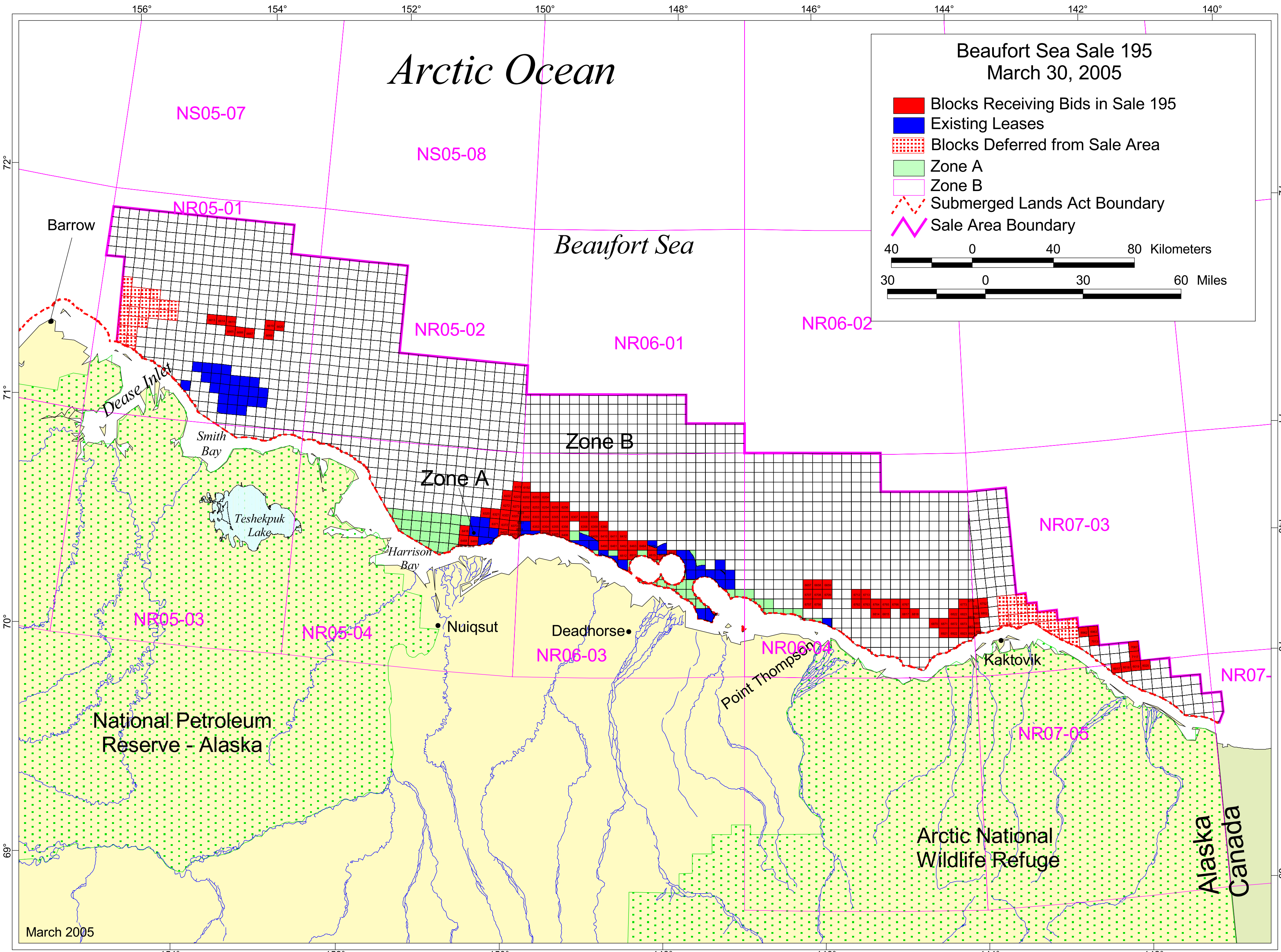
APPENDIX A

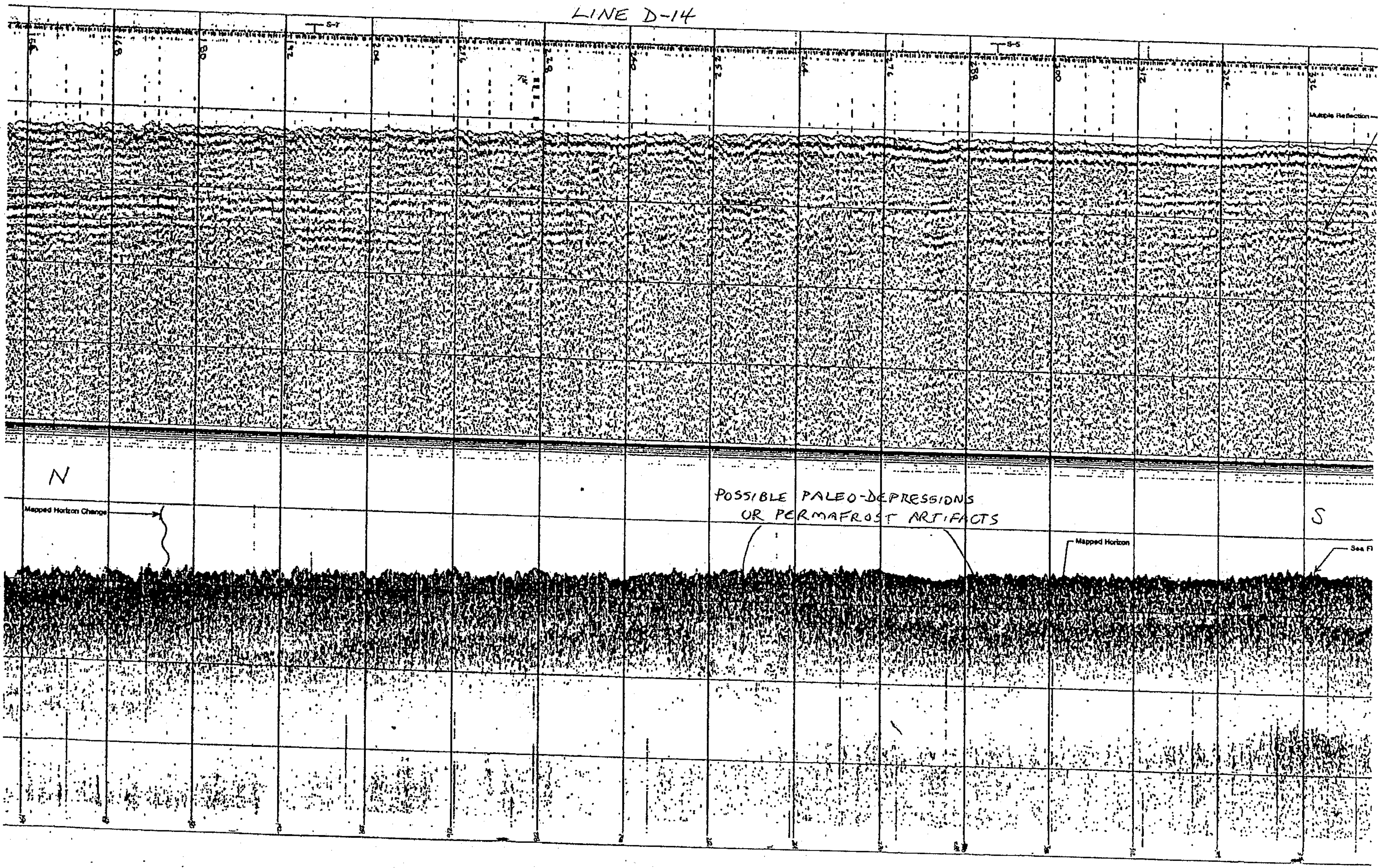
BEAUFORT SEA LEASE SALE MAP
MARCH 30, 2005


Arctic Ocean
Beaufort Sea Sale 195
March 30, 2005
Blocks Receiving Bids in Sale 195
Existing Leases
Blocks Deferred from Sale Area
Zone A
Zone B
Submerged Lands Act Boundary
Sale Area Boundary
40 0 40 80 Kilometers
30 0 30 60 Miles
NS05-07
NS05-08
NR05-01
NR05-02
NR06-01
NR06-02
NR07-03
NR05-03
NR05-04
NR06-03
NR06-04
NR07-05
NR07-
Beaufort Sea
Barrow
Dease Inlet
Smith Bay
Teshekpuk Lake
Harrison Bay
Zone A
Zone B
Nuiqsut
Deadhorse
Point Thompson
Kaktovik
National Petroleum Reserve - Alaska
Arctic National Wildlife Refuge
Alaska
Canada
March 2005
156°
154°
152°
150°
148°
146°
144°
142°
140°
72°
71°
70°
69°

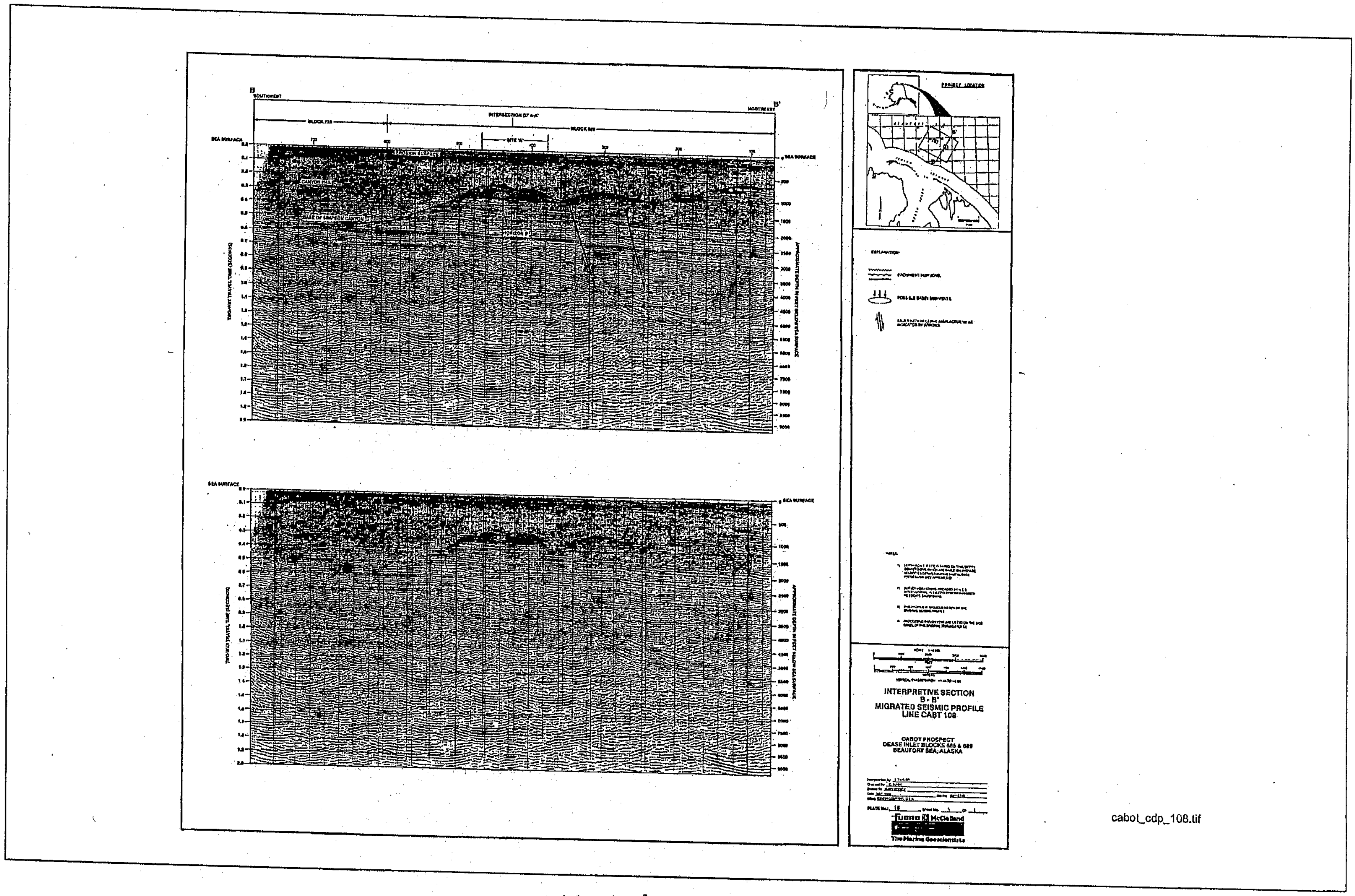
APPENDIX A-1

APPENDIX B

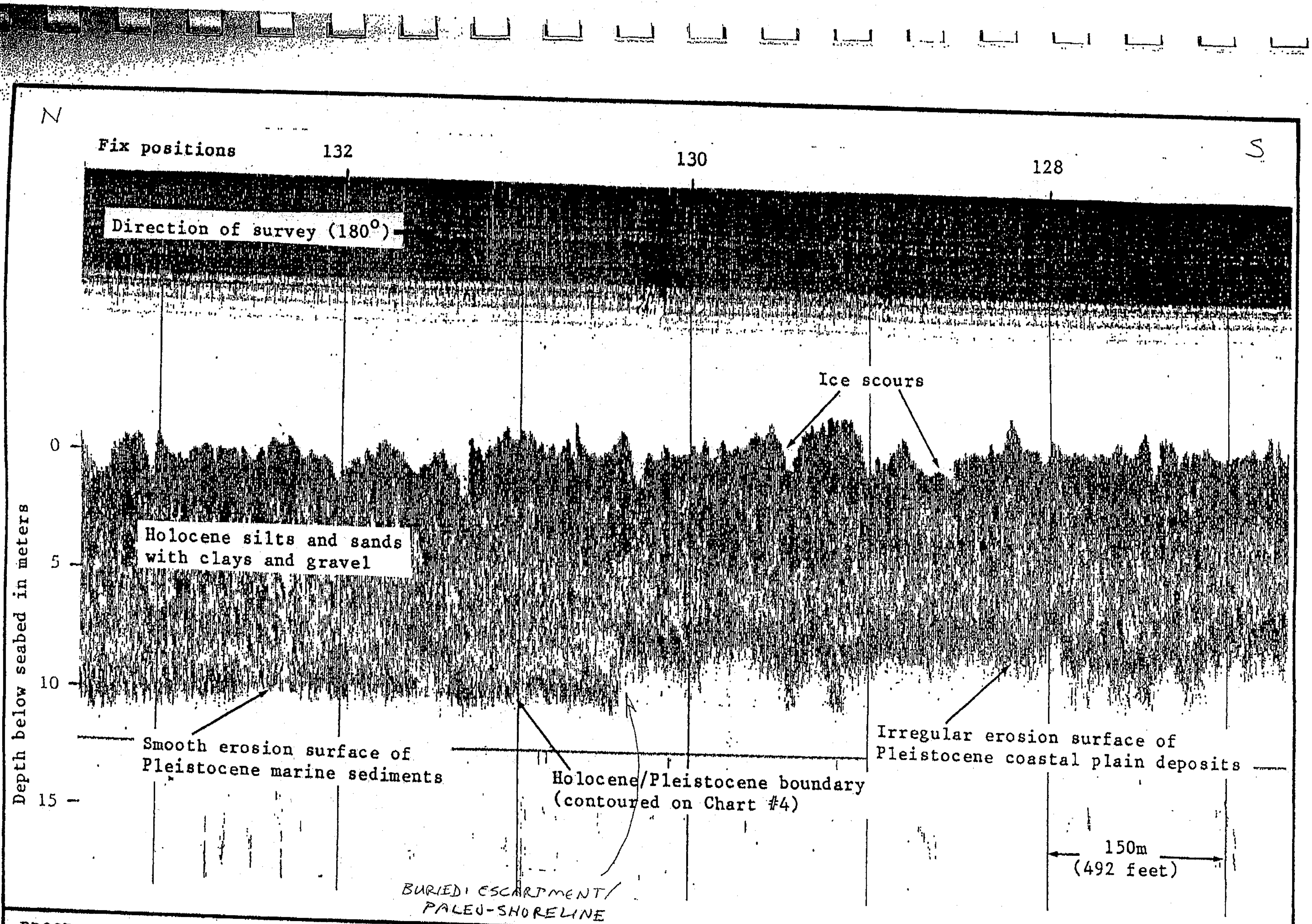
GEOPHYSICAL DATA EXAMPLES FROM SELECTED INDUSTRY SITES: AURORA, CABOT, FIREWEED-ARCO, MARS, PHOENIX, SANDPIPER, WARTHOG



AURORA SITE
(Pelagos, 1987)



CABOT SITE
(Fugro-McClelland, 1990; MMS, 2002)

