24th Williston Basin Petroleum Conference
May 24-26, 2016
Bismarck, ND

2016 Core Workshop

Red River Formation
Three Forks Formation
Inyan Kara Formation

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GEOLOGIC INVESTIGATION NO. 191
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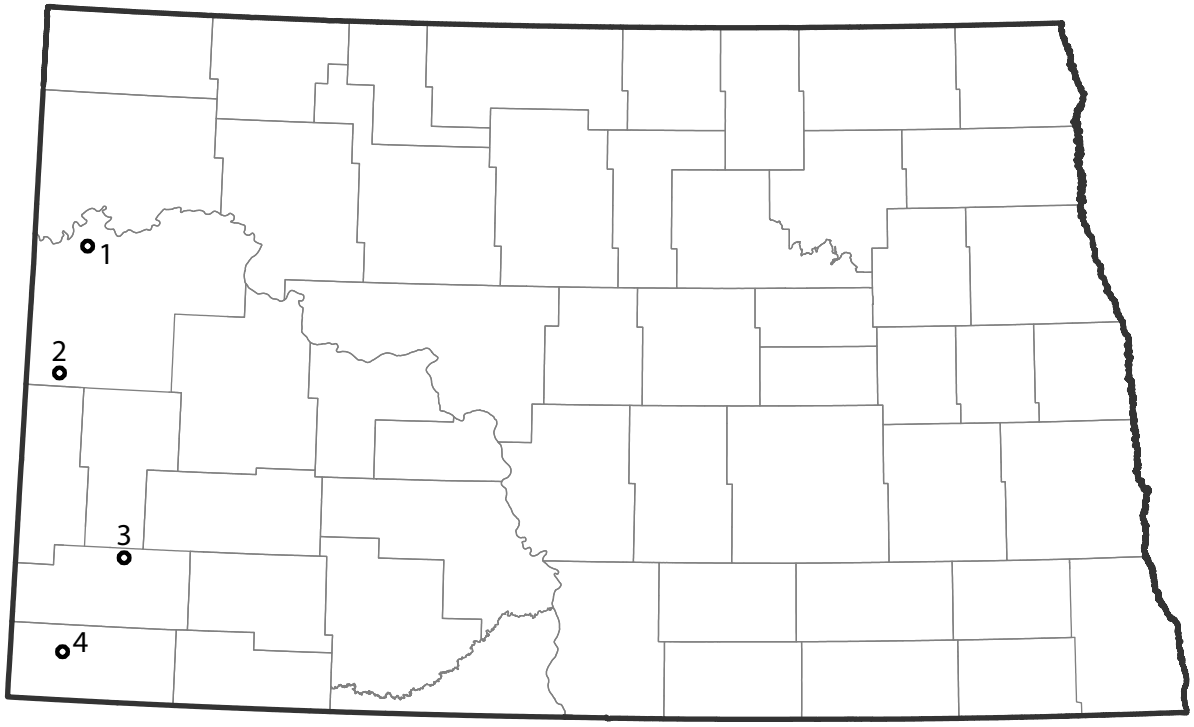
2016

WILLISTON BASIN PETROLEUM CONFERENCE
Core Workshop

Red River Formation: Kukersites

Timothy O. Nesheim
North Dakota Geological Survey



No.	Well	Core Interval
1	Superior Oil Company - Novak #1 NWSE Sec. 35, T152N, R102W, McKenzie County NDIC: 9618, API: 33-053-01542-00-00	13,621'-13,681'
2	Terra Resources, Inc. - BNRR #1-17 NWSW Sec. 17, T145N, R103W, McKenzie County NDIC: 7218, API: 33-053-00955-00-00	12,775'-13,034'
3	H. L. Hunt - N.P.R.R. "A" #3 NENW Sec. 23, T136N, R101W, Slope County NDIC: 4241, API: 33-087-00011-00-00	11,510'-11,568'
4	H. L. Hunt - N.P.R.R. "A" #3 NENW Sec. 23, T136N, R101W, Slope County NDIC: 4241, API: 33-087-00011-00-00	9,825'-9,863'

Overview of Red River Kukersites in western North Dakota

Introduction

The Ordovician Red River Formation has cumulatively produced more than 600 million barrels of oil equivalent from over 2,700 wells extending from southern Saskatchewan, through eastern Montana and western North Dakota, to northwestern South Dakota. Early work by Dow (1974) and Williams (1974) that dealt with identifying and evaluating petroleum source beds in the Williston Basin concluded that Red River hydrocarbons were externally sourced by the underlying Icebox Formation. However, numerous studies since have identified prospective sourced beds (referred to as kukersites) within the Red River Formation (reviewed below). Ongoing work by the North Dakota Geological Survey is focusing on delineating the extent of these prospective Red River source beds and evaluating their thermal maturity to determine the quantity and distribution of hydrocarbon generation within the Red River Formation (e.g. Nesheim et al., 2015).

Stratigraphy

The Red River Formation reaches a maximum thickness of over 700 ft. and has been informally divided into upper and lower subunits (Fig. 1). The lower Red River is made up of burrow-mottled fossil wackestone that comprises two-thirds of the Red River section in the central basin. The lower Red River becomes less fossiliferous, less burrow-mottled, and grades into dense dolostone towards that margins of the basin (Carroll, 1979). The upper Red River is composed of three shallowing, brining upward cycles referred to as the "A", "B", and "C" cycles in descending order (Longman, 1987; Fox, 1993). Each upper Red River cycle consists of the following lithologies in ascending order: burrowed lime mudstone to fossil wackestone, laminated microcrystalline dolostone, nodular to laminated anhydrite, and a thin argillaceous-dolomitic mudstone. Most of the Red River hydrocarbon production comes from the laminated dolomites within the "B" and "C" cycles and the underlying burrow-mottled "D" zone (Fig. 1).

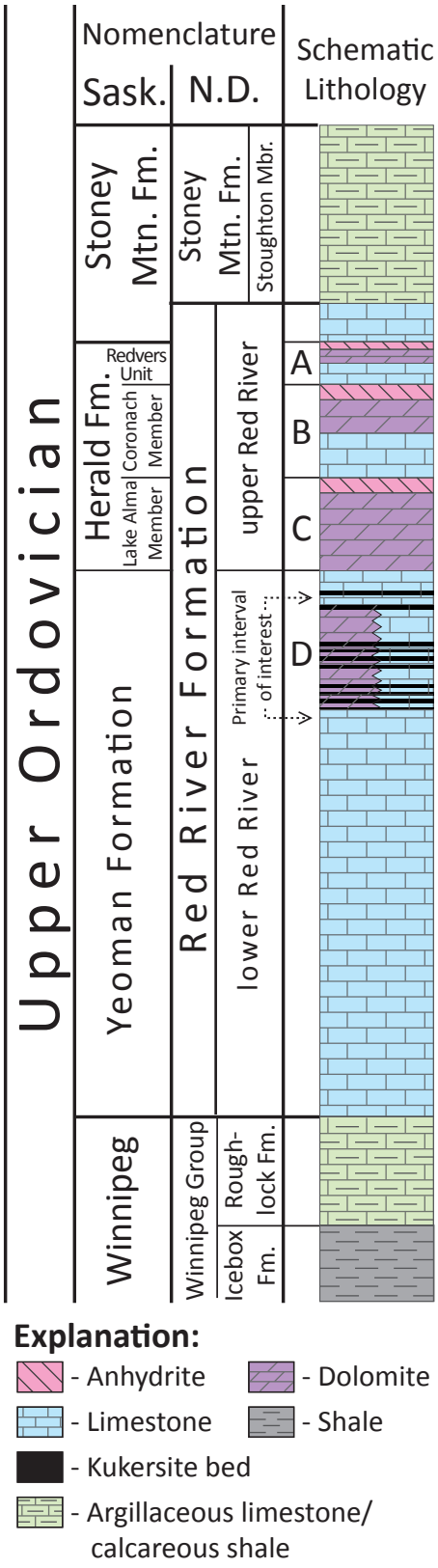


Figure 1. Stratigraphic column of the Red River Formation and surrounding units with approximate nomenclature correlations between Saskatchewan (Sask.) and North Dakota (N.D.).

Previous Work

Petroleum source beds, commonly referred to as kukersites or kerogenites, have been previously described within the Red River "D" zone (equivalent to the "C" burrow member/upper Yeoman Formation) (Fig. 1) (Kendall, 1976; Kohm and Louden, 1978; Carroll, 1979; Longman et al., 1983). Kukersites contain abundant concentrations of the algae microfossil *Gloeocapsomorpha Prisca* (*G. Prisca*) (Stasiuk and Osadetz, 1990). Osadetz and Snowdon (1995) reported a 9.07% total organic carbon (TOC) average for kukersite samples from southern Saskatchewan with an average hydrogen index (HI) of 956 for immature samples, demonstrating that kukersites were deposited as very organic-rich and oil-prone source beds. Red River kukersites are interpreted to have formed within a subtidal marine setting with accumulation models that include: benthic algal mats that grew on the sea floor (Stasiuk and Osadetz, 1990), suspension settling of algae out of the water column during periodic algal bloom events (Pak et al., 2010), and periodic basin restriction where euxinic bottom water conditions developed (Kendall, 1976; Kohm and Louden, 1978). Kukersites are described as relatively thin (<2 ft thick), but have been noted to correlate from a local, field level scale (Kendall, 1976; Kohm and Louden, 1978) to a regional, basinwide scale (Longman et al., 1983).

Preliminary Summary of Red River Kukersites within North Dakota

Ten individual kukersites, referred to as K1 to K10 beds in ascending order, can be identified and correlated across western North Dakota using wireline logs and cores (Fig. 2). In core, kukersites are typically one to two feet thick and display significant textural/lithological variations including: fossil grain concentrations, amount and type of bioturbation, discontinuous-irregular bedding/laminations, and coloration which also reflects organic richness (e.g. Fig. 3). Kukersites grade laterally into marginally organic-rich (0.5-1.0% TOC) to organic-lean beds (<0.5% TOC) and are interbedded with burrow-mottled lime to dolomitic mudstone (e.g. Fig. 4). Kukersites sampled by this study were found to contain highly variable average TOC

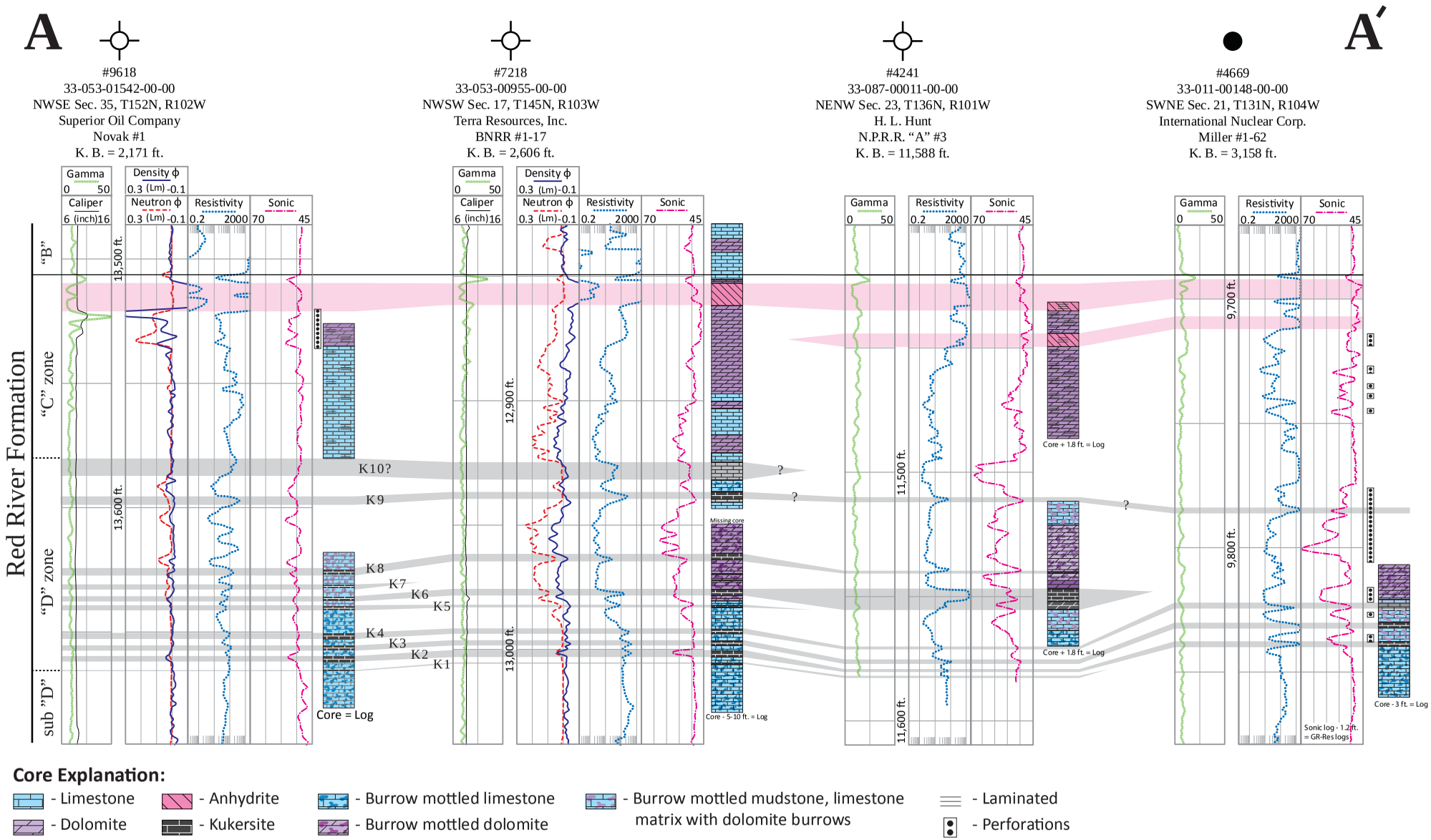


Figure 2. Stratigraphic cross-section of the Red River "C" and "D" zones correlating kukersites between the selected core workshop cores.

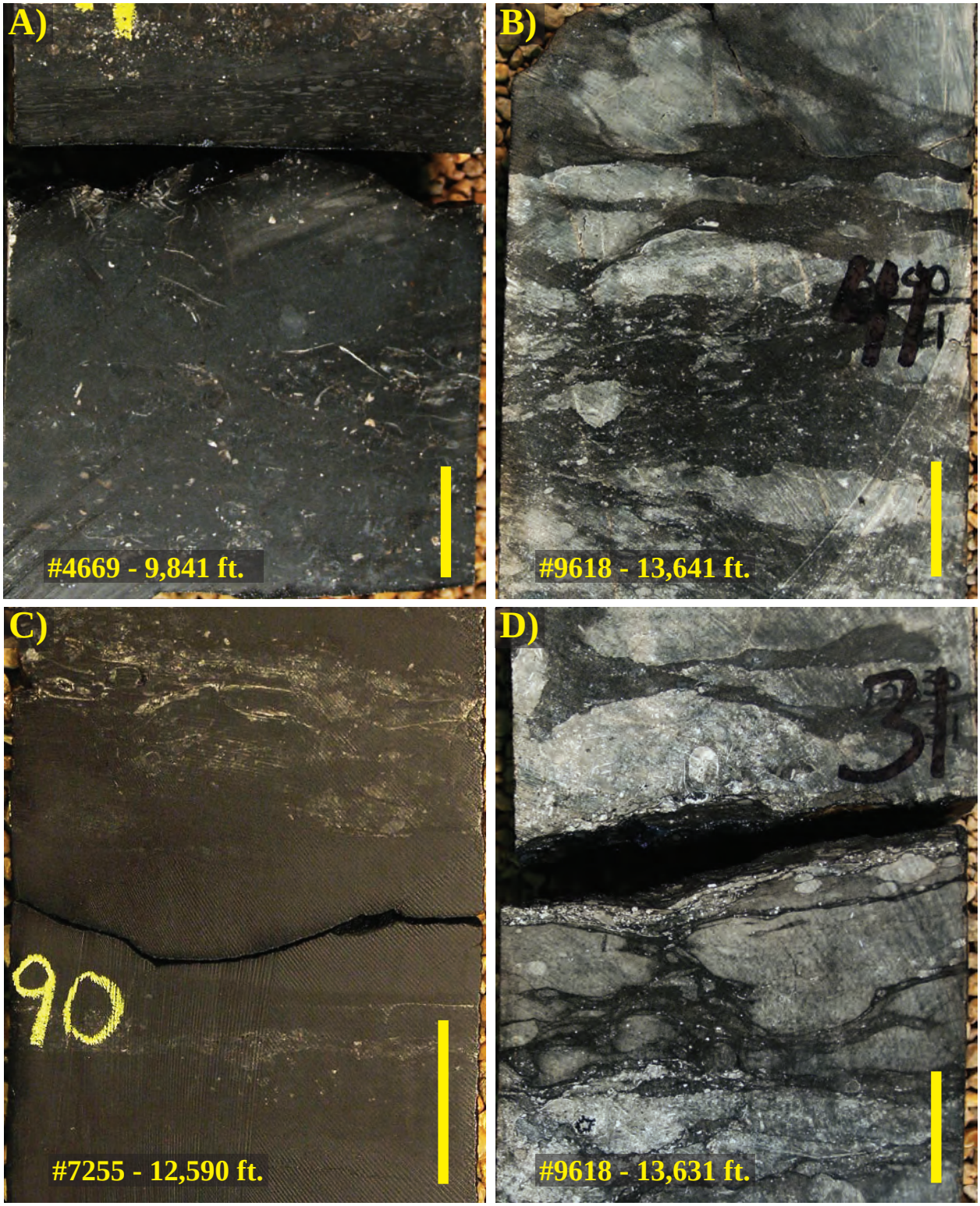


Figure 3. Core photograph examples of kukersites from the Red River "D" zone. A) K2 kukersite containing 6.9 to 20.5 wt. % TOC (12.4% average), B) K5 kukersite containing 0.2 to 3.2 wt. % TOC (1.1% average), C) K6 kukersite containing 2.0 to 12.6 wt. % TOC (8.5% average), and D) K7 kukersite containing 0.2 to 0.6 wt. % T OC (0.4% average). One inch scale bar in the bottom right corner and NDIC well number with approximate core depth in the bottom left corner of each photograph.

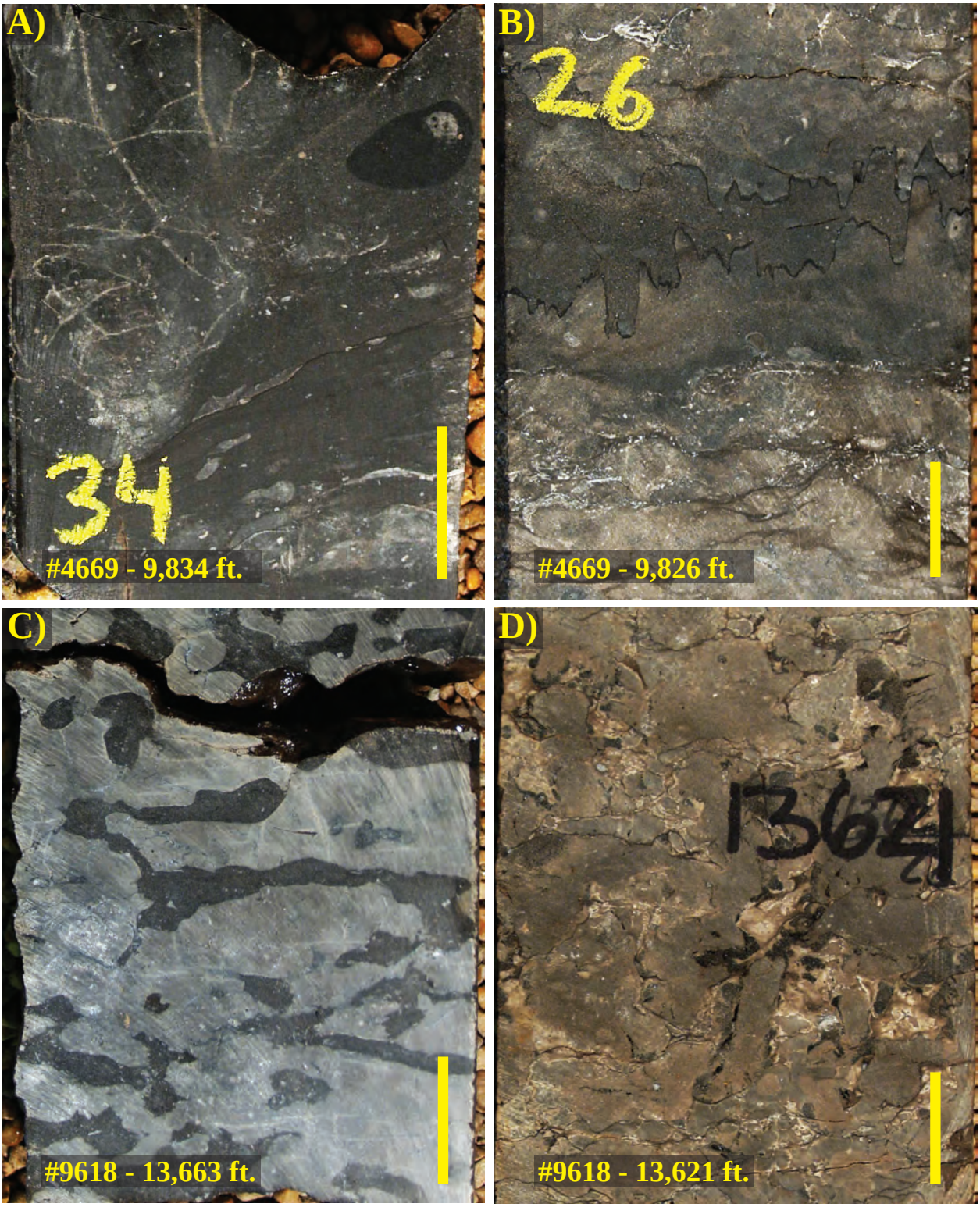


Figure 4. Core photographs from the Red River "D" zone. A) Dark grey, moderately organic-rich kukersite, K3 which contains 0.9 to 1.3 wt.% TOC, B) organic-lean (<0.5 wt. %), lateral equivalent of the K4 kukersite, C) light and dark grey, burrow-mottled lime mustone (<1% porosity), and D) tan-brown, burrow-mottled dolomitic mudstone (~9% porosity). One inch scale bar in bottom right corner and NDIC well number with approximate core depth in the bottom left corner of each photograph.

concentrations ranging from <1% to over 10%. On wireline logs, Kukersites that are ~1 ft. thick or more can be identified by subtle to pronounced high resistivity signatures (e.g. Fig. 2 The K2 and K6 beds tend to be more organic rich, containing TOC concentrations of 5% to 10% or more which results in subtle sonic and porosity wireline log responses. Each of these kukersite beds has a unique lateral extent along, thickness, and organic-richness variations which is still being delineated by the author. Overall, Red River kukersites extend approximately 20-30 miles east of the Montana border into western North Dakota, and from the Saskatchewan to South Dakota borders (Fig. 5). While kukersites are typically relatively thin (≤ 2 ft.) individually, they combine to commonly reach net thicknesses of 6 to 12 ft. or more within their area of extent in western North Dakota (Fig. 5).

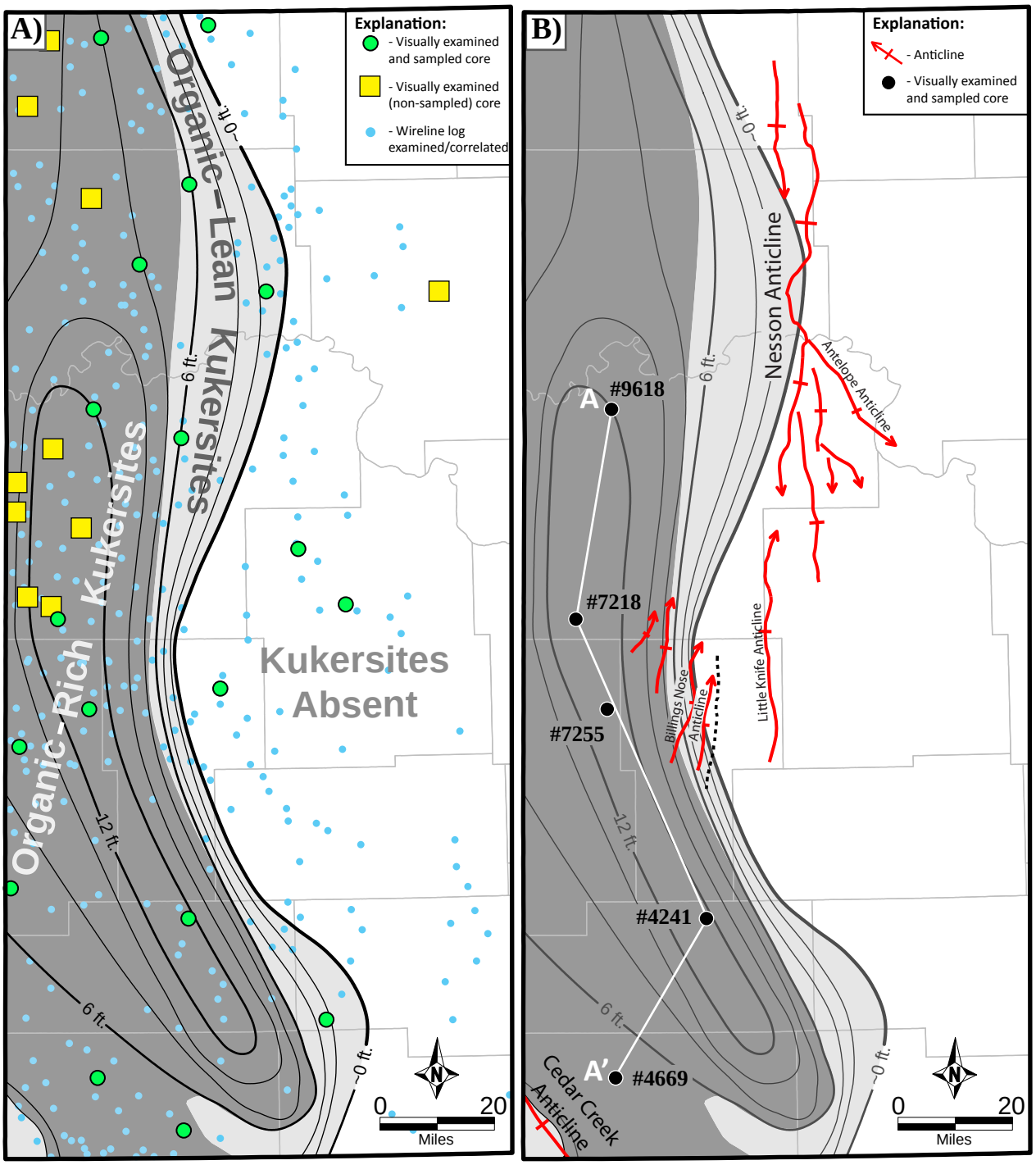


Figure 5. Kukersite extent and thickness maps for western North Dakota with A) well and core control, and B) cores of interest and various structures. The black/dark grey lines represent isopach contours of kukersite net thickness.

References

Carroll, W.K., 1979, Depositional environments and paragenetic porosity controls, upper Red River Formation, North Dakota: North Dakota Geological Survey, Report of Investigation No. 66, 51 p.

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.

Fox, J.S., 1993, Depositional and diagenetic controls on porosity evolution in the "C" zone, Red River Formation (Upper Ordovician), Divide County, North Dakota: M.S. Thesis, University of North Dakota, Grand Forks, 311 p.

Kendall, A. C., 1976, The Ordovician carbonate succession (Big Horn Group) of southeastern Saskatchewan: Department of Mineral Resources, Saskatchewan Geological Survey Report 180, 185 p.

Kohm, J. A., and R. O. Louden, 1978, Ordovician Red River of eastern Montana-western North Dakota: relationship between lithofacies and production: Montana Geological Society Guidebook, 1978 Williston Basin Symposium, p. 99-117.

Longman, M.W., Fertal, T.G., and Glennie, J.S., 1983, Origin and Geometry of Red River Dolomite Reservoirs, Western Williston Basin: AAPG Bulletin, v. 67, no. 5, p. 744-771.

Nesheim, T.O., Nordeng, S.H., and Bader, J.W., 2015, Stratigraphic correlation and geochemical analysis of Kukersite (source rock) beds within the Ordovician Red River Formation, southwestern North Dakota: North Dakota Geological Survey, Geological Investigation No, 186, 1 pl.

Osadetz, K.G., and Snowdon, L.R., 1995, Significant Paleozoic Petroleum Source Rocks in the Canadian Williston Basin: Their Distribution, Richness, and Thermal Maturity (Southeastern Saskatchewan and Southwestern Manitoba): Geological Survey of Canada, Bulletin 487, 60 p.

Pak, R., Pemberton, S.G., and Stasiuk, L., 2010, Paleoenvironmental and taphonomic implications of trace fossils in Ordovician kukersites: Bulletin of Canadian Petroleum Geology, vol. 58, no. 2, p. 141-158.

Stasiuk, L.D., and Osadetz K.G., 1990, The life cycle and phyletic affinity of *Gloeocapsomorpha Prisca* Zalessky 1917 from Ordovician rocks in the Canadian Williston Basin: in Current Research, Part D, Geological Survey of Canada, Paper 89-1D, p. 123-137.

Williams, J. A., 1974, Characterization of oil types in Williston Basin: American Association of Petroleum Geologists Bulletin: V 58, p 1243-1252.

NDIC File No: **9618** API No: **33-053-01542-00-00** County: **MCKENZIE**
Well Type: **OG** Well Status: **IA** Status Date: **3/20/2009** Wellbore type: **VERTICAL**
Location: **NWSE 35-152-102** Latitude: **47.938932** Longitude: **-103.69771**
Current Operator: **VANGUARD OPERATING LLC**
Original Operator: **SUPERIOR OIL CO.**
Current Well Name: **NOVAK 1**
Original Well Name: **NOVAK #1**
Elevation(s) (ft.): **2,171 KB 2,146 GL** Total Depth: **13,805** Field: **ELK**
Spud Date(s): **7/9/1982**

Formation Tops (true vertical depth in ft.)

K-P 1926 K-GH 4666 K-M 5081 K-N 5233 K-IK 5443 J-S 5983 J-R 6496 T-S 7038 PM-MK 7397 PM-OP 7423 PM-EBA 7650 PN-T 7894 M-BS 8045 M-KL 8397 M-MD 8540 M-MDR 9155 M-MDLS 9220 M-MDFA 9415 M-MDLP 9940 MD-B 10723 D-TF 10775 D-BB 10988 D-DP 11081 D-SR 11506 D-DB 11761 D-PE 11878 D-W 12028 S-I 12312 S-CL 12658 O-G 13240 O-ST 13332 O-RR 13390

Completion Data (true vertical depth in ft.)

Pool: MADISON Perfs: 9,278-9,452 G Comp Dt: 3/20/2009 Status: AL Status Dt: 3/20/2009 Spacing: SE
Pool: RED RIVER Perfs: 13,469-13,536G Comp Dt: 12/20/1982 Status: PNA Status Dt: 6/20/1991 Spacing: E2
Pool: STONEWALL Perfs: 13,165-13,214G Comp Dt: 6/29/1991 Status: PNA Status Dt: 3/20/2009 Spacing: S2

Cumulative Production Data (reported in barrels)

Pool: STONEWALL Cum Oil: 268,672 Cum MCF Gas: 371,894 Cum Water: 219,933
Pool: RED RIVER Cum Oil: 225,482 Cum MCF Gas: 239,694 Cum Water: 237,886
Pool: MADISON Cum Oil: 10,190 Cum MCF Gas: 9,632 Cum Water: 22,757

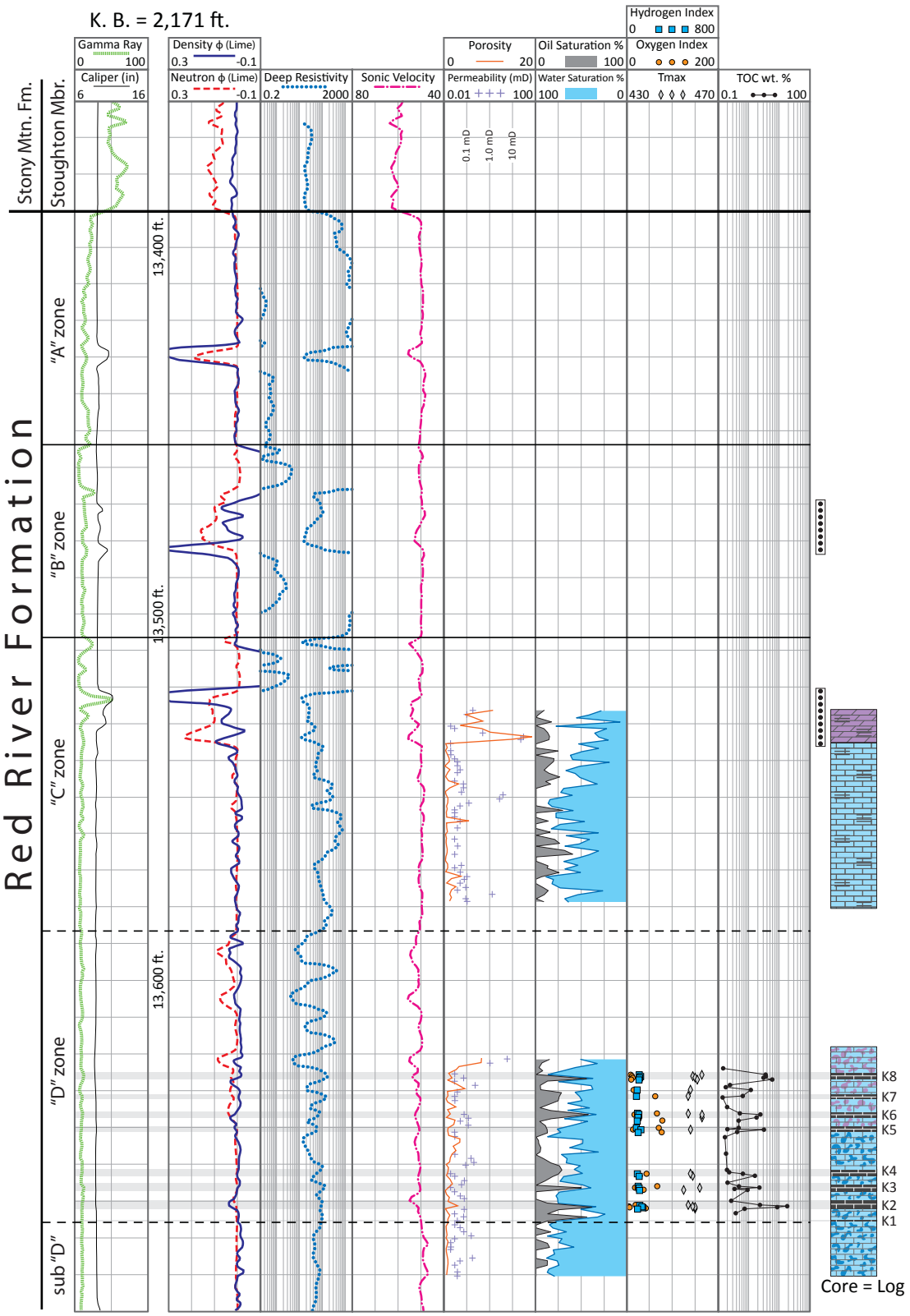
Production Test Data (reported in barrels)

IP Test Date: 12/20/1982 Pool: RED RIVER IP Oil: 115 IP MCF: 0 IP Water: 11
IP Test Date: 6/29/1991 Pool: STONEWALL IP Oil: 381 IP MCF: 440 IP Water: 19
IP Test Date: 3/21/2009 Pool: MADISON IP Oil: 3 IP MCF: 2 IP Water: 10

Cores: (true vertical depth in ft.)

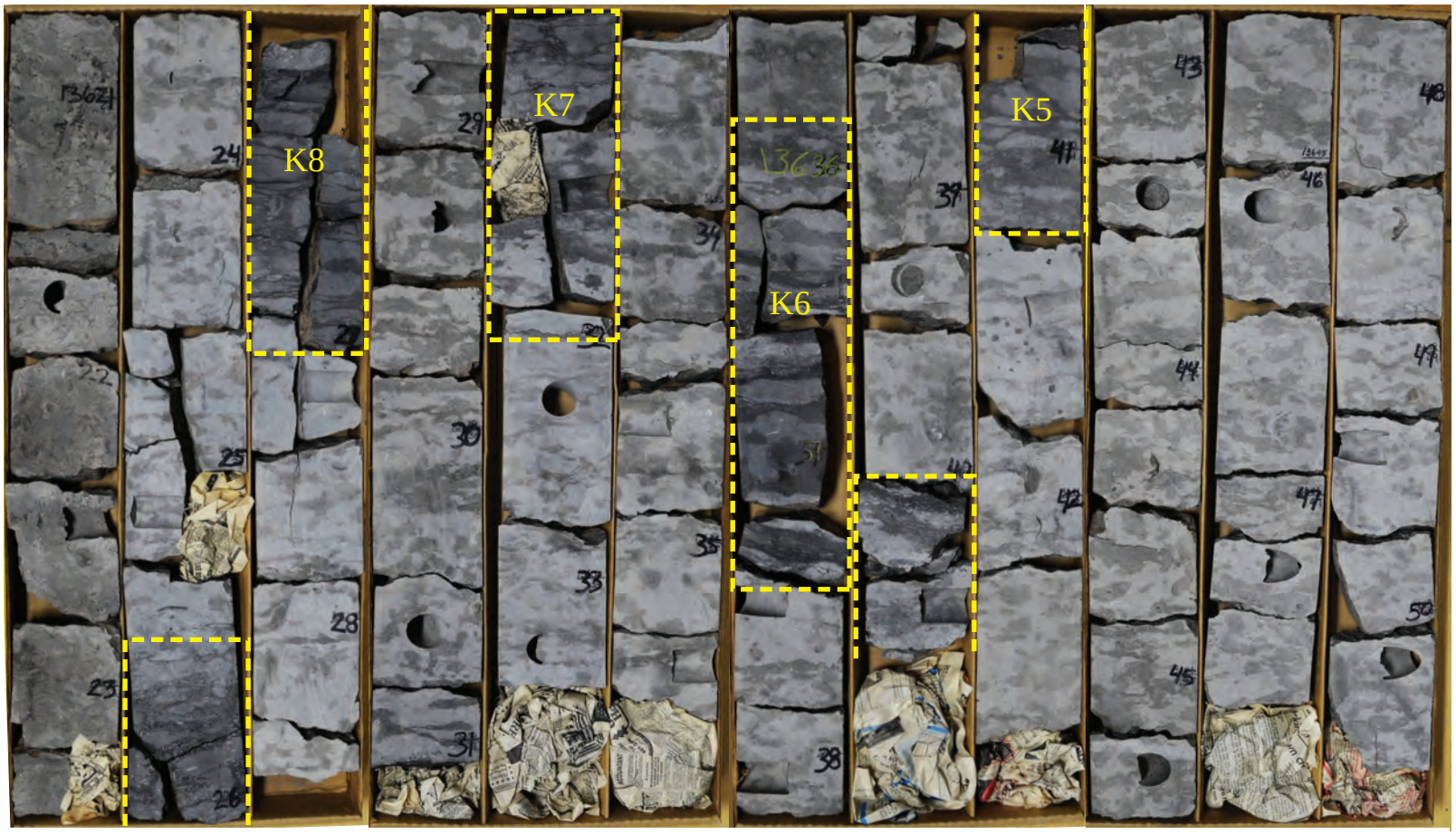
Type: RS Top: 13,526 Bottom: 13,535 Formation: O-RR
Type: RS Top: 13,535 Bottom: 13,543 Formation: O-RR
Type: RS Top: 13,552 Bottom: 13,580 Formation: O-RR
Type: RS Top: 13,621 Bottom: 13,681 Formation: O-RR

#9618
33-053-01542-00-00
NWSE Sec. 35, T152N, R102W
Superior Oil Company
Novak #1
K. B. = 2,171 ft.



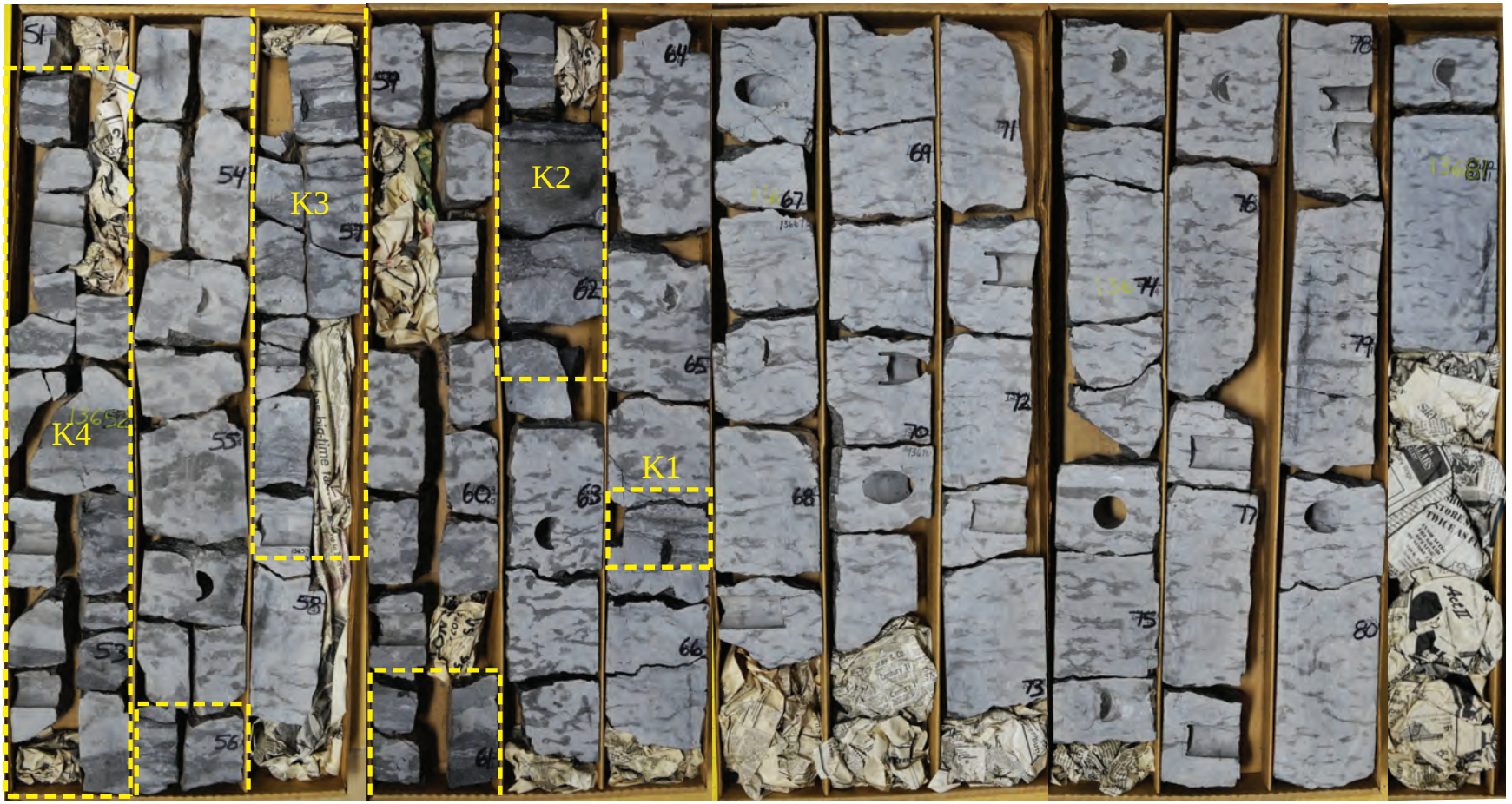
NDIC: 9618, API: 33-053-01542-00-00
NWSE Sec. 35, T152N, R102W
Superior Oil Company - Novak #1

Core Interval 13,621 - 13,650 ft.



NDIC: 9618, API: 33-053-01542-00-00
NWSE Sec. 35, T152N, R102W
Superior Oil Company - Novak #1

Core Interval 13,650 - 13,681 ft.



NDIC File No: **7218** API No: **33-053-00955-00-00** County: **MCKENZIE**
Well Type: **OG** Well Status: **DRY** Status Date: **4/26/1980** Wellbore type: **VERTICAL**
Location: **NWSW 17-145-103** Latitude: **47.379808** Longitude: **-103.839497**
Current Operator: **TERRA RESOURCES, INC.**
Original Operator: **TERRA RESOURCES, INC.**
Current Well Name: **BNRR 1-17**
Original Well Name: **BNRR #1-17**
Elevation(s) (ft.): **2,606 KB** Total Depth: **13,125** Field: **BICENTENNIAL**
Spud Date(s): **1/28/1980**

Formation Tops (true vertical depth in ft.)

K-GH 4772 K-M 5210 K-N 5350 K-IK 5660 J-S 6083 J-R 6664 T-S 7138 PM-MK 7550 PM-OP 7586 PM-BC 7848 PN-T 8192 M-BS 8296 M-KL 8630 M-MD 8776 M-MDR 9295 M-MDLS 9353 M-MDFA 9539 M-MDLP 10012 MD-B 10791 D-TF 10807 D-BB 10958 D-DP 11036 D-SR 11374 D-DB 11569 D-PE 11634 D-W 11707 S-I 11872 S-CL 12115 O-G 12599 O-ST 12677 O-RR 12742

Cumulative Production Data

Pool: RED RIVER Comp Dt: 4/26/1980 Status: DRY Status Dt: 4/26/1980

Production Test Data (reported in barrels)

DST: 10,750-10,836 Recovery: 1000' WATER CUSHION, 5975' DRILLING MUD - SAMPLER: 2000 CC MUD

DST: 12,457-12,517 Recovery: ** MISRUN **, TOOL COULD NOT BE ROTATED

DST: 12,451-12,517 Recovery: ** MISRUN **, TOOL DID NOT OPEN., 1935' FRESH WATER, 103' NH3 & WTR CUSH C MUD - SAMPLER: 900 CC MUD

DST: 12,451-12,517 Recovery: ** MISRUN **, PACKER SEAT FAILURE., 2000' FRESH WATER, 2422' DRILLING MUD - SAMPLER: 300 CC MUD

DST: 12,775-12,835 Recovery: 2800' WATER CUSHION, TESTER VALVE DID NOT OPEN - SAMPLER: 1750 CC WATER

DST: 12,818-12,950 Recovery: 2790' WATER CUSHION, 1395' HEAVY MUD - SAMPLER: 1850 CC MUD

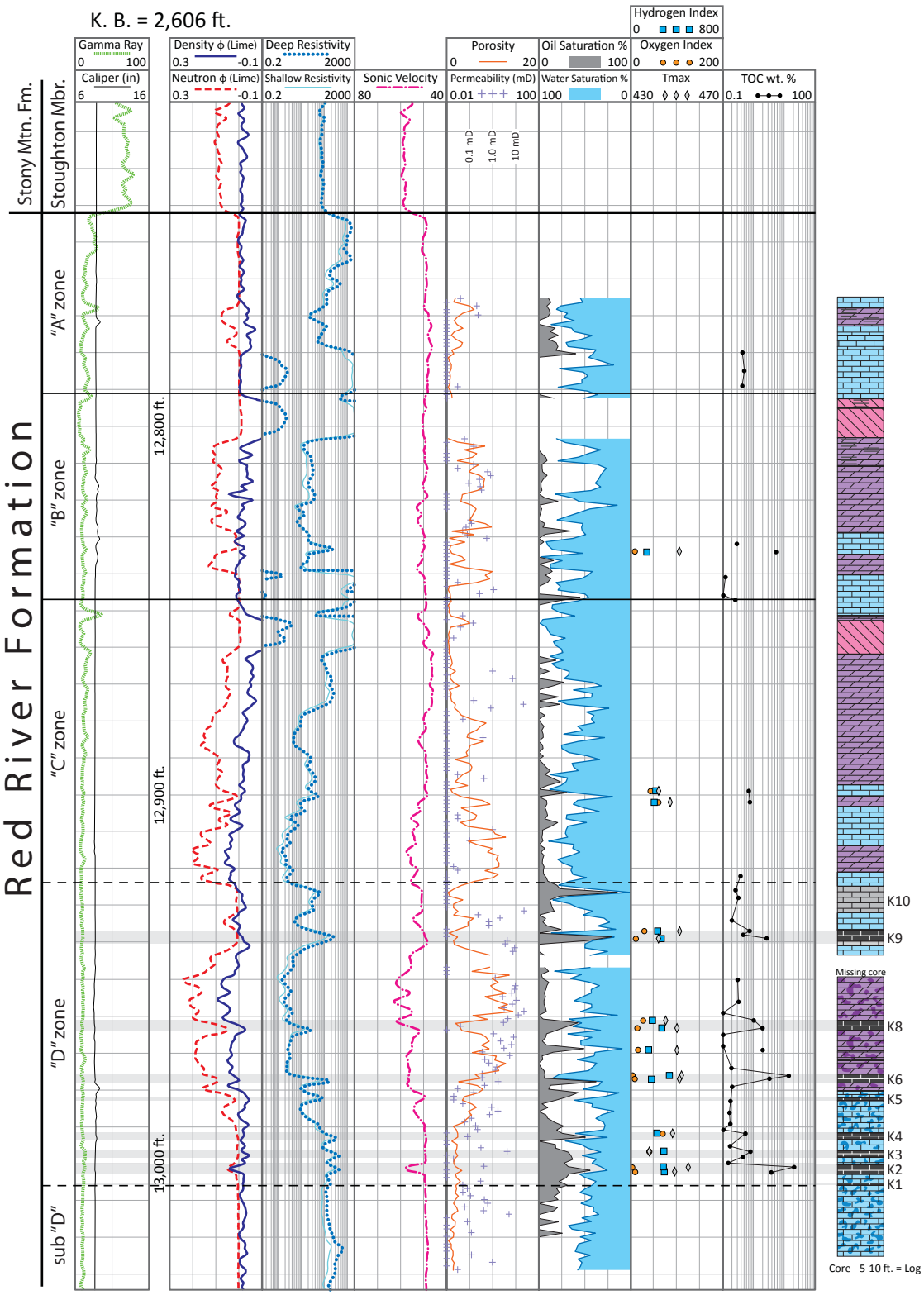
DST: 12,950-13,035 Recovery: 50' GAS CUT OIL, 2800' GAS CUT WATER CUSH, 2180' GAS CUT SALT WATER - SAMPLER: 2.11 CF GAS GOR 8387, 40 CC OIL 41 @ 60 DEG, 1800 CC WATER

DST: 12,936-13,124 Recovery: 30' OIL, 2548' GC WTR CUSH/TR OIL, 372' WATER, GAS CUT MUD, 3194' GAS CUT SALT WATER - SAMPLER: 1.8 CF GAS GOR 7155, 40 CC OIL, 1840 CC WATER

Cores: (true vertical depth in ft.)

Type: CS Top: 12,775 Bottom: 12,866 Formation: O-RR
Type: CS Top: 12,866 Bottom: 13,030 Formation: O-RR
Type: LS Top: 12,775 Bottom: 12,797 Formation: O-RR
Type: LS Top: 12797 Bottom: 12952 Formation: O-RR
Type: LS Top: 12952 Bottom: 13034 Formation: O-RR

#7218
33-053-00955-00-00
NWSW Sec. 17, T145N, R103W
Terra Resources, Inc.
BNRR #1-17
K. B. = 2,606 ft.



NDIC: 7218, API: 33-053-00955-00-00
NWSW Sec. 17, T145N, R103W
Terra Resources, Inc. - BNRR #1-17

Core Interval 12,931 - 12,971 ft.

NDIC: 7218, API: 33-053-00955-00-00
NWSW Sec. 17, T145N, R103W
Terra Resources, Inc. - BNRR #1-17

Core Interval 12,972 - 13,015 ft.

NDIC File No: **4241** API No: **33-087-00011-00-00** County: **SLOPE**
Well Type: **OG** Well Status: **DRY** Status Date: **5/3/1967** Wellbore type: **VERTICAL**
Location: **NENW 23-136-101** Latitude: **46.581042** Longitude: **-103.334736**
Current Operator: **H. L. HUNT**
Original Operator: **H. L. HUNT**
Current Well Name: **NPRR A 3**
Original Well Name: **N.P.R.R. "A" #3**
Elevation(s) (ft.): **2,868 KB** Total Depth: **11,588** Field: **ELEVEN BAR**
Spud Date(s): **3/13/1967**

Formation Tops (true vertical depth in ft.)

K-P 1747 K-GH 4415 K-M 4962 K-N 5107 K-IK 5351 J-S 5711 J-R 6120 T-S 6576 PM-MK 7173 PM-OP 7217 PM-BC 7283 PN-T 7910 M-KL 8199 M-MD 8340 M-MDR 8578 M-MDLS 8602 M-MDFA 8770 M-MDFY 8900 M-MDLP 9230 D-TF 9907 D-BB 10044 D-DP 10115 D-SR 10380 S-I 10692 O-G 11185 O-ST 11247 O-RR 11325

Completion Data

Pool: RED RIVER Comp Dt: 5/3/1967 Status: DRY Status Dt: 5/3/1967

Production Test Data (reported in barrels)

DST: 10,192-10,245 Recovery: 2200' WATER CUSHION, 1660' HGC SW W/TRACE OIL, 4437' SALT WATER

DST: 11,366-11,384 Recovery: 3000' WATER CUSHION, 6019' SLIGHTLY GAS CUT SALT WATER - SAMPLER: 2300 CC FLUID - NO BREAKDOWN GIVEN

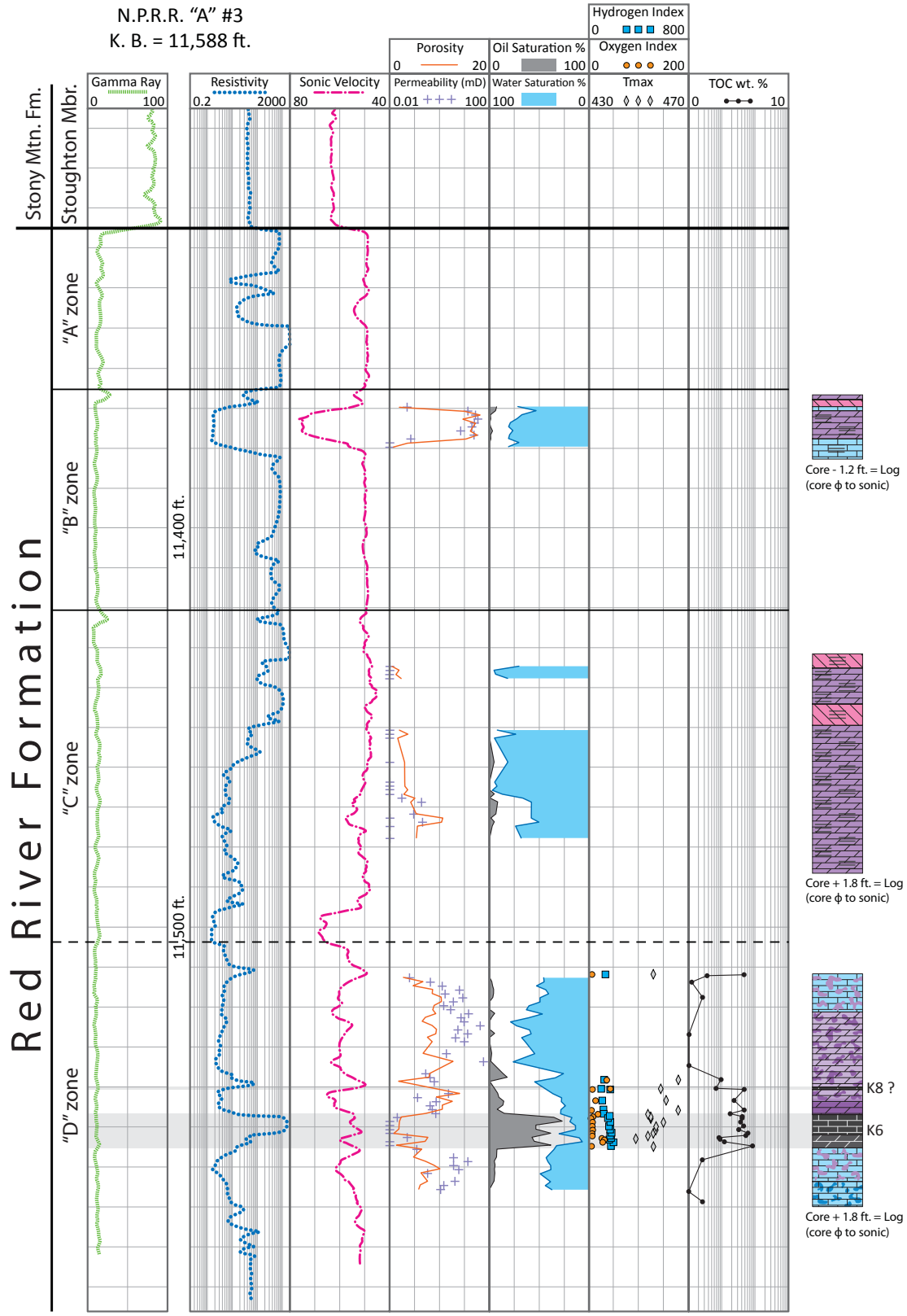
DST: 11,426-11,487 Recovery: 3036' WATER CUSHION, 2446' WATER, 590' SLIGHTLY GAS CUT MUD

DST: 11,498-11,568 Recovery: 3100' WATER CUSHION, 6875' SALT WATER - SAMPLER: 2400 CC WATER

Cores: (true vertical depth in ft.)

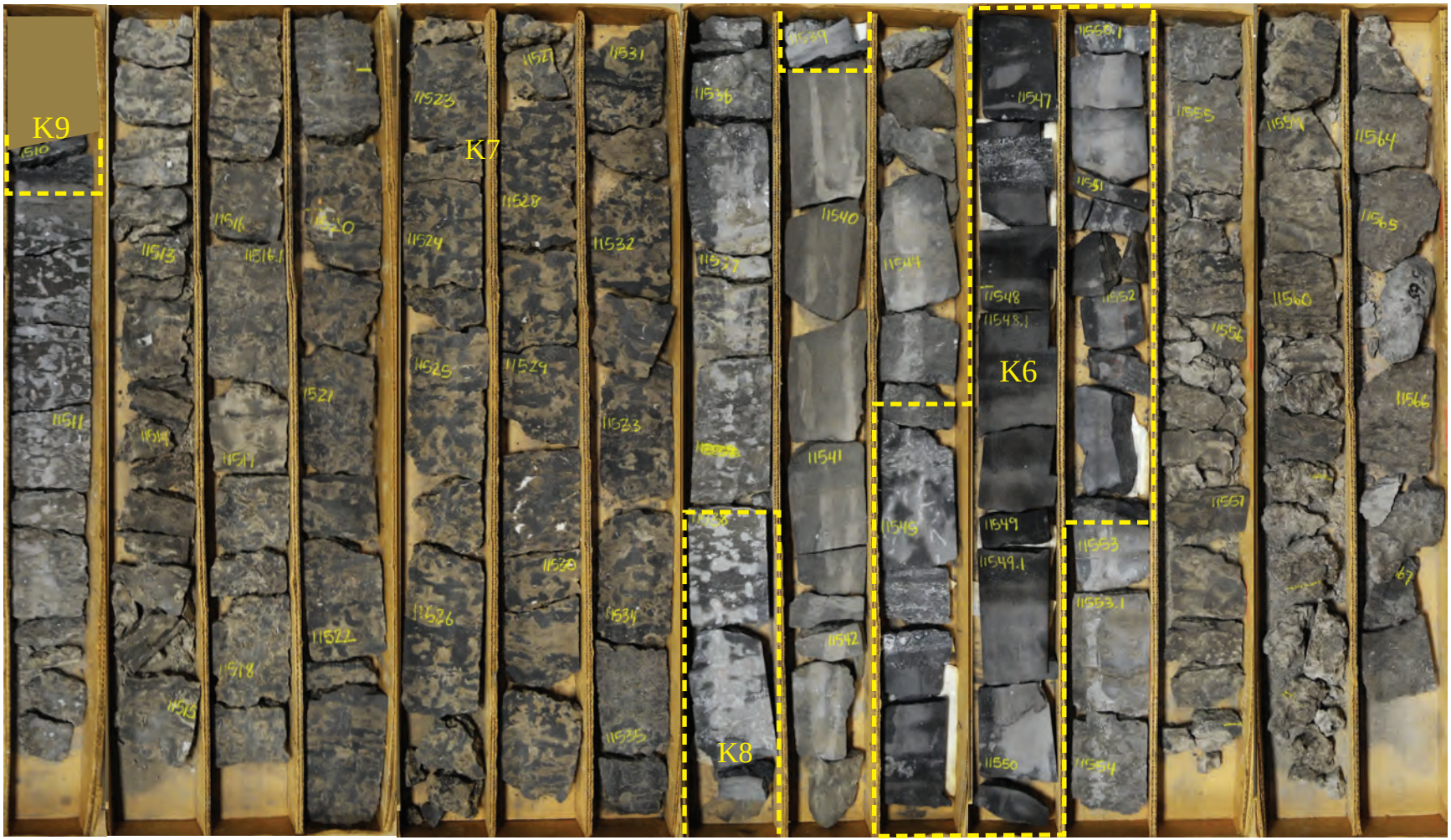
Type: CH Top: 11,369 Bottom: 11,459 Formation: O-RR
Type: CH Top: 11,459 Bottom: 11,547 Formation: O-RR
Type: CH Top: 11,547 Bottom: 11,569 Formation: O-RR
Type: CS Top: 11,368 Bottom: 11,568 Formation: O-RR
Type: RS Top: 11,368 Bottom: 11,568 Formation: O-RR

#4241
33-087-00011-00-00
NENW Sec. 23, T136N, R101W
H. L. Hunt
N.P.R.R. "A" #3
K. B. = 11,588 ft.



NDIC: 4241, API: 33-087-00011-00-00
NENW Sec. 23, T136N, R101W
H. L. Hunt - N.P.R.R. “A” #3

Core Interval 11,510 - 11,568 ft.



NDIC File No: **4669** API No: **33-011-00148-00-00** County: **BOWMAN**
Well Type: **OG** Well Status: **IA** Status Date: **6/27/1969** Wellbore type: **VERTICAL**
Location: **SWNE 21-131-104** Latitude: **46.157292** Longitude: **-103.68832**
Current Operator: **ABRAXAS PETROLEUM CORP.**
Original Operator: **INTERNATIONAL NUCLEAR CORP.**
Current Well Name: **MILLER 1-21**
Original Well Name: **MILLER #1-62**
Elevation(s) (ft.): **3,158 KB** Total Depth: **9,930** Field: **COYOTE CREEK**
Spud Date(s): **5/8/1969**

Formation Tops (true vertical depth in ft.)

K-GH 3900 K-M 4475 K-N 4611 K-IK 4886 J-S 5310 J-R 5683 T-S 6033 PM-MK 6600 PM-OP 6646 PM-BC 6763 M-KL 7295 M-MD 7409 M-MDR 7602 M-MDLP 8220 D-DV 8826 S-I 9110 O-G 9485 O-ST 9533 O-RR 9604

Completion Data (true vertical depth in ft.)

Pool: RED RIVER Perfs: 9,648-9,838 G Comp Dt: 6/27/1969 Status: AL Status Dt: 6/18/2013 Spacing: E2

Cumulative Production Data (reported in barrels)

Pool: RED RIVER Cum Oil: 1,021,567 Cum MCF Gas: 298,756 Cum Water: 2,727,004

Production Test Data (reported in barrels)

IP Test Date: 6/27/1969 Pool: RED RIVER IP Oil: 332 IP MCF: 0 IP Water: 17

DST: 7653-7669 Recovery: 10' MUD CUT SALT WATER WITH FLECKS OF BROWN OIL, 1326' MUD CUT SALT WATER CLEARED UP AT THE BASE - SAMPLER: 2100 CC WATER, TRACE OF MUD

DST: 7882-7930 Recovery: 6330' SALT WATER (MUD CUT AT THE TOP) - SAMPLER: 2100 CC WATER, TRACE OF OIL

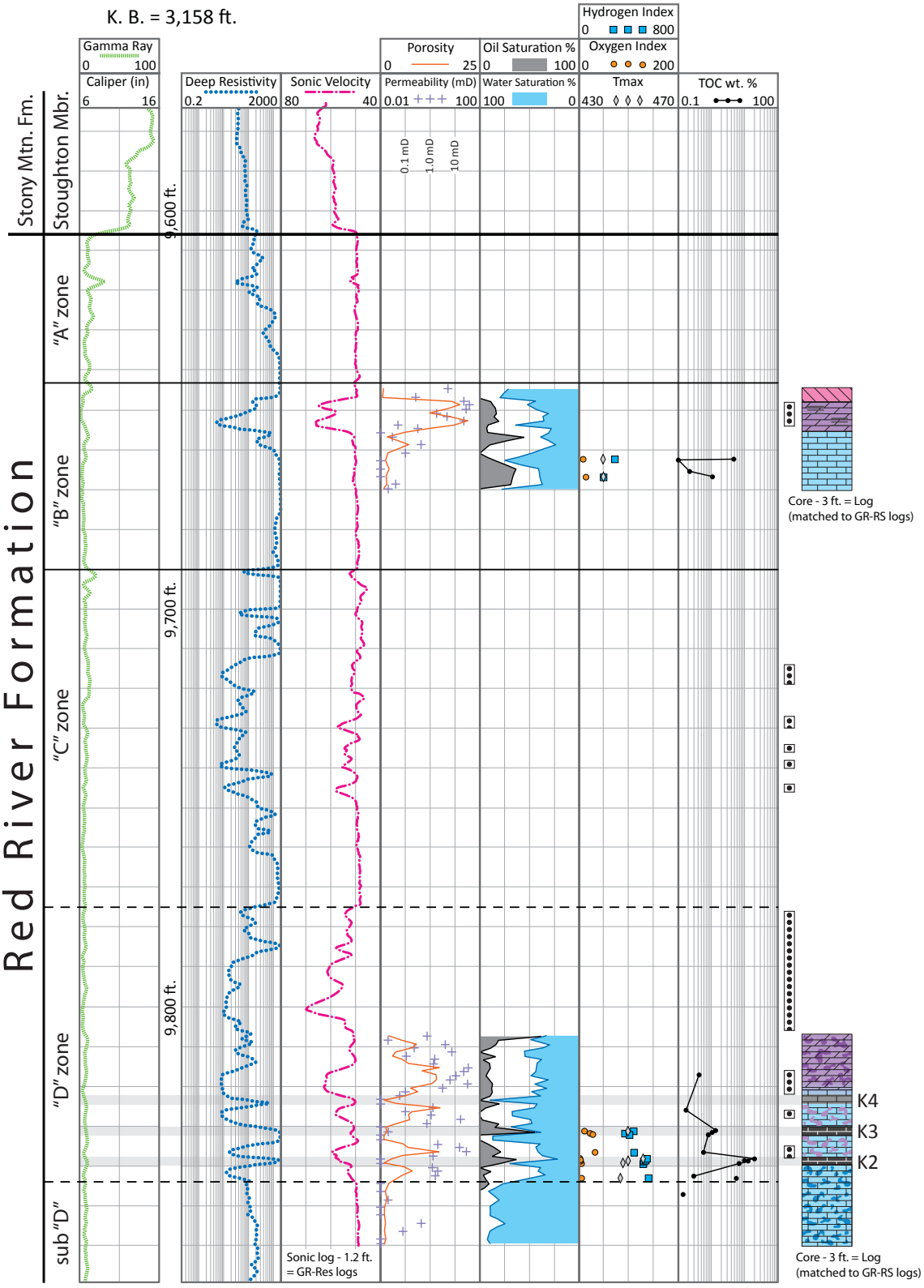
DST: 8734-8766 Recovery: 1500' WATER CUSHION, 976' SALT WATER (MUD CUT AT TOP) - SAMPLER: 2100 CC WATER

DST: 9774-9810 Recovery: 1500' HEAVY GAS CUT, OIL & MUD CUT WATER CUSHION, 5179' CLEAN OIL - SAMPLER: 2.8 CF GAS GOR 243, 1900 CC OIL 28.7 @ 60 DEG

Cores: (true vertical depth in ft.)

Type: **CS** Top: **9647** Bottom: **9673** Formation: **O-RR**
Type: **LS** Top: **9647** Bottom: **9673** Formation: **O-RR**
Type: **LS** Top: **9810** Bottom: **9813** Formation: **O-RR**
Type: **LS** Top: **9817** Bottom: **9821** Formation: **O-RR**
Type: **LS** Top: **9825** Bottom: **9860** Formation: **O-RR**
Type: **LS** Top: **9860** Bottom: **9863** Formation: **O-RR**
Type: **PH** Top: **9811** Bottom: **9859** Formation: **O-RR**
Type: **TS** Top: **9811** Bottom: **9839** Formation: **O-RR**
Type: **TS** Top: **9841** Bottom: **9859** Formation: **O-RR**

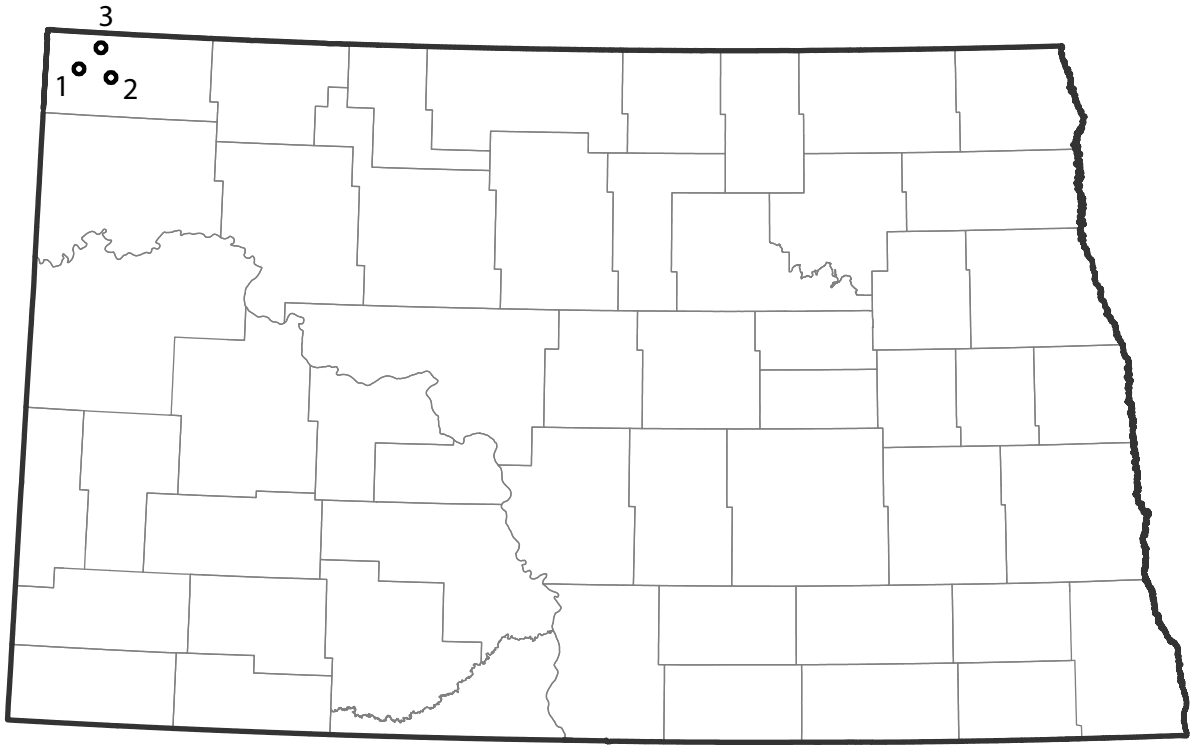
#4669
33-011-00148-00-00
SWNE Sec. 21, T131N, R104W
International Nuclear Corp.
Miller #1-62
K. B. = 3,158 ft.



WILLISTON BASIN PETROLEUM CONFERENCE
Core Workshop

Three Forks Formation: Divide County

Julie A. LeFever
North Dakota Geological Survey



No.	Well	Core Interval
1	Murex Petroleum Corp. - Jennifer Abigail 16-21H NWNE Sec. 16, T162N, R101W, Divide County NDIC: 24642, API: 33-023-00975-00-00	8,287'-8,350'
2	SM Energy Company - Tomlinson 3-1HN Sec. 1, T161N, R100W, Divide County NDIC: 26745, API: 33-023-01120-00-00	8,708'-8,748'
3	SM Energy Company - Torgeson 2-15HS NWNE Sec. 15, T163N, R100W, Divide County NDIC: 28042, API: 33-023-01190-00-00	7,975'-8,010'

Preliminary Look at the Three Forks Formation, Divide-Williams Counties, North Dakota

Julie A LeFever[1], Stephan H. Nordeng[2], Richard D. LeFever [2], and Kilynn Sandberg[2]

North Dakota Geological Survey[1], Grand Forks, North Dakota 58202
University of North Dakota[2], Grand Forks, North Dakota 58202

Introduction

The Bakken and Three Forks formations cover a significant portion of North Dakota, South Dakota, and Montana in the United States; and, Saskatchewan and Manitoba in Canada. Drilling activity since 2000 has been primarily focused on these two formations because of new advances in horizontal drilling technology. With these advances, the need for additional cores and data has enabled investigations into previous undrilled portions of the basin. This has resulted in good well and excellent core control (17 wells) in the study area (Fig. 1). A contour map of Three Forks production (Fig. 2) shows an anomalous high trend in Divide County that is the focus of this investigation. This study will examine the cores from four wells in Divide County across that production increase (Fig. 2).

Statigraphy

The Three Forks Formation conformably overlies the Birdbear Formation (Devonian) and can be divided into three informal members, in ascending order: lower, middle, and upper (Bottjer et al, 2011; Nordeng and LeFever, 2015; Nordeng et al, 2015). It reaches a maximum thickness of 255 ft and is present in the western half of North Dakota. Top of the Three Forks is marked by a significant unconformity and, in turn, is overlain by the Pronghorn or Lower Member of the Bakken Formation.

This workshop will focus on the upper half of the Three Forks Formation (Fig. 3). The lower half consists predominantly of silty and sandy dolomitic red beds with anhydrite nodules or beds. This interval is capped by a pervasive, basin-wide, clay-rich marker bed with larger dolostone clasts. Lithologies are similar for both the middle and upper portions of the Three Forks. Basal units for both are pink to tan mottled dolostones with interfingering green clay stringers. Soft-sediment deformation is predominantly due to dewatering of clay intervals. This section may be overlain by a parallel laminated to massive pink to tan dolostones followed by an interbedded sequence of apple green and tan mudstones and dolostones. Numerous structures are present in the interbedded sequence including uni- and bi-directional ripple laminations, mudcracks, soft-sediment deformation, and parallel to sub-parallel laminations. Capping the middle member is another grey-green silty mudstone bed with suspended dolostone clasts. This mudstone bed is also a basin-wide marker bed.

The upper member is unconformably overlain by either the Pronghorn or Lower Member of the Bakken Formation. Where present, the Pronghorn is 2 to 5 ft thick and is represented by a silty mudstone. Burrowed layers are common. Where the upper member is overlain by the Lower Member of Bakken, the contact is sharp with a thin lag deposit. Dark brown mudstone or dark black shale comprises the Lower Member of the Bakken.

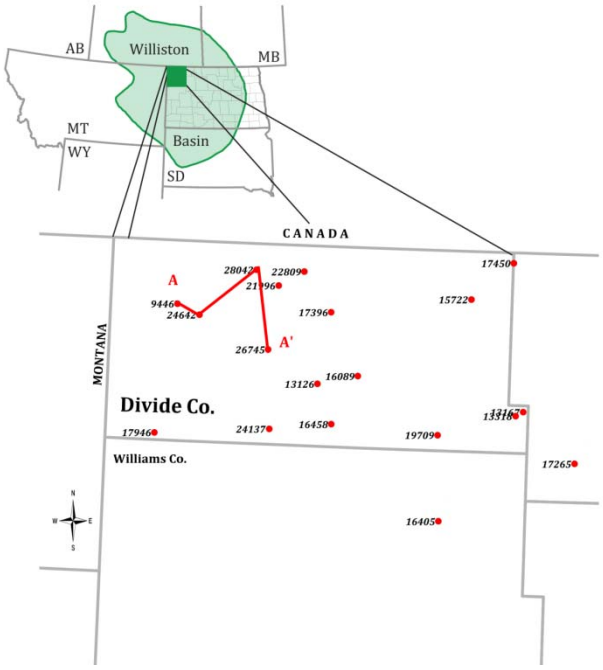


Figure 1 – Index map of the study area in Divide and Williams counties. Cores available are labeled with NDIC numbers. Cross-section of interest (A-A') is shown in red.

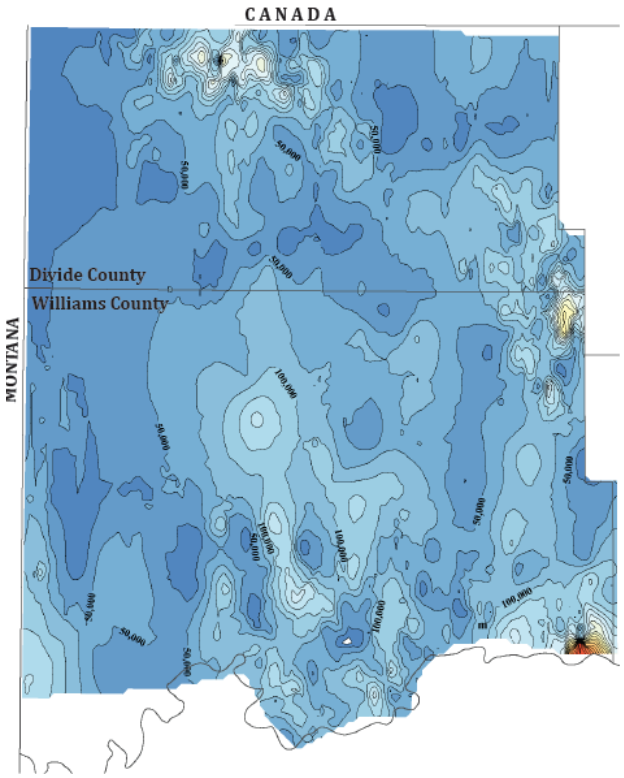


Figure 2 – Cumulative production map for the Three Forks Formation for Divide and McKenzie counties. Contour interval is 50,000 barrels.

The uppermost Three Forks Formation serves as the reservoir in the Divide County region. Permeabilities are low with porosities ranging from 5 to 8 %. Better reservoir rocks occur where the green, silty clay layers are at a minimum (Fig. 4).

Production in this area is poor from the Middle Member of the Bakken Formation. Grain size tends to be larger and subject to cementation. That in combination with the immaturity of the overlying upper shale makes it poor producer.

Discussion

Eight hundred wells were mapped to construct a series of isopach and geochemical maps for Divide County and the surrounding area. The Lower Member of the Bakken Formation is fairly constant

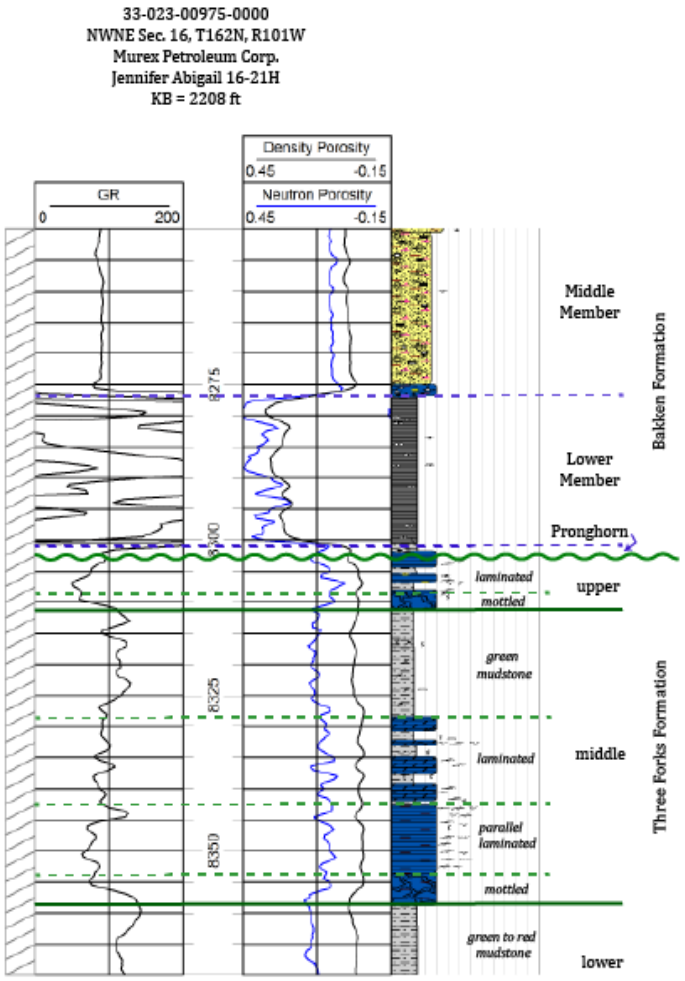


Figure 3 - Representative log section for Divide County showing the relationship between the uppermost Three Forks and the Bakken Formation.

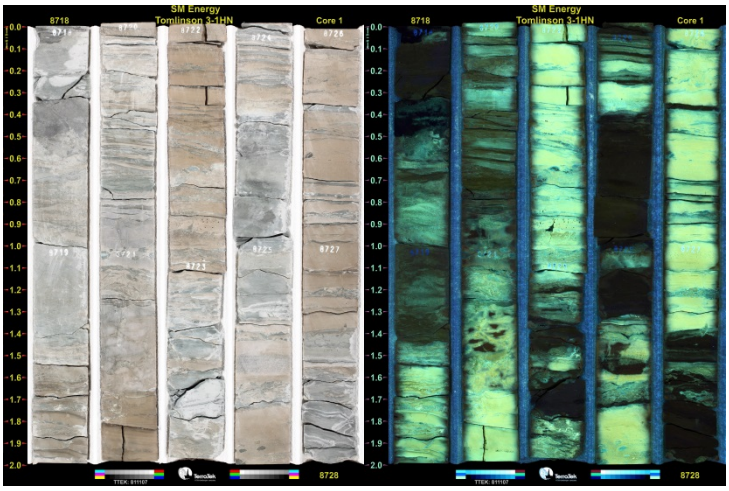


Figure 4 – Plain and black light photographs representative of the upper Three Forks Formation from SM Energy Company – Tomlinson #3-1HN (Lot 3 Sec. 1, T161N, R100W).

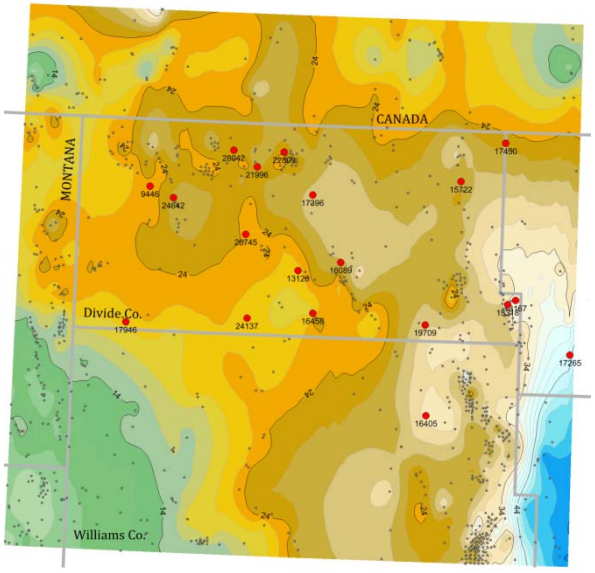


Figure 5a – Isopach of the Lower Member of the Bakken Formation. The thickness reaches a maximum of 54 ft towards the depocenter shown in blue. The central portion of the study area in Divide County is marked by an increase in shale thickness. Control points are in black and cored wells are indicated in red. Contour interval is 2 ft.

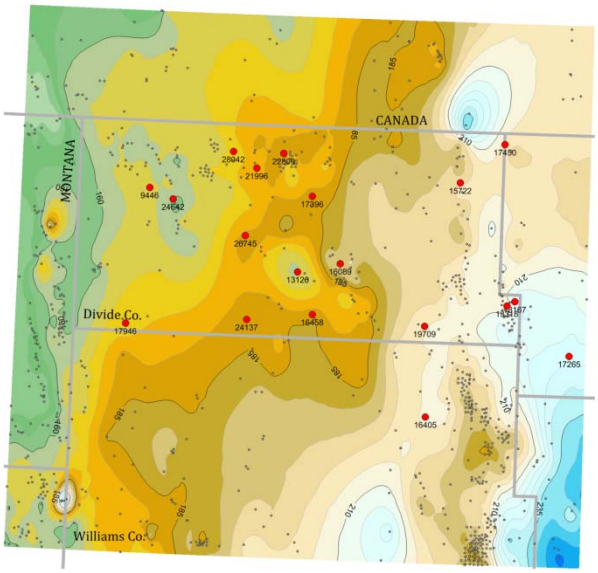


Figure 5b – Isopach of the Three Forks Formation. The Nesson Anticline was a prominent feature during the deposition of the formation as indicated by the isopach thins. Much of Divide County appears to be a gradual shelf. Control points are indicated in black with cored wells indicated in red. Contour interval is 2 ft.

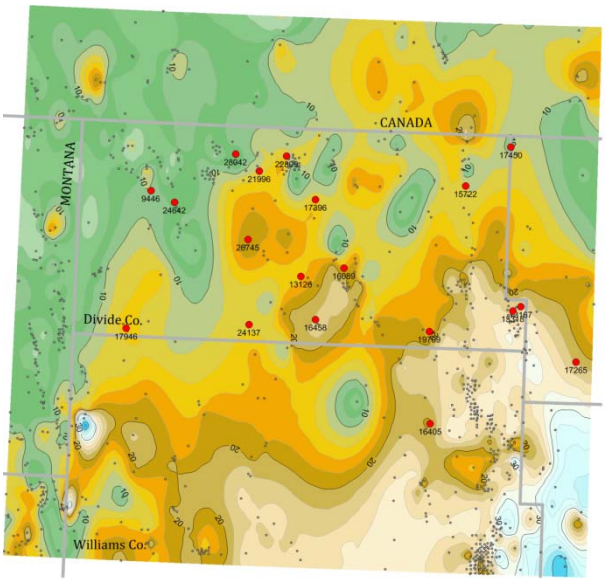


Figure 5c – Isopach of the upper member of the Three Forks Formation appears similar to that of the total Three Forks Formation. Control points are indicated in black with cored wells indicated in red. Contour interval is 2 ft.

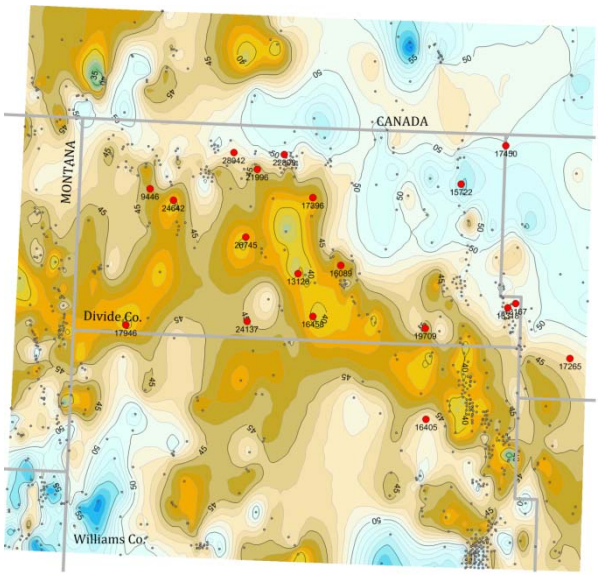


Figure 5d – In contrast, the isopach of the middle member of the Three Forks Formation shows an increase in thickness over the northeastern portion of the county. Control points are indicated in black with cored well indicated in red. Contour interval is 2 ft.

over the county ranging in thickness from 22 to 26 ft (Fig. 5a). Isopach of the total Three Forks Formation (Fig. 5b) suggests a gentle shelf on the western side of the Elk Point Basin. This is also suggested by the contour map of the upper member (Fig. 5c). It also shows a limited thickness change. In contrast, the middle member appears to show a low ridge stretching from the Nesson Anticline, across the Divide County, into Montana (Fig. 5d).

The geochemical maps are presented as evidence of increased production noted in the study area. Geochemical data is from the Lower Member of the Bakken Formation because it is likely to be the primary source of oil. The Upper Member of Bakken appears immature in core. Figure 6 outlines a north-south area of lower total organic carbon,

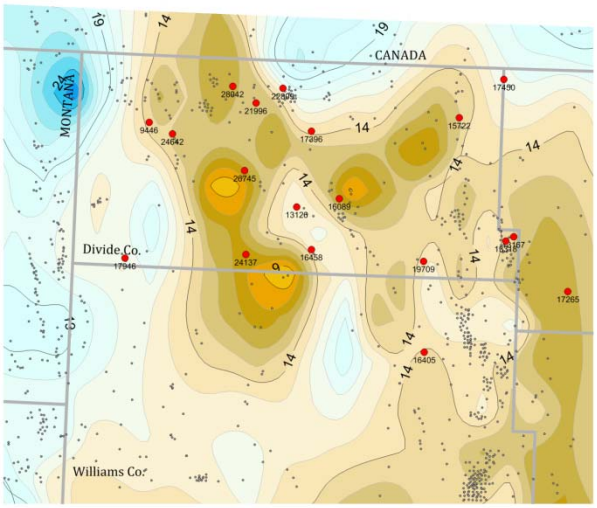


Figure 6 – Map of the Total Organic Carbon (TOCs) measured for the Lower Member of the Bakken Formation. Note the north-south oriented trend in lower TOCs indicated in tans and orange. Contour interval is 2 ft.

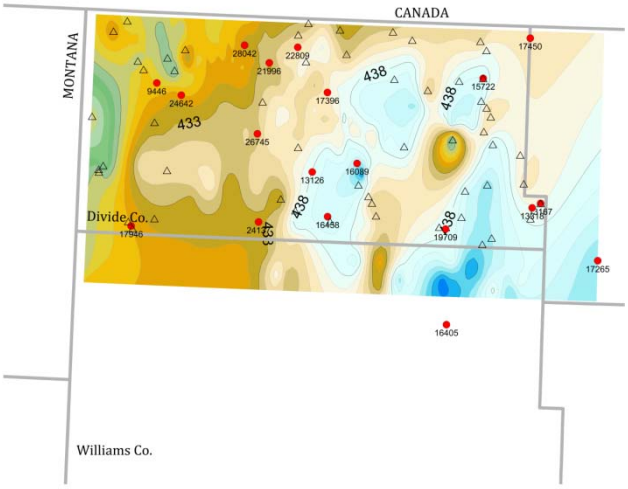


Figure 7 – Contour map of TMAX values for the Lower Member of the Bakken Formation shows a similar north-south trend with higher TMAX values. Triangles indicate TMAX data point with cored locations indicated in red. Contour interval is 5 degrees.

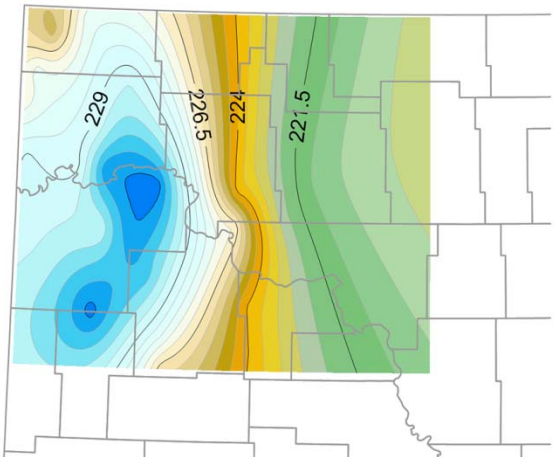


Figure 8 – Contour map of Bakken Formation kinetics continuing the northward trend through the center of Divide County. Contour interval is .5 ft.

suggesting that the area is marginally mature. This is supported by the contour maps of TMAX (Fig. 7) and kinetics (Fig. 8). The area of maturation is generally considered to be more southerly.

References Cited

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

Nordeng, S. H. and LeFever J. A., 2015, A plea for a standardized Three Forks stratigraphy, Williston Basin Petroleum Conference, (abst,with program), Regina, SK

Nordeng, S.H, LeFever, J.A., LeFever, R.D., and X. Hou, 2015, RMAG Core Symposium: Upper and Middle Three Forks Formation, Williston Basin: RMAG, Denver, CO

NDIC File No: **24642** API No: **33-023-00975-00-00** County: **DIVIDE** CTB No: **124642**
Well Type: **OG** Well Status: **A** Status Date: **9/12/2013** Wellbore type: **HORIZONTAL**
Location: **NWNE 16-162-101** Latitude: **48.864955** Longitude: **-103.801611**
Current Operator: **MUREX PETROLEUM CORPORATION**
Original Operator: **MUREX PETROLEUM CORPORATION**
Current Well Name: **JENNIFER ABIGAIL 16-21H**
Original Well Name: **JENNIFER ABIGAIL 16-21H**
Elevation(s) (ft): **2,208 KB 2,192 GR 2,192 GL** Total Depth: **18,206** Field: **FORTUNA**
Spud Date(s): **7/22/2013**

Formation Tops (true vertical depth in ft.)

K-P 1190 K-GH 3765 K-M 4051 K-N 4159 K-IK 4352 J-R 5296
T-S 5928 M-KL 6283 M-MD 6405 M-MDR 6813 M-MDLS 6868 M-MDFA 7175
MD-B 8205 D-TF 8301 D-BB 8467

Completion Data

Pool: BAKKEN Perfs: 8579-18206 Comp Dt: 9/12/2013 Status: AL
Status Dt: 10/17/2013 Spacing: 2SEC

Cumulative Production Data

Pool: BAKKEN Cum Oil: 97,285 Cum MCF Gas: 58,517 Cum Water: 264,457

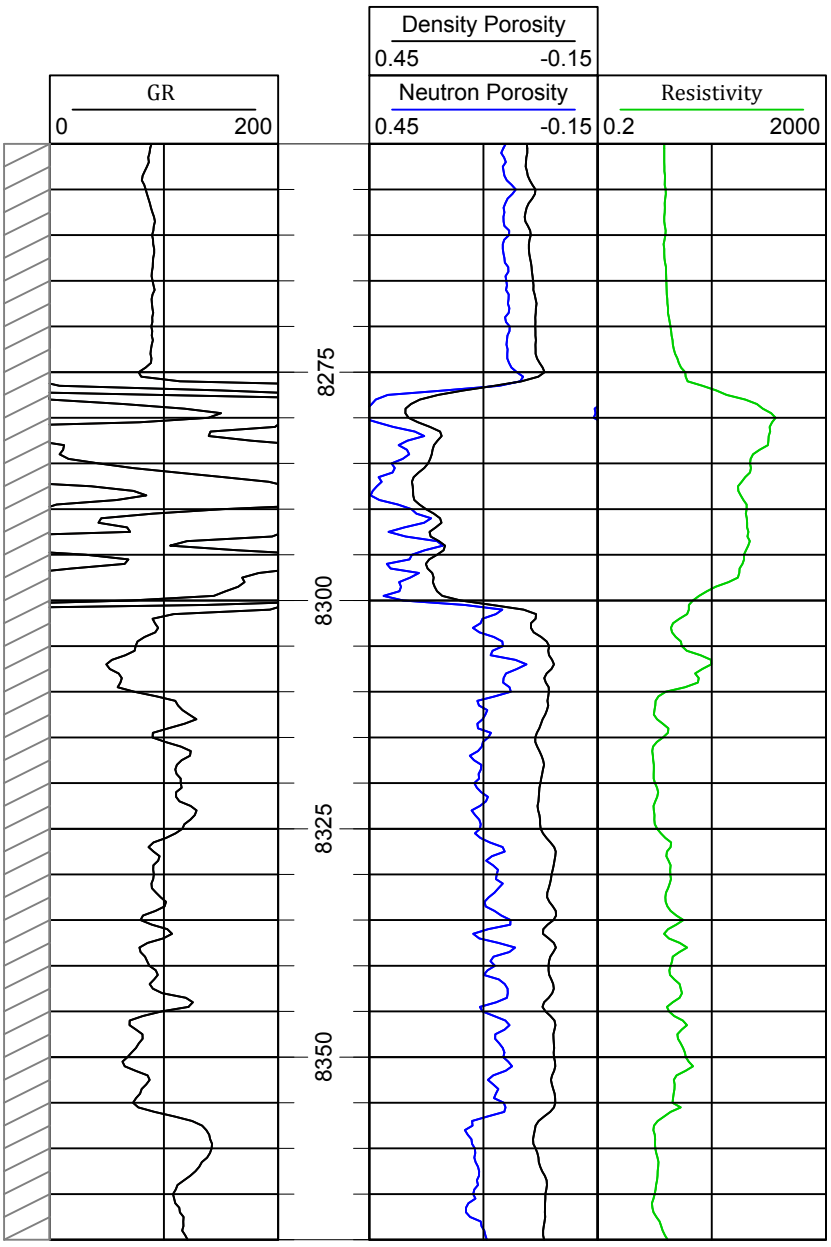
Production Test Data (reported in barrels)

IP Test Date: 9/17/2013 Pool: BAKKEN IP Oil: 42 IP MCF: 19 IP Water: 570

Cores (true vertical depth in ft.)

Type: **LS** Top: **8169** Bottom: **8200** Formation: **M-MDLP**
Type: **LS** Top: **8200** Bottom: **8208** Formation: **MD-B**
Type: **LS** Top: **8208** Bottom: **8269** Formation: **MD-B**
Type: **LS** Top: **8269** Bottom: **8294** Formation: **MD-B**
Type: **LS** Top: **8294** Bottom: **8475** Formation: **D-TF**

33-023-00975-0000
#24642
NWNE Sec. 16, T162N, R101W
Murex Petroleum Corp.
Jennifer Abigail #16-21H
KB = 2208 ft



Core -6 = Log

NWNE Sec. 16, T.162N., R.101W
Murex Petroleum Corp.
Jennifer Abigail #16-21H

Cored Interval: 8287 - 8320 ft.

NWNE Sec. 16, T.162N., R.101W
Murex Petroleum Corp.
Jennifer Abigail #16-21H

Cored Interval: 8320 - 8354 ft.

NDIC File No: **26745** API No: **33-023-01120-00-00** County: **DIVIDE** CTB No: **221888**
Well Type: **OG** Well Status: **A** Status Date: **3/14/2014** Wellbore type: **HORIZONTAL**
Location: **LOT3 1-161-100** Latitude: **48.806839** Longitude: **-103.608352**
Current Operator: **SM ENERGY COMPANY**
Original Operator: **SM ENERGY COMPANY**
Current Well Name: **TOMLINSON 3-1HN**
Original Well Name: **TOMLINSON 3-1HN**
Elevation(s): **2,326 KB 2,300 GR 2,303 GL** Total Depth: **19,201** Field: **WEST AMBROSE**
Spud Date(s): **12/9/2013**

Formation Tops (true vertical depth in ft.)

K-P 1536 K-GH 3976 K-M 4240 K-N 4383 K-IK 4627 J-S 5060
J-R 5524 T-S 6146 M-KL 6691 M-MD 6862 M-MDR 7219 M-MDLS 7278
M-MDFA 7563 MD-B 8620 D-TF 8722

Completion Data

Pool: BAKKEN Perfs: 9090-19201 Comp Dt: 3/14/2014 Status: F
Status Dt: 4/19/2014 Spacing: 2SEC

Cumulative Production Data

Pool: BAKKEN Cum Oil: 107,078 Cum MCF Gas: 77,428 Cum Water: 175,777

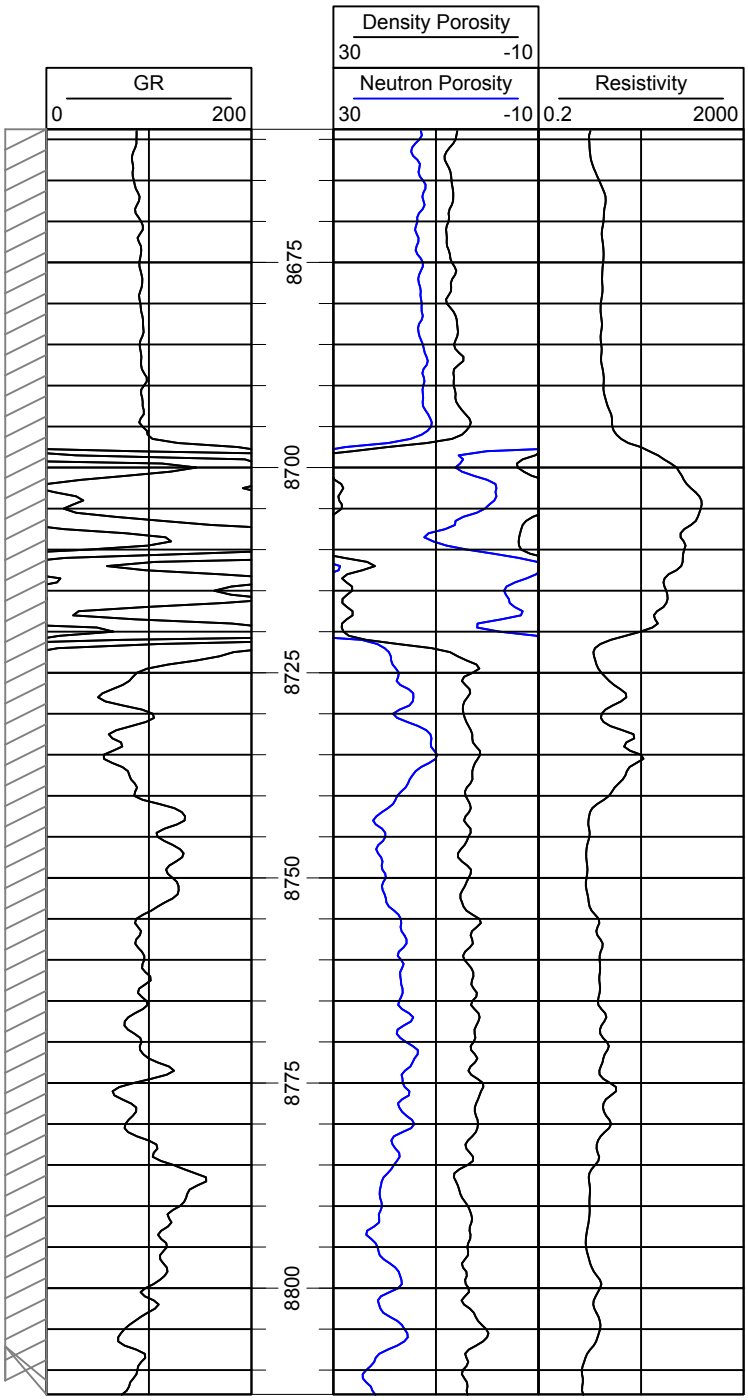
Production Test Data

IP Test Date: 4/19/2014 Pool: BAKKEN IP Oil: 717 IP MCF: 518 IP Water: 1,403

Cores (true vertical depth in ft.)

Type: **LS** Top: **8618** Bottom: **8733** Formation: **MD-B**
Type: **LS** Top: **8733** Bottom: **8806** Formation: **D-TF**

33-023-01120-0000
#26745
Lot 3 Sec. 1, T161N, R101W
SM Energy Company
Tomlinson #3-1HN
KB = 2326 ft



Core + 5 = Log

Lot 3 Sec. 1, T.161N., R.101W
SM Energy Company
Tomlinson #3-1HN

Cored Interval: 8708 - 8727 ft.

Lot 3 Sec. 1, T.161N., R.101W
SM Energy Company
Tomlinson #3-1HN

Cored Interval: 8728 - 8748 ft.

NDIC File No: **28042** API No: **33-023-01190-00-00** County: **DIVIDE** CTB No: **220216**
Well Type: **OG** Well Status: **A** Status Date: **11/24/2014** Wellbore type: **HORIZONTAL**
Location: **NWNE 15-163-100** Latitude: **48.951477** Longitude: **-103.648983**
Current Operator: **SM ENERGY COMPANY**
Original Operator: **SM ENERGY COMPANY**
Current Well Name: **TORGESON 2-15HS**
Original Well Name: **TORGESON 2-15HS**
Elevation(s): **2,167 KB 2,142 GR 2,145 GL** Total Depth: **17,868** Field: **WEST AMBROSE**
Spud Date(s): **6/25/2014**

Formation Tops (true vertical depth in ft.)

K-P 1144 K-GH 3612 K-M 3856 K-N 4000 K-IK 4240 J-S 4580
J-R 5062 T-S 5682 M-KL 6022 M-MD 6161 M-MDR 6528 M-MDLS 6588
M-MDFA 6844 M-MDLP 7357 MD-B 7883 D-TF 7991

Completion Data

Pool: BAKKEN Perfs: 8210-17868 Comp Dt: 11/24/2014 Status: AL
Status Dt: 12/19/2014 Spacing: 2SEC

Cumulative Production Data

Pool: BAKKEN Cum Oil: 59,921 Cum MCF Gas: 34,183 Cum Water: 110,856

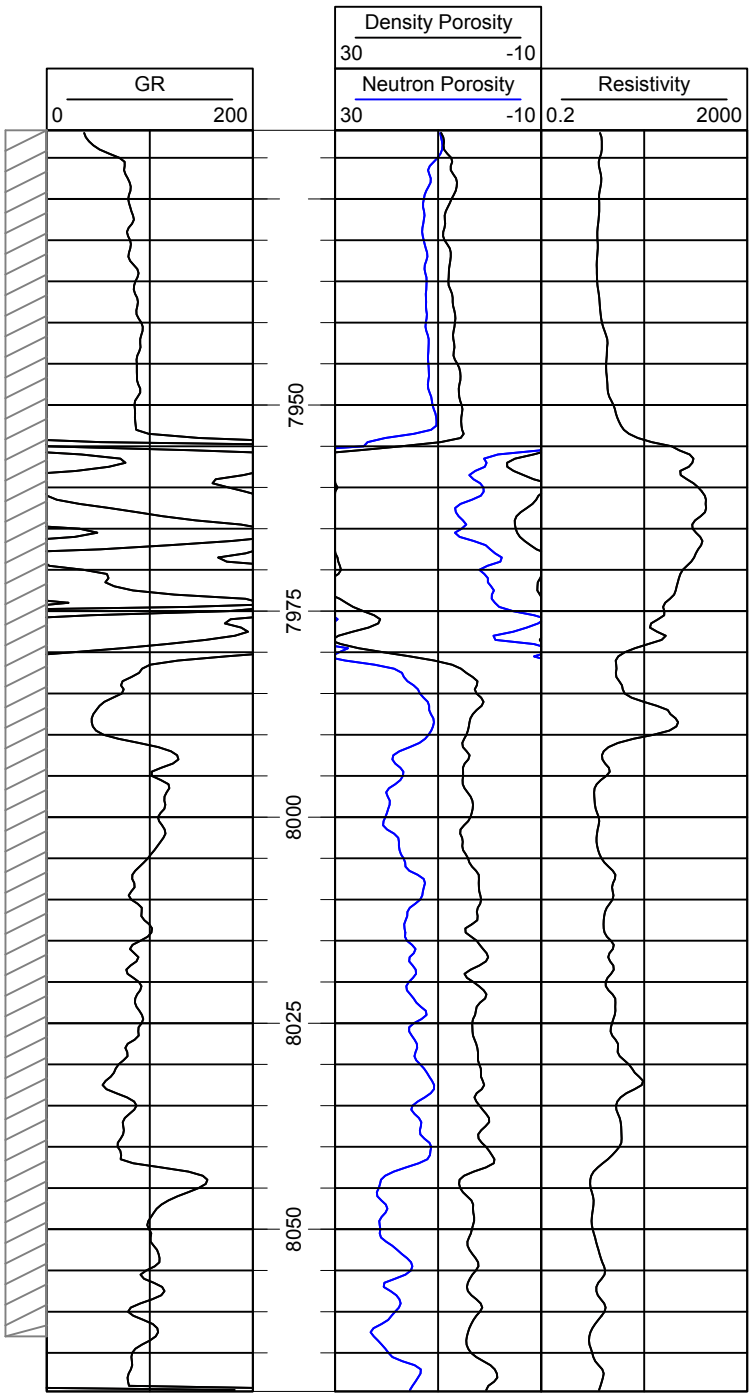
Production Test Data

IP Test Date: 12/19/2014 Pool: BAKKEN IP Oil: 236 IP MCF: 102 IP Water: 375

Cores (true vertical depth in ft.)

Type: **LS** Top: **7883** Bottom: **7995** Formation: **MD-B**
Type: **LS** Top: **7995** Bottom: **8063** Formation: **D-TF**

33-023-01190-0000
#28042
NWNE Sec. 15, T163N, R100W
SM Energy Company
Torgeson #2-15HS
KB = 2167

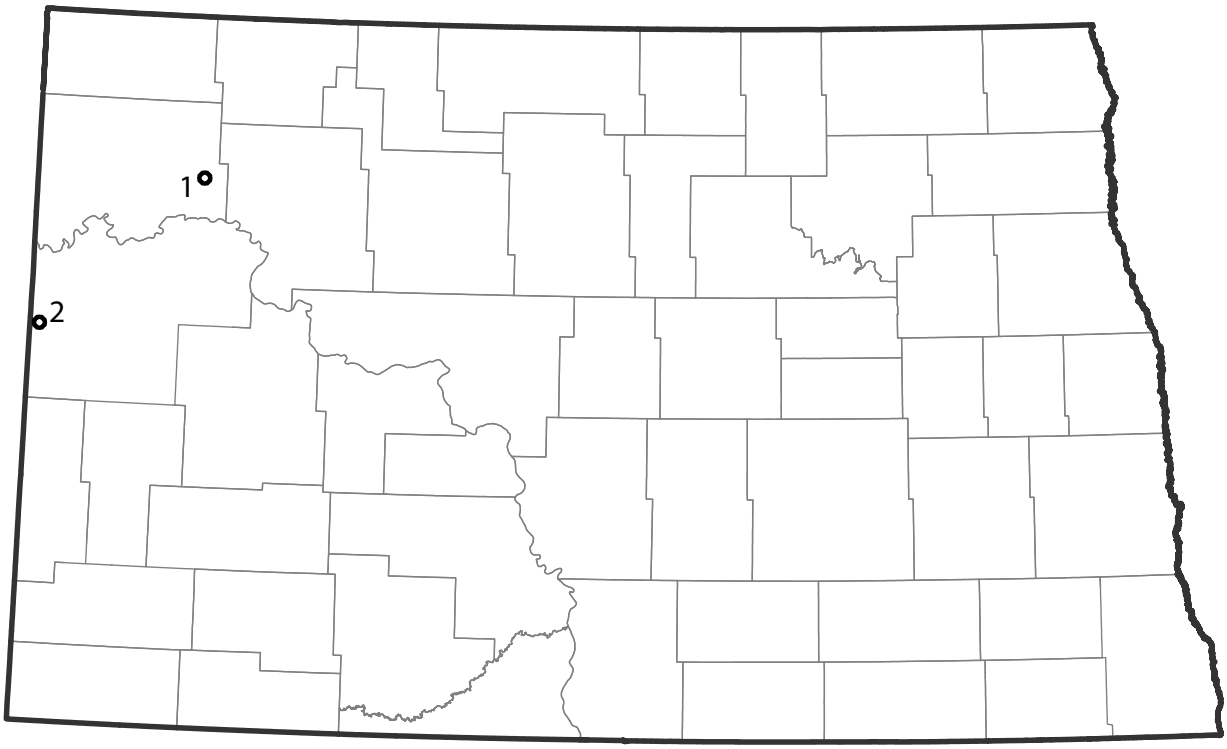


Core = Log

WILLISTON BASIN PETROLEUM CONFERENCE
Core Workshop

Inyan Kara Formation

Jeffrey W. Bader
North Dakota Geological Survey



No.	Well	Core Interval
1	Amerada Petroleum Corporation - Math Iverson #1 SWNW Sec. 1, T155N, R96W, Williams County NDIC: 165, API: 33-105-00097-00-00	4,590'- 4,647' 4,937'- 4,980'
2	Shell Oil Company - USA #42-10 SENE Sec. 10, T148N, R105W, McKenzie County NDIC: 90015, API: 33-053-90015-00-00	5,165'-5,257'

Overview of the Inyan Kara Formation, Western North Dakota

Introduction

Significant volumes of co-produced water are generated daily during production operations for oil and gas in North Dakota. Produced water is an oil and gas industry term that describes the formation water that is generated as a by-product of oil and gas production. Formation water, also referred to as connate water, exists naturally within the formation along with the hydrocarbons which, because of lower density, float on the water. Formation water initially reflects the water quality of the depositional environment of the petroleum reservoir: marine, brackish, or fresh water. Approximately 7 to 10 barrels, equivalent to 280-400 gallons of water, are generated for every barrel of oil produced worldwide (USDI, 2011). Oil reservoirs generally contain significantly greater volumes of water than gas reservoirs; therefore, the amount of produced water in North Dakota is significant with approximately 13,000 producing oil wells currently in the state (NDIC, 2015). In North Dakota, over a million barrels of produced water are generated daily. In addition, the amount of produced water generated usually increases over the life of a well because oil and gas is depleted as hydrocarbons are extracted from the subsurface.

Injection of Produced Water into Favorable Geologic Units

Geology of the area is the major factor in determining if injection is a viable option for produced water disposal. North Dakota's Williston Basin has an ideal sequence of geologic units (Dakota Group) present at an optimal depth for produced water disposal. The Lower Cretaceous (~100-113 million years) Dakota Group of North Dakota consists of four formations (fig. 1). In descending order they are:

- Mowry Formation-marine shale
- Newcastle Formation-marginal marine sandstone
- Skull Creek Formation-marine shale
- Inyan Kara Formation-marginal marine and non-marine sandstone and shale

Overlying the Dakota Group are several thousand feet of Cretaceous marine deposits including the 2300-foot-thick Pierre Formation. The Jurassic (~150-200 million years) Swift Formation unconformably underlies the Dakota Group and consists of up to 725 ft. (221 m) of marginal marine shale with interbedded limestone. The Dakota Group is present at approximately 5,000-6,200 ft. (1524-1890 m) in the heart of the Williston basin.

These Cretaceous and Jurassic rocks are present throughout the Williston Basin of North Dakota and provide a complete succession of rocks for produced water injection. Of specific importance is the Inyan Kara Formation, which consists of sandstones and shales deposited in incised valleys along the coastline of the Cretaceous Western Interior Seaway (figs. 2 and 3). These valleys were cut by north-northwesterly flowing rivers that drained into the seaway from highlands in southern North Dakota, Minnesota, and Canada. The valleys formed as the Cretaceous seaway withdrew (regressed) from North Dakota twice over a period of approximately 10 million years. The seaway transgressed back into the area forming estuaries, and sands were deposited in the valleys as sea-level rose, again in two transgressive events.

Inyan Kara sandstones deposited in these valleys are thick, porous (20-30% porosity), and permeable (Darcy level) enough to accept the injected water and the lateral continuity of the units allows for injected water to easily move into the formation (fig. 4), especially along valley trends. Between these valleys, in the interfluve area, sandstones are thinner, much less continuous, and have porosity/permeability an order of magnitude lower than incised valley sandstones. Therefore interfluve sandstones are not optimal for injection of produced water.

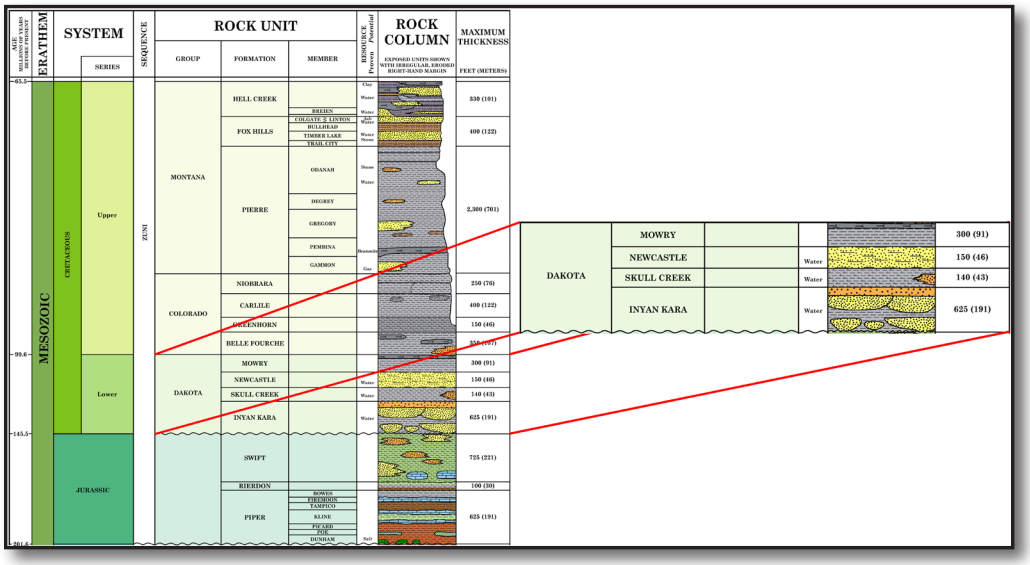


Figure 1. North Dakota stratigraphic column showing the Lower Cretaceous Dakota Group (Murphy and others, 2009).

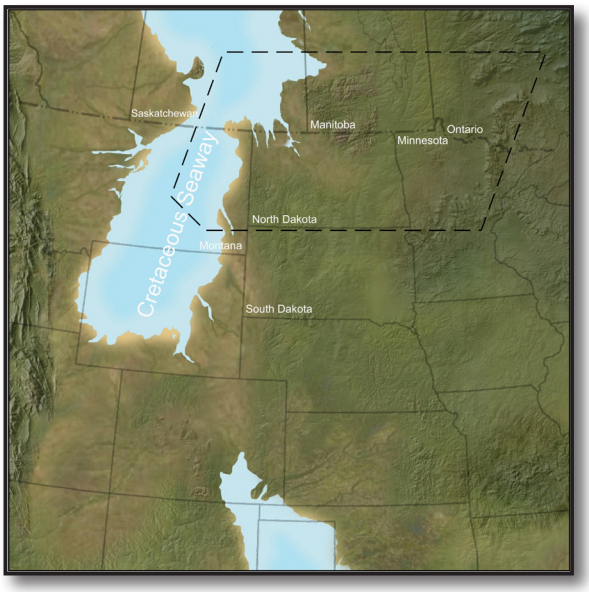


Figure 2. Paleogeographic map of North Dakota area during Inyan Kara time (c.a., 106 Ma). Dashed line shows figure 3 area. Modified from Blakey, 2014.

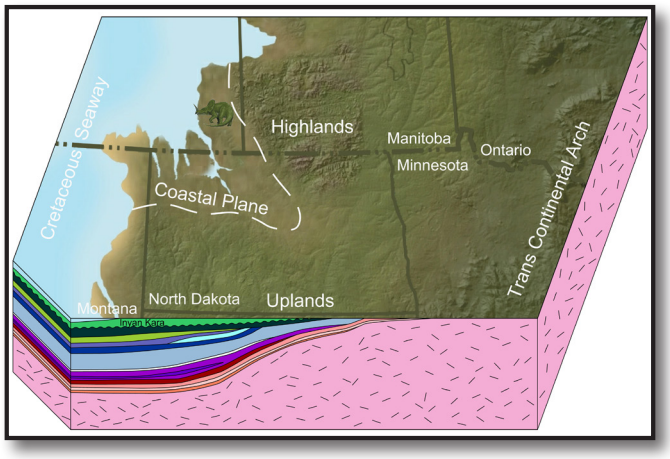


Figure 3. Block diagram of North Dakota area showing paleogeography and geologic setting during Inyan Kara time (c.a., 106 Ma). Modified from Blakey, 2014.

Although some lateral continuity is important, these units must have good seals above to protect shallow aquifers. The thick shales of the Pierre Formation provide such a seal and it, along with the underlying Swift Formation, allow for excellent confining layers that will vertically contain injected brines within the Inyan Kara Formation.

Summary

North Dakota produced its three billionth barrel of oil in January 2015 (NDIC, 2015) and it is estimated that four billion barrels will be achieved by 2018. That is four billion barrels or more of produced water that must be disposed. North Dakota will need to have new, innovative, and environmentally sound practices in managing these prodigious amounts of produced water.

An understanding of the depositional environment of the Inyan Kara Formation is critical in determining saltwater disposal well placement. This understanding begins with a thorough core and log analysis with emphasis on sequence stratigraphic concepts prior to mapping sandstone bodies, both in plain view (isopachs) and cross-sections.

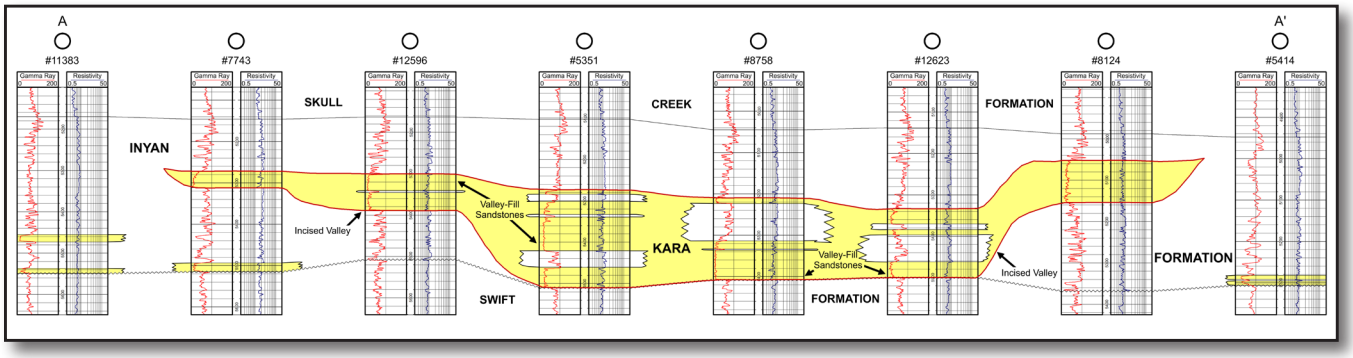


Figure 4. Geologic cross-section from the eastern half of the Watford City 100K Sheet showing incised valley and valley fill deposits of the Inyan Kara Formation.

References

Blakey, R.C., 2014, History of Western Interior Seaway, North America (Jurassic-Cretaceous): Colorado Plateau Geosystems, Inc., http://cpgeosystems.com/index.html, (retrieved May 4, 2015).

Murphy, E.C., Nordeng, S.H., Juenker, B.J., and Hoganson, J.W., 2009, North Dakota stratigraphic column: North Dakota Geological Survey Miscellaneous Series no. 91.

North Dakota Industrial Commission (NDIC), 2015, https://www.dmr.nd.gov/oilgas/, (retrieved August 24, 2015).

United States Department of the Interior (USDI), 2011, Oil and gas produced water management and beneficial use in the western United States: Science and Technology Report No. 157.

NDIC File No: **165** API No: **33-105-00097-00-00** County: **WILLIAMS**
Well Type: **OG** Well Status: **PA** Status Date: **6/25/1987** Wellbore type: **VERTICAL**
Location: **SWNW 1-155-96** Latitude: **48.278661** Longitude: **-102.975888**
Current Operator: **AMERADA HESS CORPORATION**
Original Operator: **AMERADA PETROLEUM CORP.**
Current Well Name: **BEAVER LODGE-MADISON UNIT G-11**
Original Well Name: **MATH IVERSON #1**
Elevation(s) (ft.): **2,340 KB 2,329 GL** Total Depth: **8,430** Field: **BEAVER LODGE**
Spud Date(s): **4/16/1953**

Formation Tops (true vertical depth in ft.)

K-P 1415 K-GH 3849 K-M 4196 K-N 4316 K-IK 4533 J-S 4973 J-R 5400 T-S 5988 PM-MK 6313 PM-OP 6340 PN-T 6794 M-KL 7385 M-MD 7522 M-MDR 8107 M-MDLS 8170 M-MDFA 8367

Completion Data (true vertical depth in ft.)

Pool: MADISON Perfs: 8,370-8,408 G Comp Dt: 6/7/1953 Status: PNA Status Dt: 6/25/1987 Spacing: U

Cumulative Production Data (reported in barrels)

Pool: MADISON Cum Oil: 1,016,716 Cum MCF Gas: 102,167 Cum Water: 1,575,950

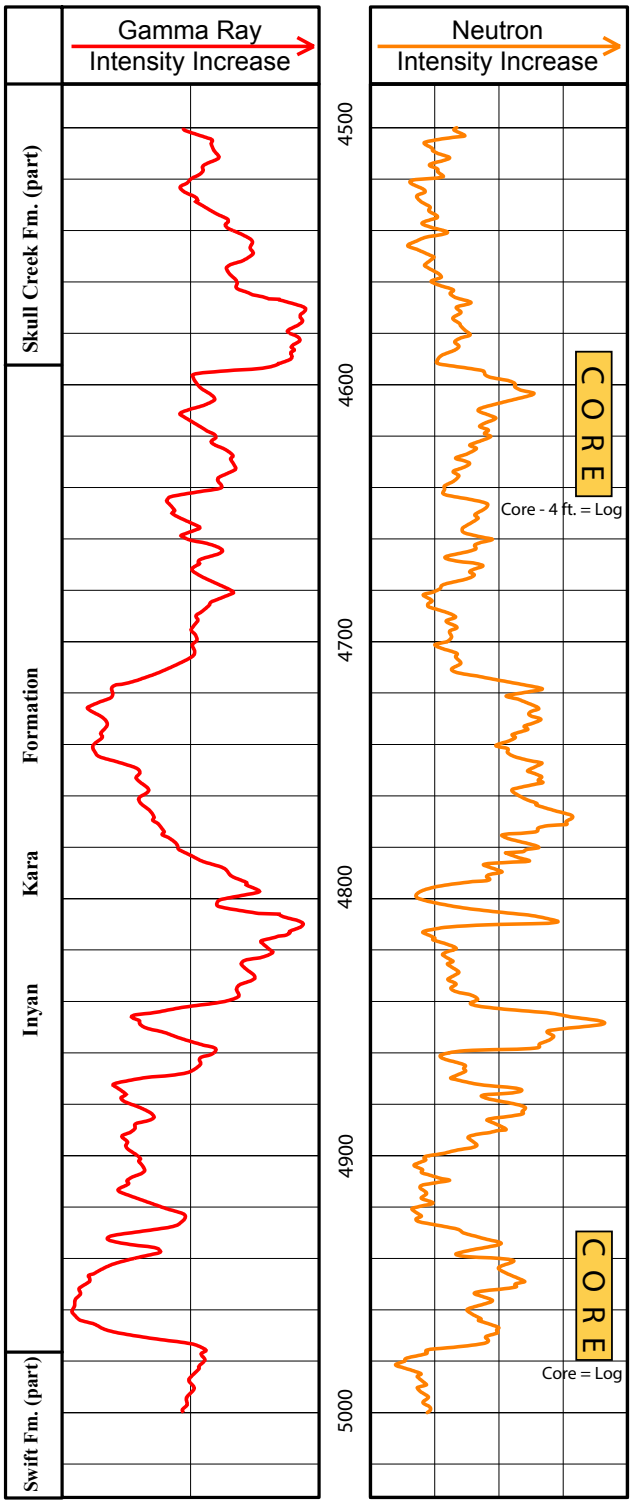
Production Test Data (reported in barrels)

IP Test Date: 6/7/1953 Pool: MADISON IP Oil: 645 IP MCF: 668 IP Water: 1
DST: 4,599-4,647 Recovery: 3360' VERY SLIGHTLY MUD CUY WATER
DST: 4,939-4,988 Recovery: 4110' SLIGHTLY MUDDY BRACKISH WATER
DST: 5,174-5,273 Recovery: 306' DRILLING MUD

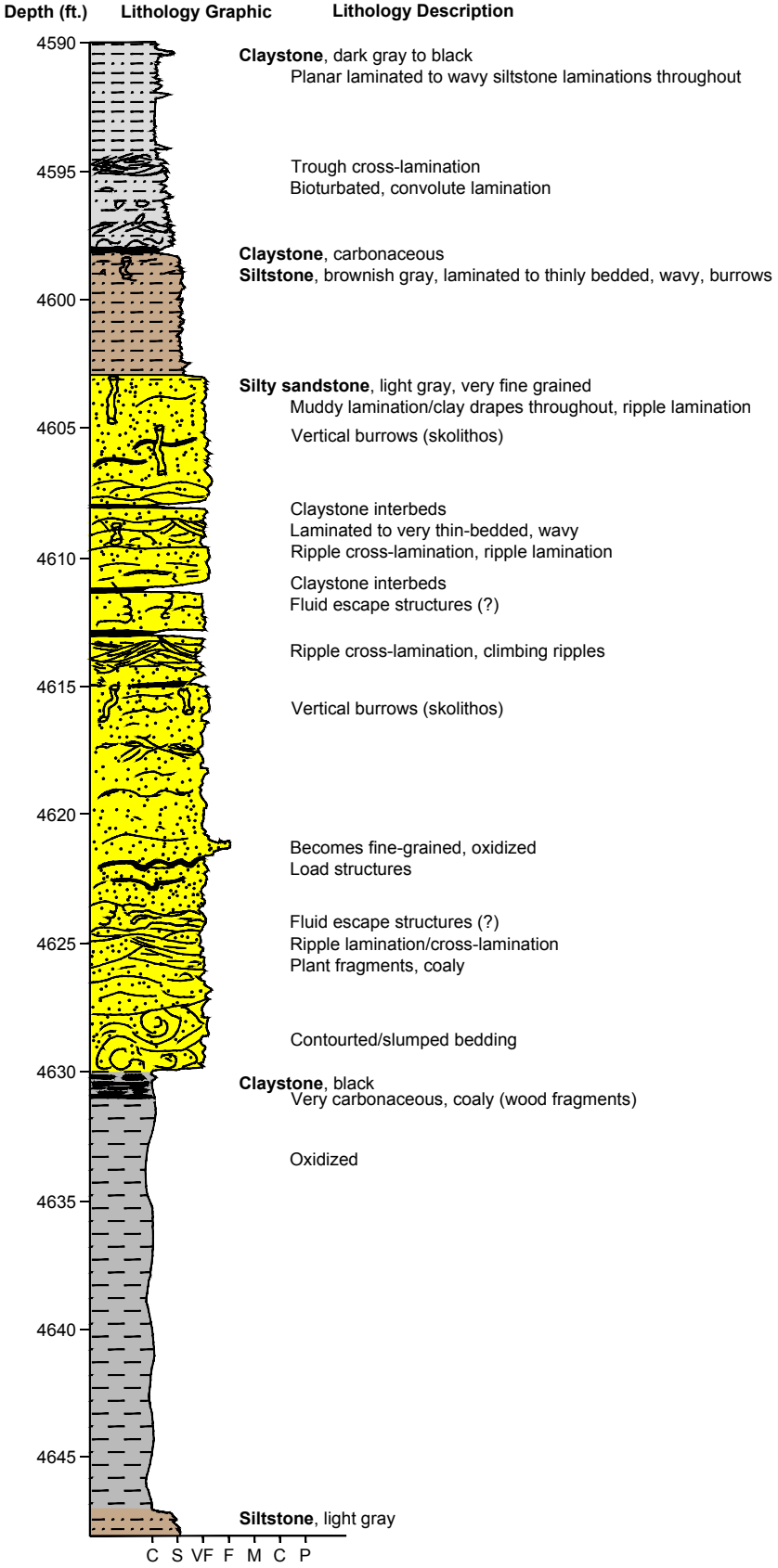
Cores: (true vertical depth in ft.)

Type: CH	Top: 4,590	Bottom: 4,647	Formation: K-IK
Type: CH	Top: 4,628	Bottom: 4,634	Formation: K-IK
Type: CH	Top: 4,930	Bottom: 4,990	Formation: K-UN
Type: DC	Top: 4,500	Bottom: 5,300	
Type: DC	Top: 5,310	Bottom: 6,110	
Type: DC	Top: 6,110	Bottom: 6,880	
Type: DC	Top: 6,880	Bottom: 7,600	
Type: DC	Top: 7,600	Bottom: 8,430	
Type: LS	Top: 4,590	Bottom: 4,597	Formation: K-IK
Type: LS	Top: 4,597	Bottom: 4,615	Formation: K-IK
Type: LS	Top: 4,614	Bottom: 4,647	Formation: K-IK
Type: LS	Top: 4,937	Bottom: 4,952	Formation: K-IK
Type: LS	Top: 4,956	Bottom: 4,980	Formation: K-IK

#165
33-105-00097-0000
SWNW Sec. 1, T155N R96W
Amerada Petroleum Corporation
Math Iverson #1
K.B. = 2,340 ft.

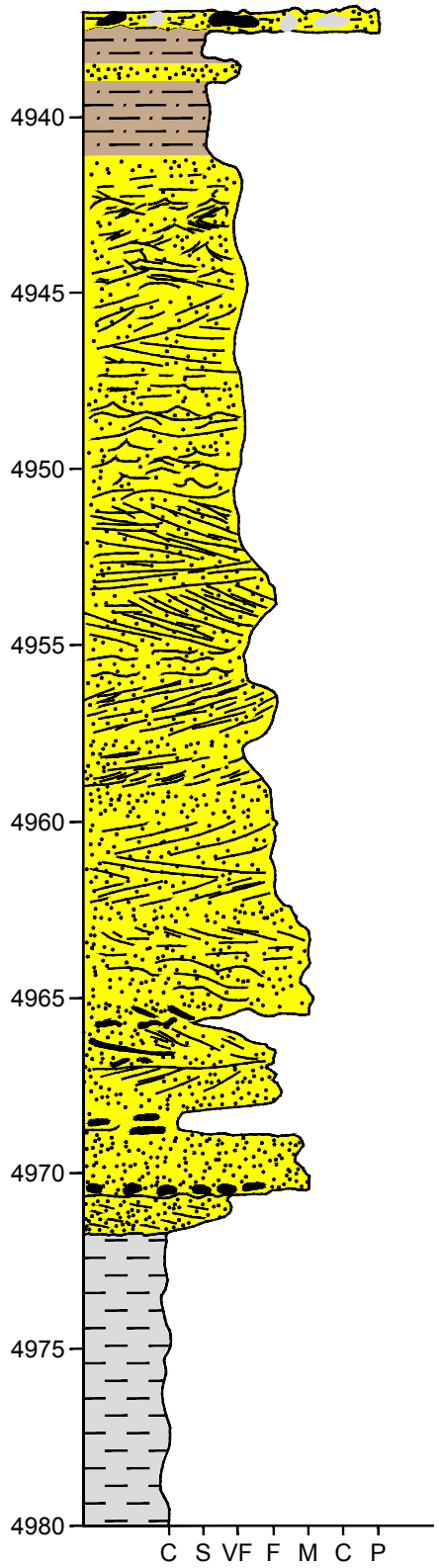


Math Iverson #1
33105000970000
#165
4590 - 4648 ft. (Core - 4 ft. = Log)



Math Iverson #1
33105000970000
#165
4937 - 4980 ft. (Core = Log)

Depth (ft.) **Lithology Graphic**



Lithology Description

Sedimentary breccia, brownish black, poorly sorted
Iron oxide cement

Siltstone, gray

Sandstone, light gray, very fine to fine grained, ripple cross lamination

Low-angle, multi-directional cross beds (tabular planar)

Ripple cross-laminated/ripples, climbing ripples

Low-angle, multi directional cross beds (tabular planar)

Wavy bedding

Tabular planar to trough cross-bedding

Multi-directional, planar tabular cross-bedding
Becomes dark gray and fine to medium grained

Carbonaceous; coal, sulfer

Lag with clasts of green claystone up to 2 cm
Sandstone, light gray
Very fine grained; undirectional, gently inclined,
very low-angle planar lamination

Claystone, green

SWNW Sec. 1, T.155N, R.96W
Amerada Petroleum Corporation
Math Iverson #1

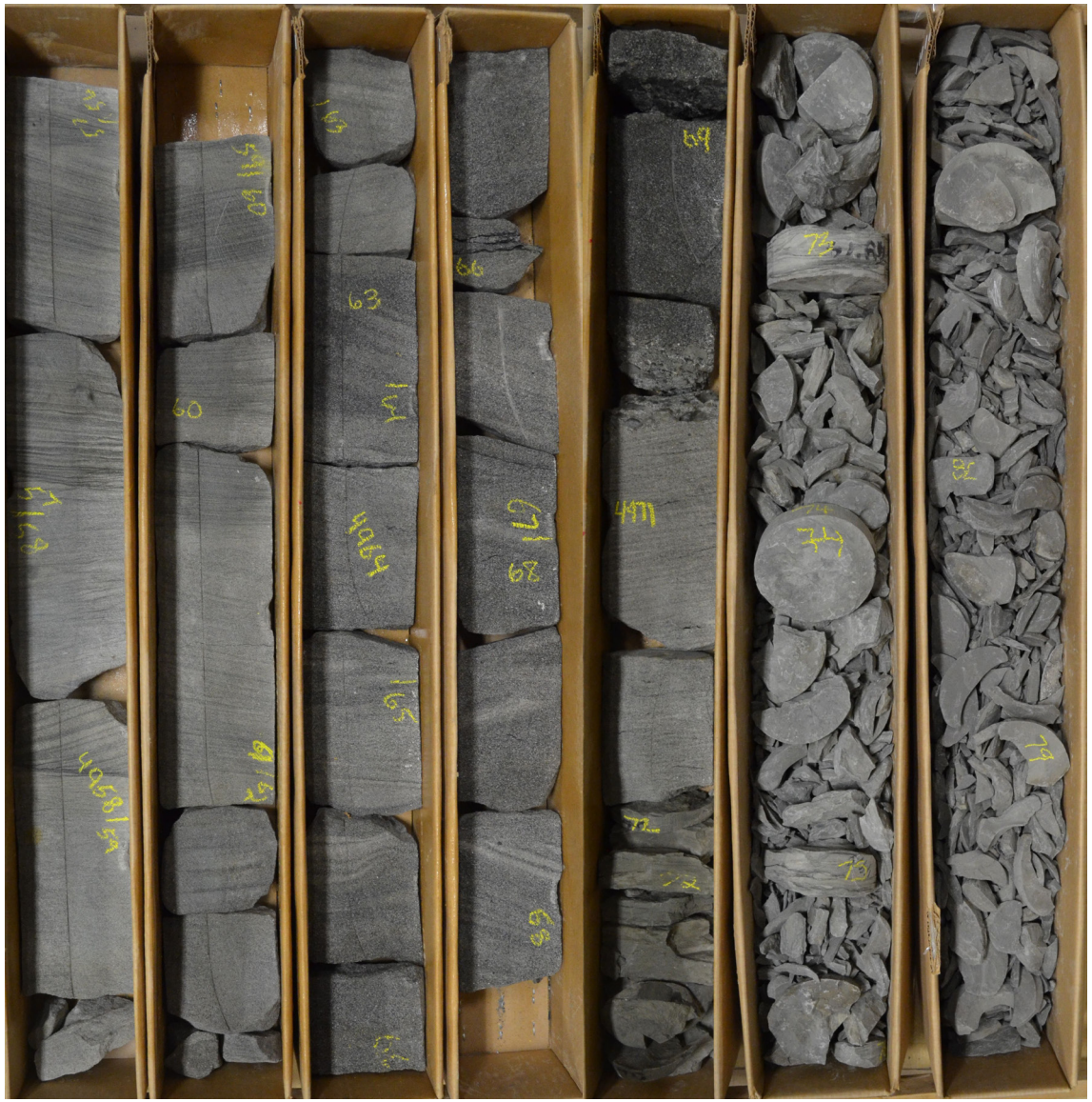
Cored Interval: 4590 - 4631 ft.

SWNW Sec. 1, T.155N, R.96W
Amerada Petroleum Corporation
Math Iverson #1

Cored Interval: 4631 - 4647 ft.
4937 - 4956 ft.

SWNW Sec. 1, T.155N, R.96W
Amerada Petroleum Corporation
Math Iverson #1

Cored Interval: 4956 - 4980 ft.



NDIC File No: **90015** API No: **33-053-90015-00-00** County: **MCKENZIE**
Well Type: **SWD** Well Status: **IA** Status Date: **6/18/1979** Wellbore type: **VERTICAL**
Location: **SENE 10-148-105** Latitude: **47.658097** Longitude: **-104.03483**
Current Operator: **XTO ENERGY, INC.**
Original Operator: **SHELL OIL CO.**
Current Well Name: **USA 42-10**
Original Well Name: **USA #42-10**
Elevation(s) (ft.): **1,980 KB 1,967 GL** Total Depth: **5,670** Field: **MONDAK**

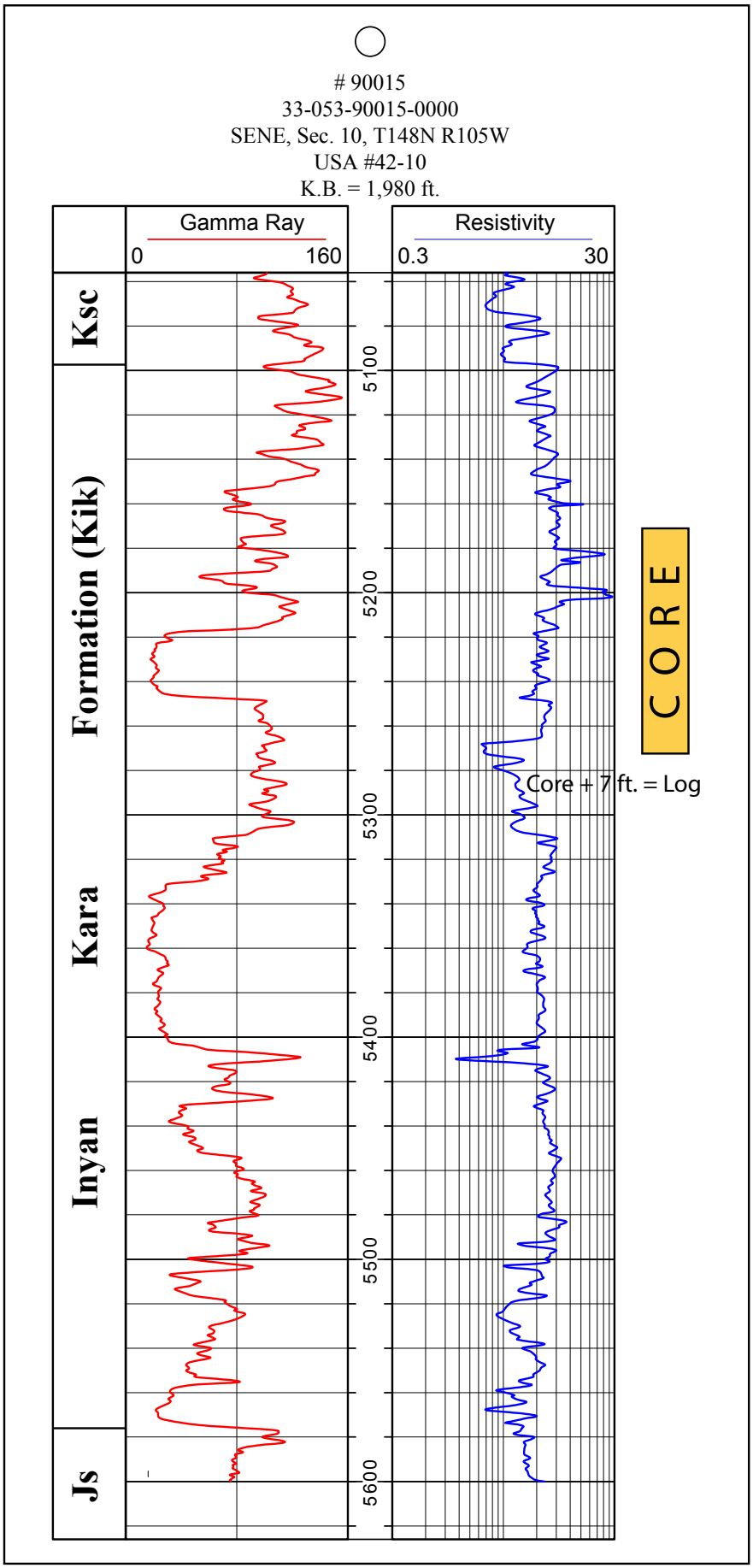
Formation Tops (true vertical depth in ft.)
K-GH 4243 K-M 4676 K-N 4835 K-IK 5060 J-S 5576

Cumulative Production Data
Pool: DAKOTA Comp Dt: 6/18/1979 perfs: 5217-5574 Status: SWD Status Dt: 6/18/1979

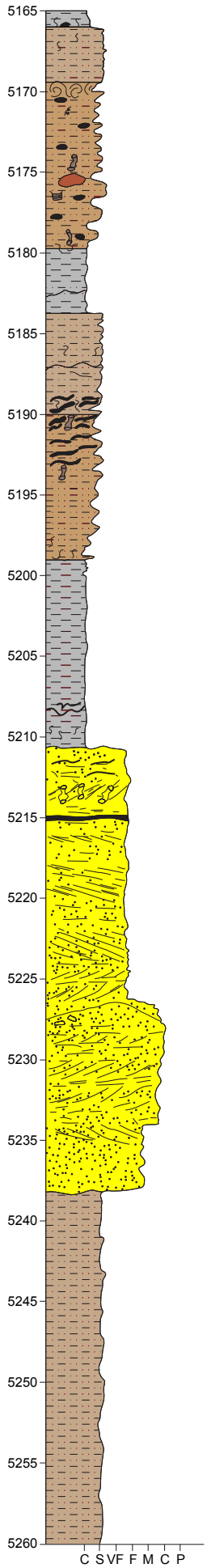
Cumulative Injection Data (reported in barrels)
UNIC NO: A0072S0119D Pool: DAKOTA Cum Salt Water Disposed: 19,432,897

Cores: (true vertical depth in ft.)

Type: CC	Top: 5,165	Bottom: 5,177	Formation: K-IK
Type: CC	Top: 5,177	Bottom: 5,260	Formation: K-IK
Type: CP	Top: 5,196	Bottom: 5,250	Formation: K-IK
Type: CS	Top: 5,165	Bottom: 5,183	Formation: K-IK
Type: CS	Top: 5,183	Bottom: 5,257	Formation: K-IK
Type: RS	Top: 5,165	Bottom: 5,258	Formation: K-IK


90015
33-053-90015-0000
SENE, Sec. 10, T148N R105W
USA #42-10
K.B. = 1,980 ft.
Gamma Ray
0
160
Resistivity
0.3
30
Ksc
Formation (Kik)
Kara
Inyan
Js
5100
5200
5300
5400
5500
5600
CORE
Core + 7 ft. = Log

USA #42-10
33053900150000
5165-5260 ft. (C + 7 ft. = Log)



Lithology Description

Claystone, black

Siltstone, gray, planar to convolute/contorted bedding

Siltstone/claystone interbedded, light gray to black, bioturbated (planolites throughout, skolithos, and technichnus), fluid escape structures

Ironstone concretion

Convolute laminations

Claystone, dark gray

Siltstone, light gray, clayey, wavy, and ripple laminations throughout

Burrowed

Siltstone/claystone interbedded, planar laminated to wavy laminated/ ripple cross-laminations and climbing ripples, bioturbated in silty zones

More clayey

Planar laminated claystone with thin silty laminations

Siderite precipitates?

Claystone, light to dark gray

Bioturbated

Sandstone, gray, very fine to fine grained
Oxidized

Skolithos burrows

Gently inclined, planar laminated

Sandstone, gray, medium grained (upper)
Cross-laminated to planar laminated (multi-directional)

Sandstone, gray, medium grained (lower), massive

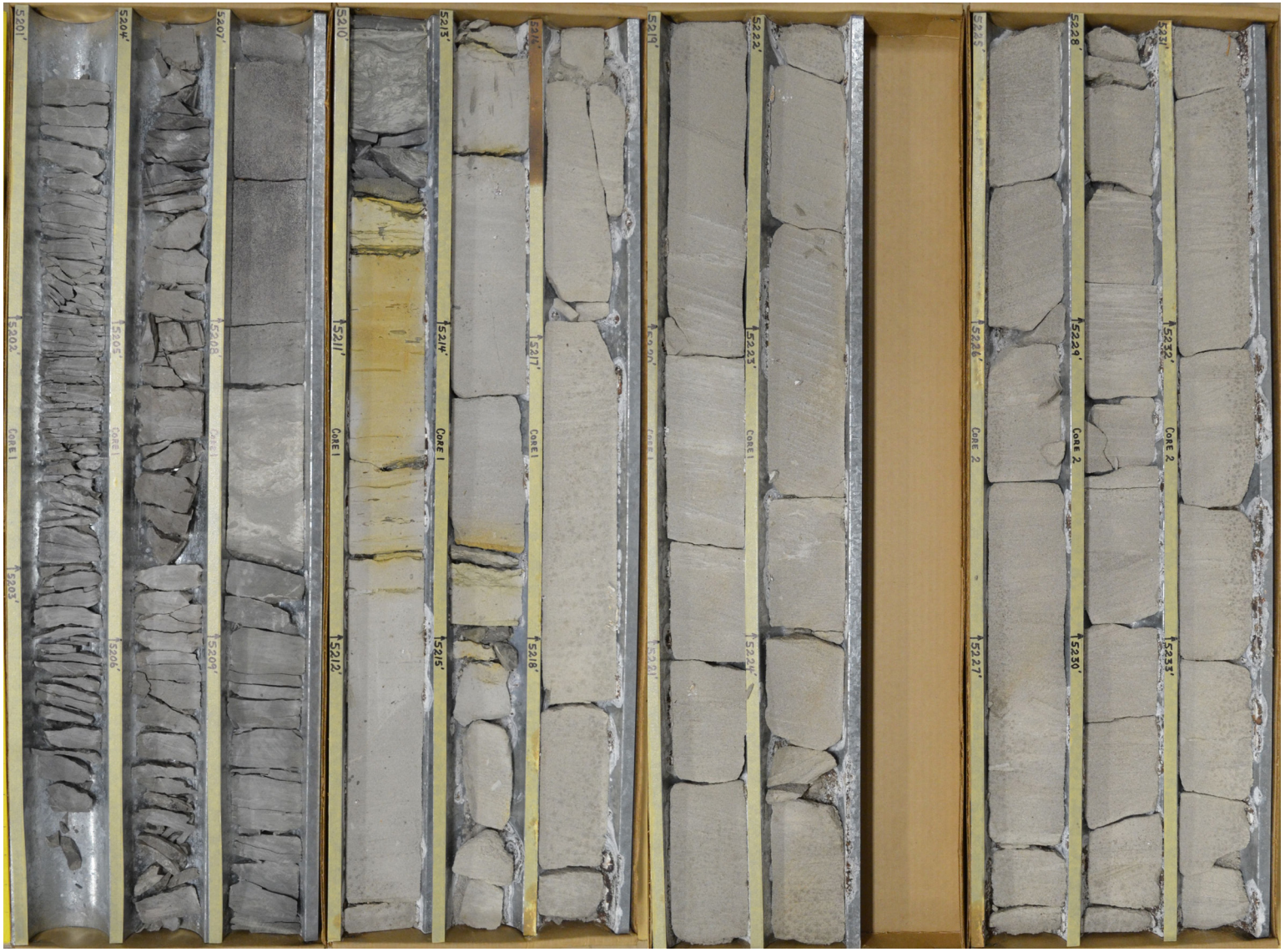
Siltstone, mottled, maroon to gray, argillaceous

SENE Sec. 10, T.148N., R.105W
Shell Oil Company
USA #42-10

Cored Interval: 5165-5201 ft.

SENE Sec. 10, T.148N., R.105W
Shell Oil Company
USA #42-10

Cored Interval: 5201-5234 ft.



SENE Sec. 10, T.148N., R.105W
Shell Oil Company
USA #42-10

Cored Interval: 5234-5257 ft.