-rock maturity indicated in Fig. 10.

(Meissner, 1978)

Fluid pressure analysis is one method that can aid in addressing oil migration.

Previously, Meissner examined fluid pressures in the Bakken Formation, and found that in the deeper part of the Williston Basin the Bakken has abnormally high fluid pressure (>0.46 psi/ft.) and normal, or hydrostatic fluid pressure in shallower parts of the basin (≈0.46 psi/ft.). Meissner attributed the abnormally high fluid pressure to intense oil generation by the upper and lower organic-rich shales of the Bakken Formation, generated oil that moved into adjacent, low permeable rock which overcharged the formation fluid system thereby causing the overpressure.

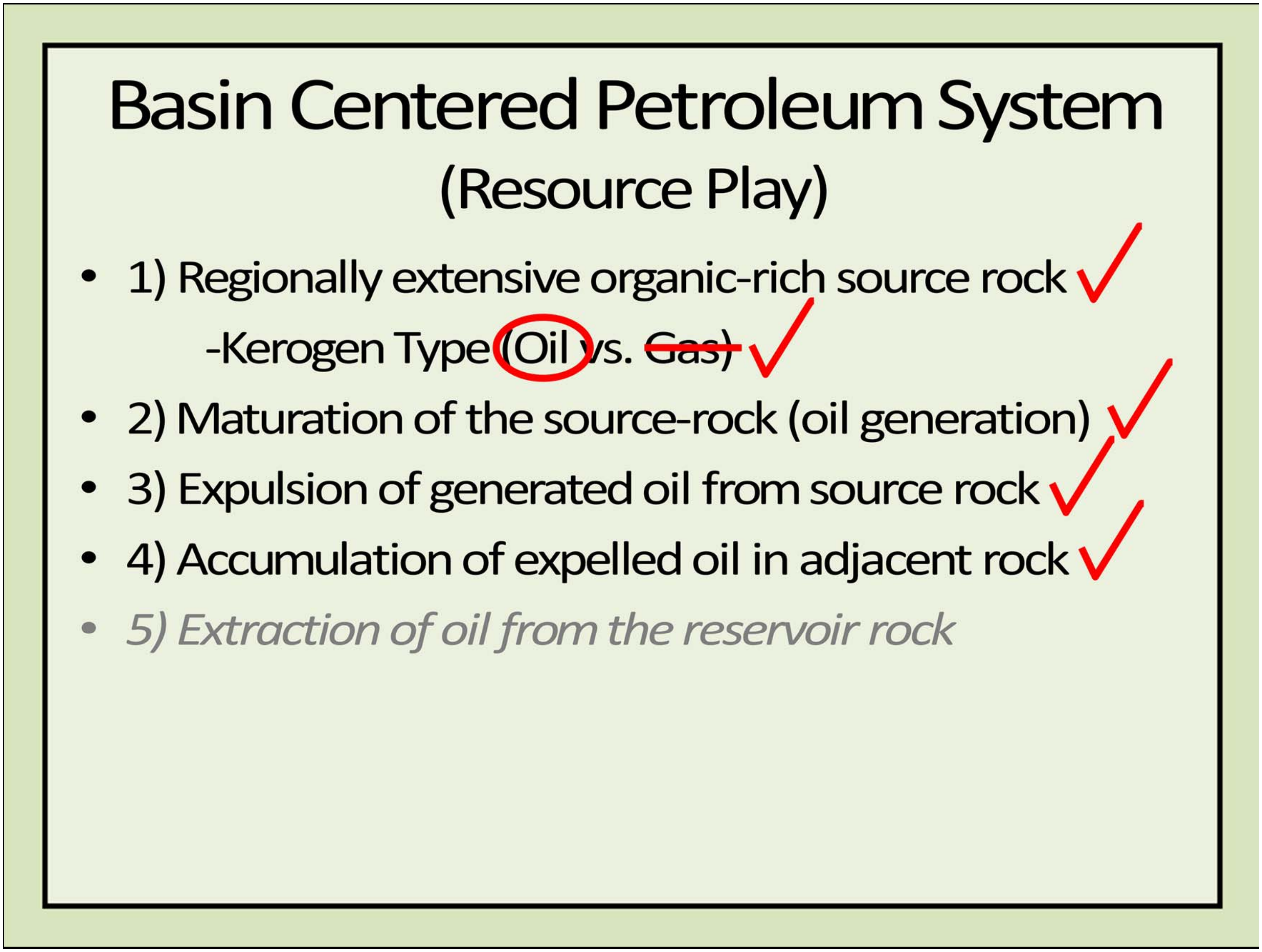
Today, the overpressured area of the Bakken Formation modeled by Meissner is essentially one giant oil field that is currently under development, because the Bakken generated oil was unable to significantly migrate out of the Bakken petroleum system.



