22nd Williston Basin Petroleum Conference
May 20 – 22, 2014
Bismarck, ND

2014 Core Workshop

Tyler Formation
Pronghorn Member - Bakken Formation
Red River Formation

Julie A. LeFever
Stephan H. Nordeng
Timothy O. Nesheim

GEOLOGIC INVESTIGATION NO. 176
NORTH DAKOTA GEOLOGICAL SURVEY
Edward C. Murphy, State Geologist
Lynn D. Helms, Director Dept. of Mineral Resources
2014

Core Workshop sponsored by

SUNBURST CONSULTING

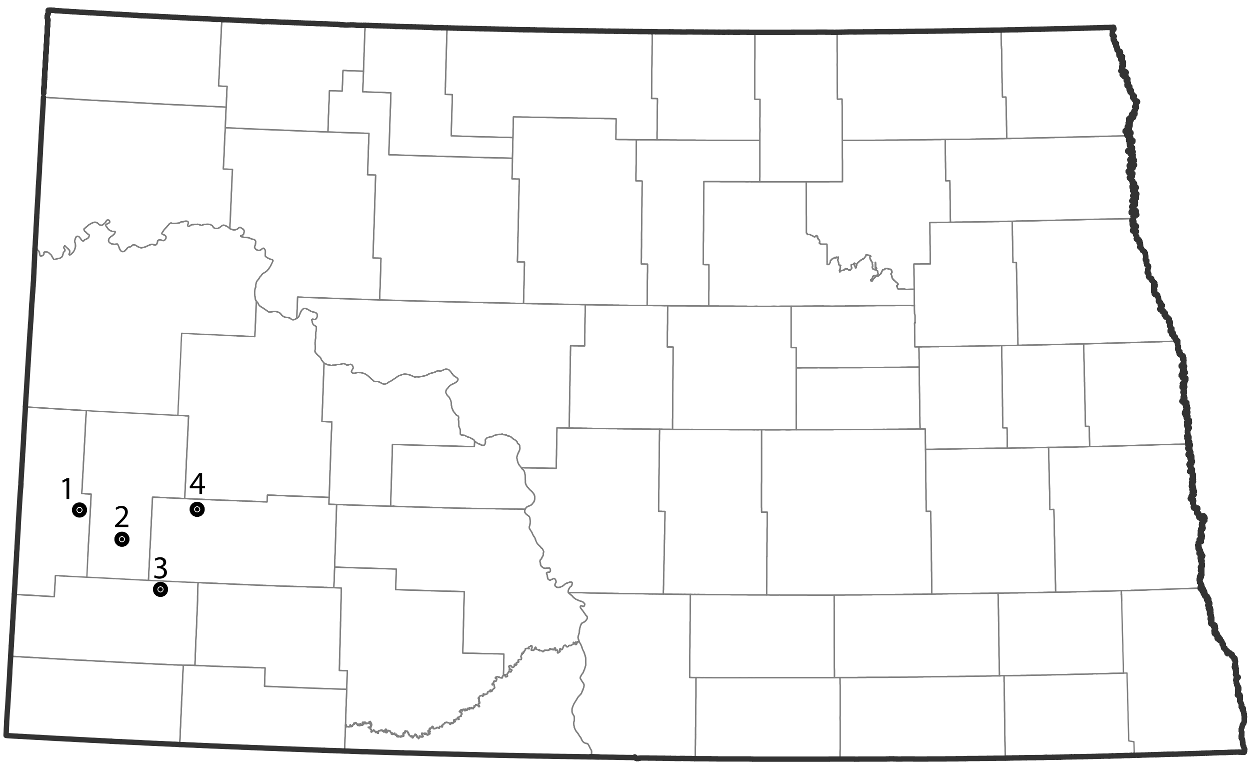
A GEOLOGY SERVICE

Table of Contents

WILLISTON BASIN PETROLEUM CONFERENCE
Core Workshop

Tyler Formation, Southwestern North Dakota

Timothy O. Nesheim and Stephan H. Nordeng
North Dakota Geological Survey



No.	Well	
1	Government Taylor #1-449 Mule Creek Oil Company SE, SE 9-139-103, Golden Valley County (#4627)	7940'-8001'
2	Jiggs #32-16 Duncan Energy Company SW, NE 16-138-101, Billings County (#13396)	8026'-8084'
3	Gardner #41-9 Shell Oil Company NE, NE 9-136-99, Slope County (#4849)	7725'-7792
4	Kostelecky #1-30 Inexco Oil Company NE, SE 30-140-97, Stark County (#5476)	8004'-8050'

Stratigraphy of the upper Tyler Formation (Pennsylvanian) across southwestern North Dakota

Timothy O. Nesheim and Stephen H. Nordeng

Introduction

The Tyler Formation (Pennsylvanian) extends across most of western North Dakota and into eastern Montana and northwestern South Dakota (Fig. 1). Within southwestern North Dakota, the Tyler Formation has previously been broken down informally into upper and lower units that were deposited through at least three marine transgressive-regressive cycles (Fig. 2) (Sturm 1983; 1987; Barwis, 1990). The first two transgressive-regressive cycles deposited the lower Tyler, which consists red to varicolored to very dark grey shale and mudstone with localized fluvial-deltaic sandstone intervals deposited within deltaic plain to anoxic marine conditions (Sturm (1983; 1987). The upper Tyler Formation was deposited during a third transgressive-regressive cycle and has been further broken down by Sturm (1983; 1987) into upper and lower subunits, which may correlate with the Cameron Creek and Bear Gulch Members from Maughan (1984) (Fig. 2). The lower subunit of the upper Tyler (~Bear Gulch Member) consists of interbedded dark grey to black limestone and shale deposited during the Tyler sea's final transgression, and the upper subunit (~Cameron Creek Member) is made up of red to grey to varicolored shale-mudstone and limestone deposited in an intertidal to supratidal setting during the following final regression of the Tyler sea (Fig. 2) (Sturm 1983; 1987). Lenticular bar-type sandstone bodies, which served as reservoirs along the Dickinson-Fryburg Trend, were deposited during the initial phases of the third transgressive cycle and are positioned stratigraphically near the base of the upper Tyler section (Sturm, 1987).

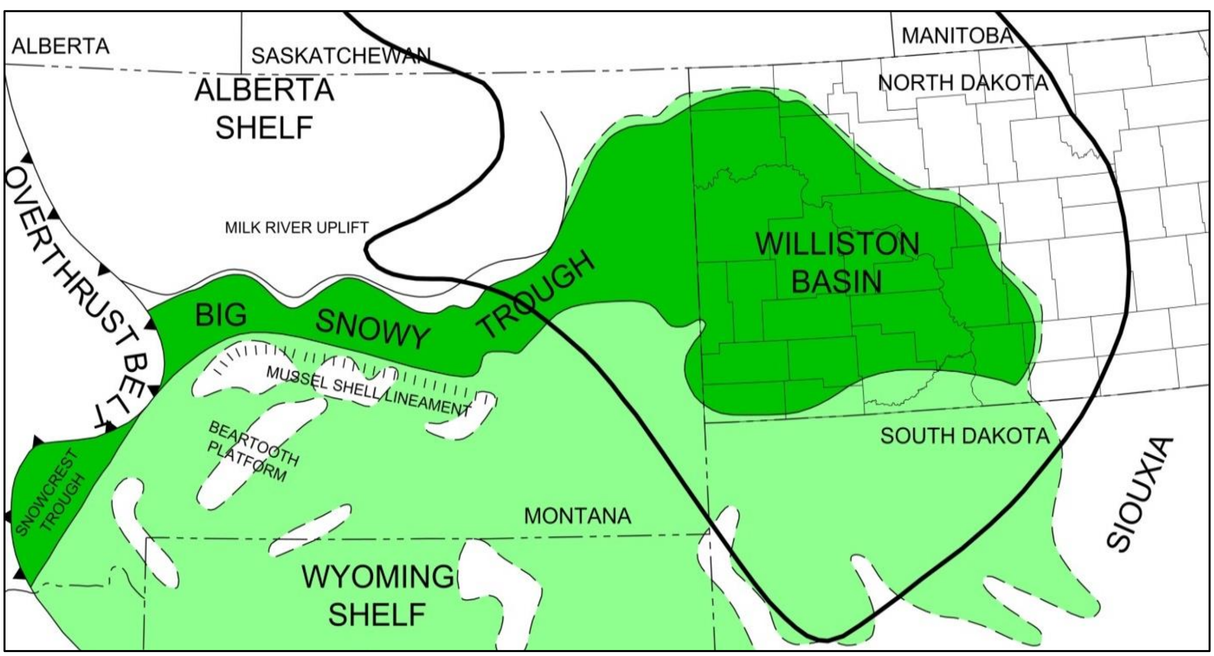


Figure 1. Regional extent map of the Tyler Formation and equivalent units. Modified after Maughan (1984): light green = Cameron Creek Member, dark green = Stonehouse Canyon and Bear Gulch Members.

The upper Tyler Formation has previously been documented to contain thermally mature source rock within part of southwestern North Dakota (Nordeng and Nesheim 2012; Nesheim and Nordeng, in prep). The upper Tyler Formation has previously been described to contain an interval of darkly colored interbedded limestone and shale within both central Montana and southwestern North Dakota (Sturm, 1983; 1987, Maughan, 1984; Barwis, 1990). Sturm (1983; 1987) reported an interval of "interbedded grey to black argillaceous limestone and calcareous shale," which he referred to as the lower subunit of the upper Tyler Formation within southwestern North Dakota. Spanning central Montana to North Dakota, Maughan (1984) observed a unit of "medium-grey to dark-grey, laminated to thinly bedded, argillaceous limestone and very calcareous mudstone" which he referred to as the Bear Gulch Member. Barwis (1990) also described a very comparable lithologic section of interbedded shale and limestone, which he referred to as the Bear Gulch Limestone and stated that this interval correlates westwards into the Big Snow Trough of central Montana. All of these previous publications appear to describe the same lithological-stratigraphic interval, which is the focus of this study.

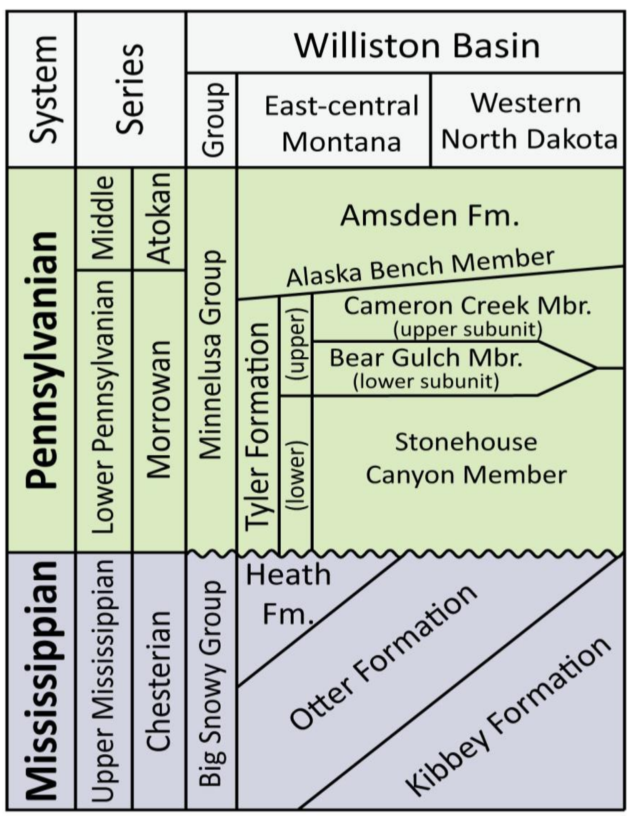


Figure 2. Stratigraphic nomenclature chart for eastern to central Montana and western North Dakota. Modified after Maughan (1984). Sturm's (1983; 1987) terminology is displayed in parentheses.

Grenda (1978) described the Tyler's overall depositional setting as shallow, warm water with brackish to marine salinity conditions and an abundant nutrient supply based on core fossil assemblages. Maughan (1984) interpreted his Bear Gulch Member of central Montana to have been deposited within a brackish lake and/or shallow lagoon to a normal marine setting. Sturm (1984) interpreted his equivalent upper Tyler, lower subunit of southwestern North Dakota to have been deposited within a lagoonal-estuarine to marginal-marine environment. Barwis (1990) referred to his Bear Gulch Limestone as a "marine lime mudstone." While these interpretations vary slightly, and focus on differing areas, they combine to suggest a brackish to marine water depositional setting for the upper Tyler interval of interest.

Geological Overview

The upper Tyler Formation consists in part of a ~30-50 ft. thick interval of grey to black interbedded shale and limestone (Fig. 3 & 4). This darkly colored shale-limestone interval is thought to correlate with Sturm's (1983; 1987) lower subunit of the upper Tyler section and Maughan's Bear Gulch Member (Fig.

2). There are at least four distinct limestone beds (A-D) within the upper Tyler section that have lateral continuity and can be traced across much of southwestern North Dakota (Fig. 3). Each limestone bed typically displays a low gamma ray and high resistivity wireline log signature (Fig. 3). These upper Tyler limestone beds range from organic-lean, non-source rock to organic-rich, excellent quality source rock depending on stratigraphic position and geographic location. Some of the interbedded shale also has moderate source rock potential, but to an overall lesser extent than the organic-rich limestone (Nesheim and Nordeng, in prep).

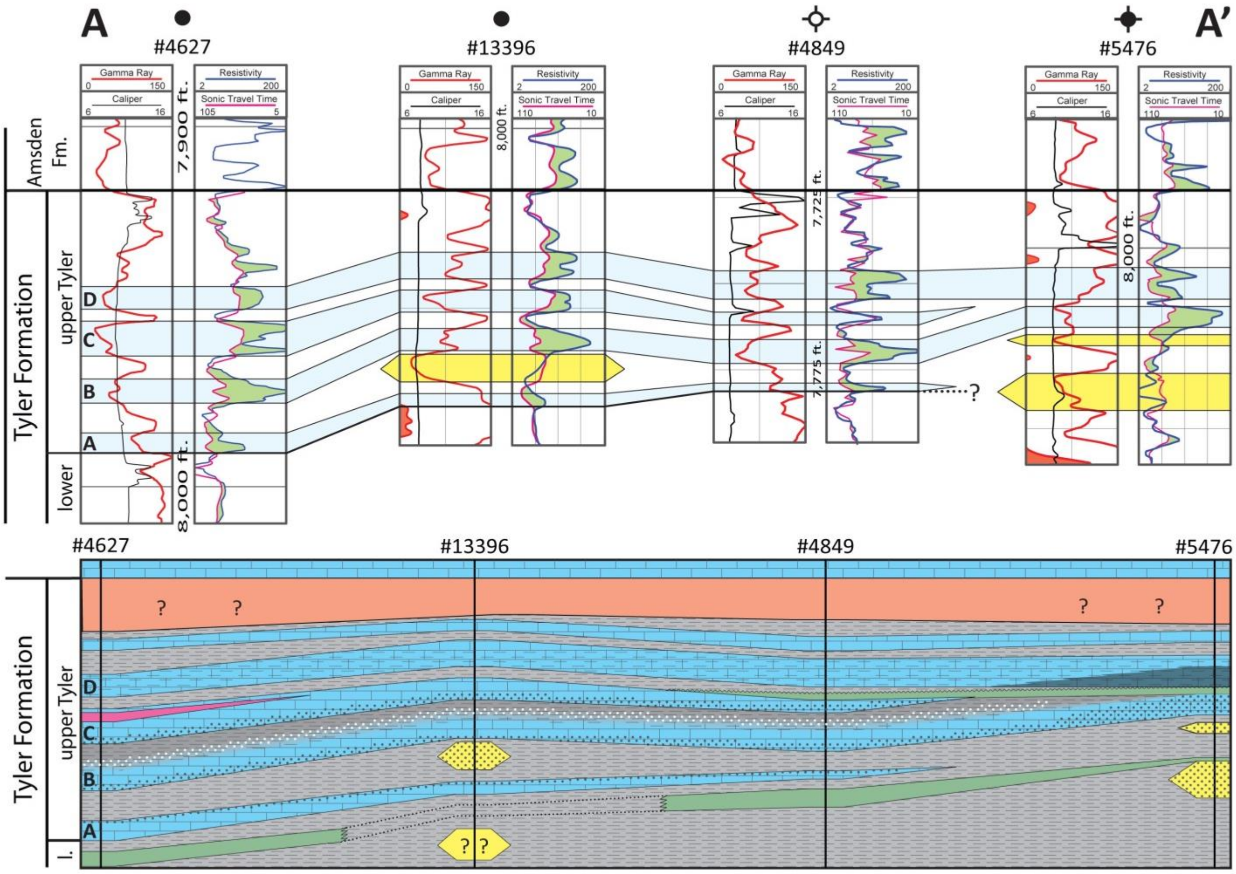


Figure 3. Wireline log (top) and illustrated (base) cross-section of the Tyler Formation. The blue shaded/colored intervals in both cross-sections indicate limestone beds and the yellow intervals indicate sandstone bodies.

Limestone A reaches a maximum thickness of 3 ft. in the western most core examined (#4627 – Fig. 4), where it may technically classify as calcareous shale. Limestone A typically consists of the following stratigraphic progression: several inches of very dark grey/black fossil lime wackestone (base), 1-2 ft. of dark grey to black argillaceous lime mudstone to calcareous shale (middle), and several inches of grey to black, very finely crystalline laminated lime boundstone (top) (Fig. 5 A-C). The boundstone consists of medium to dark grey lime packstone-grainstone laminations that are bound together by thin, black, presumably organic-rich algal (?) mudstone laminae. Wireline log mapping of Limestone A can be difficult due to its thin nature and high argillaceous content, which can seemingly blend the wireline log signature of Limestone A in with the surrounding shale. Limestone A is observed, when present, to be stratigraphically below the oil-productive bar-type sandstone/s along the Dickinson-Fryburg trend.

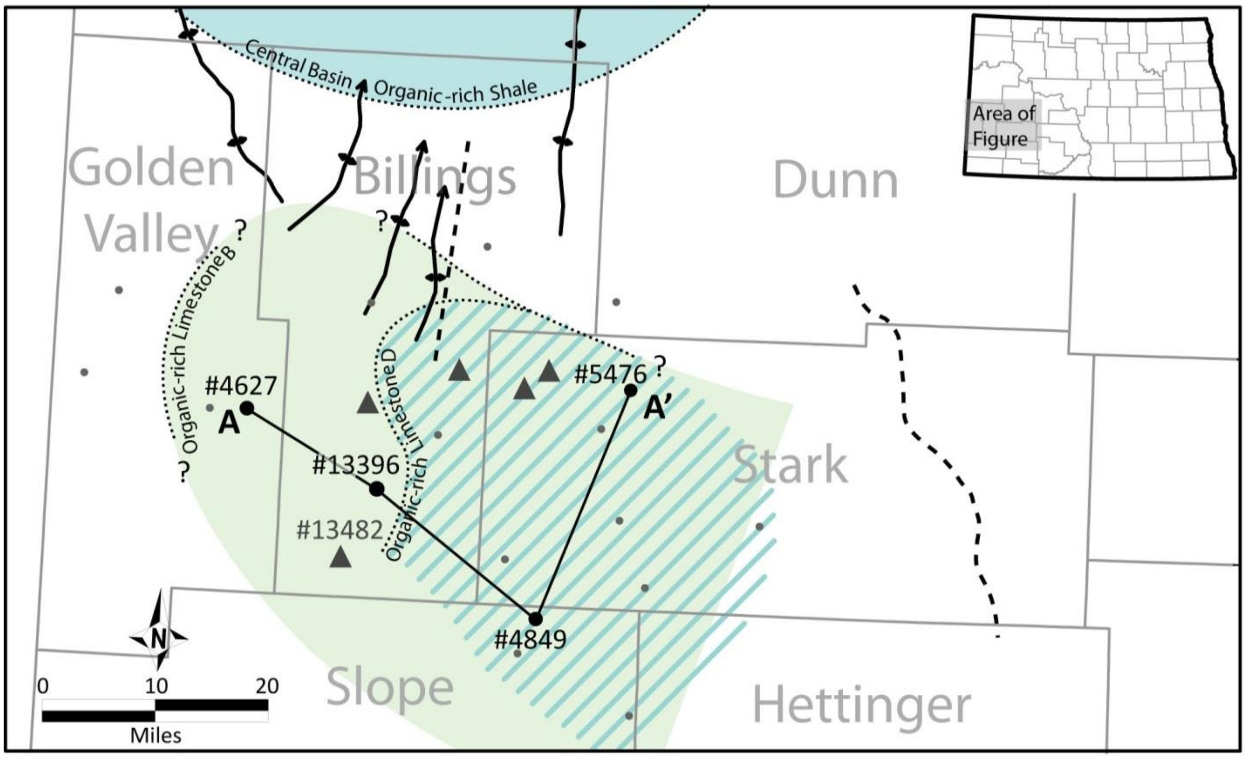


Figure 4. Field map of the study area displaying locations of cores included within this workshop volume (black circles) and additional cores examined spanning the interval of interest (dark grey triangles). The color shaded areas depicted where various intervals of the Tyler Formation classify as excellent quality source rock based by core and log analysis data. Significant anticline (solid black lines) and fault (dashed black lines) structures are also shown within the study area.

Limestone B typically consists of similar lithologies as Limestone A, but in a different stratigraphic sequence. Within the three westward located cores included in this study (#4627, #13396, and #4849 – Fig. 4), Limestone B consists of the following lithologic sequence: very fine to finely crystalline laminated lime boundstone (base) that is very similar to the boundstone described in limestone A, non-argillaceous lime mudstone (middle), and interbedded argillaceous lime mudstone and calcareous shale (top) (Fig. 5D-F). Limestone B tends to be 6-8 ft. thick within the study area and displays a sharp lower contact versus a more gradational upper contact. Within the upper portions of limestone B, and extending into the overlying shale, is an interval several feet thick containing abundant amounts of "white specs" that form parallel horizontal laminations, which may in part consist of ostracod fossils (Fig. 5D). Limestone B is positioned stratigraphically above, and sometimes lies directly on, the top of the productive bar-type sandstones along the Dickinson-Fryburg Trend. Limestone B lithologically transitions moving laterally towards the east-northeast (Zenith-Newton-Dickinson Field areas) into more grey-tan wacke-packstone to grainstone (e.g. #5476 – Fig. 4).

Limestone C varies in thickness from being absent in the eastern side of the study area, to being 10 ft. thick (including an interbedded nodular anhydrite) in the western most core included in this study. When present, limestone C typically begins with ~2 ft. of laminated to faintly bedded lime packstone-grainstone overlain by 1-4 ft. of tan to grey to black ~non-argillaceous lime mudstone (Fig. 6). In the

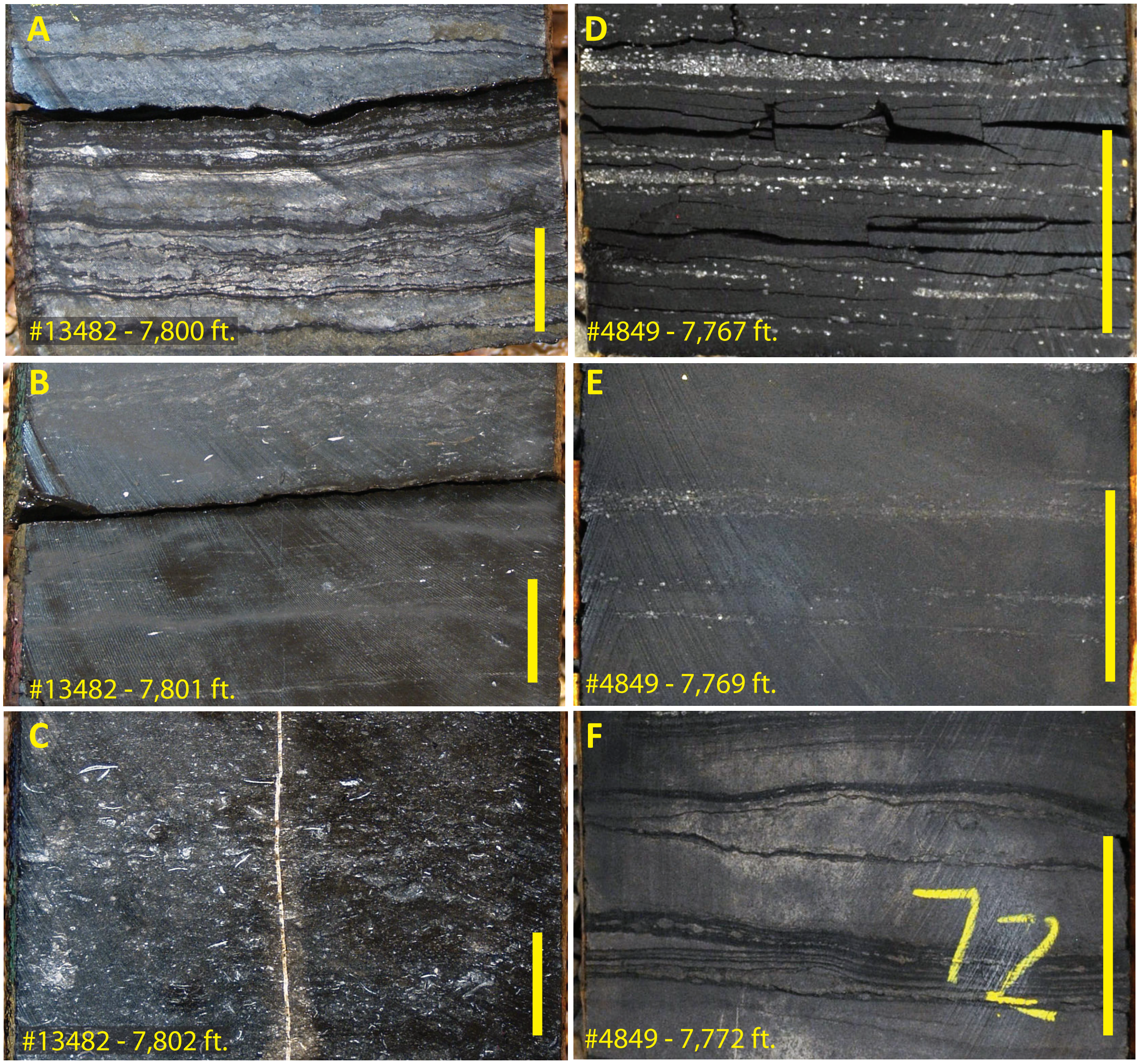


Figure 5. Core photograph examples of limestone bed A from Duncan Energy's Gerbig #21-20 (A-C) and limestone bed B from Shell Oil's Gardner #41-9 (D-F). Both sets of core photographs display to typical lithologic progressions from the top (A & D) to bottom (C & F) of each limestone bed. A) Grey and black laminated lime boundstone (medium grey finely crystalline packstone-grainstone laminations bound by black very thin algal (?) mudstone laminae), B) very dark grey to black argillaceous lime mudstone, and C) very dark grey/black massive fossil lime wackestone from Duncan Energy's Gerbig #21-20. D) Very dark grey/black laminated fissile ostracod (?) argillaceous lime wackestone/calcareous shale, E) very dark grey to black faintly laminated to thinly bedded lime mudstone, and F) grey and black laminated lime boundstone (medium grey finely crystalline packstone-grainstone laminations bound by black very thin algal (?) mudstone laminae) from Shell Oil's Gardner #41-9. NDIC well numbers and approximate core depths are listed in the bottom left of each photograph and 1 inch scale bars in the bottom right.