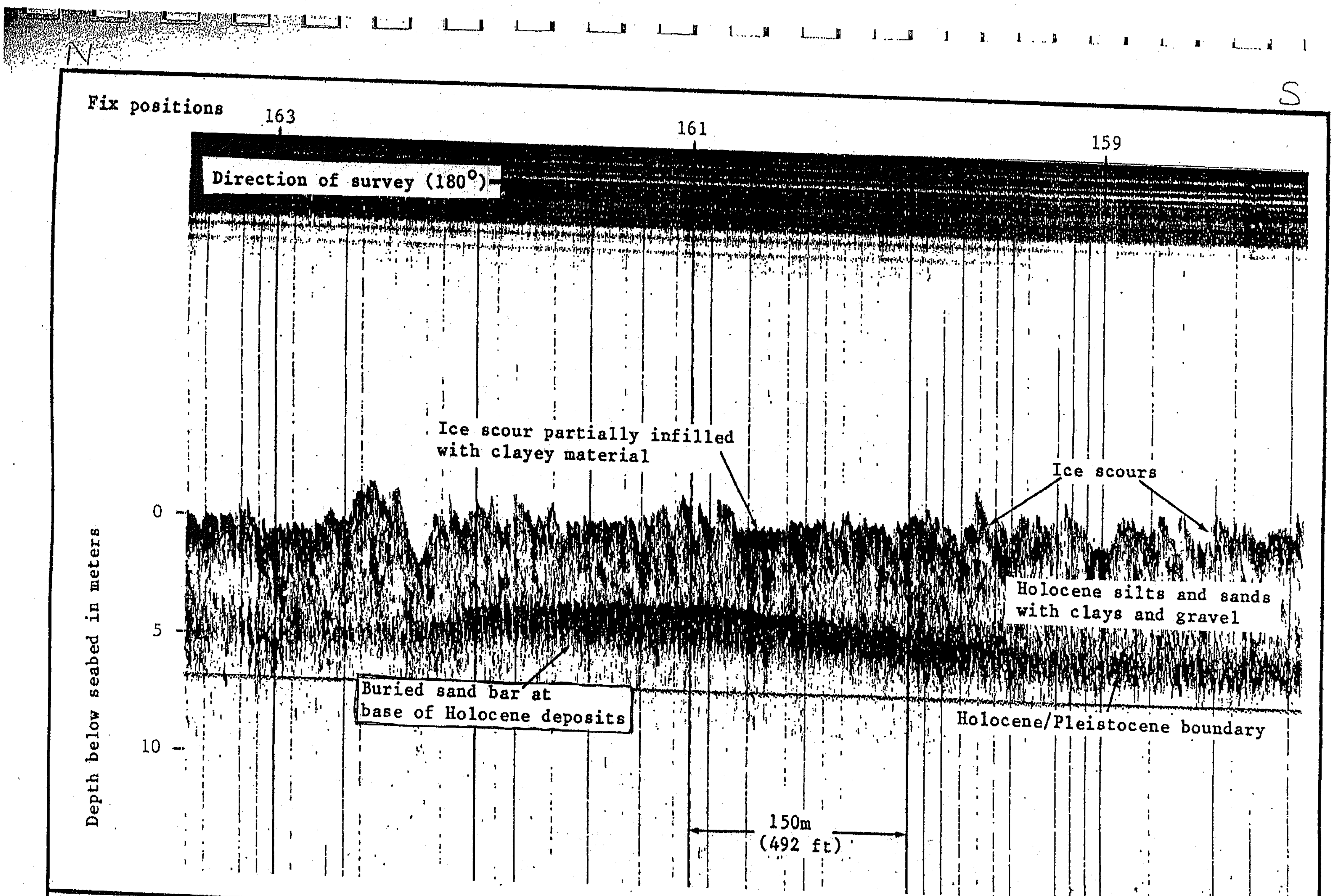


PROSPECT FIREWEED
Line 139

FIGURE 4: SUB-BOTTOM PROFILER DATA EXAMPLE

Comap

FIREWEED - ARCO
(Comap, 1985)

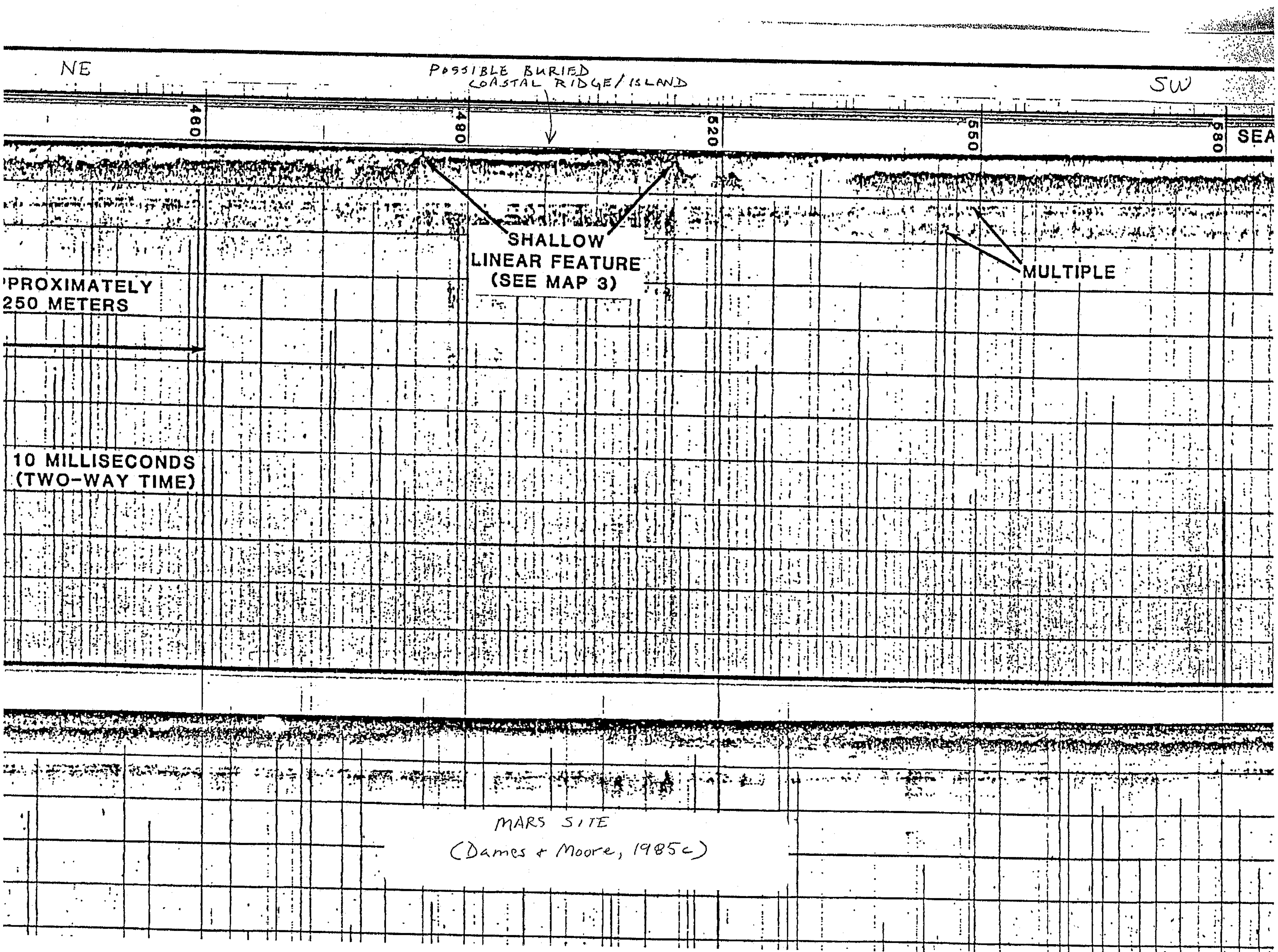


PROSPECT FIREWEED
Line 131A

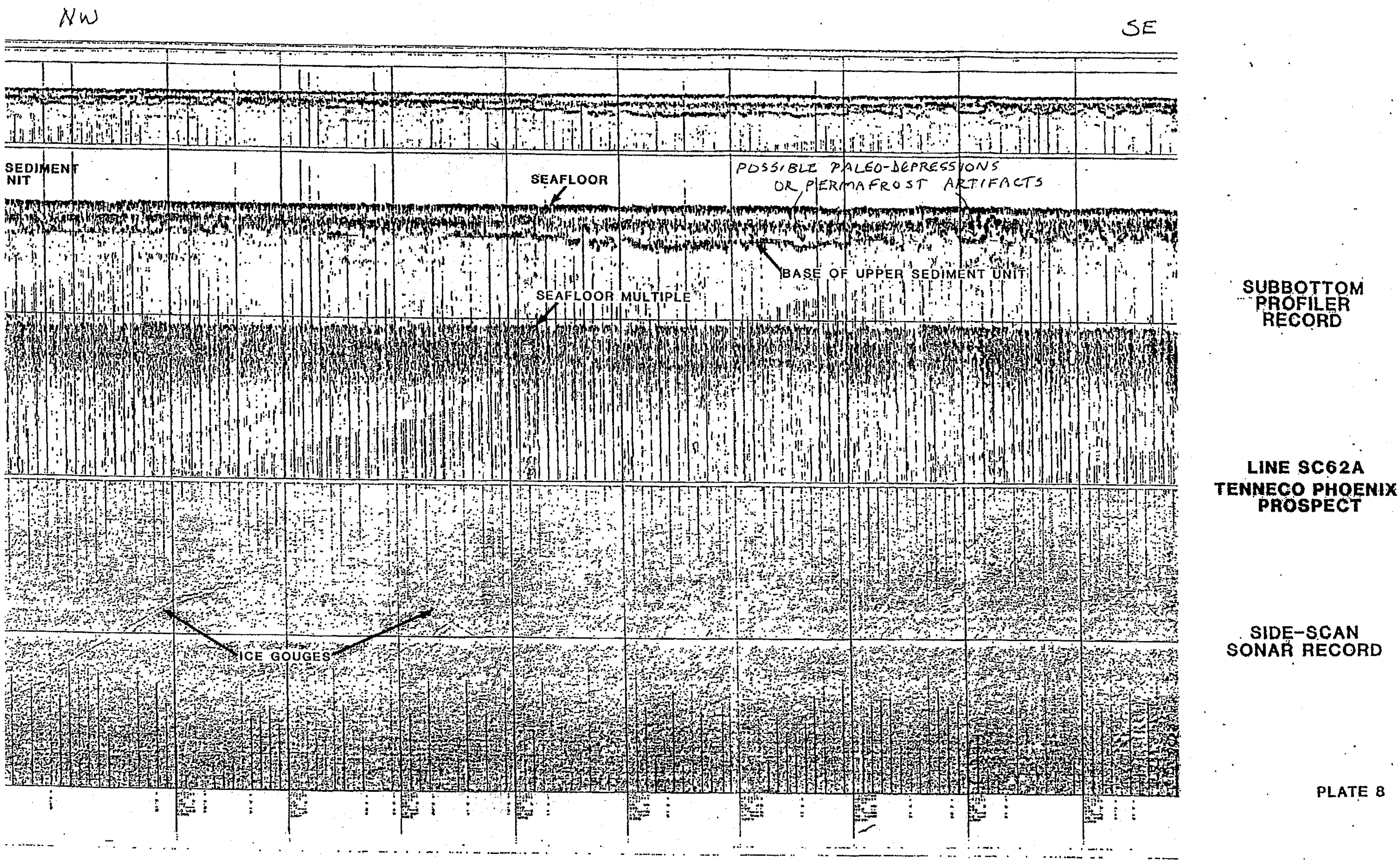
FIGURE 5: SUB-BOTTOM PROFILER DATA EXAMPLE

Comap

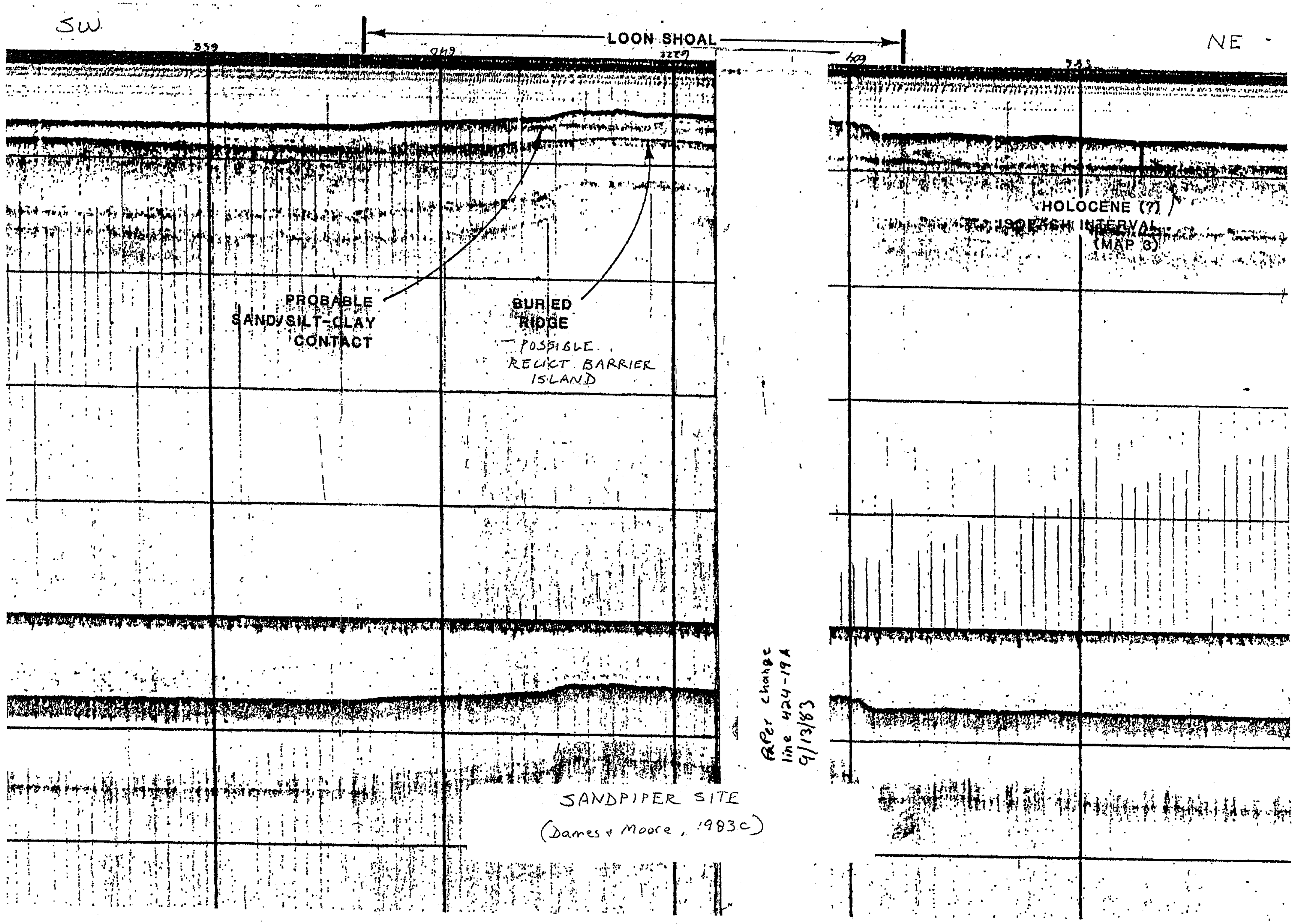
FIREWEED - ARCO
(Comap, 1985)