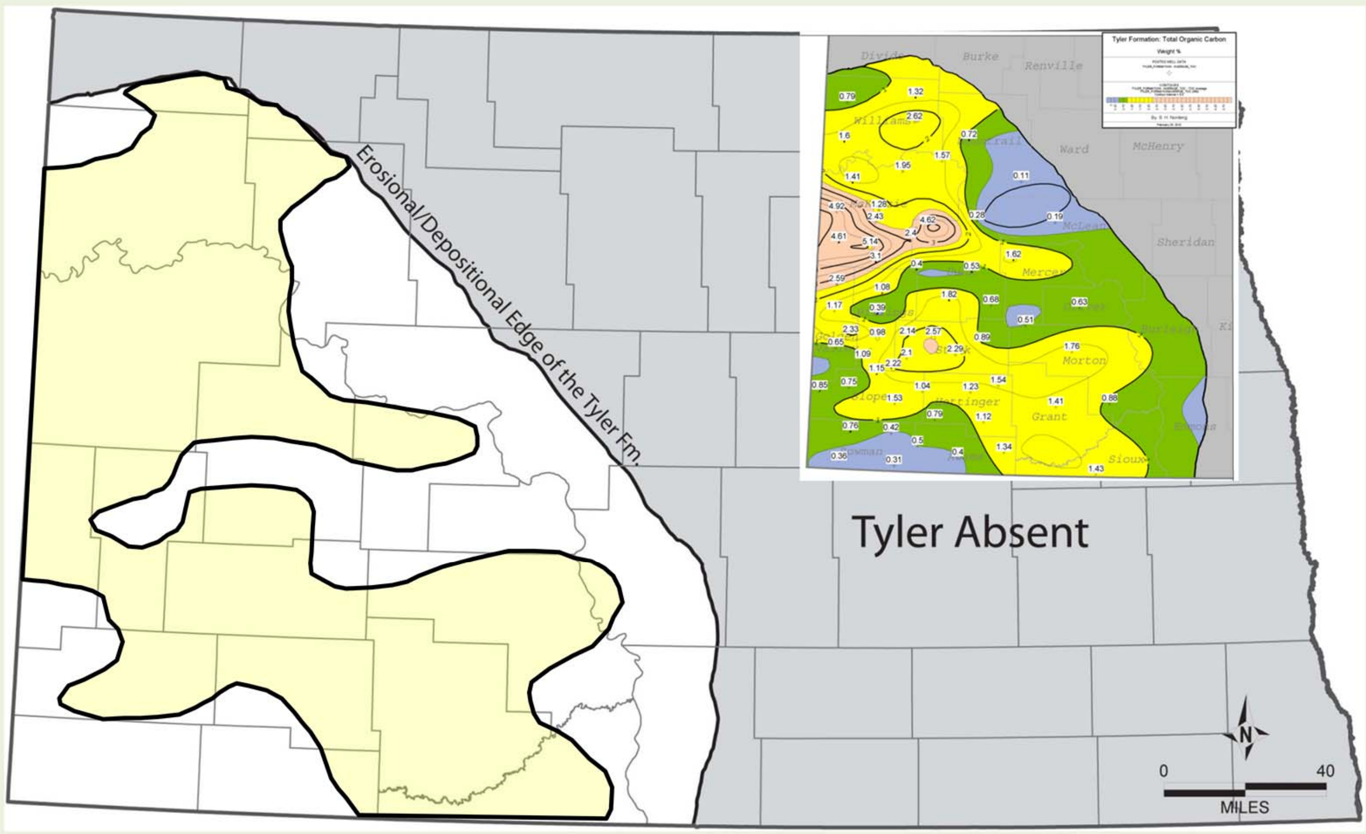
We decided to do a similar study of the Tyler Formation. The above map is a fluid pressure map of the Tyler Formation with red areas showing where the Tyler is overpressured and blue areas, normal pressure. This map was generated using 30 Drill Stem Test's (DST's) run on the Tyler Fm. from wells drilled as either wildcats, wells in fields removed from Tyler production and injection, or wells from producing fields that were drilled prior to significant production and before any injection.

