North Dakota Geological Survey

Core Based Examination of Upper Tyler Formation Source Rocks within Southwestern North Dakota

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Abstract

Geochemical data recently produced from a near complete Tyler Formation core, Shell Oil's Gardner #41-9, reveals a series of three organic-rich limestone beds in the upper Tyler section that have a composite thickness of ~15 ft. Each limestone bed consists of dark grey to black, laminated to thinly bedded lime mudstone to finely crystalline lime boundstone-packstone that is argillaceous in part. Interbedded with these organic-rich limestone beds is calcareous to non-calcareous shale, which is also moderately organic-rich in part, and a fourth limestone bed that is similar in texture but organic-lean. Analyzed samples from the organic-rich limestone beds of the Gardner core average 5.4% TOC with an S2 of approximately 38 mg/g and an S3 of <1 mg/g which classifies as excellent quality, oil-prone source rock. Corresponding Tmax values of 434° to 448° (average of ~443°) indicate the Tyler Formation has reached significant levels of thermal maturation resulting in intense oil generation. The upper Tyler shale and limestone beds appear to be distinct, laterally continuous intervals that may record regional phases of carbonate versus clastic dominated sedimentation. The organic-richness of each limestone and shale interval may also vary with regional trends. Within the lower Tyler section of the Gardner core is ~29 ft. of dark grey to black shale that may represent a local, thermally mature source rock interval located within the Rocky Ridge Field area.

Introduction

Previous work has identified the Tyler Formation as a self-sourced petroleum system, containing both source rock and reservoir (Dow, 1974; Nordeng, 2011; Nordeng and Nesheim, 2010; 2011; 2012[1, 2]). Nordeng and Nesheim (2012[2]) conducted a preliminary basin-wide investigation examining the Tyler Formation's organic-richness by analyzing drill cuttings of the entire Tyler section from numerous wells (Fig. 1). Based on drill cutting, core, and wireline log analysis, the Tyler Formation appears to contain two sets of organic-rich source rock intervals that are spatially and stratigraphically separated (Nesheim and Nordeng, 2012; Nordeng and Nesheim, 2012[2]). In the central portions of the Williston Basin, the lower Tyler section contains a series of up to three organic-rich marine shale intervals that presumably correlate with high gamma ray wireline log signatures (Nordeng and Nesheim, 2012). In southwestern North Dakota, the upper Tyler section appears to contain organic-rich source rock within a 30-40 ft. thick interval of interbedded shale and limestone. This study examines the geology and geochemistry of a near complete Tyler core collected from Shell Oil's Gardner #41-9 (API: 33-087-00057-00-00, NDIC: 4849, Sec. 9, T136N, R99W, Slope County) to gain a better understanding of the source rock interval/s within the Tyler Formation of southwestern North Dakota. The upper portion of the Gardner core is also compared with an upper Tyler core from Mule Creek Oil's Government Taylor #1-449 (API: 33-033-00018-00-00, NDIC: 4627, Sec. 9, T139N, R103W, Golden Valley County), which has a geochemical data set that was previously collected by Exxon (original data is on file at the Wilson M. Laird Core and Sample Library, also compiled with Nordeng and Nesheim, 2012[2]).

Geologic Background

The Tyler Formation across southwestern North Dakota has previously been split informally into upper and lower units by Sturm (1983) (Fig. 2). Sturm (1983) described the lower Tyler Formation as primarily shale and mudstone deposited within interdistributary bay and deltaic-plain environments. Sturm (1983) also noted that as many as two fluvial-deltaic sandstone intervals may be present within the basal to middle portion of the lower Tyler section. Sturm (1987) suggested the Tyler Formation was deposited during three regressive-transgressive cycles, with the lower Tyler section being deposited during the first two cycles. Barwis (1990) described much of the lower Tyler as two stacked channel-fill sequences along the Medora-Dickinson trend while containing some very shallow marine deposits.

Sturm (1983) split the upper Tyler Formation into two subunits. Sturm (1983) described his lower subunit of the upper Tyler as interbedded grey to black argillaceous limestone and calcareous shale deposited within a lagoonal-estuarine to marginal-marine environment. Sturm's lower subunit of the upper Tyler likely correlates with a 30 ft. thick interval described by Barwis (1990) of interbedded dark grey to black, thin, micritic limestone and shale within the upper portions of the Tyler section that he referred to as the Bear Gulch Limestone. The upper subunit of the upper Tyler section, as described and interpreted by Sturm (1983), consists of grey to black shales and limestones interbedded with greyish-red to reddish brown, anhydritic limestones and calcareous shales deposited in a tidal-flat to marsh setting.

Gardner #41-9 Well History

Shell Oil's Gardner #41-9 (Fig. 1 and 2) was spudded on December 20th, 1969. Drilled as a step out well to the Tyler productive Rocky Ridge Field, the Gardner well cut a near complete core of the Tyler Formation (Pennsylvanian) along with several feet of the underlying Otter Formation (Mississippian Big Snowy Group). While the Gardner well was a dry hole (failing to encounter any permeable, oil saturated sandstone) the collected core provides an invaluable look at the complicated lithological sequence of the Tyler Formation in southwestern North Dakota and the opportunity to examine the source rock potential of the entire Tyler section.

Gardner #41-9 Core Description and Correlation

The Gardner's lower Tyler core begins with red to green-grey, clay-bearing, very fine grained sandstone (Fig. 3a). Faint cross-bedding may be present within this basal sandstone interval. The remainder of the lower Tyler consists of medium grey to black laminated shale that is both overlain and underlain by green-grey silty nodular mudstone with slickensides (Fig. 3b and 4). Most of the grey to black shale within the lower Tyler section contains red colored, well indurated nodules and/or laminae which may be mudstone (Fig. 4a and 4b). Several feet of black shale is also present that does not contain any of the red nodules/laminae. The upper portions of the lower Tyler shale interval within the Gardner core is light to medium grey and contains semi-continuous thin white sandstone laminations in addition to the red mudstone nodules/laminae (Fig. 4b). The green-grey silty mudstone intervals within the lower Tyler section are very poorly indurated and may contain a combination of nodules (calcium carbonate-?) that formed in situ and pebble sized clasts.

The upper Tyler is made up mostly of laminated to thinly bedded, argillaceous in part, limestone interbedded with grey to black, calcareous to non-calcareous shale (Fig. 5 and 6). Limestone intervals consist primarily 1) dark grey to black, laminated to thinly bedded, lime wacke-mudstone to mudstone, and 2) lime boundstone made up of interlaminated, grey to very dark grey, very fine to finely crystalline packstone-grainstone and black mudstone. Laminations in the limestone intervals tend to be horizontal, parallel, and semi-continuous to continuous with a flat to wavy texture. Lime mudstone varies from being non-argillaceous with conchoidal fracturing to very argillaceous and moderately fissile. The interbedded upper Tyler shale intervals vary from being calcareous and only moderately fissile to non-calcareous and very fissile. Calcareous shale tends to contain a higher concentration of "white specks" forming horizontal laminations. These white specks consist, at least in part, of ostracod fossils. Most of the shale interbedded within the limestone tends to be calcareous. The final 20 ft. of upper Tyler core consists of interbedded medium grey to green to red shale/claystone (Fig. 7) and lime mudstone. The upper most several feet of non-limey shale at the top of the core displays possible desiccation cracks and/or root traces.

Four limestone beds, A-D (in ascending order), are defined based on depositional timing within the Gardner's upper Tyler core (Fig. 2). Three of these limestone beds are largely colored dark grey to black (A, B, and D) while the fourth limestone bed is colored tan to medium tan-gray (C) (Fig. 2). The upper most Limestone D appears to be more argillaceous than the other three limestone beds and contains thin (<1 ft.) interbedded shale intervals. Limestone D also does not contain any readily apparent lime boundstone-packstone.

All four of these limestone beds can be correlated for over 30 miles between the Gardner and Government Taylor cores (Figs. 1, 8 and 9). Limestone beds A and B are lithologically and texturally similar between the two cores, although Limestone A is slightly thicker in the Government Taylor well/core. Limestone C is also thicker within the Government Taylor and contains nodular pink anhydrite near the top of the interval (Figs. 8 and 9). Limestone D has a similar thickness between the two cores, but transitions from a dark grey to black argillaceous lime mudstone (Gardner core) to a medium grey-tan lime mudstone with possible root traces and bioturbation capped by a packstone (Government Taylor core).

Geochemical Analysis

METHODOLOGY

One to two gram samples were collected from pre-existing parting surfaces of the Gardner core in approximately 1 ft. intervals (all depths are ± 2 inches) across the core interval 7,739 to 7,848 ft. Each collected sample represents a single point of depth and therefore does not represent a 1 ft. interval average. Samples were collected in ~1 ft. intervals in attempt to minimize sampling bias. However, collecting from pre-existing parting surfaces may have biased the data toward lithological variations that allow for parting surfaces to more readily form. The sampled interval consists primarily of grey to black shale and limestone. Rock types above and below the primary sampled core interval (7,739 to 7,848 ft.) tend to be more lightly to red colored (oxidized) which visually indicates low source rock potential. Additional samples were collected both above and below the primary sampled core interval wherever the rock was more darkly colored.

All of the samples were sent to Weatherford Labs and analyzed for their Total Organic Carbon weight percent (TOC) using the LECO® TOC analysis technique (Fig. 2, Table 1). Samples that measured ≥1% TOC were also analyzed using RockEval 6 to additionally examine source rock potential (S2), kerogen type (HI vs. OI), and thermal maturity (Tmax) (Fig. 2, Table 1).

A geochemical data set from an upper Tyler core cut from Mule Creek Oil Company's Government Taylor #1-449 was generated prior to, and independent of, this study (Fig. 8, Table 2). The Government Taylor's older geochemical data set was very likely produced using different methods and/or instrumentation, but yielded similar results to the upper Tyler core samples produced by this study from the Gardner core.

RESULTS

Measured TOC values from the Tyler portion of the Gardner core ranged from 0.15% to 15.58% TOC with an overall average of 1.9% TOC. If the entire Tyler portion of the core had been sampled in 1 ft. intervals, the overall average Tyler TOC would likely have been closer to 1.6% TOC (assuming the basal sandstone averages 0.1% TOC and the non-sampled ~mudstone intervals contain 0.5% TOC). A TOC average of either 1.6% or 1.9% is similar to the previously reported TOC averages yielded from drill cuttings analyzed across the entire Tyler Formation from surrounding wells (Fig. 1, Nordeng and Nesheim, 2012[2]).