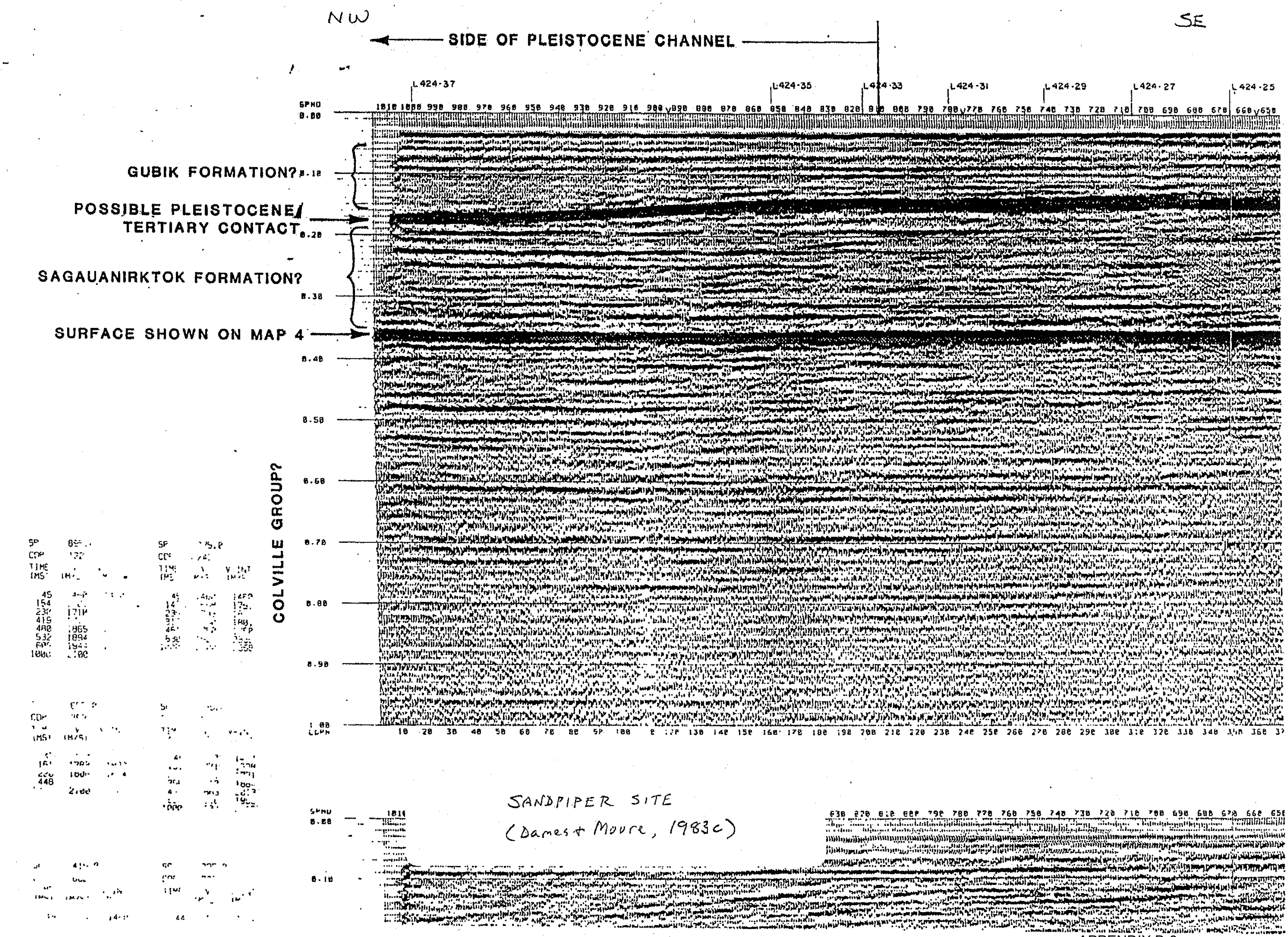


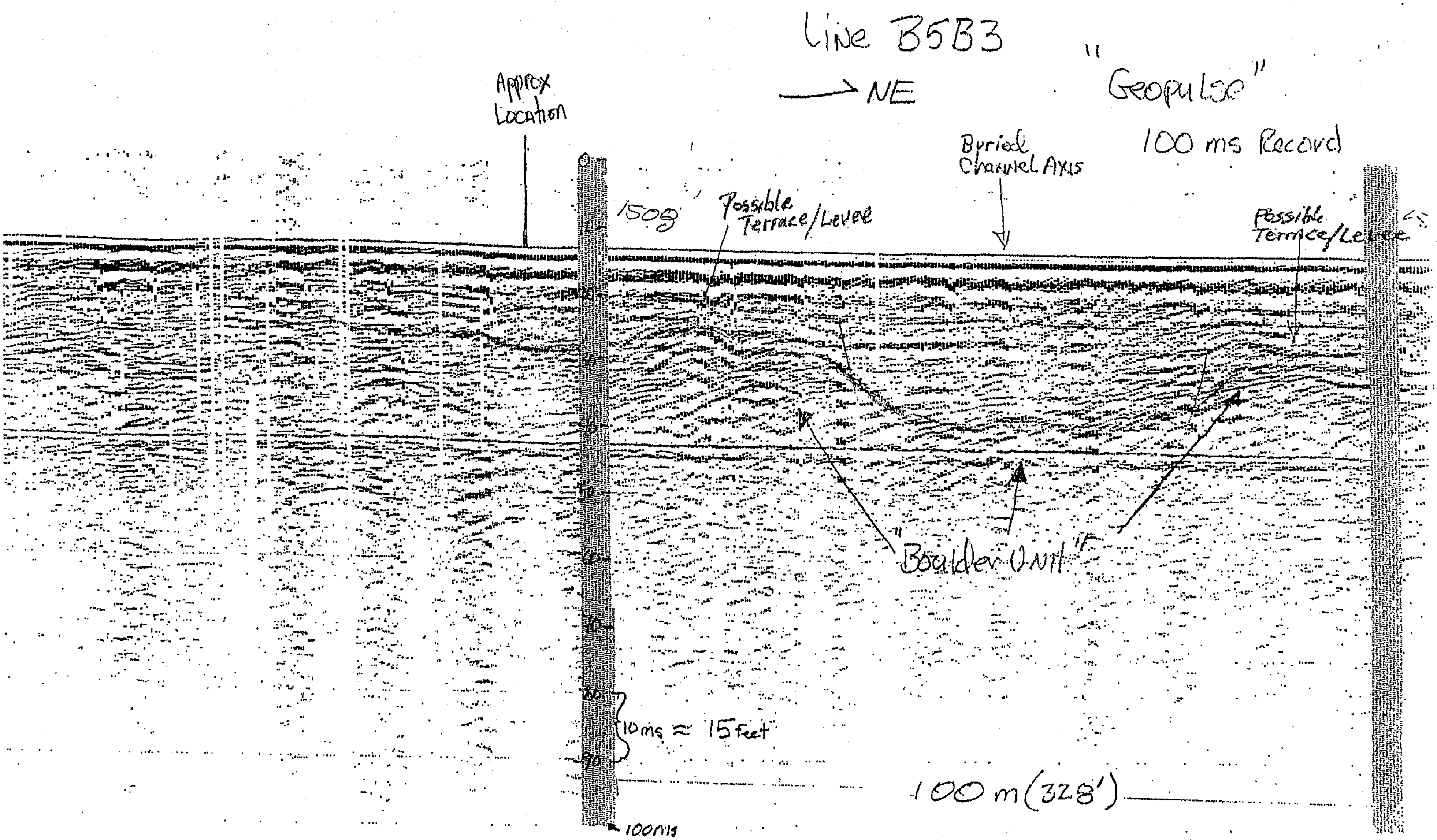
NE
POSSIBLE BURIED COASTAL RIDGE/ISLAND
SW
460
480
520
550
580
SEA
SHALLOW LINEAR FEATURE (SEE MAP 3)
MULTIPLE
'PROXIMATELY 250 METERS
10 MILLISECONDS (TWO-WAY TIME)
MARS SITE
(Dames + Moore, 1985c)



PHOENIX SITE
(McClelland-EBA, 1986)


SW
LOON SHOAL
NE
PROBABLE
SAND/SILT-CLAY
CONTACT
BURIED
RIDGE
POSSIBLE
RELICT BARRIER
ISLAND
HOLOCENE (?)
ISOPACH INTERVAL
(MAP 3)
SANDPIPER SITE
(Dames & Moore, 1983c)
Paper change
line 424-19A
9/13/83

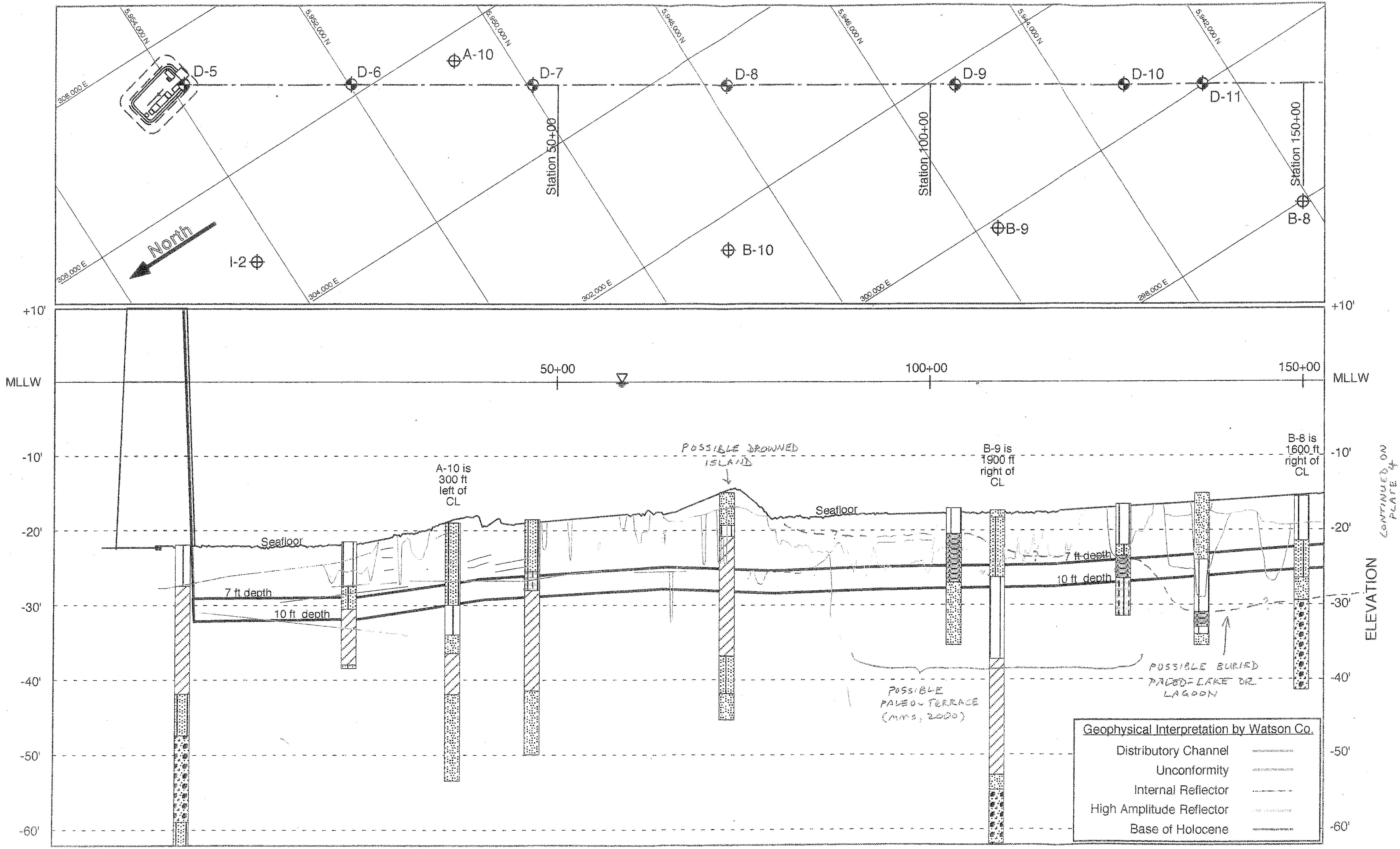

NW
SE
SIDE OF PLEISTOCENE CHANNEL
L424-37
L424-35
L424-33
L424-31
L424-29
L424-27
L424-25
GUBIK FORMATION?
POSSIBLE PLEISTOCENE/
TERTIARY CONTACT
SAGAUANIRKTOK FORMATION?
SURFACE SHOWN ON MAP 4
COLVILLE GROUP?
SANDPIPER SITE
(Dames + Moore, 1983c)



WARTHOG SITE
(Choromanski et al., 1997)

APPENDIX C

LIBERTY SITE:
INTERPRETIVE CROSS-SECTIONS, GEOPHYSICAL DATA EXAMPLES, AND SELECTED BORING LOGS



Symbols

Stiff Clayey Silt	Sand	Sandy Gravel	Organic Silt
Soft Silt	Silty Sand/ Sandy Silt	Silty Gravel	Peat

Horizontal Scale 1" = 1200'

0 600' 1200' 1800' 2400'

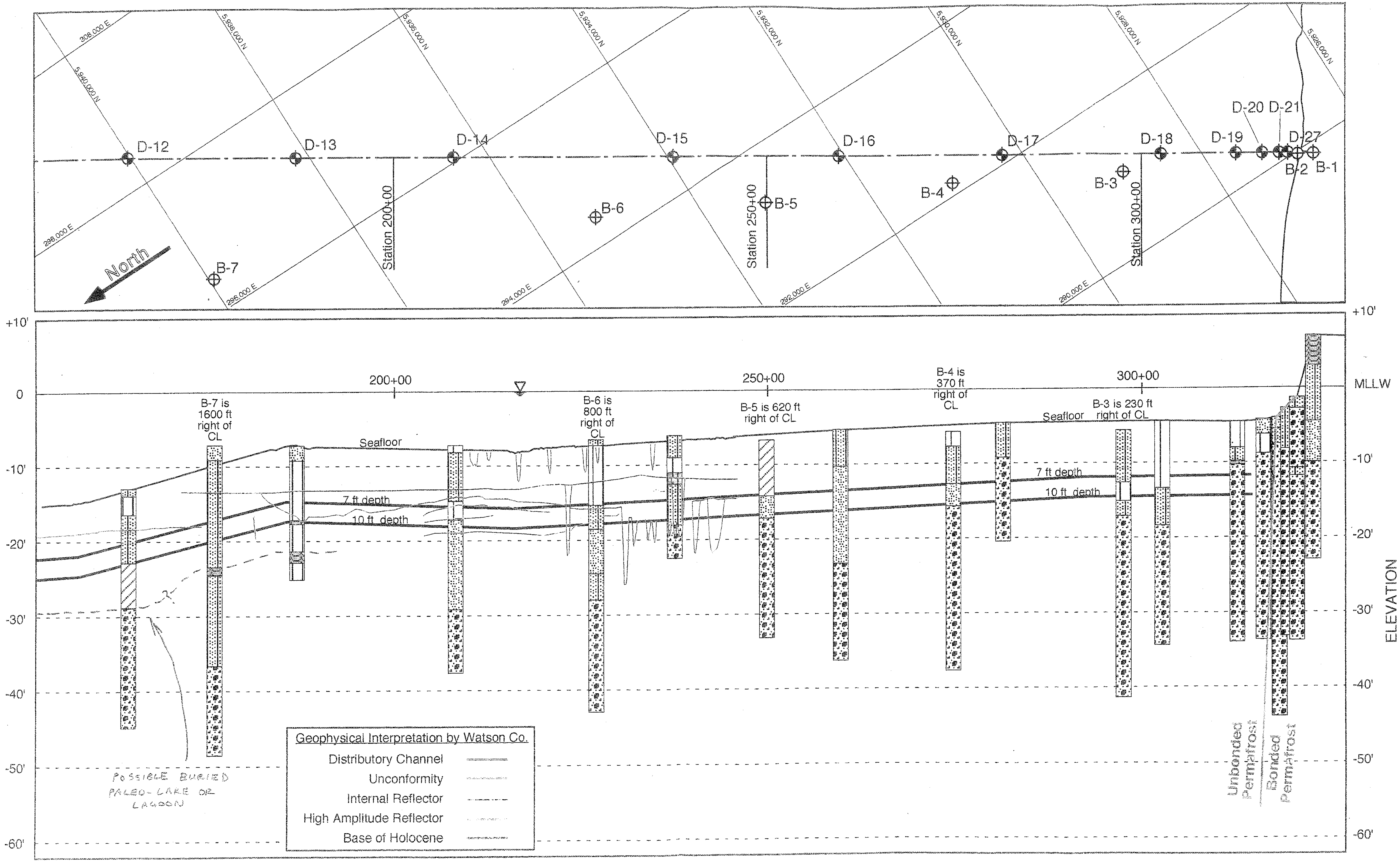
Vertical to Horizontal is 1:100

Duane Miller & Associates
Arctic & Geotechnical Engineering
Job No.: 4119.23
Date : May 1998

Boring Locations and Cross Section (1 of 2)
Liberty Development
Foggy Island Bay, Alaska

Plate
3

APPENDIX C-1



Symbols

Stiff Clayey Silt | Sand | Sandy Gravel | Organic Silt

Soft Silt | Silty Sand/Sandy Silt | Silty Gravel | Peat

Horizontal Scale 1" = 1200'

0 600' 1200' 1800' 2400'

Vertical to Horizontal is 1:100

Duane Miller & Associates

Arctic & Geotechnical Engineering

Job No.: 4119.23

Date : May 1998

Boring Locations and Cross Section (2 of 2)