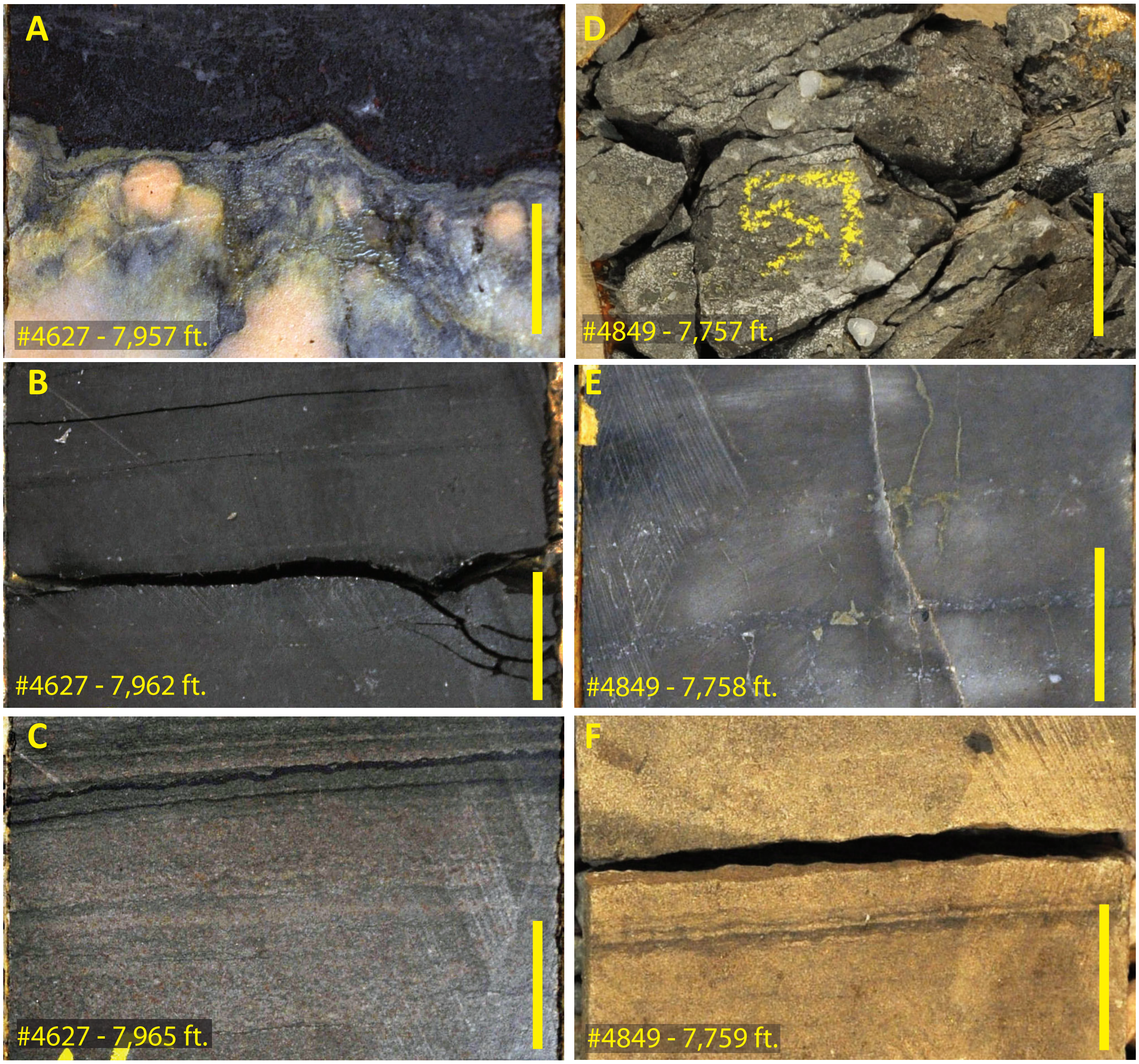


Figure 6. Core photograph examples of limestone bed C from Mule Creek Oil's Government #1-449 (A-C) and Shell Oil's Gardner #41-9 (E-F). Both sets of core photographs go in stratigraphic order from the top (A & D) to bottom (C & F) of the limestone bed B section. A) Nodular anhydrite overlain by very dark grey mudstone, B) very dark grey to black lime mudstone, and C) tan-grey laminated lime grainstone from Mule Creek Oil's Government #1-449. D) Greenish grey silty, pebble bearing, poorly indurate mudstone (paleosol), E) greyish-tan mudstone, and F) orange-tan oil-stained, laminated to bedded lime grainstone from Shell Oil's Gardner #41-9. NDIC well numbers and approximate core depths are listed in the bottom left of each photograph and 1 inch scale bars in the bottom right.

most western located core included in this study (#4627 – Fig. 4), the upper portions of limestone C contains nodular anhydrite, indicative of hypersaline water conditions (Fig. 6A). Within the two centrally located cores, limestone C contains rip-up clasts along its upper boundary within the Jiggs #32-16 (#13396 – Fig. 4) and is overlain by a possible thin paleosol within the Gardner #41-9 (#4849 – Fig. 4, Fig. 6D), marking a possible unconformity over limestone C within part of the study area. Within the eastern most core, the Kostelecky #1-30 (#5476 – Fig. 4), limestone C appears to be absent and a thin green mudstone occupies its approximate stratigraphic position.

Limestone bed D does not appear to display a recognizable vertical lithological progression that can be correlated between the examined cores. Limestone bed D also displays more lithological and textural variations between the examined cores and displays a less consistent log signature than limestone beds B and C. Therefore, the correlation of Limestone D between various core and logs is questionable. Limestone bed D contains laminations to thin beds of calcareous to non-calcareous shale and tends to be overall more argillaceous in composition based on visual examination than either limestone beds B or C. Limestone D is typically ~10 ft. thick and ranges from an organic-rich source rock (~4% TOC) within the Gardner #41-9 (#4849 – Fig. 4) to an organic-lean non-source rock (<1% TOC) within the Government Taylor #449-1 (#4627- Fig. 4), and also changes texturally between the two cores (Fig. 7) 1-2 inch thick horizontal bands of reddish coloration occur within the middle to upper portions of Limestone D (e.g. Fig. 7A & B) within the three northern cores included in this study (#4627, #13396, #5476 – Fig. 4). Bioturbation and possible root traces were observed in the western most core examined (Government Taylor #1-440, #4627- Fig. 4). 1-2 ft. of laminated lime packstone is sometimes present near the top of the Limestone B.

The shale intervals interbedded between Limestone beds A-D range from calcareous to non-calcareous shale (Fig. 8) and are typically 2-6 ft. thick. Discontinuous mudstone laminations are sometimes present within the interbedded shale intervals (e.g. Fig. 8B & C). The shale interval between limestone beds A and B tends to be sandy in part, which is the stratigraphic equivalent interval to most of the productive bar type sandstone along the Dickinson-Fryburg trend (e.g. Fig. 8D). Also to note, non-calcareous shale (determined by negligible reaction to HCl acid) tends to be more fissile than calcareous shale (moderate reaction to HCl acid).

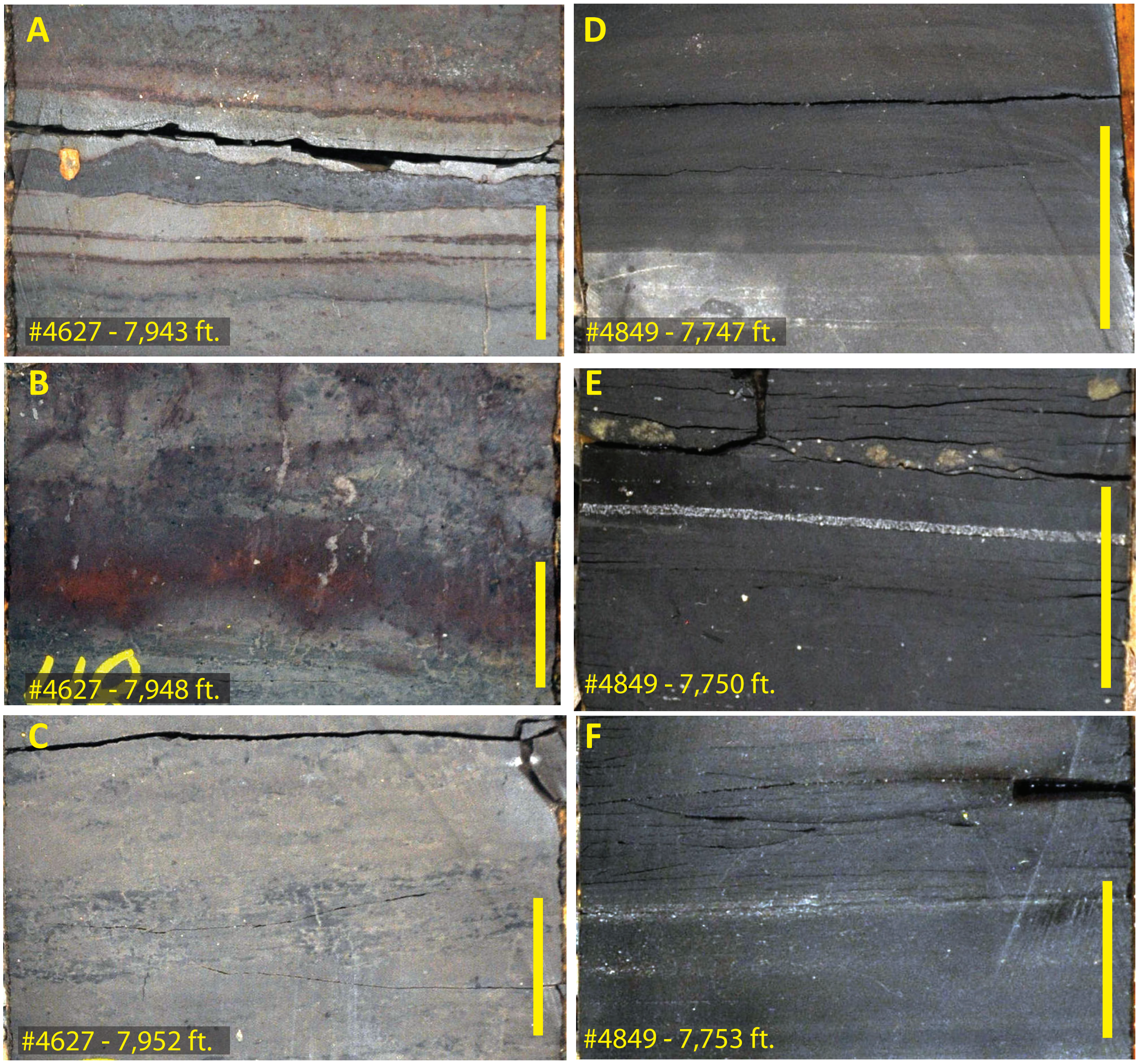


Figure 7. Core photograph examples of limestone bed D from Mule Creek Oil's Government Taylor #1-449 (A-C) and Shell Oil's Gardner #41-9 (D-F). Both sets of core photographs are displayed in stratigraphic order from top (A & D) to bottom (C & F) through limestone bed D. A) Reddish grey to grey laminated very finely crystalline limestone, B) red to medium grey lime wacke-mudstone, and C) tan to grey argillaceous lime mudstone from Mule Creek Oil's Government Taylor #1-449. D-F) Dark grey to black, slighty to very argillaceous fissile lime mudstone to calcareous shale from Shell Oil's Gardner #41-9. NDIC well numbers and approximate core depths are listed in the bottom left of each photograph and 1 inch scale bars in the bottom right.

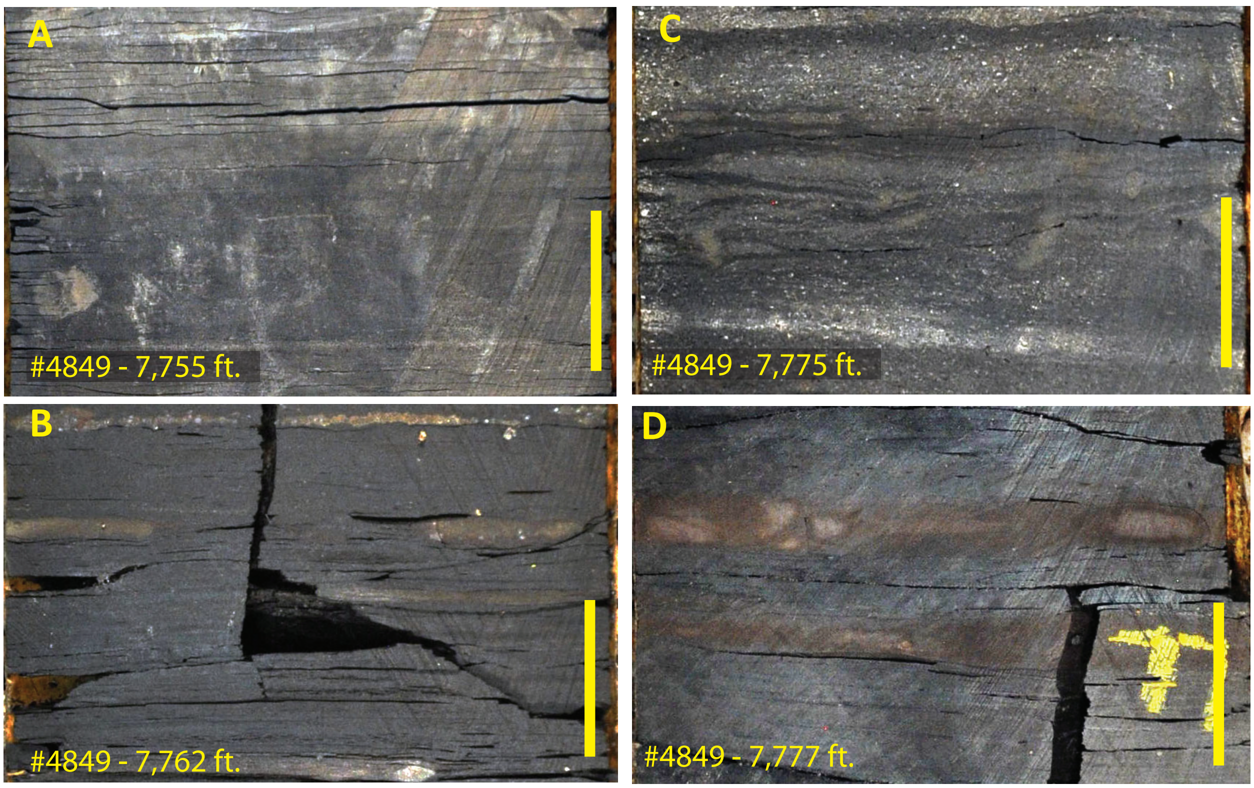


Figure 8. Core photograph examples from the shale intervals interbedded between limestone beds A-D from Shell Oil's Gardner #41-9 . A) Dark grey very fissile shale, B) very dark grey very fissile shale with faint discontinuous laminations, C) dark grey sandy shale, and D) very dark grey fissile shale with reddish brown mudstone laminations. NDIC well numbers and approximate core depths are listed in the bottom left of each photograph and 1 inch scale bars in the bottom right.

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.

Grenda, J.C., 1978, Paleozoology of oil well cores from the Tyler Formation (Pennsylvanian) in North Dakota, U.S.A., The economic geology of the Williston Basin; Montana, North Dakota, South Dakota, Saskatchewan, Manitoba: 24th Annual Conference, Williston Basin Symposium, Montana Geological Survey, p. 249-260.

Maughan, E. K., 1983, Paleogeographic Setting of Pennsylvanian Tyler Formation and Relation to Underlying Mississippian Rock in Montana and North Dakota: AAPG Bulletin, v. 68, no. 2, p. 178-195.

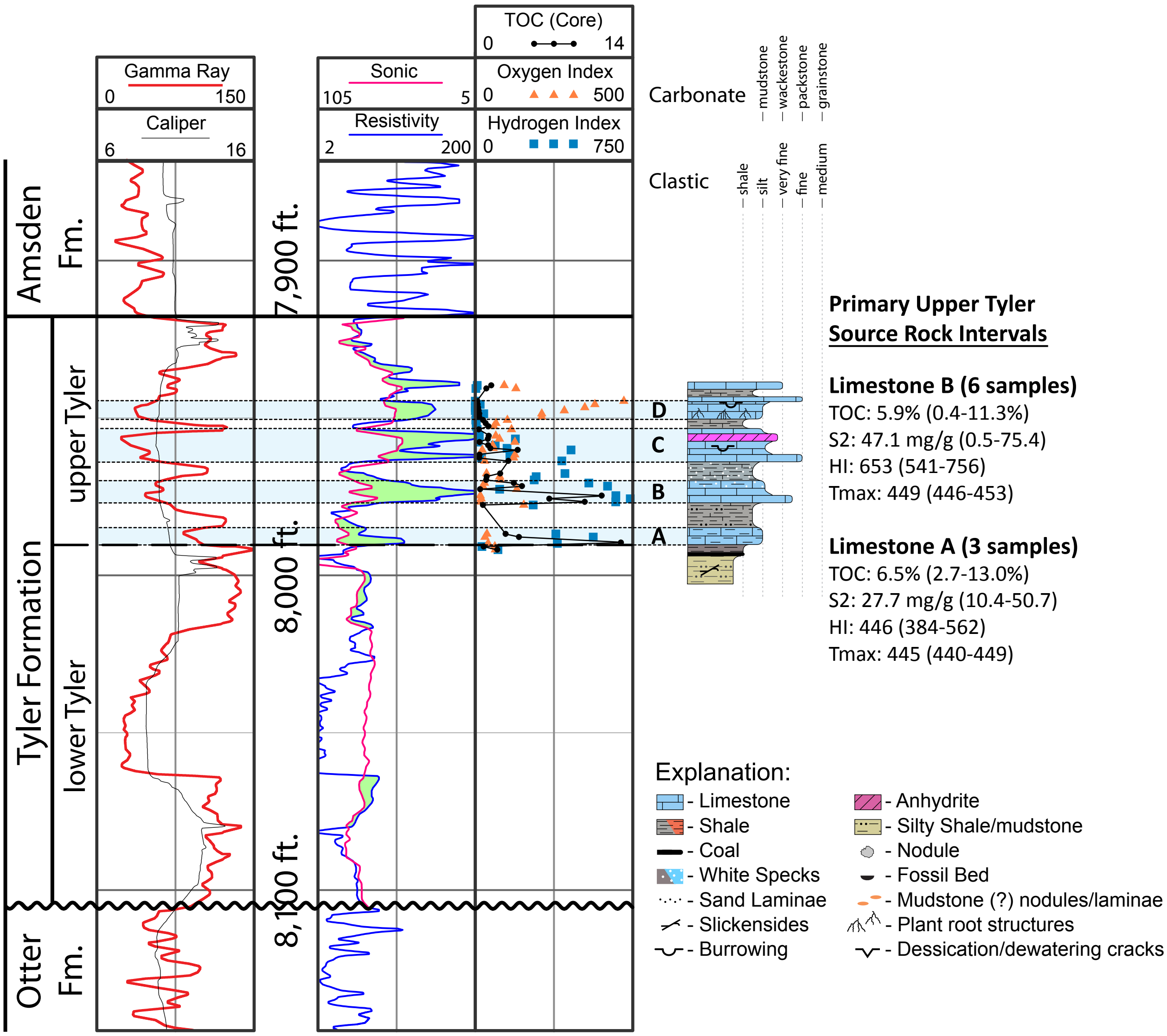
Nesheim, T. O., and Nordeng, S. H., in prep, Core Based Examination of Upper Tyler Formation Source Rocks within Southwestern North Dakota: North Dakota Geological Survey, Geological Investigation.

Nordeng, S. H., and Nesheim, T. O., 2012, 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.

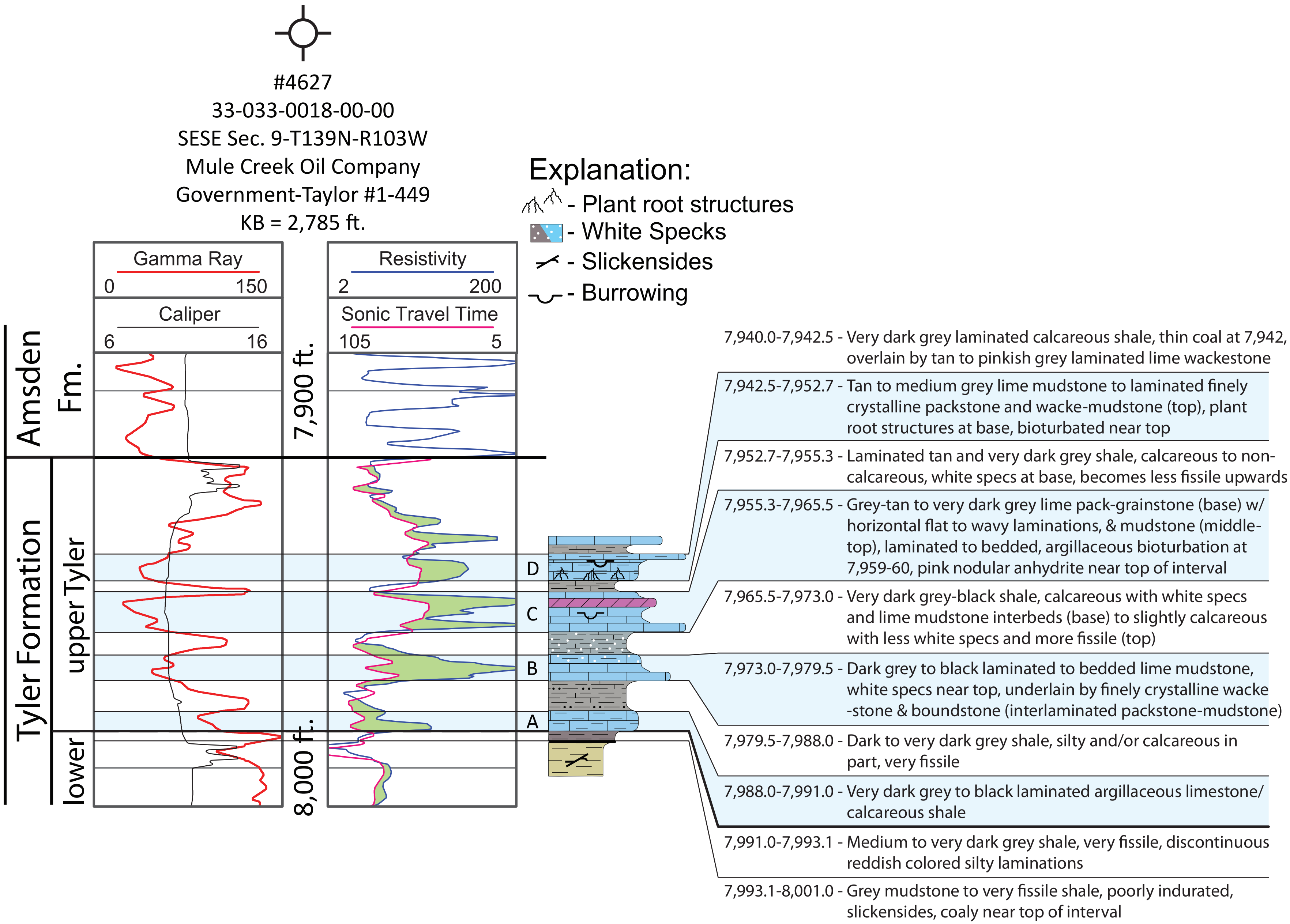
Sturm, S. D., 1983, Depositional Environments and Sandstone Diagenesis in the Tyler Formation (Pennsylvanian), Southwestern North Dakota: North Dakota Geological Survey, Report of Investigation No. 76, 48 p.

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

#4627
33-033-00018-00-00
SESE Sec. 9-T139N-R103W
Mule Creek Oil Company, Inc.
Government Taylor #1-449
KB = 2,785 ft.

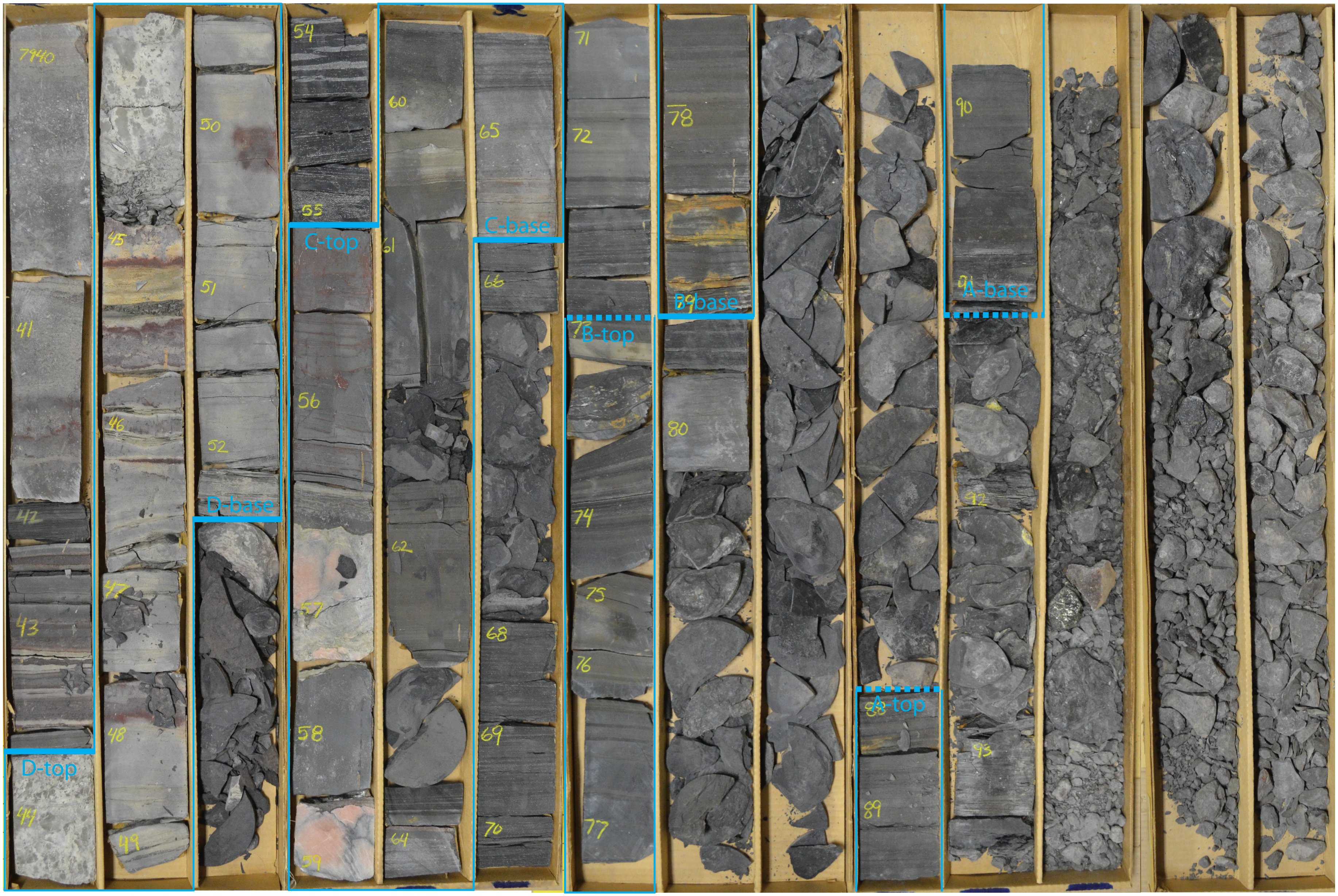


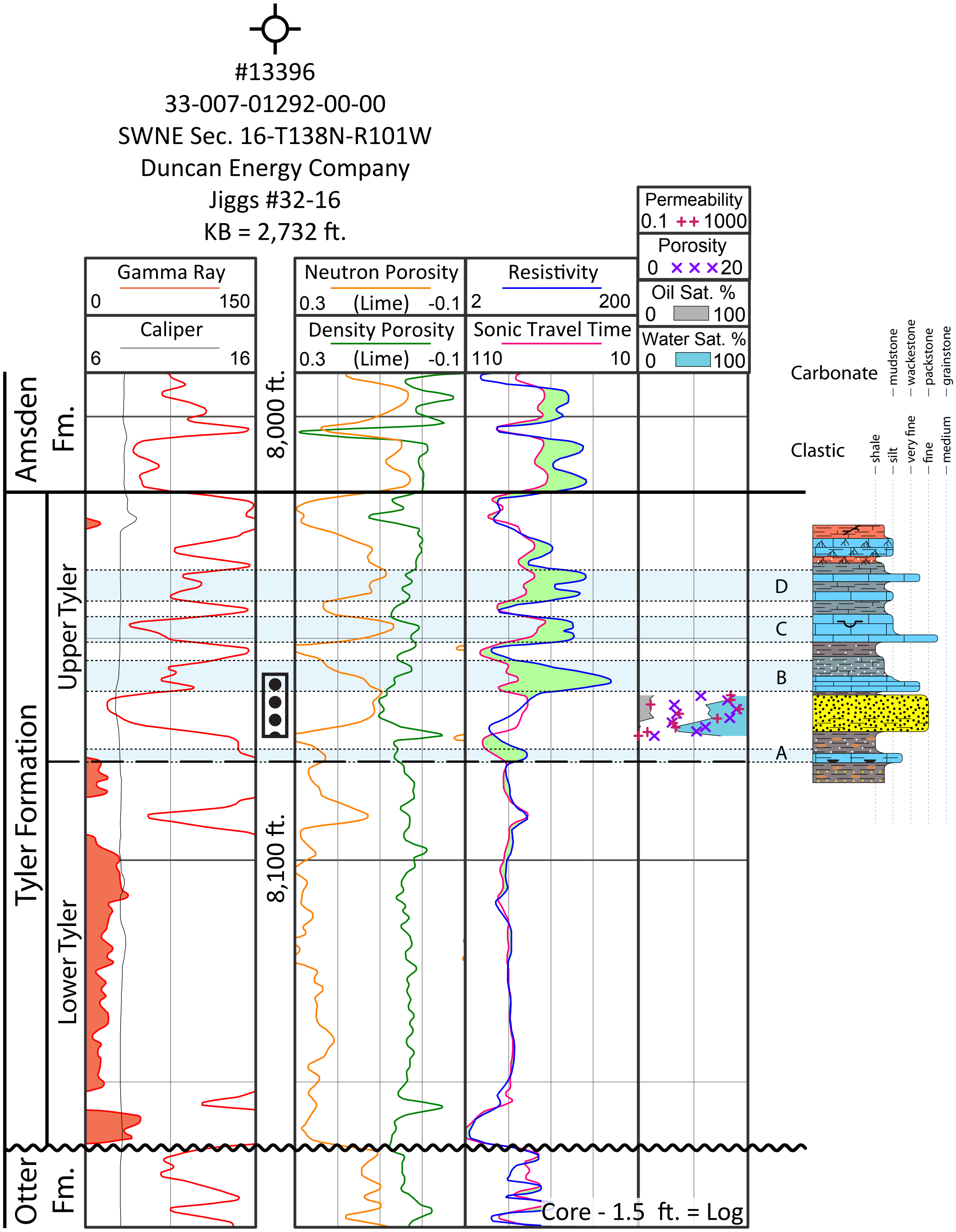
Wireline log of the Tyler Formation with illustrated core and geochemical data from Mule Creek Oil's Government Taylor A #1-449. The TOC, S2, HI, and Tmax values listed to the right of the log are average values with the value ranges listed in parantheses. The Government Taylor A #1-449 is currently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