The lower Tyler core interval of 7,809 to 7,838 ft. (29 ft. thick) from the Gardner core yielded TOC values ranging from 1.01 to 10.60% TOC (overall 2.55% average). Near the base of this interval is ~2 ft. of shale (7,830-7,831 ft.) that averages 10.57% TOC and an S2 of 47.2 mg/g, which classifies as excellent quality source rock (Fig. 2, 10 and 11 – lower Tyler shale-2). However, Tmax values measured off this excellent quality source rock shale are only 433° and 434° (Table 1), indicating it is immature (Tmax ≥435° ≈ thermally mature). Samples from the remaining portion of the interval average 1.97% TOC with an S2 of

3.34 mg/g, which classifies as fair to good quality source rock (Fig. 10 – lower Tyler shale-1). Hydrogen and Oxygen Index values plot intermediately between Type I/II and Type III kerogen curves (Fig. 11 – lower Tyler shale-2). Tmax values range from 435° to 447° (most tend to be ≥439°) indicating significant levels of thermal maturation which may have lowered the original TOC and S2 values (Table 1).

The remaining lower Tyler section of the Gardner core appears to be overall organic-lean with minimal hydrocarbon generation potential. The green-grey silty, nodular mudstone intervals near the top and base of the lower Tyler section yielded TOC values of 0.38% to 0.68% TOC (0.52% average). The grey shale with sandstone laminae located near the top of the lower Tyler section yielded TOC values of 0.15% to 0.39% TOC (0.27% average). Since the TOC values were less than 1%, none of the samples were analyzed using RockEval 6. With such low TOC values, these intervals likely contain negligible source rock potential.

Three of the four upper Tyler limestone beds within the Gardner core averaged ≥4 % TOC with corresponding S2 values that classify these limestone beds as excellent quality source rocks (A, B, and D in Fig. 2, and upper Tyler limestone in Figs. 10 and 11). Most of the interbedded shale samples yielded TOC values of <2% and low S2 values, indicating fair to good quality source rock at best. The shale interval directly above Limestone B, however, contains TOC values of 1-3% with S2 values that classify as good quality source rock (Fig. 2, 10, Table 1). Overall, the primary upper Tyler source rock intervals within the Gardner core appear to be the limestone beds while the interbedded shale intervals provide source rock potential to a lesser degree.

Limestone beds A and B are very organic-rich (>5% TOC average) within both of the cores examined whereas Limestone bed C is overall organic-lean within both cores (Fig. 2, 8, & 10, Table 1). The upper most limestone bed D varies from being organic-rich, averaging 4.1% TOC within the Gardner core (Fig. 2, Table 1), to being completely organic-lean within the Government Taylor core (Fig. 8, Table 2).

Discussion

The lower Tyler within the Gardner core consists in part of darkly colored shale that classifies as thermally mature, fair to good quality source rock (TOC: 0.5-2.0% TOC, S2: 3-10 mg/g). Some of the lower Tyler cores collected from surrounding wells within the Rocky Ridge Field area also contain similar looking dark grey to black shale, which may also represent similar potential source rock as observed within the lower Tyler portion of the Gardner core. Lower Tyler cores from southwestern North Dakota collected outside of the Rocky Ridge Field area often contain only lightly colored grey to red to vari-colored shale and mudstone, which visually appears to have low source rock potential and may correlate with Sturm's (1983) fluvial-deltaic deposits. The Rocky Ridge Field and surrounding area may have been a localized interdistributary bay surrounded by a fluvial-deltaic plain environment during part of the lower Tyler's deposition. Organic carbon would have been deposited and preserved more readily within the interdistributary bay than the surrounding fluvial-deltaic plain area. The well indurated, red mudstone laminations and nodules may be the product of periodic subarial exposure that may have occurred on the margins of the bay area as water levels fluctuated. Localized lower Tyler source rock may be the reason lower Tyler sandstone bodies are sometimes hydrocarbon charged within the Rocky Ridge Field and largely water saturated elsewhere across southwestern North Dakota.

There appear to be four possible paleosol intervals within the Tyler portion of the Gardner core (Fig. 2, 3). Each of the four interpreted paleosol intervals are poorly sorted with seemingly high clay content and display compaction slickensides, color mottling, and nodules that appear to have formed in situ, all of which are diagnostic features of paleosols (Blatt and Tracy, 1995). The lower two interpreted paleosols (P1 and P2) have gradational/transitional lower boundaries and relatively sharp upper contacts. The upper two interpreted paleosol intervals are thinner and are not as conclusively interpreted as paleosols as the thicker, lower two paleosols.

Interpreted paleosol intervals are present near the upper/lower Tyler boundary zone within both the Gardner core and the Government-Taylor A-1 Tyler cores, which are located >30 miles apart (Fig. 1). If these potential paleosol intervals correlate, they may record a regional regressive event (and therefore an unconformity) that separates the deposition of the upper and lower Tyler intervals. Speculatively, localized lacustrine and/or fluvial sequences may correlate with and/or have removed this paleosol interval in other stratigraphically equivalent cored intervals.

The upper Tyler section was deposited within a geological setting that transitioned several times between clastic and carbonate dominated sedimentation which resulted in several distinct limestone versus shale dominated intervals. Limestone beds A-D and the interbedded shale intervals can be continuously, stratigraphically correlated over much of southwestern North Dakota and are interpreted to record separate, basin-wide phases of carbonate versus clastic dominated sedimentation. Most of these interpreted limestone beds have been previously depicted and correlated in past publications but have not been examined in great detail (Sturm, 1987; Barwis, 1990). Based on the contacts between the clastic shale and limestone intervals, some of the clastic-carbonate transitions were gradational while others were more abrupt. Moving upwards in section, the shale to limestone transitions within the Gardner and Government Taylor cores appear to be abrupt whereas the limestone to shale transitions are more gradational.

A well-defined, definitive depositional interpretation for the interbedded shale and limestone of the upper Tyler section is beyond the scope of this study. However, previous studies may suggest a brackish to marine depositional setting. Grenda (1978) described terrestrial plant fragments, fresh water ostracods, and marine brachiopods within Tyler cores from southwestern North Dakota. He did not closely tie his paleontological data with the Tyler's stratigraphy. Sturm (1983; 1987) interpreted the darkly colored shale and limestone of the upper Tyler Formation as lagoonal-estuarine (back barrier) and anoxic shallow-marine to marginal-marine (front barrier) deposits. Barwis (1990) referred to the 30 ft. thick upper Tyler carbonate interval he described in North Dakota, the Bear Gulch Limestone, as a marine lime mudstone that is regionally extensive.

The geochemical data from the Gardner core indicates there is a similar net thickness of organic-rich shale and organic-rich limestone, where organic-rich equates with $\geq$ 1% TOC. However, the limestone is significantly more organic-rich on average than the shale. Interbedded between the upper Tyler limestone beds, the Gardner core contains ~15 ft. of organic-rich shale (≥1% TOC) which is approximately the same net thickness of organic-rich limestone (≥1% TOC) (Table 1). The organic-rich shale samples with ≥1% TOC combine to average 1.7% TOC with an S2 of 5.1 mg/g while the organic-rich limestone samples combine to average 5.7% TOC with an S2 of 38.1 mg/g. Overall, the organic-rich limestone intervals contain approximately three times the TOC and seven times the S2 content as the organic-rich shale intervals. Previous investigations have cited shale as the source rock for the upper Tyler Formation hydrocarbons (Sturm, 1983; Barwis, 1990). However, identifying and characterizing Tyler source rock intervals was not the focus of these previous studies. The Tyler geochemical core data set produced and compiled by this study suggests that laterally continuous limestone beds serve as the primary source of hydrocarbons within the upper Tyler petroleum system of southwestern North Dakota.

The variance in organic-richness of limestone bed D between the Gardner and Government Taylor cores appears to be a facies change. Within the more western located Government Taylor core, Limestone D exhibits potential root traces and bioturbation which indicates terrestrial to oxygenated water depositional conditions that are not favorable to the preservation of organic carbon. There are no obvious root traces or significant bioturbation with the Gardner's Limestone D interval, indicating a non-terrestrial, anoxic water depositional setting that allowed for the accumulation and preservation of significant organic material. On a more regional scale, the other limestone beds, A-C, may exhibit similar facies changes that correlate with variations in organic-richness.

The change in organic-richness within Limestone D can be observed within the sonic log signature. Within the Gardner core, Limestone D averages 4.1% TOC from core data and has a corresponding wireline log sonic travel time of ~80 microseconds per foot (µs/ft) (Fig. 2). Within the Government Taylor, Limestone D averages 0.4% TOC from core data and a wireline log sonic travel time of only ~60 µs/ft (Fig. 8). Sonic waves take longer to travel through low density organic carbon (1.1-1.4 g/cc) than most typical sedimentary rock forming minerals which have higher densities (2.6-3.0 g/cc) (Passey, 1991). Within the organic-rich limestone beds A and B of both the Gardner and Government Taylor cores, the average sonic travel time averages approximately 80 µs/ft. whereas the organic-lean Limestone C averages approximately 60 µs/ft. (Fig. 2 and 8). Therefore, examining the sonic travel times across Limestone bed A-D may be a quick and effective way to determine whether they are organic-rich or not within a given well.

Conclusions

Across southwestern North Dakota, the upper Tyler Formation contains four continuous limestone beds (A-D). Each limestone bed tends to be dark grey to black, laminated to thinly bedded and argillaceous in part while consisting of lime mudstone to finely crystalline lime boundstone-packstone. Depending on location, the upper two limestone beds contain anhydrite and possible plant root structure, features that were absent in the lower two limestone beds within both examined cores. Interbedded within the limestone intervals is primarily dark grey to black, calcareous to non-calcareous shale.

Depending on location, two to three of these limestone beds (A, B, and sometimes D) may be organic rich with net thicknesses of approximately 9 ft. (Government Taylor) and 15 ft. (Gardner). When these limestone beds are organic-rich, they average as excellent quality source rock with typically 4-6 wt. % TOC with S2 values of >25 mg/g. Hydrogen versus oxygen index values indicate these organic-rich limestone beds consist of oil-prone Type I to Type I/II kerogen which has undergone sufficient levels of thermal maturation for intense oil generation, indicated by Tmax values of around 443°.

In addition to the organic-rich limestone, the upper Tyler section also contains varying amounts of moderately organic-rich shale. Upwards of 10-15 ft. of upper Tyler shale contains 1-3 wt. % TOC with S2 values of 3-14 mg/g, which classifies as fair to good quality source rock. With measured Tmax values of typically >440°, the upper Tyler organic-rich shale is also thermally mature generating secondary amounts of oil and gas in comparison with the organic-rich limestone.

As observed in the Gardner core, the lower Tyler section may contain a localized interval with moderately organic-rich shale. Most of the samples analyzed from this interval yielded 1-4 wt. % TOC with S2 values of 2-5 mg/g and Tmax values of 439° to 447° which classifies overall as thermally mature, fair to good quality source rock. Two samples from this lower Tyler interval yielded TOC and S2 values of ~10.5% and ~48 mg/g, which indicates significant source rock potential. However, these more organic-rich samples yielded Tmax values of only 433° and 434° indicating immature to marginal levels of thermal maturation.