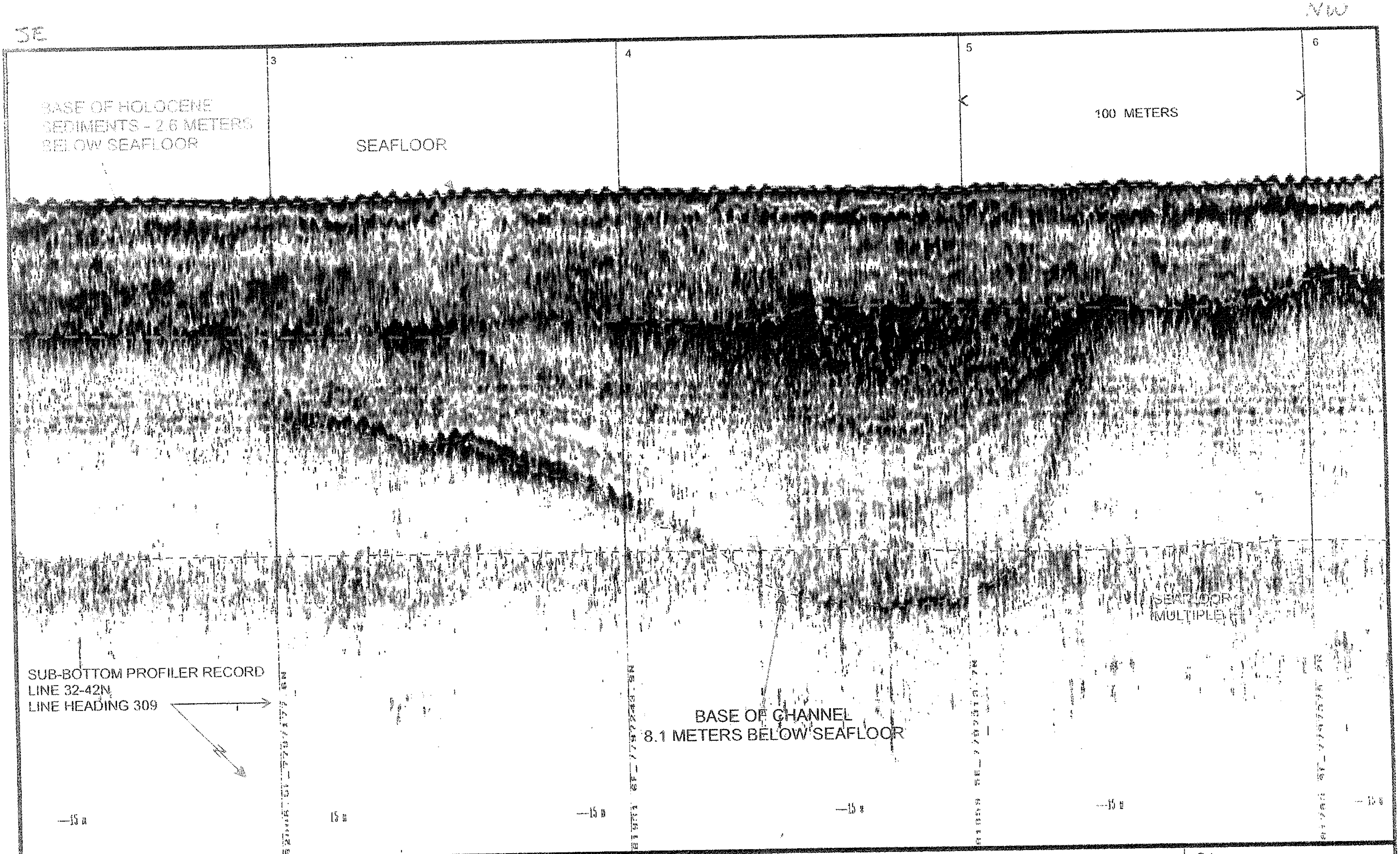
Liberty Development

Foggy Island Bay, Alaska

Plate

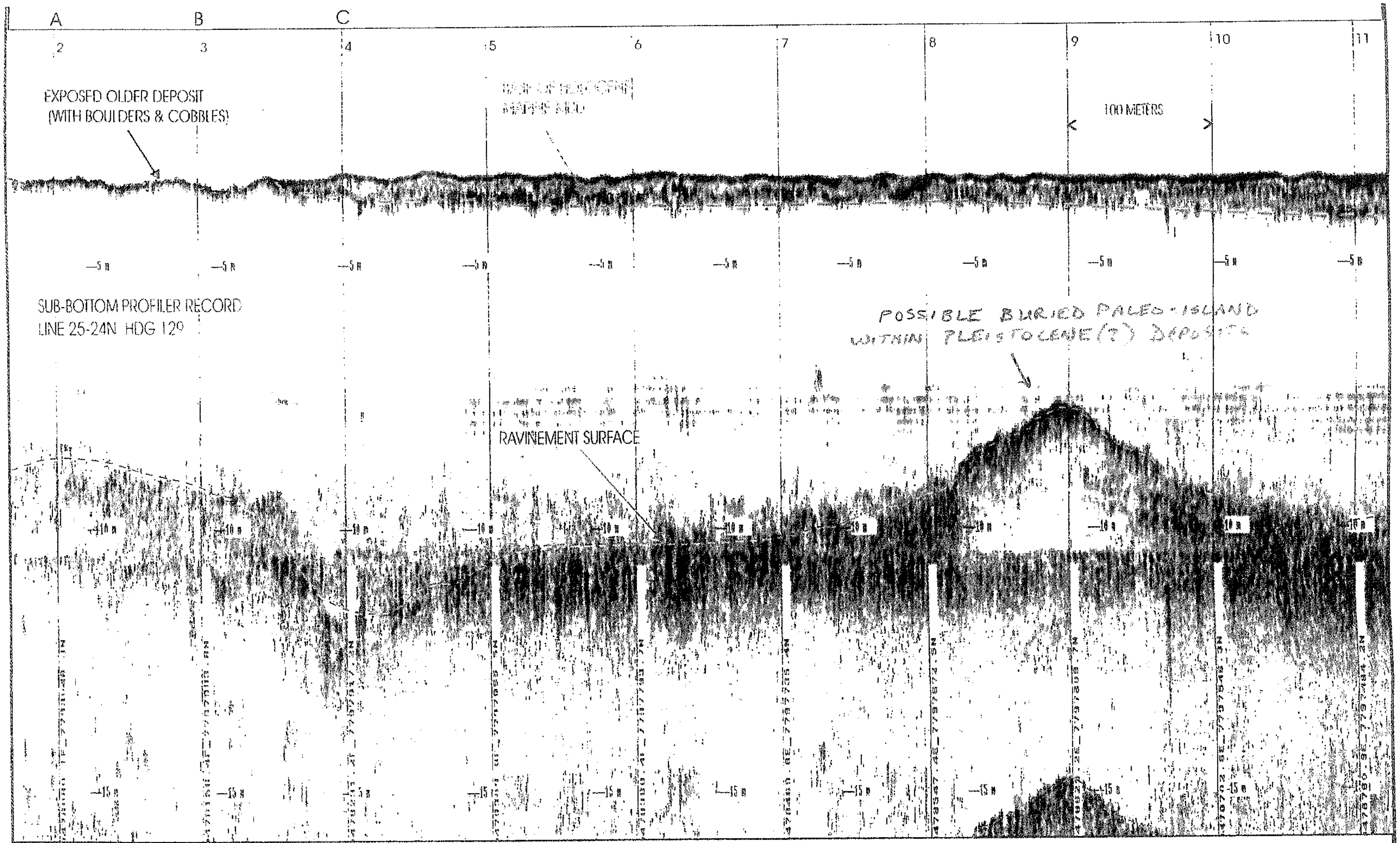
4

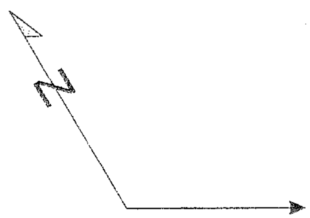
APPENDIX C-2



WATSON COMPANY Anchorage, Alaska	Prepared For: BP EXPLORATION (ALASKA), INC.		Date: AUGUST 1997
Subject: SITE CLEARANCE SURVEY	LIBERTY - SUB-BOTTOM PROFILER DATA EXHIBIT		Figure: 8

NORTHEAST CORNER OF LIBERTY SITE
(Watson 1998)





LINE HEADING 129°

Note: All Coordinates
in UTM 6
NAD 27 Meters

NORTHWEST QUADRANT,
LIBERTY SITE
(Watson, 1998)

WATSON CO. Anchorage, Alaska	
Prepared for: BP EXPLORATION (ALASKA), INC.	
SITE CLEARANCE SURVEY - PHASE II	
Location: LIBERTY FOGGY ISLAND BAY	
PHASE II - NEAR SURFACE CONDITIONS	
Subject: SIDE SCAN AND SUB-BOTTOM EXHIBITS	
Date: AUGUST 1997	Drawn: GA
Scale: AS NOTED	Checked: WW
FIGURE NO. 9	

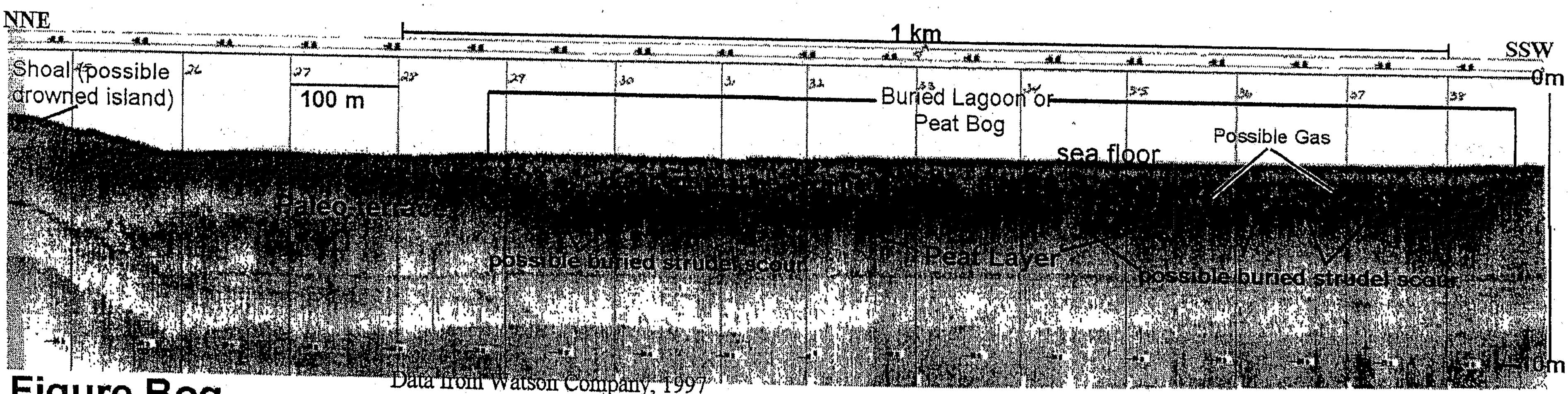


Figure Bog

LIBERTY SITE - WEST PIPELINE ROUTE
(MMS, 2000)

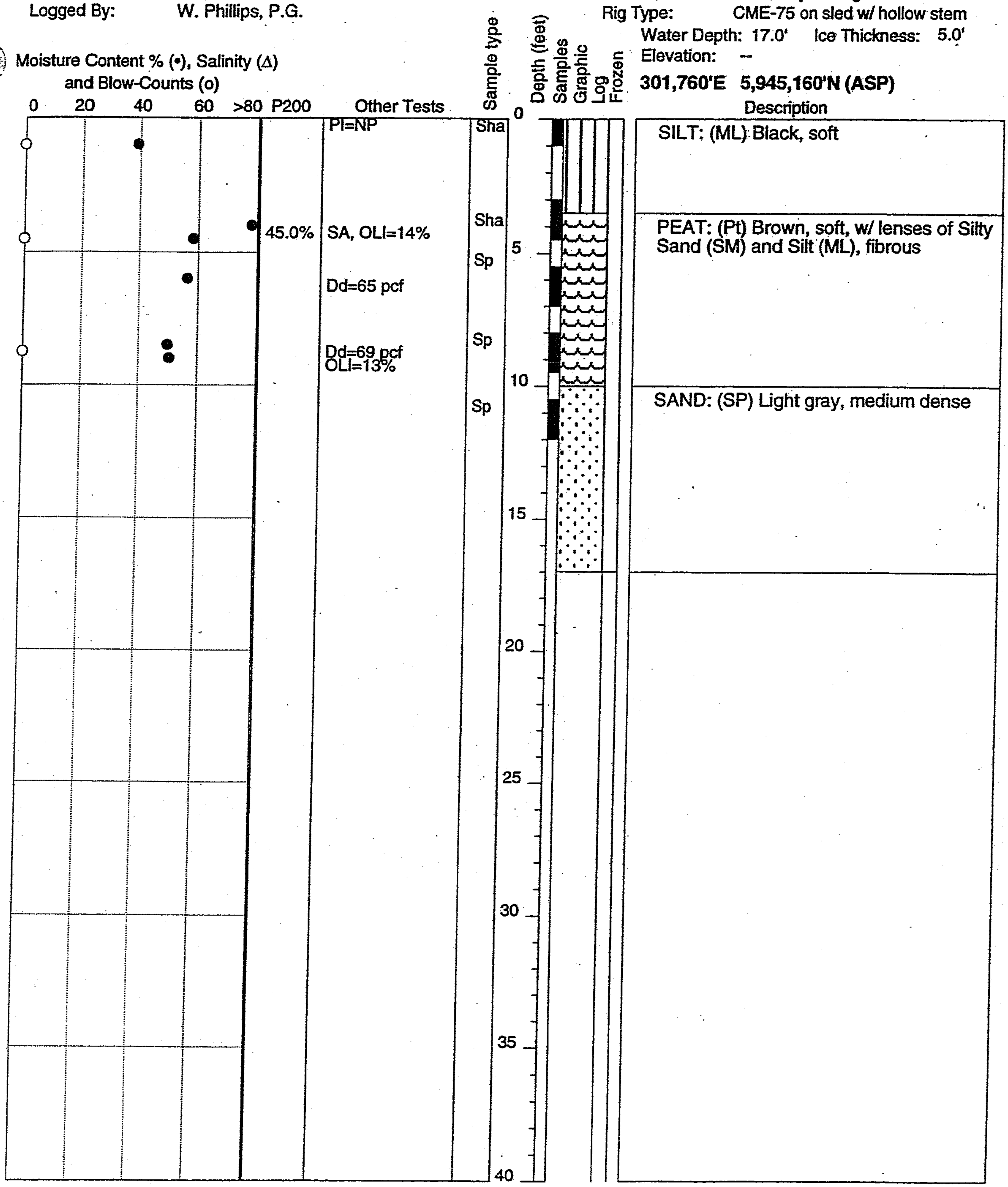
19.1

DUANE MILLER & ASSOCIATES

Project: **Liberty**
DM&A Job No. : 4119.23
Logged By: W. Phillips, P.G.

Log of HOLE : D-9

Date Drilled: March 21, 1998
Contractor: Discovery Drilling/CATCO
Rig Type: CME-75 on sled w/ hollow stem
Water Depth: 17.0' Ice Thickness: 5.0'
Elevation: --
301,760'E 5,945,160'N (ASP)



Duane Miller & Associates
Arctic & Geotechnical Engineering
Job No.: 4119.23
Date: July 1998

LOG OF BORING D-9
Liberty Development
Beaufort Sea, Alaska

Plate
A-14

DUANE MILLER & ASSOCIATES

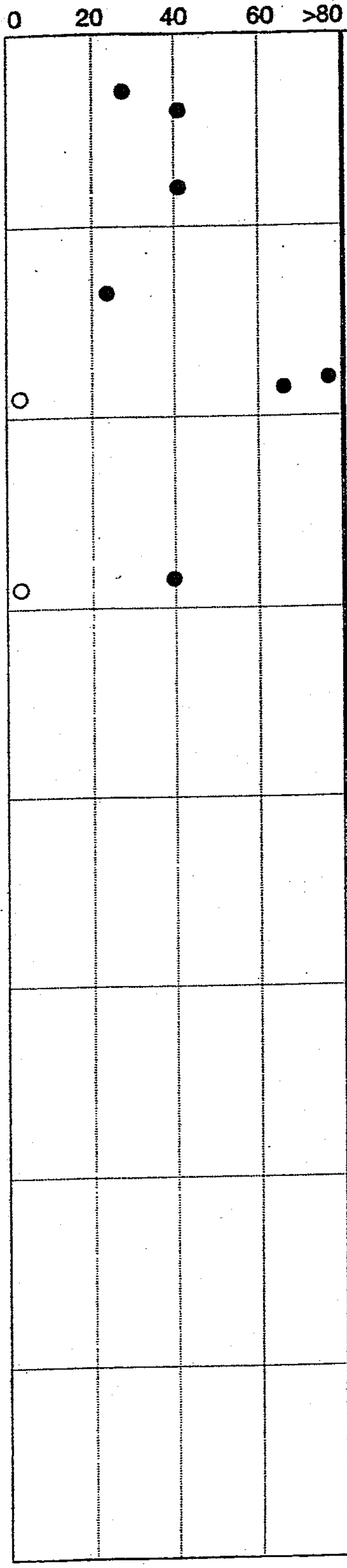
Project: **Liberty**
DM&A Job No. : 4119.23
Logged By: W. Phillips, P.G.

Log of HOLE : D-10

Date Drilled: March 21, 1998
Contractor: Discovery Drilling/CATCO
Rig Type: CME-75 on sled w/ hollow stem
Water Depth: 11.2' Ice Thickness: 5.0'
Elevation: --
300,524'E 5,943,265'N (ASP)

Moisture Content % (•), Salinity (Δ) and Blow-Counts (o)

0 20 40 60 >80



P200	Other Tests	Sample type	Depth (feet)	Description
		Sp	0	SILT: (ML) Dark gray, soft, 2" layer of Silty Sand (SM) at surface, lenses of Sand (SP-SM) and Organic Silt (OL)
73.0%	Dd=90 pcf MA, OLI=4%, PI=NP, Dd=85 pcf	Sp		
	Dd=79 pcf	Sp	5	
18.0%	SA	Sp		SILTY SAND: (SM) Gray, loose, fine grained
				PEAT: (Pt) Brown, soft, trace light gray silt, fibrous
	OLI=26%	Sha	10	ORGANIC SILT: (OL) Black, soft, w/ wood fragments and occasional Sand (SP-SM) lenses
		Sha	15	
			20	
			25	
			30	
			35	
			40	

Samples | Graphic | Log | Frozen

Duane Miller & Associates
Arctic & Geotechnical Engineering
Job No.: 4119.23
Date: July 1998

LOG OF BORING D-10
Liberty Development
Beaufort Sea, Alaska

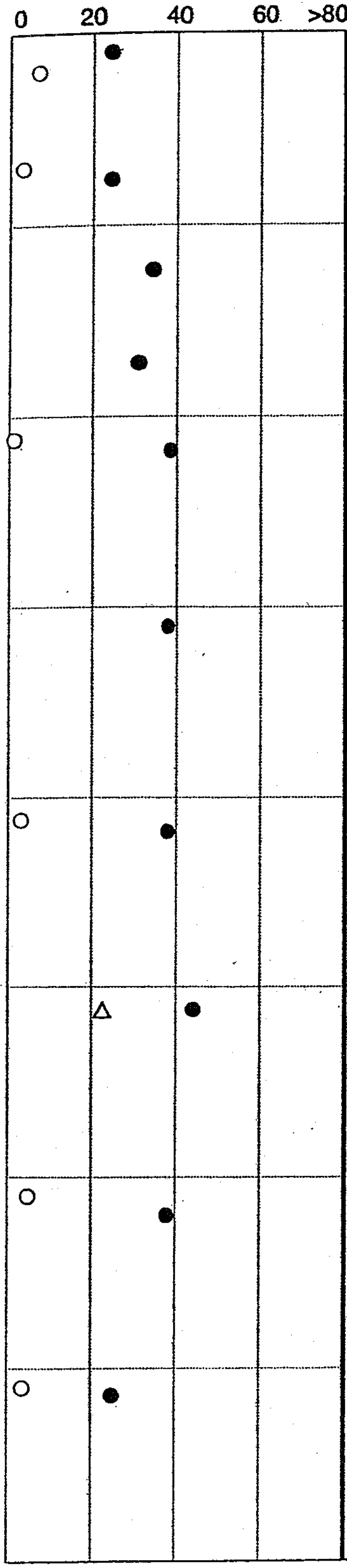
Plate
A-15

DUANE MILLER & ASSOCIATES

Project: **Liberty**
DM&A Job No.: 4119.22
Logged By: W. Phillips, P.G./E. Bashaw

Log of HOLE: B-9

Date Drilled: February 18, 1997
Contractor: Catco/Discovery Drilling
Rig Type: CME-75 on sled w/ hollow stem
Water Depth: 17.3 Ft. Ice Thickness: 4.0 Ft.
Elevation:
N70° 15' 20.78" W147° 37' 1.90"



Depth (feet)	P200	Other Tests	Sample type	Description
0	16.0%	SA	Sh	SILTY SAND: (SM) Gray, fine, layer of black organic material on top
			Sh	SILT: (ML) Gray, soft to medium stiff
		Dd=100 pcf		SILT: (ML) Gray, w/ organic fragments, soft to medium stiff w/ interbedded loose fine Sand
5	99.0%	SA, Dd=86 pcf	Tw	
		Dd=90 pcf	Tw	
10			Sh	
		Dd=83 pcf		
			Tw	
15		Dd=80 pcf	Tw	
20			Sh	Medium stiff Silt (MH) below 20 ft.
		Dd=83 pcf		
25		LL=51, PI=15 Dd=75 pcf	Tw	
30			Sh	6" Layer light gray Organic Silt (OL) w/ wood fragments at 30 ft.
		Dd=82 pcf		
35			Sh	SAND: (SP-SM) Fine, loose
		Dd=100 pcf		
				SANDY GRAVEL: (GP) Gray, gravel is round to subround 1/2" to 3/4" diameter, loose to medium dense.
40			Sh	

Boring B-9 is continued on Plate A-22

Duane Miller & Associates
Arctic & Geotechnical Engineering
Job No.: 4119.22
Date: June 1997

LOG of BORING B-9
Liberty Development
Beaufort Sea, Alaska

Plate
A-21

DUANE MILLER & ASSOCIATES

Project: **Liberty**
DM&A Job No.: 4119.22
Logged By: W. Phillips, P.G./E. Bashaw

Log of HOLE : B-9 Cont.

