Methane Hydrate Production from Alaskan Permafrost

Logging Operations

Topical Report

January 28, 2003 to March 19, 2004

by

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Disclaimer

Abstract

Natural-gas hydrates have been encountered beneath the permafrost and considered a nuisance by the oil and gas industry for years. Engineers working in Russia, Canada and the USA have documented numerous drilling problems, including kicks and uncontrolled gas releases, in arctic regions. Information has been generated in laboratory studies pertaining to the extent, volume, chemistry and phase behavior of gas hydrates. Scientists studying hydrate potential agree that the potential is great – on the North Slope of Alaska alone, it has been estimated at 590 TCF. However, little information has been obtained on physical samples taken from actual rock containing hydrates.

This gas-hydrate project was a cost-shared partnership between Maurer Technology, Noble Corporation, Anadarko Petroleum, and the U.S. Department of Energy's Methane Hydrate R&D program. The purpose of the project is to build on previous and ongoing R&D in the area of onshore hydrate deposition to identify, quantify and predict production potential for hydrates located on the North Slope of Alaska.

The work scope included drilling and coring a well (Hot Ice No. 1) on Anadarko leases beginning in FY 2003 and completed in 2004. During the first drilling season, operations were conducted at the site between January 28, 2003 to April 30, 2003. The well was spudded and drilled to a depth of 1403 ft. Due to the onset of warmer weather, work was then suspended for the season. Operations at the site were continued after the tundra was re-opened the following season. Between January 12, 2004 and March 19, 2004, the well was drilled and cored to a final depth of 2300 ft.

An on-site core analysis laboratory was built and utilized for determining the physical characteristics of the hydrates and surrounding rock. The well was drilled from a new Anadarko Arctic Platform that has a minimal footprint and environmental impact. The final efforts of the project are to correlate geology, geophysics, logs, and drilling and production data and provide this information to scientists planning hydrate exploration and development projects. No gas hydrates were encountered in this well; however, a wealth of information was generated and is contained in this and other project reports.

This Topical Report contains details describing logging operations.

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Appendix A: Summary Open-Hole and Lithologic Log for Hot Ice No. 1 Well

1. Introduction

The purpose of this project is to plan, design and implement a program that will safely and economically drill/core and produce natural gas from arctic hydrates. The project team has documented planning, operations and lessons learned to assist in future hydrate research and field operations to make an objective technical and economic assessment of this promising natural gas reservoir potential.

On February 7, 2004 the well reached its planned depth of 2300 ft, about 300 ft below the zone where temperature and pressure conditions would theoretically permit hydrates to exist. Although significant gas shows were encountered in highly porous sandstones, no methane hydrates were found. The continuous coring rig used in the project proved to be a safe and efficient drilling system, with 93% of core recovered.

This project used a special purpose on-site laboratory to help analyze hydrate cores. Live data and images were transmitted from the rig over the internet, which reduced the number of engineers and scientists required to oversee the project. Additionally, the well was drilled from a special purpose-built arctic platform. A massive 3D VSP seismic survey was also conducted to investigate lateral variations of the potential hydrate reservoir. (Results of the VSP are described in a companion Topical Report – *3D Vertical Seismic Profile Survey*.)

2. Experimental

2.1 Task Statement

The original wellbore logging task as outlined in the Statement of Work is:

Task 10.0 – Well Logging

The project team shall run a suite of logs in the well(s) to characterize the gas hydrate-bearing intervals, including the following: 1) Electrical Resistivity (Dual Induction), 2) Spontaneous Potential, 3) Caliper, 4) Acoustic Transit-Time, 5) Neutron Porosity, 6) Density, 7) Formation Micro Image, and 8) Nuclear Magnetic Resonance. Core data will be used to calibrate and quantify log information.

2.2 Logging Operations

Logs run in the Hot Ice No. 1 well are listed below for both drilling seasons.

Trip 1 @ 1500', 8½" hole, log beginning 22 Mar 2003:

Descent 1: PEX/ML/DSI; DSI downlog P&S + Stonely, uplog P&S + Expert modes

Descent 2: CMR+/HNGS; CMR in sandstone mode, 1500 fph

Trip #2: TD = 2300 ft; open hole = 5⅞ in.; 7-in. csg. @ 1357 ft; log beginning 9 Feb 2004. Down logs required on all logs. All logs run from TD to 7 in. casing.

Descent 1: PEX/NGT (AIT, Density/Neutron/Pe, GR, ML)

Descent 2: DSI/GPIT

- DSI downlog P&S + Stonely, uplog P&S + Expert modes

Descent 3: CMR+ (note: the marginal hole size may necessitate conveying the CMR on tubing or drill pipe. Arrangements have been made if needed.)

- Mode: Expert Depth Log – B Mode
- Echo Spacing (us): (200, 200)
- Polarization Time (s): (5.458, 0.02)
- Number of Echoes: (1800, 30)
- Repetition: (1, 10)
- Sample Interval (in): 9
- Log Speed (ft/hr): 1700

Descent 4: VSP

3. Results and Discussion

3.1 Summary Results for Logging Tasks

The Hydrate Project Team ran a suite of logs in the well(s) to characterize gas hydrate-bearing intervals, including the following: 1) electrical resistivity (dual induction), 2) spontaneous potential, 3) caliper, 4) acoustic transit-time, 5) neutron porosity, 6) density, and 7) nuclear magnetic resonance. Core data were used to calibrate and quantify log information. A summary log of the Hot Ice No. 1 well is presented in **Appendix A**.

3.2 Synopsis of Logging Runs from 2003 Season

3.2.1 Well Data

- Hot Ice No. 1
- Lat. 70°, 06', 31.39", Long. 150°, 12', 43.23"
- 1510 FNL, 1510 FWL, Sec. 30 T9N R8E, Umiat Meridian
- Wildcat: North Slope, Alaska
- Surface Casing 9⅝" 40# @ 120'
- Intermediate Casing 7" 26# L-80 @ 1500'
- Casing 4½" 9.5# @ 2700'
- GL = 187.9', KB = ?
- Water Base Muds approximately 9 ppg
- (Temperature not an issue)

3.2.2 Logging Program

Trip 1 @ 1500', 8½" hole, log beginning 22 Mar 2003:

Descent 1: PEX/ML/DSI; DSI downlog P&S + Stonely, uplog P&S + Expert modes

Descent 2: CMR+/HNGS; CMR in sandstone mode, 1500 ft/hr

3.2.3 Operator's Observations

These notes were recorded by Steve Runyon of Anadarko regarding logging operations on April 15-16, 2003.

1. Initiated trip no.1 (logs running in hole) at 4:50 PM on Tuesday, 4/15/2003. Total depth by driller was 1403 ft and stratigraphic interval at TD was the shale that separates the underlying West Sak sequence from the Ugnu interval above. Hole size was 8½ inches. Logging off Rolligon. Trip no. 1 was with the PEX (Platform Express) that consisted of an Induction, Gamma Ray, caliper, density and neutron porosity, SP, and tension devices.

    a. Logging tools would not go below a ledge at 1357 ft. This ledge is the top of shale that separates underlying West Sak from Ugnu sequence above.

    b. At 9:00 PM of same day, logging tool became stuck in casing. Base of casing was at 107 ft. Cause of problem was centralizer and stand-offs hanging up on casing that was positioned slightly off vertical. Tools were free by 1:00 AM Wednesday morning.

2. Following discussion with Tommy Thompson and company manager, concerning type and number of centralizers and stand-offs for combination sonic DSI and natural gamma ray NGT tools, ran in with same for trip no. 2 at 3:30 AM Wednesday morning. Centralizers and stand-offs needed to obtain good data because of washed-out condition of borehole, but could pose a sticking problem in surface casing when POOH. Finished logging (tool out of hole) at 6:30 AM Wednesday morning. No problems encountered with base of casing at 107 ft.

3. Ran in hole for trip no. 3 with combinable magnetic resonance log (CMR) at 10:00 AM Wednesday morning.

    a. Problem with tool telemetering data intermittently. POOH with tool and replaced head. RIH with tool again at 1:00 PM Wednesday afternoon.

    b. Data telemetry problems continued. Able to log only 50-100 ft at a time. No other tool available so continue to log at intermittent rate.

    c. Last reading is at 165 ft because top of tool in casing. CMR finished logging at 4:38 PM Wednesday afternoon, 4/16/2003. CMR POOH at 5:30 PM.

    d. Overall data quality poor due to borehole rugosity.

4. Post operational work.

    a. Verified with Anadarko that quality of data from logging job was acceptable.

    b. Schlumberger ran three sets of field prints and CD-ROMs for company man, Anchorage office and logger.

    c. Invoicing by Schlumberger included a charge for 5 hours of pre-logging standby time and a deduction for 5 hours of lost time due to logging problems with the CMR tool. Total invoice was $120,776.65.

5. Evaluation of Schlumberger job, personal, and equipment.

   a. Excellent rating for crew, although very tired from little sleep between this and the previous job. Logging engineer requested that Schlumberger replace personal due to lack of sleep but was not possible.

   b. CMR tool failed to work properly. No back-up equipment available. After analyzing the results of the induction data, we wanted to run a laterolog device but Schlumberger's only laterolog tool was being used in the Cook Inlet and not available.

   c. Overall job performance was good since this was the first time that Schlumberger had ever rigged up and logged from a Rolligon platform. Ingenious technique used to release stuck PEX tool combo from surface casing eliminating costly and time consuming fishing operations.

6. Recommendations:

   a. Anadarko needs a secure method to send logging data to petrophysicists in Houston for log/data quality control. Real time would even be better. Schlumberger did not have this capability on the North Slope at this time.

3.3 Synopsis of Logging Runs from 2004 Season

3.3.1 Well Data

- API: 50-103-20451-00
- Lat. 70°, 06', 31.39", Long. 150°, 12', 43.23"
- 1510 FNL, 1510 FWL, Sec. 30 T9N R8E, Umiat Meridian Wildcat: North Slope, Alaska
- Surface Casing 9⅝ in. 40# @ 120 ft
- Intermediate Casing 7 in. 26# L-80 @ 1367 ft
- GL = 187.9 ft, KB = 213.9
- Water-based muds KCl polymer approx. 9.3-9.5 ppg
- Temperature 31° @ 1268 ft; 2.2°/100 ft thereafter

3.3.2 Logging Program

Trip #2: TD = 2300 ft; open hole = 5⅞ in.; 7-in. csg. @ 1357 ft; Start date = 9 Feb 2004. Down logs required on all logs. All logs run from TD to 7 in. csg.

Descent 1: PEX/NGT (AIT, Density/Neutron/Pe, GR, ML)

Descent 2: DSI/GPIT

DSI downlog P&S + Stonely, uplog P&S + Expert modes

Descent 3: CMR+ (note: the marginal hole size may necessitate conveying the CMR on tubing or drill pipe. Arrangements have been made if needed.)

- Mode: Expert Depth Log – B Mode
- Echo Spacing (us): (200, 200)
- Polarization Time (s): (5.458, 0.02)
- Number of Echoes: (1800, 30)
- Repetition: (1, 10)
- Sample Interval (in): 9
- Log Speed (ft/hr): 1700

Descent 4: VSP

3.3.3 Operator's Observations

These notes were recorded by Steve Runyon of Anadarko regarding logging operations on February 7-9, 2004.

1. Prior to the operation, Schlumberger printed schematics of each tool. Tommy Thompson (drilling superintendent) and Steve Runyon discussed logging operation, tool size, sequence of tools to be run, tool combinations, stand-offs, centralizer positions and pad locations, weather, etc.

2. Printed lithology log to compare to logging responses. Emailed a list of show zones and tops from lithology log to Tommy Thompson.

3. TD of 2300 ft MD was reached at 1:00 PM on Saturday 2/7/2004. Circulated and conditioned hole. Schlumberger on location at 5:43 PM Saturday. Discussed and reviewed logging operation with Aaron Green (engineer for Schlumberger) until 6:30 PM. Received mud properties report from mud man.

4. Fire drill, safety meeting, rigging up from 6:30 PM to 10:00 PM. Rigging-up operations slow due to cold weather and small area to work on rig floor. Ran cable through man door rather than bomb-bay doors because of weather. Temperature at beginning of logging operation was -32ºF and dropped to -40ºF that night. Wind was 10 mph causing wind chill of -55ºF.

5. Ran PEX/NGT (AIT, Density/Neutron/Pe, GR and ML) tools in hole at 10:00 PM. Ran tools in slow to allow them to warm up. Mud chlorides were 86,000 mg/liter or 16-18% saturation by weight. Rm and Rmf were 0.05 and 0.046 Ohm-m @ 62ºF, respectively. Rm at TD @ 26ºF was 0.07-0.09 Ohm-m. Mud weight was 9.6 ppg at 26ºF. Overall grain density from core measurements in the upper cased portion of the hole was 2.64 g/cm^3.

6. Logged going down into hole per Anadarko's requirements. Ran repeat section and main pass. Tool calibrations were correct, and repeat/main pass comparisons were excellent. High permeabilities and porosities (darcys of kmd and high 30s porosity percent) resulted in very high invasion profiles for all array induction resistivity curves from casing at 1359 ft to approximately 1960 ft MD. Discussed with Schlumberger engineer the possibility of running a laterolog tool to help compensate for the high brine (KCl) saturation in the mud system. Runyon ordered two laterolog tools from the Schlumberger base to accompany the logging team already scheduled to arrive with the equipment needed to run the CMR on pipe. No additional costs were incurred for bringing lateralogs out to location.

7. Ran log up into casing and tied depths to first run. Hole was in excellent shape and in gauge. Caliper indicated a hole size of 5⅞ to 6 in. for most of the section. Largest hole size was 7.5 in. TD was 2299 ft MD and casing shoe was at 1359 ft MD. SP tool could not be grounded properly and was not recorded.

8. Out of hole with PEX tool and rigging down at 12:30 AM Sunday, February 8, 2004.

9. Sent Mike Globe an LAS/PDS file of the first logging (PEX) run at 2:30 AM. The small size of the digital logging data allowed us to send these files to Houston over Anadarko's secure intranet network. Schlumberger could not transmit by satellite because the North Slope is not within satellite coverage.

10. Ran in hole with sonic (GSI) and deviation tool (GPIT) at 2:30 AM. Ran down-log recording P, S and Stonely wave forms.

11. Ran repeat section and main pass. Calibrations and comparisons of passes were acceptable. Ran P, S and expert mode on up-log. Finished logging main section and logged up into casing and tied depths to first run at 4:00 AM Sunday morning. Sent digital files to Mike Globe for inspection.

12. Rigging down sonic tool and rigging up CMR with TLC equipment was a very tedious and long process due to freezing hydraulic system, rig floor crews and logging personal taking breaks to warm up, small area for working, etc.

13. Throughout the day discussed the possibility of running laterolog to obtain better resistivity data. Cost to run the tool was an additional $10,000. The decision was made to not run laterolog tool because the primary problem of invasion effects could not be resolved by any resistivity device. The lack of a deep invasion profile below about 1960 ft MD to total depth appears to be related to compaction effects and reduction in overall grain size and porosity and permeability. A noticeable increase in hardness in the core was noted by inspection below about 1960 ft MD, which correlated to reduced invasion of the drilling fluid from that point to total depth.

14. Ran in hole at 40 ft per stand with coring-rod-conveyed CMR tool at 8:00 PM Sunday on 2/8/2004. Ran 200 ft repeat section by 10:00 PM and checked quality control by comparing repeat section to main pass, comparing CMR porosity to cross plot of neutron/density porosity and inspecting T2 response in varying lithologies. In shale, T2 should exhibit high bound water and in sands low bound water. With the high lithic content, Runyon was curious to see if sandstones contain high clay content (high bound water) as indicated by the high overall GR response that is prevalent in the West Sak interval. The CMR measured very low clay content and concomitant low bound water with

very high porosity and permeabilities, which were corroborated by core plug measurements. The high lithic component of these sands has not been diagenetically altered to clay because of non-compaction due to shallow depth of burial. In fact, at this depth the irregular shape of the lithic fragments actually enhances porosity and permeability by resisting compaction as compared to uniform sand size particles.

15. Main pass with the CMR finished at midnight Sunday. Sent LAS/PDS files to Houston for inspection by Mike Globe. He confirmed CMR data were good and rigging down commenced. Four sets of prints and CD-ROMS were made on location. Two sets of log prints, digital files and lithology logs were left on site for the drilling superintendent and for Donn McGuire, APC geophysicists for use in VSP acquisition. One set was carried by Runyon to the Anchorage office for Tommy Thompson and one to Houston. Additional prints will be made by Schlumberger and sent later. Runyon reviewed with Schlumberger engineer the instructions for compositing runs 1 and 2, the distribution list for composite prints, sending APC the digital data, and processing the anisotropy log and deviation survey log.

16. Invoice was reviewed with drilling superintendent, Schlumberger engineer and Runyon. No down-time was experienced and the logging job was completed to everyone's satisfaction. The operation was judged excellent by all parties. Invoice amount was $101,511.10. The logging operation was completed by 6:00 AM on February 9, 2004.

3.4 Analysis of Logs

At the time of logging, the wellbore contained water based mud with a measured density of 9.6 ppg, and a resistivity of 0.05 Ohm-m at 62°F. Bit size used for this section of the well was 5⅞ in. The borehole was generally in gauge, with hole size rarely exceeding 6.5 in. Well log data were generally of good quality. However, invasion of the high-conductivity mud did have an effect on the induction-based resistivity measurements. This was particularly noticeable in the profile of the array resistivity measurements in sediments above 1900 ft. Although conductive mud is not generally a favorable environment for induction-based electrical logging, the relatively small wellbore in this well should have mitigated any significant unfavorable borehole signal.

The interval from 1400–2250 ft was evaluated using the Baker Atlas petrophysical analysis package RECALL SANDS. Clay volume was computed using a Hodges-Lehmann average of clay volumes computed from the density/neutron cross-plot, and gamma-ray techniques. Effective porosity was computed using the clay-corrected density/neutron cross-plot technique, based on an assumed 2.65 gm/cc matrix density. Effective water saturation was calculated using the modified Simandoux equation. Electrical exponents M and N were assumed to be equal to 2, and an Rw was assigned a value of 0.6 at 60°F.

Results of the evaluation indicate that there is likely a gas-saturated, porous and permeable sandstone in the interval 1460–1510 ft. In this interval, porosity of the sandstone beds ranges from 21% to 33%, and water saturation values from 15% to 50% depending on reservoir quality. There are interbedded zones with very low resistivities through this interval that most likely are associated with clay-rich beds, but remain unexplained. One of these low-resistivity beds occurs at the base of the sand interval at 1506–1508', and could be associated with a gas/water contact.

4. Conclusions

The work scope for this project included drilling and coring a well (Hot Ice No. 1) on Anadarko leases beginning in FY 2003 and completed in 2004. During the first drilling season (January 28, 2003 to April 30, 2003) the well was spudded and drilled to a depth of 1403 ft. Open-hole logging was conducted April 15-16, 2003.

Due to the onset of warmer weather, work was then suspended for the season. Operations at the site were continued after the tundra was re-opened the following season. Between January 12, 2004 and March 19, 2004, the well was drilled and cored to a final depth of 2300 ft.

Open-hole logging was conducted February 8–9, 2004. Measurements taken included array resistivity, litho-density, compensated neutron, dipole-acoustic, and spectral gamma ray. Results of log evaluation indicate that there is likely a gas-saturated, porous and permeable sandstone in the interval 1460–1510 ft. Here porosity of the sandstone beds ranges from 21% to 33%, and water saturation from 15% to 50% depending on reservoir quality. There are interbedded zones with very low resistivities through this interval that most likely are associated with clay-rich beds, but remain unexplained. One of these low-resistivity beds occurs at the base of the sand interval at 1506–1508 ft, and could be associated with a gas/water contact.

Appendix A includes summary open-hole and lithologic logs for Hot Ice No. 1.

5. References

(No references are cited in this report.)

Appendix A:
Summary Open-Hole and Lithologic Logs for Hot Ice No. 1 Well

Anadarko
Petroleum Corporation

LITHOLOGIC LOG

WELL NAME: **HOT ICE #1**	COMPLETION STATUS: **Suspended**

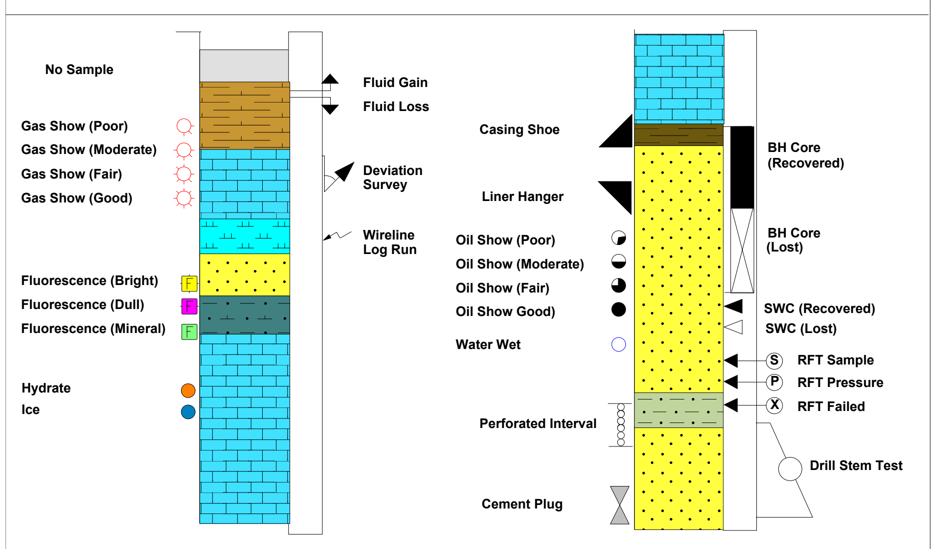
RIG COORDINATES: **NW/4, Sec. 30, T9N, R8E, Umiat Meridian, North Slope Borough, Alaska**	WELL CLASSIFICATION: **Exploratory**	RIG: **NANA/Dynatec UDR1500 Core Rig**
	TOTAL DEPTH: **2300 ft.**	HOLE SIZE: to / **5 7/8"** to **1400'** / **8 1/2"** to **1403'** / **5 7/8"** to **2300'** / to / to
CONCESSION:	FORMATION AT T.D.: **Mudstone**	CASING RECORD: **9 5/8"** at **107'** / **7"** at **1358'** / at / at / at / at
FIELD:	DATE SPUDDED: **03:25 01 April 2003**	
WATER DEPTH:	DATE T.D. REACHED: **6 February 2004**	
ELEVATION K.B.: **214' MSL (26' above GL of 188')**	DATE OPERATIONS COMPLETED:	
GEOLOGISTS: **J. Ebanks W. Zogg**	CONTRACTOR: **NANA/Dynatec**	MUD TYPES: to / to / to
ENGINEERS:	DATE: **25 June 2003**	
	REVISED: **25 February 2004**	

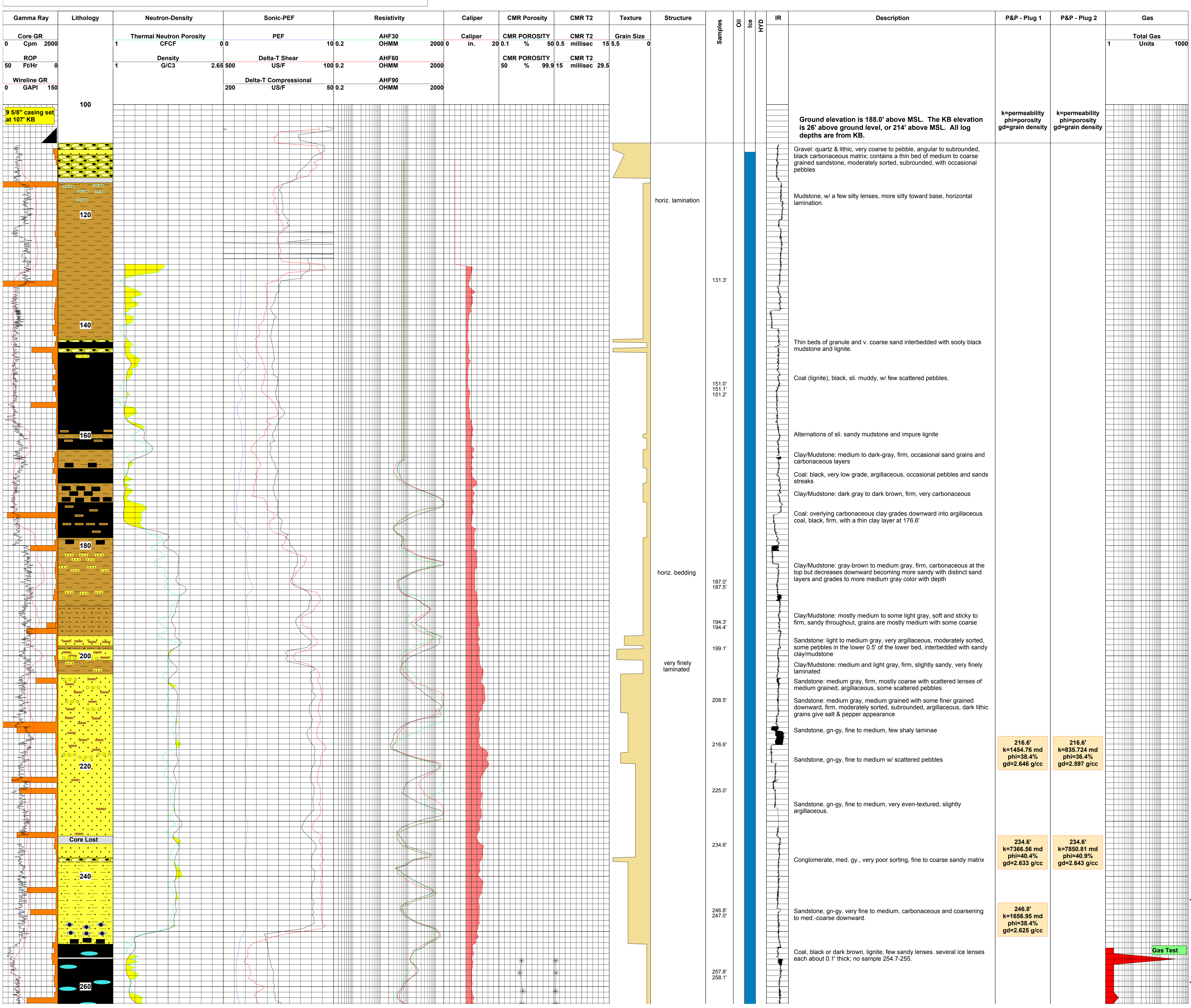
Legend of Lithological Symbols

Anhydrite	Coal	Igneous (Volcanic)	Salt (Na-Sodium)
Breccia	Conglomerate	Limestone	Sandstone
Breccia (Fault)	Dolomite	Limestone (Offset)	Sandstone (Calc)
Cement	Dolomite (Offset)	Limestone (Arg)	Sandstone (Silty)
Chalk	Dolomite (Arg)	Limestone (Dolomitic)	Shale
Chert	Dolomite (Calc)	Limestone (Sandy)	Shale (Sandy)
Clay	Gypsum	Limestone (Silty)	Siltstone
Clay (Sandy)	Igneous (Extrusive)	Marl	Siltstone (Calc)
Claystone	Igneous (Intrusive)	Metamorphic	Slate
Claystone (Calc)	Igneous (Plutonic)	Salt (K-Potassium)	Tuff

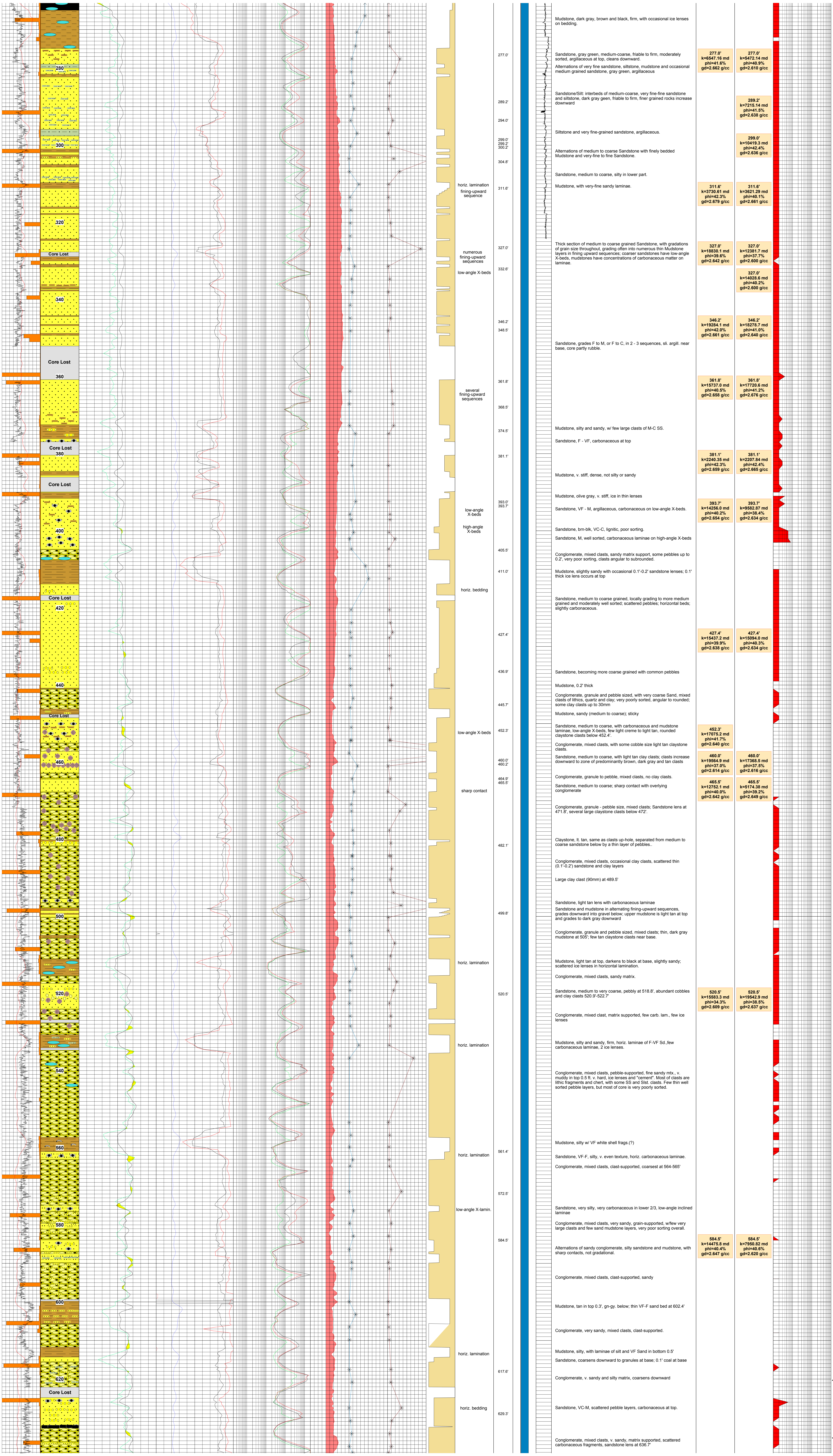
Anhydritic	Clay Clasts	Kaolinitic	Plant Debris
Argillaceous	Conglomeratic	Limestone Stringer	Pyritic
Belemnitic	Dolomitic	Marly	Salty
Bituminous	Root Zone	Micaceous	Sandy
Burrowed	Bioturbated	Micro-Fossiliferous	Shell Debris
Calcareous	Ferruginous	Oncolithic	Sideritic
Calcitic	Fossiliferous	Oolithic	Silty
Carbonaceous	Glauconitic	Pebbly	Spicular
Cherty	Gypsiferous	Pelletal	Stylolitic
Chloritic	Ice Lens	Peloidal	Tuffaceous

Legend of General Symbols





Hot Ice No. 1 Well (Sheet 1 of 7)



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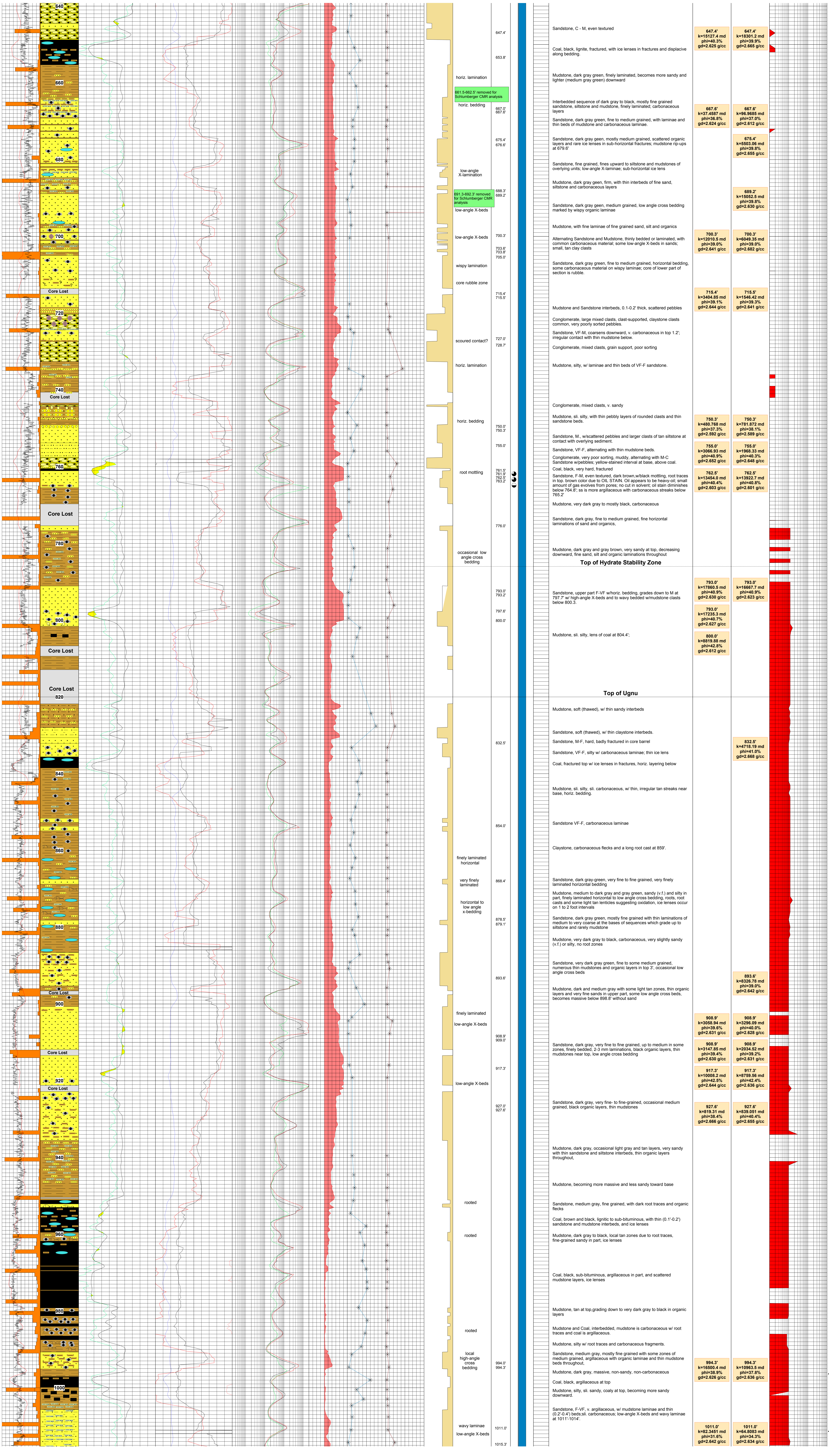

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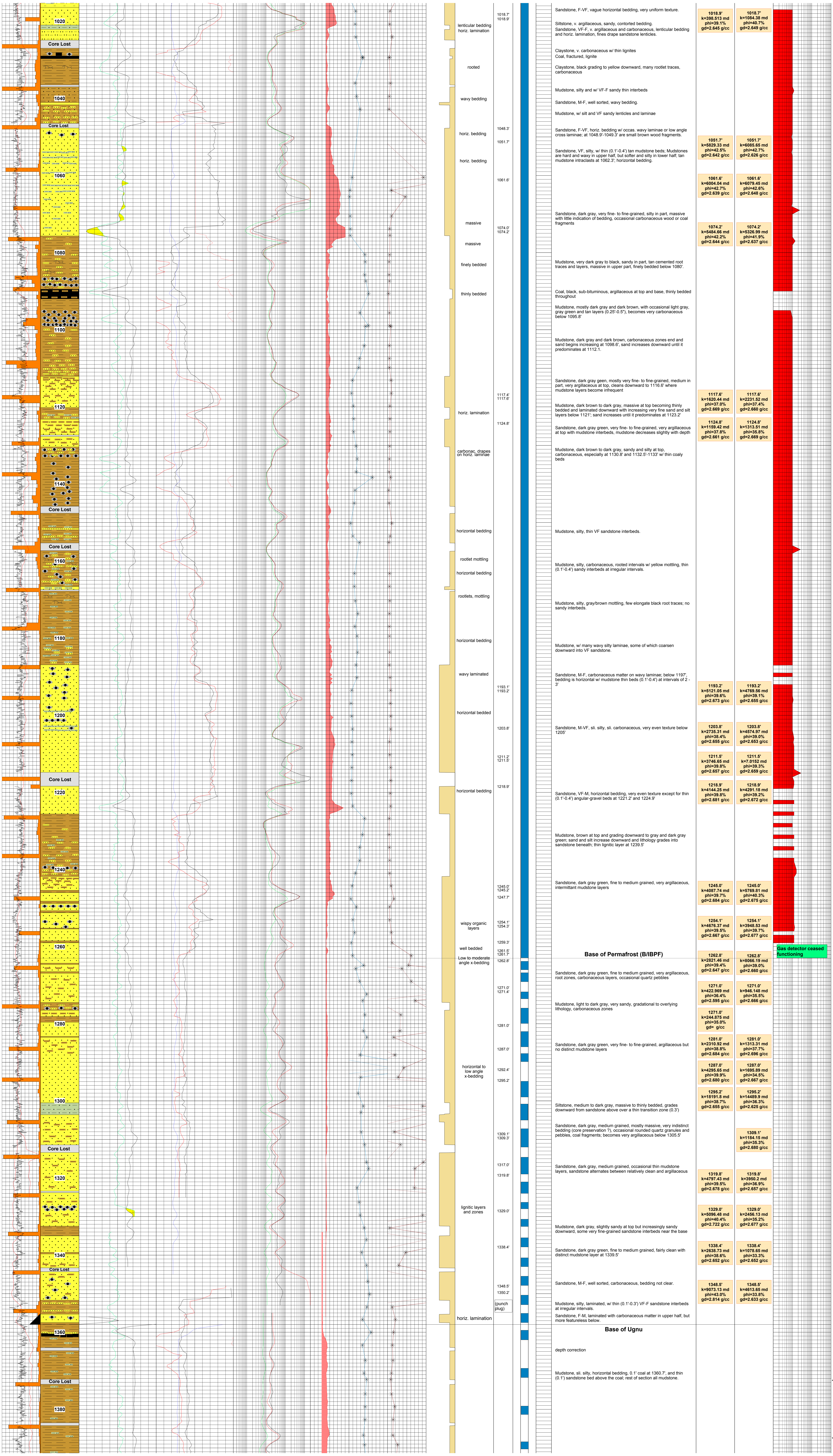
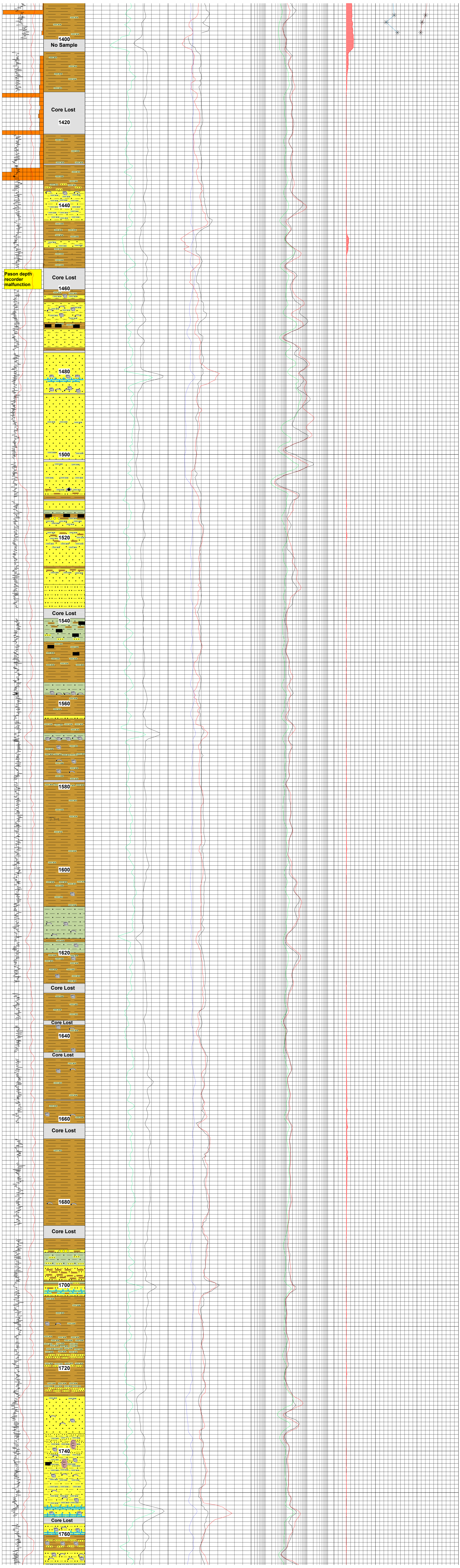


Hot Ice No. 1 Well (Sheet 4 of 7)



Bottom of the cored interval is 1400 ft. Three additional feet of rathole were drilled for casing purposes, but there was no sample recovery.

Mudstone, very dark gray, firm to sticky, horizontal bedding, slightly silty, no visible sand layers

Core lost 1412.7'-1422.9'; core evidently fell from tube during the first retrieval and was washed away on the second attempt to retrieve it.

horiz. lamin. — Mudstone, dk gn-gy, sli. silty, firm, vague horiz. lamin., lost core:1430'-30.3', (1430.3'-1432.9' soft, poor recovery, picked up on later run with core barrel).

no visible bedding — Sandstone, v. silty and argill., dk gn-gy, soft, few fossil frags. at top (unidentified small, chalky white shell frags.), no visible bedding.

Mudstone, dk gy-gn, sli. silty, firm, sli. fossilif

Sandstone, dk gy, VF-F, very argill., sli. calcareous.

Mudstone, dk gy-gn, silty, v. firm, sli. calcareous.

Lost core 1455.1'-1460.3'

horiz. lamin. — Alternating thin sandstone and mudstone, calcareous, fossilif.

Top of West Sak

sli. incl. lamin. / **massive** — Sandstone, soft, v. fossilif., calcareous, becomes massive downward.

Mudstone, v. silty and sli. sandy, firm, coal lamin. @ 1468.4', fossilif.

coarsening upward — Sandstone as previous but increasing silt and clay downward, grading to mudstone below

Mudstone, dark gray, very silty, firm

fining upward / **cemented** / **horiz. bedding** — Sandstone, dark gray, very fine to fine grained and very silty at top; generally unconsolidated to soft; coarsens and cleans downward becoming fine to medium grained with little or no clay or silt below 1479'; distinct shell layers down to 1485.5'; very hard cemented zone (calcareous?) with sharp boundaries at 1481.1'-1482.5'; sands are quartz-lithic, sub-ang to sub-rdd, immature

horiz. to massive — thin silty layer at 1492.1'; clay clast or concretion at 1497.4'

Sandstone, dark gray, fine to medium grained, friable to firm

horiz. to sli. inclined — thin, tan silty/clay layers below 1498.9', at 1-2/ft.

horiz. to sli. inclined — tan, silty layer 1505.9'

Zone of silty, argillaceous sandstone with carbonized wood fragments, 1508.5'-08.9'

Sandstone, very fine-fine grd, firm, silty and argillaceous

horizontal — Claystone, dark gray, silty, firm, massive

horizontal to massive — Siltstone, very dark gray, very argillaceous, firm, gas-bearing

Mudstone, very carbonaceous at the top, decreasing downward and becoming more silty and sandy, firm, gas-bearing

horizontal to very slightly inclined — Sandstone, very fine to fine grained, fining upward, firm, very silty and argillaceous at the top

Mudstone, dark gray, firm, grades down into sandstone below

horizontal to very slightly inclined — Sandstone, very fine to fine grained, very silty, dark gray, argillaceous, firm, fining upward to siltstone

fine horiz. laminations — Siltstone/Mudstone; v. dark gray, finely laminated, firm, carbonaceous in part, more silty to very fine sandy in lower part

fine horiz. laminations — Mudstone/Siltstone, very dark gray, firm, carbonaceous in part, increasing silt in lower part; locally appears to be a fissile, black shale

horiz. lamin. — Siltstone, VF sandy and clayey, firm, shell lag at 1557.7'

color mottled? — Silty mudstone, gray and dark gray mottled, firm

VF silty sandtone, soft, badly broken, too soft to plug

horiz. lamin. — Silty mudstone, soft, w/ siltstone interbed

Siltstone, dk. gn-gy, v. firm, packs off core barrel

horiz. lamin. — Mudstone, dk gn-gy, locally mottled, firm, siltstone interbed at 1572' and at 1579', few shelly layers above 1580'.

horiz. lamin.

carb. tubules (rootlets?)

horiz. bedding — Mudstone, dk gn-gy, sli. more silty than above, scattered shell fragments.

no visible bedding — Siltstone, clayey, no visible structure, firm to friable, scattered shell fragments, thin mudstone at 1616.6'.

horiz. lamin. (weak) — Mudstone, dk gy, v. silty, firm, grades upward into siltstone, friable, scattered shell frags., at 1627.3' is a large, irreg. calcite (?)concretion (?).

Claystone, v. sli. silty, firm to very firm, shell frags. at 1637.5', 1643.8' and 1648.6'.

Mudstone, dark to very dark gray, v. sli. silty, very firm, massive to very weak horizontal laminations, shell frags. at 1658.9'.

horizontal laminations — Mudstone, dark to very dark gray, v. sli. silty, very firm, massive to very weak horizontal laminations, shell frags. at 1680.4'.

Sandstone, dark gray, very fine grained, very firm, very silty, argillaceous, with occasional lithic pebbles up to 1 cm.

weak horiz. laminations — Siltstone, very dark gray, very argillaceous, firm, sandy in part grading to very fine grained sandstone, especially below 1695'

Sandstone, very dark gray, very fine grained, firm, very silty and argillaceous

Alternating Siltstone and mudstone layers, very dark gray, firm, weakly laminated, locally sandy

Sandstone, very fine grained, very silty, argillaceous, friable to firm; very hard cemented zone 1701.7'-1702.7'; thin, laminated mudstone 1701.6'-1701.7'

weak horiz. laminations — Mudstone, very dark gray, firm, weakly laminated, silty in part, especially 1712.6'-1714.5'; shell debris 1709.2'

Succession of fining upward sequences beginning with a very fine to fine and some medium grained sandstone, grading upward to siltstone and capped with thicker mudstone; all lithologies are dark gray and some show horizontal laminations, generally firm but some sands unconsolidated

horiz. lamin. — Sandstone, dk gy, F, v. well sorted, horiz. lamin., scattered shell frags., unconsolidated to soft, capped by ol.gn. mudst.

horiz. bedding / **bioturbation?** — Alternations (14) of F-VF dk.gy. Sand and dk.ol.gy Mudstone. Sand is soft, friable, Mudstone is soft, plastic, range in thickness from 0.1-1.4', and Mudstones from 0.1-1.2'. Scattered shell frags. carbonaceous frags. in Mdst. and Sands, possible bioturbation in some sands.

low-angle cross lamin. — Sandstone, lt.gy., VF, hard cemented, low angle cross lamin., sharp contacts above and below.

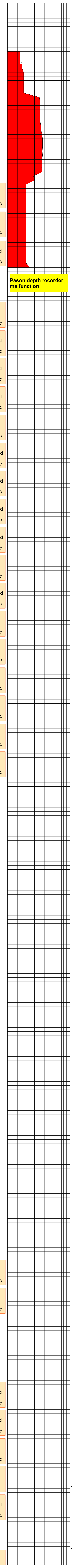
Sand, dk gy, VF-F, silty, unconsolidated

Sandstone, lt.gy., VF-F, hard cemented as at 1753.4 above

Mudstone, dk gy, soft to firm, w/3 thin, VF sand interbeds, several shelly layers at 1762-1762.5' and

Sand, VF, unconsolidated, silty, mollusk shell bed at 1766.7'

Depth	k	phi	gd	Depth	k	phi	gd
1438.6'	318.65 md	38.04%	2.660 g/cc	1438.7'	61.19 md	34.08%	2.671 g/cc
1442.6'	20.03 md	32.96%	2.697 g/cc	1442.7'	38.08 md	34.20%	2.711 g/cc
1449.5'	1744.47 md	36.17%	2.707 g/cc	1449.6'	1413.20 md	37.50%	2.698 g/cc
1467.6'	3.161 md	21.96%	2.538 g/cc	1467.7'	2.612 md	23.15%	2.560 g/cc
1472.0'	7211.14 md	40.51%	2.624 g/cc	1472.1'	6288.15 md	41.30%	2.649 g/cc
1477.6'	1186.64 md	38.42%	2.697 g/cc	1477.7'	1296.08 md	38.84%	2.690 g/cc
1480.1'	2310.76 md	38.97%	2.688 g/cc	1480.2'	2970.47 md	39.97%	2.687 g/cc
1481.4'	0.001 md	1.28%	2.679 g/cc	1481.8'	0.0001 md	1.09%	2.668 g/cc
1487.6'	16788.56 md	40.45%	2.647 g/cc	1487.7'	17524.23 md	40.68%	2.642 g/cc
1489.4'	17179.35 md	40.49%	2.670 g/cc	1489.4'	15288.69 md	40.54%	2.663 g/cc
1493.5'	11145.67 md	38.79%	2.634 g/cc	1493.6'	13098.20 md	43.94%	2.636 g/cc
1498.4'	21466.99 md	40.70%	2.653 g/cc	1498.4'	18431.27 md	39.88%	2.650 g/cc
1502.3'	10233.77 md	40.74%	2.625 g/cc	1502.4'	926.95 md	41.82%	2.632 g/cc
1506.0'	16597.42 md	43.17%	2.610 g/cc	1506.1'	16393.04 md	41.10%	2.644 g/cc
1517.2'	628.98 md	38.44%	2.694 g/cc	1517.3'	646.74 md	36.93%	2.689 g/cc
1520.2'	2.71 md	33.22%	2.714 g/cc	1520.3'	5.40 md	34.54%	2.717 g/cc
1525.3'	390.30 md	37.78%	2.699 g/cc	1525.4'	526.96 md	38.71%	2.695 g/cc
1528.7'	510.36 md	39.92%	2.719 g/cc	1528.8'	586.59 md	39.84%	2.723 g/cc
1530.6'	766.77 md	38.26%	2.714 g/cc	1530.7'	735.26 md	39.24%	2.720 g/cc
1535.3'	596.06 md	38.38%	2.707 g/cc	1535.4'	707.47 md	36.95%	2.710 g/cc
1697.0'	155.77 md	36.78%	2.725 g/cc	1697.2'	37.78 md	32.52%	2.708 g/cc
1701.9'	0.0017 md	10.19%	2.692 g/cc	1702.1'	0.0175 md	18.08%	2.704 g/cc
1730.1'	5211.21 md	40.86%	2.660 g/cc	1730.2'	4940.13 md	39.88%	2.681 g/cc
1734.8'	903.04 md	37.67%	2.706 g/cc	1734.9'	1313.90 md	38.48%	2.707 g/cc
1740.2'	3.523 md	31.89%	2.761 g/cc	1740.3'	2.681 md	32.19%	2.681 g/cc
1745.0'	144.07 md	35.17%	2.734 g/cc	1745.1'	20.26 md	%	g/cc
1750.1'	2101.71 md	35.52%	2.790 g/cc	1750.2'	1774.85 md	35.84%	2.789 g/cc
1754.8'	0.0004 md	2.21%	2.686 g/cc				
1758.4'	1005.92 md	[illegible]		1758.5'	761.66 md	[illegible]	



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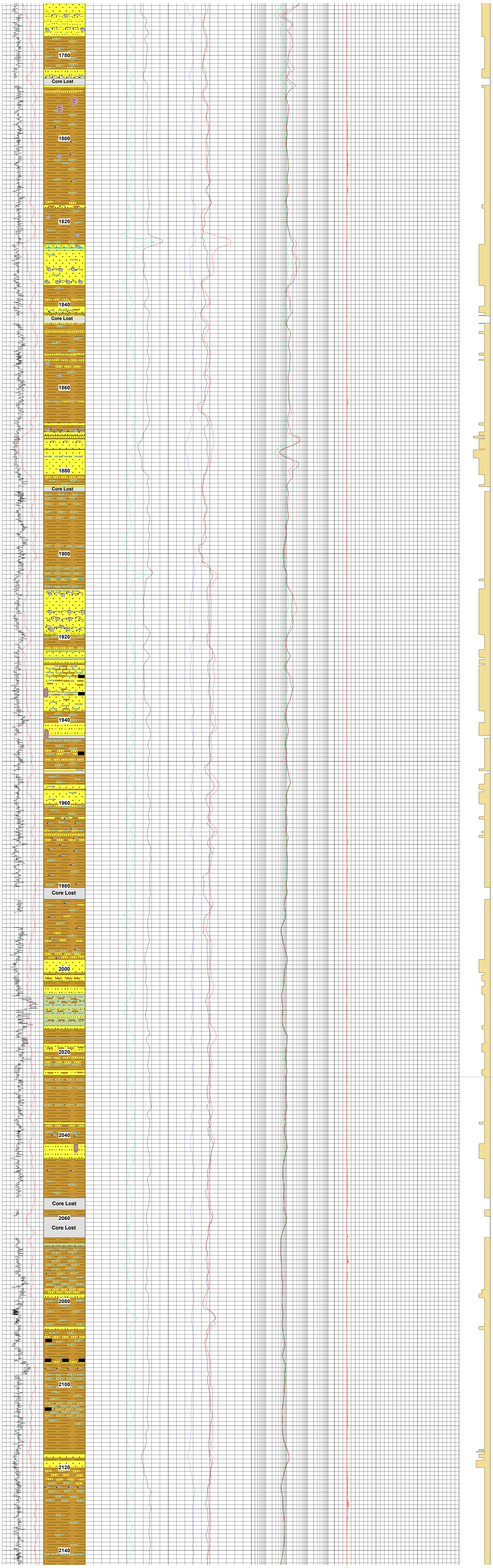
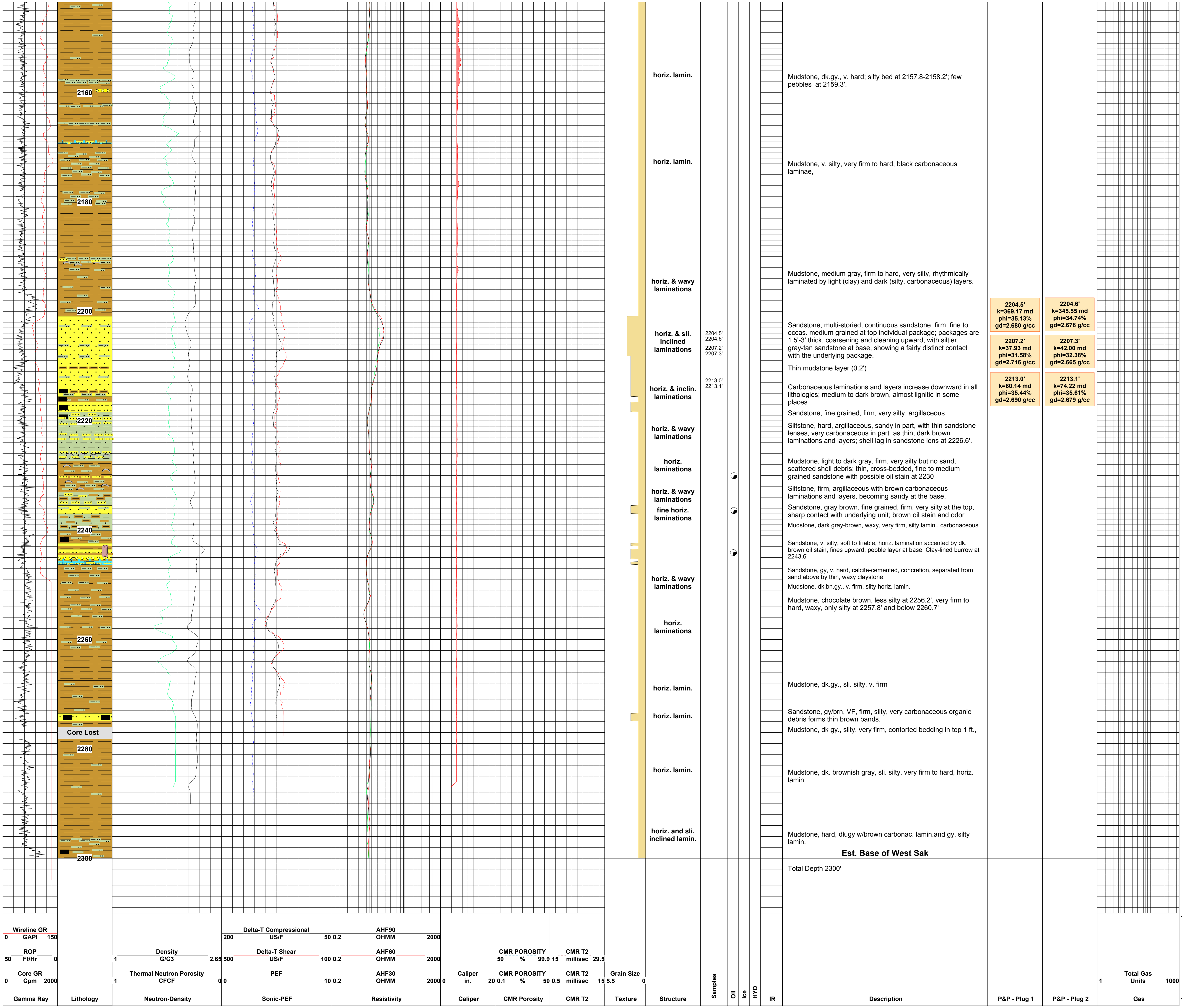


	1768.7' 1768.8'	Sand, VF, overlain by thin mudstone	phi=36.04% gd=2.700 g/cc	phi=36.87% gd=2.730 g/cc
sand-mud interbedding	1773.7' 1773.8'	Sand, unconsolidated to soft, and Mudstone, firm, in 7 interbedded couplets (Mudst. above SS). shelly layers at 1770' and 1773.9'	1768.8' k=3943.89 md phi=41.49% gd=2.703 g/cc	
		Mudstone, dk gy, silty, firm	1773.7' k=835.38 md phi=37.29% gd=2.717 g/cc	1773.8' k=1555.08 md phi=38.82% gd=2.700 g/cc
	1784.7'	Sand, VF, silty, soft, shell frags. at 1785.3'	1784.7' k=2559.50 md phi=37.55% gd=2.695 g/cc	1784.7' k=2673.66 md phi=38.99% gd=2.701 g/cc
bioturbation? horiz. lamin.		Mudstone, dk.gy. in top 3 ft., olive gy. below, firm; 2 thin Sands near top, dk.gy., v. silty.		
sli. inclined laminations	1800.0'	Mudstone, dk.ol.gy., sli. silty, few scatt. shell frags.		
horiz. lamin.		Mudstone, dk. gy., sli.silty, firm, horiz. lamin., grades down into the silty sand below.		
		Sandstone, very fine grained, friable to firm, very silty, argillaceous with scattered shell fragments		
		Mudstone, very dark gray, firm, slightly silty, scattered shell fragments, sharp contact with sandstone above and somewhat gradational contact with sandstone below		
fine horiz. laminations		Sandstone, very dark gray, quartz-lithic, fine grained, hard, calcareous cemented, preserved whole shells		
	1828.0'	Sandstone, very dark gray, fine grained, well sorted, fossiliferous, as previous but completely uncemented, soft and friable; shell zones at 1831.6' and 1835' to 1835.3'; sharp contact with underlying mudstone.	1828.0' k=1245.25 md phi=39.25% gd=2.708 g/cc	1828.0' k=1259.27 md phi=39.25% gd=2.731 g/cc
inclined laminations	1833.4'	Mudstone, very dark gray, firm, slightly silty, sharp contact with overlying sandstone; thin sandstone layer at 1838.35'-1838.5'	1833.4' k=711.34 md phi=37.96% gd=2.723 g/cc	1833.4' k=710.32 md phi=37.94% gd=2.725 g/cc
fine horiz. laminations		Sandstone, very dark gray, soft, silty and argillaceous, shell frags at 1841.6'		
		Lost core interval was probably sandstone		
		Mudstone, very dark gray, firm, slightly sandy and silty, with sandstone zones at several intervals, shell fragments		
horiz. lamin.				
	1873.9'	Interbedded thin sands, soft, and silty claystones, firm, abund. fossil shells (mollusks); clay ironstone concret. at 1873.3'. Hard, yellow claystone layer at 1874.8' irreg. in thickness.	1873.9' k=11309.38 md phi=39.34% gd=2.654 g/cc	1873.9' k=12437.90 md phi=38.80% gd=2.663 g/cc
horiz. and low-angle cross lamin.	1877.8'	Sand, M-VF, soft, coarsens upward, few clay-rich streaks, lamin. is both horiz. and low-angle cross lam.	1877.8' k=969.88 md phi=35.55% gd=2.705 g/cc	
		Mudstone, dk.ol.gy., firm, silty w/few sandy lamin.; thin sand at 1883.4' is soft and has v. carbonac. laminae at base, possibly burrowed; sharp contact w/underlying mudstone.		
horiz. lamin.		Mudstone, dk.gy., very firm, silty streaks within claystone interval (not dissem. silt), few carbonac. streaks (black).		
		Mudstone, dk.gy., silty; hard cemented sandstone bed at 1906.1-06.5'		
horiz. lamin. at top	1911.8'	Sand, VF-F, dk.gy., friable, v. silty at top, shell frag. beds at 1903.5, 1914.8', 15.8, 17.4, 18.1'; thin pebble layer at base	1911.8' k=706.88 md phi=37.01% gd=2.718 g/cc	1911.8' k=638.26 md phi=36.64% gd=2.736 g/cc
horiz. lamin.	1918.1' 1918.4'	Mudstone, ol.gy./dk.gy., silty in top 1', thin silty sand bed at 1922.8'.	1918.1' k=1898.98 md phi=39.10% gd=2.695 g/cc	1918.4' k=2014.50 md phi=39.76% gd=2.708 g/cc
	1924.2'	Sandstone, VF-F, dk.gy., soft, friable, thin mudst. at 1923.3-.4' Siltstone, thin, gy, hard, vertical fracture Sandstone, dk.gy., firm, thin, v. silty and clayey Mudstone, thin, dk.gy., firm, silty, carbonaceous lam. at base inclined.	1924.2' k=1824.46 md phi=38.98% gd=2.705 g/cc	1924.2' k=2738.59 md phi=37.80% gd=2.715 g/cc
burrowed claystone	1930.1' 1933.0'	Sandstone, VF-F, dk.gy., well sorted, soft, friable, numerous thin clayst. lamin. or very clayey sand, carbonac. lamin. at 1929.4' and 1933.7' inclined.	1930.1' k=1094.21 md phi=35.87% gd=2.721 g/cc	1930.1' k=1377.33 md phi=37.41% gd=2.712 g/cc
horiz. lamin.		Mudstone, silty, firm, sli. carbonaceous	1933.0' k=1127.08 md phi=37.86% gd=2.710 g/cc	1933.0' k=995.23 md phi=36.74% gd=2.723 g/cc
burrowed?	1941.0' 1941.1'	Sandstone, VF-F, soft, silty, burrowed (?), claystone lamin. at 1943.6'	1941.0' k=363.65 md phi=36.28% gd=2.729 g/cc	1941.0' k=287.83 md phi=34.63% gd=2.723 g/cc
horiz. lamin.		Mudstone and claystone, dk.ol.gy., firm, silty and sli. sandy, horiz. lamin., carbonaceous at 1948', sand lens at 1950', silt dissem.	1941.1' k=497.35 md phi=37.18% gd=2.730 g/cc	
weak horiz. laminations		Sandstone, VF, dk.gy., soft/friable, well sorted, sli. silty		
		Mudstone, very dark gray, firm, slightly silty		
massive ?	1959.0'	Sandstone, very dark gray, fine grained, soft to firm, well sorted, slightly silty; thin mudstone interval 1956.8'-59.3'	1959.0' k=1.38 md phi=31.92% gd=2.727 g/cc	1959.0' k=12.34 md phi=29.99% gd=2.738 g/cc
distinct horiz. laminations		Mudstone, very dark gray, firm, very sandy and silty above 1961', slightly silty below with well formed, light and dark gray laminations		
		Sandstone, very dark gray, fine grained, soft to firm, very silty & argillaceous, scattered shell debris		
distinct horiz. laminations		Mudstone, very dark gray, firm, slightly silty, scattered shell debris, sandy & silty zones at 66.8'-67.2', 67.8'-68.3', 68.8'-		
predom. horiz. laminations		Mudstone, medium gray, with light and dark gray , firm, mostly horizontal laminations, very slightly silty, sparsely scattered shell debris; inclined laminations 1978.7'-79.2'; possible soft sediment deformation or rippling in light gray clay layer at 1979.6'.		
horiz. & sub-horiz. laminations		Mudstone, medium gray, with light and darker gray laminations, firm, slightly silty with occasional very thin laminations of very fine to fine grained sandstone, sparse shell debris		
horiz. & inclined laminations		Mudstone, medium gray, with light and dark gray to black (carbonaceous) laminations, firm; occas. tan, hard cemented clay streaks, occas. shell debris; increas. silt and sand downward		
horiz. laminations	1999.0'	Sandstone, fine grained, firm, well sorted with occas. silt, clay, and tan, hard clay laminations; tiny shell fragment debris		
		Sandstone, medium gray, fine grained, firm, silty		
horiz. laminations		Siltstone, light to medium gray, hard, argillaceous, occas. sandy; light and dark horiz. laminations; possible root zone at 2007.9'.		
horiz. & sli. inclined laminations				
horiz. & wavy laminations	2019.0'	Sequence of silty, sandy mudstones, sandy, argillaceous siltstones and silty, argillaceous, fine grained sandstones; occas. tan, hard clay streaks and carbonaceous laminations; sandstones are generally firm and siltstones and mudstones are firm to hard.	2019.0' k=69.64 md phi=35.76% gd=2.747 g/cc	
horiz. laminations		**Base of Hydrate Stability Zone**		
horiz. & wavy laminations	2030.0'	Mudstone, medium to dark gray, silty, firm, light & dark laminations		
		Mudstone, v. dk.gy., very firm, sandy in top 0.5', grades into thin, soft sand above and silty, VF, firm sand below, shell frags. at 2040.5'.		
burrows ?		Sandstone, VF, firm, silty, may be burrowed		
horiz. lamin.		Mudstone, dk.ol.gy., firm to plastic, several silty laminae, shell frags at 2048.3'		
		Two intervals of lost core in mudstone.		
weak horiz. laminations		Siltstone, dark gray, firm, argillaceous, fairly sharp contact with overlying mudstone		
horiz. laminations		Mudstone, medium gray, firm to hard, extremely silty, with horizontal and wavy, light and dark laminations		
		Sandstone, dark gray, fine grained, firm, silty, argillaceous		
		Mudstone, dark gray, firm, silty, with hard, tan clay concretions or clasts (ovoid to sub-spherical), esp. at 2079.4' & 80.8'		
horiz. laminations		Sandstone, dark gray, fine grained, hard to firm, well sorted, slightly silty, hard cemented top		
		Mudstone, medium to dark gray, firm, silty, sandy in part, esp. 2088.4'-88.6'; some black carbonaceous laminations at 2089.6'.		
horiz. & inclin. laminations		Mudstone, medium to dark gray, firm, silty, sandy; dark carbonaceous laminations (coaly?) overlie a 0.1' thick med-cse sandstone 2094.5'-94.9'; shell zone at 2096.0'.		
		Mudstone, medium to dark gray, firm, silty, with a rythmically layered zone of cm and 0.5 cm beds of mudstone and siltstone from 2104.7'-2107.8'; some dark carbonaceous layers at 2106'.		
cross bedded horiz. lamin.		Sandstone, brown, fine to medium grained, firm, well sorted, mostly very well bedded with fine laminations of silt and clay; uppermost sand is cross bedded, lower zones are horizontal; upper part of lower zone is massive down to 2119.3' and finely bedded below; good brown oil stain and odor from all zones		
		Mudstone, light to dark gray, firm, silty throughout, sandy in upper part with occas. oil stained sands lenses, <0.1' thick; shell zone (lag) at 2124.8' at contact with a silty mudstone below (no sand lenses).		
horiz. lamin.		Mudstone, dk.ol.gy., firm to very firm, silty, hard "streak" 2130'-2130.6'		
		Mudstone, dk.bn.gy., sli. silty, v. firm		



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