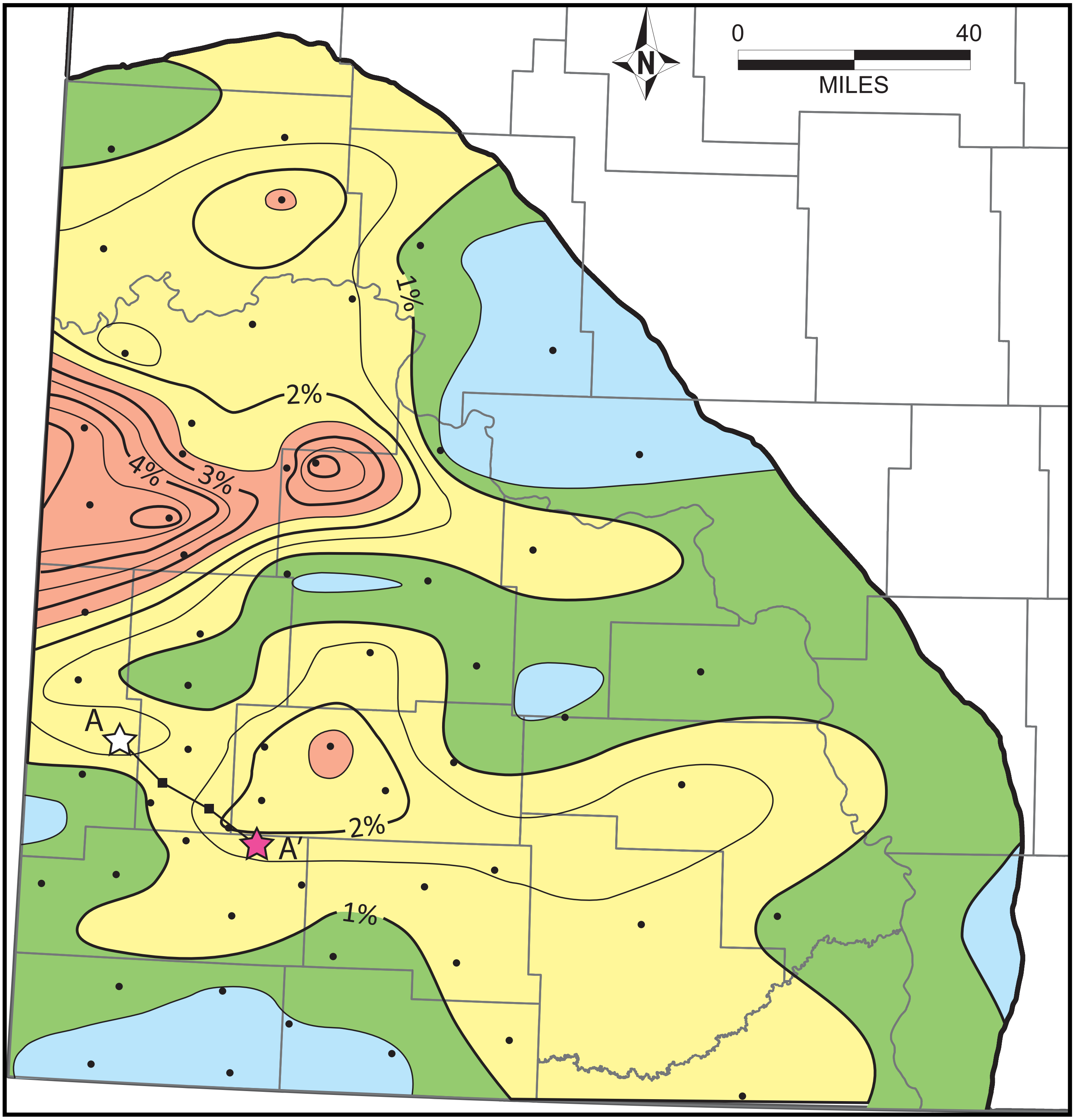

Figure 1. Total Organic Carbon (TOC) map of the Tyler Formation, modified from Nordeng and Nesheim (2012). Black Dots show the location of wells from which drill cuttings from the entire Tyler section were sampled, analyzed, and averaged by well to generate the above map. Contours are in 0.5 wt. % TOC intervals. The pink star shows the location of Shell Oil's Gardner #41-9 (NDIC: 4849, API: 33-087-0057-00-00, NENE Sec. 9 T136N R99W) and the white star shows the location of Mule Creek Oil's Government Taylor #1-449. The black squares represent cross-section wells used in figure 9.

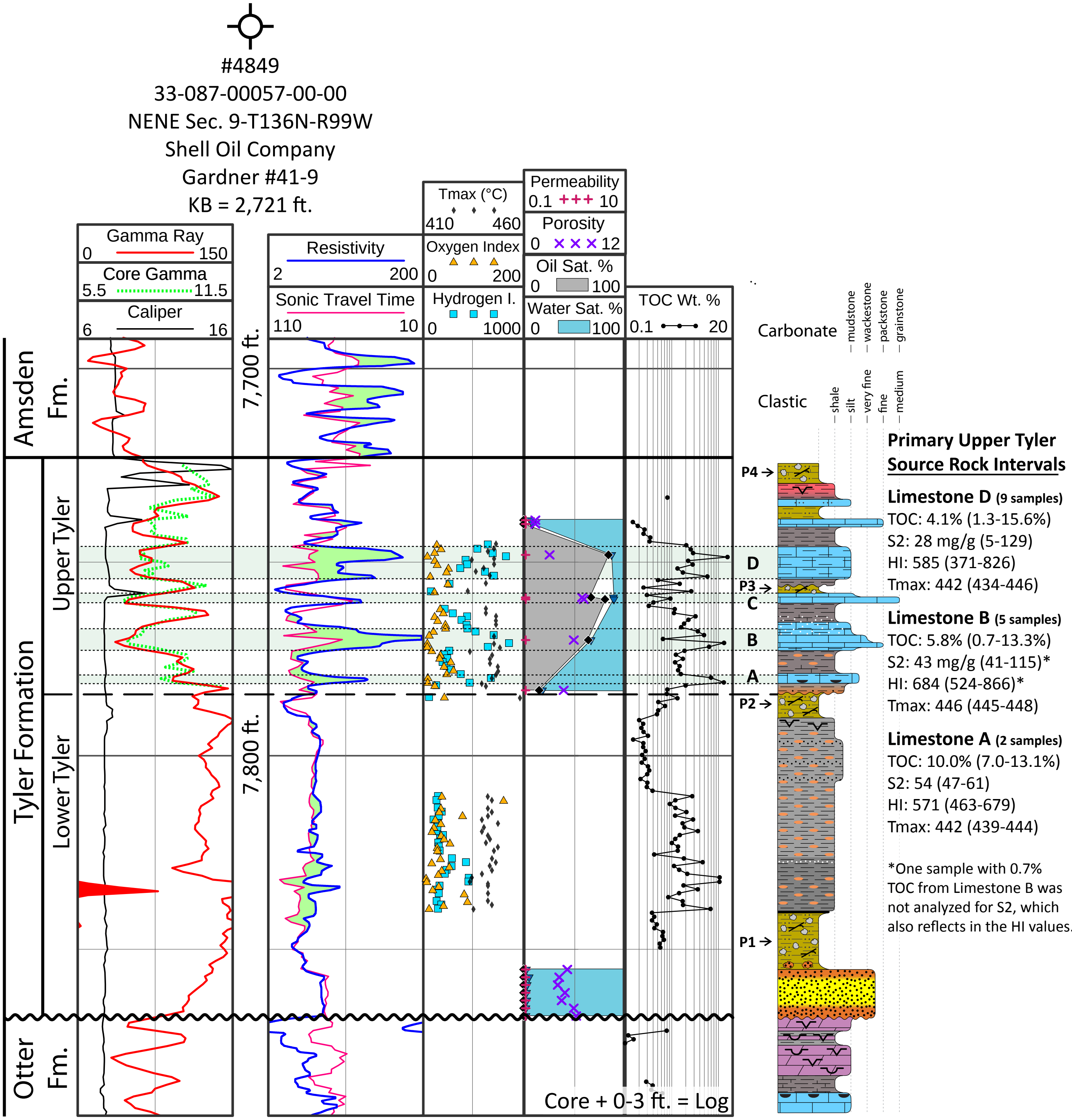

Figure 2. Wireline log of the Tyler Formation with illustrated core, standard core analysis and geochemical data from Shell Oil's Gardner #41-9. Drilled as a wildcat well targeting the Tyler Formation near the Rocky Ridge Field, the Gardner #41-9 was plugged and abandoned as a dry hole. The core symbol explanation is listed on Figure 8. The core to log correlation is approximately core = log for the upper portion of the core and up to core + 3 ft. = log for the lower portions of the core. Log and core illustration modified from LeFever et al. (2012). P1-P4 indicate interpreted paleosol intervals.

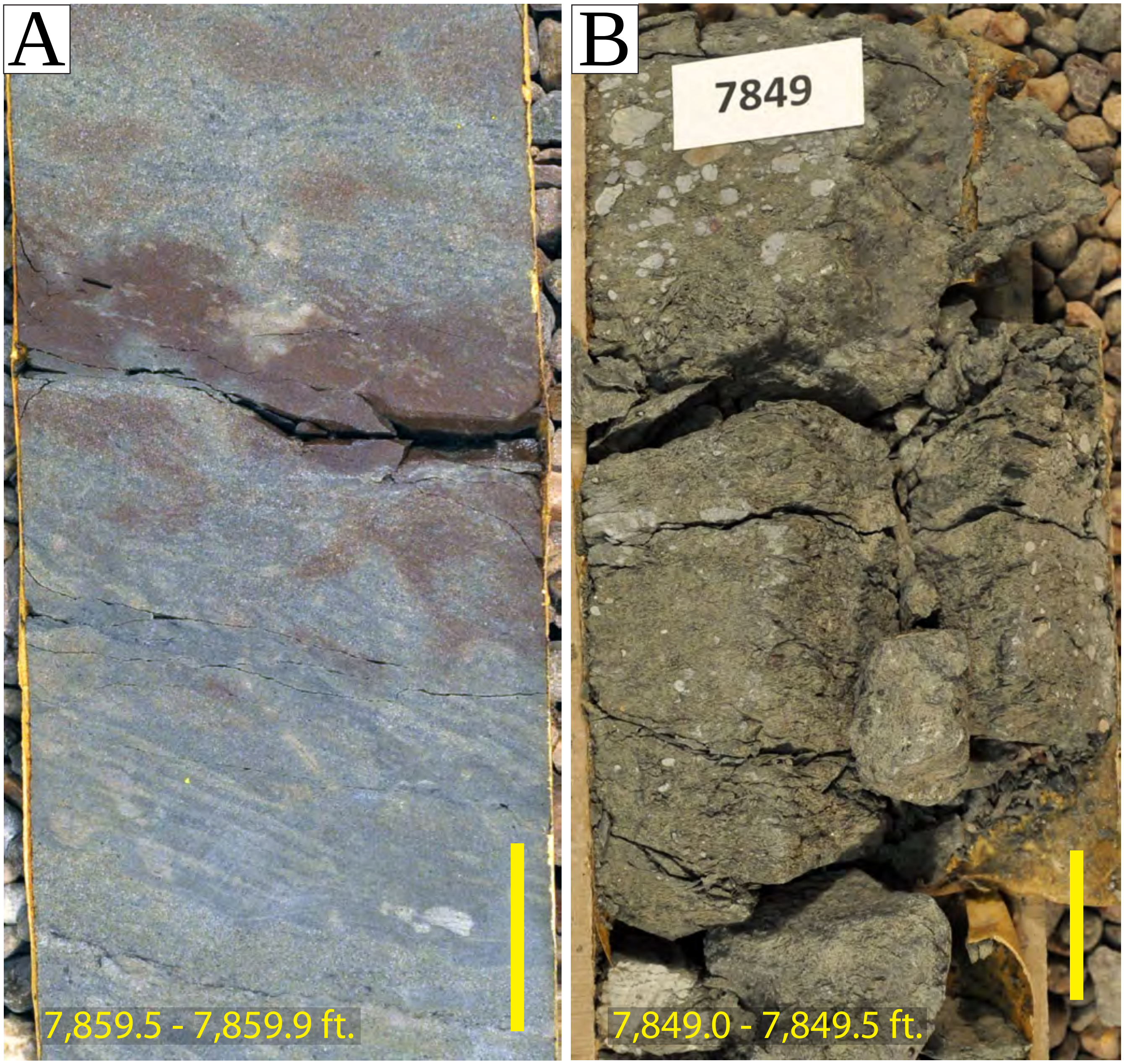

Figure 3. Core photographs of the Tyler Formation from Shell Oil's Gardner #41-9. A) Red to greenish grey sandy claystone to very fine grained sandstone from a core depth of 7,960 ft. B) Green-grey poorly indurated silty to conglomeritic mudstone from a core depth of 7,849 ft. These photographed intervals correlate with Sturm's (1983) lower Tyler Formation and may correlate with fluvial-deltaic (A) and terrestrial/paleosol (B) depositional settings. The yellow line in the bottom right hand corner of each core photograph is 1 inch long.

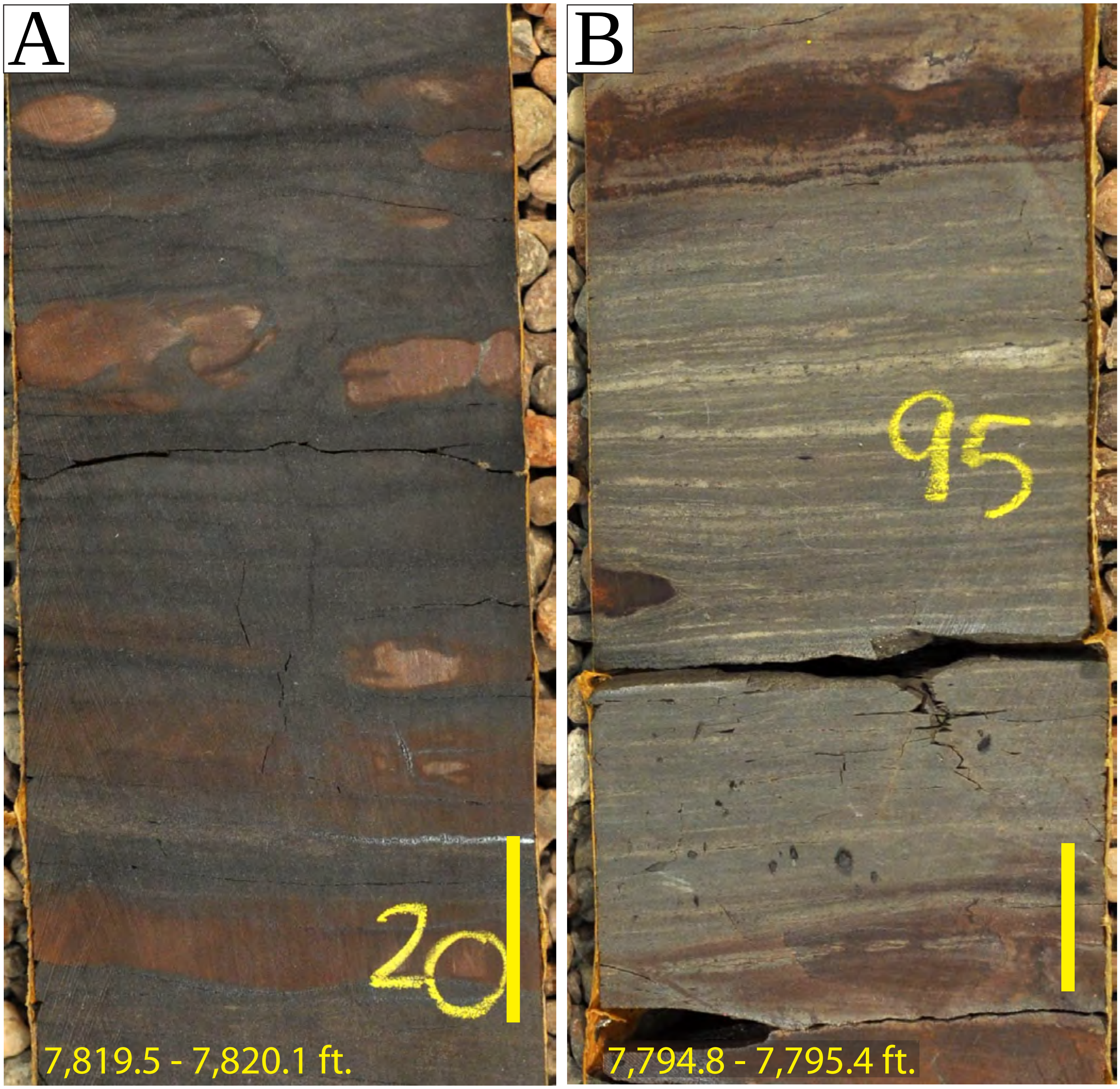

Figure 4. Core photographs of the Tyler Formation from Shell Oil's Gardner #41-9. A) Very dark grey shale with dark red, well indurated mudstone nodules/laminations from a core depth of 7,820 ft. A sample analyzed from the dark grey shale portion of this interval yielded 1.19 wt. % TOC with an S2 of 1.9 mg/g and a Tmax of 443°. B) Grey shale containing thin white quartz sandstone and thick red mudstone laminations from a core depth of 7,895 ft. A sample analyzed from the shale portion of this interval yielded 0.15 wt. % TOC. These photographed intervals correlate with Sturm's (1983) lower Tyler Formation. The yellow line in the bottom right hand corner of each core photograph is 1 inch long.

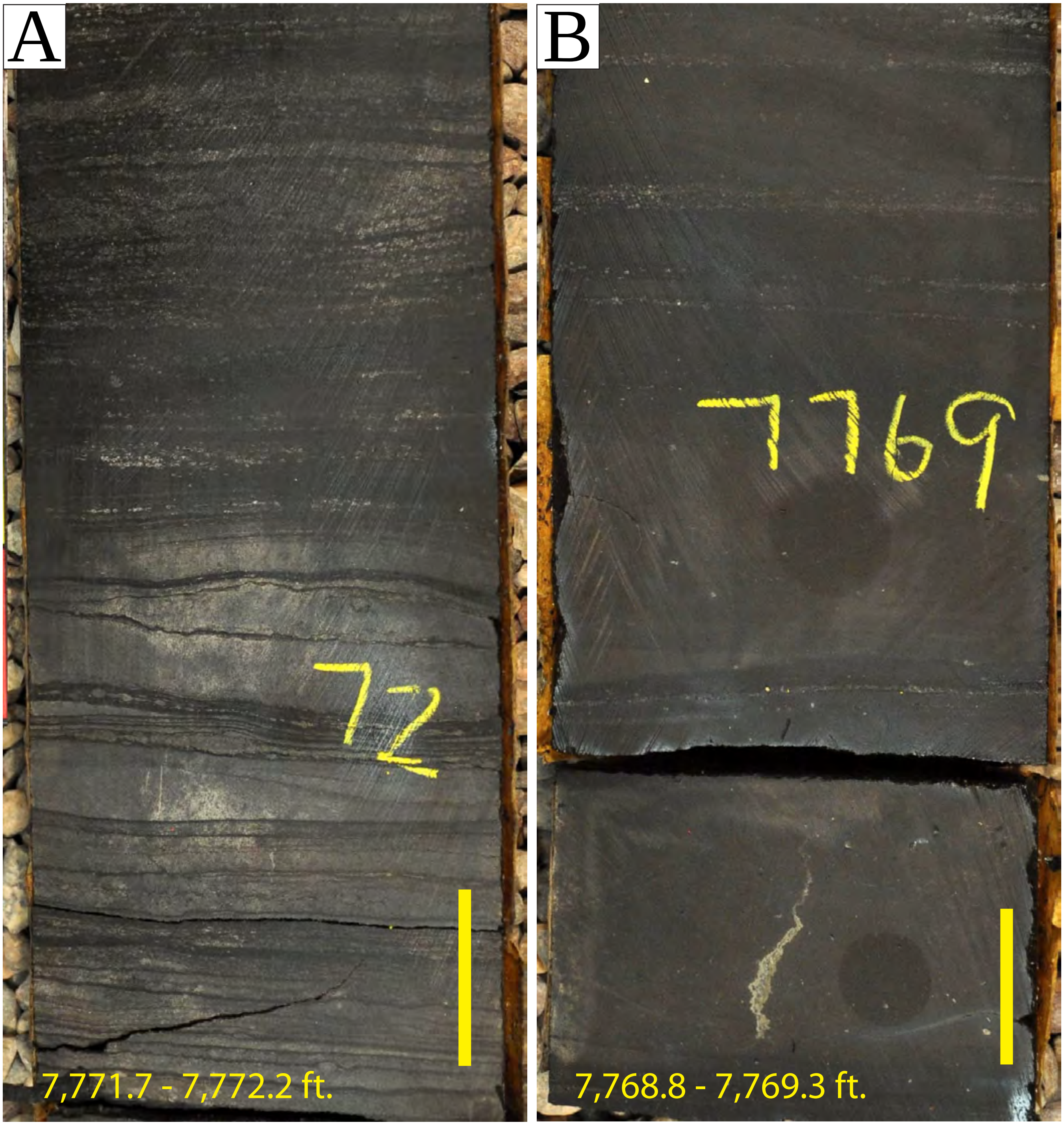

Figure 5. Core photographs of the Tyler Formation from Shell Oil's Gardner #41-9. A) Grey to black laminated lime boundstone that consists of finely crystalline packstone-grainstone laminations (lighter colored intervals) and very thin black, presumably organic-rich, mudstone laminae (base) and lime wackestone (top) from a core depth of 7,772 ft. A sample analyzed from this interval yielded 6.3 wt. % TOC with an S2 of 40.8 mg/g and Tmax of 448°. B) Very dark grey, faintly laminated lime mudstone from a core depth of 7,769 ft. A sample from this interval yielded 4.9 wt. % TOC with an S2 of 34.6 mg/g and Tmax of 445°. These photographed intervals correlate with Sturm's (1983) lower subunit of the upper Tyler Formation which is interpreted to have been deposited within a brackish to shallow marine setting, possibly within an estuary. The yellow line in the bottom right hand corner of each core photograph is 1 inch long.

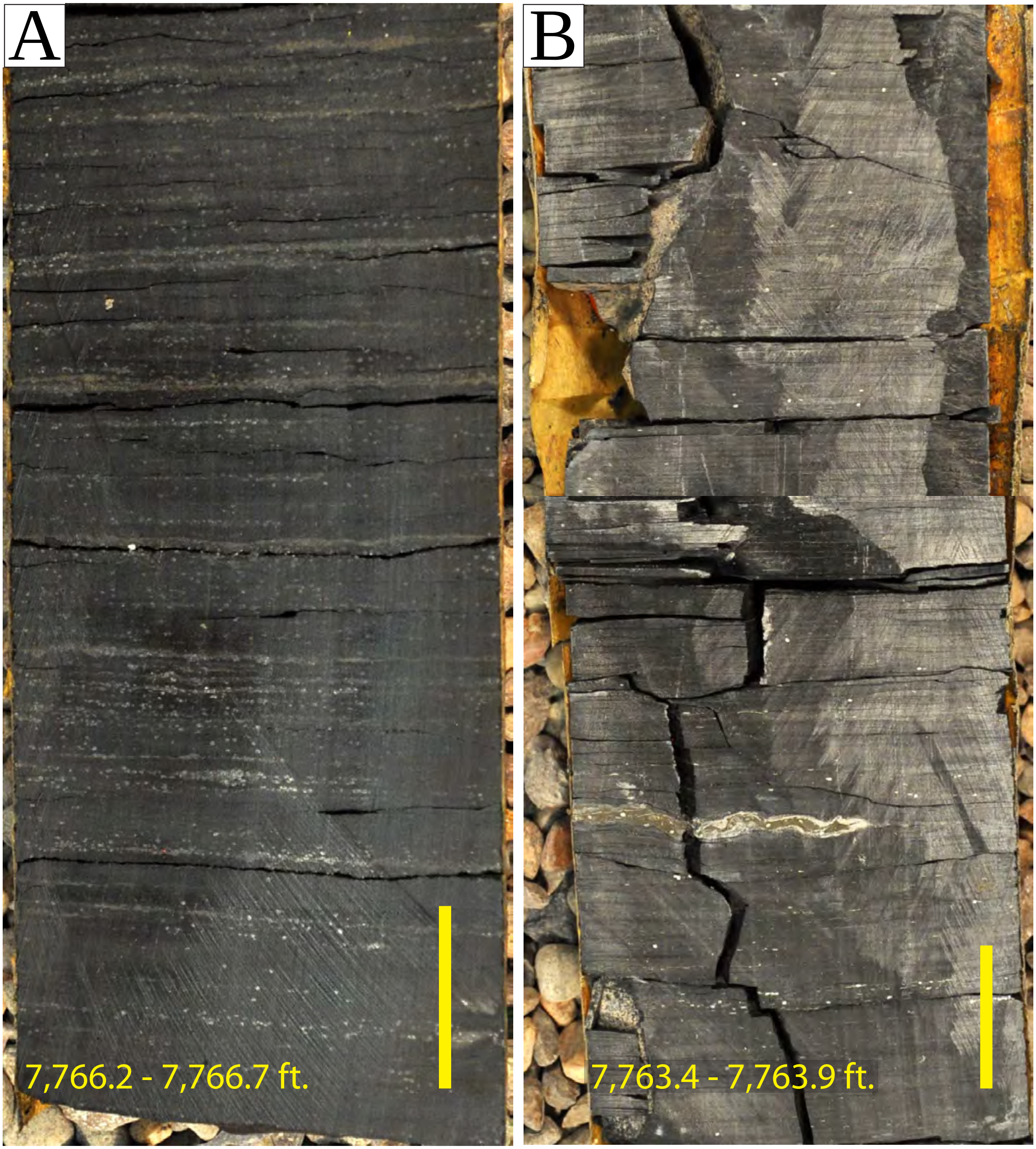

Figure 6. Core photographs of the Tyler Formation from Shell Oil's Gardner #41-9. A) Very dark grey to black moderately fissile shale with white specks (ostracods) for horizontal laminations. Core sample is from a core depth of 7,766 ft. A sample analyzed from just above this interval yielded 1.9 wt. % TOC with an S2 of 8.0 mg/g and Tmax of 446°. B) Dark grey, very fissile, slightly to non-calcareous shale from a core depth of 7,763 ft. A sample analyzed from just below this interval yielded 3.2 wt. % TOC with an S2 of 14.1 mg/g and Tmax of 446°. These photographed intervals correlate with Sturm's (1983) lower subunit of the upper Tyler Formation which is interpreted to have been deposited within a brackish to shallow marine setting, possibly within an estuary. The yellow line in the bottom right hand corner of each core photograph is 1 inch long.

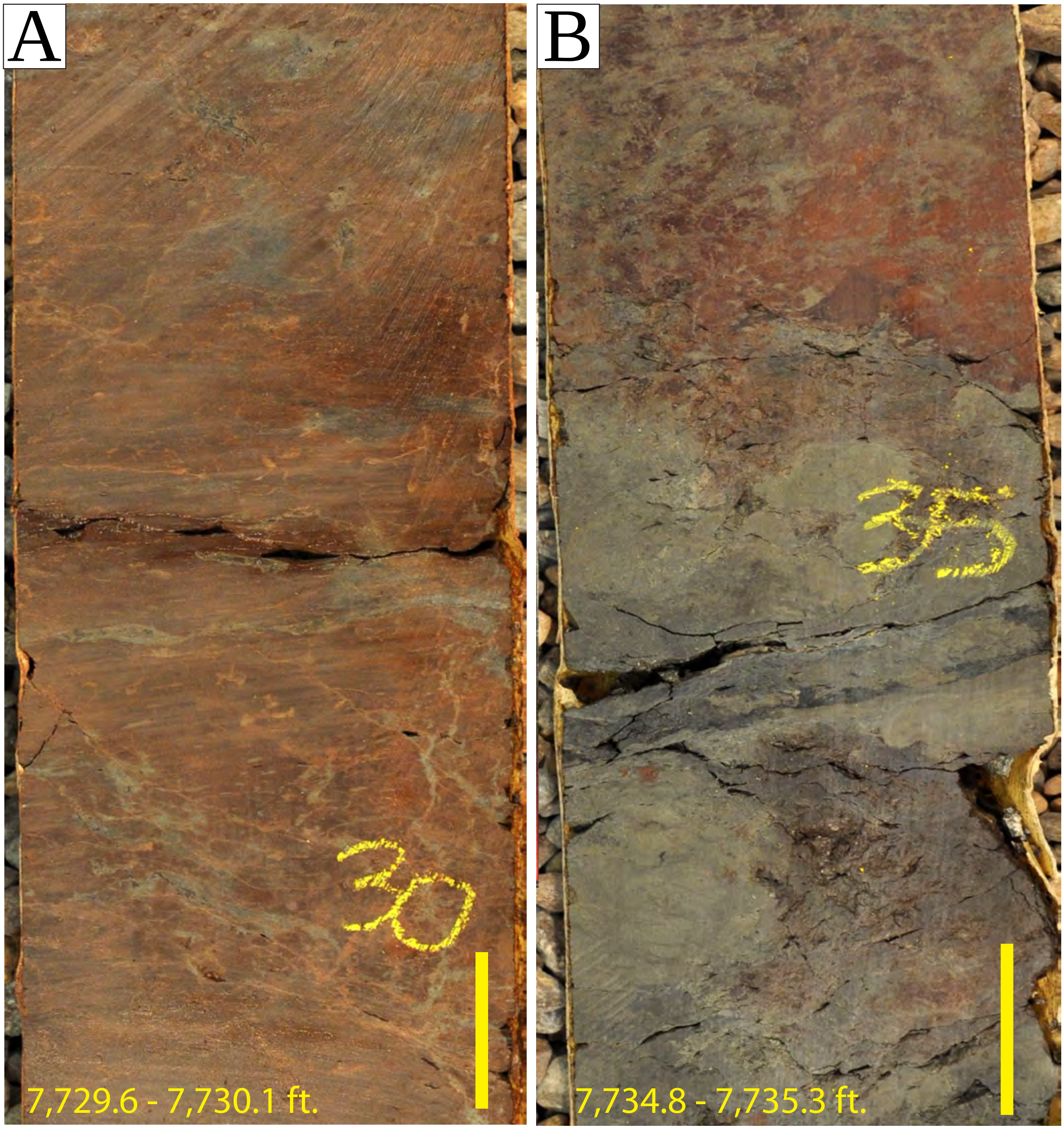

Figure 7. Core photographs of the Tyler Formation from Shell Oil's Gardner #41-9. A) and B) Grey to red non-calcareous shale-mudstone from core depths of 7,730 and 7,735 ft. These photographed intervals correlate with Sturm's (1983) upper subunit of the upper Tyler Formation which he interpreted to have been deposited within a tidal flat to marsh setting. The yellow line in the bottom right hand corner of each core photograph is 1 inch long.

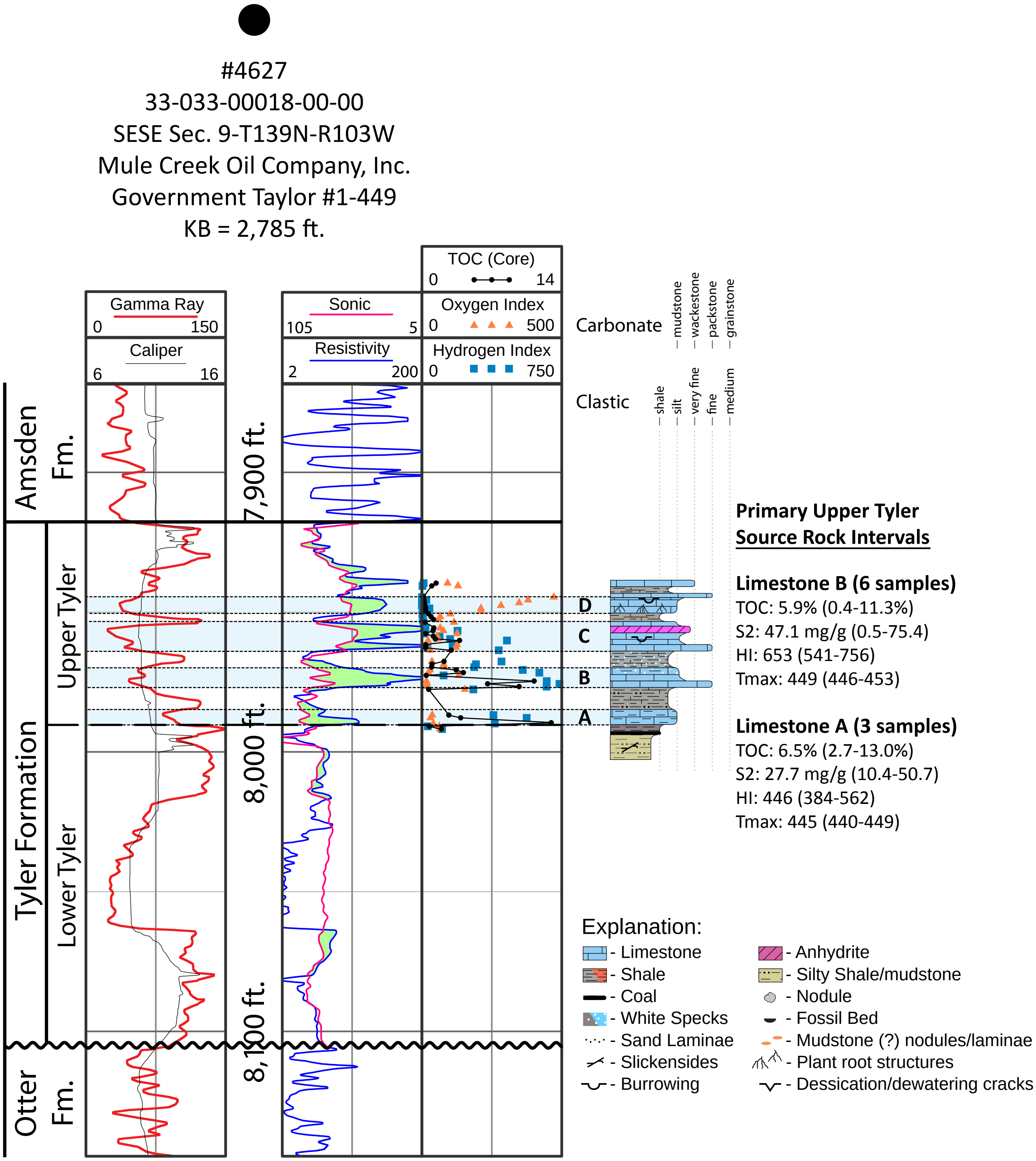

Figure 8. Wireline log of the Tyler Formation with illustrated core and geochemical data from Mule Creek Oil's Government Taylor A #1-449. The TOC, S2, HI, and Tmax values listed to the right of the log are average values with the value ranges listed in parantheses. The Government Taylor A #1-449 is currently an active oil well producing from the Madison Pool within the Square Butte Field. The "Explanation" key above corresponds with Figures 2, 8, and 9.

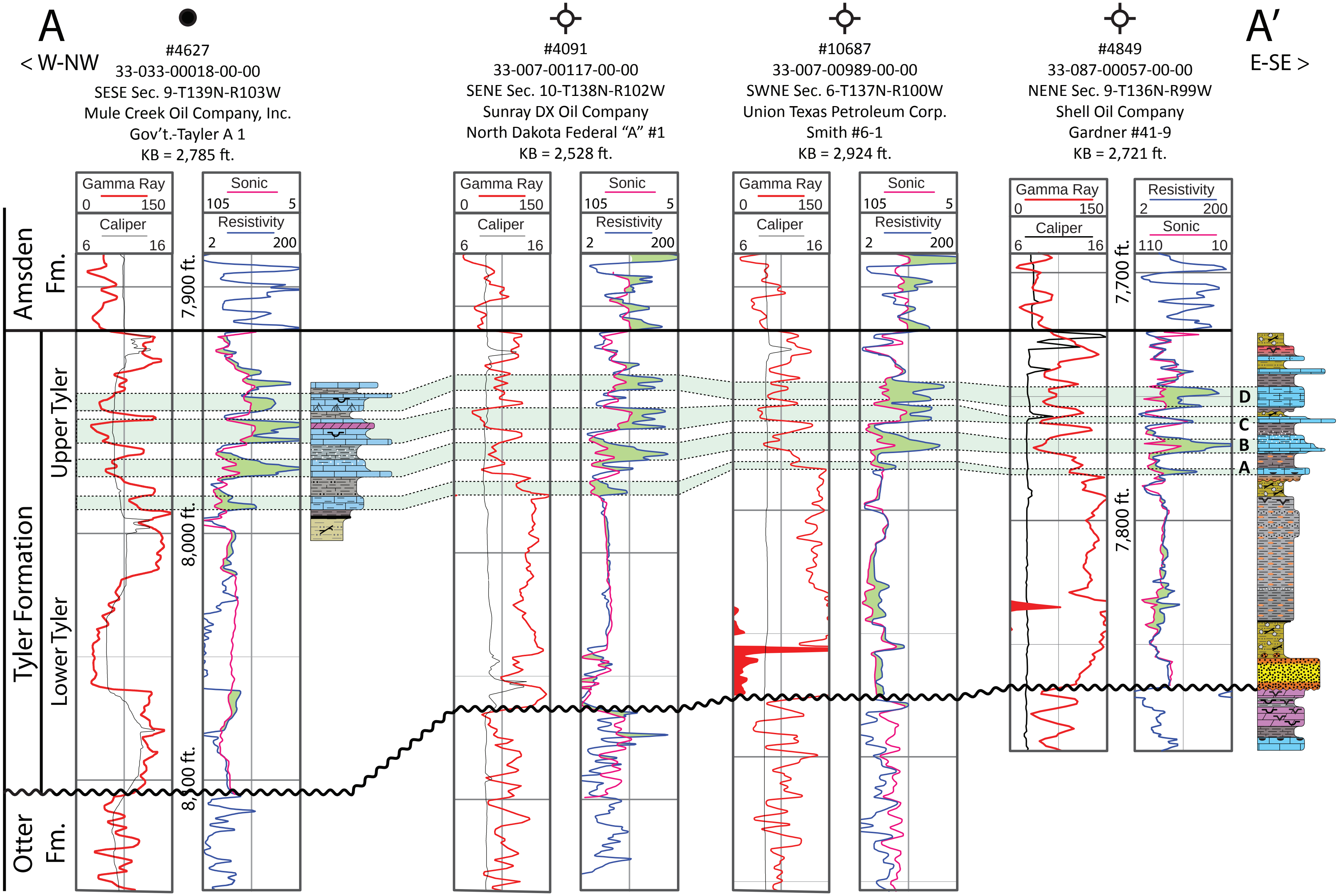

Figure 9. Stratigraphic cross-section of the Tyler Formation correlating the upper Tyler limestone beds across southwestern North Dakota. Note that limestone beds A and B have similar thicknesses (A thickens westward) and log signatures across each well. Limestone bed C varies in thickness from approximately 2-3 ft. to 10 ft. Limestone bed D has a moderately consistent thickness but its log signature changes, especially the sonic travel time.

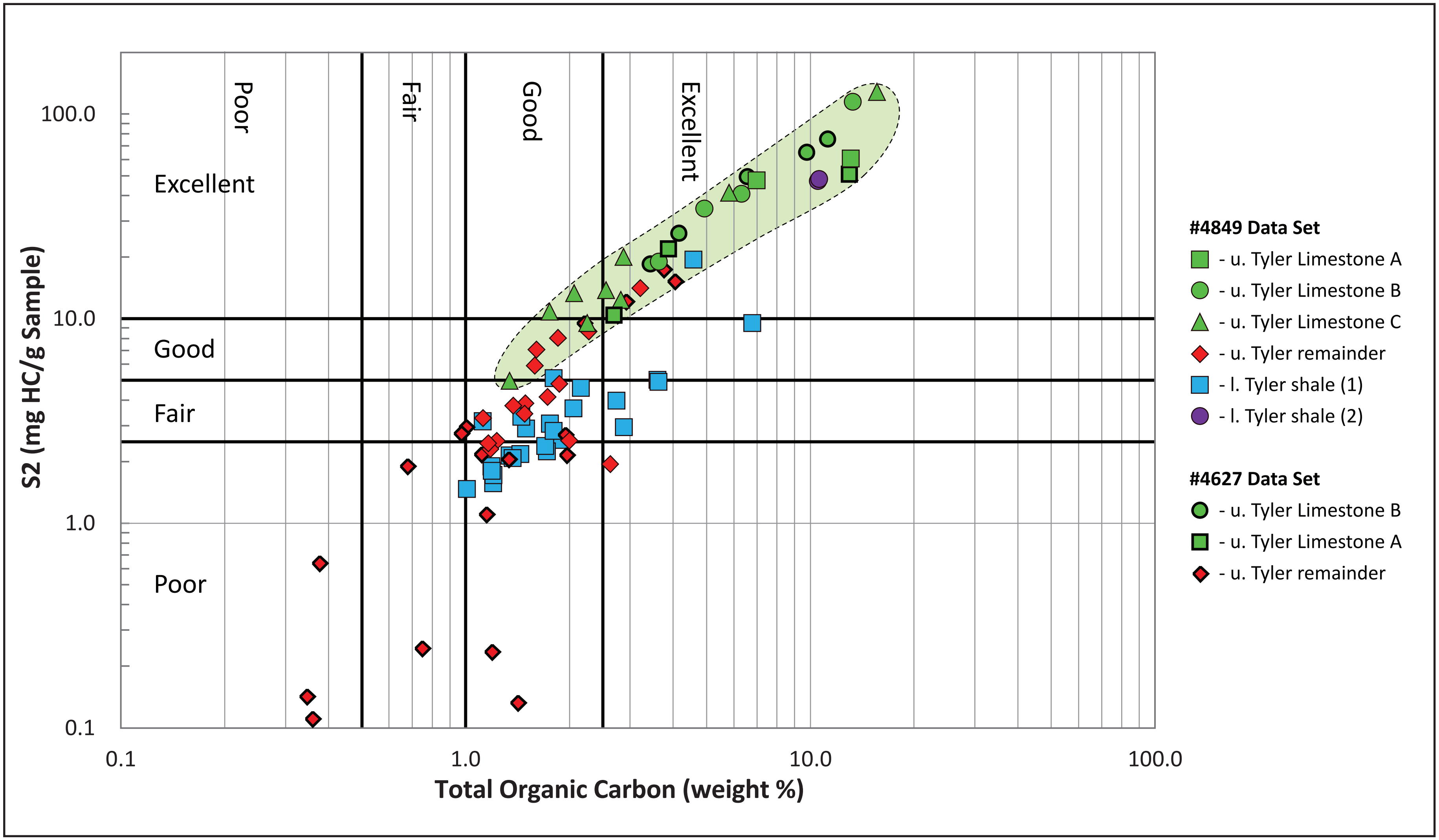

Figure 10. Organic-richness plot (Dembicki, 2009) of Tyler samples analyzed for RockEval from Mule Creek Oil Company's Government Taylor #1-449 and Shell Oil's Gardner #41-9. For #4849, only samples with greater than 1 wt. % TOC were analyzed for RockEval. The shaded green area outlines the analyzes from the upper Tyler organic-rich limestone beds.

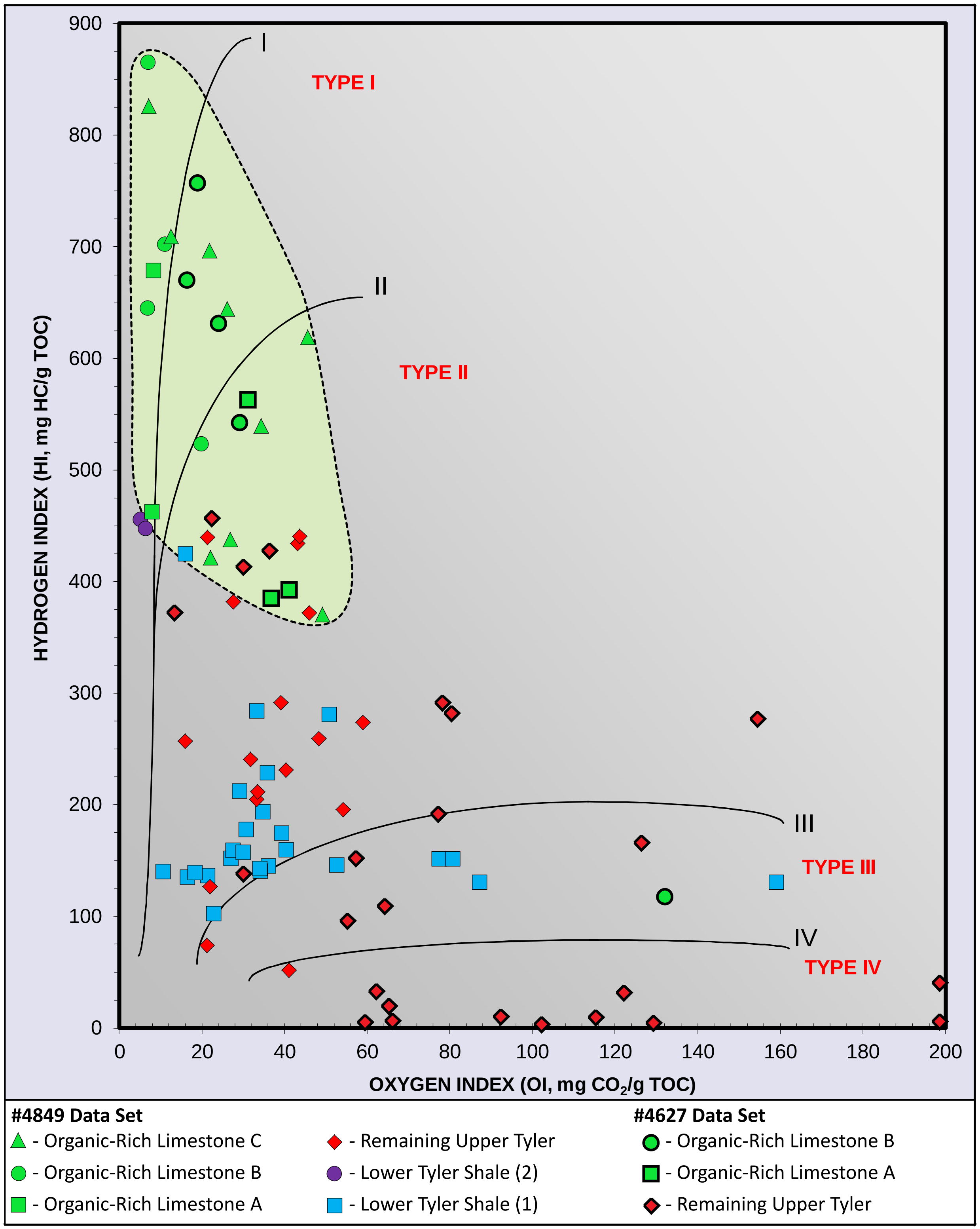

Figure 11. Modified Van Krevelen diagram diplaying Hydrogen (HI) vs. Oxygen (OI) Index values from Mule Creek Oil Company's Government Taylor #1-449 (#4627) and Shell Oil's Gardner #41-9 (#4849). The green shaded area spans the primary data range of samples from the upper Tyler organic-rich limestone intervals.

Table 1. TOC and Rock Eval data set

Well Name	NDIC	Location	Source	Depth (ft.)	TOC (wt. %)	S1 (mg/g)	S2 (mg/g)	S3 (mg/g)	Tmax (°C)	HI	OI	PI	Classification used for Figures 10 and 11
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7734	0.81								
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7739	0.15								
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7740	0.19								
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7741	0.26								
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7742	0.25								
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7743	0.35								
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7744	0.34								
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7745	2.06	2.32	13.3	0.54	446	644	26	0.15	Limestone D
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7746	2.56	2.7	13.79	0.88	445	540	34	0.16	Limestone D
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7747	2.87	2.52	20.02	0.63	442	697	22	0.11	Limestone D
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7748	15.58	5.89	128.7	1.12	445	826	7	0.04	Limestone D
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7749	2.25	3.07	9.5	0.5	434	421	22	0.24	Limestone D
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7750	2.82	2.15	12.33	0.76	445	438	27	0.15	Limestone D
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7751	1.34	1.21	4.97	0.66	440	371	49	0.20	Limestone D
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7752	1.75	2.9	10.84	0.8	436	619	46	0.21	Limestone D
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7753	5.81	3.93	41.19	0.73	443	709	13	0.09	Limestone D
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7754	0.51								
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7755	1.49	0.77	3.86	0.72	441	259	48	0.17	upper Tyler remainder
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7756	0.25								
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7757	2.63	1.46	1.94	0.56	432	74	21	0.43	upper Tyler remainder
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7758	0.30								
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7759	0.94								
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7760	0.41								
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7761	0.32								
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7762	1.16	0.44	2.46	0.39	441	212	34	0.15	upper Tyler remainder
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7763	1.12	0.41	3.27	0.44	441	291	39	0.11	upper Tyler remainder
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7764	3.22	1.54	14.13	0.69	446	440	21	0.10	upper Tyler remainder
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7765	2.28	1.12	8.69	0.63	446	382	28	0.11	upper Tyler remainder
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7766	1.85	1.34	8.04	0.8	446	434	43	0.14	upper Tyler remainder
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7767	1.60	1.45	7.06	0.7	444	440	44	0.17	upper Tyler remainder

Well Name	NDIC	Location	Source	Depth (ft.)	TOC (wt. %)	S1 (mg/g)	S2 (mg/g)	S3 (mg/g)	Tmax (°C)	HI	OI	PI	Classification used for Figures 10 and 11
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7768	3.63	2.95	19.01	0.72	445	524	20	0.13	Limestone B
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7769	4.93	2.85	34.6	0.54	445	703	11	0.08	Limestone B
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7770	0.65								
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7771	13.28	4.98	114.98	0.93	445	866	7	0.04	Limestone B
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7772	6.32	3.65	40.76	0.43	448	645	7	0.08	Limestone B
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7773	1.87	1.85	4.8	0.3	433	257	16	0.28	upper Tyler remainder
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7774	1.23	0.46	2.52	0.41	444	205	33	0.15	upper Tyler remainder
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7775	1.73	0.91	4.15	0.55	443	240	32	0.18	upper Tyler remainder
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7776	1.18	0.51	2.31	0.64	443	196	54	0.18	upper Tyler remainder
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7777	1.48	0.31	3.43	0.6	447	231	40	0.08	upper Tyler remainder
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7778	1.37	0.4	3.76	0.81	447	274	59	0.10	upper Tyler remainder
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7779	1.59	0.66	5.9	0.73	446	372	46	0.10	upper Tyler remainder
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7780	6.98	2.73	47.38	0.58	444	679	8	0.05	Limestone A
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7781	13.10	5.18	60.61	1.03	439	463	8	0.08	Limestone A
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7782	2.00	0.76	2.53	0.44	441	127	22	0.23	upper Tyler remainder
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7783	0.81								
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7784	0.79								
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7785	1.31	0.17	0.68	0.54	458	52	41	0.20	upper Tyler remainder
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7786	0.51								
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7787	0.71								
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7788	0.52								
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7789	0.48								
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7790	0.20								
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7791	0.25								
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7792	0.23								
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7793	0.25								
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7794	0.31								
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7795	0.15								
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7796	0.25								
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7797	0.25								
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7798	0.28								
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7799	0.23								

Well Name	NDIC	Location	Source	Depth (ft.)	TOC (wt. %)	S1 (mg/g)	S2 (mg/g)	S3 (mg/g)	Tmax (°C)	HI	OI	PI	Classification used for Figures 10 and 11
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7800	0.27								
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7801	0.23								
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7802	0.32								
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7803	0.33								
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7804	0.30								
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7805	0.22								
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7806	0.30								
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7807	0.29								
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7808	0.39								
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7809	2.74	0.85	3.98	0.99	442	145	36	0.18	lower Tyler shale-1
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7810	1.20	0.24	1.57	1.91	444	131	159	0.13	lower Tyler shale-1
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7811	0.92								
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7812	1.20	0.23	1.72	0.41	442	143	34	0.12	lower Tyler shale-1
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7813	2.05	0.53	3.65	0.63	444	178	31	0.13	lower Tyler shale-1
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7814	1.19	0.31	1.8	0.92	442	151	77	0.15	lower Tyler shale-1
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7815	2.88	0.69	2.95	0.66	439	103	23	0.19	lower Tyler shale-1
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7816	1.70	0.39	2.39	0.58	447	141	34	0.14	lower Tyler shale-1
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7817	1.87	0.5	2.56	0.4	440	137	21	0.16	lower Tyler shale-1
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7818	3.63	0.71	4.91	0.6	439	135	17	0.13	lower Tyler shale-1
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7819	1.50	0.54	2.9	0.52	442	194	35	0.16	lower Tyler shale-1
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7820	1.19	0.27	1.9	0.48	443	160	40	0.12	lower Tyler shale-1
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7821	1.01	0.28	1.47	0.53	441	146	53	0.16	lower Tyler shale-1
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7822	1.37	0.26	2.08	0.37	447	152	27	0.11	lower Tyler shale-1
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7823	1.34	0.33	2.14	0.37	445	159	28	0.13	lower Tyler shale-1
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7824	0.42								
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7825	1.80	0.5	5.12	0.6	444	284	33	0.09	lower Tyler shale-1
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7826	4.57	1.68	19.43	0.73	446	425	16	0.08	lower Tyler shale-1
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7827	1.12	0.41	3.15	0.57	443	281	51	0.12	lower Tyler shale-1
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7828	1.45	0.51	3.32	0.52	444	229	36	0.13	lower Tyler shale-1
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7829	2.16	1.06	4.59	0.63	439	213	29	0.19	lower Tyler shale-1
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7830	10.60	5.78	48.3	0.54	434	456	5	0.11	lower Tyler shale-2
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7831	10.52	5.7	47.13	0.66	433	448	6	0.11	lower Tyler shale-2