Date Drilled: February 18, 1997
Contractor: Catco/Discovery Drilling
Rig Type: CME-75 on sled w/ hollow stem
Water Depth: 17.3 Ft. Ice Thickness: 4.0 Ft.

N70° 15' 20.78" W147° 37' 1.90"

Moisture Content % (•), Salinity (Δ) and Blow-Counts (o)

0 20 40 60 >80 P200 Other Tests

Sample type	Depth (feet)	Samples	Graphic Log	Frozen	Description
	40				SANDY GRAVEL: (GP)
Ag					
	45				
Ag					
	50				
	55				
	60				
	65				
	70				
	75				
	80				

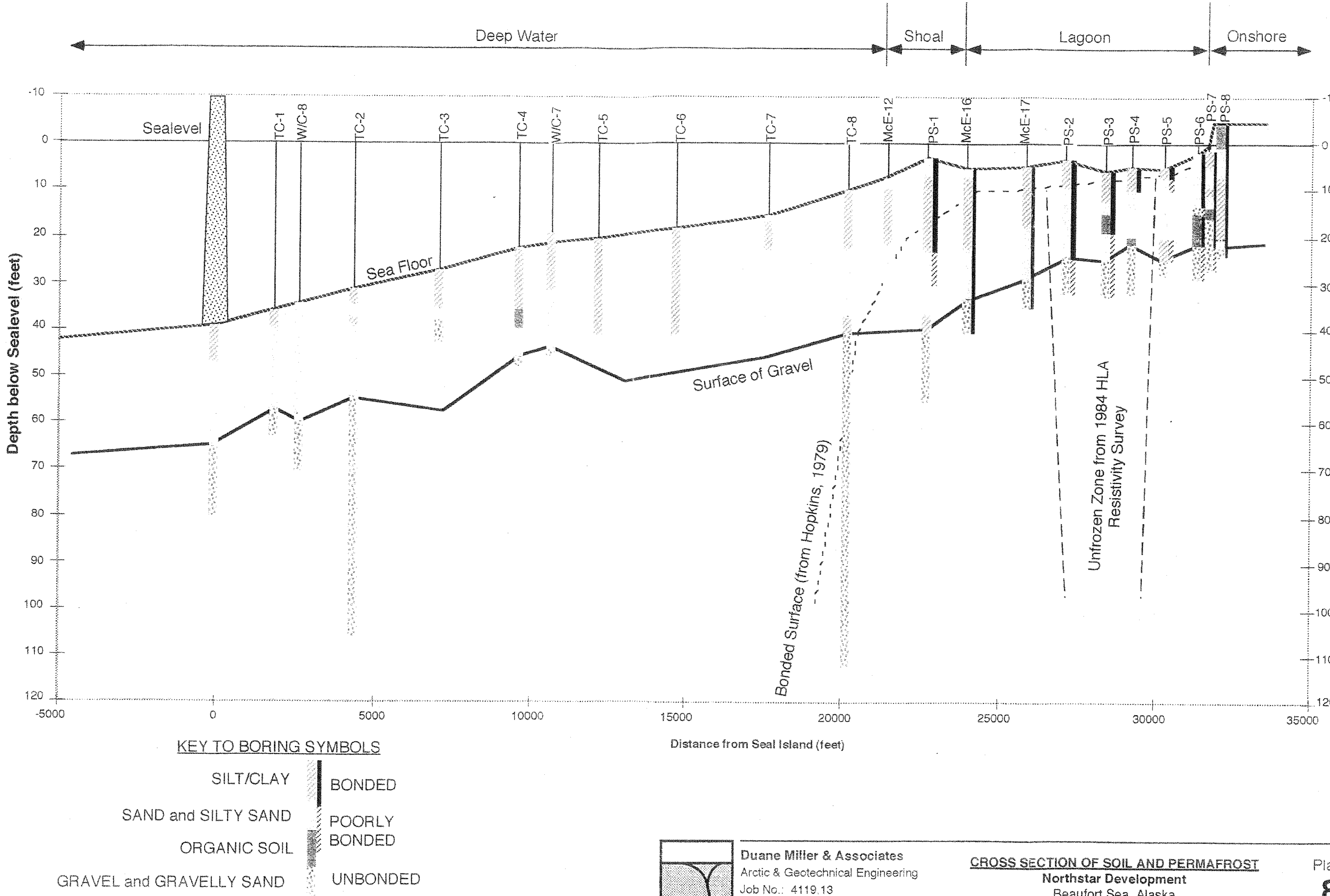
Duane Miller & Associates
Arctic & Geotechnical Engineering
Job No.: 4119.22
Date: June 1997

LOG of BORING B-9 cont.
Liberty Development
Beaufort Sea, Alaska

Plate
A-22

APPENDIX D

NORTHSTAR SITE:
INTERPRETIVE CROSS-SECTION AND SELECTED BORING LOGS



Duane Miller & Associates
Arctic & Geotechnical Engineering
Job No.: 4119.13
Date : May 1996

CROSS SECTION OF SOIL AND PERMAFROST
Northstar Development
Beaufort Sea, Alaska

Plate
8

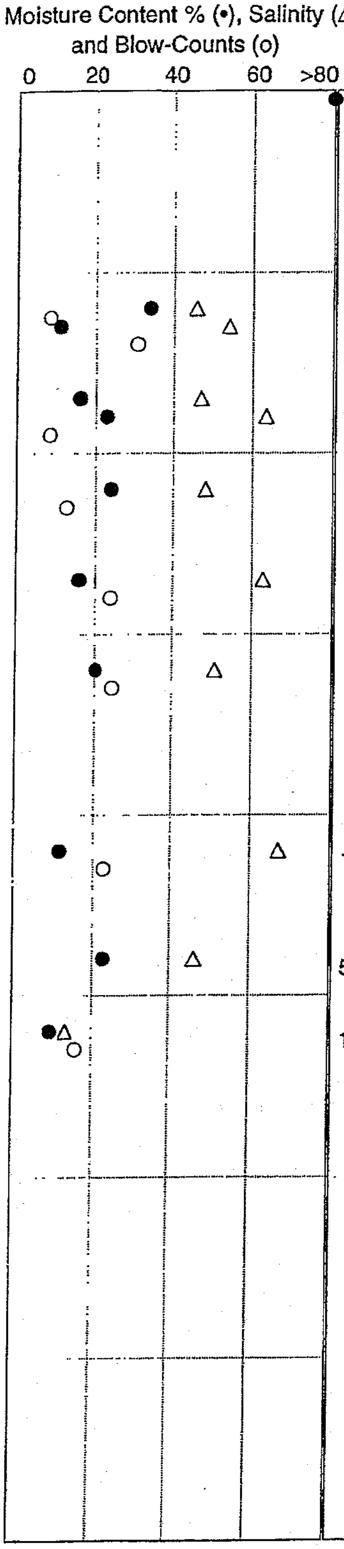
DUANE MILLER & ASSOCIATES

Project: **Northstar**
DM&A Job No. : 4119.13
Logged By: W. Phillips, P.G.

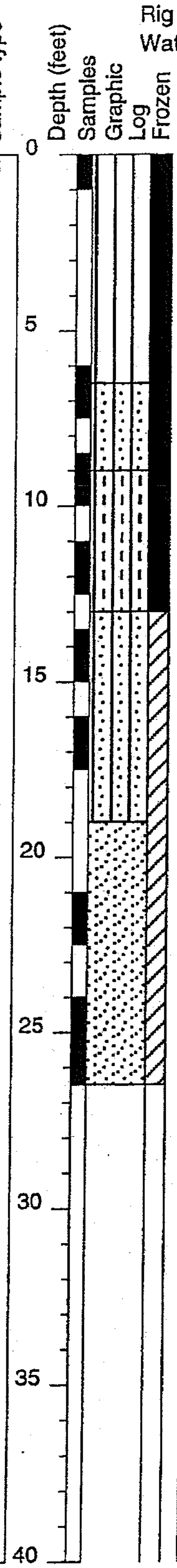
Log of HOLE : Boring PS-3

Date Drilled: May 14, 1996
Contractor: Discovery Drilling/CATCO
Rig Type: CME-75/Rolligon
Water Depth: -- Ice Thickness: 6.0 Ft.*

N70° 24' 51.2" W148° 41' 14.0"



P200	Other Tests	Sample type
		Ag
12.1%	OLI=14.9%	Sh
21.0%	SA, OLI=8.9%, LL=33, PI=9	Sh
	OLI=11.1%	Sh
19.0%	SA	Sh
		Sh
1.3%	SA	Sh
58.0%	SA, OLI=11.0%, LL=29, PI=9	Ag Sh
1.0%		



Description

SILT: (ML) Dark gray, w/ some organic material

SILTY SAND: (SM) Brown

ORGANIC SILT: (OL) Black w/ trace sand and gravel (pebbles), very weak frost bond w/ <1% visible ice (Vx)

SILTY SAND: (SM) Dark gray, sand is medium to fine, medium dense w/ trace gravel below 16.5'

GRAVELLY SAND: (GP) Gray, medium to coarse (maximum size gravel <1"), w/ interbedded zones of dark gray Sandy Clay w/ organic material, medium dense

*Sea ice is bottom fast

Duane Miller & Associates
Arctic & Geotechnical Engineering
Job No.: 4119.13
Date: May 1996

LOG of BORING PS-3
1996 Northstar Development
Beaufort Sea, Alaska

Plate
A-55

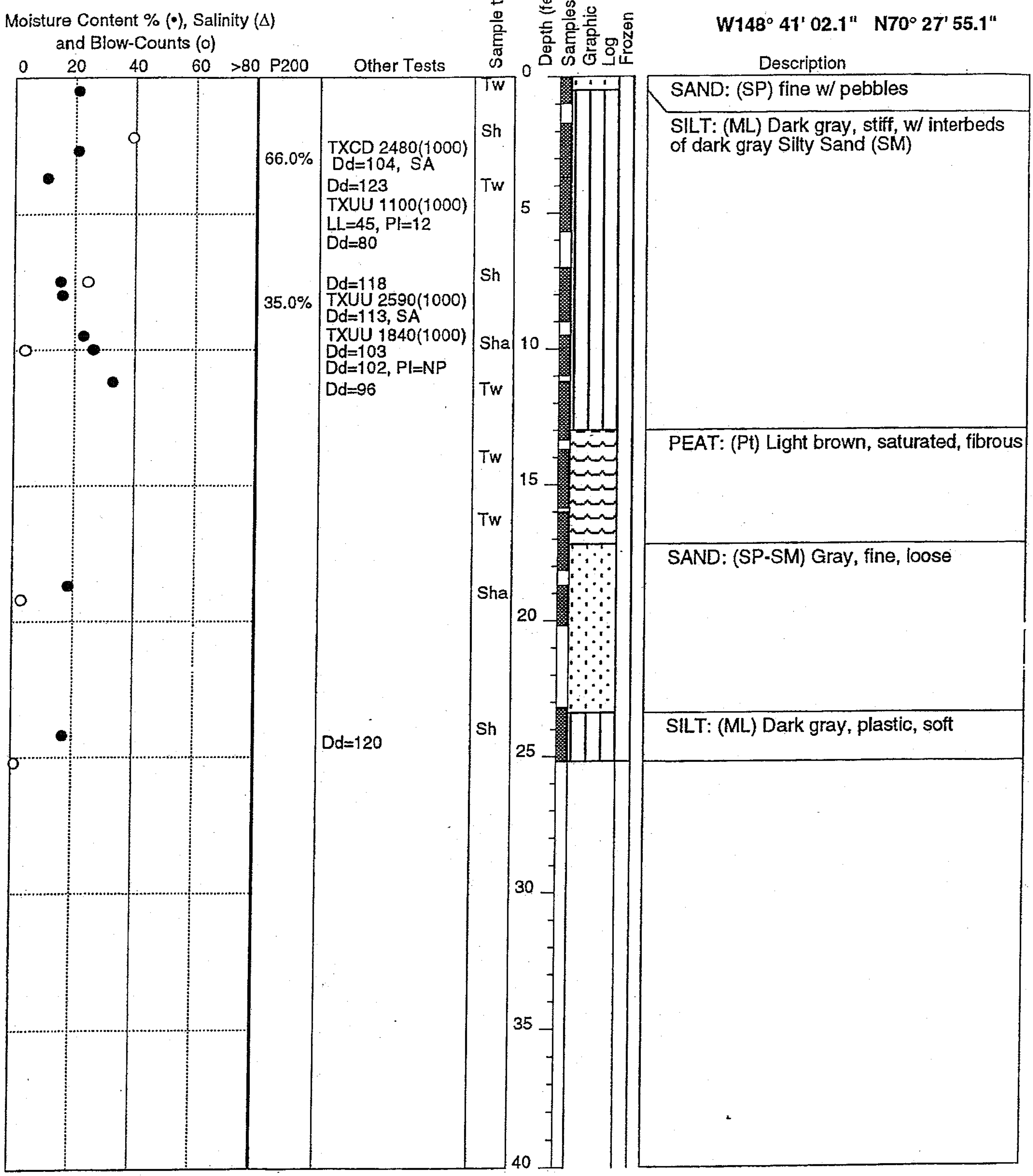
DUANE MILLER & ASSOCIATES

Project: **Northstar**
DM&A Job No.: 4119.13
Logged By: E. Bashaw

Log of HOLE: Boring TC-4

Date Drilled: February 18, 1996
Contractor: Discovery Drilling/CATCO
Rig Type: CME-75/Rolligon
Water Depth: 22.3 Ft. Ice Thickness: 10.7 Ft.

W148° 41' 02.1" N70° 27' 55.1"



Duane Miller & Associates
Arctic & Geotechnical Engineering
Job No.: 4119.13
Date: May 1996

LOG of BORING TC-4
Northstar Development
Beaufort Sea, Alaska

Plate
A-7

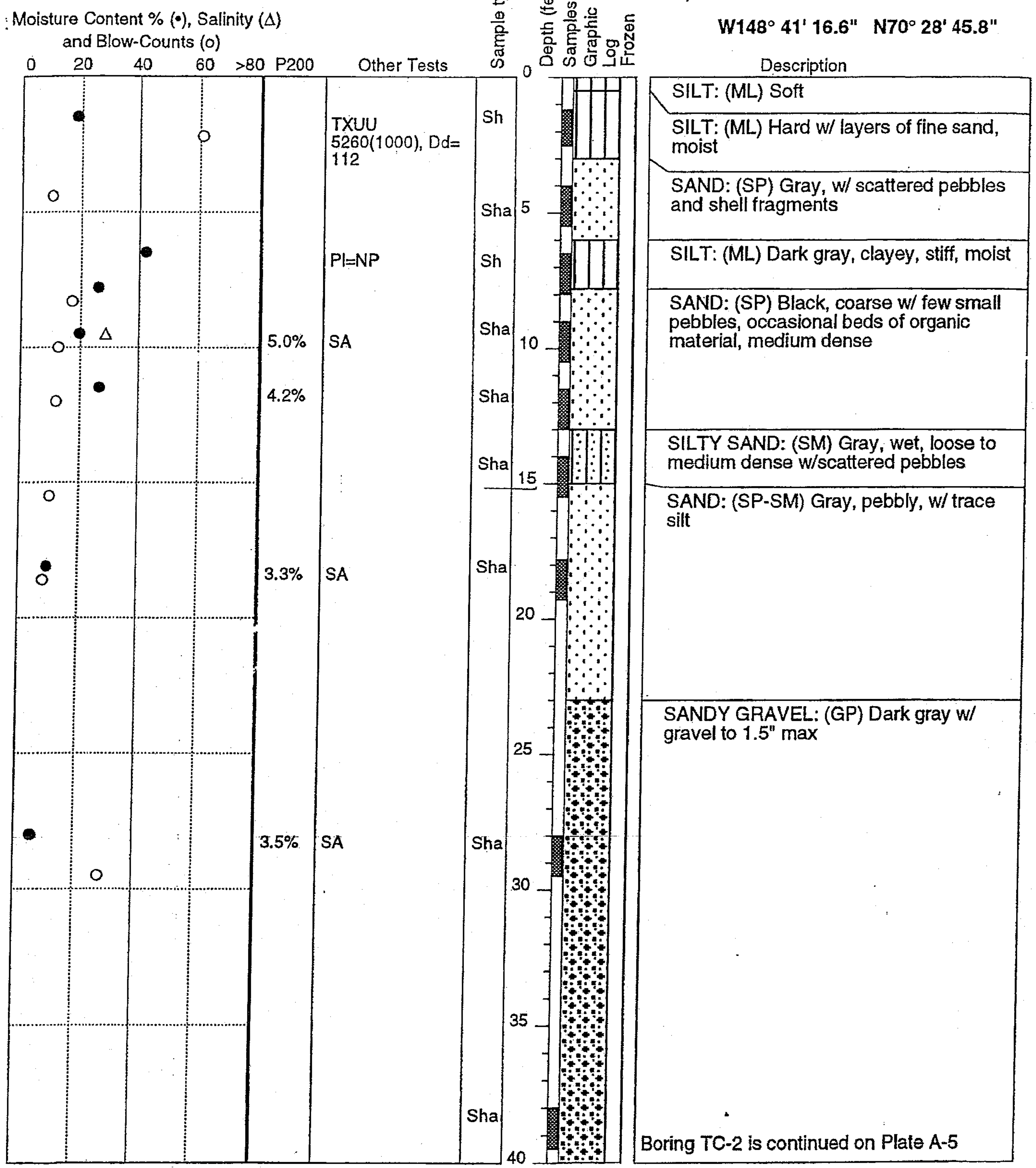
DUANE MILLER & ASSOCIATES

Project: **Northstar**
DM&A Job No. : 4119.13
Logged By: W. Phillips, PG

Log of HOLE : Boring TC-2

Date Drilled: February 18, 1996
Contractor: Discovery Drilling/CATCO
Rig Type: CME-75/Rolligon
Water Depth: 31.0 Ft. Ice Thickness: 5.0 Ft.