#4627
33-033-0018-00-00
SESE Sec. 9-T139N-R103W
Mule Creek Oil Company
Government-Taylor #1-449
KB = 2,785 ft.
Explanation:
- Plant root structures
- White Specks
- Slickensides
- Burrowing
Gamma Ray
0 150
Caliper
6 16
Resistivity
2 200
Sonic Travel Time
105 5
7,900 ft.
8,000 ft.
Amsden Fm.
Tyler Formation
upper Tyler
lower
D
C
B
A
7,940.0-7,942.5 - Very dark grey laminated calcareous shale, thin coal at 7,942, overlain by tan to pinkish grey laminated lime wackestone
7,942.5-7,952.7 - Tan to medium grey lime mudstone to laminated finely crystalline packstone and wacke-mudstone (top), plant root structures at base, bioturbated near top
7,952.7-7,955.3 - Laminated tan and very dark grey shale, calcareous to non-calcareous, white specs at base, becomes less fissile upwards
7,955.3-7,965.5 - Grey-tan to very dark grey lime pack-grainstone (base) w/ horizontal flat to wavy laminations, & mudstone (middle-top), laminated to bedded, argillaceous bioturbation at 7,959-60, pink nodular anhydrite near top of interval
7,965.5-7,973.0 - Very dark grey-black shale, calcareous with white specs and lime mudstone interbeds (base) to slightly calcareous with less white specs and more fissile (top)
7,973.0-7,979.5 - Dark grey to black laminated to bedded lime mudstone, white specs near top, underlain by finely crystalline wacke-stone & boundstone (interlaminated packstone-mudstone)
7,979.5-7,988.0 - Dark to very dark grey shale, silty and/or calcareous in part, very fissile
7,988.0-7,991.0 - Very dark grey to black laminated argillaceous limestone/calcareous shale
7,991.0-7,993.1 - Medium to very dark grey shale, very fissile, discontinuous reddish colored silty laminations
7,993.1-8,001.0 - Grey mudstone to very fissile shale, poorly indurated, slickensides, coaly near top of interval

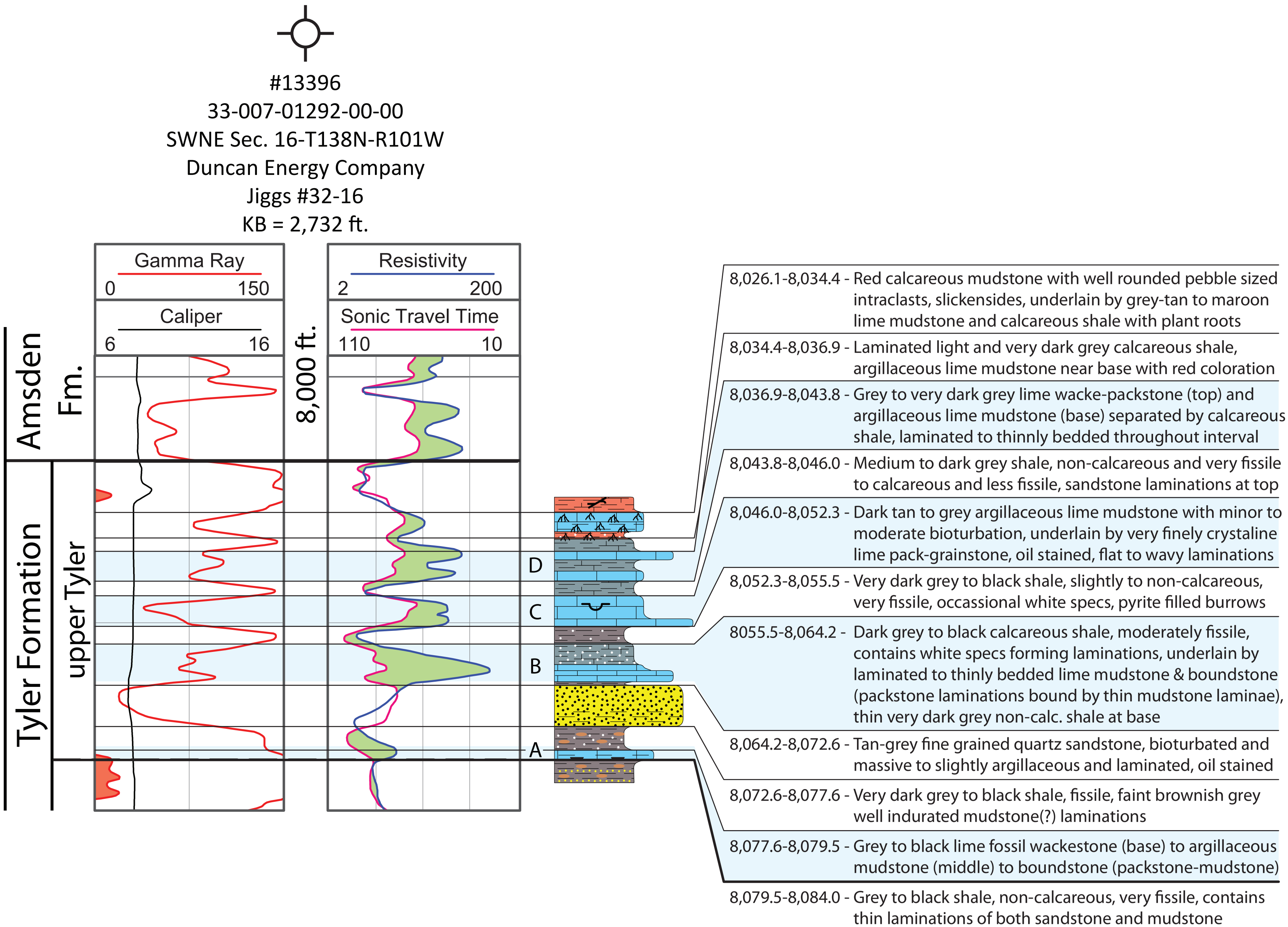
SESE Sec. 9, T.139N., R.103W.
Mule Creek Oil Company
Government Taylor #1-449

Cored Interval: 7,940-8,001 ft.





Wireline log of the Tyler Formation from Duncan Energy's Jiggs #32-16 with standard core analysis data and illustrated core lithologies. Perforations are indicated within the depth column by outlined black dots. The Jiggs #32-16 was drilled within the Tracy Mountain Field and has cumulatively produced 183,728 BBLS oil, 15,291 MCF gas, and 116,190 BBLS water from its vertical perforations and is currently under Temporaily Abandoned status. Perforations were completed with 4 holes per foot and 500 gallons of 15% HCl.

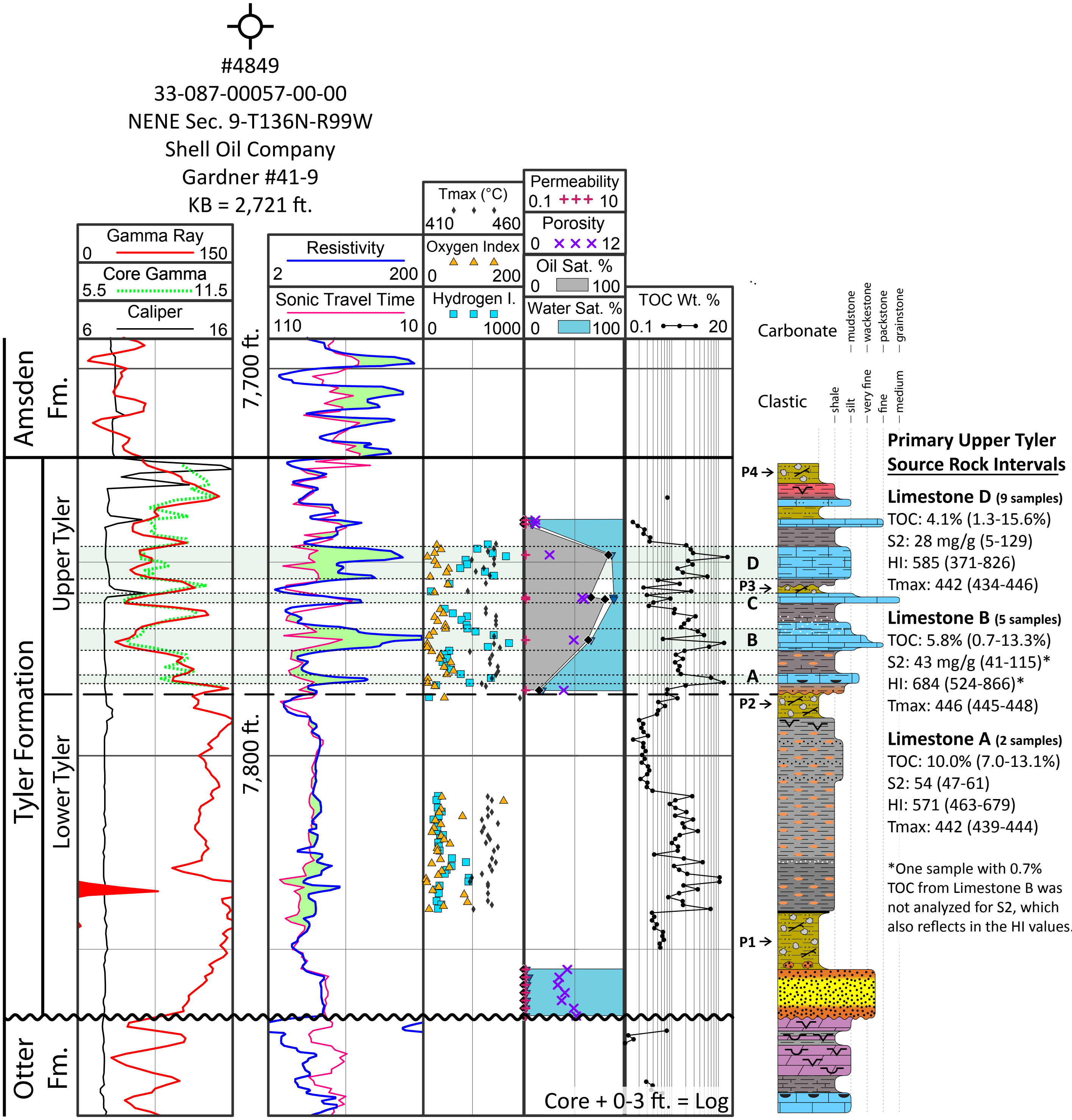

#13396
33-007-01292-00-00
SWNE Sec. 16-T138N-R101W
Duncan Energy Company
Jiggs #32-16
KB = 2,732 ft.
Gamma Ray
0 150
Caliper
6 16
8,000 ft.
Resistivity
2 200
Sonic Travel Time
110 10
Amsden Fm.
Tyler Formation
upper Tyler
D
C
B
A
8,026.1-8,034.4 - Red calcareous mudstone with well rounded pebble sized intraclasts, slickensides, underlain by grey-tan to maroon lime mudstone and calcareous shale with plant roots
8,034.4-8,036.9 - Laminated light and very dark grey calcareous shale, argillaceous lime mudstone near base with red coloration
8,036.9-8,043.8 - Grey to very dark grey lime wacke-packstone (top) and argillaceous lime mudstone (base) separated by calcareous shale, laminated to thinnly bedded throughout interval
8,043.8-8,046.0 - Medium to dark grey shale, non-calcareous and very fissile to calcareous and less fissile, sandstone laminations at top
8,046.0-8,052.3 - Dark tan to grey argillaceous lime mudstone with minor to moderate bioturbation, underlain by very finely crystaline lime pack-grainstone, oil stained, flat to wavy laminations
8,052.3-8,055.5 - Very dark grey to black shale, slightly to non-calcareous, very fissile, occassional white specs, pyrite filled burrows
8055.5-8,064.2 - Dark grey to black calcareous shale, moderately fissile, contains white specs forming laminations, underlain by laminated to thinly bedded lime mudstone & boundstone (packstone laminations bound by thin mudstone laminae), thin very dark grey non-calc. shale at base
8,064.2-8,072.6 - Tan-grey fine grained quartz sandstone, bioturbated and massive to slightly argillaceous and laminated, oil stained
8,072.6-8,077.6 - Very dark grey to black shale, fissile, faint brownish grey well indurated mudstone(?) laminations
8,077.6-8,079.5 - Grey to black lime fossil wackestone (base) to argillaceous mudstone (middle) to boundstone (packstone-mudstone)
8,079.5-8,084.0 - Grey to black shale, non-calcareous, very fissile, contains thin laminations of both sandstone and mudstone

SWNE Sec. 16, T.138N., R.101W.
Duncan Energy Co.
Jiggs #32-16

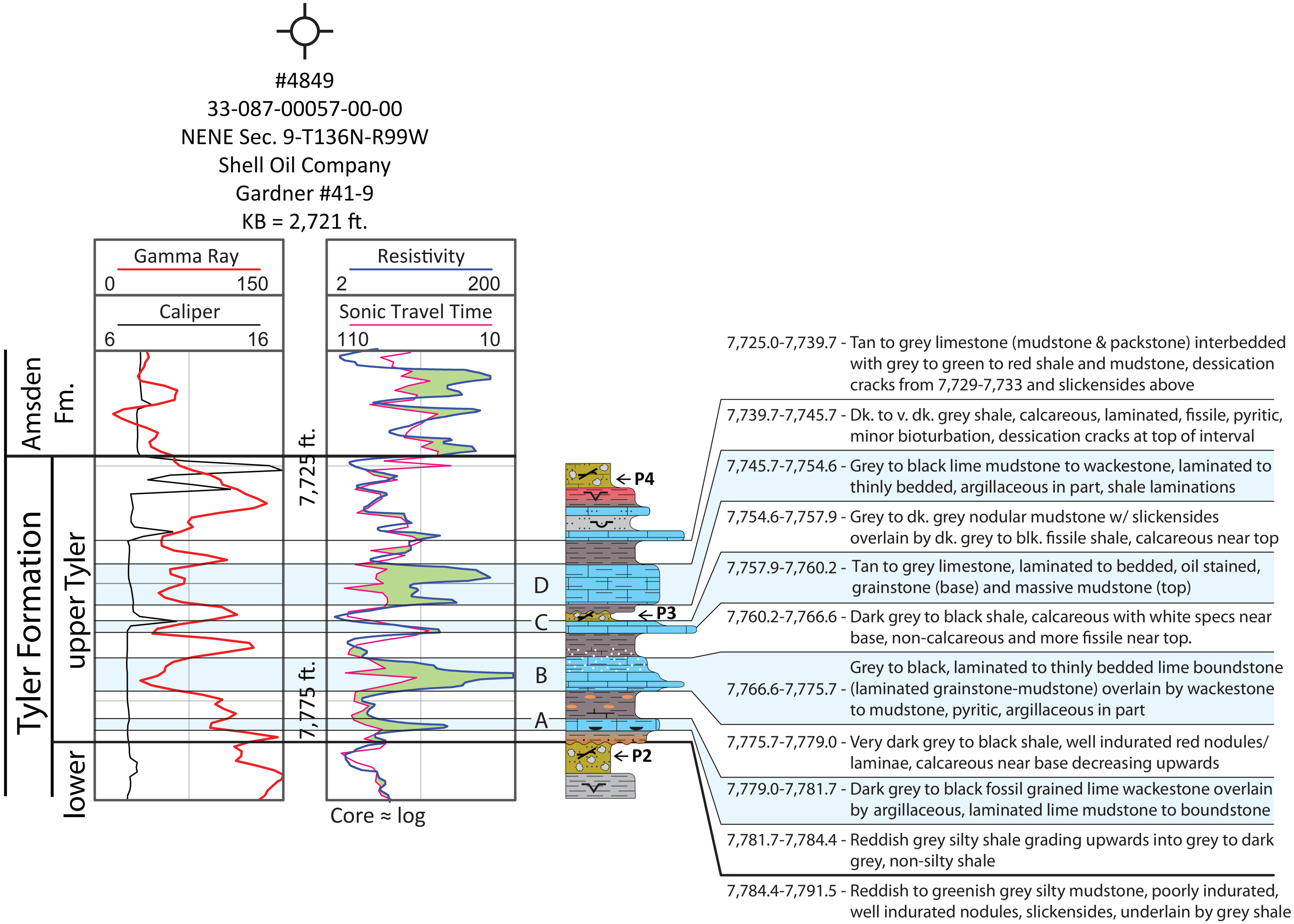
Cored Interval: 8,026-8,055 ft.

SWNE Sec. 16, T.138N., R.101W.
Duncan Energy Co.
Jiggs #32-16

Cored Interval: 8,055-8,084 ft.

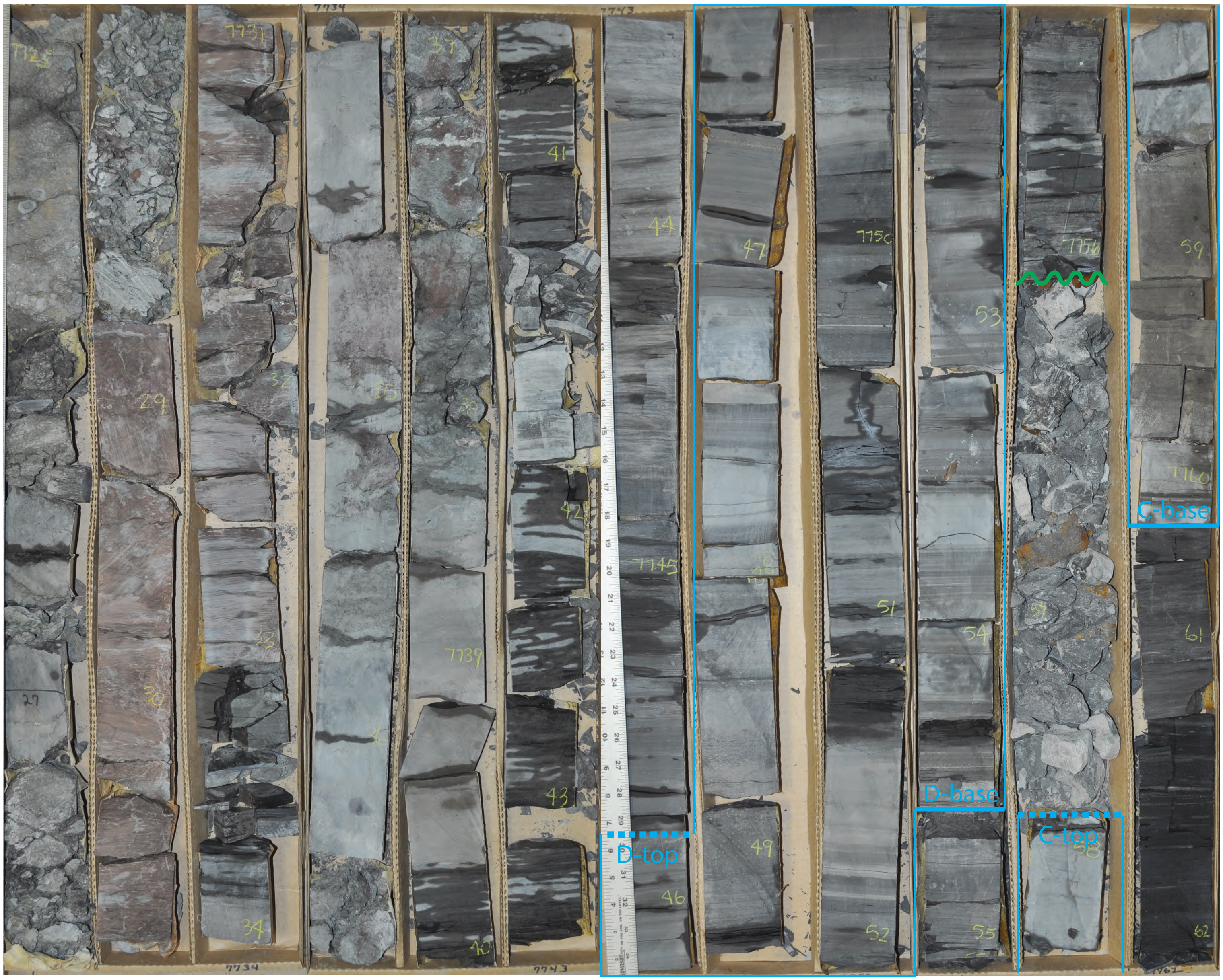


Wireline log of the Tyler Formation with illustrated core, standard core analysis and geochemical data from Shell Oil's Gardner #41-9. Drilled as a wildcat well targeting the Tyler Formation near the Rocky Ridge Field, the Gardner #41-9 was plugged and abandoned as a dry hole. The core to log correlation 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.


#4849
33-087-00057-00-00
NENE Sec. 9-T136N-R99W
Shell Oil Company
Gardner #41-9
KB = 2,721 ft.
Gamma Ray
0 150
Caliper
6 16
Resistivity
2 200
Sonic Travel Time
110 10
Amsden Fm.
Tyler Formation
upper Tyler
lower
7,725 ft.
7,775 ft.
D
C
B
A
P4
P3
P2
Core ≈ log
7,725.0-7,739.7 - Tan to grey limestone (mudstone & packstone) interbedded with grey to green to red shale and mudstone, dessication cracks from 7,729-7,733 and slickensides above
7,739.7-7,745.7 - Dk. to v. dk. grey shale, calcareous, laminated, fissile, pyritic, minor bioturbation, dessication cracks at top of interval
7,745.7-7,754.6 - Grey to black lime mudstone to wackestone, laminated to thinly bedded, argillaceous in part, shale laminations
7,754.6-7,757.9 - Grey to dk. grey nodular mudstone w/ slickensides overlain by dk. grey to blk. fissile shale, calcareous near top
7,757.9-7,760.2 - Tan to grey limestone, laminated to bedded, oil stained, grainstone (base) and massive mudstone (top)
7,760.2-7,766.6 - Dark grey to black shale, calcareous with white specs near base, non-calcareous and more fissile near top.
7,766.6-7,775.7 - Grey to black, laminated to thinly bedded lime boundstone (laminated grainstone-mudstone) overlain by wackestone to mudstone, pyritic, argillaceous in part
7,775.7-7,779.0 - Very dark grey to black shale, well indurated red nodules/ laminae, calcareous near base decreasing upwards
7,779.0-7,781.7 - Dark grey to black fossil grained lime wackestone overlain by argillaceous, laminated lime mudstone to boundstone
7,781.7-7,784.4 - Reddish grey silty shale grading upwards into grey to dark grey, non-silty shale
7,784.4-7,791.5 - Reddish to greenish grey silty mudstone, poorly indurated, well indurated nodules, slickensides, underlain by grey shale

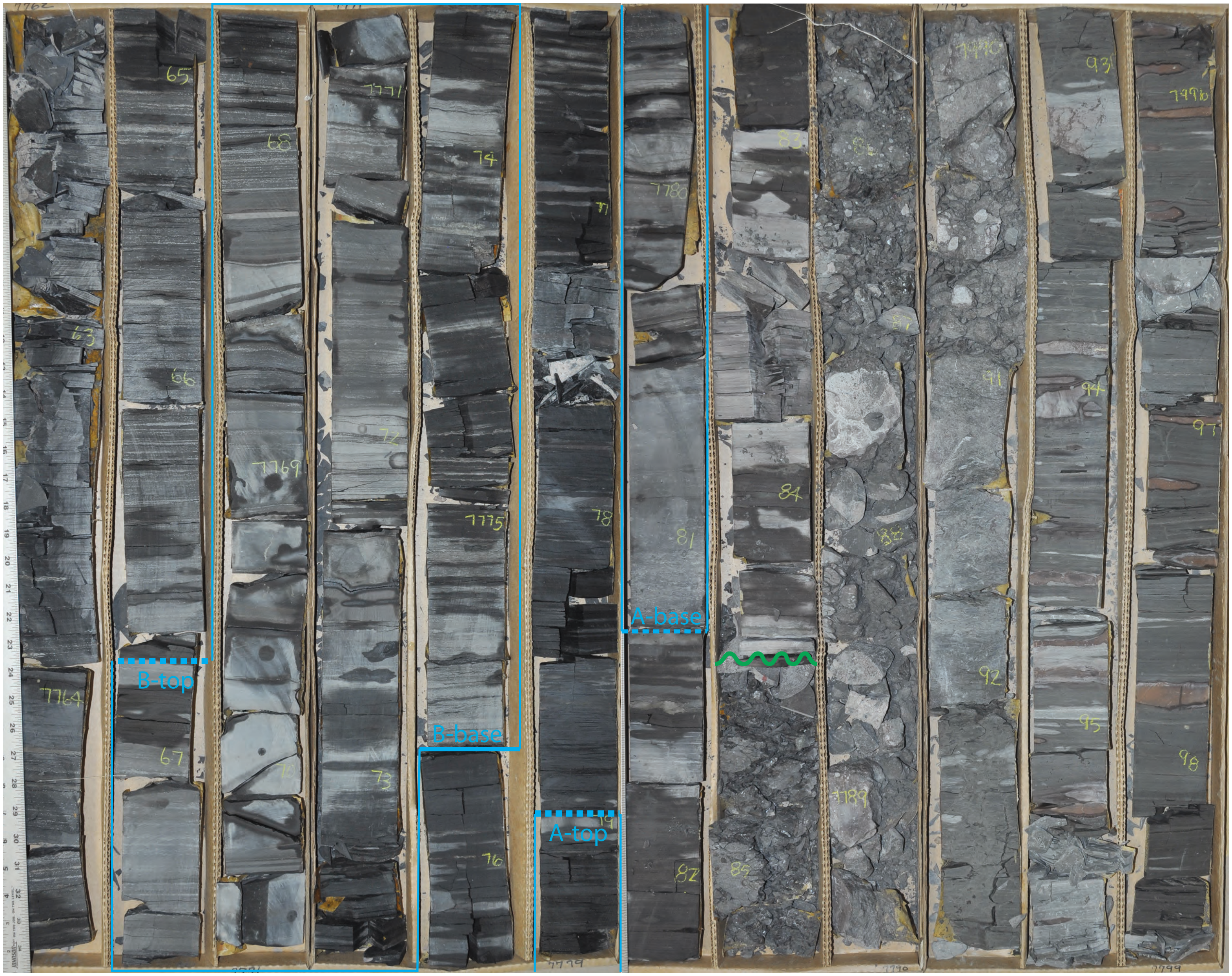
NENE Sec. 9, T.136N., R.99W.
Shell Oil Co.
Gardner #41-9

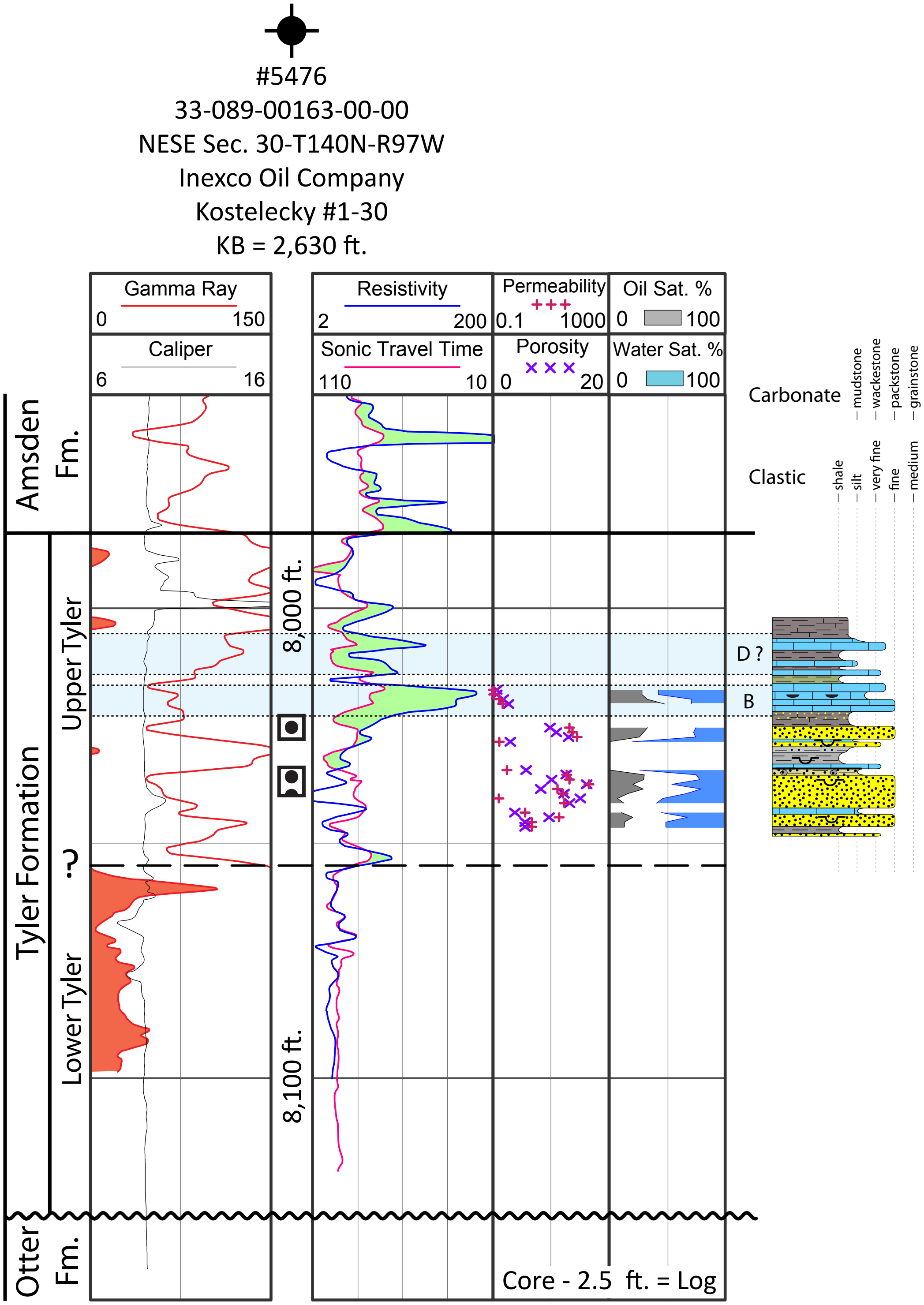
Cored Interval: 7725 - 7762 ft.



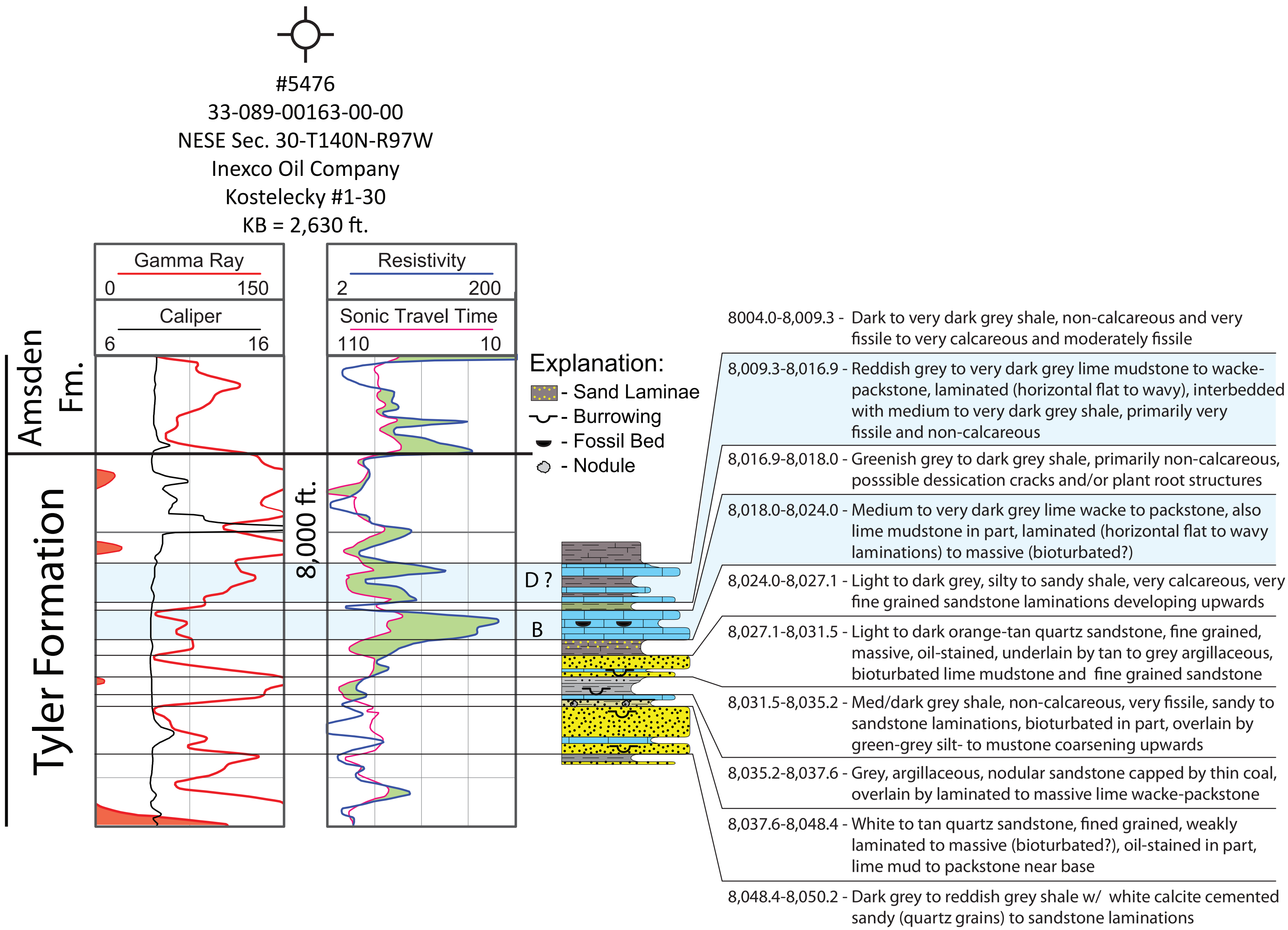
NENE Sec. 9, T.136N., R.99W.
Shell Oil Co.
Gardner #41-9

Cored Interval: 7763 - 7798 ft.



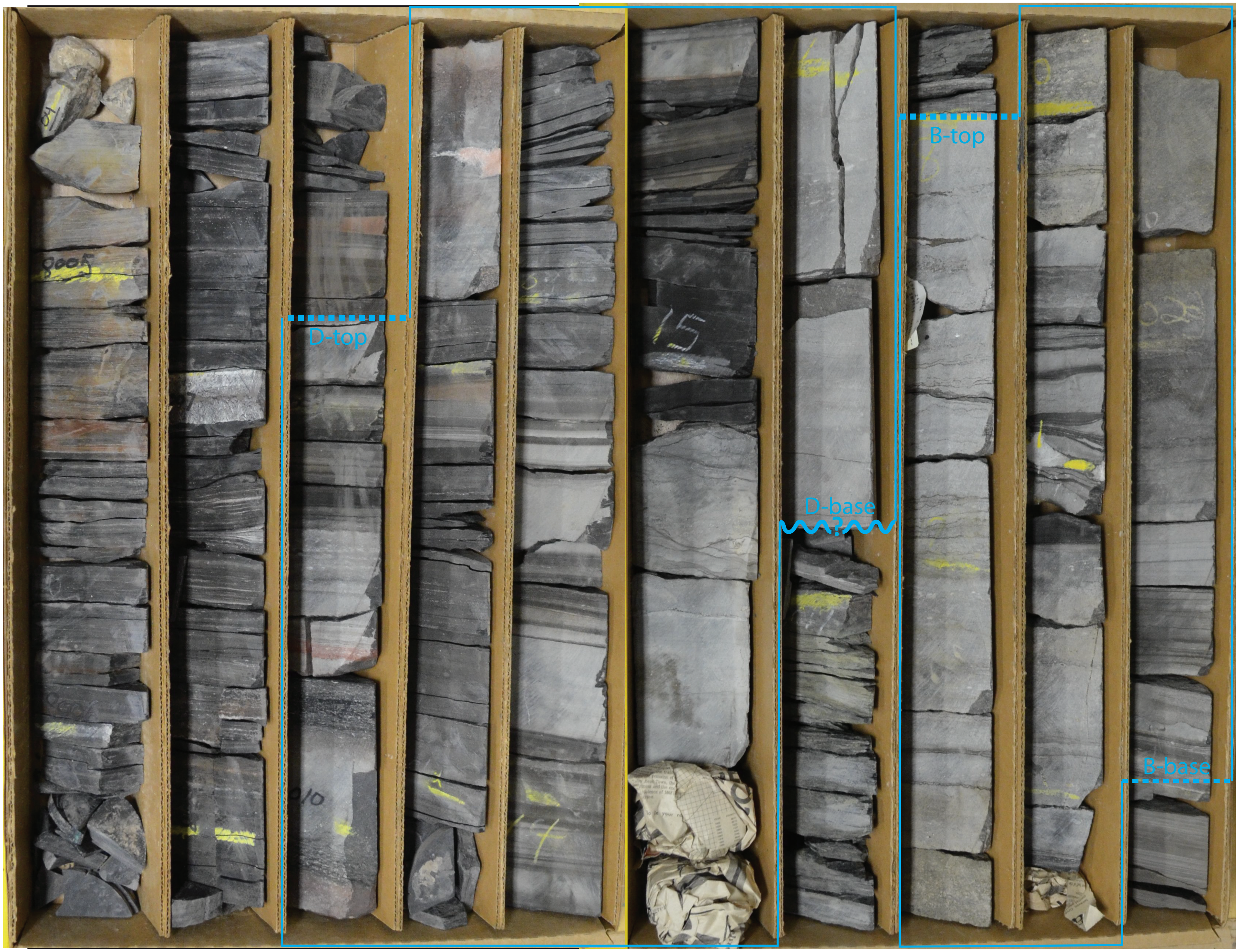


Wireline log of the Tyler Formation from Inexco Oil's Kostelecky #1-30 with standard core analysis data and illustrated core lithologies. Perforations are indicated within the depth column by outlined black dots. The Kostelecky #1-30 cumulatively produced 65,788 BBLS oil and 166,717 BBLS water with no reported gas from its vertical perforations before being plugged and abandoned. Perforations were completed with 4 holes per foot and a fracture treatment of 50,000 gallons of gelled water containing sand.


#5476
33-089-00163-00-00
NESE Sec. 30-T140N-R97W
Inexco Oil Company
Kostelecky #1-30
KB = 2,630 ft.
Gamma Ray
0
150
Caliper
6
16
Resistivity
2
200
Sonic Travel Time
110
10
Amsden Fm.
Tyler Formation
8,000 ft.
D ?
B
Explanation:
- Sand Laminae
- Burrowing
- Fossil Bed
- Nodule
8004.0-8,009.3 - Dark to very dark grey shale, non-calcareous and very fissile to very calcareous and moderately fissile
8,009.3-8,016.9 - Reddish grey to very dark grey lime mudstone to wacke-packstone, laminated (horizontal flat to wavy), interbedded with medium to very dark grey shale, primarily very fissile and non-calcareous
8,016.9-8,018.0 - Greenish grey to dark grey shale, primarily non-calcareous, posssible dessication cracks and/or plant root structures
8,018.0-8,024.0 - Medium to very dark grey lime wacke to packstone, also lime mudstone in part, laminated (horizontal flat to wavy laminations) to massive (bioturbated?)
8,024.0-8,027.1 - Light to dark grey, silty to sandy shale, very calcareous, very fine grained sandstone laminations developing upwards
8,027.1-8,031.5 - Light to dark orange-tan quartz sandstone, fine grained, massive, oil-stained, underlain by tan to grey argillaceous, bioturbated lime mudstone and fine grained sandstone
8,031.5-8,035.2 - Med/dark grey shale, non-calcareous, very fissile, sandy to sandstone laminations, bioturbated in part, overlain by green-grey silt- to mustone coarsening upwards
8,035.2-8,037.6 - Grey, argillaceous, nodular sandstone capped by thin coal, overlain by laminated to massive lime wacke-packstone
8,037.6-8,048.4 - White to tan quartz sandstone, fined grained, weakly laminated to massive (bioturbated?), oil-stained in part, lime mud to packstone near base
8,048.4-8,050.2 - Dark grey to reddish grey shale w/ white calcite cemented sandy (quartz grains) to sandstone laminations

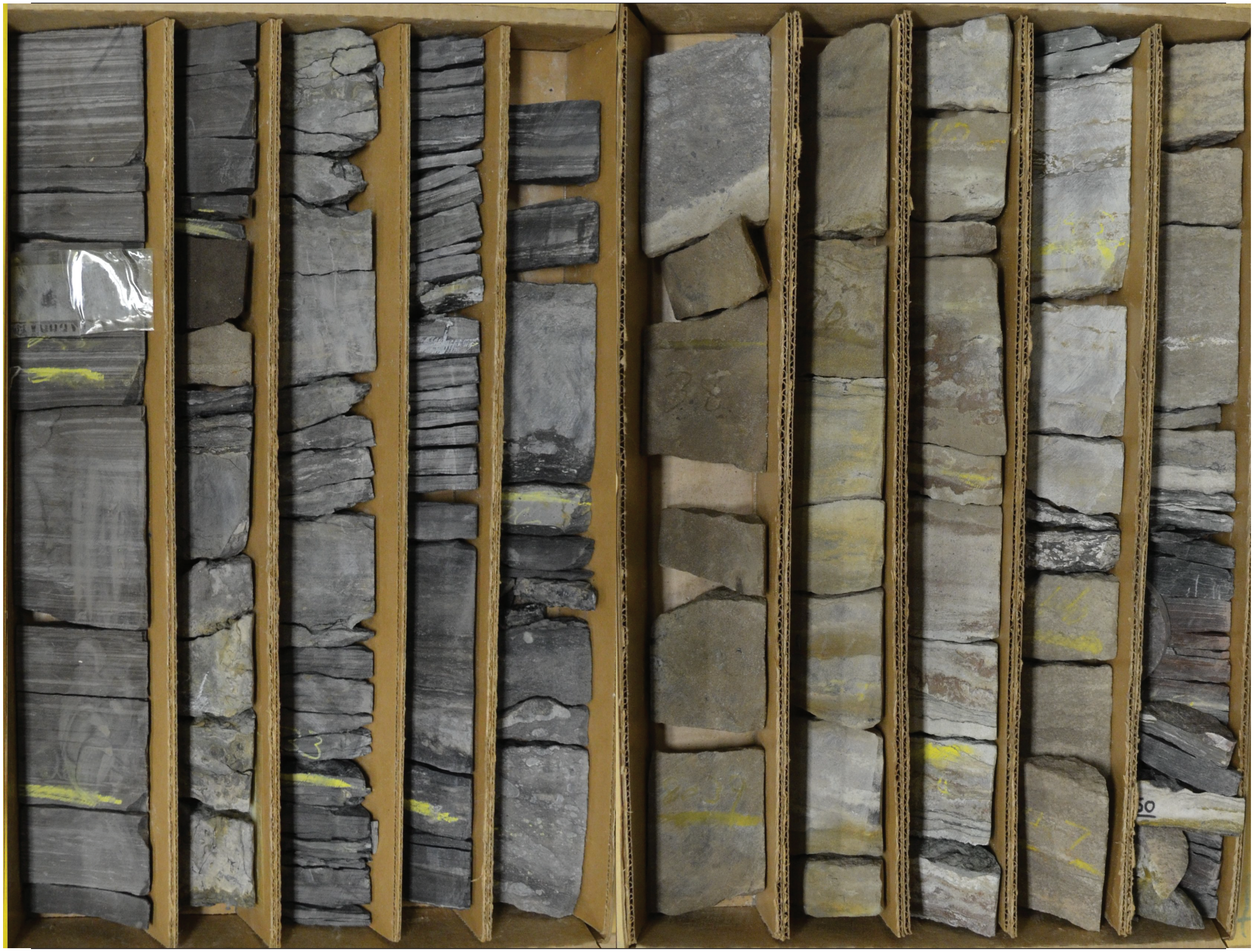
NESE Sec. 30, T.140N., R.97W.
Inexco Oil Company
Kostelecky #1-30

Cored Interval: 8,004-8,024 ft.



NESE Sec. 30, T.140N., R.97W.
Inexco Oil Company
Kostelecky #1-30

Cored Interval: 8,024-8,050 ft.

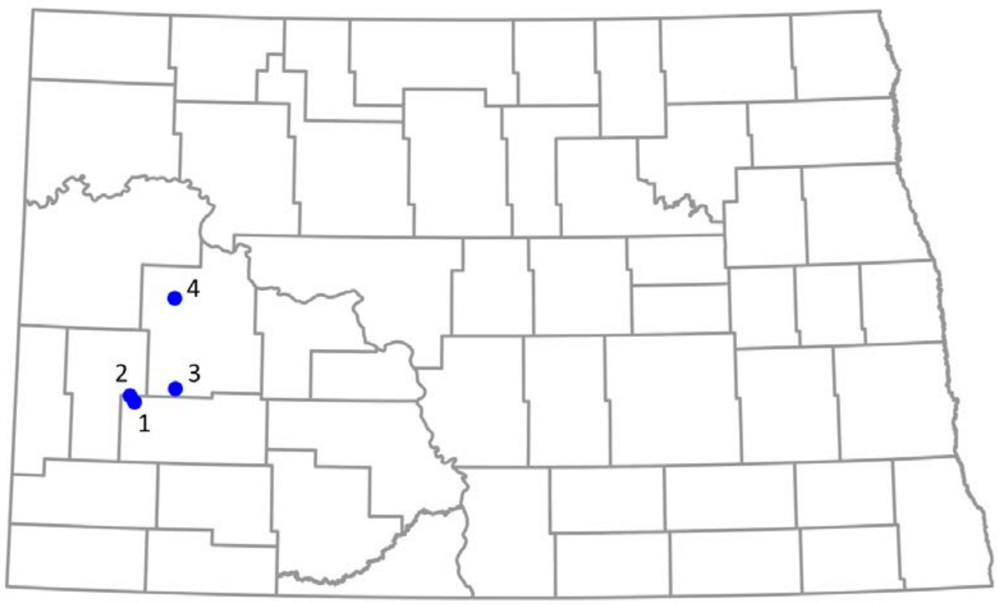


WILLISTON BASIN PETROLEUM CONFERENCE

Core Workshop

Pronghorn Member Bakken Formation

Julie A. LeFever
North Dakota Geological Survey



Workshop Cores

	Well	Cored Interval
1	Lot 3 Sec. 3, T140N, R99W Continental Resources, Inc. - Debrecen #1-3H NDIC#: 20034	10765-10815
2	NWNW Sec. 13, T140N, R99W Whiting Oil and Gas Corp. - Kubas #11-13TFH NDIC#: 18837	10635-10675
3	SESW Sec. 14, T141N, R96W Anschutz Exploration Corp. - Sadowsky #24-14H NDIC#: 17808	10480-10538
4	SESW Sec. 31, T147N, R95W Burlington Resources Oil & Gas, Co. - Prairie Rose #24-31H NDIC#: 16798	11115-11132

A Brief Examination of the Pronghorn Member , Bakken Formation (Mississippian-Devonian)

Julie A. LeFever

The Pronghorn Member of the Bakken Formation was formally proposed in 2011 by LeFever et al. for the strata underlying the Lower Member and overlying the Three Forks Formation. These strata had been previously included in the Three Forks and referred to as the "Sanish sand". Examination of these rocks revealed a significant basinwide unconformity at the top of the Three Forks section. Lithologies present within the Pronghorn section are more consistent with those observed within the Middle Member of the Bakken Formation and are mappable.

The continued development of the oilfields has increased the information and available cores for this section. It appears that there are some constraints placed on production by the lithofacies present. Further examination of the Pronghorn may result in adjustments to completion techniques enabling better production.

The Pronghorn Member is located throughout the Williston Basin. It divides easily into two parts, proximal and distal beds. The proximal beds occur primarily in the southwestern portion of the basin whereas the distal portion is more centrally located (Fig. 1).

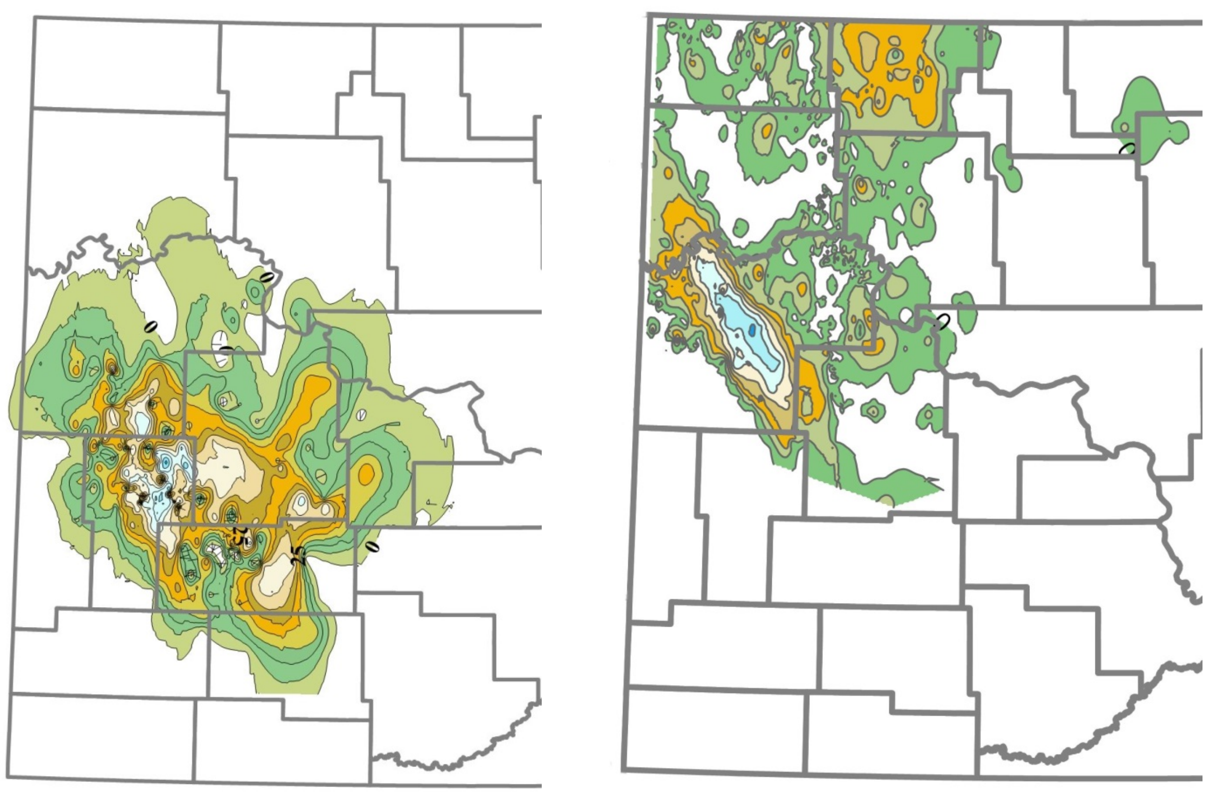


Figure 1 – *Left map* – Isopach of the proximal beds of the Pronghorn Member. *Right map* – Isopach of the distal beds of the Pronghorn Member.

The Section

Three Forks Formation

The uppermost portion of the Three Forks Formation consists of an alternating sequence of apple green and tan dolomudstones and claystones with uni- and bi-directional ripples, parallel laminations, flaser beds, scours, fluid escape structures, and rip-ups clasts (Fig. 2; Dumonceaux, 1984; Berwick, 2008; 2011; LeFever and Nordeng, 2009; Bottger et al, 2011). These beds reflect a shallowing upward sequence of rocks representing subtidal to supratidal environments. A significant regional unconformity occurs at the top of this section relating to a major scale regression corresponding to the break between the Kaskaskia I and II sequence boundary (Fig. 2).

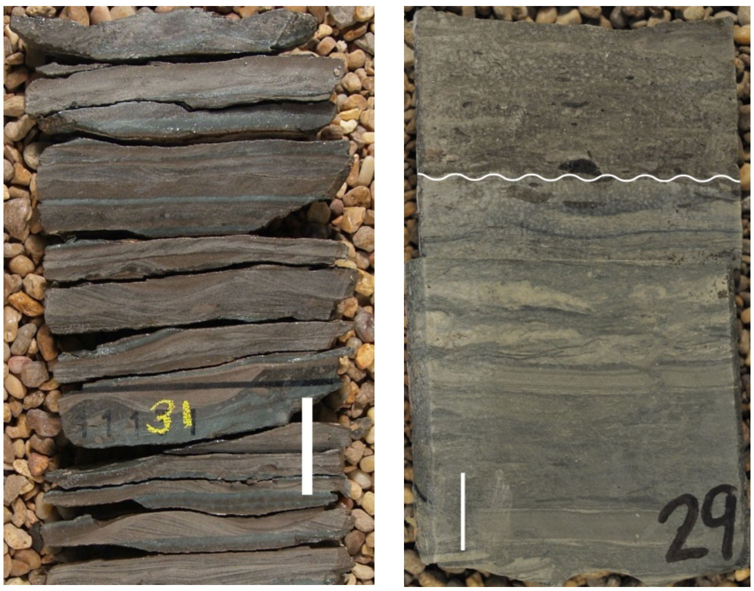


Figure 2 - *Left photo* – Typical apple green and tan beds of the uppermost Three Forks Formation from Burlington Resources Oil and Gas, Inc.-Prairie Rose 24-31H (SESW Sec. 31-T147N-R95W) at a depth of 11131 ft. *Right photo* – Significant unconformity surface at the top of the Three Forks Formation at a depth of 10529 ft in the Anschutz Exploration Corp.-Sadowsky 24-14H (SESW Sec. 14, T141N, R96W). White bars represent 1 inch.

Pronghorn Member Bakken Formation

The Pronghorn Member of the Bakken Formation can be divided into 5 informational lithofacies described here, in ascending order from A-E.

<u>Basal Sandstone</u>

The lowermost sandstone lithofacies is a thin, fine- to very fine-grained quartz sandstone that is characterized by abundant *Skolithus* burrows. A lesser amount of dolomite is also present (Fig. 3; Sesack, 2011).

Its distribution is varied across the basin and is difficult to identify with certainty on wireline logs without good core control (Fig. 3).

Depositionally, A is probably lower to middle shoreface based on the extensive *Skolithus* ichnofacies.

<u>HCS Beds</u>

The second interval consists of a dolomitic mudstone with HCS beds of very fine- to fine-grained quartz (Fig. 4). Minor amounts of calcite and illite are present (Sesack, 2011). There appears to be a minor unconformity in the middle of the section related to a shift in depositional environments (Fig. 5). Below the surface, the lithofacies consists of a grey-green silty mudstone with tan interbeds. There is less cross-bedding, burrowing, and more mud representing an upper offshore environment.

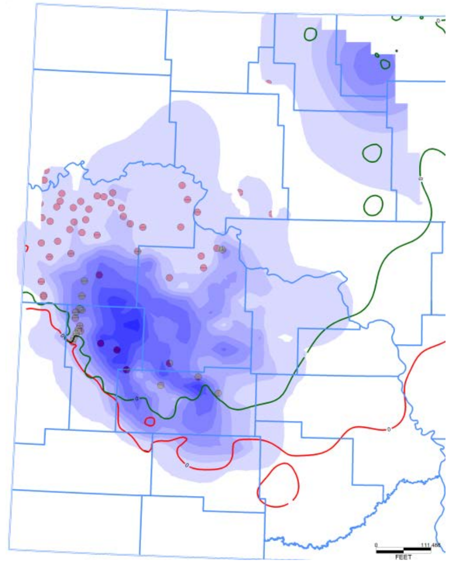


Figure 3 - *Left photo* – Basal lithofacies of the Pronghorn Member showing the extensive *Skolithus* burrowing and bioturbation from the Raymond T. Duncan-#1 Rose (SENE Sec. 33-T152N-R94W) at a depth of 10601 ft. Penny for scale. *Right map* – Preliminary map of western North Dakota showing the distribution of the proximal Pronghorn beds. Rose colored dots mark where the A facies has been observed.. Extent of the Upper Member (red) and Middle Member (green) of the Bakken Formation are also shown.

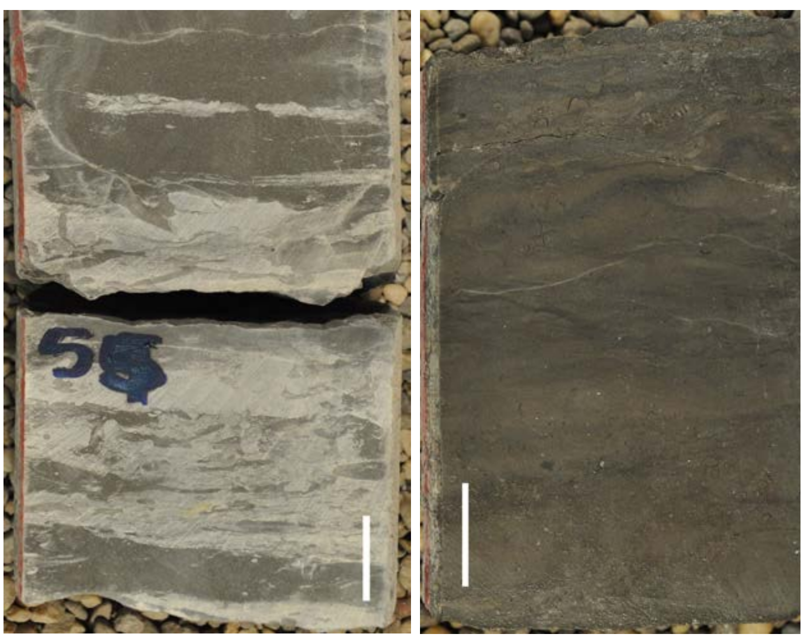


Figure 4 - *Left photo* - Photograph of HCS Beds at a depth of 10655 ft from the Whiting Oil & Gas Corp-Kubas#11-13THF (NWNW Sec. 13, T140N, R99W). *Right photo* – Core photograph of the lime mudstone lithofacies from Anschutz Exploration Corp.-Sadowsky #24-14H (SESW Sec. 14, T141N, R96W) at a depth of 10488.5 ft. White bars represents 1 inch.

The upper portion of interval consists of medium brown dolomitic mudstones with tan, very fine-grained sandstone HCS beds. Burrows include Chondrites, Asteroma, Teichichnus, Planolites, and Thalassinoides. Environment of deposition for this portion is lower to middle shoreface.

It becomes significant when examining production. While the porosities are similar throughout the interval, the upper portion of the lithofacies appears to have better permeability than the underlying portion.

Lime Mudstone

The third lithofacies is a thin medium brown-grey mudstone to siltstone with Brachiopods.

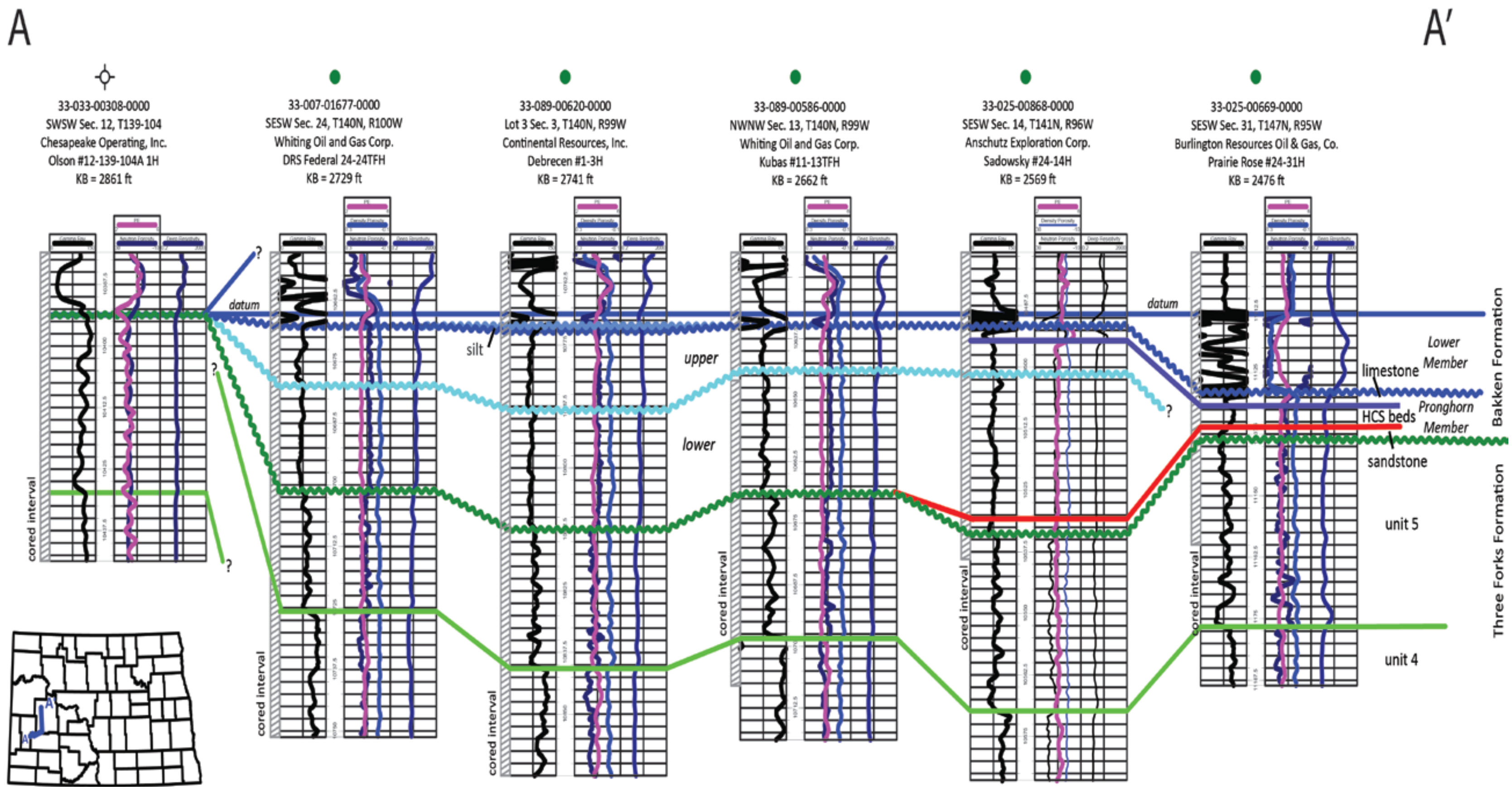


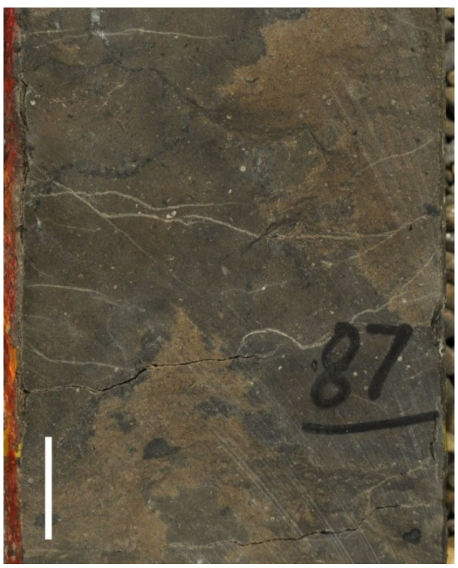
Figure 5 - Cross –section A-A’ across the area of interest showing the breakdown and distribution of the intervals within the Pronghorn Member of the Bakken Formation and their relationships with the underlying Three Forks Formation and overlying Lower Member.

Contact with the underlying HCS beds is conformable. The contact with overlying limestone is irregular. The environment represented by this lithofacies is lower offshore.

Distribution is difficult to determine without core control due to lack of definition on wireline logs.

Limestone

The fourth lithofacies consists of a medium grey nodular-bedded limestone with crinoids, brachiopods and other skeletal fragments. This lithofacies represents an open marine environment (Fig. 6). Contact with overlying Lower Member of the Bakken is generally unconformable. Difficulties occur in mapping this interval on wireline logs, its signature is similar to that of the sandstone lithofacies requiring careful core to log control.



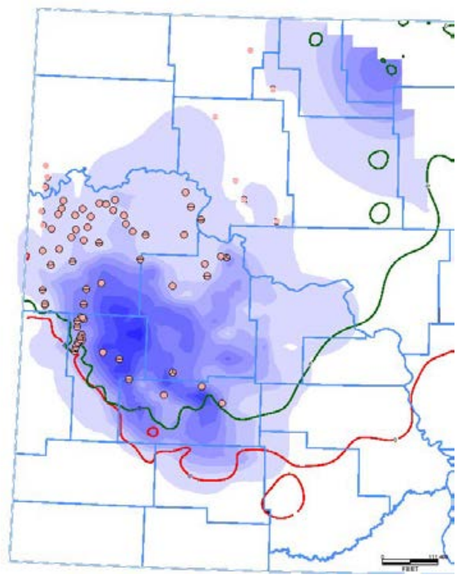


Figure 6 - *Left photo* – Core photograph of limestone lithofacies from the Raymond T. Duncan-#1 Rose (SENE Sec. 33-T152N-R94W) at a depth of 10601 ft. White bar is 1 inch. *Right map* – Preliminary map of western North Dakota showing the distribution of the proximal Pronghorn beds. Rose colored dots mark where the limestone lithofacies has been observed. Extent of the Upper Member (red) and Middle Member (green) of the Bakken Formation are also shown.

Silt

The uppermost lithofacies has been previous referred to as the “Bakken silt” and is possibly the distal equivalent to the proximal lithofacies – the sandstone, HCS beds, lime mudstone, and limestone. It is described as medium dark brown to brown-black mudstone with thin laminae of fine-grained sand (Fig. 7). Burrowing becomes prevalent towards the lower contact. Organic values are significantly less than the overlying Lower Member of the Bakken Formation. Environment

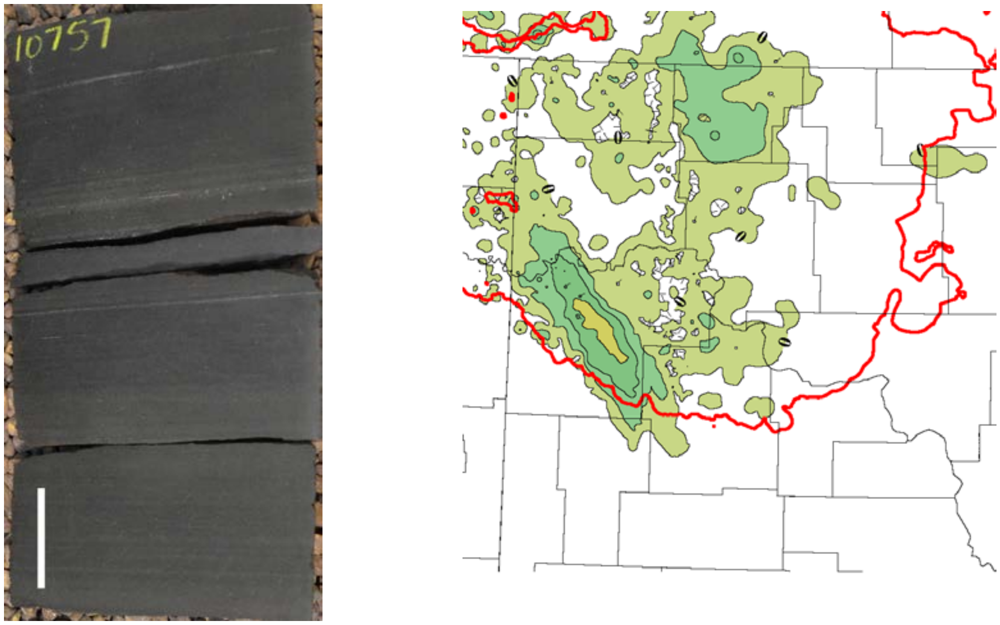


Figure 7 **-** *Left photo* – Core photograph of the silt lithofacies at 10757 ft. from the Continental Resources, Inc.-Debrecen #1-3H (Lot 3, Sec. 3, T140N, R99W). White bar is 1 inch. *Right map* – Map of the silt lithofacies through western North Dakota. Red line indicates the edge of the Prairie salt.

The lithofacies is unconformable with the Three Forks and conformable in the central portion of the basin with the overlying Lower Member (LeFever et al., 2011).

Lower Member

Lower Member of the Bakken Formation consists of a dark brown to black organic-rich shale (Fig. 8). Pyrite is also abundant as thin wispy laminae, lenses or nodules or disseminated throughout. Fossils present include *Tasmanites*, condonts, brachiopods, and fish teeth, scales, and bones. Minor amounts of calcite occur as fracture fill.

The Lower Member was deposited in a restricted marine setting allowing for the stratification of the water column and the development of anoxic conditions.

Preservation of the Pronghorn Section

The lithofacies of the Pronghorn Member are irregularly distributed over the western portion of the basin (Figs. 6 and 7). Noticeably thicker section is found along the southwestern and north-central portion of the state and appear to be related to areas of dissolution and collapse of the underlying Prairie salt. The majority of the dissolution is related to faulting within the basin.

Figure 8 - Core photograph of the Lower Member of the Bakken Formation from the Continental Resources, Inc.-Charlotte #1-22H (SWSE Sec. 22, T152N, R99W) at a depth of 11,340 ft. White bar is 1 inch.

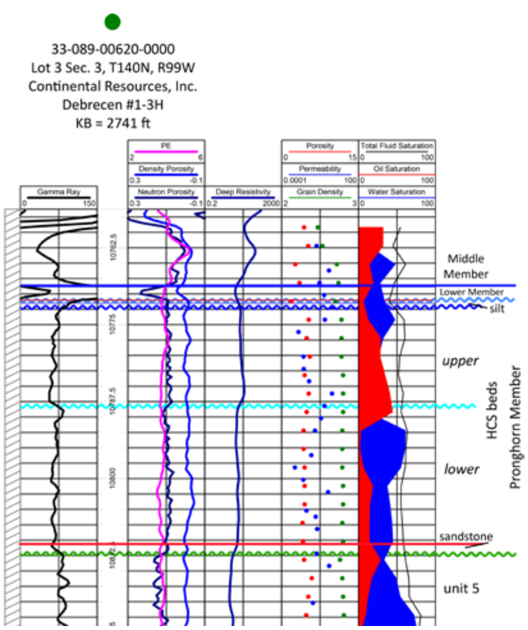


Figure 9 Core analyses show the variation of oil-water saturations between the upper and lower HCS beds within the Pronghorn Member in the Continental Resources-Debrecen #1-3H (Lot 3, Sec. 3, T140N, R99W).

Relationship of Facies to Production

Minor changes in the depositional environment of the HCS beds appear to have an effect on production. Although porosity over the section is consistent, the permeability decreases from the upper section to the lower section (Fig. 9). This decrease is probably due to an increase in the amount of dolomitic mud present resulting from deposition in a slightly deeper more offshore environment. The silt interval of Pronghorn negatively effects production.

Sequence Stratigraphy

The Pronghorn Member of the Bakken Formation overlies the sequence boundary that occurs at the top of the Three Forks Formation. The section represents and overall transgressive sequence culminating with the deposition of the Lower Member. The lower portion of the HCS beds probably represents rapid change in accommodation space resulting in deeper water conditions and a slight change in environment.

Further Research

On-going research of this member will include basinwide mapping and correlation of these lithofacies, analysis of the HCS beds with x-ray diffraction data.

References Cited:

Berwick, B.R., 2008, Depositional environment, mineralogy, and sequence stratigraphy of the Late Devonian Sanish Member (Upper Three Forks Formation), Williston Basin, North Dakota: Colorado School of Mines Master's Thesis, Colorado, 263p.

Berwick, B.R. and Michael L. Hendricks, 2011, Depositional lithofacies of the Upper Devonian Thee Forks Formation and the Grassy Butte Member of the Lower Bakken Shale in the Williston Basin, *in*, Robinson, J.W., LeFever, J.A., and Gaswirth, S. B., eds., The Bakken-Three Forks Petroleum System in the Williston Basin: RMAG, Denver, CO, p. 159-172.

Bottjer, R.J., Grau, A., Sterling, R., and P. Dea, 2011, Stratigraphic relationships and reservoir quality at the Three Forks-Bakken unconformity, Williston Basin, North Dakota, *in*, Robinson, J.W., LeFever, J.A., and Gaswirth, S. B., eds., The Bakken-Three Forks Petroleum System in the Williston Basin: RMAG, Denver, CO, p. 173-228.

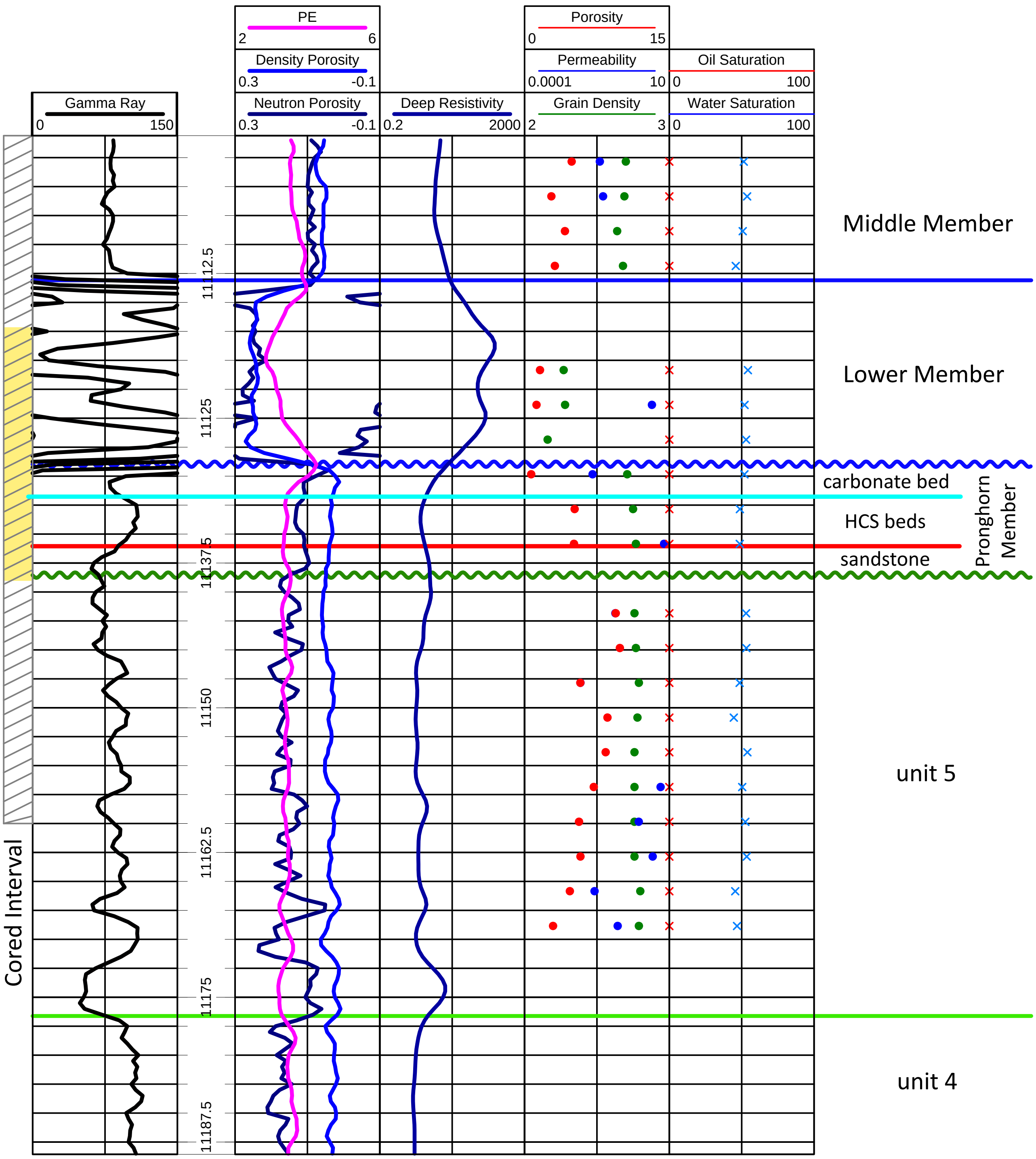
Dumonceaux, G.M., 1984, Stratigraphy and depositional environments of the Three Forks Formation (Upper Devonian), Williston Basin, North Dakota: University of North Dakota Master's Thesis, North Dakota, 202 p.

LeFever, J.A. and S.H. Nordeng, 2009, Three Forks Formation Log to Core Correlation: Geologic Investigations No. 75: NDGS, Poster 2009.

LeFever, J.A., LeFever, R.D., and S.H. Nordeng, 2011, Revised nomenclature for the Bakken Formation (Mississippian-Devonian), North Dakota: *in*, Robinson, J.W., LeFever, J.A., and Gaswirth, S. B., eds., The Bakken-Three Forks Petroleum System in the Williston Basin: RMAG, Denver, CO, p. 11-28.

Sesack, S.A., 2011, Sequence stratigraphy, depositional environments, and regional mapping of the Late Devonian interval, Upper Three Forks Formation, Sanish Member, and Lower Bakken Shale, U.S. portion of the Williston Basin: West Virginia University Master's Thesis, West Virginia, 212 p.

33-025-00669-0000
SESW Sec. 31, T147N, R95W
Burlington Resources Oil & Gas, Co.
Prairie Rose #24-31H
KB = 2476 ft



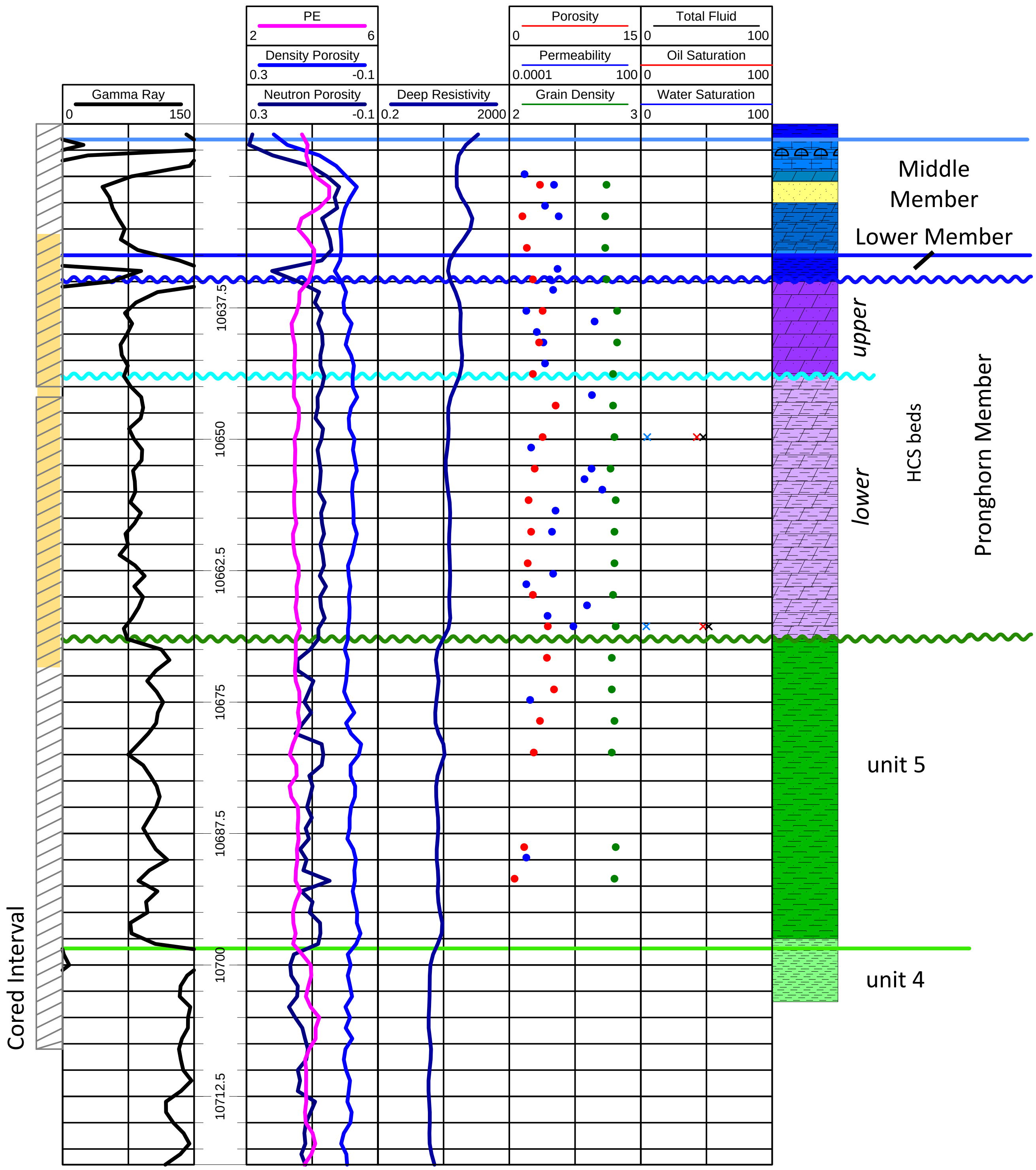
Core Available - 11036-11160

Core + 8.5 = Log

SESW Sec. 31, T147N, R95W
Burlington Resources Oil & Gas, Co.
Prairie Rose #24-31H

Cored Interval: 11115 - 11132 ft

33-089-00586-0000
NWNW Sec. 13, T140N, R99W
Whiting Oil and Gas Corp.
Kubas #11-13TFH
KB = 2662 ft



Core Available - 10582-10708

Core + 4.5 = Log

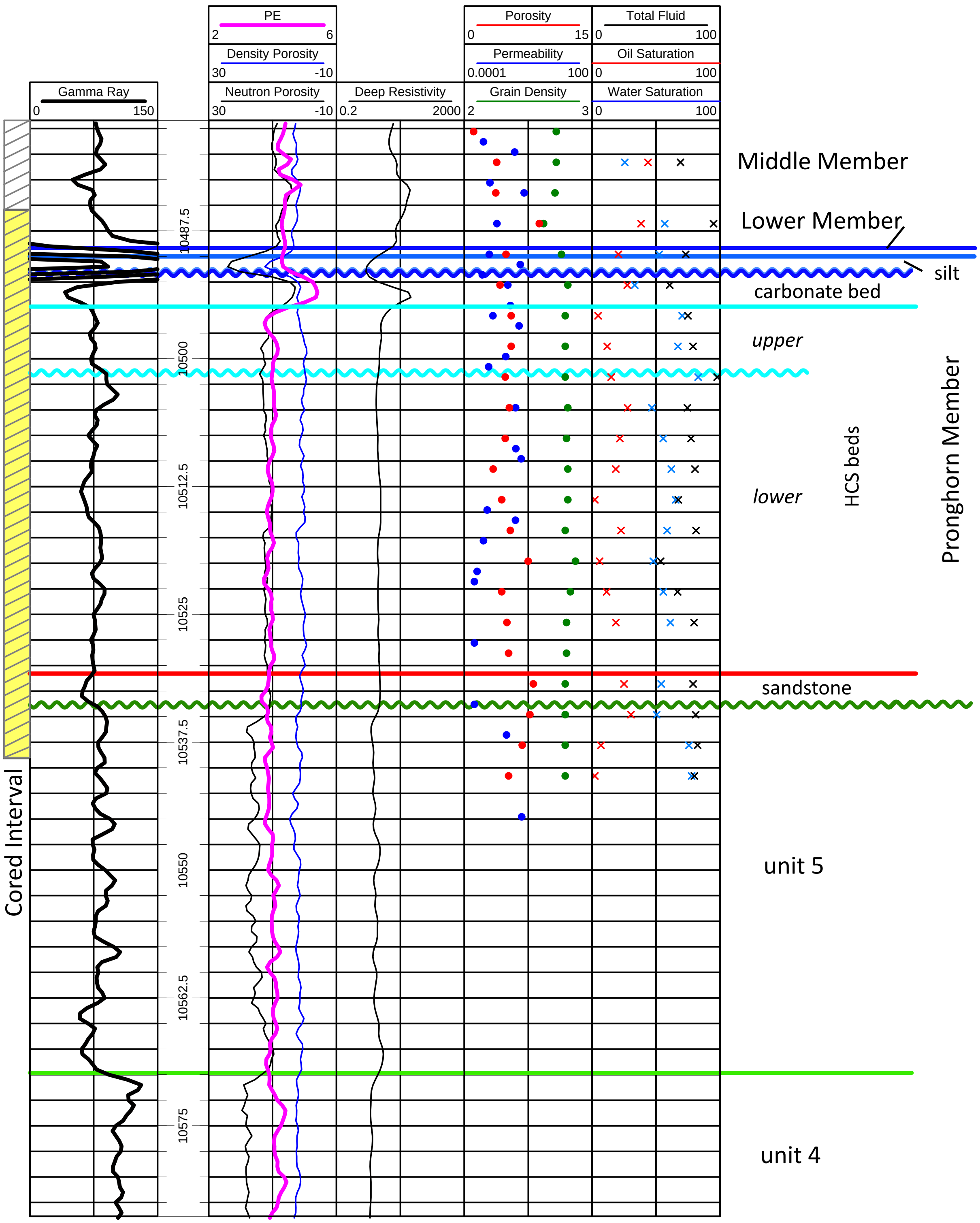
NWNW Sec. 13, T140N, R99W
Whiting Oil and Gas Corp.
Kubas #11-13TFH

Cored Interval: 10630-10654 ft

NWNW Sec. 13, T140N, R99W
Whiting Oil and Gas Corp.
Kubas #11-13TFH

Cored Interval: 10654-10677 ft

33-025-00868-0000
SESW Sec. 14, T141N, R96W
Anschutz Exploration Corp.
Sadowsky #24-14H
KB = 2569 ft



Core Available - 10455.9-10543.9

Core + 5.9 = Log

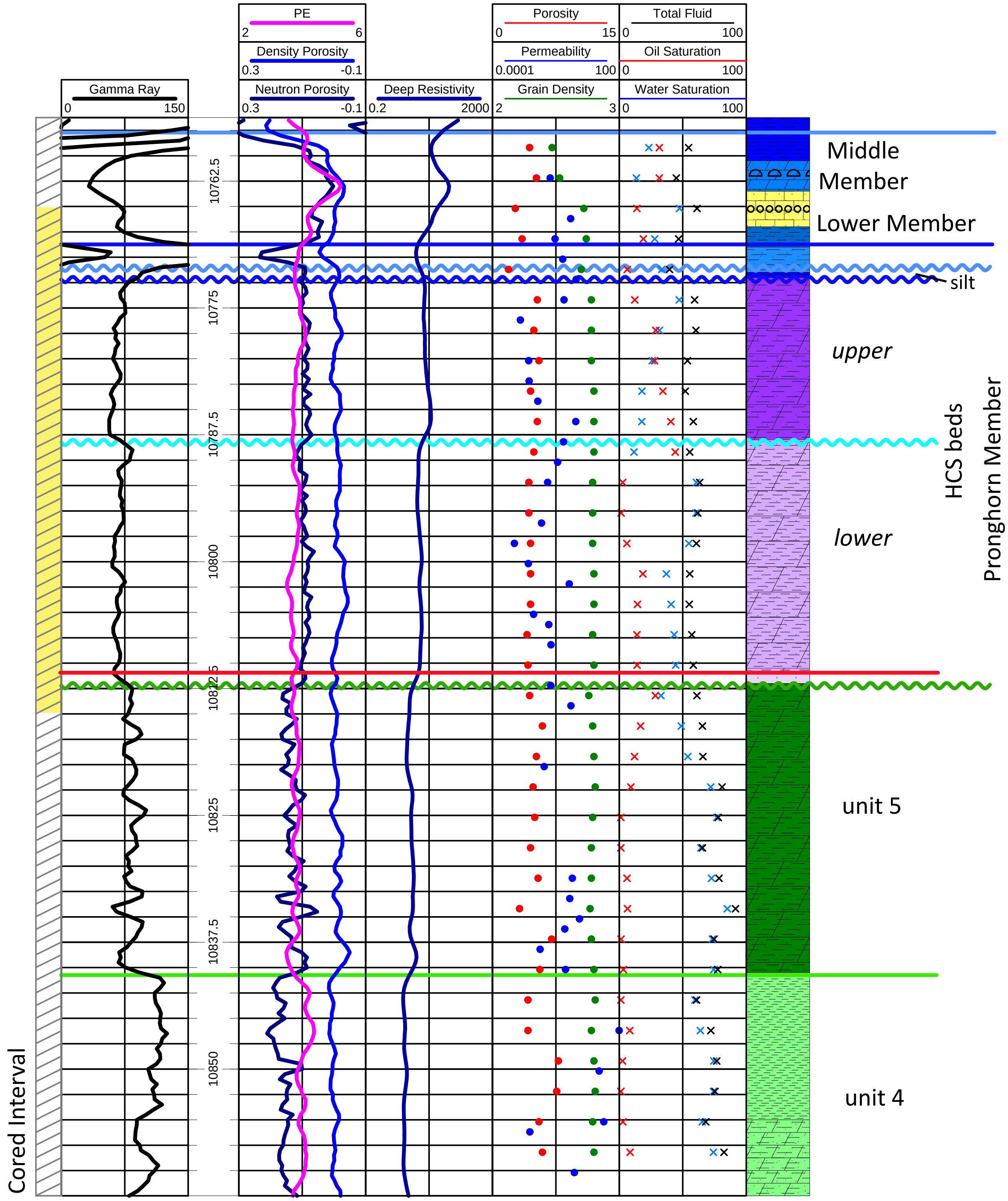
SESW Sec. 14, T.141N., R.96W.
Anschutz Exploration Corporation
#24-14H Sadowsky

Cored Interval: 10483 - 10516.5 ft

Cored Interval: 10516.5 - 10538 ft

SESW Sec. 14, T.141N., R.96W.
Anschutz Exploration Corporation
#24-14H Sadowsky

33-089-00620-0000
Lot 3 Sec. 3, T140N, R99W
Continental Resources, Inc.
Debrecen #1-3H
KB = 2741 ft

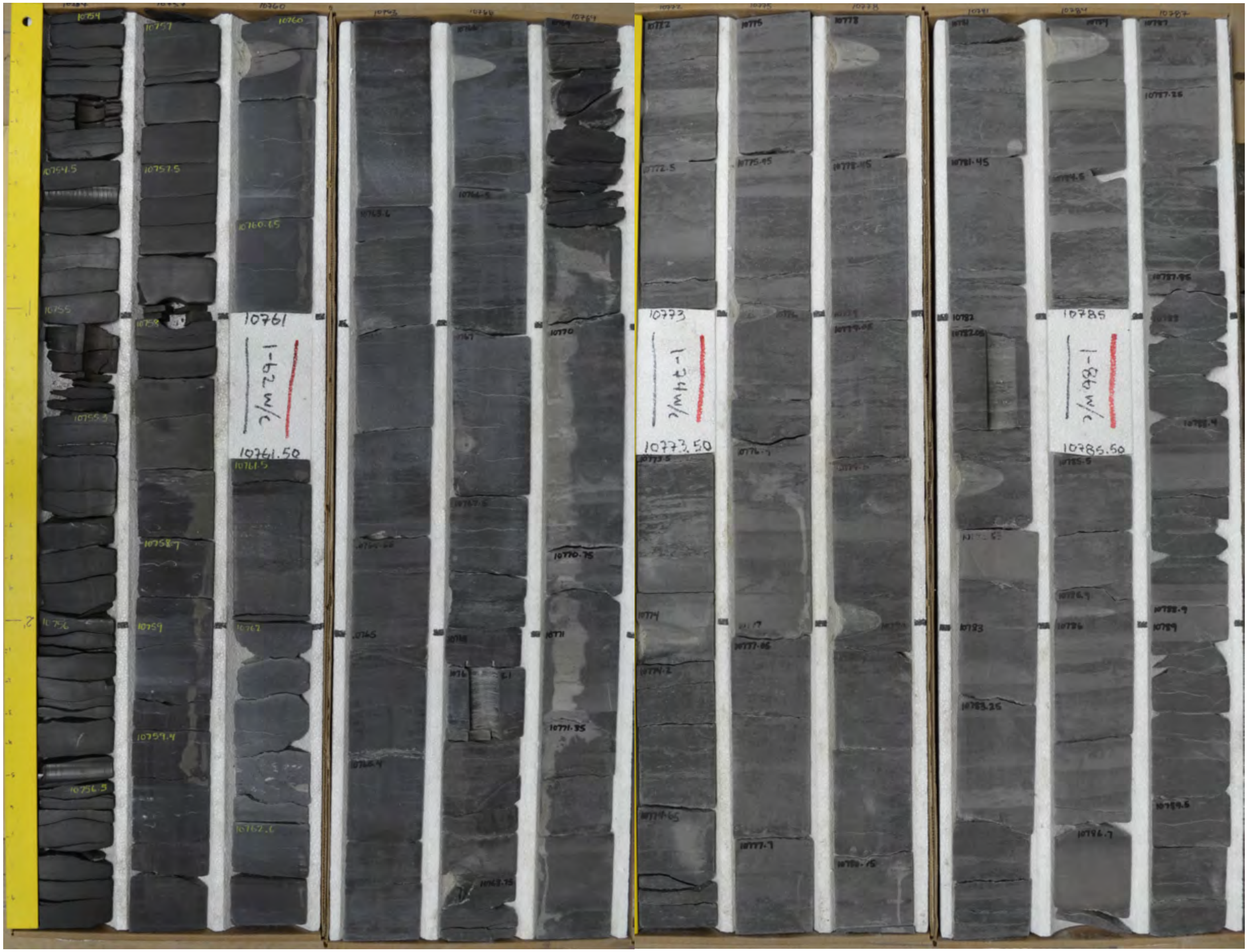


Core Available - 10702-11063

Core + 2 = Log

Lot 3 Sec. 3, T140N, R99W
Continental Resources, Inc.
Debrecen 1-3H

Cored Interval: 10754 - 10790 ft



Lot 3 Sec. 3, T140N, R99W
Continental Resources, Inc.
Debrecen 1-3H

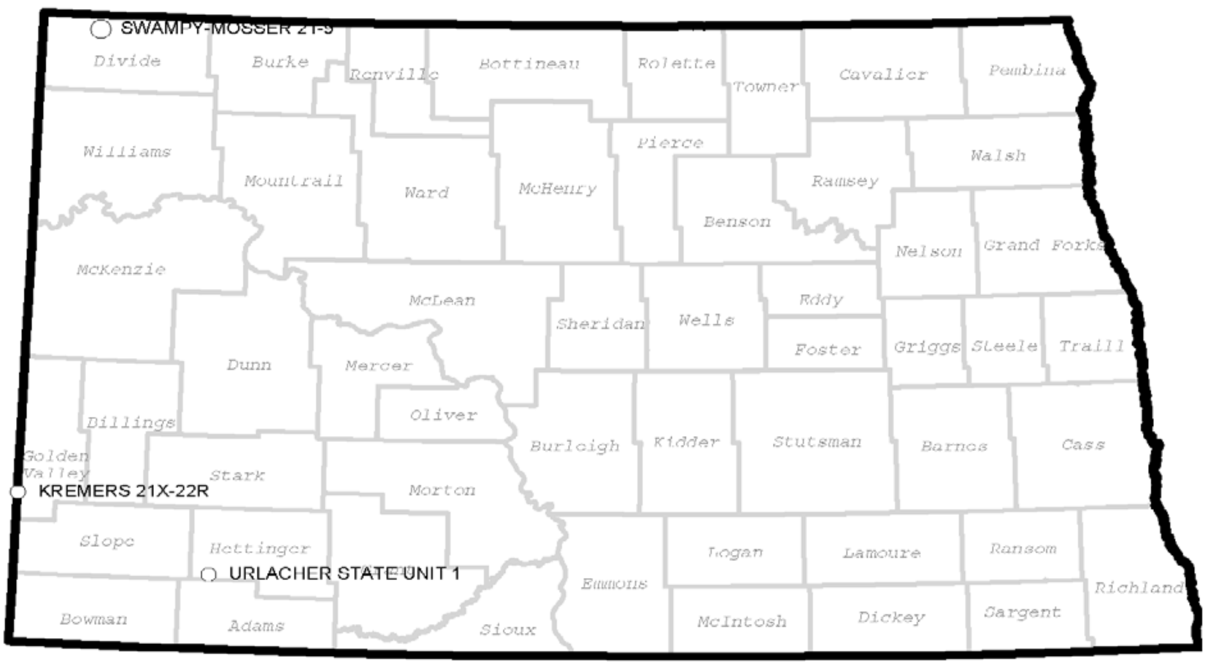
Cored Interval - 10790 - 10817 ft

WILLISTON BASIN PETROLEUM CONFERENCE

Core Workshop

Red River Formation

Stephan H. Nordeng
North Dakota Geological Survey



No.	Well	Depths
1	Urlacher State Unit #1 NDIC: 8010 API: 33041000240000 NW,NW Sec. 25, T 133 N, R 97 W, Hettinger County	10,072' – 10119'
2	Kremers 21X-22R NDIC: 6272 API: 33033000440000 LT 2, Sec. 22, T 137 N, R 106 W, Golden Valley County	10,575' – 10,683'
3	Swampy-Mosser 21-9 NDIC: 11302 API: 33023003280000 NE, SE Sec. 21, T 163 N, R 100 W, Divide County	10,849' – 10,909' 10,929' – 10,977'

Introduction

The Red River Formation is an Ordovician-aged carbonate section that is the third largest oil producing petroleum system in the Williston Basin (Fig. 1). Much of the production has been from horizontal wells drilled along CedarHills anticline in the southwestern portion of North Dakota. Notable, though localized production has been found across much of the central portion of the Williston Basin of North Dakota (Fig. 2). This widespread distribution of production is associated with a rather "unconventional" source rock that might be interesting to examine from the standpoint of a basin centered petroleum system. Even though production from the Red River is conventional, questions exist as to whether it is capable of being exploited as a nonconventional resource play.

Conventional oil accumulations are usually found in structural or stratigraphic traps that accumulate oil that is in the process of migrating away from the rocks from which it was generated. As an extreme end member condition this migration from the source beds to the reservoir could be considered to be completely unimpeded by the intervening rock column so that migration is driven solely by density differences between petroleum and formation water (Dow, 1974). This would constitute an "open" hydraulic system in which pore fluid pressures simply reflect the weight of the overlying water column (hydrostatic pressure). Conversely, a truly "closed" petroleum system is one in which oil generated within a source bed is completely prevented from escaping. In this case, the overall volume expansion that accompanies the kerogen to oil transition results in a petroleum accumulation that has formation pressures significantly above hydrostatic pressures.

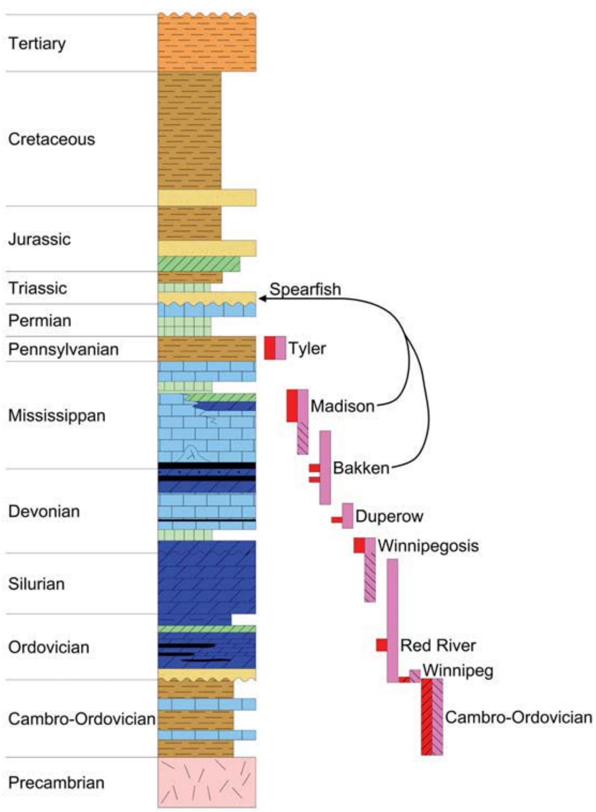


Figure 1. Generalized stratigraphic column of the Williston Basin showing the distribution of the eight recognized petroleum systems. The approximate location of source beds is shown in red and the range of associated reservoir beds is shown in pink (Modified from Jarvie, 2001).

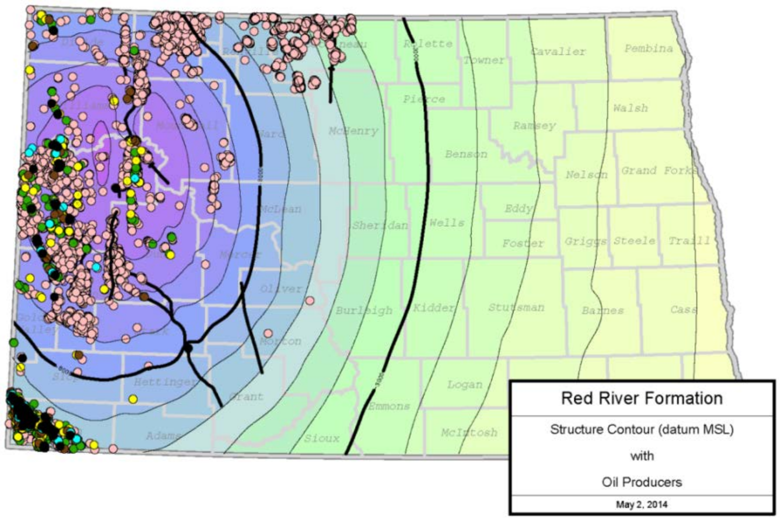


Figure 2. Map of North Dakota showing the elevation of the top of the Red River Formation in feet above mean sea-level. The color filled circles represent the location of wells that have produced from the Red River Formation. Well locations are color coded on the basis of cumulative production as follows: 0 to 100,000 bbls are tan, 100,000 to 200,000 bbls are in green, 200,000 to 300,000 are in yellow, 300,000 to 400,000 bbls are in brown, 400,000-500,000 bbls are blue and wells with more than 500,000 bbls are black.

There are three primary features that are needed to form a basin centered petroleum system. These include 1) a regionally extensive source rock, 2) neighboring porous rocks that are very poorly permeable and 3) burial to depths with temperatures capable of generating petroleum at a rate that exceeds the transmission capacity of the adjacent rocks (Meissner, 1978). The most significant physical manifestation of this is the development of formation fluid pressures that are significantly above simple hydrostatic pressures.

Obviously, between these two end member conditions there is a point that divides “closed” petroleum systems from those that are “open”. This point could be important in evaluating whether or not a particular source system is capable of producing an economic basin centered petroleum accumulation. In a pseudo-algebraic fashion the difference between open and closed petroleum systems might be stated as follows:

Generation Rate < Migration Rate → Open System (Hydrostatic - Conventional)

Oil Generation Rate = Migration Rate → “Semi-Closed” System (Hydrostatic (?) - Accumulation?)

Oil Generation Rate > Migration Rate → Closed System (Overpressured - Basin Centered - Unconventional)

The Red River Formation is interesting from a couple of standpoints. Even though there is no evidence that the formation is overpressesurized (see Fig.4 and Fig. 5 for examples) the widespread distribution of marginal production together with significant oil saturations (see Fig. 6) within rocks close to source beds raises the question as to whether or not economic production is possible from petroleum systems that may only be partially “closed” with formation pressures that are near hydrostatic. Another point, with implications for other carbonate hosted source systems, is the difficulty in locating source bed intervals using standard wireline methods. The primary reason for this is that unlike shale dominated source beds (i.e. the Bakken), kerogen-rich intervals in the Red River are typically thin and not noticeably radioactive (see Fig. 3, 6 and 7). Consequently, standard methods that rely on elevated gamma ray responses to assay the thickness and distribution of carbonate hosted source intervals are unreliable.

Oil in the Red River Formation is derived from source beds called kukersites that frequently contain very organic-rich, oil-prone (Type I) intervals that sometimes have total organic carbon (TOC) contents in excess of 50% (Kohm and Louden, 1978; Jacobson et al., 1988). The term kukersite was originally coined by Zalessky (1917) to describe source beds in Estonia that consisted almost entirely of organic matter derived from a colonial micro-organism he called *Gloeocapsomorpha prisca* (*G. prisca*). This association of *G*. *prisca* and its distinctive fingerprint is present in many mid-Ordovician oils throughout North America, Northern Europe and Australia. Fossil *G*. *prisca* not only links source beds to oil accumulations but also provides an interesting insight into mid-Ordovician life. *G*. *prisca* is readily identified because remains found in kerogen often show a distinctive microstructure that resembles some modern day cyanobacteria. However, the debate about its biological affinity is still ongoing. This debate revolves in part about whether or not *G*. *prisca* accumulated as non-photosynthetic burrow linings and bacterial mats that episodically blanketed Ordovician seafloors (Longman and Palmer, 1987) or whether it was a photosynthetic, planktonic organism that occasionally "bloomed" (Derenne et al., 1992). One part of the argument in favor of a non-photosynthetic life style is inferred from associated oils that typically contain very low concentrations organic fragments (pristine and phytane) derived from photosynthetic chlorophyll (Longman et al., 1987). The relatively small abundance of these two organic markers helps distinguish oils generated in mid-Ordovician kukersites from other source beds such as the Bakken Formation that contains significantly greater amounts of these compounds. In addition to the near absence of these organic fragments, oil derived from *G*. *prisca* has an unusual tendency to contain hydrocarbon chains dominated by odd numbers of carbon. A third distinctive feature is the near absence of hydrocarbons containing more than 20 carbon atoms. The combination of these factors makes the connection between the Red River kukersites and oils in the Red River and elsewhere possible (Jarvie, 2001).

Stratigraphy

The Red River consists of three sequences that generally range from a distinctive burrowed facies containing open marine lime mudstones and wackestones that grade up section into intertidal microbial laminates, supratidal intraformational breccias and in the central portion of the basin, supratidal or more commonly subaqueous anhydrites. Longman and Haidl (1996) considered the anhydrite caps to mark parasequence boundaries that cap an overall "brining upward" succession. These three sequences are labeled in descending order "A", "B", "C". `

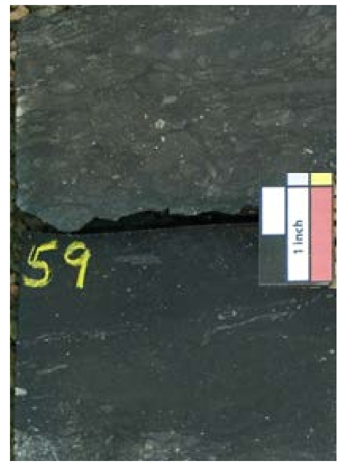
Illustrated Facies

Anhydrite Facies (supratidal and subaqueous?) Dark gray to off white, frequently banded or thinly layered, occasionally nodular. Usually associated with an underlying microbial laminate. In the complete section there are three anhydrites that cap, in descending order, the “A”, “B” and “C” sequences.

Microbial laminate Facies (intertidal). Dark brown to tan, frequently dolomitized. millimeter scale laminations near the top that become thicker down section. Usually finely crystalline but may be locally sucrosic with secondary pinpoint vuggy porosity. Constitutes the so called “A”, “B” and “C” porosity zones when developed in the corresponding sequence.

Planar burrows Facies. (Open marine) Small elliptical features in cross section in which the long axis is nearly horizontal. Usually found near the top of the burrowed facies and is frequently associated with keragonites.

“Kukersite” (Open marine) Brown to black with color variations being influenced by organic maturation. Primary source beds of the Red River Petroleum System. Thinly laminated microbial boundstone to occasionally massive. Often associated with normal open marine fossil debris and small elliptical burrows. Almost always contains small amplitude styolites. Total organic content may vary significantly depending upon the amount of limestone present. TOCs measured in the cores presented here can be in excess of 10% by weight with hydrogen indices in excess of 500.



3-D Burrow Facies (*Thalissanoides*?) Present as the basal lithofacies of each of the Red River parasequences. In general this facies thins up section within each parasequence. Characteristic branching burrows frequently dolomitized. Matrix varies from mudstone to floatstone containing open marine fossils (corals and brachiopods). It occasionally contains multiple generations of burrows within burrows. Frequently burrows are preferentially dolomitized within an otherwise limestone matrix. Dolomitization locally associated with increased visual porosity and usually associated with planar burrows.

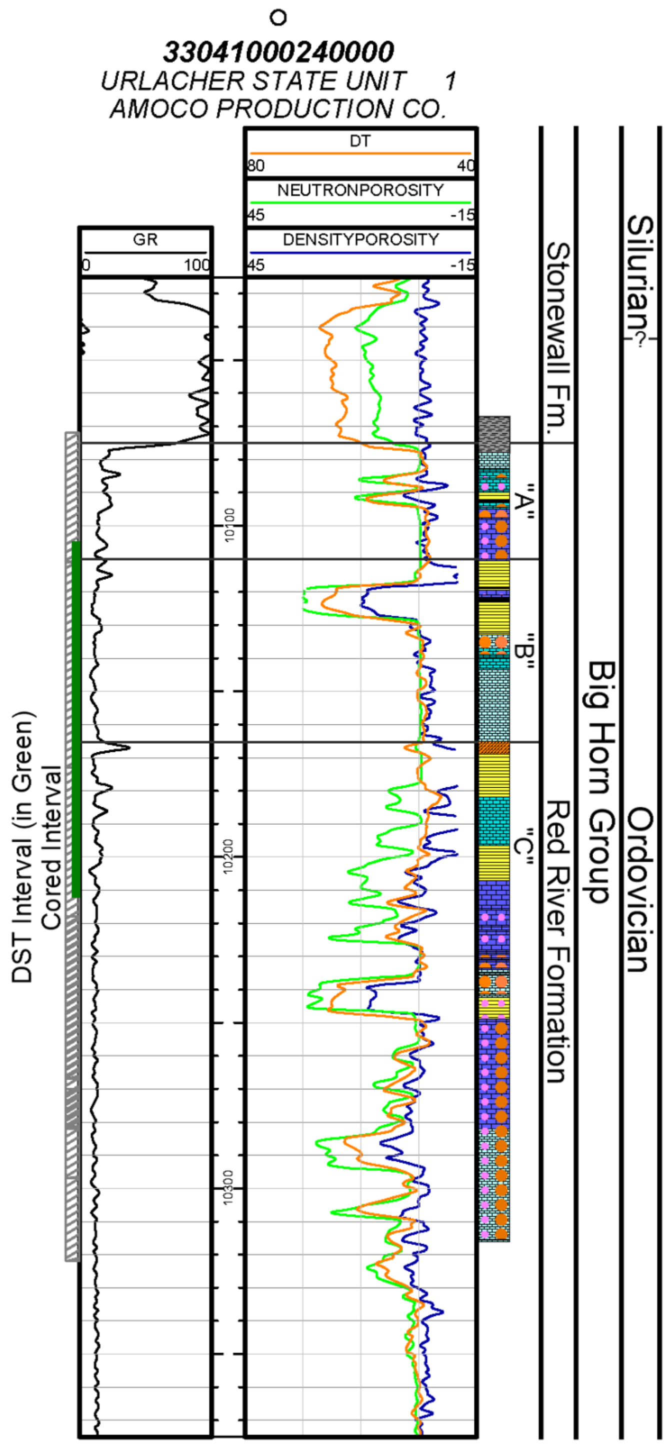


Figure 3. Urlacher State Unit 1, NDIC #: 8010. Located in NW, NE Sec. 25, T 133 N, R 97 W, Hettinger County. Lithologic features on the strip log include 3-D burrows (large filled circles), planar burrows (small filled circles), microbial laminates (horizontal ruled lines), kukersites (black filled) and anhydrite (diagonally ruled).

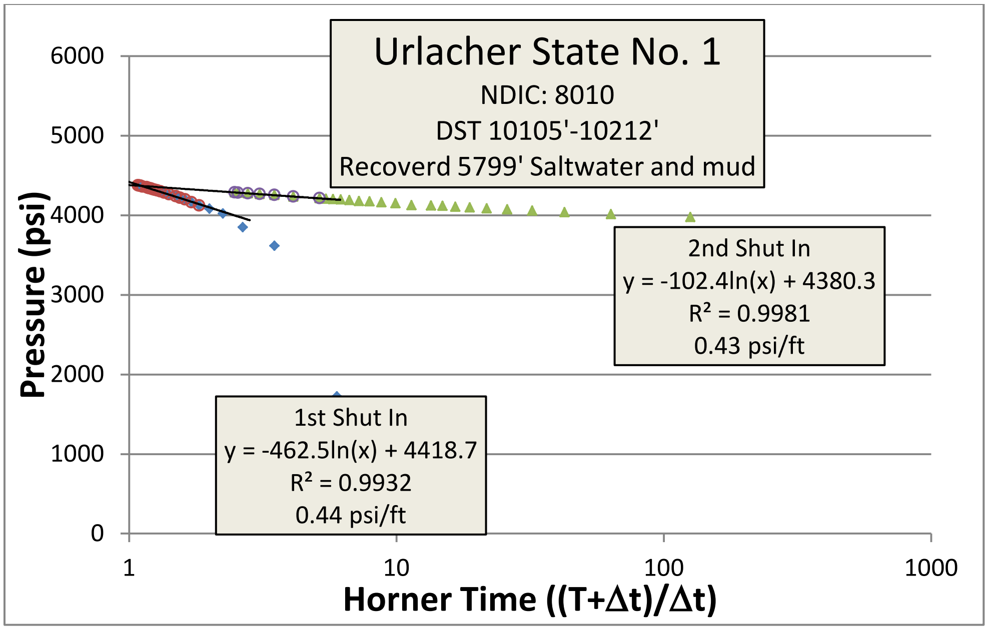


Figure 4. Plot of DST pressure versus Horner time that shows that the pressures within the tested portion of the Red River are within the range of values consistent with hydrostatic conditions. Fluid recovery details are contained on the attached scout ticket. DST data available under the "Well File" option of the DMR scout ticket for this well. https://www.dmr.nd.gov/oilgas/

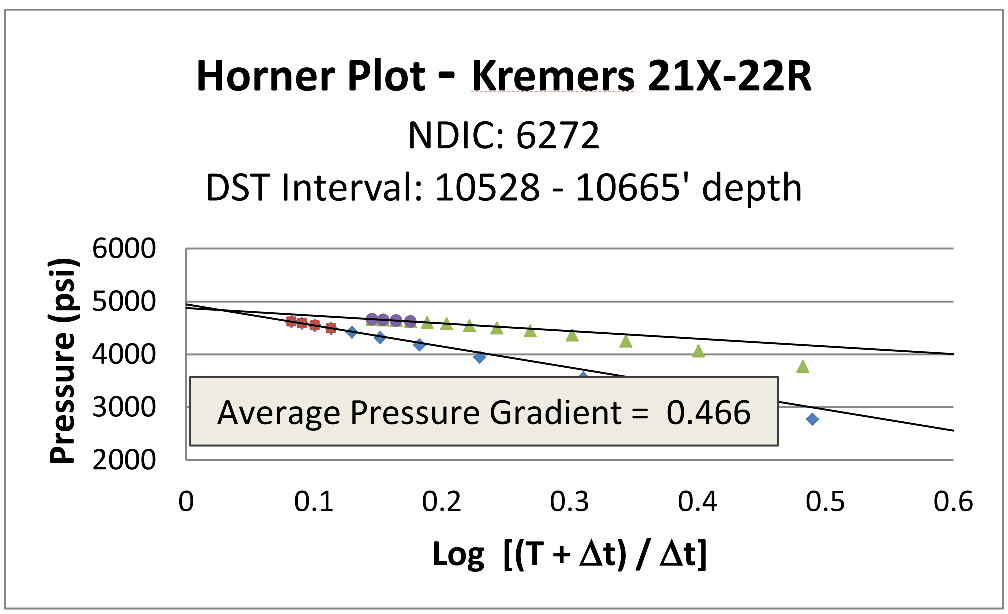


Figure 5. Horner Plot of a drill stem test (DST) conducted over the cored interval in the Kremers 21X-22R indicating that the section that includes the kukersites is consistent with the fluid pressure expected for an "open" reservoir. DST data available under the "Well File" option of the DMR scout ticket for this well. https://www.dmr.nd.gov/oilgas/

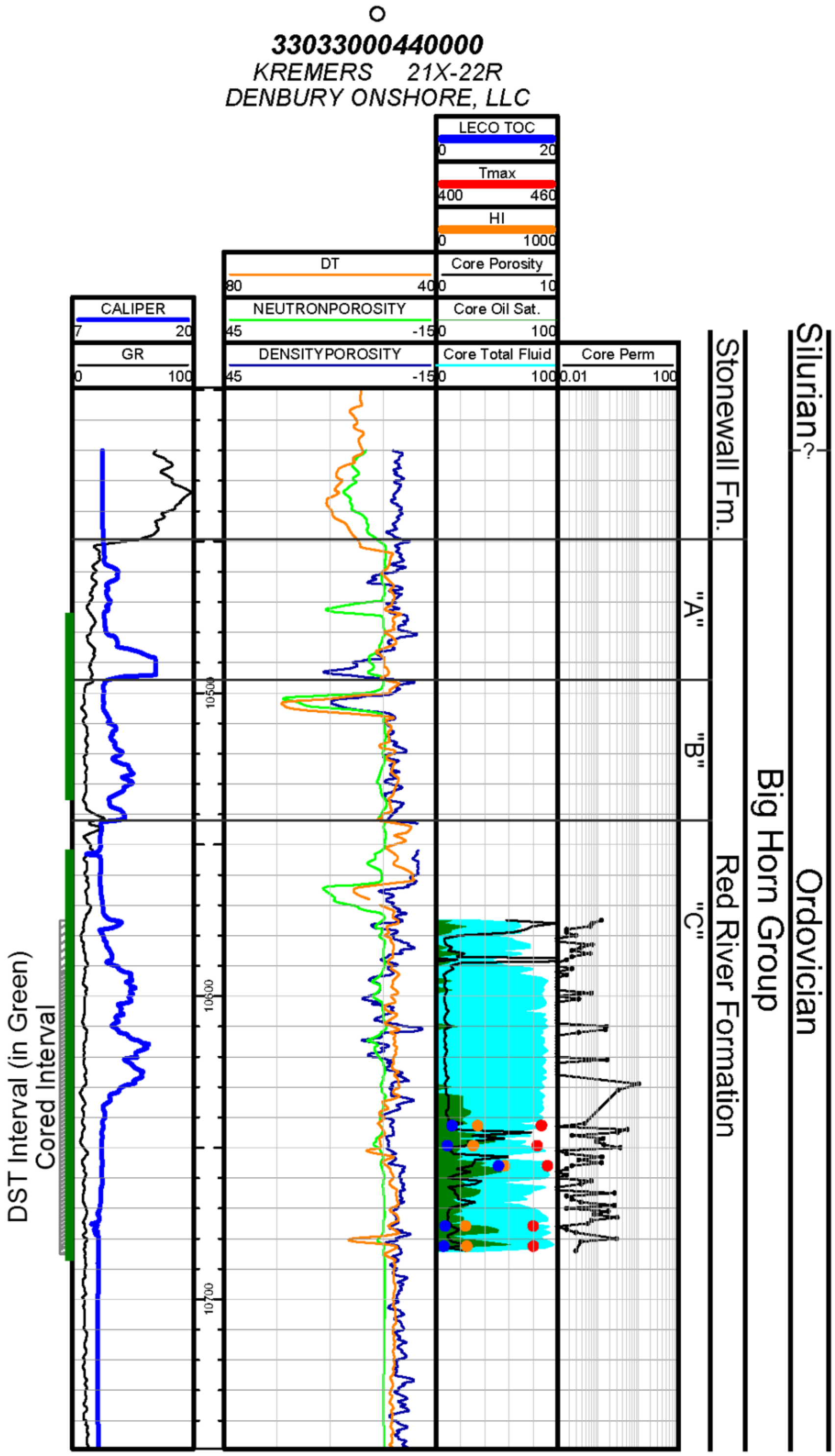


Figure 6. Kremers 21X-22R, NDIC #6272, located in Lot 2, Sec. 22 T 137 N, R 106 W, Golden Valley County. Wireline logs plotted alongside core analyses of porosity, permeability (md), oil saturation (green filled curve), water saturation (blue filled curve) and porosity (black line). Results from LECO TOC analyses are shown as blue dots and the results from RockEval 6 are shown as orange dots (hydrogen index) and T_{max} (Red dots).

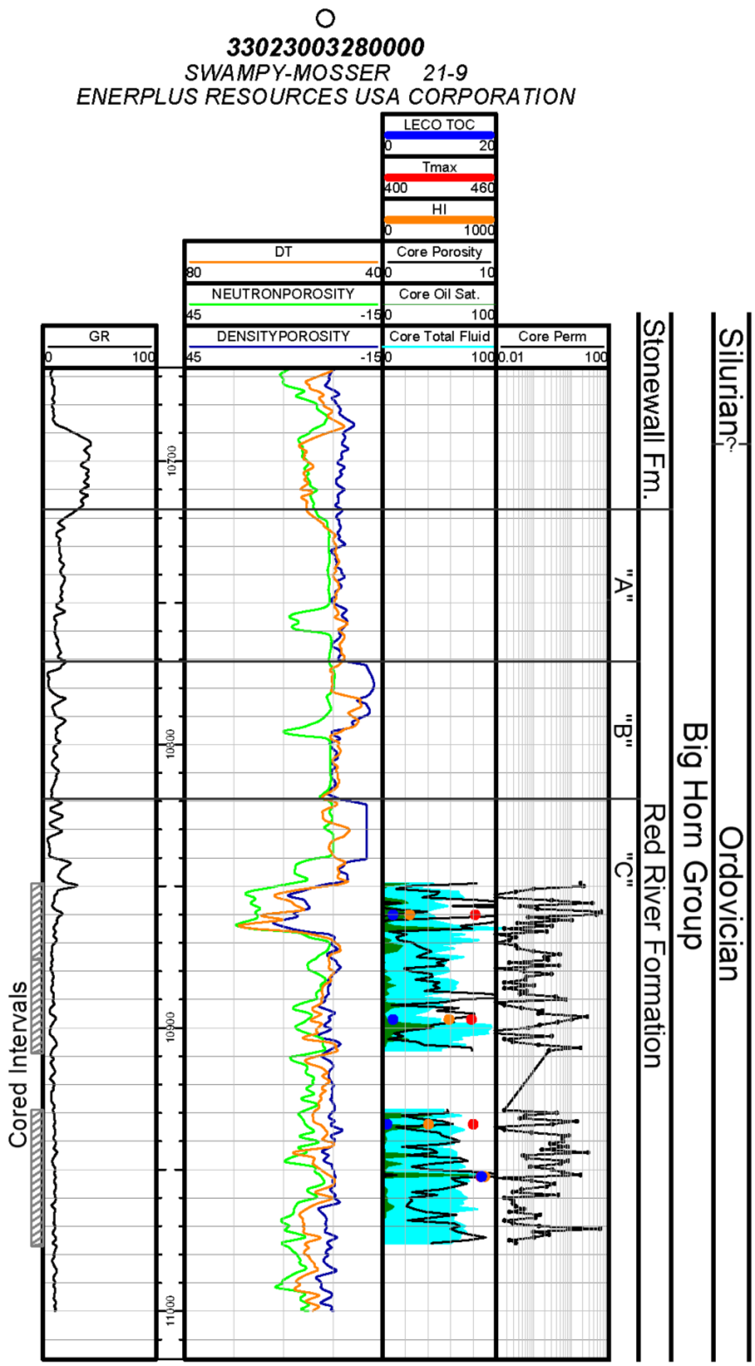


Figure 7. Swampy-Mosser 21-9, NDIC# 11302, located in then NE, SE Sec. 21, T 163 N, R 100 W, Divide County. Wireline logs plotted alongside core analyses of permeability (black line, far right track in md), oil saturation (green filled curve), water saturation (blue filled curve) and porosity (black line). Results from LECO TOC analyses are shown as blue dots and the results from RockEval 6 are shown as orange dots (hydrogen index) and T_{max} (Red dots). The T_{max} values all suggest that the Red River has generated oil, a result that is consistent with the high oil saturations found in the core analyses. However, the high water saturations combined with relatively high permeabilites suggest that the generation rate is less than the migration rate.

References

Derenne, S., Metzger, P., and Lareau, C., 1992, Similar morphological and chemical variations of *Gloeocapsomorphaprisca*. Ordovician sediments and cultured *Botryococcus braunii* as a response to changes in salinity: Organic Geochemistry, 19 p. 299-313.

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.

Kohm, J.A., and Louden, R.O., 1978, Ordovician Red River of eastern Montana and western North Dakota — Relationships between lithofacies and production, *in*, Rehig, D., ed., Williston Basin Symposium: Montana Geological Society, Billings, p. 99-117.

Jarvie, D.M., 2001, Williston Basin petroleum systems —Inferences from oil geochemistry and geology: The Mountain Geologist, v. 38, no. 1, p. 19-41.

Jarvie, D.M., and Walker, P.R., 1997, Correlation of oils and source rocks in the Williston Basin using classical correlation tools and thermal extraction high resolution C7 gas chromatography: 18th International Meeting on Organic Geochemistry, September 22-26, 1997, Maastricht, The Netherlands, oral presentation.

Longman, M. W. and Haidl, F. M., 1996, Cyclic deposition and development of porous dolomites in the Upper Ordovician Red River Formation, Williston Basin; Paleozoic Systems of the Rocky Mountain Region in M.W. Longman and M.D Sonnenfeld, eds., 1996, Paleozoic Systems of the Rocky Mountain Region, Rocky Mountain Section SEPM p. 29-46.

Meissner, F.F., 1978, Petroleum geology of the Bakken Formation Williston Basin, North Dakota and Montana, in, Rehig, D., ed., Williston Basin Symposium: Montana Geological Society, Billings, p. 207-227.

Zalessky, M., 1917, On marine sapropelite of Silurian age formed by a blue green alga: Bulletin De L'Académie Des Sciences De Russie, VI Série., v. 11, no. 1, p. 3-18. [in Russian]

Scout Tickets

NDIC File No: **8010** API No: **33-041-00024-00-00** County: **HETTINGER**
Well Type: **OG** Well Status: **DRY** Status Date: **1/16/1981** Wellbore type: **DIRECTIONAL**
Location: **NWNE 25-133-97** Footages: **1233 FNL 1910 FEL** Latitude: **46.307075** Longitude: **-102.806441**
Directional Bottom Hole Coordinates **445 N 248 W** From Wellhead Get Survey Data
Current Operator: **AMOCO PRODUCTION CO.**
Original Operator: **AMOCO PRODUCTION CO.**
Current Well Name: **URLACHER STATE UNIT 1**
Original Well Name: **URLACHER STATE UNIT #1**
Elevation(s): **2678 KB** Total Depth: **10415** Field: **TEPEE BUTTE**
Spud Date(s): **11/25/1980**
Digital or Image Log(s) available: **BCS** 6.6MB, **CND** 4.7MB, **DIP** 3.3MB, **DLL** 7.3MB, **FIL** 7MB
Formation Tops
K-GH 4027 K-M 4524 K-IK 4880 J-S 5175 J-R 5721 T-S 6056 PM-MK 6268 PM-OP 6312 PM-BC 6415 PN-T 6939 M-KL 7176 M-MD 7303 M-MDR 7497 M-MDSA 7693 M-MDLP 8070 D-TF 8705 D-BB 8862 D-DP 8935 D-SR 9155 D-DB 9253 S-I 9403 O-G 9946 O-ST 9993 O-RR 10075
Casing String(s): **9-5/8" 2018' 7" 10415'**
Completion Data
Pool: **RED RIVER** Comp Dt: **1/16/1981** Status: **DRY** Status Dt: **1/16/1981**
Production Test Data
DST: **10105-10212** Recovery: **120' AMMONIA & INHIBITOR, 541' SLIGHTLY MUD CUT SALT WATER, 5138' SALT WATER - SAMPLER: 2100 CC SALT WATER**
Cores and Samples View Core Photos
Type: **DC** Top: **4000** Bottom: **7400**
Type: **DC** Top: **7400** Bottom: **9700**
Type: **DC** Top: **7500** Bottom: **8300**
Type: **DC** Top: **8300** Bottom: **8620**
Type: **DC** Top: **9700** Bottom: **10416**
Type: **LS** Top: **10072** Bottom: **10119** Formation: **O-RR**
Type: **LS** Top: **10119** Bottom: **10280** Formation: **O-RR**
Type: **LS** Top: **10280** Bottom: **10356** Formation: **O-RR**
Type: **TS** Top: **0** Bottom: **10094** Formation: **O-RR**
Type: **TS** Top: **0** Bottom: **10094** Formation: **O-RR**
Type: **TS** Top: **0** Bottom: **10134** Formation: **O-RR**
Type: **TS** Top: **0** Bottom: **10176** Formation: **O-RR**
Type: **TS** Top: **0** Bottom: **10233** Formation: **O-RR**
Type: **TS** Top: **0** Bottom: **10280** Formation: **O-RR**

Type: **TS** Top: **0** Bottom: **10300** Formation: **O-RR**

NDIC File No: **6272** API No: **33-033-00044-00-00** County: **GOLDEN VALLEY** CTB No: **106272**
Well Type: **OG** Well Status: **PA** Status Date: **10/4/2001** Wellbore type: **DIRECTIONAL**
Location: **LT2 22-137-106** Footages: **1100 FNL 900 FWL** Latitude: **46.670066** Longitude: **-104.041191**
Directional Bottom Hole Coordinates **475 S 500 E** From Wellhead
Side Track **1** Start Coordinates **5 S 10 E** From Wellhead, End Coordinates **533 S 538 E** From Wellhead
Current Operator: **XTO ENERGY INC.**
Original Operator: **SHELL OIL CO.**
Current Well Name: **KREMERS 21X-22R**
Original Well Name: **KREMERS #21-22**
Elevation(s): **3034 KB** Total Depth: **11989** Field: **WILLIAMS CREEK**
Spud Date(s): **8/17/1977**
Digital or Image Log(s) available: **BCS1** 2.3MB, **BCS2** 4.7MB, **CBL** 2.6MB, **CND1** 2.4MB, **CND2** 4.5MB, **DLL1** 3.9MB, **DLL2** 1.1MB
Formation Tops
K-GH 4035 K-M 4610 K-IK 5040 J-S 5224 J-R 5936 T-S 6344
PM-MK 6864 PM-OP 6900 PM-BC 7205 PN-T 7562 M-EBS 7713 M-KL 7925
M-MD 8069 M-MDR 8270 M-MDFA 8436 M-MDLP 8932 D-BB 9545 D-DP 9556
D-SR 9777 S-I 9905 O-G 10323 O-ST 10390 O-RR 10452 O-WR 10960
O-WI 10975 O-BI 11065 CO-D 11080 PC 11500
Casing String(s): **13-3/8" 315'; 9-5/8"3310'; 5-1/2" 10805'**
Completion Data
Pool: **PRECAMBRIAN** Comp Dt: **5/15/1978** Status: **DRY** Status Dt: **5/15/1978**
Pool: **RED RIVER** Perfs: **10479-10580G** Comp Dt: **1/14/1979** Status: **PNA** Status Dt: **10/4/2001** Spacing: **N2**

Cumulative Production Data
Pool: **RED RIVER** Cum Oil: **199782** Cum MCF Gas: **97083** Cum Water: **57587** [Interactive Performance Curve] [PDF Curve]
Production Test Data
IP Test Date: **1/14/1979** Pool: **RED RIVER** IP Oil: **130** IP MCF: **45** IP Water: **10**
DST: **8261-8367** Recovery: **464' AMMONIA WATER, 637' GAS CUT MUD - SAMPLER: 0.0069 CF GAS, 1950 CC MUD**
DST: **8460-8568** Recovery: **633' WATER CUSHION & AMMONIA - SAMPLER: 4.792 CF GAS GOR 15213, 50 CC OIL, 1200 CC MUD**
DST: **8453-8631** Recovery: **701' GAS CUT OIL & MUD EMULSION, 800' M,O&GC NH3 WTR CUSH, 2140' SULFUR WATER - SAMPLER: 0.638 CF GAS GOR 55.8, 420 CC OIL, 1460 CC OIL & WATER EMULSION**
DST: **10474-10535** Recovery: **535' HIGHLY GAS CUT OIL, 2000' HIGHLY GAS CUT WATER CUSHION - SAMPLER: 0.735 CF GAS GOR 77.77, 1500 CC OIL 41.3 @**

60 DEG, 100 CC MUD
DST: **10552-10687** Recovery: **2214' AMMONIA & VERY SLIGHT MUD CUT WATER CUSHION - SAMPLER: 1850 CC MUD**

Cores and Samples
Type: **CC** Top: **8578** Bottom: **8622**
Type: **CC** Top: **8622** Bottom: **8625**
Type: **CC** Top: **10575** Bottom: **10669**
Type: **CC** Top: **10669** Bottom: **10685**
Type: **CS** Top: **8517** Bottom: **8625** Formation: **M-MD**
Type: **CS** Top: **10575** Bottom: **10592** Formation: **O-RR**
Type: **CS** Top: **10592** Bottom: **10685** Formation: **O-RR**
Type: **DC** Top: **300** Bottom: **4030**
Type: **DC** Top: **4030** Bottom: **8020**
Type: **DC** Top: **8020** Bottom: **9640**
Type: **DC** Top: **9640** Bottom: **11380**
Type: **DC** Top: **9640** Bottom: **11380**
Type: **DC** Top: **11380** Bottom: **11990**
Type: **DC** Top: **11380** Bottom: **11996**
Type: **RS** Top: **8517** Bottom: **8625** Formation: **M-MD**
Type: **RS** Top: **10575** Bottom: **10683** Formation: **O-RR**

NDIC File No: **11302** API No: **33-023-00328-00-00** County: **DIVIDE** CTB No: **111302**
Well Type: **OG** Well Status: **PA** Status Date: **2/25/2000** Wellbore type: **HORIZONTAL RE-ENTRY**
Location: **NESE 21-163-100** Footages: **1867 FSL 774 FEL** Latitude: **48.928651** Longitude: **-103.665086**
Lateral **1** Start Coordinates **2 S 2 W** From Wellhead, End Coordinates **154 S 1257 W** From Wellhead
Lateral **2** Start Coordinates **146 S 1037 W** From Wellhead, End Coordinates **169 S 1604 W** From Wellhead
Side Track **1** Start Coordinates **105 S 414 W** From Wellhead, End Coordinates **201 S 1224 W** From Wellhead Get Survey Data
Current Operator: **ENERPLUS RESOURCES USA CORPORATION**
Original Operator: **LOUISIANA LAND & EXPLORATION CO.**
Current Well Name: **SWAMPY-MOSSER 21-9**
Original Well Name: **MOSSER 43-21 #2**
Elevation(s): **2176 KB** Total Depth: **12210** Field: **WILDCAT**
Spud Date(s): **11/28/1984 9/7/1997 3/8/1998**
Digital or Image Log(s) available: **BCS** 1.8MB, **CBL** 2.4MB, **CND** 1.8MB, **DLL** 2.4MB, **DT1** 217KB, **DT2** 185KB, **DT3** 201KB, **DTSM1** 3.5MB, **DTSM2** 13.8MB
Formation Tops
K-GH 3640 K-M 3899 K-N 4043 K-IK 4280 J-S 4647 J-R 5135 T-S 5790 M-EBS 6052 M-KL 6086 M-MD 6219 M-MDR 6601 M-MDLS 6679 M-MDFA 6952 MD-B 7988 D-TF 8084 D-BB 8259 D-DP 8360 D-SR 8833 D-DB 9187 D-PE 9331 D-W 9648 S-I 9874 S-CL 10050 O-G 10627 O-ST 10690 O-RR 10717
Casing String(s): **9.625" 2951' 7" 11015'**
Completion Data
Pool: **DUPEROW** Perfs: **8610-8722 G** Comp Dt: **2/25/2000** Status: **DRY** Status Dt: **2/25/2000**
Pool: **RED RIVER** Comp Dt: **1/15/1985** Status: **DRY** Status Dt: **1/15/1985**
Pool: **RED RIVER** Perfs: **11015-12210G** Comp Dt: **11/1/1997** Status: **PNA** Status Dt: **2/25/2000** Spacing: **S2**
Cumulative Production Data Get Production History
Pool: **RED RIVER** Cum Oil: **707** Cum MCF Gas: **0** Cum Water: **1905** [Interactive Performance Curve] [PDF Curve]
Production Test Data
IP Test Date: **11/1/1997** Pool: **RED RIVER** IP Oil: **13** IP MCF: **0** IP Water: **81**
DST: **8481-8537** Recovery: **90' G&OC MUD, 30' WATER - SAMPLER: 0.18 CF GAS, 2500 CC G&OC MUD**
DST: **10825-10854** Recovery: **0.10 BBLS DRILL MUD - SAMPLER: 1900 CC DRILL MUD**
DST: **10829-10858** Recovery: **8.05 BBLS HGC DRILL MUD, 14.75 BBLS HGC,SOC DR MUD, 10.74 BBLS SGC SALTWATER, 22.17 BBLS SALTWATER - SAMPLER: 1.19 CF GAS, 2150 CC SALTWATER, 850 CC SOC,GC DRILL MUD, TRACE OF OIL**

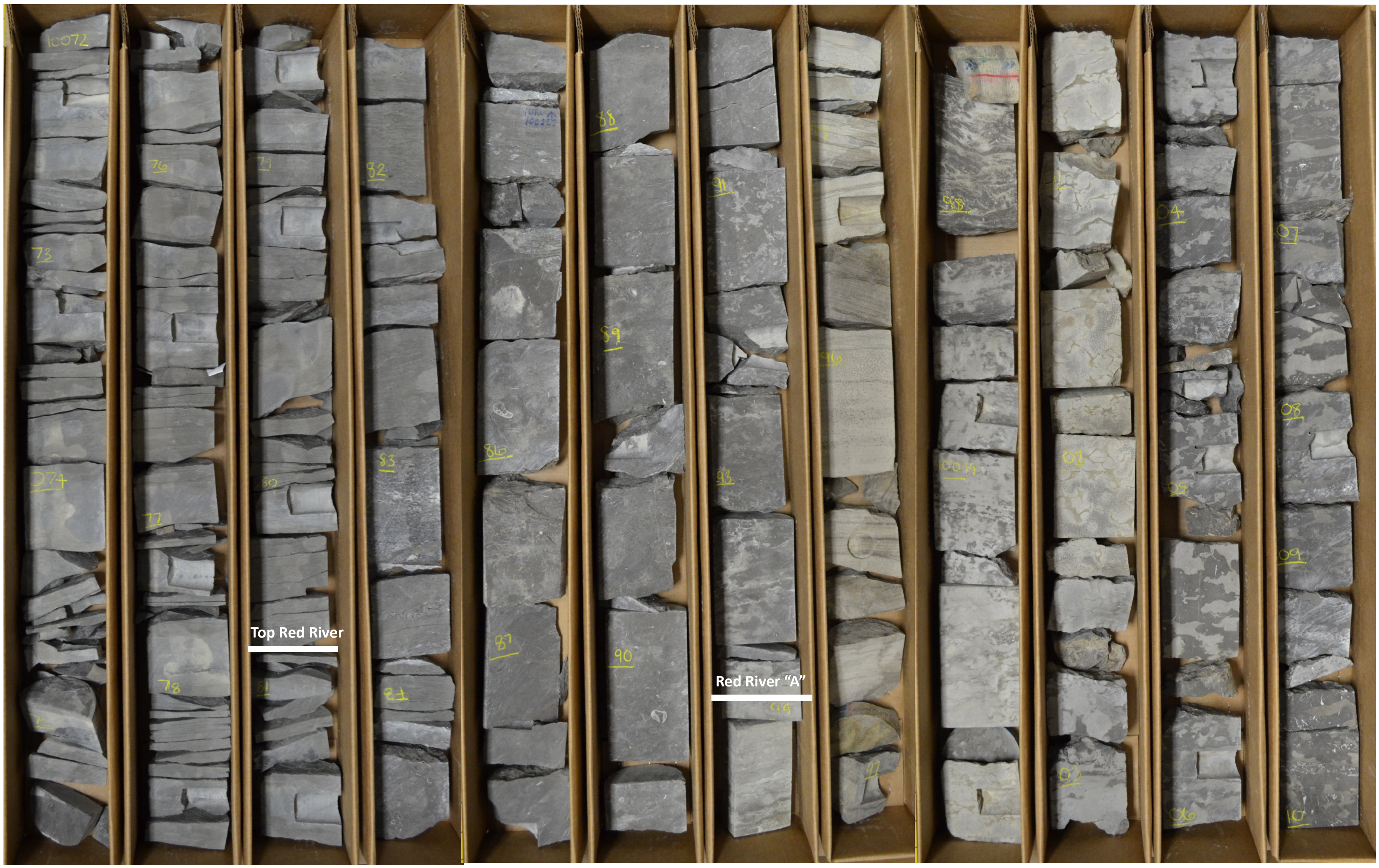
DST: **10834-10865** Recovery: **** MISRUN **, PACKER SEAT FAILED**
DST: **10834-10868** Recovery: **8 BBLS HGC OIL, 16 BBLS GC SALT WATER - SAMPLER: 0.91 CF GAS GOR 964, 150 CC OIL, 2050 CC WATER**

Cores and Samples View Core Photos

Type: **CH** Top: **8484** Bottom: **8538** Formation: **M-MD**
Type: **CH** Top: **10849** Bottom: **10977** Formation: **O-RR**
Type: **CS** Top: **8482** Bottom: **8538** Formation: **M-MD**
Type: **DC** Top: **6100** Bottom: **6800** Formation: **M-MD**
Type: **DC** Top: **6800** Bottom: **7700**
Type: **DC** Top: **7700** Bottom: **8537**
Type: **DC** Top: **8537** Bottom: **9200**
Type: **DC** Top: **9200** Bottom: **9900**
Type: **DC** Top: **9900** Bottom: **10600**
Type: **DC** Top: **10600** Bottom: **11030**
Type: **DC** Top: **11720** Bottom: **12209**
Type: **LS** Top: **8482** Bottom: **8538** Formation: **M-MD**
Type: **LS** Top: **10849** Bottom: **10876** Formation: **O-RR**
Type: **LS** Top: **10876** Bottom: **10883** Formation: **O-RR**
Type: **LS** Top: **10883** Bottom: **10909** Formation: **O-RR**
Type: **LS** Top: **10929** Bottom: **10977** Formation: **O-RR**

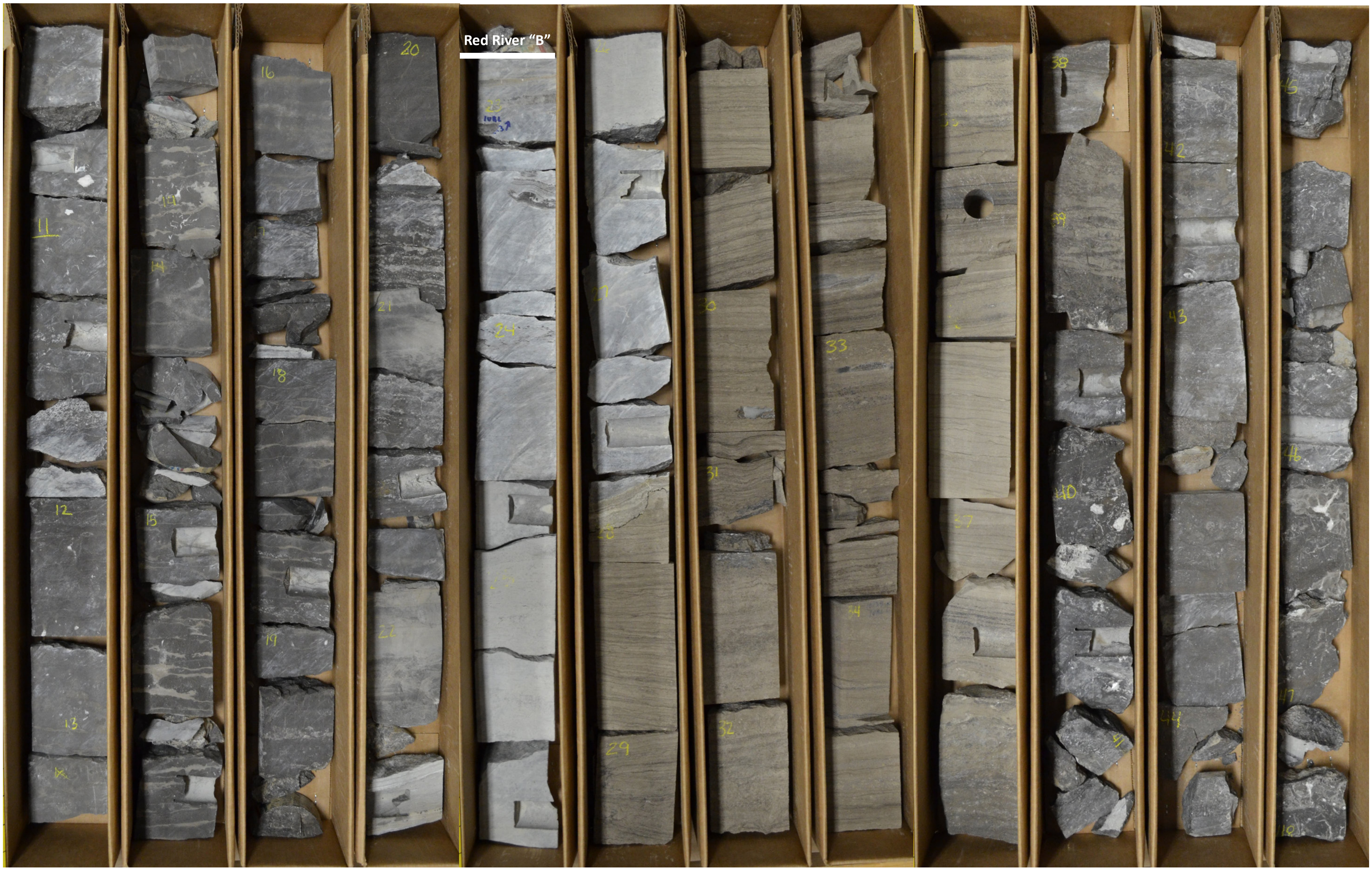
NW, NW Sec. 25, T 133 N, R 97 W
Hettinger County
NDIC: 8010
Urlacher State Unit #1

Cored Interval: 10,072 - 10,110’



NW, NW Sec. 25, T 133 N, R 97 W
Hettinger County
NDIC: 8010
Urlacher State Unit #1

Cored Interval: 10,111' - 10,148'



NW, NW Sec. 25, T 133 N, R 97 W
Hettinger County
NDIC: 8010
Urlacher State Unit #1

Cored Interval: 10,149’ - 10,187’

NW, NW Sec. 25, T 133 N, R 97 W
Hettinger County
NDIC: 8010
Urlacher State Unit #1

Cored Interval: 10,188' - 10,226'

NW, NW Sec. 25, T 133 N, R 97 W
Hettinger County
NDIC: 8010
Urlacher State Unit #1

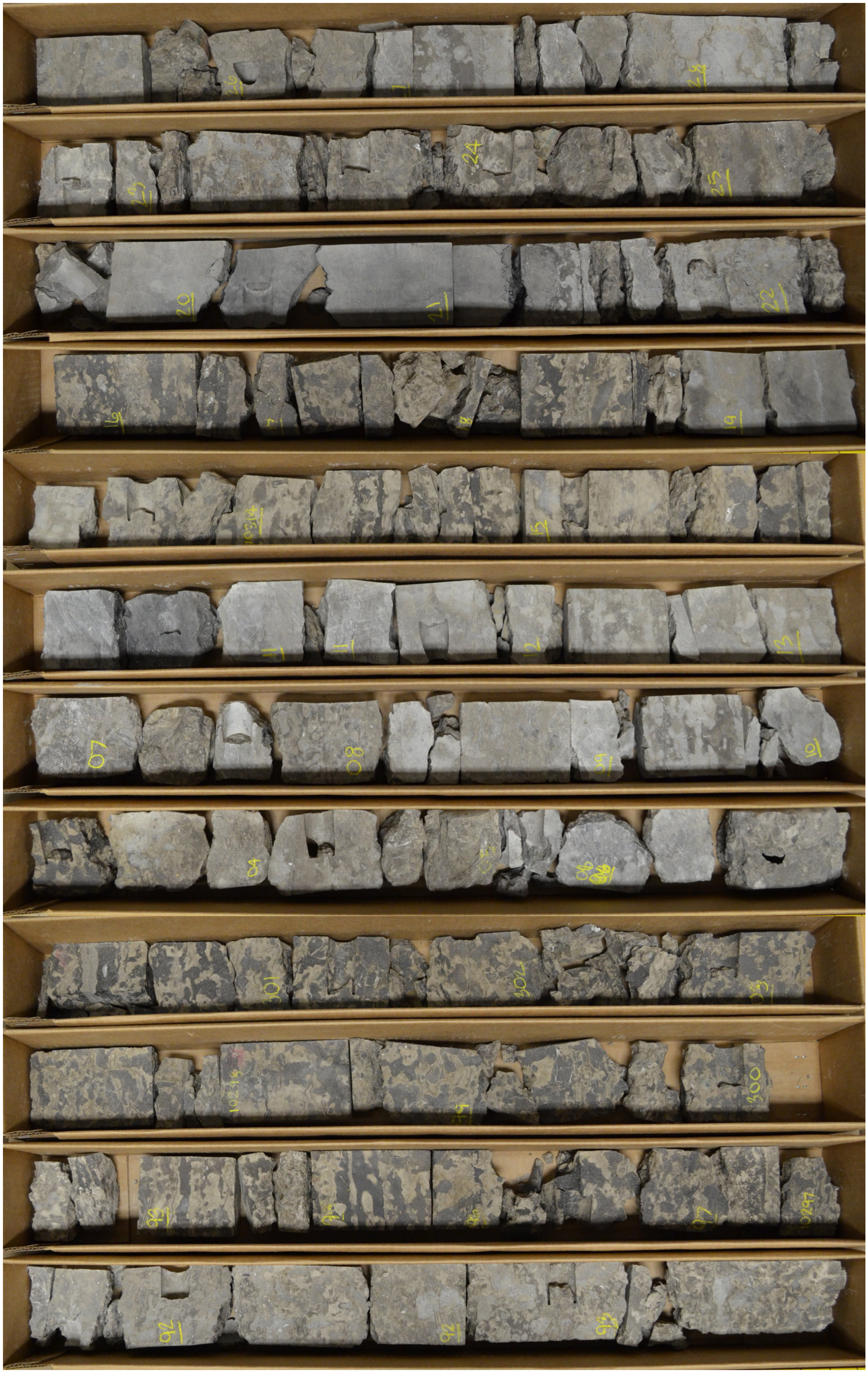
Cored Interval: 10,227' - 10,250

NW, NW Sec. 25, T 133 N, R 97 W
Hettinger County
NDIC: 8010
Urlacher State Unit #1

Cored Interval: 10,251’ - 10,291’

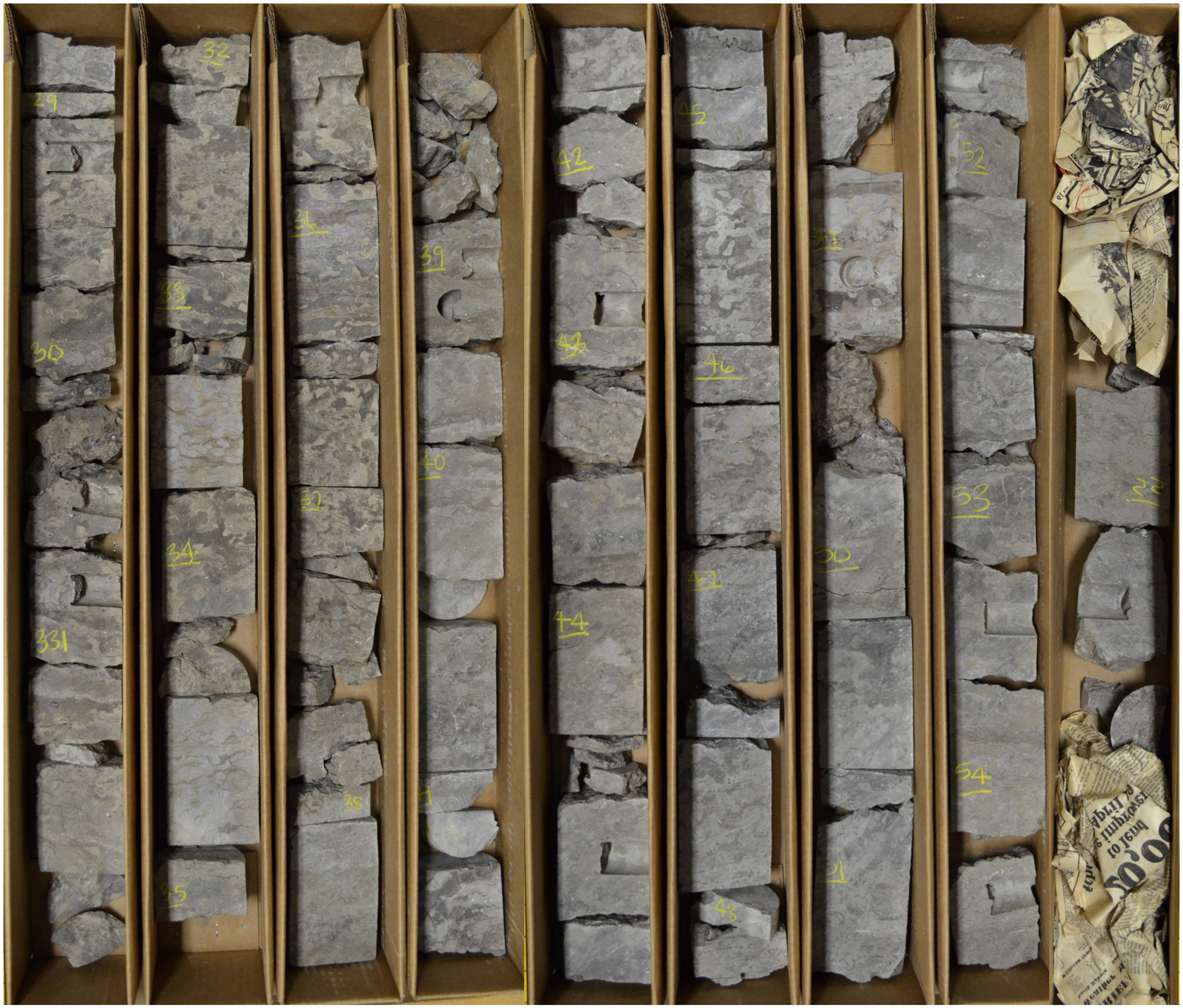
NW, NW Sec. 25, T 133 N, R 97 W
Hettinger County
NDIC: 8010
Urlacher State Unit #1

Cored Interval: 10,292' - 10,328'



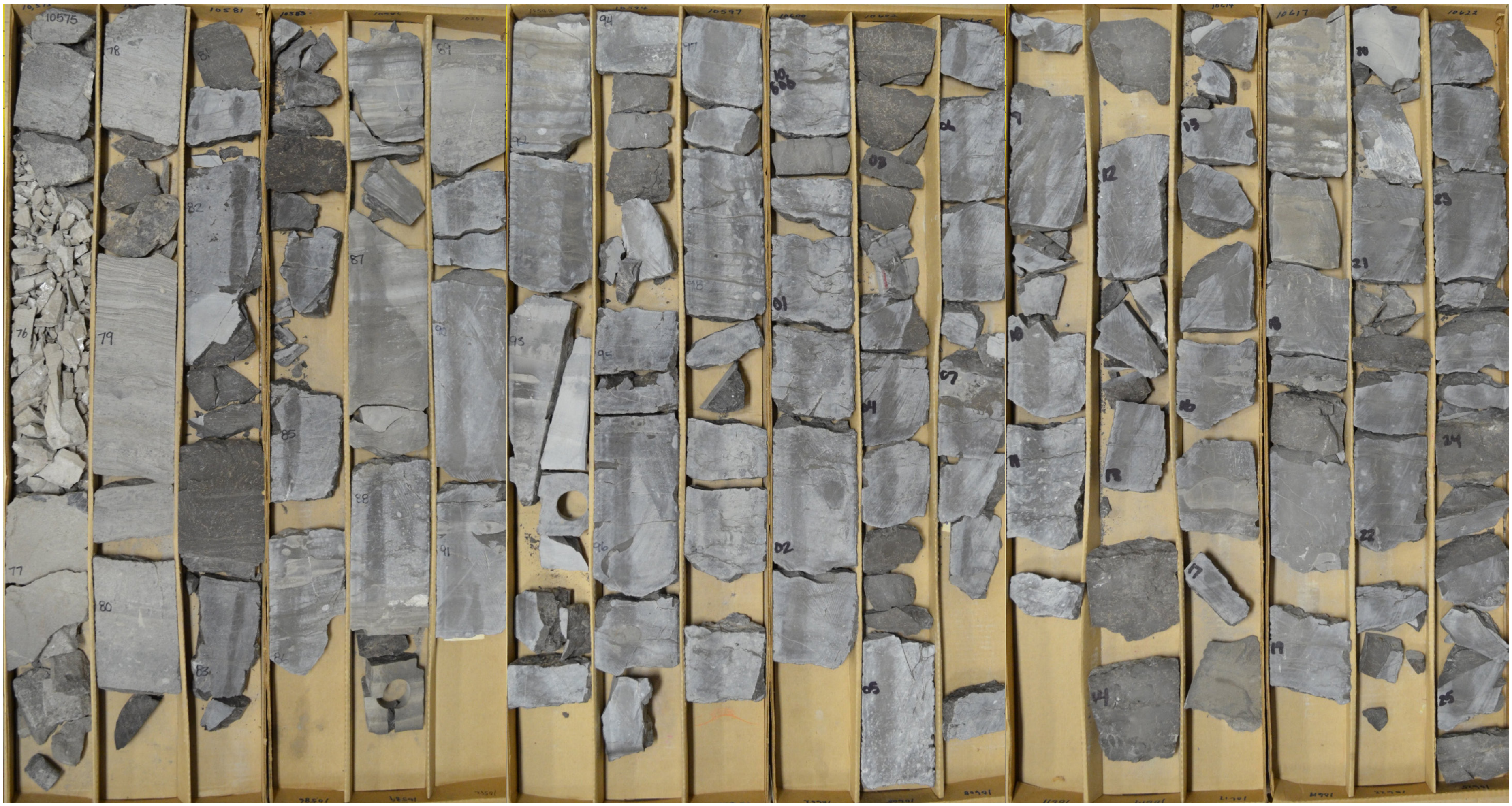
NW, NW Sec. 25, T 133 N, R 97 W
Hettinger County
NDIC: 8010
Urlacher State Unit #1

Cored Interval: 10,329' - 10,355'



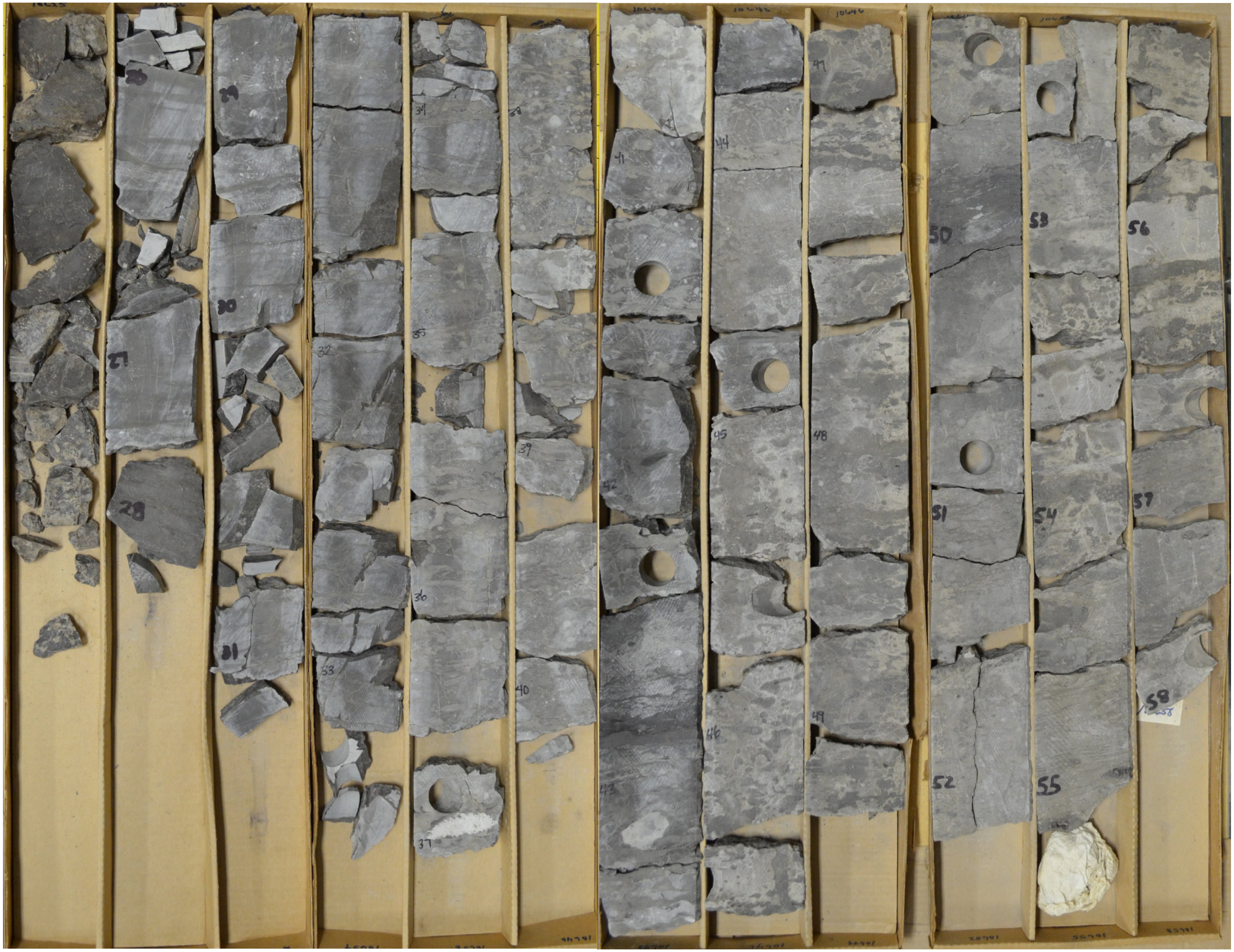
LT 2, Sec 22, T 137 N, R 106 W
Golden Valley County
NDIC: 6272
Kremers 21X-22R

Cored Interval: 10,575' - 10,625'



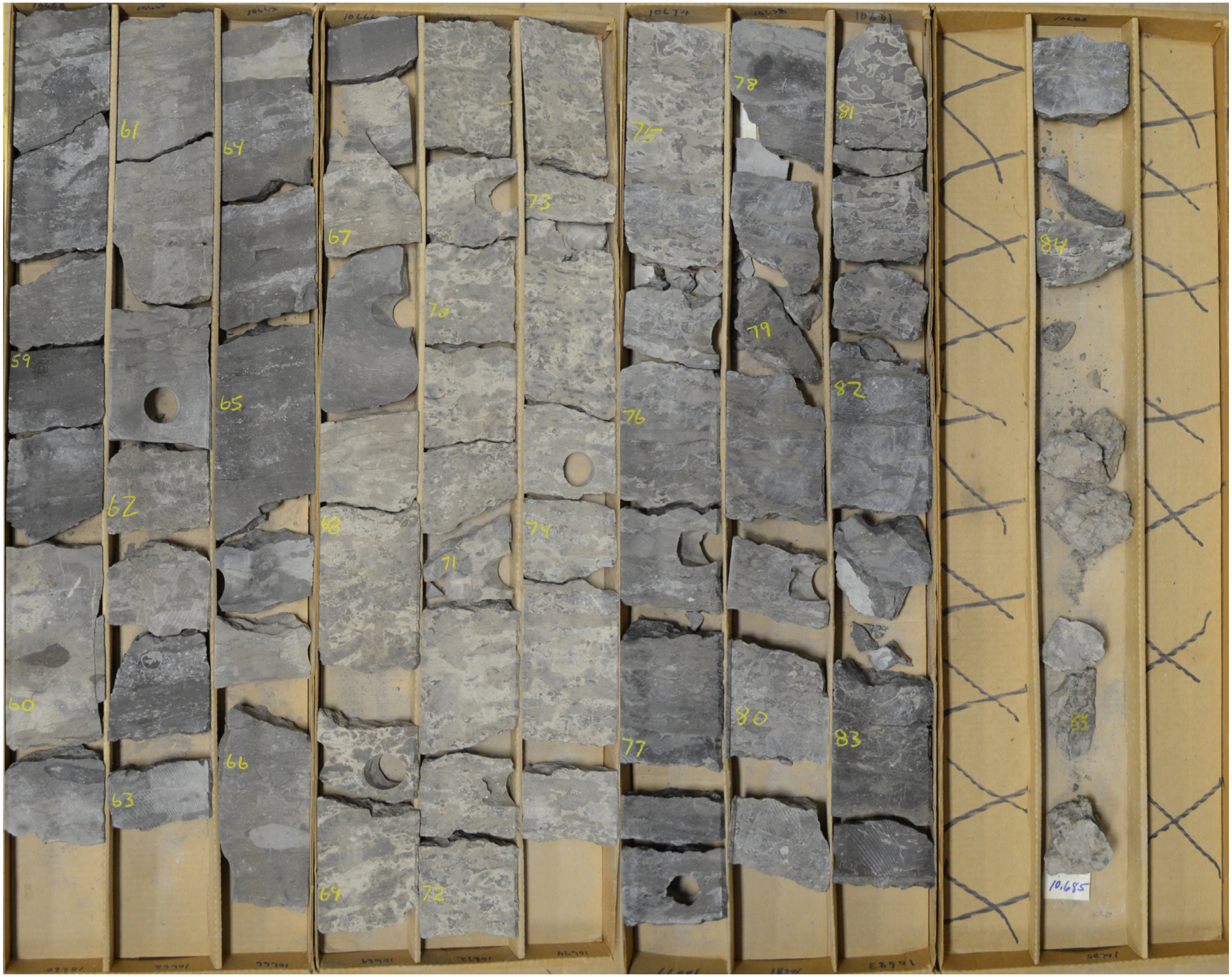
LT 2, Sec 22, T 137 N, R 106 W
Golden Valley County
NDIC: 6272
Kremers 21X-22R

Cored Interval: 10,626' - 10,658'

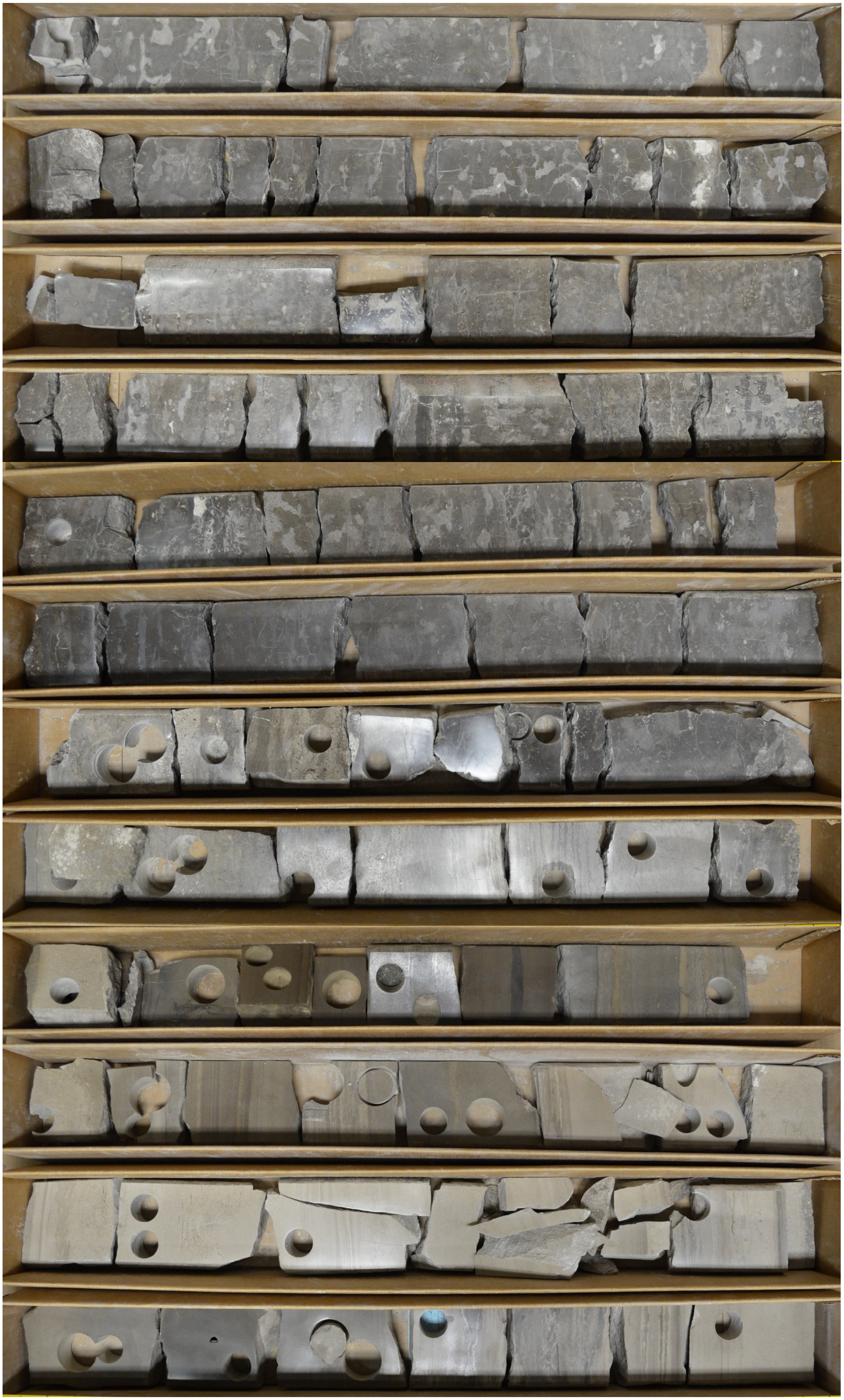


LT 2, Sec 22, T 137 N, R 106 W
Golden Valley County
NDIC: 6272
Kremers 21X-22R

Cored Interval: 10,659' - 10,683'



NE, SE Sec 21, T 163 N, R 100 W
Divide County
NDIC: 11302
Swampy-Mosser 21-9



NE, SE Sec 21, T 163 N, R 100 W
Divide County
NDIC: 11302
Swampy-Mosser 21-9

NE, SE Sec 21, T 163 N, R 100 W
Divide County
NDIC: 11302
Swampy-Mosser 21-9