Well Name	NDIC	Location	Source	Depth (ft.)	TOC (wt. %)	S1 (mg/g)	S2 (mg/g)	S3 (mg/g)	Tmax (°C)	HI	OI	PI	Classification used for Figures 10 and 11
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7832	1.80	0.59	2.83	0.54	442	157	30	0.17	lower Tyler shale-1
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7833	3.61	0.98	5.02	0.66	442	139	18	0.16	lower Tyler shale-1
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7834	1.44	0.45	2.18	1.16	442	152	81	0.17	lower Tyler shale-1
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7835	0.85								
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7836	1.72	0.53	2.25	1.5	442	131	87	0.19	lower Tyler shale-1
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7837	1.76	0.49	3.07	0.69	444	175	39	0.14	lower Tyler shale-1
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7838	6.79	1.24	9.52	0.72	435	140	11	0.12	lower Tyler shale-1
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7839	0.38								
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7840	0.42								
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7841	0.38								
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7842	0.48								
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7843	0.43								
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7844	0.65								
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7845	0.63								
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7846	0.68								
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7847	0.56								
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7848	0.57								
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7867	0.79	0.2	0.89	0.63	439	113	80	0.18	
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7868	0.12								
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7869	0.15								
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7870	0.04								
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7880	0.29								
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7881	0.39								
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7882	0.37								
Gardner #41-9	4849	Sec. 9-T136N-R99W	NDGS	7883	0.63	0.31	0.65	1.01	400	103	160	0.32	
Gov't Taylor #449-1	4627	Sec. 9-T139-R103W	?	7942	1.42	0.05	0.13	1.31	450	9	92	0.28	Remaining upper Tyler
Gov't Taylor #449-1	4627	Sec. 9-T139-R103W	?	7943	0.99	0.06	0.03	1.28	338	3	129	0.75	Remaining upper Tyler
Gov't Taylor #449-1	4627	Sec. 9-T139-R103W	?	7947	0.18	0.03	0.01	0.85	217	1	472	1.00	Remaining upper Tyler
Gov't Taylor #449-1	4627	Sec. 9-T139-R103W	?	7948	0.21	0.07	0.05	0.8	266	23	380	0.58	Remaining upper Tyler
Gov't Taylor #449-1	4627	Sec. 9-T139-R103W	?	7949	0.25	0.04	0.01	0.87	434	1	348	1.00	Remaining upper Tyler
Gov't Taylor #449-1	4627	Sec. 9-T139-R103W	?	7950	0.30	0.03	0.01	0.85	353	1	283	1.00	Remaining upper Tyler
Gov't Taylor #449-1	4627	Sec. 9-T139-R103W	?	7951	0.35	0.03	0.14	0.74	364	40	211	0.19	Remaining upper Tyler

Well Name	NDIC	Location	Source	Depth (ft.)	TOC (wt. %)	S1 (mg/g)	S2 (mg/g)	S3 (mg/g)	Tmax (°C)	HI	OI	PI	Classification used for Figures 10 and 11
Gov't Taylor #449-1	4627	Sec. 9-T139-R103W	?	7952	0.35	0.03	0.02	0.74	257	5	211	0.75	Remaining upper Tyler
Gov't Taylor #449-1	4627	Sec. 9-T139-R103W	?	7953	0.70	0.03	0.02	0.72	252	2	102	0.75	Remaining upper Tyler
Gov't Taylor #449-1	4627	Sec. 9-T139-R103W	?	7954	0.92	0.04	0.05	0.61	257	5	66	0.50	Remaining upper Tyler
Gov't Taylor #449-1	4627	Sec. 9-T139-R103W	?	7955	1.17	0.05	0.05	0.7	271	4	59	0.50	Remaining upper Tyler
Gov't Taylor #449-1	4627	Sec. 9-T139-R103W	?	7956	0.32	0.03	0.03	0.37	294	9	115	0.50	Remaining upper Tyler
Gov't Taylor #449-1	4627	Sec. 9-T139-R103W	?	7958	1.20	0.08	0.23	0.79	306	19	65	0.27	Remaining upper Tyler
Gov't Taylor #449-1	4627	Sec. 9-T139-R103W	?	7959	1.12	0.27	2.14	0.87	435	191	77	0.11	Remaining upper Tyler
Gov't Taylor #449-1	4627	Sec. 9-T139-R103W	?	7960	0.38	0.28	0.63	0.48	406	165	126	0.31	Remaining upper Tyler
Gov't Taylor #449-1	4627	Sec. 9-T139-R103W	?	7961	1.15	0.11	1.1	0.64	442	95	55	0.09	Remaining upper Tyler
Gov't Taylor #449-1	4627	Sec. 9-T139-R103W	?	7962	1.34	0.09	2.03	0.77	449	151	57	0.04	Remaining upper Tyler
Gov't Taylor #449-1	4627	Sec. 9-T139-R103W	?	7963	3.78	0.5	17.27	0.85	444	456	22	0.03	Remaining upper Tyler
Gov't Taylor #449-1	4627	Sec. 9-T139-R103W	?	7964	0.38	0.28	0.63	0.48	406	165	126	0.31	Remaining upper Tyler
Gov't Taylor #449-1	4627	Sec. 9-T139-R103W	?	7965	0.36	0.16	0.11	0.44	331	30	122	0.62	Remaining upper Tyler
Gov't Taylor #449-1	4627	Sec. 9-T139-R103W	?	7966	2.94	0.28	12.12	0.9	448	412	30	0.02	Remaining upper Tyler
Gov't Taylor #449-1	4627	Sec. 9-T139-R103W	?	7966	4.08	0.47	15.16	0.54	452	371	13	0.03	Remaining upper Tyler
Gov't Taylor #449-1	4627	Sec. 9-T139-R103W	?	7970	2.22	0.29	9.48	0.8	450	427	36	0.03	Remaining upper Tyler
Gov't Taylor #449-1	4627	Sec. 9-T139-R103W	?	7971	1.01	0.18	2.93	0.79	447	290	78	0.06	Remaining upper Tyler
Gov't Taylor #449-1	4627	Sec. 9-T139-R103W	?	7972	0.97	0.16	2.73	0.78	447	281	80	0.06	Remaining upper Tyler
Gov't Taylor #449-1	4627	Sec. 9-T139-R103W	?	7973	3.43	1.02	18.57	1.01	448	541	29	0.05	Limestone B
Gov't Taylor #449-1	4627	Sec. 9-T139-R103W	?	7974	4.16	0.62	26.21	1.03	448	630	24	0.02	Limestone B
Gov't Taylor #449-1	4627	Sec. 9-T139-R103W	?	7975	0.43	0.11	0.5	0.57	439	116	132	0.18	Limestone B
Gov't Taylor #449-1	4627	Sec. 9-T139-R103W	?	7977	11.25	2.17	75.43	1.87	449	670	16	0.03	Limestone B
Gov't Taylor #449-1	4627	Sec. 9-T139-R103W	?	7978	6.59	1.17	49.88	1.3	453	756	19	0.02	Limestone B
Gov't Taylor #449-1	4627	Sec. 9-T139-R103W	?	7979	9.74	1.25	65.19	1.58	446	669	16	0.02	Limestone B
Gov't Taylor #449-1	4627	Sec. 9-T139-R103W	?	7980	1.96	0.14	2.69	0.6	444	137	30	0.05	Remaining upper Tyler
Gov't Taylor #449-1	4627	Sec. 9-T139-R103W	?	7980	0.68	0.17	1.88	1.05	444	276	154	0.08	Remaining upper Tyler
Gov't Taylor #449-1	4627	Sec. 9-T139-R103W	?	7988	2.70	0.51	10.37	1	449	384	37	0.05	Limestone A
Gov't Taylor #449-1	4627	Sec. 9-T139-R103W	?	7989	3.89	1.75	21.88	1.24	445	562	31	0.07	Limestone A
Gov't Taylor #449-1	4627	Sec. 9-T139-R103W	?	7991	12.96	2.82	50.72	5.32	440	391	41	0.05	Limestone A
Gov't Taylor #449-1	4627	Sec. 9-T139-R103W	?	7992	0.75	0.1	0.24	0.47	436	32	62	0.29	Remaining upper Tyler
Gov't Taylor #449-1	4627	Sec. 9-T139-R103W	?	7993	1.97	0.12	2.13	1.27	442	108	64	0.05	Remaining upper Tyler

References

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

Blatt, H., and Tracy, R., 1995: Petrology: Igneous, Sedimentary, and Metamorphic: 2nd edition, W.H. Feeman and Company, New York, 529 p.

Dembicki, H., 2009, Three common source rock evaluation errors made by geologists during prospect or play appraisals: American Association of Petroleum Geologists Bulletin, v. 93, p. 341-356.

Dow, W. G., 1974, Application of oil-correlation and source-rock data to exploration in Williston Basin, American Association of Petroleum Geologists Bulletin: v. 58, p 1253-1262.

LeFever, J. A., Nordeng, S. H., Nesheim T. O., 2012, 2012 Core Workshop Booklet: North Dakota Geological Survey, Geologic Investigation No. 127, 91 p.

Nesheim, T. O. and Nordeng, S. H., 2012, Source Rock Intervals within the Tyler Formation, ND: North Dakota Geological Survey, Geologic Investigation No. 151.

Nordeng, S. H., 2011, Reviewing the Resource Potential of the Pennsylvanian Tyler Formation: North Dakota Geological Survey Geo News, v. 38, No. 1, p. 21-25.

Nordeng, S. H., and Nesheim, T. O., 2010, Resource Potential of the Tyler Formation: North Dakota Geological Survey, Geologic Investigation No. 127.

Nordeng, S. H., and Nesheim, T. O., 2011, Determination of Subsurface Temperatures and the Fraction of Kerogen Converted to Petroleum within the Rauch Shapiro Fee #21-9, Billings Co.: North Dakota Geological Survey, Geologic Investigation No. 146.

Nordeng, S. H., and Nesheim, T. O., 2012[1], A Preliminary Evaluation of the Resource Potential of the Tyler Formation (Penn.) Based on a Combination of a Kinetically Based Maturation Index, Organic Carbon Content & Interval Thickness: North Dakota Geological Survey, Geologic Investigation No. 148.

Nordeng, S. H., and Nesheim, T. O., 2012[2], An Evaluation of the Resource Potential of the Tyler Formation (Pennsylvanian) using a Basin Centered Petroleum Accumulation Model: North Dakota Geological Survey, Report of Investigation No. 111, 60 p.

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

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.

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