W148° 41' 16.6" N70° 28' 45.8"



Duane Miller & Associates
Arctic & Geotechnical Engineering
Job No.: 4119.13
Date: May 1996

LOG of BORING TC-2
Northstar Development
Beaufort Sea, Alaska

Plate
A-4

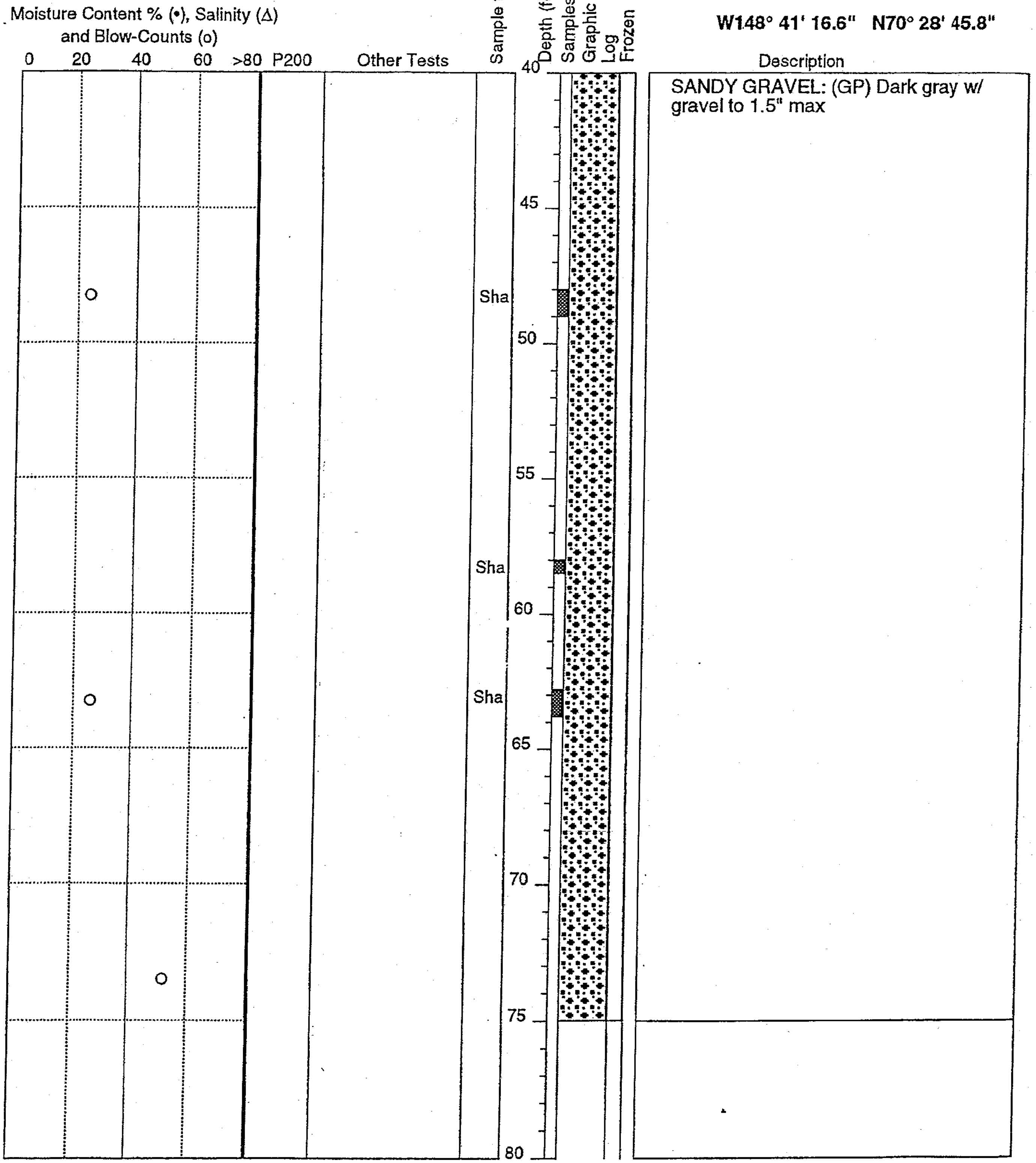
DUANE MILLER & ASSOCIATES

Project: **Northstar**
DM&A Job No. : 4119.13
Logged By: W. Phillips, PG

Log of HOLE : Boring TC-2 cont.

Date Drilled: February 18, 1996
Contractor: Discovery Drilling/CATCO
Rig Type: CME-75/Rolligon
Water Depth: 31.0 Ft. Ice Thickness: 5.0 Ft.

W148° 41' 16.6" N70° 28' 45.8"



Duane Miller & Associates
Arctic & Geotechnical Engineering
Job No.: 4119.13
Date: May 1996

LOG of BORING TC-2 cont.
Northstar Development
Beaufort Sea, Alaska

Plate
A-5

APPENDIX E

BEAUFORT SEA RADIOCARBON DATABASE AND IMPLICATIONS FOR PALEOGEOGRAPHY

E1.0 REGIONAL CONTEXTS FOR UNDERSTANDING SEA LEVEL HISTORY OF THE BEAUFORT SEA

E1.1 Sea Level History in Western Beringia: the Chukchi and Laptev Seas

The entire western Arctic from the Beaufort Sea across the Northern Chukchi Sea to the Laptev Sea and southward across Bering Strait lies within a single sea level response zone (Devoy 1987). The unglaciated shelf, the northern part of Beringia, underwent little or no isostatic compensation during the last transgression and exhibits only local tectonism (Fujita et al. 1990). Because of the general similitude across this area, data from the Lena and Yukon Rivers to the Mackenzie River act as a preface to the discussion of Beaufort Sea data sets.

A handful of data points constrain the late Pleistocene sea level history of the Chukchi Sea; including four ^{14}C dates within a shore-perpendicular transect of vibracores obtained by Lawrence Phillips of the USGS off Icy Cape, 800 km southwest of Barrow. The cores reflect a well-conceived sampling strategy (Elias et al. 1992); a series of cores that traced paleo-landforms, employing pollen microfossils, ostracodes and insect faunas for evidence of terrestrial environments (Elias et al. 1992, 1996). The four ages are on terrestrial peat indicating that sea level was *below* 50 m below modern sea level (bsl) 12,000-11,000 ^{14}C years (yrs) B.P. The appearance of Pacific clams on the Yukon coast around 10,500 yrs ago (Dyke et al. 1996:150) is a second proxy for the post-glacial flooding of Bering Strait, which is controlled by a sill about 50 m below sea level. The post-glacial breaching of this water plane, 50 m bsl, is the only firm reference point for sea level in the Chukchi Sea and should be valid for the Beaufort Sea as well.

Between 11,000 and 5,000 ^{14}C yrs B.P., dated, firm *in situ* evidence is lacking to reconstruct sea level history in the Chukchi and Bering Seas. To some measure, the limited data is related to the absence of research in shallow nearshore areas or in estuaries. Secondarily, rarity of adequate data is an artifact of the rapid rate of sea level rise during the period and the circumstance that sea level stabilized near only 5,000 yrs ago (Jordan and Mason 1999; Mason and Jordan 2002).

Submarine topographic and depositional features from the Bering and Chukchi shelves may be evidence for sea levels during the last 12,000 years (Nelson et al. 1982). First, shore-parallel gravel lineaments from Cape Woolley to Point Spencer and off northwest St. Lawrence Island are likely reworked or residual barrier island massifs, i.e., “ancient shoreline shoals” (Nelson et al. 1982:42); the four belts occur at 38, 30, 20 to 24, and 10 to 12 m bsl and all are undated. Second, wave cut cliffs near Deering, in Kotzebue Sound, appear on side-scan sonar at 12 m bsl (Hunter and Reiss 1984). A third line of evidence from 16 to 18 m bsl within Norton Sound includes two boxcores that contain terrestrial peat dated about 10,000 B.P. in the former case and an organic rich marine silt from 18 m dated 7,500-7,000 B.P. capped by a brackish fauna dated to 6,240±115 (I-7481) (Nelson and Creager 1977:144). The 10,000 yr old sample seems too high and is likely redeposited while the 6,000 yr old sample may be a solid datum for sea level and it is close to a datum near Barrow.

Near Pt. Barrow, a core transect across Nerravak slough traced a purported marine sand bed 11 m bsl as it intruded into a coastal lagoon; associated drift wood[1] dated 6450±200 BP (Tx-220) Faas 1966:92) 6080-4489 cal BC. Presumably, the overwash sand was associated with a single large storm, 1 to 3 m above sea

[1] In his Ph.D., Faas (1964:92) describes the sample as wood obtained from two levels about 30 cm apart.

level, the range of storm surges in the Chukchi Sea (Hume and Schalk 1967). Although Faas (1966) argued that the driftwood was a sea level indicator because of its incorporation within a sand bed by a storm that breached the lake margin, its elevation within the lagoon reflects the lower erosion limit of the thaw lake. The lake was likely 1 to 3 m deep—possibly canceling part of the surge elevation; thus, sea level might have been around 12 m bsl and, possibly as low as 14 m bsl, as late as 4400 BC.

Significantly, a box core in Norton Sound contained a brackish water fauna dated between 5469-4856 BC [6240±115 BP (I-7481)] at 18 m bsl, capping a sample of marine silt that dated around 7200-7000 BP (Nelson and Creager 1977:144).[2] Considering the Nerravak datum for the northern Chukchi Sea, only the older part of the Norton Sound age estimates (ca 5500 BC) seems credible. Thus, hypothetically, sea level was 18 m bsl around 5500 BC [7500 cal BP] and by 4500 BC [6500 cal BP] sea level must have attained a level around 14 below sea level. This rate of rise, 0.3 cm per year, is about ten times the present rate (0.3mm/yr) of eustatic sea level rise (Mason and Jordan 1999). Between 4500 and 2500 BC, sea level rose from 14 m bsl to 1.5 m bs, roughly 0.625 cm per year, a doubling of the rate of sea level rise which may account for the preservation of still stand features.

E1.2 Sea Level Data from the Eastern Beaufort Sea

Canadian research in the eastern Beaufort Sea allows the reconstruction of the history of relative sea level rise during the Holocene. Hill et al. (1993) employed thirty-six (36) ^{14}C ages from vibracores, boreholes and archaeological sites to constrain a RSL curve.[3] For the early record, fibrous peat, inferred as *in situ* and terrestrial from sedge microfossils by Hill et al. (1993), provides two early Holocene data points at 45.2 to 46.6 m bsl; 9,900±150 to 7,900±130 ^{14}C yrs B.P.), a comparable elevation to terrestrial peat dated in the northern Chukchi Sea near Icy Cape (Elias et al. 1992). On the upper (i.e., younger) range, peat samples were obtained from coastal marshes. Peat samples dated between 5,000 and 1,300 ^{14}C yrs B.P. were between 20 and 70 cm below sea level (Hill et al. 1993:Table 1). Lake breaching events that were recorded in two marshes atop lake basins indicate that peat aggraded relatively slowly—3,000 yr old peat is separated by only 10 cm of clay from an overlying 1,200 yr old peat. Quite significantly, these data approximate similar dated peat samples from the Chukchi Sea (Mason and Jordan 2002; Jordan and Mason 1999). In addition, the hazards of using shell for radiocarbon ages were apparent considering that 2,400-1,300 yr old shells were found between 7 to 10 m bsl—after subtracting the likely 800 yr old carbon correction, providing only very distant lower limiting ages on sea level (Hill et al. 1993). Diatoms allowed Campeau et al. (2000) to propose a more precise sea level curve for the last 3,000 years; these researchers placed five cores within breached lakes in the eastern Beaufort Sea and documented only a slight rise in sea level.

In summary, a broad but thin array of data from across the western Arctic Ocean reveal a consistent portrait of sea level rise that serves as a baseline for interpreting the borehole and radiocarbon data sets examined by the NLUR team during the course of this project. It is essential to bear in mind the common threads across thousands of km as the Beaufort Sea data are examined.

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[2] Adjacent peat samples, at higher elevations, dated older, ca. 10,000 BP (Nelson 1982); these are likely recycled peat.

[3] The effort of Hill et al. (1993) synthesizes and incorporates two other earlier studies, not cited in the present report, cf. that paper for details on the earlier data base.

E2.0 THE RADIOCARBON DATABASE FROM THE ALASKAN BEAUFORT SEA SHELF

This project assembled[4] thirty-eight (38) ^{14}C ages (Table E-1) that span the last 50,000 years. Most remain unpublished or semi-published (n=23) including six (n=6) radiocarbon ages[5] from the Beaufort Sea shelf submitted for this project. About one quarter (n=9) were run by industry; the remainder the product of the USGS program of the 1970s, largely of Barnes et al. (1979), Naidu (1978), Naidu et al. (1984) and McDougall et al. (1986). About one third (n=12) of the dates are older than 13,000 B.P., the accepted range for the peopling of the Americas (Jablonski 2002). Most samples (n=21) derive from vibracores placed by the U.S. Geological Survey during the 1970s from off the Colville River delta to Stefansson Sound. Eleven samples are from industry borehole drill programs: five from three Warthog boreholes,[6] four from Mukluk, with two from a British Petroleum (BP) oil well at Prudhoe Bay. The assays are primarily conventional ^{14}C analyses, run by the USGS laboratory in Menlo Park (USGS-laboratory numbers).

Dating results from several vibracores are posted on the USGS web site.[7] Following a visit to the USGS core archives in Menlo Park (Appendix F), the NLUR team obtained and dated six (n=6) samples from vibracores V-9 and V-18, drilled by Peter Barnes in the late l970s. The six ^{14}C assays submitted to Beta Analytic, Inc. in 2005 employed the accelerator mass spectrometer (AMS) method. Information is lacking for some of the ages (n=13), which are mostly laboratory numbers. However, despite the seemingly impressive number of ages, very few contribute solid evidence for either reconstructing paleogeography or sea level history of the Beaufort Sea shelf.

E2.1 Problems in the Interpretation of ^{14}C ages from the Beaufort Sea

Geological interpreters of radiocarbon ages from shelf sediments face a variety of challenges; some methodological while others are within the systemic, geologic framework of the continental shelf. Of the existing ^{14}C database, most derive from laboratory analyses during the 1970s and 1980s, preceding the AMS refinement of the radiocarbon dating method that has allowed the dating of very small samples with more precise contextual possibilities, in contrast to larger "bulk" samples that may average considerable

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[4] Eight are from private industry: the four Warthog samples reported in Bergman (1997) and four from the Mukluk prospect obtained by Dames & Moore (1983). Published radiocarbon date lists include: Sheppard and Chatters (1976:148) for three WSU lab samples for a Prudhoe Bay borehole; Trimble and Robinson (1989:75) for three USGS (Menlo Park) assays from the Colville River delta, and Simpson lagoon. Four Colville delta front ages were reported earlier in *Radiocarbon* by Robinson and Trimble (1981:319-320). The latter four samples were also plotted (without laboratory numbers) in Barnes et al. (1979:unnumbered appendices for core V-23 for V-18 core, but also posted on the USGS web site). Four Prudhoe Bay boreholes are documented in McDougall et al. (1986) with some dates reported in Hopkins and Robinson 1981).

[5] Two samples (one from V-48, one from V-49) are not graphically portrayed in Figure E-1, E-2 because of missing data: primarily the standard deviation, as well as a laboratory number. The sample from V-49 was published in Naidu et al. (1984:280) with further contextual data in Barnes et al. 1979:Appendix). One peat sample from Pingok Island was published with only a year referent and appears to correspond to a date in the file of the author (cf. Naidu 1978:665, 674).

[6] Three of these ages are excluded from the following discussion because the assays were on the less reliable carbonate fraction; only the organic fraction is used and cited on Table E-1.

[7] <<http://walrus.wr.usgs.gov/infobank/k/k177ar/samp/k-1-77-ar.onoff.cores.vibracores.html>>

length of time. Bulk samples may contain samples of diverse ages. In the Chukchi Sea, AMS samples led Elias et al. (1992) to revise the sea level curve and chronology developed by McManus and Creager (1984) based on nine bulk samples. The physical basis for the systematic errors often inherent in bulk samples were identified for terrestrial peats by Nelson et al. (1988): any detrital peat might contain diverse populations of carbon, with the older, possibly finer fraction easily contaminating bulk samples. Lake basin peat can be even more complex, containing both suspension derived organic detritus and eroded bank material. Several examples from the Beaufort Sea shelf can elucidate the perils of uncritically accepting the age relationships of ^{14}C ages from shelf boreholes.

One apparently anomalously deep sample (USGS-132, cf. Table E-1) from Prudhoe Bay borehole #1 (PB-1) illuminates the difficulties in accepting or employing borehole or vibracore ages as evidence of sea level position; in this core, wood fragments from 6.5 m bsl dated between 490±90 yrs B.P. or calibrated years between AD 1298 and 1634. One sample, ca. 3 m higher, at 2.7 m bsl, from nearby PB-6, yielded a ^{14}C age of 8453-7940 BC [9020±90 yrs B.P. (USGS-783) (cf. MacDougall et al. 1986:16)]. Data from the Chukchi and Bering Seas indicate a much lower sea level during the early Holocene, at least 20 to 30 m deeper below present (cf. Elias et al. 1992, 1996; Jordan and Mason 1999; Mason and Jordan 2002). Thus, both Beaufort Sea samples are likely inaccurate: apparently, younger wood was either transported onto the shelf or eroded from bluffs. The processes that led to the deposition of wood in this borehole illustrate most of the other anomalous or ambiguous ages in the date list.

Similarly, late Pleistocene peat (samples 95M0001 and 95M0007), minimally about 18,000 yrs old, from Warthog were extracted from levels presently between 3 and 5.8 m bsl. Apparently, older peat was eroded, re-transported and deposited on the shelf. To minimize sampling ambiguous contexts, it seems advisable to exclude shell, wood and thin organic stringers (Section E2.3); this leaves only fibrous peat beds as reliable indicators of past sea levels (Fig. E-2)[8]. However, peat may accumulate rapidly under a number of circumstances in addition to at or above the high tide level within a marsh. Eight of the 38 samples were fibrous peat, obtained within 5 m of present sea level (Fig. E-2). However, ambiguities and complications arise in the vibracores within delta front depositional environments. Modern facies relationships may assist in clarifying the context of some of these samples. The sediment flushed into the sea beyond from the river mouth serves as the actively accreting, incipient delta, forming a “2 m bench” (Barnes et al. 1979:6). At each spring flood, organic detritis is flushed across the submarine bench. Thus, minimally, organics on the delta reflect a 2 m offset in relation to sea level. Employing this offset may be useful in interpreting and correcting the samples from the delta front.

E2.2 Age and Elevation of the Beaufort Shelf Radiocarbon Ages

E2.2.1 Problematic Late Pleistocene (40,000 to 10,000 ^{14}C yrs B.P.) Peat Ages

Nine Pleistocene ages were obtained from two localities between 50 and 15 m bsl and either off Prudhoe Bay or the Colville River delta; all resulted from the activities of industry. The five ages >20000 yrs B.P. serve only as limiting ages on outwash deposits that may actually be over 60,000 yrs old; a period older

[8] It is important to note that peat is not a good indicator of terrestrial archaeological sites, especially on the North Slope (Bowers et al. 2001; Mason et al. 2001; Potter et al. 2003; see also Marmaduke and Watson 1999:20).

than any documented, widely accepted archaeological remains in the New World and are of little consequence for the present discussion.

At first glance, four late Pleistocene ages between 18,000 and 11,500 B.P. offer some potential for sea level reconstruction. Three samples were obtained from the Mukluk gravel site No. 1 by Sohio Construction Co. in the early 1970s, while one is from Prudhoe Bay borehole PB-2. In sum, the samples from the Mukluk lease area, off the Colville River delta, and Prudhoe Bay cluster between 14 and 15 m bsl and date between the Last Glacial Maximum (ca. 18,000 yrs B.P.) and the onset of the Holocene. Several circumstances suggest the four samples are unreliable.

Despite the high silt and organic fraction within the Mukluk core, shell fragments occur within the core to a depth of 10 m below the core top. The ages on terrestrial organics conceivably provide a limiting age for deposition on the shelf. From these ages, one might conclude that late Pleistocene age organics, interbedded with shell, were deposited about at 20 m below surface; hence, sea level must have been above that level. These data are considerably higher than dated peat either off Icy Cape (Elias et al. 1992) or in the eastern Beaufort Sea (Hill et al. 1993). Thus, sea level was substantially lower, by at least 30 m. Is there a means by which late Pleistocene organics may be deposited at a higher level than the contemporary sea level (possibly the core-penetrated part of a lake that received older materials)?

E2.2.2 Sea Level Rise or Peat Recycling Recorded by Dates from the Early/Middle Holocene (8 to 6 kyr)?

Can archaeologists entertain any hope that the Beaufort Sea peat reflects sea level during the early Holocene, between 12,000 and 6,000 ^{14}C yrs B.P.? Several factors would seem to mitigate against such a scenario. For example, the assays are likely bulk samples and reflect several materials; shell and wood having considerable mobility while only one is possibly an *in situ* fibrous peat. For example, peat within core V-29 within Stefansson Sound, off the Sagavanirtok River delta, implies at face value that sea level was at -5.7 m during 7,560±100 B.P. (6440-6404 BC). Another peat, possibly two millennia older (9,020±90 B.P., 8453-7940 BC), leads to an even more problematic elevation: this sample, USGS-783, was obtained from Prudhoe Bay borehole PB-6 from only -2.7 m bsl, 3 m higher than the V-29 sample. Again, peat from PB-6 seems to reflect the re-deposition of terrestrial, bluff-eroded peat.

Three younger ages from core V-9, run on the AMS method in 2005 may enable some informed speculation concerning paleo-sea level position. Core V-9 was located 6.5 m below sea level on the shelf on Stefansson Sound, south of Narwhal Island. Considering that shell occurs below the three dated samples, it must be concluded that the entire core is submarine in origin. Two of the three samples, those on shell, yielded consistent results; the one on wood differs from the shell within the same level (135-140 cm below core top). The uppermost shell age (Beta-202445) seems to indicate that sea level was *above* 7 m bsl by 2000 BC.[9] The lower shell sample (Beta-202446) would indicate that sea level was *above* 8 m bsl prior to 4500 BC, two millennia older if the less acceptable wood age is accepted. These data suggest higher sea levels compared to the few other referents for the Chukchi Sea and eastern Beaufort Sea, as described elsewhere, thus, the recycling of older, eroded peat must explain the discrepancy.

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[9] The fractionation values $-7^{0}/_{00}$ indicate that old carbon is likely involved and the calibrated ages on shell, presented in Table E-1 are probably too old by up to 800 years: a local correction factor is not established for the Beaufort Sea.

The variable addition of sediment into the cores may be informative about river or bluff erosion processes or shelf movements due to littoral currents, as in core V-9, thick, inorganic fine sand dominated deposition after 4500 BC until 2000 BC (6,500-4,000 B.P.). Considering that the V-9 core was extracted from the center of Stefansson Sound 15 km from the delta of a braided river, the lack of detrital organics may reflect the erosion of older bluffs or sand dunes lacking in peat, or the possibility that peat was less common on the landscape (Mann et al. 2002). The lessening of sand following 2500 BC might reflect an increase in the amount of peat across the landscape.

E2.2.3 Late Holocene Radiocarbon Ages: Sea Level and Coastal Evolution

By contrast, several late Holocene ^{14}C ages may be useful in reconstructing the course of sea level rise, with several caveats. First, several discrepancies in elevations are evident from reported sources; for example, between those presented in Barnes et al. (1979) and in Robinson and Trimble (1989:75)[10]. Nonetheless, most of these ages cannot be precisely related to a sea level datum plane and their reliability is contingent on accepting the 2 m correction factor alluded to in Section E2.1. The ambiguity of these samples reflects the depositional complexity of the vibracore locations; possible subsidence issues are not considered in the following.

On the Colville River delta front, fibrous peat presently at -3 to -4 m bsl dated between 2,930±50 yrs B.P. (USGS-575), 1300-974 BC and 2,490±90 yrs B.P. (USGS-577), 788-481 BC. At a comparable depth, 2.5 m bsl, and farther offshore, but still within the influence of the Colville delta, vibracore V-23 contained a peat that dated within the earlier part of this period: 1520-1210 BC. If one applies the 2 m offset based on modern facies relationships, the Colville delta data indicate that eustatic sea level was 0.5 to 1 m bsl during the period from 1500 to 500 BC. This water plane is correlative with the curve reconstructed from shallow cores along the Chukchi Sea (Jordan and Mason 1999, Mason and Jordan 2002).

A peat sample from western Pingok Island—the north margin of Simpson lagoon—seems to offer a firm context for past sea-levels in the Beaufort Sea; however, only a few details are available (Naidu 1978). The "basal" peat lived around 2,600 yrs B.P., according to Naidu (1978:665) and in the 1970s was 84 cm below the high tide mark (Naidu 1978:674), capped by beach gravels, deposited during the last several thousand years.[11] Significantly, the elevation of the Pingok Island peat is correlative with several marsh peat samples in the Chukchi Sea that also date to the 2nd millennium BC (Jordan and Mason 1999; Mason and Jordan 2002).

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[10] The description in *Radiocarbon*, authored by Robinson and Trimble (1989:75), with input from Erk Reimnitz, is ambiguous; e.g., for USGS-575: "Sample at 2.0 m depth, 110 cm below sea floor, from layer of fibrous organic matter, 30 cm thick." This apparently refers to a depth below sea level of 3.11 m based on the circumstance that similar language (on pg. 75-76) for USGS-578: "Coll at water depth of 2.5 m with vibracore, 100 cm below lagoon floor" [hence, 3.5 m bsl] differs with Barnes et al. 1979 placement (1.5 m bsl) for V-49 core (at 3 m water depth)—hence a depth of 4.5 m bsl. Apparently, the latter depth is more reliable.

[11] This peat is, apparently, sample Pi-5, dated by the Isotopes Laboratory in 1978 (I-10,182) and reported as 2500± 105 B.P. and calibrates to 826-396 BC (copy of report, in the files of the authors). Email correspondence with Dr. Naidu (2005) seems to confirm this assignment.

Within Simpson Lagoon, fibrous peat from core V-48, was associated with several paleo-thaw lake basins and lie 3.5 m bsl: sample USGS-578 dated within 3768-3342 BC. Another sample from nearby core V-49 in central Simpson Lagoon reportedly dated to ca. 4,500 yrs B.P. (Naidu et al. 1984:277, 289).[12] Based on the presence of freshwater gastropods in V-49, Naidu et al. (1984:289) argue that the peat was an *in situ* lake deposit (not a redeposited block) that was later covered by marine silts deposited as the lake margin was breached by rising sea levels. The depth of the paleo-lake remains uncertain, but the banks were probably >1 m (possibly more) higher. Thus, the sample provides no firm reference point for sea level position. Hence, these samples provide only distant limiting ages in relation to sea level: minimally, one can infer that the thaw lake margins were breached following the 4th millennium BC and sediments within the marine water column were deposited atop on lacustrine surfaces. Several non-marine processes may have produced the peat within the lagoon basin (Murton 1996); following the breaching of the lakes, additional processes were added (Naidu et al. 1984:282ff). Based on the comparative linearity of the Simpson Lagoon coast,[13] considerable time was involved in reshaping the several thaw lake basins that preceded the lagoon (Ruz et al. 1992:256-257; Naidu et al. 1984). The process of marine penetration of the Simpson Lagoon system probably resembled the situation on the eastern Beaufort Sea coast where exposed brackish peat dated to 1,300 yrs B.P. and is now only 50 cm below sea level (Ruz et al. 1992:267).

Reversed chronometric, i.e., stratigraphic, relationships within the four samples from core V-18 further elucidate the considerable volatility in the submarine environment; the core lies just 2 km beyond the lower aggrading margin, the 2 m bench, of the Colville River. The assays, run by NLUR in 2005, employed the AMS method, a considerable improvement in precision from the 1980s. One of the NLUR assays, Beta-202442, was about 1 m below the core top, 3 m bsl, and dated to the late 3rd century AD (1,660±40 yrs B.P.). The 1970s ages were significantly older—1,500 years—e.g., USGS-293 just above the 1 m bsl level dated to 1412-1188 BC, 1181-1149 BC, 1144-1123 BC (3,040±50 yrs B.P.) while USGS-294 at 54 cm below the core top dated to 400-200 BC (2,260±50 yrs B.P.), up to 800 years older than the NLUR sample at 3 m bsl. Finally, one NLUR sample (Beta-202443) at 3.5 m bsl dated within 2550-2520 BC and 2500-2310 BC.

Several cores within Gwydyr Bay and Prudhoe Bay yielded fibrous peats dated within the 1st and 2nd millennia BC. The paleo-elevations are between 1.7 and 3.8 m bsl, the lower elevations similar to data points near the Colville River delta front. One peat sample from a level 1.8 m bsl within V-27 dated to the late 2nd millennium BC (400-200 BC). Peats, only 1 m deeper, at 3 m bsl, from widely separated vibracores V-26 and V-27, in Gwydyr and Prudhoe Bays have ages significantly older, 3000-2800 BC, about 1,000-1,500 years older than the Colville River peat and comparable to the Simpson Lagoon peat. Interpreting these ages remains difficult because of the use of conventional dating methods on organic samples that might include recycled older fines (cf. Nelson et al. 1988). Notably, a 1,500-2,000 year

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[12] This age was not included in the graphic display of radiocarbon data (Table E-1) because no standard deviation is available.

[13] As noted by Ruz et al. (1992:256): "The complexity of the shoreline depends on the local size and abundance of thaw lakes on the adjacent coastal plain. Where the landscape is covered by numerous thaw lakes, the shoreline is highly indented, consisting of complex shallow embayments formed by the coalescence of breached lakes." The outlines of four or five adjoining, now merged, lakes are evident in Figure 4 (a map) in Naidu et al. (1984:283).

offset also was observed between the Chukchi bulk samples run using the conventional ^{14}C method by McManus and Creager (1984) and the smaller AMS samples run of Elias et al. (1992).

In summary, the ages obtained by NLUR in 2005 imply that older organics, up to two millennia older were recycled in the upper 1 m of core. MMS04-01 is from a 1 cm thick bed of organic detritus within horizontally bedded silty clay. In view that the core (V-18) was from the distal margin of the Colville River delta; it seems doubtful that the thin bed represents a marsh peat or any other terrestrial surface. Thus, the detrital peat off the Colville River within 3,500-2,000 yrs B.P. likely reflect heightened river erosion, that is correlative with the storm histories in Chukchi Sea beach ridges (Mason and Jordan 1993). At a general level, the Colville River delta samples are sea level indicators, if one assumes that a 2 m offset is applicable. The shelf area was receiving eroded peat from river banks, the area was below sea level as early as 2500 BC; thus, it can be concluded that sea level was above 2 m bsl by this time. The four ages from V-18, thus provide rough lower limiting ages on sea level position. Samples from the eastern Beaufort Sea shelf were equally deep (Hill et al. 1993). Marsh peats from the Barrow area indicate that sea level was about 2 m higher, ca. 1.5 m bsl by 2000 BC (Brown and Sellman 1966). This is in line with the 2 m offset for the delta front.

E2.2.4 Colville River Basal Peat: A Sea Level Proxy?

Basal peat 2 to 3 m bsl within abandoned deposits of the Colville River delta dated between 2500 and 4000 BP (Jorgenson et al. 1996:142; Jorgenson et al. 1998:528). The elevations of the Colville River samples are similar to the detrital peat on the delta front dated by Barnes et al. 1979, *this report*). Jorgenson et al. (1998:528) argued that some of the peat could be employed as sea level proxies. However, the context of the delta samples is uncertain; some occur within low-centered polygons (Jorgenson et al. 1996:87, Fig. 3-10, core X.09). In one case, a 600 yr old peat lies 1.6 m below sea level (core X11.03 in Fig. 3-10), while in another, a 2000 yr old peat was 58 cm below sea level (core X11.9a). Of the roughly 40 ages reported by Jorgenson et al. (1996:Appendix Table B-5), no clear age to elevation relationship can be observed. In addition to subsidence, it would seem that the cryogenic processes within polygons might be complicating factors. Until more contextual data are available, the sea level significance of the Colville River peat data remains uncertain.

E2.3 Complicating Depositional Factors in Interpreting Radiocarbon Samples from the Beaufort Sea Shelf

Several geomorphic processes constrain the entry of sediment from the Beaufort Sea shoreline as it is cycled onto the shelf. Sea level reconstructions are only convincing and valid if well-provenienced samples derive from firmly constrained *in situ* (i.e., not re-deposited) topographic indicators in relation to past sea level elevation (various in Devoy 1987; Shennan 1987; van de Plassche 1986). Many workers prefer marsh peat (and associated macrofossils such as diatoms or foraminifera) or uplifted wave cut landforms whose dimensions can be established easily across tens to hundreds of km that yield a regional perspective (van de Plassche 1986). Marsh peat bodies, a favored context, often occur at the mouths of small rivers that discharge into lagoons; these are often transient features that are recycled landward as the sea rises during eustatic pressures. One must also use caution in dating driftwood or gravel beach ridge elevation, from which early 1960s researchers (cf. Hume 1965; Moore 1966) inferred numerous short term sea level fluctuations—several meters in elevation—ignoring the possibility that short term storm surges (cf. Hume and Schalk 1967) were responsible (Mason and Jordan 1993, Jordan and Mason 1999). Larger river deltas can possess numerous distributaries, abandoned channels and are continuously overtopped as sea level rises; at one extreme is the architectural complexity of the Mississippi Delta complex. Barrier island deposits are particularly mobile, representing sand bodies that are repeatedly recycled during the process and sequence of sea level rise (e.g., Davis 1994).

However, the turbulent, wave-raked Beaufort Sea shelf environment is typically not often conducive to meeting the rigor and robustness required for convincing sea level history reconstructions. The shelf receives organic material through a variety of processes; most involve the re-deposition of peat beds. The flux of particulate carbon (POC) onto the central Beaufort Sea shelf is substantial: roughly two-thirds or 375 $g/m^2/yr$ from the Colville River, and about one-third or 200 $g/m^2/yr$ derived from bluff erosion (MacDonald 2004:190). For the entire Beaufort Sea shelf, organic carbon burial is considerably less than on the Siberian shelves; 1.5 million tons compared to 250 million tons, but still six times more than on the Chukchi Sea shelf (Stein et al. 2004:317-318). Transport distance might be significantly higher for fluvial-derived carbon which may arrive onto the shelf in smaller particulate fractions. *In situ* peat beds, in theory, could be preserved without modification if marine sedimentation was rapid and current action was insufficient for any contemporaneous or subsequent erosion. Small deltas adjacent to lagoons may represent relatively secure locales for reconstructions (Jordan and Mason 1999).

For the last 11,000 years, thaw lakes have dominated the arctic coastal plain (Dinter et al. 1990; see dates in Hopkins and Robinson 1981; Mann et al. 2002; Mason et al. 2001). Thaw lakes expand by eroding their peat-rich banks, cycling older material into the lake basins (Hopkins 1949; Hopkins and Kidd 1988). The basin of a typical thaw lake could contain peat of variable ages, the proverbial “Pleistocene in a blender” (term attributed to Daniel H. Mann, 1998, pers. comm.). Due to recycling of collapsed thaw lake materials, Campeau et al. (2000:67) discovered that marsh peat was incorporating carbon that was significantly older, up to 1,000 years; hence, a 900-year correction was necessary to interpret peat ages. Further complications arise as the sea encounters eroding bluffs; this eroded peat is added to the shelf. Peat also can enter the shelf bottom from eroded bluffs that contain thaw lake beds. In the 1970s and 1980s, core analysts rarely expended much effort to establish that peat is from a primary context.

In addition to rivers and thaw lakes, barrier islands are a common source of recycled material. Barrier islands can be depositional forms, i.e., sand deposits transported on the shelf under the force of rising sea level as on the Atlantic coast (e.g., Davis 1994). In addition, barrier islands form through the drowning of older portions of the arctic coastal plain; on occasion, these are residua of late Pleistocene barrier islands (cf. Section 4.1).

E3.0 CONCLUSIONS

E3.1 Implications for the Early Holocene Rate of Eustatic Sea Level Rise

The shore-parallel retreat massifs of the Beaufort Sea (cf. Section 3.2.11) resemble a variety of indicators in the Chukchi Sea cited as evidence of still stands of sea level. Sea level may have remained at the 12 m bsl isobath for a lengthy period, based on several data points (Nelson 1982; Nelson et al. 1982). The linear features off Port Clarence consist of gravel and sand and are oriented parallel to the coast, occurring within 10 to 12 m bsl (Nelson et al. 1982) and a seismic reflector in southern Kotzebue Sound records a drowned wave-cut terrace (Hunter and Reiss 1984). Transgressive sand bodies are also preserved in the eastern Beaufort Sea (Ruz et al. 1992:268ff; fig. 21). Marine silt caps a lake fill sequence whose base dates to 5,580±80 yrs B.P. (B-9504) and extends to -12 m bsl (Ruz et al. 1992:268, 270). However, under the present sea level regime, the shoreface is undergoing net erosion between 12 and 15 m below the surface (Hequette and Barnes 1990:128-129). The antiquity of these features is probably not comparatively great, probably less than 6,000-7,000 yrs, employing several equivocal chronological referents. Their preservation implies that a quickening of sea level rise following their formation.

Near Pt. Barrow, a core transect across Nerravak slough traced a purported marine sand bed -11 m bsl as it intruded into a coastal lagoon; associated driftwood[14] dated 6,450±200 yrs B.P. (Tx-220) (Faas 1966:92), 6080-4489 cal BC. Presumably, the overwash sand was associated with a single large storm, 1 to 3 m above sea level, the range of storm surges in the Chukchi Sea (Hume and Schalk 1967). Although Faas (1966) argued that the driftwood was a sea level indicator because of its incorporation within a sand bed by a storm that breached the lake margin, its elevation within the lagoon reflects the erosion limit of the thaw lake. The lake was possibly 1 to 3 m deep: possibly canceling part of the surge elevation; thus, sea level might have been around 12 m bsl and, possibly as low as 14 m bsl, as late as 4400 BC.

Significantly, a boxcore in Norton Sound contained a brackish water fauna dated between 5469-4856 BC [6,240±115 yrs B.P. (I-7481)] at 18 m bsl, capping a sample of marine silt that dated around 7,200-7,000 B.P. (Nelson and Creager 1977:144).[15] Considering the Nerravak datum for the northern Chukchi Sea, only the older part of the Norton Sound age estimates (ca. 5500 BC) seems credible. Thus, hypothetically, sea level was 18 m bsl around 5500 BC [7,500 cal BP], and by 4500 BC [6,500 yrs cal B.P.], sea level must have attained a level around 14 m bsl. This rate of rise, 0.3 cm per year, is about ten times the present rate (0.3 mm/yr) of eustatic sea level rise (Mason and Jordan 1999). Between 4500 and 2500 BC, sea level rose from 14 m bsl to 1.5 m bsl, roughly 0.625 cm per year, a doubling of the rate of sea level rise which may account for the preservation of still stand features.

E3.2 Comparisons of the Dated Peat from the Beaufort Sea with the Chukchi Sea Record

In general, the Beaufort Sea peat provides anomalous data points that would lead to the inference of sea levels that were higher than in the Chukchi for the earlier part of the record, prior to 8,000 yrs B.P., but lower in the last 5,000 years. In the Chukchi Sea, marsh peats within small deltas along lagoons from Wales to Shishmaref and at Barrow were about 1 m above this level during the 2nd millennium BC (Jordan and Mason 1999; Mason and Jordan 2002; Mason 1999, 2003, unpublished data from Deering and Barrow). Two data points from Barrow conform to the general trend of Chukchi Sea marsh peat derived record (Jordan and Mason 2002), and contradict the Beaufort shelf records. However, if one corrects the Colville delta and Simpson Lagoon peat with a 2 m offset, both the Chukchi and the Beaufort Seas reflect the same eustatic signal.

[14] In his Ph.D., Faas (1964:92) describes the sample as wood obtained from two levels about 30 cm apart.

[15] Adjacent peat samples, at higher elevations, dated older, ca. 10,000 B.P. (Nelson 1982); these are likely recycled peat.

E3.3 Is it Possible to Reconstruct Sea Level History from the Beaufort Sea ^{14}C data?

Of the dozen data points that cluster within 1 m of present sea level (Fig. E-2), some samples may be proxies for eustatic rise in sea level across the Alaska Beaufort Sea coast. Thin organic stringers within vibracores present significant ambiguities (Appendix E-1), but several samples from fibrous peat beds may be *in situ*. The samples derive from a variety of depositional environments: several are from deltaic sediments, others are from lagoonal clays and silts. Ancillary lines of inference are lacking to support any inference that the peat is *in situ*; lacking are data such as pollen, insect or forams (cf. various in van de Plassche 1986). Thus, none of the dates can be firmly tied to sea level; e.g., the Colville delta peats are several km beyond the present delta front; to infer that these are *in situ* would require that a former deltaic lobe was abandoned and subsequently subsided, as in the Mississippi delta. Numerous factors can influence the elevation of a peat sample, slope within depressions can range over several meters (cf. van de Plassche 1982:Fig. 3). Deposition within a breached thaw lake involves a variety of processes, including slope collapse, debris flows, and peat formation (Murton 1996:752).

E3.4 Implications of the Sea Level Data for Archaeological Prospectors

The sea-level indicators from Beaufort Sea shelf, and adjacent seas, can be very tentatively employed to hypothesize several paleo-sea levels that may serve as guide posts for archaeologists. The six guide posts should not be regarded as definitive, but as the best prognostications of past elevations.

- **At 11,000 yrs ago, sea level was at/ below 50 m bsl.**
- **After 10,500 yrs B.P., sea level had risen to at least 50 m bsl and flooded Bering Strait.**
- **By 9,000-7,500 yrs B.P., sea level was at/below 44 m bsl.**
- **Very rapid rates of sea-level rise continued, reaching 18/16 m bsl by 7,500 yrs B.P.**
- **By 6,000 yrs B.P., sea level was at/below 12 m bsl.**
- **Near modern (<2 m bsl) sea level was reached by 5,000 yrs B.P.**

As described above, only the oldest two and youngest water planes are relatively well-constrained. The early Holocene elevations are best supported by eastern Beaufort Sea data points, while the 7,500-6,000 yrs B.P. data points also have a few adequate (but widely separated) dates.

Lag deposits thought to reflect sea level "still stands" occur off Pt. Clarence at 38, 30, 20 to 24, and at 10 to 12 m bsl. Some of these linear features are receiving sediments under the effects of modern currents. These periods of relative sea level stasis can be placed in a relative chronological sequence by interpolations from the available ^{14}C ages. The 38 m bsl massif would seem a product of an early Holocene sea level, as in the Laptev Sea where sea level around 8,500-9,000 yrs B.P. was 30 m bsl. The shoreline features between 28 and 20 m bsl date between 8,000 and 7,000 yrs B.P. The most notable paleoshoreline features are between 10 and 12 m bsl and should date around 6,500 yrs B.P.; a period followed by a very rapid rate of sea level rise. Around 2500 BC, the eustatic response had lessened, with sea level increasing only a minor amount in the last 5,000 years. Very high rates of eustatic sea level rise characterize the early and middle Holocene; rates on the order of magnitude higher than the present rate of rise in the Chukchi Sea, ca. 0.3 mm/yr (Jordan and Mason 1999).

E3.5 Comparisons with the Previous Paleogeographic Reconstructions

Almost three decades ago, Dixon et al. (1978) offered a detailed, largely speculative paleogeographic reconstruction of the Beaufort Sea shelf during the last 20,000 years. This bold approach occurred prior to the completion of the research efforts of the U.S. Geological Survey and the petroleum industry. Consequently, Dixon et al. (1978) relied on extra-regional inferences (although these were not specifically referenced by Sharma (1978)). Despite the dearth of data, Dixon et al. (1978) may offer some lessons pertinent to this study. Surprisingly, the six hypothetical sea level elevations from 1978 (although not technically *still stands*) may be broadly applicable.

- *Still Stand I* -125m @ 21000-18000 yrs B.P. (Dixon et al. 1978:II-25)
- *Still Stand II* -82 m @ 15000-14800 yrs B.P. (Dixon et al. 1978:Fig. II-2)
- *Still Stand III* -66 m @ 13750 yrs B.P. (Dixon et al. 1978 :Fig. II-4)
- *Still Stand IV* -55 m @ 12700 yrs B.P. (Dixon et al. 1978:Fig. II-6)
- *Still Stand V* -38 m @ 9400 yrs B.P. (Dixon et al. 1978:Fig. II-9)
- *Still Stand VI* -28 m @ 8700 yrs B.P. (Dixon et al. 1978:Fig. II-10)

Note that of the six "still stands" hypothesized, little data were offered by Sharma (1978) to support these events; lacking are local stratigraphic, seismic or chronometric data. Several coincidences can be seen between the Dixon et al. (1978) "still stands" and the reconstructed elevation guideposts we offer above. Quite significantly, in both, the flooding of the Bering Strait occurred after the hypothetical *IV*th still stand (evidence from Elias et al. 1992). Also coincidentally, the *VI*th still stand co-occurs with the shoreline retreat massifs of the Bering to Beaufort shelves and approximates the 9,000 yrs B.P. paleoshoreline of the Laptev Sea (cf. Bauch et al. 2001). One must express a caution in employing the "still stands" from Dixon et al. (1978); the coincidental co-occurrence of the timing for various sea levels does not mean that the sedimentary evidence (i.e., depositional landforms) exists that would be useful in designing an archaeological prospecting survey. As a consequence, it is prudent to use the ecological reconstructions in Dixon et al. (1978) with caution. The detailed interpretation of the seismic data offered in this report should be consulted prior to the acceptance of previously-interpolated paleogeography.

Table E-1. Radiocarbon Ages from Beaufort Sea Cores/Boreholes[1]

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Radiocarbon Sample ID	Laboratory Number	Conventional ^{14}C age (yrs BP)	Cal Age AD/BC	Vibracore (V) or Borehole No.	Depth below sea level (m); [potential errors]	Depth below core top (m)	Material
Borehole PB-1	USGS-132	490±90	AD 1298-1528 1551-1634	Prudhoe Bay PB-1	6.5 [listed as 7.8 in Robinson & Trimble 1981:312]	3.8	Wood fragments
MMS-04-01 Colville River delta front	**Beta-202442**	**1660±40**	**AD 260-290**	**V-18**	**4.3**	**1.00-1.05**	**Plant macrofossils**
Gwydyr Bay	N.A.	2260±50	400-200 BC	V-27	1.75	0.4 to 0.5	Coarse peat
Colville R.delta front platform	USGS-294	2270±55	404-199 BC	V-18	3.84	0.54	Coarse fibrous material
Gwydyr Bay	N.A.	2490±90	796-405 BC	V-47	2.7	0.7	Fibrous organic peat
Colville R. delta front platform	USGS-577	2490±55	788-481 BC 468-447 BC 442-411 BC	--	3.7	1.2	Fibrous organic matter, 5 cm thick layer
Pingok Island	I-10,182	2500±105	826-396 BC	Sample Pi-5	0.84	--	Peat
Colville R. delta front platform	USGS-575	2930±50	1296-1273 BC 1265-996 BC 990-974 BC	--	3.1	1.10	Fibrous organic matter, 30 cm thick bed
Colville R. delta Front platform	USGS-293	3040±50	1412-1188 BC, 1181-1149 BC 1144-1123 BC	V-18	4.3	0.97-.098	Clayey silt
Colville R. delta	USGS-292	3110±70	1520-1210 BC	V-23	2.45	1.40-1.50	Organic clayey silt
Colville R. delta	USGS-291	3430±45	1880-1837 BC 1830-1620 BC	V-23	2.3	1.3	Organic clayey silt
MMS-04-02 Colville River delta front	**Beta-202443**	**3940±40**	**2550-2520 BC, 2500-2310 BC**	**V-18**	**4.75**	**1.4-1.50**	**Plant macrofossils**
MMS-04-04	**Beta-202444**	**3850±40**	**1950-1740 BC**	**08-12VS**	**20.2**	**2.15**	**Shell**
Gwydyr Bay	N.A.	4295±40	3022-2873 BC 2802-2784 BC	V-27	2.9	1.6	Silty fibrous peat
Putuligyauk R.	N.A.	4385±35	3096-2910 BC	V-26	3.1	1.6	Silty peat

[1] Three ages on the carbonate fraction from Warthog, boring # BH-1-5-1, 2-5-4 and 4-5-1, are not included.

Radiocarbon Sample ID	Laboratory Number	Conventional ^{14}C age (yrs BP)	Cal Age AD/BC	Vibracore (V) or Borehole No.	Depth below sea level (m)	Depth below core top (m)	Material
MMS-04-05	**Beta-202445**	**4450±40**	**2830-2560 BC**	**V-9**	**6.95**	**0.40-0.45**	**Shell**
Simpson Lagoon	USGS-578	4760±100	3768-3342 BC	V-48	3.5	0.9 to 1.1	2 to 4 cm th fibrous peat
Gwydyr Bay	N.A.	5520±45	4456-4323 BC	V-27	2.4	1.1	Organic rich silt
MMS-04-08a	**Beta-202446**	**6590±40**	**5260-5050 BC**	**V-9**	**7.9**	**1.35-1.40**	**Shell**
Stefansson Sound Offshore Sag River delta	N.A.	7560±100	6440-6404 BC	V-29	5.7	0.2	Fibrous peat
MMS-04-08b	**Beta-202447**	**8560±40**	**7610-7550 BC**	**V-9**	**7.9**	**1.35-1.40**	**Wood**
Prudhoe Bay	USGS-783	9020±90	8453-7940 BC	PB-6	2.7	0.8	Peat
Simpson Lagoon	*N.A.*	*10320±???*	*[Missing data]*	*V-48*	*2.5*	*1.6 to 1.7*	*Peat mixed with sandy silt*
Mukluk N1	Beta-xxxx	11810±120	13219-12810, 12324-12262, 12170-11485 BC	Geotech boring N	15.9	0.9-1.5	Organics in silt
Mukluk N2	Beta-xxxx	12470±130	13531-12182 BC	Geotech boring N	18.2	3.3-3.4	Organics in silt
Mukluk N3	Beta-xxxx	14580±130	16112-14944 BC	Geotech boring N	20.9	5.8-6	Organics in silt
Prudhoe Bay borehole	USGS-192	18,000±170	20227-18688 BC	Prudhoe Bay Borehole PB-2	14.3 [listed as 13.7 in Robinson & