Anadarko Petroleum Corporation Hot Ice No. 1 well log along with corresponding report entitled: Coring for Methane-Hydrate in shallow sands of the Sagavanirkick and Canning Formations, North Slope Alaska – Phase II Geologic Description along with Phase I Progress and Geologic Description.

Received November 2008

Total of 36 pages in report (have data CD)

Alaska Geologic Materials Center Data Report No. 356

Anadarko
Petroleum Corporation

LITHOLOGIC LOG

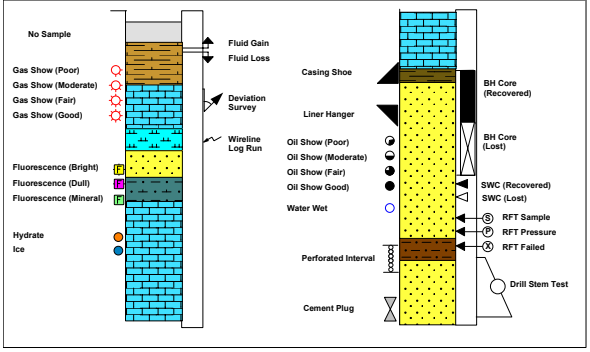
WELL NAME: **HOT ICE #1**	COMPLETION STATUS: **Suspended**	
RIG COORDINATES: **NW/4, Sec. 30, T9N, R8E Umiat Meridian North Slope Borough Alaska**	WELL CLASSIFICATION: **Exploratory**	RIG: **NANA/Dynatec UDR1500 Core Rig**
	TOTAL DEPTH: **1403 ft.**	HOLE SIZE: **5 7/8"** to **1400'** **8 1/2"** to **1403'**
CONCESSION:	FORMATION AT T.D.: **Mudstone**	
FIELD:	DATE SPUDDED: **03:25 01 April 2003**	
WATER DEPTH:	DATE T.D. REACHED: **13 April 2003**	CASING RECORD: **9 5/8"** at **107'** **7"** at **1358'** **4 1/2"** at
ELEVATION K.B.: **214' MSL (26' above GL of 188')**	DATE OPERATIONS COMPLETED:	
GEOLOGISTS: **J. Ebanks** **W. Zogg**	CONTRACTOR: **NANA/Dynatec**	MUD TYPES:
ENGINEERS:	DATE: **25 June 2003**	
	REVISED: **30 January 2004**	

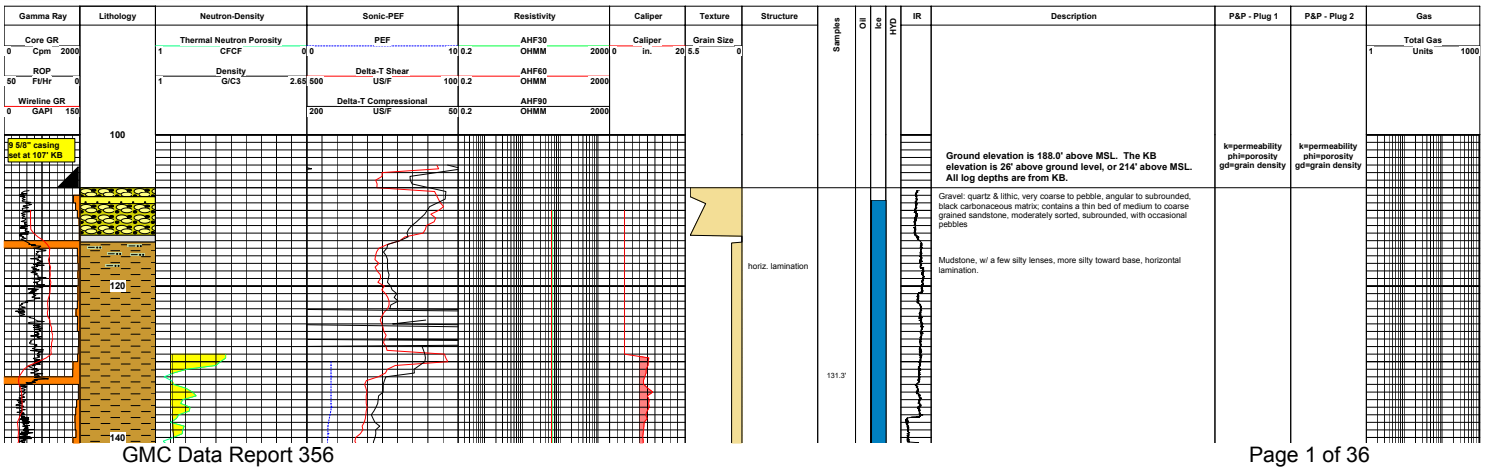
Legend of Lithological Symbols

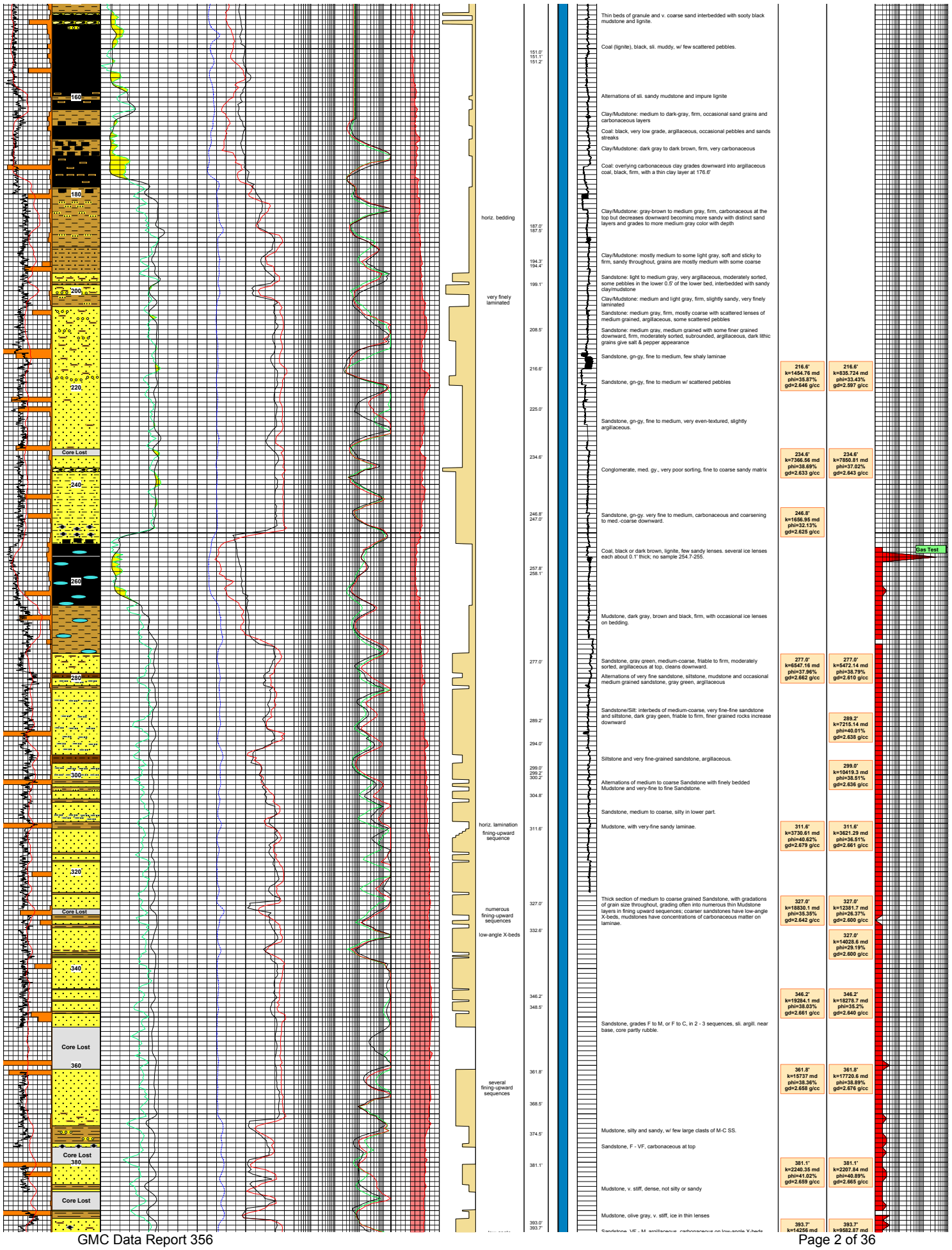
Anhydrite	Coal	Igneous (Volcanic)	Salt (Na-Sodium)
Breccia	Conglomerate	Limestone	Sandstone
Breccia (Fault)	Dolomite	Limestone (Offset)	Sandstone (Calc)
Cement	Dolomite (Offset)	Limestone (Arg)	Sandstone (Silty)
Chalk	Dolomite (Arg)	Limestone (Dolomitic)	Shale
Chert	Dolomite (Calc)	Limestone (Sandy)	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	Epidotic	Micaceous	Sandy
Burrowed	Feldspathic	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







151.0'
151.1'
151.2'

Thin beds of granule and v. coarse sand interbedded with sooty black mudstone and lignite.

Coal (lignite), black, sli. muddy, w/ few scattered pebbles.

Alternations of sli. sandy mudstone and impure lignite

Clay/Mudstone: medium to dark-gray, firm, occasional sand grains and carbonaceous layers

Coal: black, very low grade, argillaceous, occasional pebbles and sands streaks

Clay/Mudstone: dark gray to dark brown, firm, very carbonaceous

Coal: overlying carbonaceous clay grades downward into argillaceous coal, black, firm, with a thin clay layer at 176.6'

187.0'
187.5'

Clay/Mudstone: gray-brown to medium gray, firm, carbonaceous at the top but decreases downward becoming more sandy with distinct sand layers and grades to more medium gray color with depth

194.3'
194.4'

Clay/Mudstone: mostly medium to some light gray, soft and sticky to firm, sandy throughout, grains are mostly medium with some coarse

199.1'

Sandstone: light to medium gray, very argillaceous, moderately sorted, some pebbles in the lower 0.5' of the lower bed, interbedded with sandy clay/mudstone

Clay/Mudstone: medium and light gray, firm, slightly sandy, very finely laminated

Sandstone: medium gray, firm, mostly coarse with scattered lenses of medium grained, argillaceous, some scattered pebbles

208.5'

Sandstone: medium gray, medium grained with some finer grained downward, firm, moderately sorted, subrounded, argillaceous, dark lithic grains give salt & pepper appearance

Sandstone, gn-gy, fine to medium, few shaly laminae

216.6'

Sandstone, gn-gy, fine to medium w/ scattered pebbles

216.6'
k=1454.76 md
phi=35.87%
gd=2.646 g/cc

216.6'
k=835.724 md
phi=33.43%
gd=2.597 g/cc

225.0'

Sandstone, gn-gy, fine to medium, very even-textured, slightly argillaceous.

234.6'

Conglomerate, med. gy., very poor sorting, fine to coarse sandy matrix

234.6'
k=7366.56 md
phi=38.69%
gd=2.633 g/cc

234.6'
k=7850.81 md
phi=37.02%
gd=2.643 g/cc

246.8'
247.0'

Sandstone, gn-gy. very fine to medium, carbonaceous and coarsening to med.-coarse downward.

246.8'
k=1656.95 md
phi=32.13%
gd=2.625 g/cc

Coal, black or dark brown, lignite, few sandy lenses. several ice lenses each about 0.1" thick; no sample 254.7-255.

257.8'
258.1'

Mudstone, dark gray, brown and black, firm, with occasional ice lenses on bedding.

277.0'

Sandstone, gray green, medium-coarse, friable to firm, moderately sorted, argillaceous at top, cleans downward.

Alternations of very fine sandstone, siltstone, mudstone and occasional medium grained sandstone, gray green, argillaceous

277.0'
k=6547.16 md
phi=37.96%
gd=2.662 g/cc

277.0'
k=5472.14 md
phi=38.79%
gd=2.610 g/cc

289.2'

Sandstone/Silt: interbeds of medium-coarse, very fine-fine sandstone and siltstone, dark gray geen, friable to firm, finer grained rocks increase downward

289.2'
k=7215.14 md
phi=40.01%
gd=2.638 g/cc

294.0'

Siltstone and very fine-grained sandstone, argillaceous.

299.0'
299.2'
300.2'

299.0'
k=10419.3 md
phi=38.51%
gd=2.636 g/cc

Alternations of medium to coarse Sandstone with finely bedded Mudstone and very-fine to fine Sandstone.

304.8'

Sandstone, medium to coarse, silty in lower part.

311.6'

Mudstone, with very-fine sandy laminae.

311.6'
k=3730.61 md
phi=40.62%
gd=2.679 g/cc

311.6'
k=3621.29 md
phi=36.51%
gd=2.661 g/cc

327.0'

Thick section of medium to coarse grained Sandstone, with gradations of grain size throughout, grading often into numerous thin Mudstone layers in fining upward sequences; coarser sandstones have low-angle X-beds, mudstones have concentrations of carbonaceous matter on laminae.

327.0'
k=18830.1 md
phi=35.35%
gd=2.642 g/cc

327.0'
k=12381.7 md
phi=26.37%
gd=2.600 g/cc

332.6'

327.0'
k=14028.6 md
phi=29.19%
gd=2.600 g/cc

346.2'
348.5'

346.2'
k=19284.1 md
phi=38.03%
gd=2.661 g/cc

346.2'
k=18278.7 md
phi=35.2%
gd=2.640 g/cc

Sandstone, grades F to M, or F to C, in 2 - 3 sequences, sli. argill. near base, core partly rubble.

361.8'

361.8'
k=15737 md
phi=38.36%
gd=2.658 g/cc

361.8'
k=17720.6 md
phi=38.89%
gd=2.676 g/cc

368.5'

Mudstone, silty and sandy, w/ few large clasts of M-C SS.

374.5'

Sandstone, F - VF, carbonaceous at top

381.1'

381.1'
k=2240.35 md
phi=41.02%
gd=2.659 g/cc

381.1'
k=2207.84 md
phi=40.89%
gd=2.665 g/cc

Mudstone, v. stiff, dense, not silty or sandy

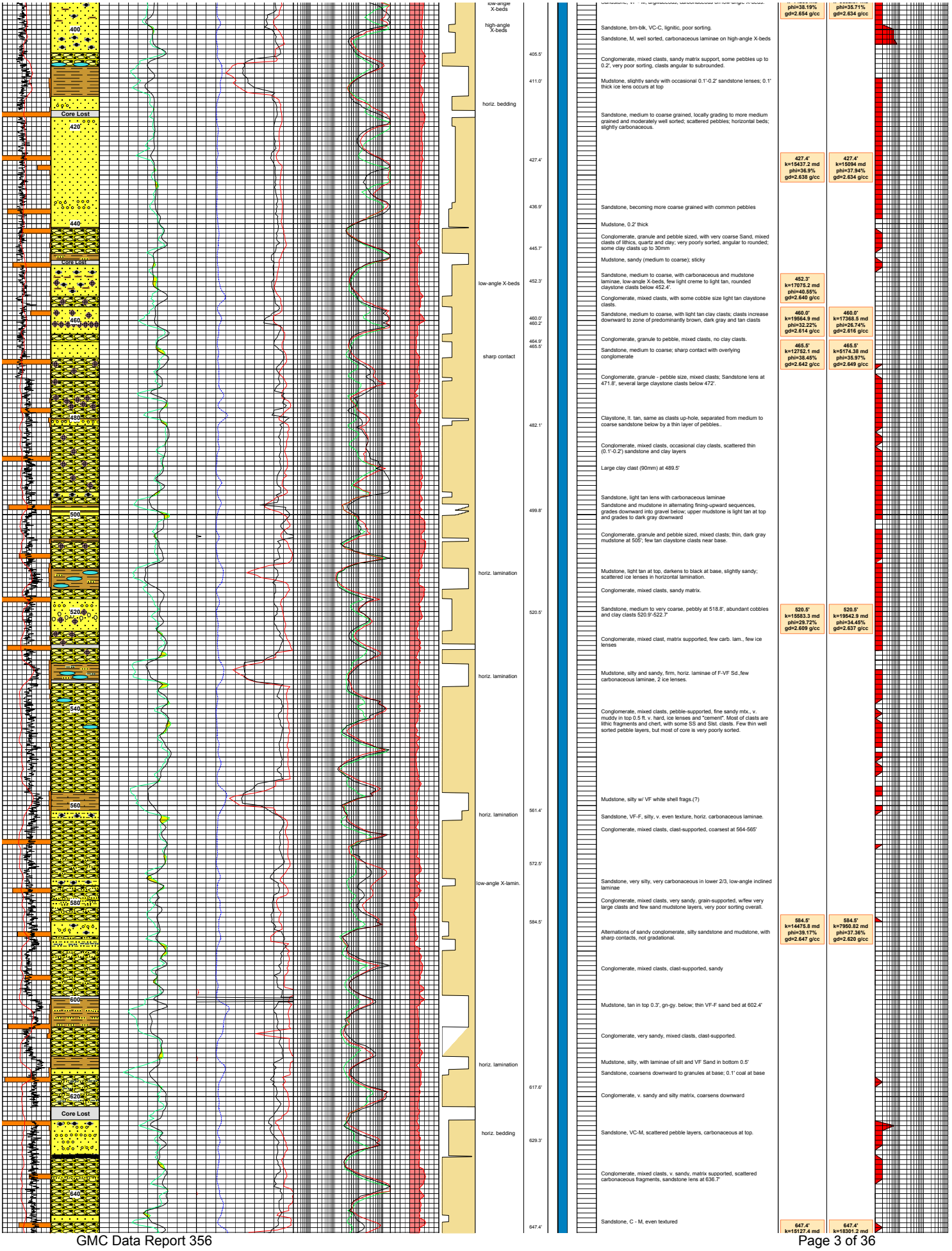
Mudstone, olive gray, v. stiff, ice in thin lenses

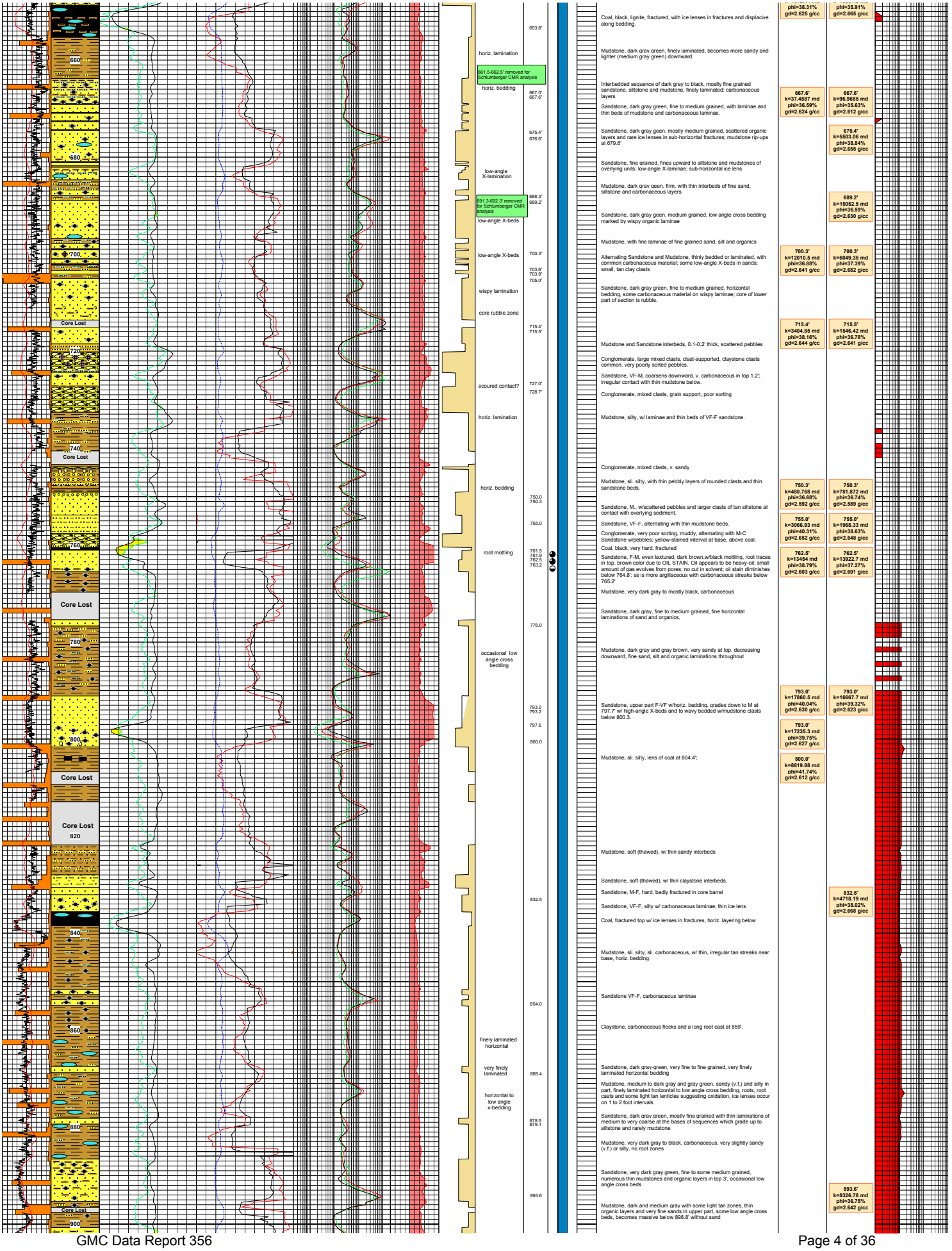
393.0'
393.7'

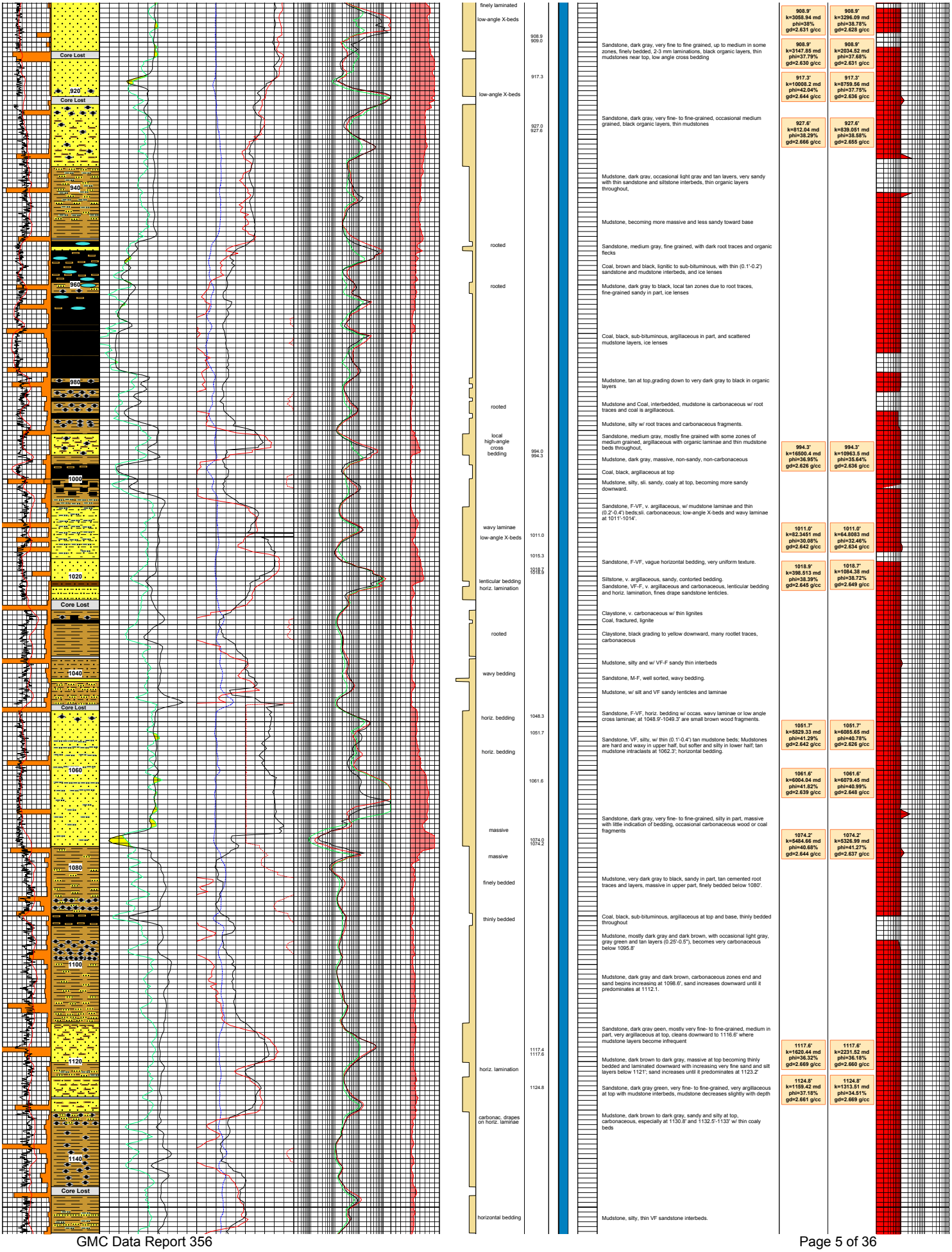
393.7'
k=14256 md

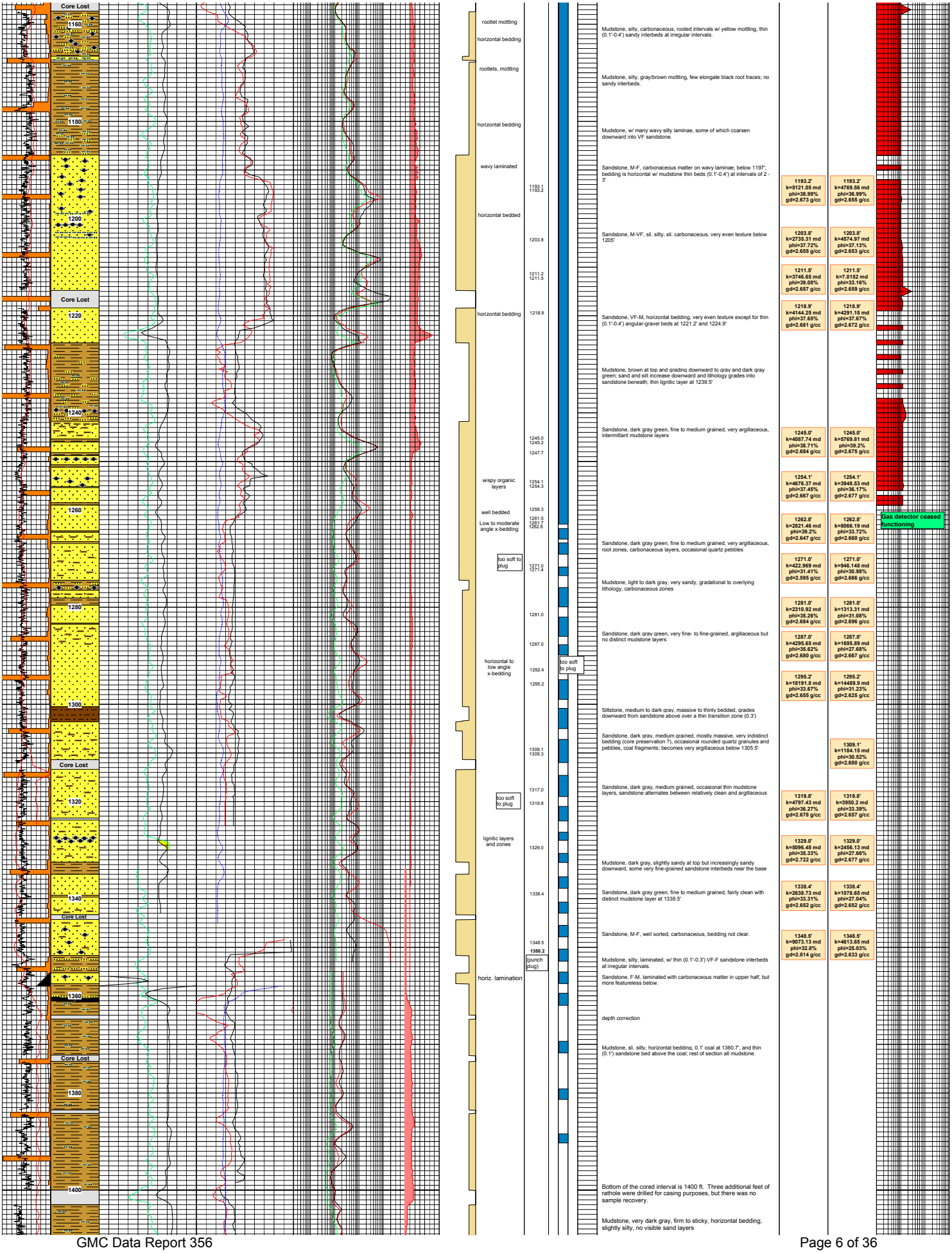
393.7'
k=9882.87 md

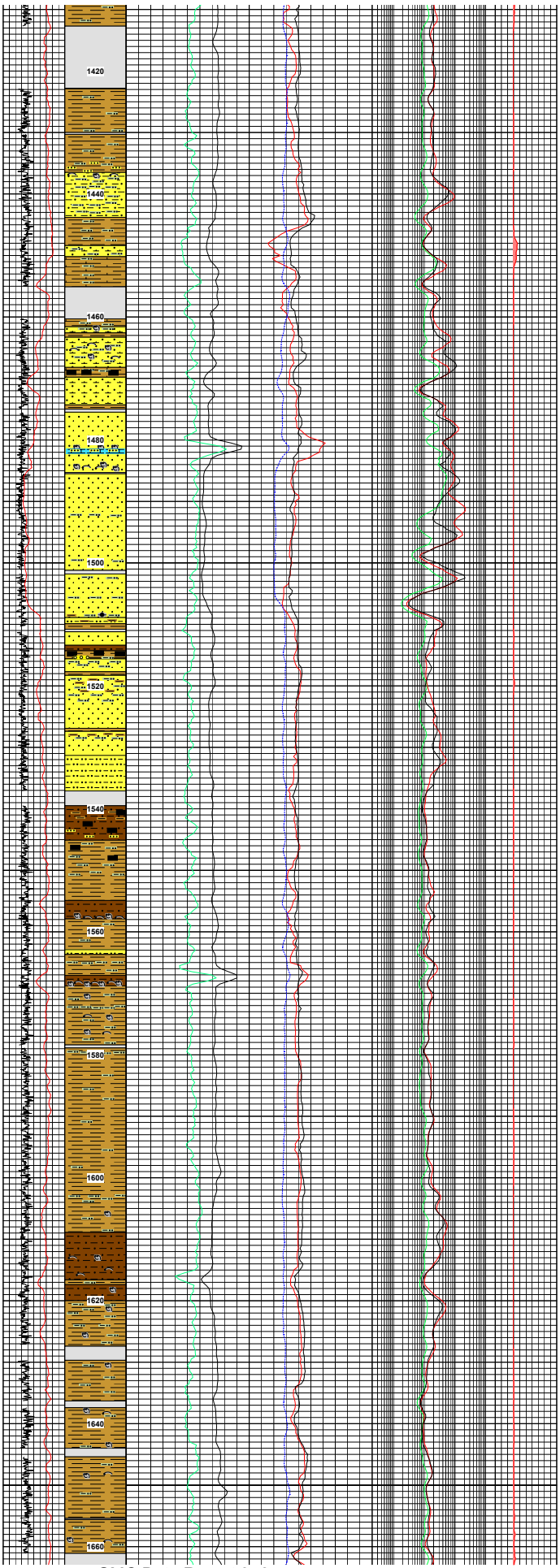
Sandstone, VF - M, argillaceous, carbonaceous on low-angle X-beds


Core Lost
Core Lost
Core Lost
low-angle X-beds
high-angle X-beds
horiz. bedding
low-angle X-beds
sharp contact
horiz. lamination
horiz. lamination
horiz. lamination
low-angle X-lamin.
horiz. lamination
horiz. bedding
405.5'
411.0'
427.4'
436.9'
445.7'
452.3'
460.0'
460.2'
464.9'
465.5'
482.1'
499.8'
520.5'
561.4'
572.5'
584.5'
617.6'
629.3'
647.4'
Sandstone, brn-blk, VC-C, lignitic, poor sorting.
Sandstone, M, well sorted, carbonaceous laminae on high-angle X-beds
Conglomerate, mixed clasts, sandy matrix support, some pebbles up to 0.2', very poor sorting, clasts angular to subrounded.
Mudstone, slightly sandy with occasional 0.1'-0.2' sandstone lenses; 0.1' thick ice lens occurs at top
Sandstone, medium to coarse grained, locally grading to more medium grained and moderately well sorted; scattered pebbles; horizontal beds; slightly carbonaceous.
427.4' k=15437.2 md phi=36.9% gd=2.638 g/cc
427.4' k=15094 md phi=37.94% gd=2.634 g/cc
Sandstone, becoming more coarse grained with common pebbles
Mudstone, 0.2' thick
Conglomerate, granule and pebble sized, with very coarse Sand, mixed clasts of lithics, quartz and clay; very poorly sorted, angular to rounded; some clay clasts up to 30mm
Mudstone, sandy (medium to coarse); sticky
Sandstone, medium to coarse, with carbonaceous and mudstone laminae, low-angle X-beds, few light creme to light tan, rounded claystone clasts below 452.4'.
452.3' k=17075.2 md phi=40.55% gd=2.649 g/cc
Conglomerate, mixed clasts, with some cobble size light tan claystone clasts.
Sandstone, medium to coarse, with light tan clay clasts; clasts increase downward to zone of predominantly brown, dark gray and tan clasts
460.0' k=19564.9 md phi=32.22% gd=2.614 g/cc
460.0' k=17368.5 md phi=26.74% gd=2.616 g/cc
Conglomerate, granule to pebble, mixed clasts, no clay clasts.
Sandstone, medium to coarse; sharp contact with overlying conglomerate
465.5' k=12752.1 md phi=38.45% gd=2.642 g/cc
465.5' k=5174.38 md phi=35.97% gd=2.649 g/cc
Conglomerate, granule - pebble size, mixed clasts; Sandstone lens at 471.8', several large claystone clasts below 472'.
Claystone, lt. tan, same as clasts up-hole, separated from medium to coarse sandstone below by a thin layer of pebbles..
Conglomerate, mixed clasts, occasional clay clasts, scattered thin (0.1'-0.2') sandstone and clay layers
Large clay clast (90mm) at 489.5'
Sandstone, light tan lens with carbonaceous laminae
Sandstone and mudstone in alternating fining-upward sequences, grades downward into gravel below; upper mudstone is light tan at top and grades to dark gray downward
Conglomerate, granule and pebble sized, mixed clasts; thin, dark gray mudstone at 505'; few tan claystone clasts near base.
Mudstone, light tan at top, darkens to black at base, slightly sandy; scattered ice lenses in horizontal lamination.
Conglomerate, mixed clasts, sandy matrix.
Sandstone, medium to very coarse, pebbly at 518.8', abundant cobbles and clay clasts 520.9'-522.7'
520.5' k=15583.3 md phi=29.72% gd=2.609 g/cc
520.5' k=19542.9 md phi=34.45% gd=2.637 g/cc
Conglomerate, mixed clast, matrix supported, few carb. lam., few ice lenses
Mudstone, silty and sandy, firm, horiz. laminae of F-VF Sd.,few carbonaceous laminae, 2 ice lenses.
Conglomerate, mixed clasts, pebble-supported, fine sandy mtx., v. muddy in top 0.5 ft. v. hard, ice lenses and "cement". Most of clasts are lithic fragments and chert, with some SS and Slst. clasts. Few thin well sorted pebble layers, but most of core is very poorly sorted.
Mudstone, silty w/ VF white shell frags.(?)
Sandstone, VF-F, silty, v. even texture, horiz. carbonaceous laminae.
Conglomerate, mixed clasts, clast-supported, coarsest at 564-565'
Sandstone, very silty, very carbonaceous in lower 2/3, low-angle inclined laminae
Conglomerate, mixed clasts, very sandy, grain-supported, w/few very large clasts and few sand mudstone layers, very poor sorting overall.
584.5' k=14475.8 md phi=39.17% gd=2.647 g/cc
584.5' k=7950.82 md phi=37.36% gd=2.620 g/cc
Alternations of sandy conglomerate, silty sandstone and mudstone, with sharp contacts, not gradational.
Conglomerate, mixed clasts, clast-supported, sandy
Mudstone, tan in top 0.3', gn-gy. below; thin VF-F sand bed at 602.4'
Conglomerate, very sandy, mixed clasts, clast-supported.
Mudstone, silty, with laminae of silt and VF Sand in bottom 0.5'
Sandstone, coarsens downward to granules at base; 0.1' coal at base
Conglomerate, v. sandy and silty matrix, coarsens downward
Sandstone, VC-M, scattered pebble layers, carbonaceous at top.
Conglomerate, mixed clasts, v. sandy, matrix supported, scattered carbonaceous fragments, sandstone lens at 636.7'
Sandstone, C - M, even textured
647.4' k=151127.4 md
647.4' k=183301.2 md

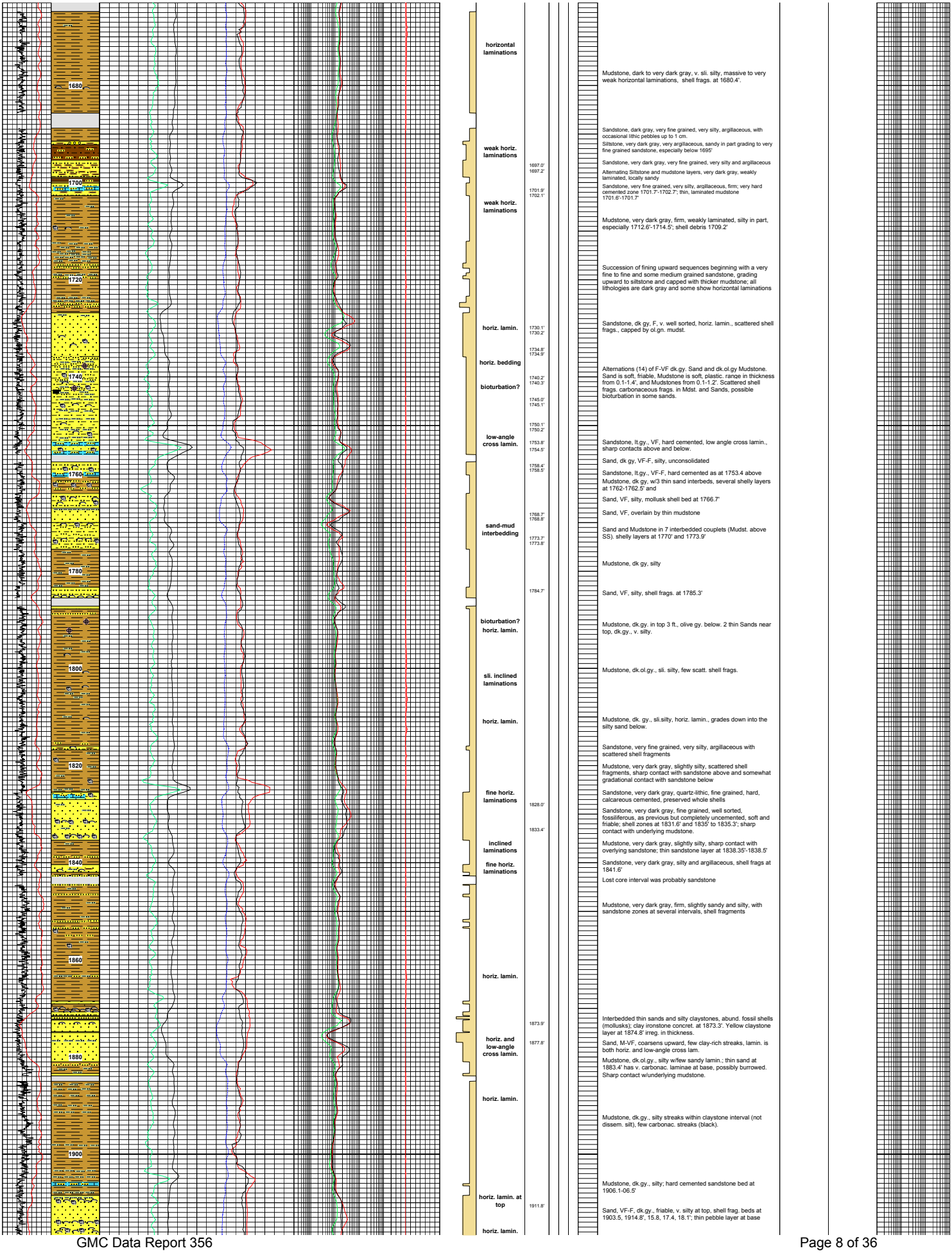

660
680
700
Core Lost
720
740
Core Lost
760
Core Lost
780
800
Core Lost
Core Lost
820
840
860
880
Core Lost
900
653.8'
horiz. lamination
661.5-662.5' removed for Schlumberger CMR analysis
horiz. bedding
667.0'
667.6'
675.4'
676.6'
low-angle X-lamination
688.3'
689.2'
691.3-692.3' removed for Schlumberger CMR analysis
low-angle X-beds
low-angle X-beds
700.3'
703.6'
703.8'
705.0'
wispy lamination
core rubble zone
715.4'
715.5'
scoured contact?
727.0'
728.7'
horiz. lamination
horiz. bedding
750.0
750.3
755.0
root mottling
761.5
761.9
762.5
763.2
776.0
occasional low angle cross bedding
793.0
793.2
797.6
800.0
832.5
854.0
finely laminated horizontal
very finely laminated
868.4
horizontal to low angle x-bedding
878.5
879.1
893.6
Coal, black, lignite, fractured, with ice lenses in fractures and displacive along bedding.
Mudstone, dark gray green, finely laminated, becomes more sandy and lighter (medium gray green) downward
Interbedded sequence of dark gray to black, mostly fine grained sandstone, siltstone and mudstone, finely laminated; carbonaceous layers
Sandstone, dark gray green, fine to medium grained, with laminae and thin beds of mudstone and carbonaceous laminae.
Sandstone, dark gray geen, mostly medium grained, scattered organic layers and rare ice lenses in sub-horizontal fractures; mudstone rip-ups at 679.6'
Sandstone, fine grained, fines upward to siltstone and mudstones of overlying units; low-angle X-laminae; sub-horizontal ice lens
Mudstone, dark gray geen, firm, with thin interbeds of fine sand, siltstone and carbonaceous layers
Sandstone, dark gray geen, medium grained, low angle cross bedding marked by wispy organic laminae
Mudstone, with fine laminae of fine grained sand, silt and organics
Alternating Sandstone and Mudstone, thinly bedded or laminated, with common carbonaceous material; some low-angle X-beds in sands; small, tan clay clasts
Sandstone, dark gray green, fine to medium grained, horizontal bedding, some carbonaceous material on wispy laminae; core of lower part of section is rubble.
Mudstone and Sandstone interbeds, 0.1-0.2' thick, scattered pebbles
Conglomerate, large mixed clasts, clast-supported, claystone clasts common, very poorly sorted pebbles.
Sandstone, VF-M, coarsens downward, v. carbonaceous in top 1.2'; irregular contact with thin mudstone below.
Conglomerate, mixed clasts, grain support, poor sorting
Mudstone, silty, w/ laminae and thin beds of VF-F sandstone.
Conglomerate, mixed clasts, v. sandy
Mudstone, sli. silty, with thin pebbly layers of rounded clasts and thin sandstone beds.
Sandstone, M., w/scattered pebbles and larger clasts of tan siltstone at contact with overlying sediment.
Sandstone, VF-F, alternating with thin mudstone beds.
Conglomerate, very poor sorting, muddy, alternating with M-C Sandstone w/pebbles; yellow-stained intervat at base, above coal.
Coal, black, very hard, fractured
Sandstone, F-M, even textured, dark brown,w/black mottling, root traces in top. brown color due to OIL STAIN. Oil appears to be heavy-oil; small amount of gas evolves from pores; no cut in solvent; oil stain diminishes below 764.8'; ss is more argillaceous with carbonaceous streaks below 765.2'
Mudstone, very dark gray to mostly black, carbonaceous
Sandstone, dark gray, fine to medium grained, fine horizontal laminations of sand and organics,
Mudstone, dark gray and gray brown, very sandy at top, decreasing downward, fine sand, silt and organic laminations throughout
Sandstone, upper part F-VF w/horiz. bedding, grades down to M at 797.7' w/ high-angle X-beds and to wavy bedded w/mudstone clasts below 800.3.
Mudstone, sli. silty, lens of coal at 804.4';
Mudstone, soft (thawed), w/ thin sandy interbeds
Sandstone, soft (thawed), w/ thin claystone interbeds.
Sandstone, M-F, hard, badly fractured in core barrel
Sandstone, VF-F, silty w/ carbonaceous laminae; thin ice lens
Coal, fractured top w/ ice lenses in fractures, horiz. layering below
Mudstone, sli. silty, sli. carbonaceous, w/ thin, irregular tan streaks near base, horiz. bedding.
Sandstone VF-F, carbonaceous laminae
Claystone, carbonaceous flecks and a long root cast at 859'.
Sandstone, dark gray-green, very fine to fine grained, very finely laminated horizontal bedding
Mudstone, medium to dark gray and gray green, sandy (v.f.) and silty in part, finely laminated horizontal to low angle cross bedding, roots, root casts and some light tan lenticles suggesting oxidation, ice lenses occur on 1 to 2 foot intervals
Sandstone, dark gray green, mostly fine grained with thin laminations of medium to very coarse at the bases of sequences which grade up to siltstone and rarely mudstone
Mudstone, very dark gray to black, carbonaceous, very slightly sandy (v.f.) or silty, no root zones
Sandstone, very dark gray green, fine to some medium grained, numerous thin mudstones and organic layers in top 3', occasional low angle cross beds
Mudstone, dark and medium gray with some light tan zones, thin organic layers and very fine sands in upper part, some low angle cross beds, becomes massive below 898.8' without sand
667.6'
k=37.4587 md
phi=36.59%
gd=2.624 g/cc
667.6'
k=96.9685 md
phi=35.63%
gd=2.612 g/cc
675.4'
k=5503.06 md
phi=38.84%
gd=2.655 g/cc
689.2'
k=15052.5 md
phi=36.59%
gd=2.630 g/cc
700.3'
k=12010.5 md
phi=36.88%
gd=2.641 g/cc
700.3'
k=6049.35 md
phi=37.39%
gd=2.682 g/cc
715.4'
k=3404.85 md
phi=38.16%
gd=2.644 g/cc
715.5'
k=1546.42 md
phi=36.78%
gd=2.641 g/cc
750.3'
k=480.768 md
phi=36.68%
gd=2.592 g/cc
750.3'
k=781.872 md
phi=36.74%
gd=2.589 g/cc
755.0'
k=3066.93 md
phi=40.31%
gd=2.652 g/cc
755.0'
k=1968.33 md
phi=38.63%
gd=2.648 g/cc
762.5'
k=13454 md
phi=38.79%
gd=2.603 g/cc
762.5'
k=13922.7 md
phi=37.27%
gd=2.601 g/cc
793.0'
k=17860.5 md
phi=40.04%
gd=2.630 g/cc
793.0'
k=16667.7 md
phi=39.32%
gd=2.623 g/cc
793.0'
k=17235.3 md
phi=38.75%
gd=2.627 g/cc
800.0'
k=8819.88 md
phi=41.74%
gd=2.612 g/cc
832.5'
k=4718.19 md
phi=38.02%
gd=2.668 g/cc
893.6'
k=8326.78 md
phi=36.75%
gd=2.642 g/cc

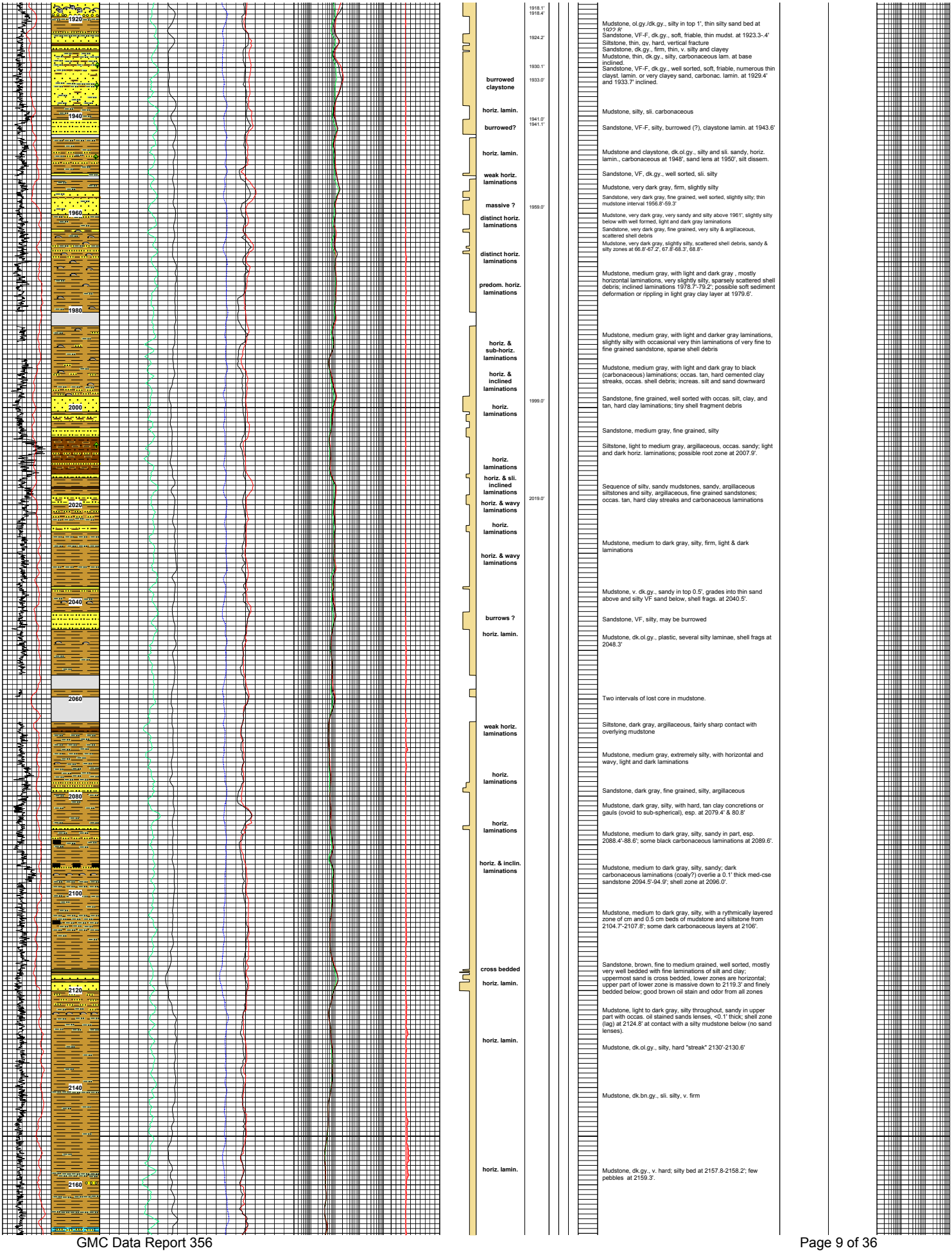

Core Lost
920
Core Lost
940
960
980
1000
1020
Core Lost
1040
Core Lost
1060
1080
1100
1120
1140
Core Lost
finely laminated
low-angle X-beds
908.9
909.0
917.3
low-angle X-beds
927.0
927.6
rooted
rooted
rooted
local high-angle cross bedding
994.0
994.3
wavy laminae
low-angle X-beds
1011.0
1015.3
1018.7
1018.9
lenticular bedding horiz. lamination
rooted
wavy bedding
horiz. bedding
1048.3
1051.7
horiz. bedding
1061.6
massive
1074.0
1074.2
massive
finely bedded
thinly bedded
1117.4
1117.6
horiz. lamination
1124.8
carbonac. drapes on horiz. laminae
horizontal bedding
Sandstone, dark gray, very fine to fine grained, up to medium in some zones, finely bedded, 2-3 mm laminations, black organic layers, thin mudstones near top, low angle cross bedding
Sandstone, dark gray, very fine- to fine-grained, occasional medium grained, black organic layers, thin mudstones
Mudstone, dark gray, occasional light gray and tan layers, very sandy with thin sandstone and siltstone interbeds, thin organic layers throughout,
Mudstone, becoming more massive and less sandy toward base
Sandstone, medium gray, fine grained, with dark root traces and organic flecks
Coal, brown and black, lignitic to sub-bituminous, with thin (0.1'-0.2') sandstone and mudstone interbeds, and ice lenses
Mudstone, dark gray to black, local tan zones due to root traces, fine-grained sandy in part, ice lenses
Coal, black, sub-bituminous, argillaceous in part, and scattered mudstone layers, ice lenses
Mudstone, tan at top,grading down to very dark gray to black in organic layers
Mudstone and Coal, interbedded, mudstone is carbonaceous w/ root traces and coal is argillaceous.
Mudstone, silty w/ root traces and carbonaceous fragments.
Sandstone, medium gray, mostly fine grained with some zones of medium grained, argillaceous with organic laminae and thin mudstone beds throughout,
Mudstone, dark gray, massive, non-sandy, non-carbonaceous
Coal, black, argillaceous at top
Mudstone, silty, sli. sandy, coaly at top, becoming more sandy downward.
Sandstone, F-VF, v. argillaceous, w/ mudstone laminae and thin (0.2'-0.4') beds;sli. carbonaceous; low-angle X-beds and wavy laminae at 1011'-1014'.
Sandstone, F-VF, vague horizontal bedding, very uniform texture.
Siltstone, v. argillaceous, sandy, contorted bedding.
Sandstone, VF-F, v. argillaceous and carbonaceous, lenticular bedding and horiz. lamination, fines drape sandstone lenticles.
Claystone, v. carbonaceous w/ thin lignites
Coal, fractured, lignite
Claystone, black grading to yellow downward, many rootlet traces, carbonaceous
Mudstone, silty and w/ VF-F sandy thin interbeds
Sandstone, M-F, well sorted, wavy bedding.
Mudstone, w/ silt and VF sandy lenticles and laminae
Sandstone, F-VF, horiz. bedding w/ occas. wavy laminae or low angle cross laminae; at 1048.9'-1049.3' are small brown wood fragments.
Sandstone, VF, silty, w/ thin (0.1'-0.4') tan mudstone beds; Mudstones are hard and waxy in upper half, but softer and silty in lower half; tan mudstone intraclasts at 1062.3'; horizontal bedding.
Sandstone, dark gray, very fine- to fine-grained, silty in part, massive with little indication of bedding, occasional carbonaceous wood or coal fragments
Mudstone, very dark gray to black, sandy in part, tan cemented root traces and layers, massive in upper part, finely bedded below 1080'.
Coal, black, sub-bituminous, argillaceous at top and base, thinly bedded throughout
Mudstone, mostly dark gray and dark brown, with occasional light gray, gray green and tan layers (0.25'-0.5"), becomes very carbonaceous below 1095.8'
Mudstone, dark gray and dark brown, carbonaceous zones end and sand begins increasing at 1098.6', sand increases downward until it predominates at 1112.1.
Sandstone, dark gray qeen, mostly very fine- to fine-grained, medium in part, very argillaceous at top, cleans downward to 1116.6' where mudstone layers become infrequent
Mudstone, dark brown to dark gray, massive at top becoming thinly bedded and laminated downward with increasing very fine sand and silt layers below 1121'; sand increases until it predominates at 1123.2'
Sandstone, dark gray green, very fine- to fine-grained, very argillaceous at top with mudstone interbeds, mudstone decreases slightly with depth
Mudstone, dark brown to dark gray, sandy and silty at top, carbonaceous, especially at 1130.8' and 1132.5'-1133' w/ thin coaly beds
Mudstone, silty, thin VF sandstone interbeds.
908.9' k=3058.94 md phi=38% gd=2.631 g/cc
908.9' k=3296.09 md phi=38.78% gd=2.628 g/cc
908.9' k=3147.85 md phi=37.79% gd=2.630 g/cc
908.9' k=2034.52 md phi=37.68% gd=2.631 g/cc
917.3' k=10008.2 md phi=42.04% gd=2.644 g/cc
917.3' k=8759.56 md phi=37.75% gd=2.636 g/cc
927.6' k=812.04 md phi=38.29% gd=2.666 g/cc
927.6' k=839.051 md phi=38.88% gd=2.655 g/cc
994.3' k=16500.4 md phi=36.95% gd=2.626 g/cc
994.3' k=10963.5 md phi=35.64% gd=2.636 g/cc
1011.0' k=82.3451 md phi=30.08% gd=2.642 g/cc
1011.0' k=64.8083 md phi=32.46% gd=2.634 g/cc
1018.9' k=398.513 md phi=38.39% gd=2.645 g/cc
1018.7' k=1084.38 md phi=38.72% gd=2.649 g/cc
1051.7' k=5829.33 md phi=41.29% gd=2.642 g/cc
1051.7' k=6085.65 md phi=40.78% gd=2.626 g/cc
1061.6' k=6004.04 md phi=41.82% gd=2.639 g/cc
1061.6' k=6079.45 md phi=40.99% gd=2.648 g/cc
1074.2' k=5484.66 md phi=40.68% gd=2.644 g/cc
1074.2' k=5326.99 md phi=41.27% gd=2.637 g/cc
1117.6' k=1620.44 md phi=36.32% gd=2.669 g/cc
1117.6' k=2231.52 md phi=36.18% gd=2.660 g/cc
1124.8' k=1159.42 md phi=37.18% gd=2.661 g/cc
1124.8' k=1313.51 md phi=34.51% gd=2.669 g/cc

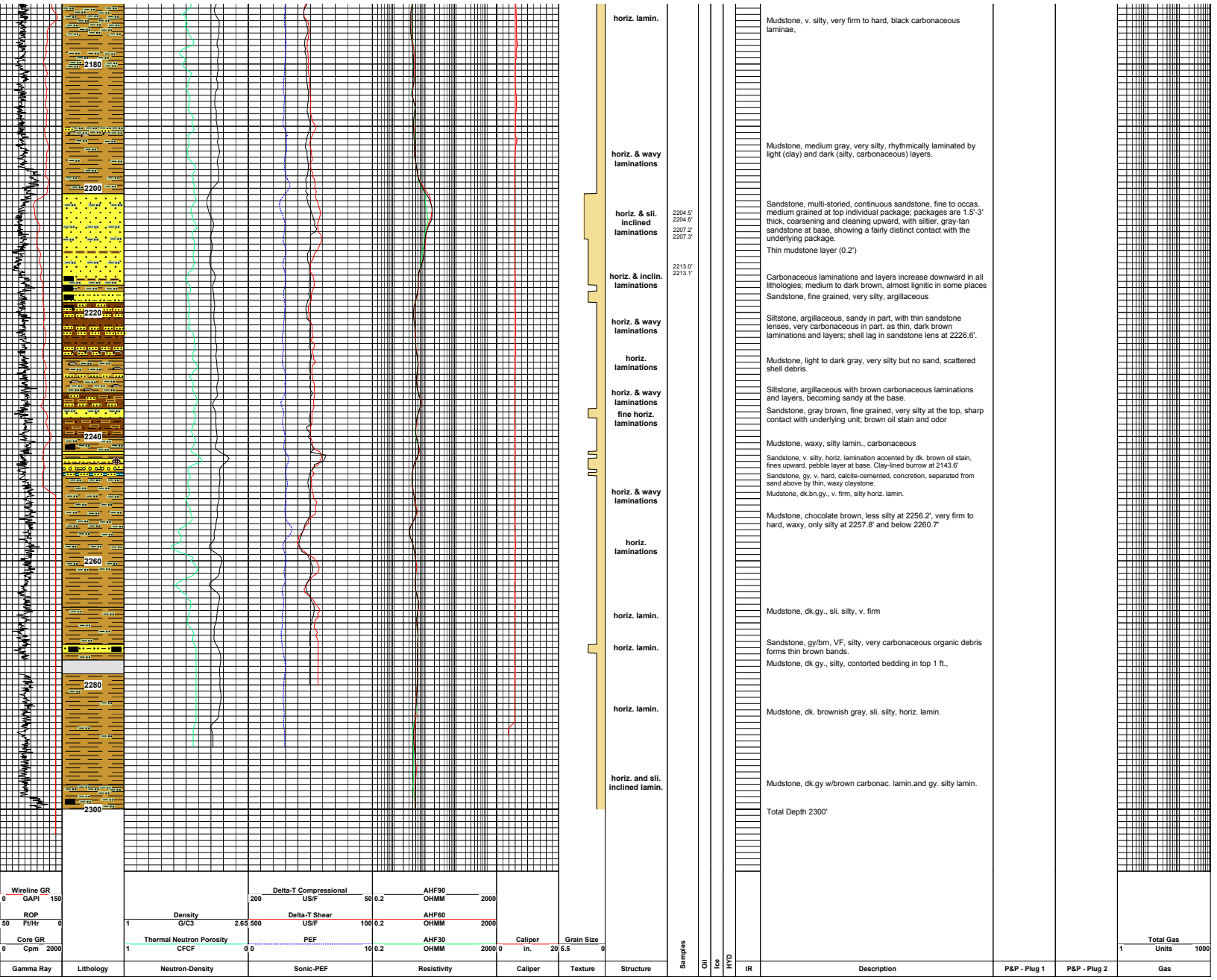

Core Lost
1160
1180
1200
Core Lost
1220
1240
1260
1280
1300
Core Lost
1320
1340
Core Lost
1360
Core Lost
1380
1400
rootlet mottling
horizontal bedding
rootlets, mottling
horizontal bedding
wavy laminated
horizontal bedded
horizontal bedding
wispy organic layers
well bedded
Low to moderate angle x-bedding
too soft to plug
horizontal to low angle x-bedding
too soft to plug
too soft to plug
lignitic layers and zones
horiz. lamination
1193.1
1193.2
1203.8
1211.2
1211.5
1218.9
1245.0
1245.2
1247.7
1254.1
1254.3
1259.3
1261.5
1261.7
1262.8
1271.0
1271.4
1281.0
1287.0
1292.4
1295.2
1309.1
1309.3
1317.0
1319.8
1329.0
1338.4
1348.5
1350.2
(punch plug)
Mudstone, silty, carbonaceous, rooted intervals w/ yellow mottling, thin (0.1'-0.4') sandy interbeds at irregular intervals.
Mudstone, silty, gray/brown mottling, few elongate black root traces; no sandy interbeds.
Mudstone, w/ many wavy silty laminae, some of which coarsen downward into VF sandstone.
Sandstone, M-F, carbonaceous matter on wavy laminae; below 1197', bedding is horizontal w/ mudstone thin beds (0.1'-0.4') at intervals of 2 - 3'
1193.2' k=5121.05 md phi=38.99% gd=2.673 g/cc
1193.2' k=4769.56 md phi=36.99% gd=2.655 g/cc
Sandstone, M-VF, sli. silty, sli. carbonaceous, very even texture below 1205'
1203.8' k=2735.31 md phi=37.72% gd=2.655 g/cc
1203.8' k=4574.97 md phi=37.13% gd=2.653 g/cc
1211.5' k=3746.65 md phi=39.08% gd=2.657 g/cc
1211.5' k=7.0152 md phi=33.16% gd=2.669 g/cc
Sandstone, VF-M, horizontal bedding, very even texture except for thin (0.1'-0.4') angular-gravel beds at 1221.2' and 1224.9'
1218.9' k=4144.25 md phi=37.65% gd=2.681 g/cc
1218.9' k=4291.18 md phi=37.67% gd=2.672 g/cc
Mudstone, brown at top and grading downward to gray and dark gray green; sand and silt increase downward and lithology grades into sandstone beneath; thin lignitic layer at 1239.5'
Sandstone, dark gray green, fine to medium grained, very argillaceous, intermittant mudstone layers
1245.0' k=4087.74 md phi=38.71% gd=2.684 g/cc
1245.0' k=5769.81 md phi=39.2% gd=2.675 g/cc
1254.1' k=4676.37 md phi=37.45% gd=2.667 g/cc
1254.1' k=3948.53 md phi=36.17% gd=2.677 g/cc
Gas detector ceased functioning
1262.8' k=2821.46 md phi=39.2% gd=2.647 g/cc
1262.8' k=8066.19 md phi=33.72% gd=2.660 g/cc
Sandstone, dark gray green, fine to medium grained, very argillaceous, root zones, carbonaceous layers, occasional quartz pebbles
1271.0' k=422.969 md phi=31.41% gd=2.595 g/cc
1271.0' k=946.148 md phi=30.98% gd=2.666 g/cc
Mudstone, light to dark gray, very sandy, gradational to overlying lithology, carbonaceous zones
1281.0' k=2310.92 md phi=35.26% gd=2.684 g/cc
1281.0' k=1313.31 md phi=31.08% gd=2.696 g/cc
Sandstone, dark gray green, very fine- to fine-grained, argillaceous but no distinct mudstone layers
1287.0' k=4295.65 md phi=35.62% gd=2.680 g/cc
1287.0' k=1695.89 md phi=27.68% gd=2.667 g/cc
1295.2' k=18191.8 md phi=33.67% gd=2.655 g/cc
1295.2' k=14489.9 md phi=31.23% gd=2.625 g/cc
Siltstone, medium to dark gray, massive to thinly bedded, grades downward from sandstone above over a thin transition zone (0.3')
Sandstone, dark gray, medium grained, mostly massive, very indistinct bedding (core preservation ?), occasional rounded quartz granules and pebbles, coal fragments; becomes very argillaceous below 1305.5'
1309.1' k=1184.15 md phi=30.52% gd=2.680 g/cc
Sandstone, dark gray, medium grained, occasional thin mudstone layers, sandstone alternates between relatively clean and argillaceous
1319.8' k=4797.43 md phi=36.27% gd=2.678 g/cc
1319.8' k=3950.2 md phi=33.39% gd=2.657 g/cc
1329.0' k=5096.48 md phi=35.33% gd=2.722 g/cc
1329.0' k=2456.13 md phi=27.66% gd=2.677 g/cc
Mudstone, dark gray, slightly sandy at top but increasingly sandy downward, some very fine-grained sandstone interbeds near the base
Sandstone, dark gray green, fine to medium grained, fairly clean with distinct mudstone layer at 1339.5'
1338.4' k=2638.73 md phi=33.31% gd=2.652 g/cc
1338.4' k=1078.65 md phi=27.04% gd=2.652 g/cc
Sandstone, M-F, well sorted, carbonaceous, bedding not clear.
1348.5' k=9073.13 md phi=32.8% gd=2.814 g/cc
1348.5' k=4613.65 md phi=25.03% gd=2.633 g/cc
Mudstone, silty, laminated, w/ thin (0.1'-0.3') VF-F sandstone interbeds at irregular intervals.
Sandstone, F-M, laminated with carbonaceous matter in upper half, but more featureless below.
depth correction
Mudstone, sli. silty, horizontal bedding, 0.1' coal at 1360.7', and thin (0.1') sandstone bed above the coal; rest of section all mudstone.
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	1438.6' 1438.7'	Sandstone, v. silty and argill., dk gn-gy, soft, few fossil frags. at top (unidentified small, chalky white shell frags.), no visible bedding.
	1442.6' 1442.7'	Mudstone, dk gy-gn, sli. silty, firm, sli. fossilif
	1449.5' 1449.6'	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.
sli. incl. lamin.		
massive	1467.6' 1467.7'	Sandstone, v. fossilif., calcareous, becomes massive downward. Mudstone, v. silty and sli. sandy, coal lamin. @ 1468.4', fossilif.
coarsening upward	1472.0' 1472.1'	Sandstone as previous but increasing silt and clay downward, grading to mudstone below
		Mudstone, dark gray, very silty
fining upward	1477.6' 1477.7'	Sandstone, very fine to fine grained and very silty at top; 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
cemented horiz. bedding	1480.1' 1480.2' 1481.4' 1481.8'	
	1487.6' 1487.7'	
horiz. to massive	1489.6'	thin silty layer at 1492.1'; clay clast or concretion at 1497.4'
	1493.5' 1493.6'	
horiz. to sli. inclined	1498.4'	thin, tan silty/clay layers below 1498.9', at 1-2/ft.
	1502.3' 1502.4'	
horiz. to sli. inclined	1506.0' 1506.1'	tan, silty layer 1505.9' Zone of silty, argillaceous sandstone with carbonized wood fragments, 1508.5'-08.9'
horizontal		Sandstone, very fine-fine grd, silty and argillaceous Claystone, dark gray, silty, massive
horizontal to massive		Siltstone, very dark gray, very argillaceous, gas-bearing Mudstone, very carbonaceous at the top, decreasing downward and becoming more silty and sandy, gas-bearing
	1517.2' 1517.3'	
horizontal to very slightly inclined	1520.2' 1520.3'	Sandstone, very fine to fine grained, fining upward, very silty and argillaceous at the top
	1525.3' 1525.4'	
	1528.7' 1528.8'	Mudstone, dark gray, grades down into sandstone below
horizontal to very slightly inclined	1530.6' 1530.7'	
	1535.3' 1535.4'	Sandstone, very fine to fine grained, very silty, dark gray, argillaceous, fining upward to siltstone
fine horiz. laminations		Siltstone/Mudstone; v. dark gray, finely laminated, carbonaceous in part, more silty to very fine sandy in lower part
fine horiz. laminations		Mudstone/Siltstone, very dark gray, carbonaceous in part, increasing silt in lower part; locally appears to be a fissile, black shale
horiz. lamin.		Siltstone, VF sandy and clayey, shell lag at 1557.7'
color mottled?		Silty mudstone
		VF silty sandtone, soft, badly broken, too soft to plug
horiz. lamin.		Silty mudstone, w/ siltstone interbed Siltstone, dk. gn-gy, v. firm, packs off core barrel
horiz. lamin.		Mudstone, dk gn-gy, 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, scattered shell fragments, thin mudstone at 1616.6'.
horiz. lamin. (weak)		Mudstone, dk gy, v. silty, grades upward into siltstone, scattered shell frags., at 1627.3' is a large, irreg. calcite (?)concretion (?).
		Claystone, v. sli. silty, shell frags. at 1637.5' ,1643.8' and 1648.6'.
		Mudstone, dark to very dark gray, v. sli. silty, massive to very weak horizontal laminations, shell frags. at 1658.9'.


1680
1700
1720
1740
1760
1780
1800
1820
1840
1860
1880
1900
horizontal laminations
Mudstone, dark to very dark gray, v. sli. silty, massive to very weak horizontal laminations, shell frags. at 1680.4'.
Sandstone, dark gray, very fine grained, very silty, argillaceous, with occasional lithic pebbles up to 1 cm.
Siltstone, very dark gray, very argillaceous, sandy in part grading to very fine grained sandstone, especially below 1695'
weak horiz. laminations
1697.0'
1697.2'
Sandstone, very dark gray, very fine grained, very silty and argillaceous
Alternating Siltstone and mudstone layers, very dark gray, weakly laminated, locally sandy
1701.9'
1702.1'
Sandstone, very fine grained, very silty, argillaceous, 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
horiz. lamin.
1730.1'
1730.2'
Sandstone, dk gy, F, v. well sorted, horiz. lamin., scattered shell frags., capped by ol.gn. mudst.
1734.8'
1734.9'
horiz. bedding
1740.2'
1740.3'
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.
1745.0'
1745.1'
1750.1'
1750.2'
low-angle cross lamin.
1753.8'
1754.5'
Sandstone, lt.gy., VF, hard cemented, low angle cross lamin., sharp contacts above and below.
Sand, dk gy, VF-F, silty, unconsolidated
1758.4'
1758.5'
Sandstone, lt.gy., VF-F, hard cemented as at 1753.4 above
Mudstone, dk gy, w/3 thin sand interbeds, several shelly layers at 1762-1762.5' and
Sand, VF, silty, mollusk shell bed at 1766.7'
1768.7'
1768.8'
Sand, VF, overlain by thin mudstone
sand-mud interbedding
Sand and Mudstone in 7 interbedded couplets (Mudst. above SS). shelly layers at 1770' and 1773.9'
1773.7'
1773.8'
Mudstone, dk gy, silty
1784.7'
Sand, VF, silty, shell frags. at 1785.3'
bioturbation?
horiz. lamin.
Mudstone, dk.gy. in top 3 ft., olive gy. below. 2 thin Sands near top, dk.gy., v. silty.
sli. inclined laminations
Mudstone, dk.ol.gy., sli. silty, few scatt. shell frags.
horiz. lamin.
Mudstone, dk. gy., sli.silty, horiz. lamin., grades down into the silty sand below.
Sandstone, very fine grained, very silty, argillaceous with scattered shell fragments
Mudstone, very dark gray, 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.
1833.4'
inclined laminations
Mudstone, very dark gray, slightly silty, sharp contact with overlying sandstone; thin sandstone layer at 1838.35'-1838.5'
fine horiz. laminations
Sandstone, very dark gray, 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 and silty claystones, abund. fossil shells (mollusks); clay ironstone concret. at 1873.3'. Yellow claystone layer at 1874.8' irreg. in thickness.
horiz. and low-angle cross lamin.
1877.8'
Sand, M-VF, coarsens upward, few clay-rich streaks, lamin. is both horiz. and low-angle cross lam.
Mudstone, dk.ol.gy., silty w/few sandy lamin.; thin sand at 1883.4' has v. carbonac. laminae at base, possibly burrowed. Sharp contact w/underlying mudstone.
horiz. lamin.
Mudstone, dk.gy., 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
horiz. lamin.


1920
1940
1960
1980
2000
2020
2040
2060
2080
2100
2120
2140
2160
1918.1'
1918.4'
1924.2'
1930.1'
1933.0'
1941.0'
1941.1'
1959.0'
1999.0'
2019.0'
burrowed claystone
horiz. lamin.
burrowed?
horiz. lamin.
weak horiz. laminations
massive ?
distinct horiz. laminations
distinct horiz. laminations
predom. horiz. laminations
horiz. & sub-horiz. laminations
horiz. & inclined laminations
horiz. laminations
horiz. laminations
horiz. & sli. inclined laminations
horiz. & wavy laminations
horiz. laminations
horiz. & wavy laminations
burrows ?
horiz. lamin.
weak horiz. laminations
horiz. laminations
horiz. laminations
horiz. & inclin. laminations
cross bedded
horiz. lamin.
horiz. lamin.
horiz. lamin.
Mudstone, ol.gy./dk.gy., silty in top 1', thin silty sand bed at 1922.8'
Sandstone, VF-F, dk.gy., soft, friable, thin mudst. at 1923.3-.4'
Siltstone, thin, qy, hard, vertical fracture
Sandstone, dk.gy., firm, thin, v. silty and clayey
Mudstone, thin, dk.gy., silty, carbonaceous lam. at base inclined.
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.
Mudstone, silty, sli. carbonaceous
Sandstone, VF-F, silty, burrowed (?), claystone lamin. at 1943.6'
Mudstone and claystone, dk.ol.gy., silty and sli. sandy, horiz. lamin., carbonaceous at 1948', sand lens at 1950', silt dissem.
Sandstone, VF, dk.gy., well sorted, sli. silty
Mudstone, very dark gray, firm, slightly silty
Sandstone, very dark gray, fine grained, well sorted, slightly silty; thin mudstone interval 1956.8'-59.3'
Mudstone, very dark gray, very sandy and silty above 1961', slightly silty below with well formed, light and dark gray laminations
Sandstone, very dark gray, fine grained, very silty & argillaceous, scattered shell debris
Mudstone, very dark gray, slightly silty, scattered shell debris, sandy & silty zones at 66.8'-67.2', 67.8'-68.3', 68.8'-
Mudstone, medium gray, with light and dark gray , 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'.
Mudstone, medium gray, with light and darker gray laminations, slightly silty with occasional very thin laminations of very fine to fine grained sandstone, sparse shell debris
Mudstone, medium gray, with light and dark gray to black (carbonaceous) laminations; occas. tan, hard cemented clay streaks, occas. shell debris; increas. silt and sand downward
Sandstone, fine grained, well sorted with occas. silt, clay, and tan, hard clay laminations; tiny shell fragment debris
Sandstone, medium gray, fine grained, silty
Siltstone, light to medium gray, argillaceous, occas. sandy; light and dark horiz. laminations; possible root zone at 2007.9'.
Sequence of silty, sandy mudstones, sandy, argillaceous siltstones and silty, argillaceous, fine grained sandstones; occas. tan, hard clay streaks and carbonaceous laminations
Mudstone, medium to dark gray, silty, firm, light & dark laminations
Mudstone, v. dk.gy., sandy in top 0.5', grades into thin sand above and silty VF sand below, shell frags. at 2040.5'.
Sandstone, VF, silty, may be burrowed
Mudstone, dk.ol.gy., plastic, several silty laminae, shell frags at 2048.3'
Two intervals of lost core in mudstone.
Siltstone, dark gray, argillaceous, fairly sharp contact with overlying mudstone
Mudstone, medium gray, extremely silty, with horizontal and wavy, light and dark laminations
Sandstone, dark gray, fine grained, silty, argillaceous
Mudstone, dark gray, silty, with hard, tan clay concretions or gauls (ovoid to sub-spherical), esp. at 2079.4' & 80.8'
Mudstone, medium to dark gray, silty, sandy in part, esp. 2088.4'-88.6'; some black carbonaceous laminations at 2089.6'.
Mudstone, medium to dark gray, 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, 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'.
Sandstone, brown, fine to medium grained, 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, 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).
Mudstone, dk.ol.gy., silty, hard "streak" 2130'-2130.6'
Mudstone, dk.bn.gy., sli. silty, v. firm
Mudstone, dk.gy., v. hard; silty bed at 2157.8-2158.2'; few pebbles at 2159.3'.


2180
2200
2220
2240
2260
2280
2300
horiz. lamin.
horiz. & wavy laminations
horiz. & sli. inclined laminations
horiz. & inclin. laminations
horiz. & wavy laminations
horiz. laminations
horiz. & wavy laminations
fine horiz. laminations
horiz. & wavy laminations
horiz. laminations
horiz. lamin.
horiz. lamin.
horiz. lamin.
horiz. and sli. inclined lamin.
2204.5'
2204.6'
2207.2'
2207.3'
2213.0'
2213.1'
Mudstone, v. silty, very firm to hard, black carbonaceous laminae,
Mudstone, medium gray, very silty, rhythmically laminated by light (clay) and dark (silty, carbonaceous) layers.
Sandstone, multi-storied, continuous sandstone, fine to occas. medium grained at top individual package; packages are 1.5'-3' thick, coarsening and cleaning upward, with siltier, gray-tan sandstone at base, showing a fairly distinct contact with the underlying package.
Thin mudstone layer (0.2')
Carbonaceous laminations and layers increase downward in all lithologies; medium to dark brown, almost lignitic in some places
Sandstone, fine grained, very silty, argillaceous
Siltstone, argillaceous, sandy in part, with thin sandstone lenses, very carbonaceous in part. as thin, dark brown laminations and layers; shell lag in sandstone lens at 2226.6'.
Mudstone, light to dark gray, very silty but no sand, scattered shell debris.
Siltstone, argillaceous with brown carbonaceous laminations and layers, becoming sandy at the base.
Sandstone, gray brown, fine grained, very silty at the top, sharp contact with underlying unit; brown oil stain and odor
Mudstone, waxy, silty lamin., carbonaceous
Sandstone, v. silty, horiz. lamination accented by dk. brown oil stain, fines upward, pebble layer at base. Clay-lined burrow at 2143.6'
Sandstone, gy, v. hard, calcite-cemented, concretion, separated from sand above by thin, waxy claystone.
Mudstone, dk.bn.gy., v. firm, silty horiz. lamin.
Mudstone, chocolate brown, less silty at 2256.2', very firm to hard, waxy, only silty at 2257.8' and below 2260.7'
Mudstone, dk.gy., sli. silty, v. firm
Sandstone, gy/brn, VF, silty, very carbonaceous organic debris forms thin brown bands.
Mudstone, dk gy., silty, contorted bedding in top 1 ft.,
Mudstone, dk. brownish gray, sli. silty, horiz. lamin.
Mudstone, dk.gy w/brown carbonac. lamin.and gy. silty lamin.
Total Depth 2300'
Wireline GR
0 GAPI 150
ROP
50 Ft/Hr 0
Core GR
0 Cpm 2000
Density
1 G/C3 2.65
Thermal Neutron Porosity
1 CFCF 0
Delta-T Compressional
200 US/F 50
Delta-T Shear
500 US/F 100
PEF
0 10
AHF90
0.2 OHMM 2000
AHF60
0.2 OHMM 2000
AHF30
0.2 OHMM 2000
Caliper
0 in. 20
Grain Size
5.5 0
Total Gas
1 Units 1000
Gamma Ray
Lithology
Neutron-Density
Sonic-PEF
Resistivity
Caliper
Texture
Structure
Samples
Oil
Ice
HYD
IR
Description
P&P - Plug 1
P&P - Plug 2
Gas

Coring for Methane-Hydrate in Shallow Sands of the Sagavanirktok Formation
North Slope, Alaska – Phase I: Progress and Geologic Description

W. J. Ebanks, Jr.[1] and W. D. Zogg[2]

Introduction

Most known, subsurface, North Slope gas-hydrates occur in lower Tertiary sandstones and conglomerates overlying the eastern part of the Kuparuk River oil field and the western part of the Prudhoe Bay oil field (Collett, 1993). On the North Slope, the methane-hydrate stability zone is areally extensive beneath most of the coastal plain province. The presence of methane-hydrate has been inferred from numerous North Slope wells on the basis of well log responses calibrated to the response of an interval in a well where gas hydrates were recovered in a core by ARCO and Exxon (Collett, 1993).

Recognizing the potential importance of this untapped source of natural gas, Anadarko Petroleum Corp. is taking cores of sedimentary deposits in the subsurface of the North Slope that will provide material for experimentation leading to further evaluation of this resource. The location chosen for drilling and coring of a well, the "Hot Ice-1", is on acreage leased earlier by Anadarko, about two miles south of the present boundary of Kuparuk River Unit and five miles east of the Meltwater development, in NW/4, Sec. 30-T9N-R8E, Umiat Meridian, on the North Slope of Alaska (Fig.1). This location was chosen to maximize the chance of encountering gas-hydrates beneath Anadarko's leases.

The Anadarko Hot Ice-1 well has surface conductor pipe set in permafrost at 107 ft. M.D. The well was drilled out of this casing on April 1, 2003. Original projected total depth was 2600 ft. Due to delays in the project commencement and subsequent early onset of spring thaw conditions on the North Slope, drilling was halted on April 13, 2003. The well was cored continuously from 107 ft. to a total depth of 1,400 ft. Surface casing was set at this depth, and the well was placed in "suspended" status. Coring is to resume during the next drilling season.

Geology

The geology of the North Slope of Alaska has been the subject of numerous earlier reports (Morgridge and Smith, 1972; Jamieson, et al., 1980; Carman and Hardwick, 1983; Molenaar, et al., 1986; Werner, 1987; Gryc, 1988; Collett, 1993). The general setting of the location where the Hot Ice-1 well is being drilled is one of surface and near-surface gravels overlying a section of Cenozoic to Upper Cretaceous sedimentary deposits, which dip east-northeastward at a rate of approximately 100 ft. per mile (Runyon, 2003). No faulting is known to affect these deposits in this local area.

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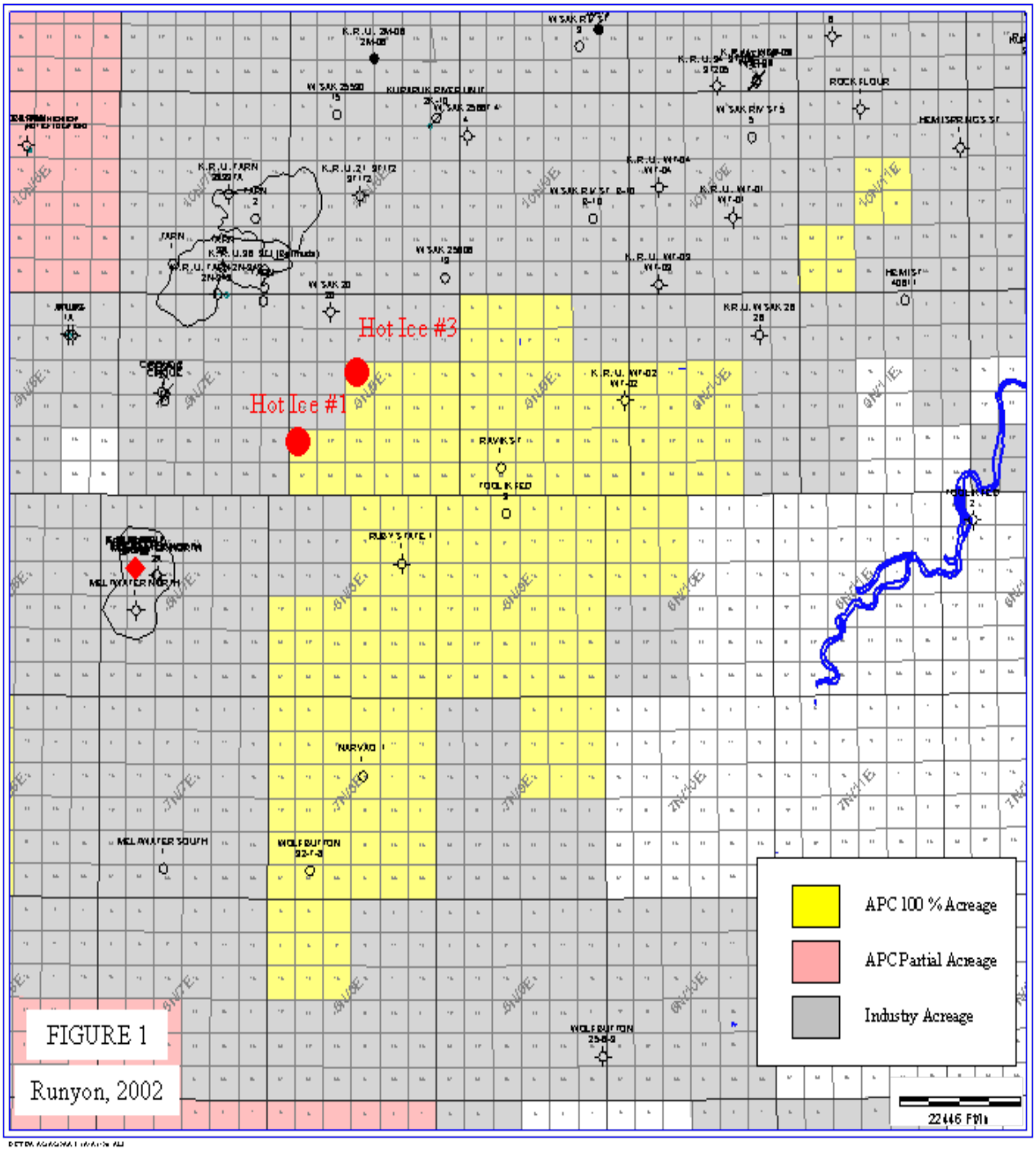


FIGURE 1

Runyon, 2002

Ice-bearing permafrost varies somewhat in thickness from-well-to-well, and the base of this interval has been found to occur at measured depths ranging from about 1100 ft. to almost 1500 ft. in wells nearest the Hot Ice-1 (Newsham, 2003). In the Hot Ice-1 well, base of ice-bearing permafrost has been found at about 1260 ft., measured depth. No methane-hydrate has been found within the permafrost zone in this well. Observation of the retrieved cores indicates that the chilled drilling mud, rapid coring rate, and wireline retrieval, contributed, as planned, to maintaining the frozen condition of the sediments from the permafrost interval. It is expected that similarly frozen, gas-hydrate-bearing intervals that may be encountered below the permafrost zone will likewise remain frozen when brought to the surface, using this coring system. This will facilitate the recognition, sampling and preservation of these gas-hydrates.

The sediments in which gas-hydrates occur in this area of the North Slope comprise parts of the Sagavanirktok Formation, a thick succession of Late Cretaceous to Early Tertiary age (Molenaar, 1986; Collett, 1993) that comprises sandstones, mudstones, conglomerates and coal. This includes the informal units, the Ugnu and West Sak sands (Collett, 1993), which are reservoirs containing heavy-oil farther north (Werner, 1987). The Hot Ice-1 well began coring in frozen surface gravels at 107 ft., probably the Gubik Formation. Having cored 7 ft. of these gravels, it passed into the Sagavanirktok Formation, but penetrated only as deep as the mudstone between the lower Ugnu sands and the West Sak sands (Werner, 1987; Runyon, 2003). No gas hydrates were encountered during the present phase of the coring operation.

The sediments above 1360 ft. in the Hot Ice-1 well, shown in the graphic log (Exhibit 1), were deposited in environments that ranged from fluvial to marginal marine and upper deltaic. Alternations of sandstone, mudstone, conglomerate and coal form sequences that indicate an overall progradation and shallowing of environments of deposition with time. There is considerable vertical variability in these shallow sediments, implying lateral variability of the surface environments in which they were deposited. This variability is common in flood plain and deltaic or other nearshore environments. Although sharp lithologic contacts are not uncommon, there are no obvious unconformities within the sediment sequences cored.

Lithologic Logging

The graphic lithologic log prepared for this report (Exhibit 1) is the primary means of communicating information about composition of the sediments in the cored interval (107 ft. – 1,400 ft.). This information provides a context for understanding the variations in reservoir properties found during analysis of the cores. A legend on the graphic log indicates the colors and symbol codes used to portray the vertical succession of sediment types encountered in coring. This lithologic log will be complemented by selected photos of whole core and of plugs taken for analysis, as well as measurements of porosity, permeability and other petrophysical properties and displays of curves from downhole wireline logs.

This log was compiled by rapid, visual examination of each 10-ft. segment of the 3.25”-diameter continuous core shortly after it was brought to the surface. This macroscopic core examination was necessarily brief because of the need to prevent the cores from thawing. Upon reaching the surface, each 10-ft. segment was further subdivided into 3 forty-inch sections and part of the drilling mud scraped from one side. These sections were scanned for natural Gamma Ray radiation to compare with downhole wireline logs, for imaging in infra-red light, for white light

photography and for logging by a surface-mounted CMR logging tool. Plugs, 1 inch in diameter, were taken from selected lithologies, and end-pieces of some of these were examined microscopically for texture and mineralogy. The 40-inch sections were then placed in transparent plastic tubes, the open ends capped, and the cores stored at sub-freezing temperature. Core recovery through the ice-bearing permafrost interval and to the total depth of the first phase of drilling, 1400 ft., was excellent, about 95%.

The aspect of core description that has been minimized here is the observation of sedimentary structures. Because core could not be slabbed and cleaned for extended examination, only a quick appraisal of those features that could be seen on the outside of scraped core surfaces were logged. Trace fossils other than root casts were not observed, possibly because of this limitation on the logging methods. Samples were not taken for micropaleontologic analysis, so there is no information of this type to contribute to interpretation of environments of deposition. However these continuous cores of the shallow formations provide a far more accurate representation of the lithologies drilled and their variability than can be obtained from logs of only cuttings.

Lithologic Description

Subdividing the lithologic section for description is based on recognition of changes in predominant rock types, on gradations in grain size within short intervals, the nature of contacts between rock types, and on correlation to nearby well logs. The sediments are given equivalent rock-names, even though they are mostly unconsolidated except for the ice cement. Table 1 summarizes the occurrences of each lithology logged, and Figures 2-A, 2-B and 2-C illustrate with charts the changes in composition encountered in the intervals described below.

114’ – 143’

Beneath the surface gravels is a thick, 29 ft., section of horizontally laminated mudstone, which contains a few silty laminae. This mudstone probably is the uppermost part of the Sagavanirktok Formation in this area. Without the aid of paleontology or palynology, its age and environment of deposition is in doubt. The same may be said for the rest of the cored interval; except that correlation with wireline logs of nearby wells may help in determining approximate age, as well as analogy with sediments in other areas may help interpret environments of deposition.

Table 1. Lithologies represented in each interval described

INTERVAL	Measure	Conglomerate	Sandstone	Mudstone	Coal	lost core
114'-143'	Thickness	6.20	1.00	28.20	0.00	0.40
	%	21.38	3.45	97.24	0.00	1.38
143'-252'	Thickness	1.60	52.00	28.50	27.10	0.00
	%	1.47	47.71	26.15	24.86	0.00
252'-446'	Thickness	8.00	142.60	26.80	12.70	3.80
	%	4.12	73.51	13.81	6.55	1.96
446'-649'	Thickness	131.85	43.50	26.30	0.15	0.80
	%	64.95	21.43	12.96	0.07	0.39
649'-760'	Thickness	13.40	60.20	24.90	5.60	4.30
	%	12.07	54.23	22.43	5.05	3.87
760'-951'	Thickness	0.00	67.90	97.80	3.50	21.40
	%	0.00	35.55	51.20	1.83	11.20
951'-1187'	Thickness	0.00	67.30	125.10	33.50	9.90
	%	0.00	28.52	53.01	14.19	4.19
1187'-1358'	Thickness	0.00	131.70	32.00	0.00	6.90
	%	0.00	77.02	18.71	0.00	4.04
1358'-1400'	Thickness	0.00	0.10	39.70	0.10	2.70
	%	0.00	0.24	94.52	0.24	6.43
TOTAL	Thickness	161.05	566.30	429.30	82.65	50.20
	%	12.46	43.80	33.20	6.39	3.88

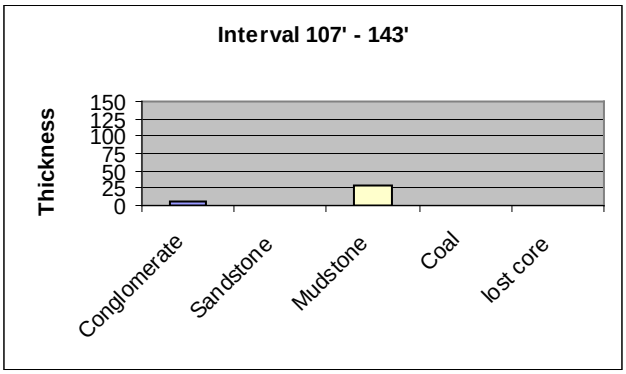
143’ – 252’

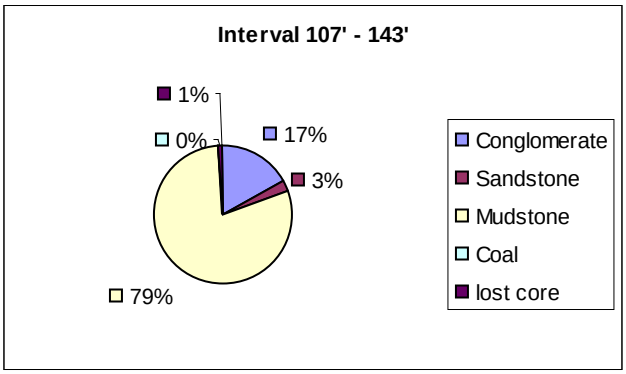
From a depth of 143 ft. to 252 ft. is an interval of sediments consisting of an overall fining-upward sandstone-mudstone sequence overlain by thick coal. The 49 feet of sandstone at the base is medium to coarse grained and contains carbonaceous fragments and disseminated organic matter probably eroded from a coal below. The sandstone becomes fine to medium grained upward and, at the top, includes scattered pebbles and a few shaly laminae. At the top, the sand is interbedded with a few thin mudstones and is overlain by 18 feet of mudstone that is silty and sandy, becoming carbonaceous just below the overlying coal. The 36 feet of coal is actually four distinct beds separated by thinner, very carbonaceous mudstones. The coal is black, soft and impure lignite containing argillaceous and sandy streaks.

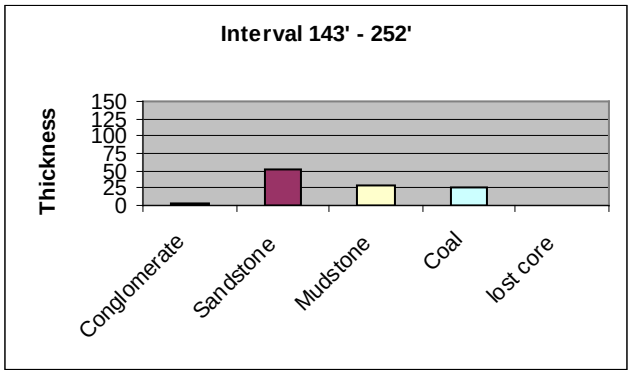
252’ – 446’

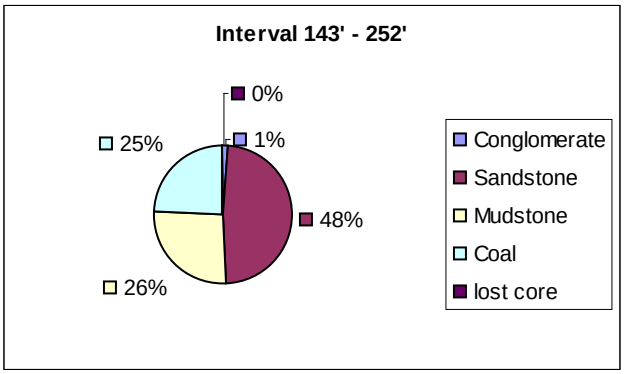
A similar sequence, sandstones below mudstone, below thick coal, is present in the interval, 252 ft.-446 ft. There are significant differences in this interval from that above. At the base are two sequences with a basal conglomerate grading upward into pebbly sandstone, then sandy mudstone. Above this is a thick interval, 110 ft., in which sandstone is the main lithology. This sandstone interval, however, comprises numerous thinner intervals in which medium-to-coarse grained sand grades to fine-to-medium sand. The coarser sandstone has low-angle cross

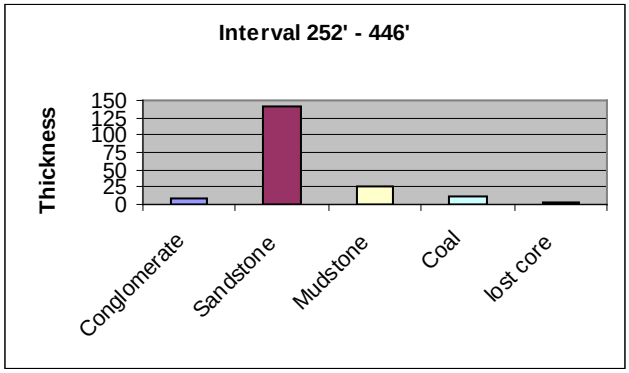
Figure 2-A

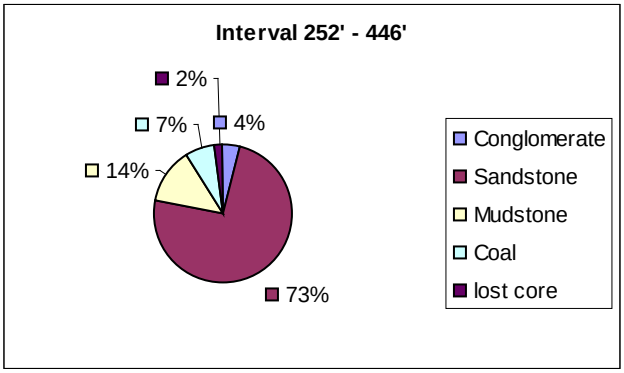

Interval 107' - 143'
Thickness
150
125
100
75
50
25
0
Conglomerate
Sandstone
Mudstone
Coal
lost core

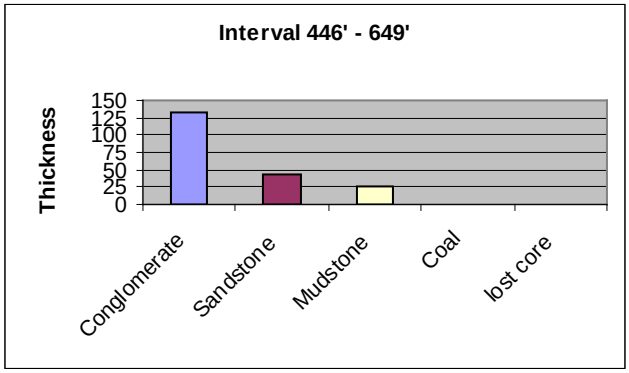

Interval 107' - 143'
1%
0%
17%
3%
79%
Conglomerate
Sandstone
Mudstone
Coal
lost core


Interval 143' - 252'
Thickness
150
125
100
75
50
25
0
Conglomerate
Sandstone
Mudstone
Coal
lost core


Interval 143' - 252'
0%
25%
1%
48%
26%
Conglomerate
Sandstone
Mudstone
Coal
lost core


Interval 252' - 446'
Thickness
150
125
100
75
50
25
0
Conglomerate
Sandstone
Mudstone
Coal
lost core


Interval 252' - 446'
2%
7%
4%
14%
73%
Conglomerate
Sandstone
Mudstone
Coal
lost core


Interval 446' - 649'
Thickness
150
125
100
75
50
25
0
Conglomerate
Sandstone
Mudstone
Coal
lost core

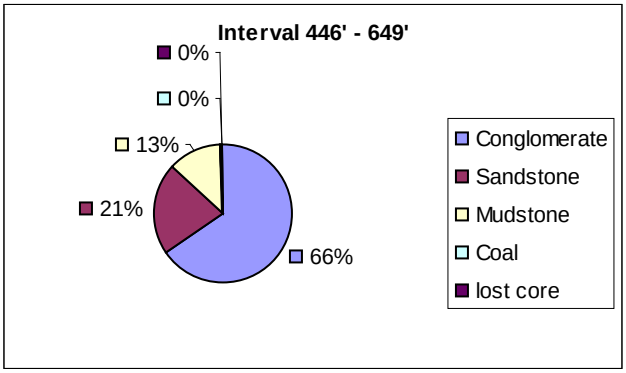
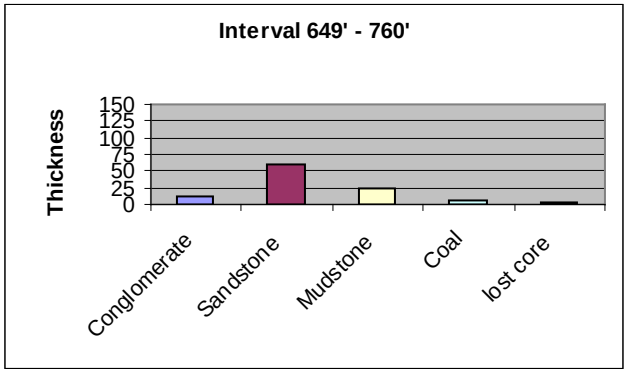
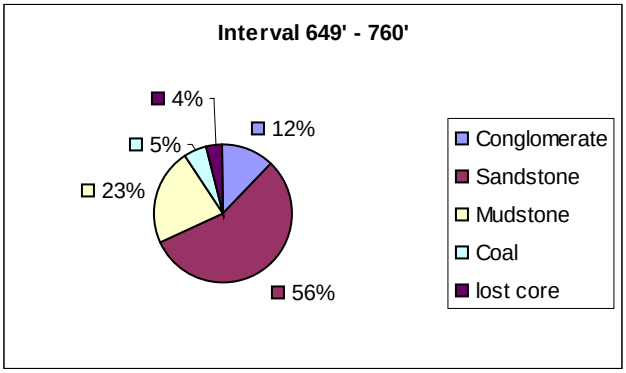
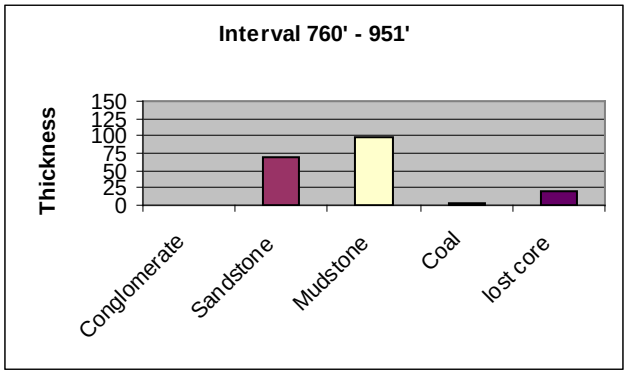
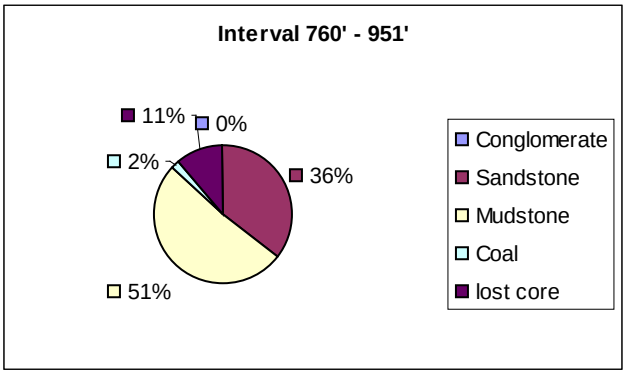

Interval 446' - 649'
0%
0%
13%
21%
66%
Conglomerate
Sandstone
Mudstone
Coal
lost core

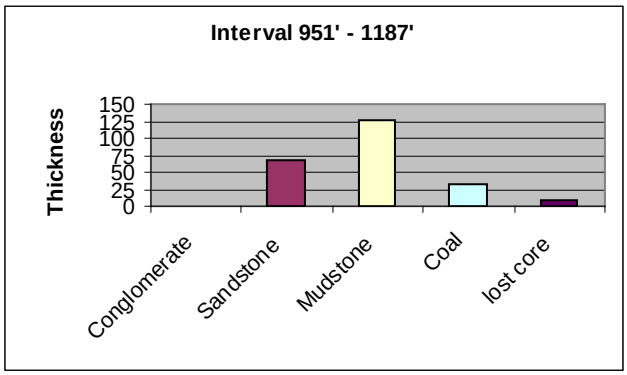
Figure 2-B

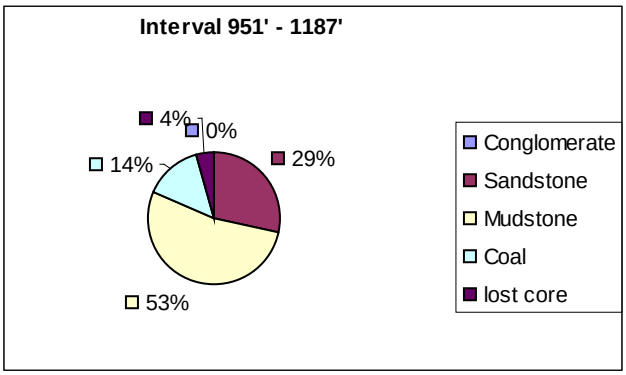

Interval 649' - 760'
Thickness
150
125
100
75
50
25
0
Conglomerate
Sandstone
Mudstone
Coal
lost core

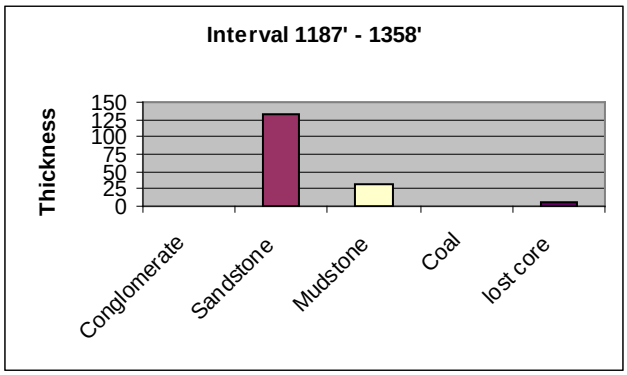

Interval 649' - 760'
4%
12%
5%
23%
56%
Conglomerate
Sandstone
Mudstone
Coal
lost core


Interval 760' - 951'
Thickness
150
125
100
75
50
25
0
Conglomerate
Sandstone
Mudstone
Coal
lost core


Interval 760' - 951'
11%
0%
2%
36%
51%
Conglomerate
Sandstone
Mudstone
Coal
lost core


Interval 951' - 1187'
Thickness
150
125
100
75
50
25
0
Conglomerate
Sandstone
Mudstone
Coal
lost core


Interval 951' - 1187'
4%
0%
14%
29%
53%
Conglomerate
Sandstone
Mudstone
Coal
lost core


Interval 1187' - 1358'
Thickness
150
125
100
75
50
25
0
Conglomerate
Sandstone
Mudstone
Coal
lost core

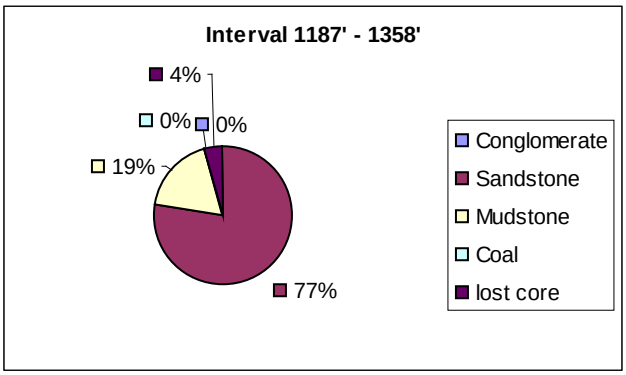
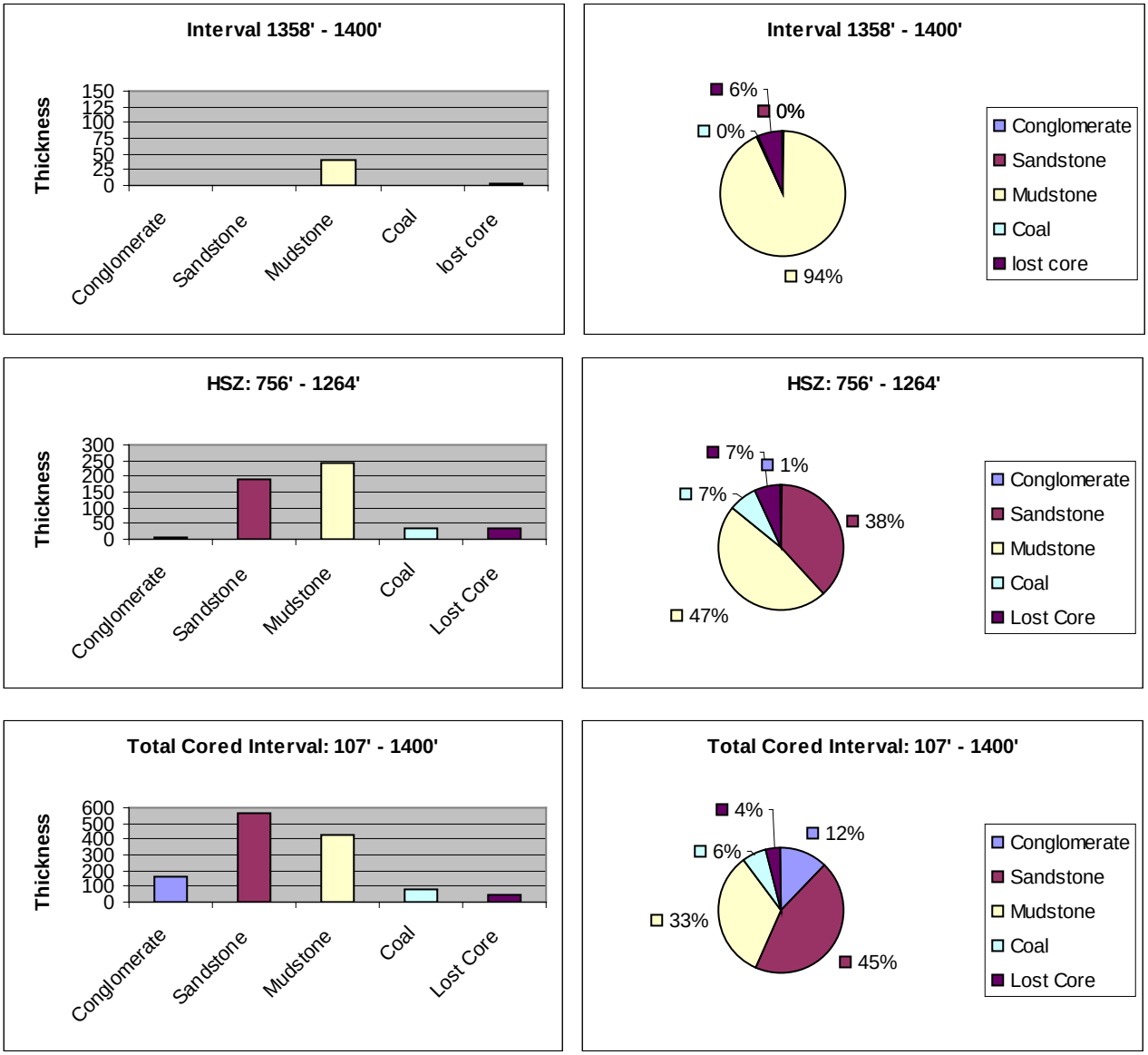

Interval 1187' - 1358'
4%
0%
0%
19%
77%
Conglomerate
Sandstone
Mudstone
Coal
lost core

Figure 2-C



bedding, while the finer grained sands have mostly horizontal bedding. Most of the thin sands grade upward into sandy mudstone. The mudstones commonly have carbonaceous particles on bedding planes. The sandstones at the top of this interval are argillaceous. Those at the base are very carbonaceous.

Above this interval of sandstones and thin mudstones is dark gray or brown and black mudstone in which lenses of ice have formed along bedding planes. Above this mudstone is a black or dark brown lignitic coal, which also includes several ice lenses.

446’ – 649’

The next deeper interval, 446 ft. to 649 ft, is distinctive in comprising mostly conglomerate, in beds as thick as 21 ft. The conglomerate beds are separated by thinner pebbly sandstones or sandy mudstones. Carbonaceous material is commonly present. The conglomerates consist of clasts of quartz, chert and lithic fragments of various types. Mudstone intraclasts also are common, most notably angular intraclasts of tan mudstone that probably are rip-up clasts, as they resemble some of the interbedded mudstones. Most of the conglomerates are clast-supported, but some more poorly sorted layers have sandy matrix support. Ice lenses are numerous in the interval, 510 ft.–540 ft.

649’ – 760’

The interval, 649 ft. to 760 ft., is very different from the interval above. This is the most complexly interbedded interval in the core. It is marked by numerous thinner sequences consisting of conglomerate or sandstone grading upward into mudstone. This variability is reflected also in the thin sandy interbeds in the mudstones and thin mudstone layers in the sands. Above 730 ft, carbonaceous matter is very common, accentuating wispy horizontal laminations and low-angle cross beds in the sandstones. The interval is capped by a 9-ft. thick mudstone and 6 ft. of argillaceous lignite coal with ice lenses.

760’ – 951’

The interval, 760 ft. to 951 ft., includes several sequences of carbonaceous sandstone that become more argillaceous and grade into sandy mudstone above. In this aspect, the interval is similar to others above. One distinctive feature is the thin, 5 ft. thick, oil-bearing sandstone beneath a 1 ft. thick coal at the top of the interval. The oil in this sand is a heavy-oil that does not “cut” with toluene solvent. Nevertheless, this occurrence is of interest, because it is the only such oil-bearing sand in the section cored.

Beneath a 3 ft. thick coal at 835 ft., is a 48 ft. thick, carbonaceous, sandy mudstone which contains fossil plant rootlets. Within this unit are several thin sandstone beds that have horizontal lamination or low-angle cross bedding. Numerous ice lenses occur in this mudstone.

In the deepest 50 ft. of this interval, 901 ft. to 951 ft is a sequence that is important because it marks a change in style of sedimentation. At the base of this unit is a mudstone that grades from slightly silty claystone below to sandy, silty mudstone, then upward to argillaceous, carbonaceous, very fine-to-fine grained sand and finally, to fine-to-medium grained sand with low-angle cross bedding at the top. This is the first sequence of sediments exhibiting this motif of coarsening and “cleaning” upward that was encountered during the coring. It may signify an important change in the environment of deposition.

951’ – 1187’

In this interval are several fining-upward sandstone-mudstone-coal sequences, as described above, but with occasional coarsening-upward sequences intervening. Intervals of each lithology tend to be thicker than the alternations cited above.

At the top of the interval is a very thick, 28 ft., lignitic coal. At the top, this coal is argillaceous with numerous ice lenses, and at its base are interbedded, carbonaceous mudstones and thinner coals. Below this, other sandier sediments and coal are present.

Between 1000 ft and 1076 ft., two prominent sandstones grade upward into sandy mudstones with thin coals. These sandstones are carbonaceous, and even contain small fragments of fossil wood. They have lenticular bedding and wavy laminae as well as horizontal bedding. Below thin coals the sediment commonly contains root traces.

The lower half of this interval, 1076 ft. to 1187 ft., is predominantly mudstone. The few sandstones are very argillaceous. Very carbonaceous intervals of mudstone are common, and some exhibit color-mottling and root traces.

1187’ – 1358’

The interval, 1187 ft. to 1358 ft., in contrast to the one above it, consists mainly of sandstone. One prominent mudstone, 1226 ft. to 1242 ft., is present, but otherwise, the frequent mudstones are very thin and sandy. The sandstones typically are fine-to-medium grained. They have horizontal or low-angle cross lamination. The sands are usually argillaceous, with occasional carbonaceous intervals. Some sands appear finer grained and more argillaceous upward, as others appear to coarsen and become less argillaceous upward.

An important aspect of this interval is that it includes the base-of-permafrost in this well, at about 1260 ft. This coincides with a noticeable change in the mechanical properties of the cored rocks, as well as changes in the resistivity and acoustic wireline log responses.

1358’ – 1400’

The top of this deepest interval cored is recognized as the base of the Ugnu sands, the informal stratigraphic unit described earlier. This interval is correlated widely as the unnamed mudstone unit between the Ugnu and underlying West Sak sands (Runyon, 2003). The core of this interval comprises only monotonous, slightly silty mudstone with only a very thin coaly bed near the top.

The well had not completely penetrated this interval of mudstone when coring was halted and surface casing set to protect the permafrost. The well was placed in suspended status.

Summary and Interpretation

A thick section of sandstones, mudstones, coals and conglomerates was cored continuously in the Anadarko Hot Ice-1 well during Phase I of the 2003 drilling program, from 107 ft. to total depth of 1400 ft. At this depth the well was temporarily suspended because of early thaw beginning to occur on the North Slope. Surface protective casing was set at this point, just below

the base of the ice-bearing permafrost. No gas-hydrate-bearing sediment had been encountered as of the suspension of coring.

Correlations with wireline logs and descriptions of cuttings taken in nearby wells lend support to the idea that the frozen sediments cored in this well are part of the Sagavanirktok Formation. The cored sediments are part of a thick sequence of rocks that are probably of late Cretaceous to early Tertiary age. Paleontologic evidence of this age is lacking, but stratigraphic position of these units and the absence of tectonic complications in this area of the North Slope support this age assignment. Like similar sequences studied in nearby outcrops of the North Slope, they have characteristics of marginal marine or deltaic deposits. Some authors refer to these sequences as the "Deltaic Unit" of the Brookian Sequence (Molenaar, 1983), referring to their origin as part of the deposits transported from the south and southwest to fill the tectonic basin that formed with uplift of the Brooks Range. If these correlations are correct, then the bottom of the cored interval at 1,400 ft. was in the mudstone that separates the Ugnu sands from the underlying West Sak sands, informal members of the Sagavanirktok Formation.

The thick mudstone at the base of the cored interval, 1,358 ft. to 1,400 ft., may be a marine tongue of fine grained sediment representing a brief transgression of the late Cretaceous sea over the mostly terrestrial environments of this area. Sandy sediments above this mudstone are thin sequences that form alternations of fining-upward and coarsening-upward units. They become very carbonaceous upward and are capped by a thick coal and mudstone interval. This overall interval includes a prominent, very sandy and carbonaceous, mudstone unit more than a hundred feet thick. These sequences, from 951 ft. to 1,358 ft., probably represent the attempted, repeated progradation of several wedges of sandy sediment from the southwest into a more marine environment to the northeast. These progradations culminated in the persistent presence of coal-forming environments in this area, such as coastal marshes and delta-top swamps, which resulted in the thick coals at the top of the sequence.

Following this time of coal formation, sand and mud sedimentation resumed, and the first fifty feet of deposits above the coal was a coarsening-upward sequence of sandy mudstone and sandstone. Following deposition of these units, however, the alternations of finer grained and coarser grained sediments mostly followed the pattern of fining-upward. These patterns suggest deposition of distributary mouth bars and crevasse splay sediments, which prograded over a subsided area of coastal swamp environments. These deposits were then buried by deltaic distributary and overbank sediments as shallow water deltas worked over the prograding coastal plain. Another coal, 6 ft. thick, was deposited at the top of these sediments, attesting to the natural variability inherent in coastal plain deposits. This sequence of events is represented by the sediments cored from 649 ft. to 951 ft.

After this period of sedimentation when alternations of coarser and finer grained sediments were so common, a thick sequence of mixed-clast conglomerates was deposited in this area, seen in the sediments from cores of the interval 446 ft. to 649 ft. This would seem to represent a time of maximum progradation of the onshore, terrestrial environments of deposition, such as when short-headed, high energy streams could have crossed a very narrow deltaic shelf and/or when there was increased tectonic activity in the source area to the south and southwest, as suggested by Molenaar (1983). This would have resulted in very coarse sediment being delivered to this area of deposition.

The next phase of sedimentation in this area resulted from return of more typical upper deltaic environments, with fluvial sequences being dominant over the area, represented by cores from 143 ft. to 446 ft. The earlier of these sediments may have been deposited by braided streams, as they contain basal units of pebbly, coarse sand, grading upward into finer grained sediment. Higher in the section, the sandstones are fine-to-medium grained, also grading upward into sandy mudstones. Two prominent coals occur within and at the top of this interval of fluvial sediments, again suggesting the shifting nature of environments of deposition and re-establishment of peat swamps and lakes or other very low energy environments in this area.

Finally, just above the uppermost coal, is a thick mudstone, from 114 ft. to 143 ft., which may represent another incursion of marginal marine conditions over the low-relief, coastal or freshwater swamp environments represented by the underlying coal. Above this mudstone are a few feet of conglomerate, stained dark by carbonaceous material from above, that probably represents the near surface gravel of the Gubik Formation, of Tertiary age.

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Coring for Methane-Hydrate in Shallow Sands of the Sagavanirktok and Canning Formations, North Slope Alaska – Phase II: Geologic Description

W. J. Ebanks, Jr.[1] and W. D. Zogg[2]

Introduction

Continuous coring in the Hot Ice-1 well resumed during January – February 2004, following suspension of coring in April 2003 (Figure 1). Cores have been recovered from the interval, 1403 ft. to total depth of 2300 ft., during this Phase II of the operation.

Background on the purpose of the project, location of the well, and geology of the cored interval are provided in the previous report on Phase I. Methods of obtaining cores and handling them following retrieval, as well as methods of describing and logging the cores are also discussed in the Phase I report.

Geology

The sediments cored during Phases I and II of the Hot Ice project comprise the Sagavanirktok Formation and part of the underlying Canning Formation, of Tertiary and latest Cretaceous age. Two informal units, the Ugnu Sands and West Sak Sands, which occur near the base of the Sagavanirktok, are separated by a regionally extensive unnamed mudstone (Collett, 1993; Werner, 1987; Runyon, 2003). Coring during Phase I ceased in this mudstone, at 1403 ft., and casing was set at 1358 ft. The base of the permafrost was found at about 1260 ft.

Coring during Phase II resumed at 1403 ft. The coring penetrated the remainder of the unnamed mudstone, the underlying West Sak Sands, and part of the Canning Formation mudstones and sandstones. The sediments, though unfrozen and somewhat unconsolidated, are competent enough to have afforded excellent recovery of 94.5% of the cores taken.

The sediments cored during Phase II, from 1403 ft. to 2300 ft., are not as variable in character as those encountered during Phase I. This reduction in variability, the overall more fine-grained texture of the sediments, and the common occurrence of layers of shell fragments and whole bivalve shells indicate deposition of these sediments in shallow marine shelf environments. Once again, support for this conclusion from paleontology or from the study of sedimentary structures and trace fossils (ichnology) is lacking because of the limited means available to analyze the cores.

Conglomerate and coal, which are so common in cores from Phase I, are not present in cores from Phase II. In these latter cores, alternations of sandstone and mudstone, across a range of scales, are common. Contacts between sandstones and mudstones are almost all gradational changes of texture, or they occur as alternations of thin beds of contrasting texture. Unlike the earlier Phase I cores, the pattern or motif that is most often seen is one of grain size coarsening upward. The sandstones are only occasionally as coarse as medium-sand size. Silt-size particles are very common in beds that are predominantly sandstone or mudstone, acting as part of the matrix in sandstones and forming thin laminae in the mudstones. No obvious unconformities occur within the cored interval.

Minor shows of heavy-oil were found in thin sandstones between 2100 ft. and 2250 ft., and very minor shows of gas were seen as bubbles breaking out of the split core tube or bleeding from tight sandstones or fractured mudstones; however, no gas hydrates were encountered during this phase of the coring operation.

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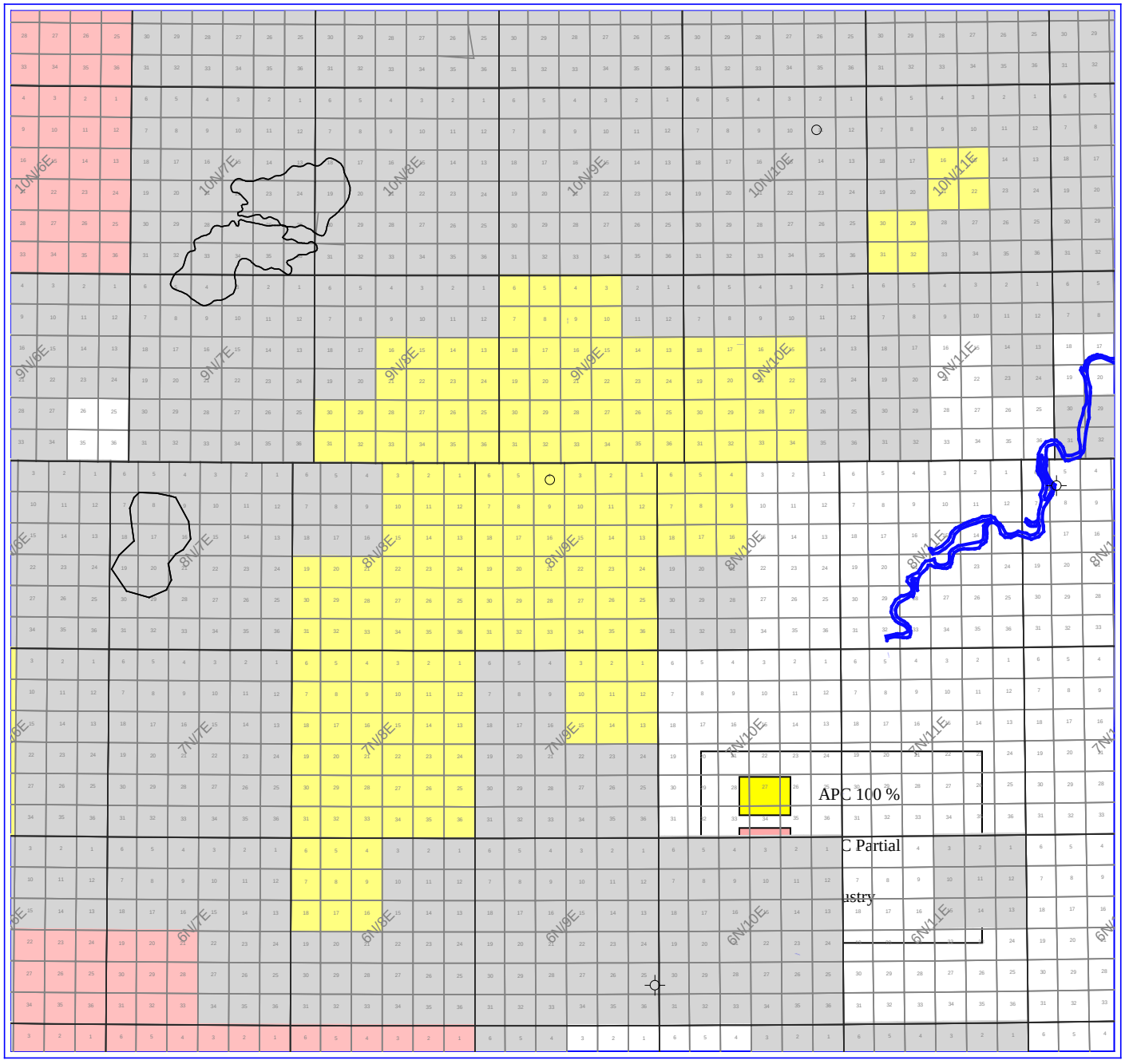


FIGURE 1 After Runyon, 2002

Lithologic Logging

As in the report of the Phase I coring, the graphic lithologic log of the sediments penetrated, Exhibit 1, is the primary means of communicating information about the composition of the sediments in the cored interval (1403 ft.-2300 ft.). This graphic information provides a context for understanding variations in physical properties of the cores found during petrophysical analysis. In addition, Figures 2-A, -B and -C graphically summarize the variations in composition of the sediments described below.

The same methods of handling and brief description have been used in Phase II as were used in Phase I, with the exception that no logging by a surface-mounted CMR logging tool was attempted. Although X-Ray imaging of selected intervals of core was performed, the results of this were not available at time of reporting.

Lithologic Description

1,403' – 1,462' (Figure 2A-1)

This shallowest section of the interval cored in Phase II is a downward continuation of the mudstone occurring from 1358 ft. to 1403 ft. in Phase I cores. Only a very silty, argillaceous sandstone from 1436 ft to 1444 ft. breaks the monotony of the thick mudstone. This mudstone is the unnamed unit that separates the Lower Ugnu Sands above from the Upper West Sak Sands below (Runyon, 2003).

1,462' – 1,537' (Figure 2A-2)

This uppermost of the sandstone intervals cored is also the thickest sandstone. Transition to the overlying mudstone is a series of three thin beds of sandstone, each underlain by carbonaceous, silty mudstone. The sandstones are fine- to very fine-grained, and contain broken shell fragments. Below this, from 1476 ft. to 1509 ft., is a fine- to medium-grained sandstone that becomes cleaner and coarser upward, and which includes several thin beds of shells. This cleaner, coarser part of the sandstone overlies several alternations of sandstone, siltstone and mudstone, which form thin, fining-upward units above the mudstone below. A hard, calcite-cemented bed at 1482 ft. has a characteristic response on wireline logs, which, like others below, is useful for calibrating the logs to the core. A coaly lamina occurs at 1468 ft. The most common sedimentary structure throughout this sandstone is horizontal or very slightly inclined parallel laminae. Between 1510 ft. and 1520 ft. gas shows were noted in the siltstones and mudstones.

1,537' – 1,727' (Figure 2A-3)

The sandstone from 1462 ft. to 1537 ft. caps a lengthy interval of mostly silty mudstone from 1537 ft. to 1727 ft. Correlation of wireline logs suggests that the upper part of this mudstone section is equivalent to sandier intervals in nearby wells, that is, the lower part of the West Sak Sands. Here, the coarser intervals are merely slightly sandy siltstones.

These siltstones cap upward-coarsening units of varying thickness. The uppermost unit contains abundant carbonaceous matter, which imparts a very dark color and horizontal lamination to the sediment. Other thin, upward-coarsening units below this one contain layers of shell fragments within the siltstones and whole or fragmented shells within the silty mudstones. Beneath the siltstone, which occurs at 1609 ft. to 1620 ft., is the thickest continuous mudstone interval cored, from 1620 ft. to 1692 ft. Scattered throughout this variably silty mudstone are whole and fragmented shells of mollusks, probably bivalves. Horizontal lamination is the only sedimentary structure observed in this unit.

Beneath this mudstone interval, from 1692 ft. to 1703 ft., is a very fine-grained sandstone with sandy siltstone interbeds. At 1701 ft. is one foot of calcite-cemented, very fine-grained, very silty sandstone, whose expression on wireline logs, like the one at 1482 ft., is a useful marker for calibrating logs and core. Beneath this sandstone

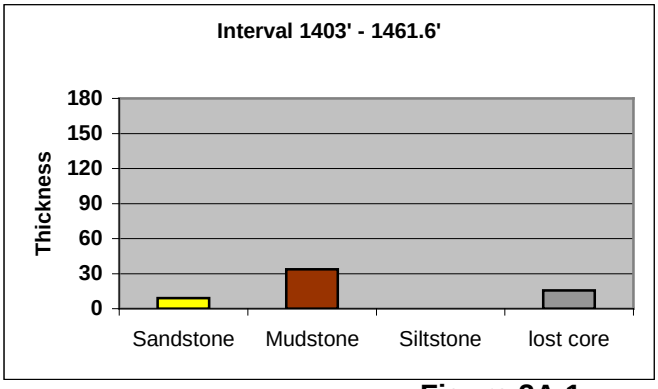
is an interval of thin, fining-upward, sandy and silty mudstones that is a transition from the sandstone below into the lengthy mudstone above.

1,727’ – 1,825’ (Figure 2A-4)

This next deeper interval comprises about equal thicknesses of sandstone and mudstone, forming a coarsening-upward pair of lithologies. The uppermost sandstone, from1727 ft. to 1788 ft., is very porous, being nine feet of well-sorted, fine-grained, friable sand. The rest of the sandstone is very fine- or fine-grained, very silty, and includes scattered carbonaceous matter and shell fragments. The mottled color and texture of the sandstone suggests the presence of burrowing. At 1753 ft. to 1760 ft. are three cemented sandstones similar to those mentioned above. Beneath these hard sandstones are interbedded, shelly, silty, sandstone-mudstone couplets forming a gradation from the mudstone below.

From 1788 ft. to 1825 ft. is another continuous silty mudstone with horizontal or inclined, parallel laminae and scattered shell fragments. Color of the mudstone ranges from olive-gray to dark gray, depending on the silt content. There is a gradational contact with the sandstone below.

FIGURE 2-A



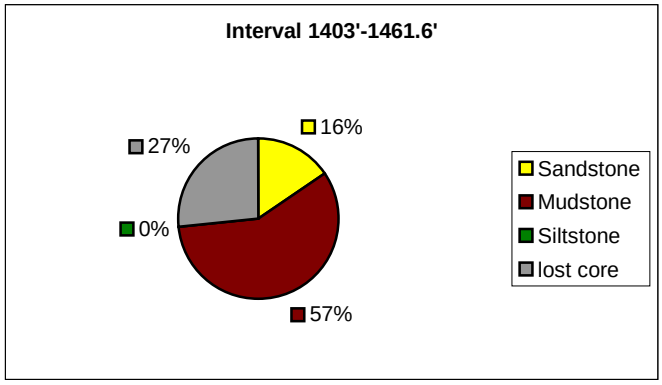
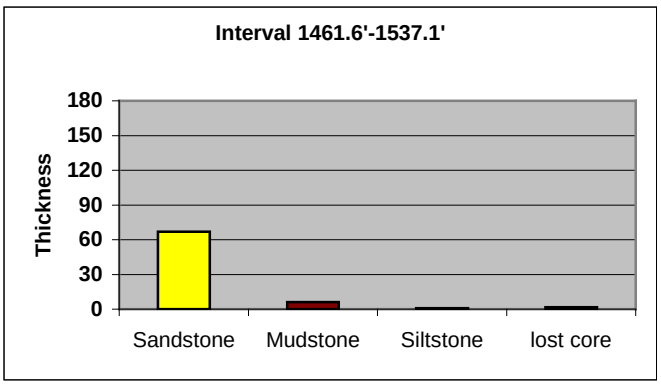


Figure 2A-1



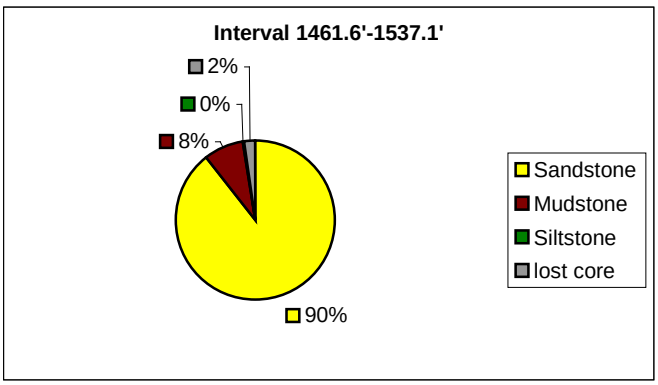
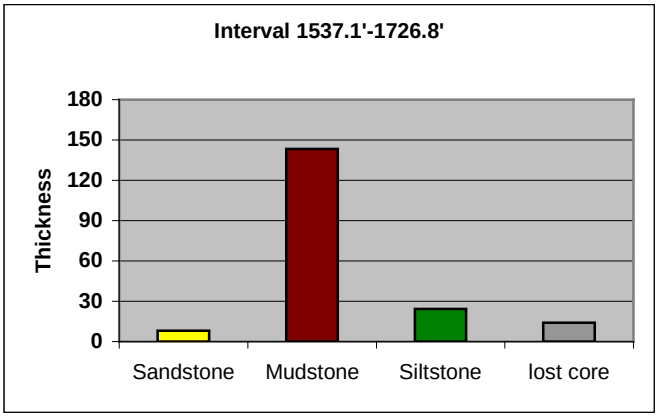


Figure 2A-2



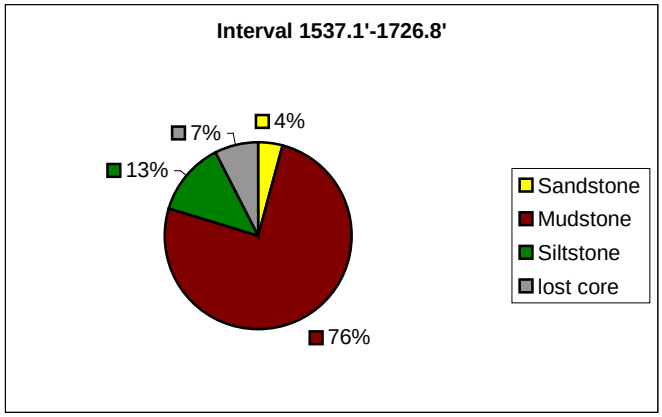
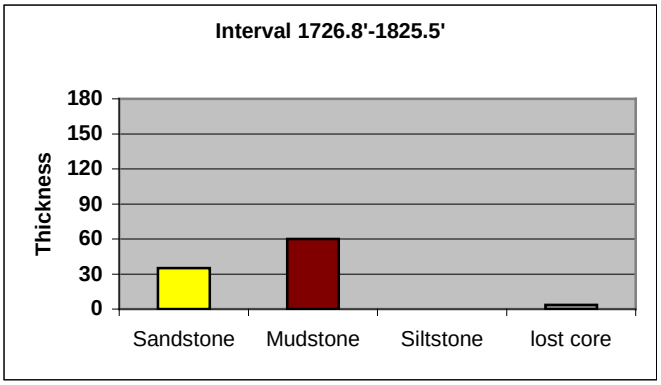


Figure 2A-3



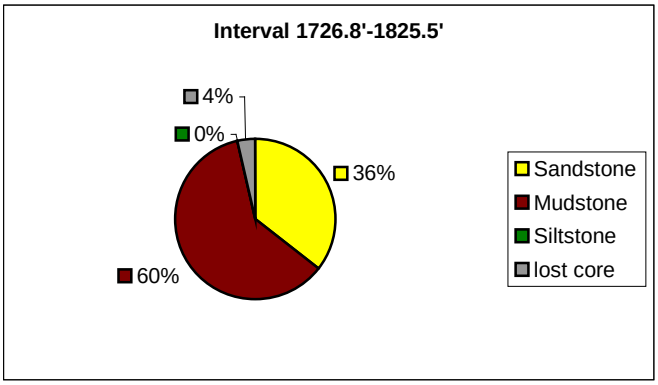


Figure 2A-4

1825’ – 1908’ (Figure 2B-1)

This interval comprises two very similar sequences of sandstones above thicker mudstones, forming coarsening-upward couplets. The sandstones are medium-to very fine-grained, silty and contain numerous shell fragments. They include several thin mudstone beds. The mudstones are slightly silty, with distinct horizontal or low-angle cross laminae of very fine-grained sand and silt. A thin, hard, calcite-cemented sandstone occurs at 1906 ft.

1,908’ – 1,998’ (Figure 2B-2)

This interval, like the ones above, consists of alternations of sandstone and mudstone, the sandstones being of greater thickness and number above, and mudstones being thicker and more continuous downward. The sandstones are dark gray, fine- or very fine-grained, silty and argillaceous, and they include numerous thin beds of silty mudstone and shell fragments. Horizontal lamination is the most common structure. A thin (<0.5 inch) layer of granule-size particles is present at the contact of the top sandstone and its underlying mudstone.

The mudstones are olive gray to dark gray, silty and slightly sandy, with scattered shell fragments being common. Carbonaceous laminae are dark gray. Thin, cemented claystone laminae at 1997 ft. are tan in color.

1,998’ – 2,201’ (Figure 2B-3)

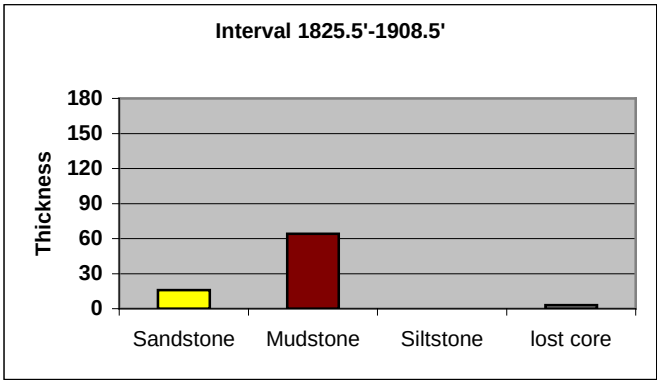
This lengthy interval includes numerous thin sandstones interbedded with thicker mudstones in repeated patterns of coarsening-upward sediment couplets. The sandstones are no thicker than three feet, but the mudstones are much thicker. Sandstones typically are very fine- to medium-grained, horizontal or low-angle cross-laminated, and they contain carbonaceous debris. Oil stain and odor are present in sandstone at 2117 ft. to 2120 ft. The oil appears to be very viscous and immobile.

Mudstones in this interval are similar to those in other intervals. They range in color from olive gray to dark gray and contain abundant silty laminae as well as disseminated silt, especially as they grade upward into sandstone. Horizontal lamination is most common. A cemented sandstone layer occurs at 2169 ft. in a thick interval of mudstone.

2,201’ – 2,300’ (Figure 2B-4)

This interval comprises three smaller intervals that, together, form an upward-coarsening sequence. The top unit, seventeen feet thick, is a series of amalgamated, thin sandstones. These sands are fine-to medium-grained, and individual sands vary in thickness from 1.5 ft. to 3 ft. Each sand coarsens and becomes cleaner upward. More argillaceous sandstone occurs at the base, interbedded with sandy, carbonaceous siltstone.

FIGURE 2B



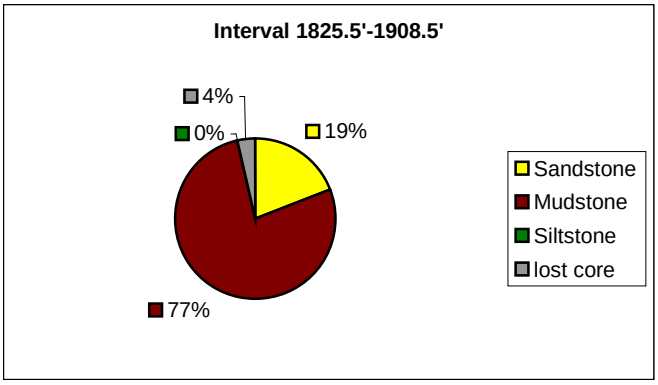
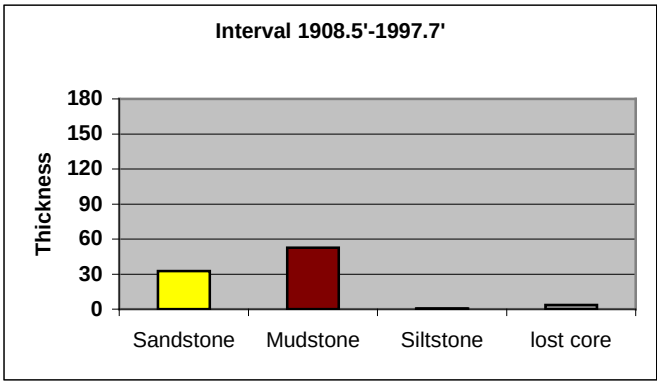


Figure 2B-1



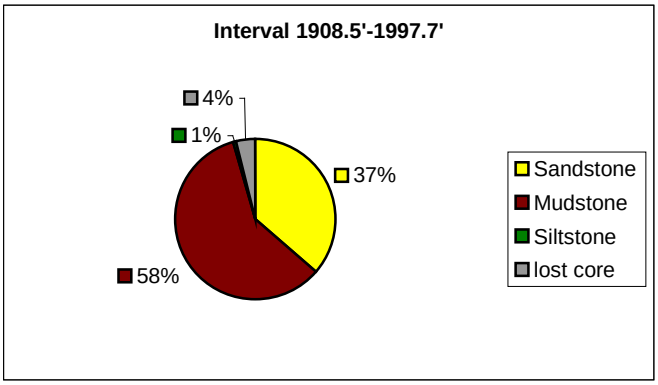
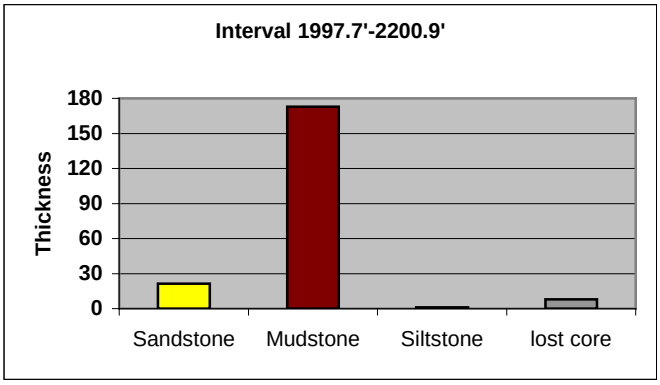


Figure 2B-2



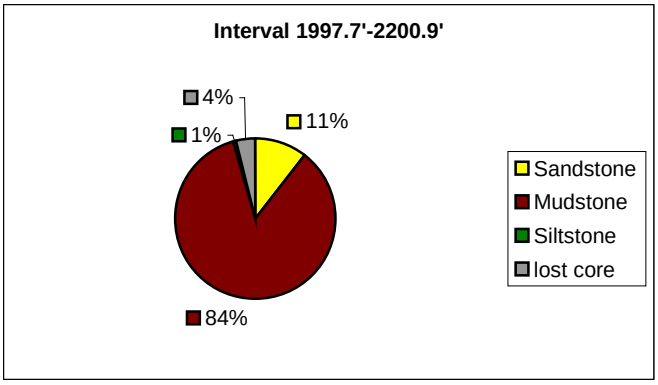
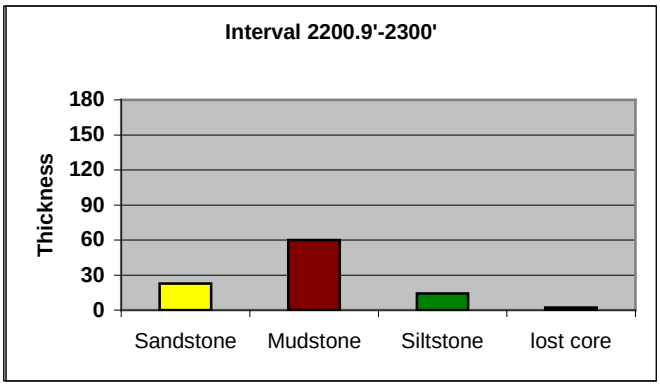


Figure 2B-3



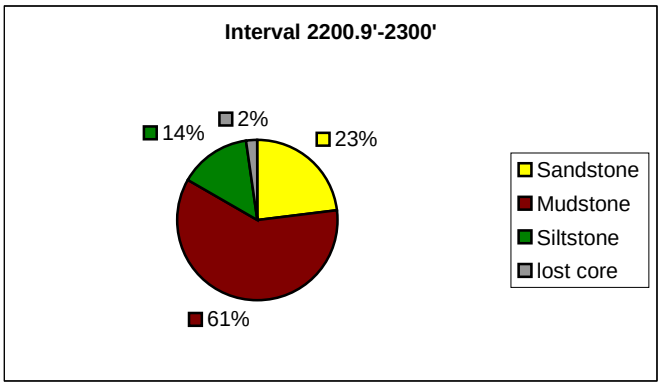


Figure 2B-4

The middle unit is a 22 foot-thick siltstone. This siltstone includes numerous sandy and argillaceous laminae and abundant shell fragments.

The deepest unit is mainly mudstone, which extends from 2240 ft. to the total depth of the well, 2300 ft. The mudstone is interbedded with thin sandstones at the top, and includes one bed of sand lower in the interval. The mudstone is silty throughout and contains dark, carbonaceous debris. Two of the thin sands in this interval contain weak shows of heavy-oil, at 2235.5 ft. and at 2243.5 ft. Horizontal laminae are the main structure, but contorted laminae occur at 2278 ft. The thin sands interbedded at the top of this mudstone include a thin layer of granule-size particles at 2245 ft. A clay-lined burrow occurs at 2143.6 ft. and a thin, calcite-cemented sandstone is present at 2246 ft. The mudstone from about 2240 ft. downward is firmer, or harder, than that at shallower depths and of a darker brownish-gray color than most of the mudstone above.

Summary and Interpretation

A thick section of mudstones and sandstones, with occasional siltstones, was cored continuously in the Anadarko Hot Ice-1 well during Phase II of the drilling program. Coring in Phase II of the operation began at 1403 ft. Total depth of the well is 2300 ft. Despite minor indications of gas being present in some low-permeability units, no gas hydrates were found.

Correlations with wireline logs and descriptions of cuttings taken in nearby wells indicate that the interval cored in Phase II is part of the lower Sagavanirktok and upper Canning Formations of Late Cretaceous age. The sequences of sediments cored probably comprise the marine equivalents of marginal marine or deltaic units of the Brookian Sequence in nearby outcrops farther south (Molenaar, 1983).

The shallowest interval cored is a continuation of the thick mudstone being cored at the end of the Phase I operation. Beneath this mudstone interval is the informal unit known as the West Sak Sands.

The sediments cored from 1462 ft. to 2300 ft. (Figure 2C) are a series of coarsening-upward mudstone-sandstone intervals. They may be grouped for descriptive purposes into four major intervals: 2300-2201 ft., 2201-1908 ft., 1908-1727 ft., and 1727-1462 ft. Each of these major subdivisions of the cored interval begins with a thick, somewhat silty, fossiliferous mudstone and is capped by a very fine-to medium-grained, upward-coarsening, fossiliferous, silty sandstone. Each major, capping sandstone, in succession upward, is thicker than the next one below it.

Within each of these major sequences are numerous smaller subdivisions, each with a prominent sandstone that lies above a silty mudstone and each of which exhibits greater or lesser degrees of interbedding of finer and coarser sediments within its interval. The mudstones and sandstones commonly have gradational contacts and there is frequent occurrence of fossil mollusk shells and thin beds of shell debris in both kinds of sediment.

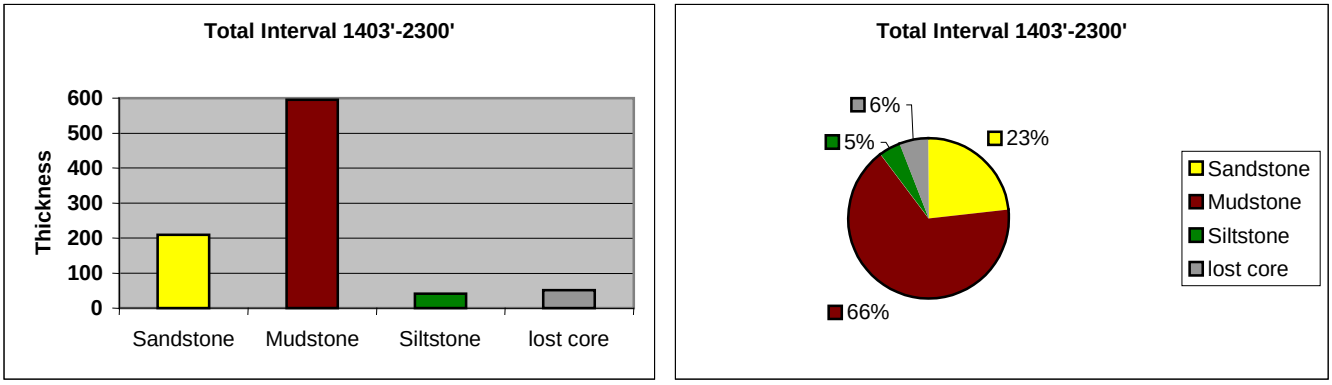


FIGURE 2C

These characteristics support the interpretation that the sediments of the entire Phase II cored interval were deposited in a shallow marine shelf environment. They probably owe their cyclic variability to differences through time in activity and location of deltaic complexes in the south and southwest, which were active at the same time (Molenaar, 1983). As coarser-grained sediment was delivered to the marine environment, it was reworked and re-distributed by marine waves and currents into offshore bars and sheets of sand, some of which may be continuous laterally with their shoreline or river mouth equivalents. Between episodes of coarser-grained sedimentation, longer periods of deposition of finer-grained sediment allowed accumulation of silt and clay burying and enclosing the sandier deposits from the last progradation of the coastal environments.

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Hot Ice - 1, Geological Report: 1/31/04- 6pm

Cored from 1422.9' to 1470.3', recovered 43.1'. Upper part of formation is mostly silty mudstone, except for one interval of very clay- and silt-rich very fine sandstone, 1436.5'-1443.8'. Below this, sandy intervals are much more common, and a slightly gas-bearing sand was encountered near the bottom, at 1469'. These sands are relatively soft, and do not contain hydrate, but they indicate proximity to the most prospective section of sands and the presence of gas in the section.

Hot Ice #1 – Geological Report – 2/1/04 – 6 am

Cored interval from 1470.3' to 1551.0' (80.7 ft.); recovered 77.0 ft. (95% recovery). The formations are firming as we progress and thus recoveries are improving. The drilled formation is predominantly sandstone with minor amounts of mudstone and siltstone in the upper part. Most of the upper section drilled shows evidence of gas-bearing zones with the finer grained ones more evident as they retain the gas and bubble after the core is removed from the core tube. The lower part of the section is definitely finer grained with a marked increase in siltstone and mudstone from 1510' to 1551'.

Hot Ice – 1, Geological Report: 2/1/04, 6 p.m.

Drilled 1551.3' – 1645.4' (94.1'), and recovered 89.4'.
The sediments drilled are a continuation downward of the silty, calcareous mudstones drilled at the end of the previous tour. The favorable sandstones seen early yesterday are not present below 1540'; only fossil-bearing, marine mudstones and siltstones are present in the section drilled during the daylight tour today.

Hot Ice #1 – Geological Report – 2/1/04 – 6 am

Cored interval from 1470.3' to 1551.0' (80.7 ft.); recovered 77.0 ft. (95% recovery). The formations are firming as we progress and thus recoveries are improving. The drilled formation is predominantly sandstone with minor amounts of mudstone and siltstone in the upper part. Most of the upper section drilled shows evidence of gas-bearing zones with the finer grained ones more evident as they retain the gas and bubble after the core is removed from the core tube. The lower part of the section is definitely finer grained with a marked increase in siltstone and mudstone from 1510' to 1551'.

Hot Ice – 1 Geological Report – 2/2/04 – 6 p.m.
Cored the interval 1726.1' – 1816.1'(90'), recovered 90' (100%).
The uppermost core is 9 ft. of sandstone, which is fine-grained, very even textured, and unconsolidated, with excellent permeability; no gas or hydrate occurred in this unit. Below this sand is about 40 ft. of interbedded sands and mudstones, which are fossiliferous, with many thin layers of shell fragments. Within this interval are 3 layers of thin, very hard sandstones, cemented by calcite. Below this section of interbedded

lithologies is about 40 ft. of mostly mudstone, which includes only a few beds of silty, very fine sand and shell fragments.

Hot Ice – 1 Geological Report – 2/3/04 – 6 a.m.
Cored the interval 1816.1' to 1865.9' (49.8'), recovered 41.1' (82%).
Most of the cored interval is mudstone with thin sandy and silty intervals and scattered shell fragments as seen previously. One, very good sandstone interval occurs from 1825' to 1835'; the top 1.5' of this sandstone is strongly cemented by calcareous cement, as has also been seen previously. This sandstone is fine grained, quartz-lithic, well-sorted, fossiliferous and probably has excellent permeability where it is not cemented but no gas was seen here.

Cored the interval 1865.9' – 1953.0'(95.2'), recovered 91.2' (95.8%).
The upper half of the cored interval consists of a 10 ft. thick sandstone overlying a 30 ft. thick mudstone. This fossiliferous sand coarsens upward from VF to Medium grainsize. It includes numerous thin claystone and siltstone layers that reduce vertical permeability. The mudstone includes numerous thin silty laminae. Below this, at about 1910' begins a section about 40 ft. thick of mostly VF-Fine grained sandstone that is very soft and friable. There are many thin, silty or clayey laminae and thin beds with fossil fragments, a cemented layer, and two thin mudstones, which all impair vertical permeability. Even in the better quality sands, no hydrate or bleeding gas was seen. This sandy interval overlies another mudstone and the bottom of the cores ends in a sandstone.

Hot Ice – 1 Geological Report – 2/4/04 – 6 a.m.
Cored the interval 1953.0' to 2033.0' (80.0'), recovered 77.2' (96%).
The entire upper part of this interval is mudstone except for a fine-grained, dark gray, slightly silty, well sorted sandstone from 1955.5' to 1960.3'. It contained no hydrate and no bleeding gas was observed. Below this lies a thick mudstone interval until another sandstone is encountered at about 1998'. The upper part of this sandstone zone (approximately 3 feet) is fine grained, well sorted sandstone. Below, this the sand becomes increasingly silty and argillaceous before an 8' thick siltstone interval is encountered at about 2006'. Below this siltstone is an alternating sequence of silty, sandy mudstones, sandy argillaceous siltstones and silty, argillaceous, fine grained sandstone stringers. No gaseous zones were encountered during this tour and the background mud gas measured by the Pason instruments is about 20% of the levels measured in the Upper West Sak sands.

<u>Hot Ice – 1 Geological Report – 2/4/04 – 6 p.m.</u>

Cored the interval 2033.0' – 2064.7'(31.7'), recovered 24.4' (77%).

The tour began with a broken retrieval wireline and having to pull the drill string to recover it, which reduced effective coring time. Coring did not resume until 1 p.m. The malfunctioning gamma ray logger is being investigated and may require re-running some of the core. Plugs are being taken from previous cores at depths where R. Sigal specified.

The cored interval consists of mostly mudstone, with scattered silty laminae and shell frags. Only one, very fine, silty sand was encountered, from 2042-2046', and no shows of hydrate were found.

Hot Ice – 1 Geological Report – 2/5/04 – 6 a.m.
Cored the interval 2064.7' to 2129.4' (64.7'), recovered 64.1' (99%).

The entire upper part of the interval encountered during this tour from 2064.7' to 2115.7' (51') consists of silty mudstone with rare, thin interbeds of fine grained silty sandstone; sandstone makes up less than 5% of this interval. At 2115.7' a fine to medium grained, brown, oil stained sandstone was encountered. The sandstone was interbedded with light to medium gray mudstone and contained fine laminations of siltstone and mudstone. Good oil odor was noted throughout the interval and a gas increase to 20 units (~5X background) was detected by the Pason mud gas detector. The total sandstone in this interval was 3.15'. Mudstone, with several very thin (<0.1'), oil stained sandstone lenses was encountered below the oil bearing sandstone and this mudstone continued to the final depth at 2129.4'.

Hot Ice – 1 Geological Report – 2/5/04 – 6 p.m.

Cored the interval 2128.8' – 2195.5'(66.7'), recovered 63.7' (95%).

Following the more sandy intervals encountered in previous drilling, and after discovery of the thin, oil-bearing sandstone last tour (depth 2115.7'), the section cored this tour has been completely mudstone. There has been slight variation in the amount of silt and the carbonaceous partings in the mudstone. Hardness varies slightly also, causing some problems with the core bit "balling-up" and slowing drilling progress. We are now about 760' below "Top of West Sak Formation".

Hot Ice – 1 Geological Report – 2/6/04 – 6 a.m.
Cored the interval 2195.5' to 2246.8' (51.3'), recovered 44.3' (86%).

The mudstone encountered during the previous tour continued until 2210' where a relatively clean sandstone interval was entered. The interval is a multi-storied sandstone approximately 18 feet thick and comprises at least 8 sand packages, fine to medium grained at the top, coarsening upward and having a silty sand base. These sand packages are 1.5 to 3 feet in thickness and are occasionally separated by thin mudstone layers (0.2' thick). The lower part of the sand interval becomes increasingly silty and carbonaceous. No oil stain or odor was detected in this interval. Below the sandstone is approximately 17 feet of sandy, argillaceous siltstone and silty mudstone. Then a 1.5-foot thick oil stained sandstone was encountered. This sandstone is fine grained and very silty at the top; it has a sharp basal contact with the underlying mudstone. The sand shows good brown oil stain and had some oil odor. Below this sandstone approximately 3 feet of mudstone were recovered before a broken wireline cable halted coring operations. Seven feet of core have been cut and remained to be recovered.

Hot Ice – 1 Geological Report – 2/6/04 – 6 p.m.

The core referred to in the previous tour's report, which was recovered when pipe was pulled, consists of mostly mudstone with a thin, 2243.5'-2245.3', weakly oil stained sand. Coring did not resume during this tour.

Hot Ice – 1 Geological Report – 2/7/04 – 6 a.m.
Cored the interval 2246.8' to 2261.2' (14.4'), recovered 14.4' (100%).

The only lithology encountered during this tour was mudstone. BOP testing was completed during the first part of the tour, then the wireline was replaced and pipe was run back in the hole. Coring did not begin until the early morning hours

Hot Ice – 1 Geological Report – 2/7/04 – 6 p.m.

Cored the interval 2261.2' to 2300' (38.8'), recovered 38' (97.9%).

The cores recovered this tour were almost all mudstone, except for a thin, very fine grained sand that occurs at 2273.5'-2274.9', but which contains no shows. About 17' of the mudstone appears dark brown in color, possibly signifying unusually high content of organic matter (macerated plant debris). Total depth of 2300' was reached at about noon. The last one-foot of core was hard mudstone.