20 of the DST's indicated the Tyler Formation was at normal, or hydrostatic pressure, and produced primarily formation water. Those wells are shown by the blue dots. 10 of the DST's, however, demonstrated fluid overpressure and produced oil and/or gas with minimal water. Wells with Tyler overpressure are shown by the red dots, which indicate that there are two regions of fluid overpressure within the Tyler that are spatially separated. The northern area of fluid overpressure was estimated using the -5,650 ft. sub-sea level contour while the southern region was estimated using control points.

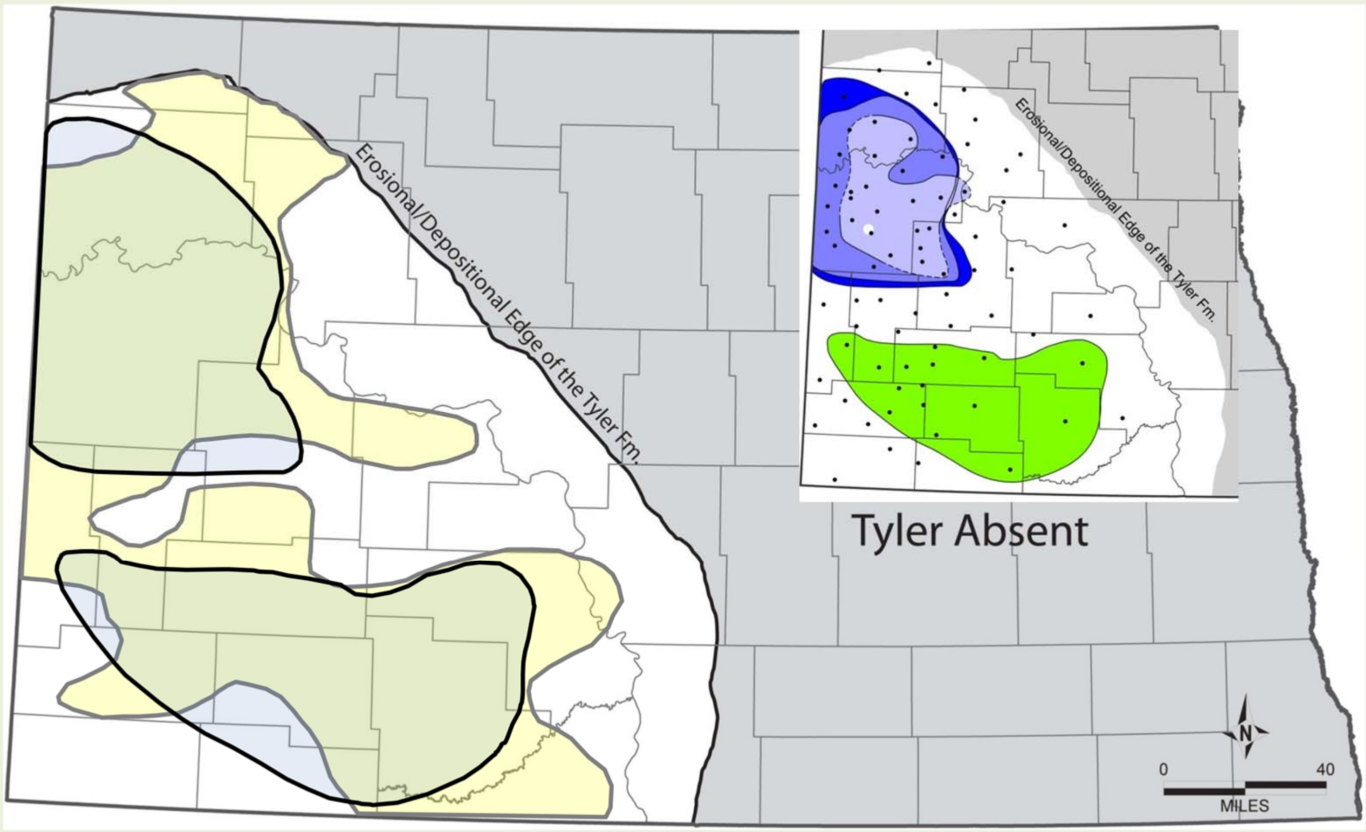
The areas of regional fluid overpressure indicate that the oil generated by Tyler source rocks has accumulated in adjacent, low permeable rock, and that it has not significantly migrated out of the Tyler system.



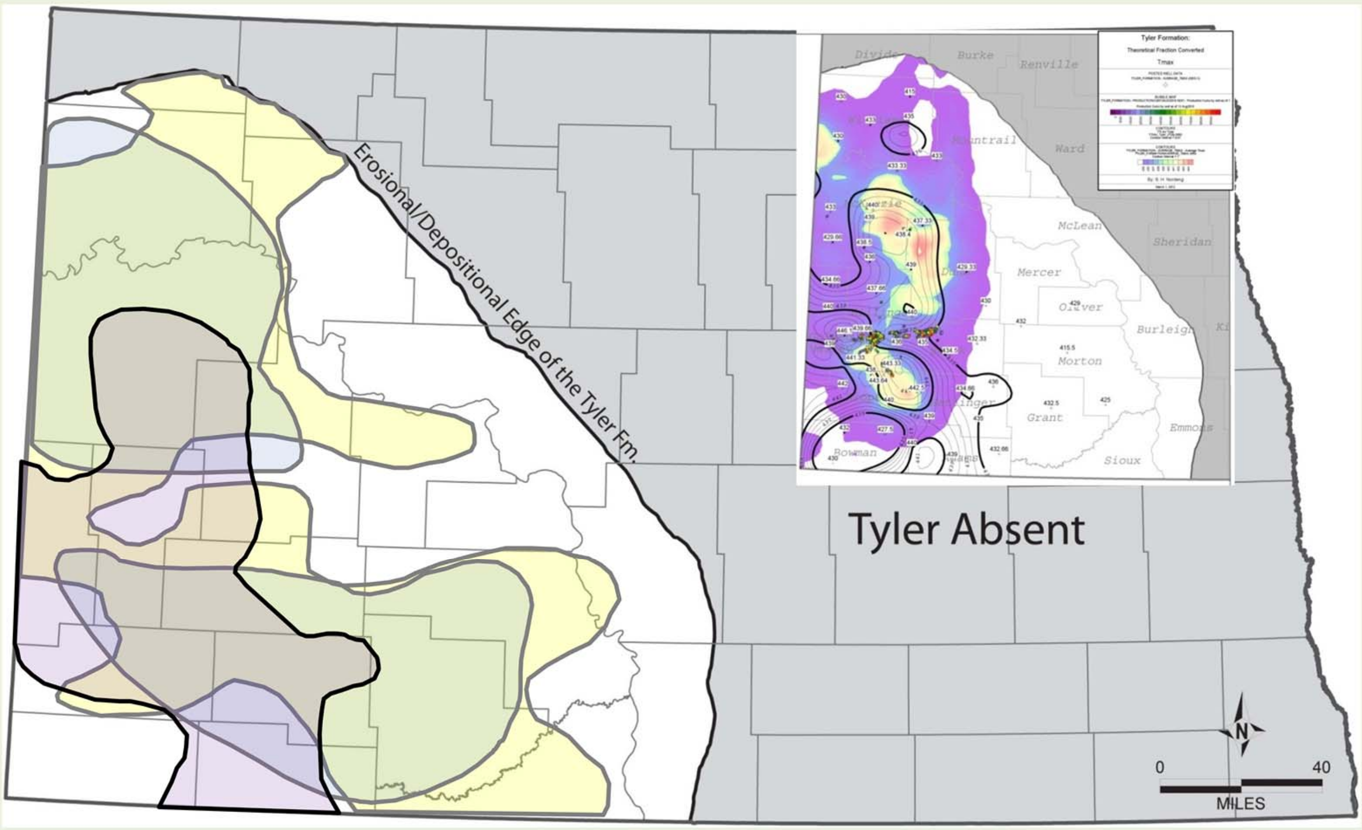
So now that we've established the Tyler contains the necessary components to be an oil-producing resource play, we'll put all the components together to look at where oil extraction may be a worth while endeavor.



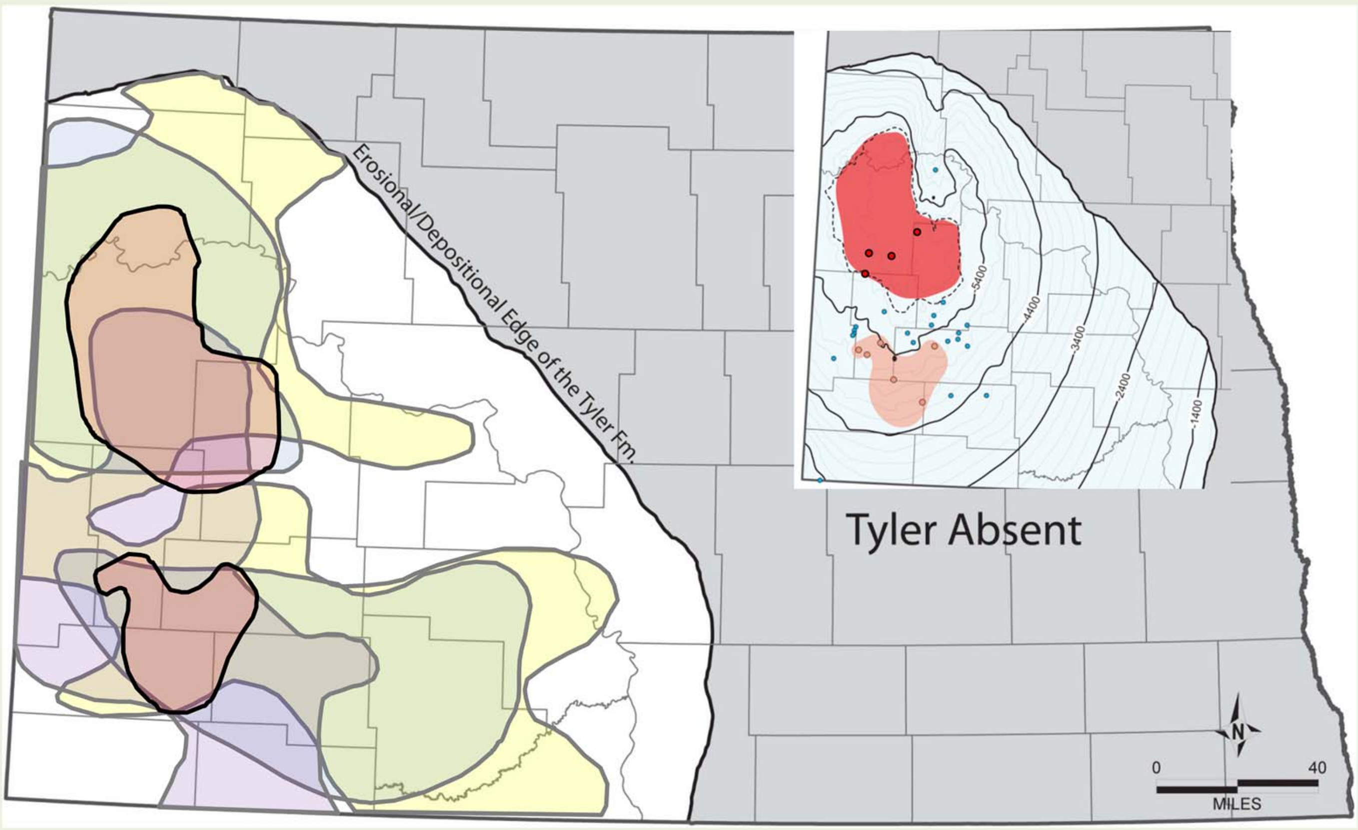
The first layer to add in is the Total Organic Carbon Map. For this exercise, we will consider the area where the entire Tyler section averages greater than one percent Total Organic Carbon, shown by the yellow shaded area.



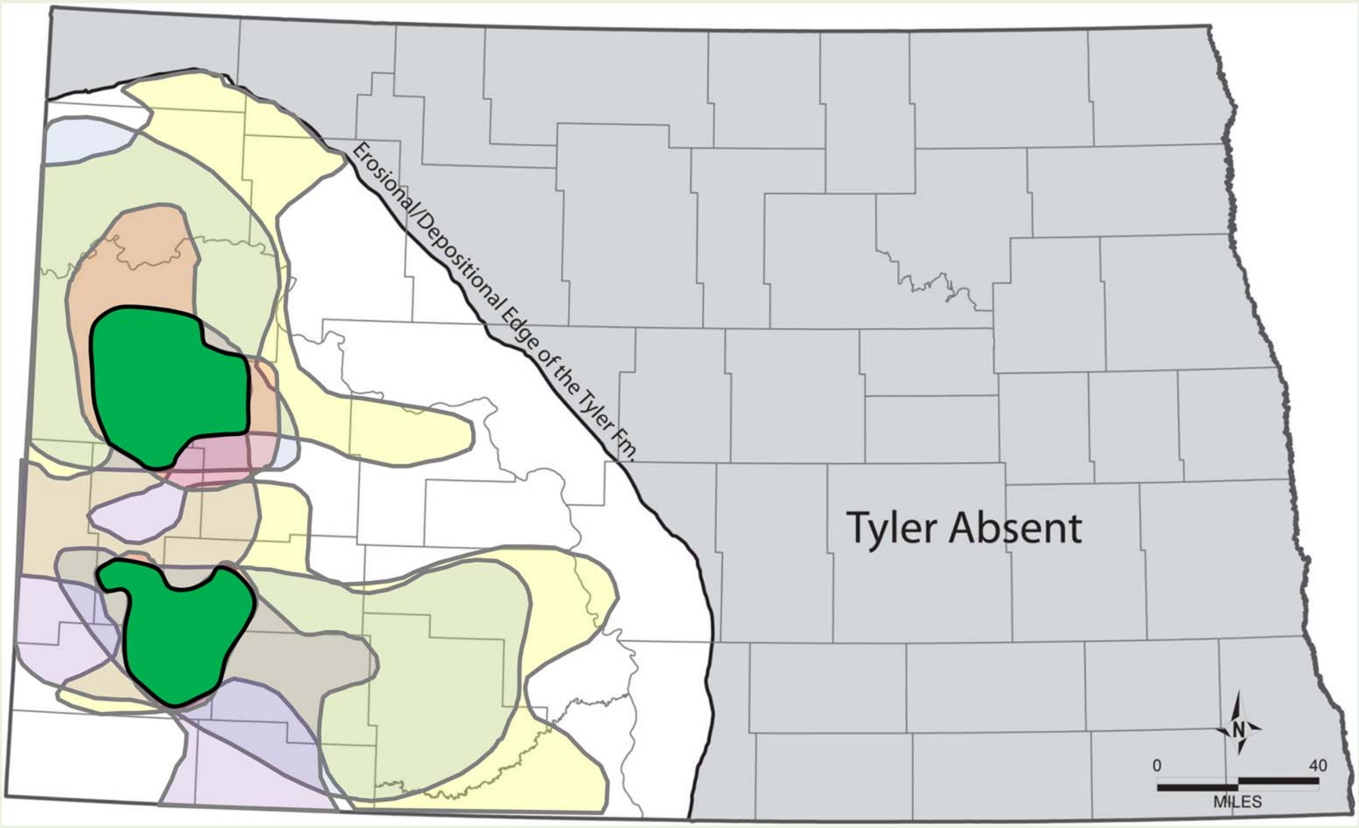
Along with this, we'll add in the approximate extent of source rocks "a" through "c" and "d," which overlaps fairly well with the previous layer.



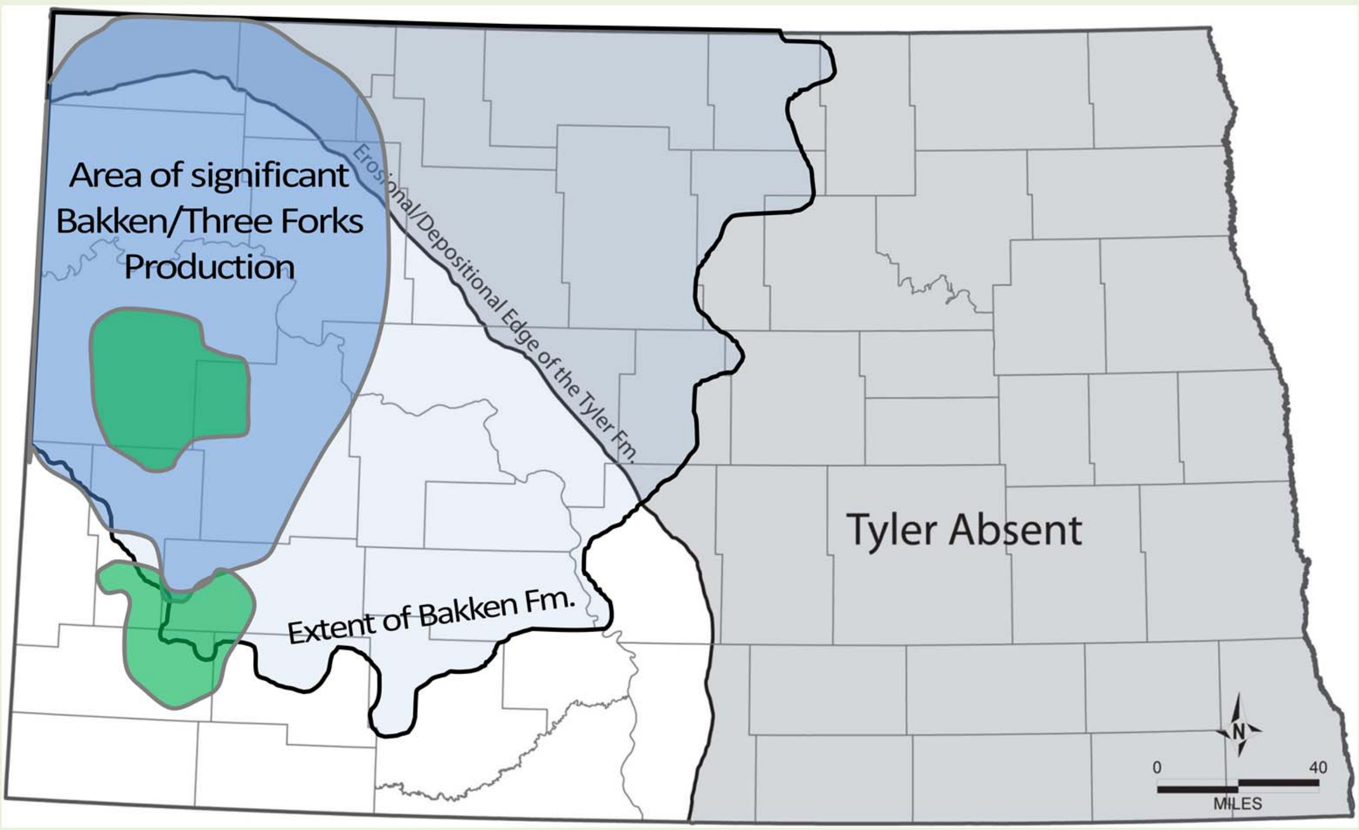
To figure out where the organic-rich source rocks have not only generate some oil but have undergone intense oil generation, we'll use the area with a Tmax of 435 or greater.



And finally, we'll add in the areas with fluid overpressure. So not only do we have organic-rich, oil-prone source rocks that have undergone intense oil generation, but the oil generated is still trapped within the Tyler section, waiting to be extracted.



Tracing out where all of these layers overlap, you can see there are two areas for potential exploration. A northern petroleum system, which has not yet been developed to any real degree, and a southern petroleum system, which has only been explored and developed and a vertical play. These two petroleum systems look to be spatially separate and will likely be vary different plays based on their differing geology, which was only briefly touched on in this presentation.



Considering the Bakken extent, and the area where the Bakken-Three Forks are currently being developed, the northern petroleum system falls within the Bakken-Three Forks development area and may be just another layer to the cake. However, the southern Tyler petroleum system may extend beyond the Bakken-Three Forks play, pushing development further south.

Conclusions:

1) The Tyler Formation contains organic-rich intervals consisting of Type I/Type II kerogen (excellent quality, oil-prone source rocks).

2) TTI modeling and Tmax data indicate Tyler source rocks are thermally mature and have undergone intense oil generation.

3) Fluid overpressure in the Tyler Fm. further indicates thermally maturity of source rocks and that generated Tyler oil is still in place (minimal migration).

4) Two separate petroleum systems exist within the Tyler Formation, a northern petroleum system and a southern petroleum system.

5) The southern Tyler petroleum system may extend beyond the current Bakken/Three Forks play.

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Future Study

Data to Collect: Cut several spatially distributed, complete cores of the Tyler Formation for both the northern and southern petroleum systems. **Benefit:** Better understand the geology -> find potential horizontal targets that are laterally continuous.

Data to Collect: Core analysis data (porosity, permeability, oil saturation % vs. water saturation %). **Benefit:** Figure out the vertical extent and distribution of generated oil.

Data to Collect: Wirelogs of the Tyler section (e.g. Neutron-Density Porosity, Sonic Travel Time, Gas Log-Chromatograph). **Benefit:** Geologic mapping of source rocks and potential reservoirs. Log analysis techniques (e.g. Oil saturations).

Data to Collect: Drill Stem Tests. **Benefits:** Test productive capability.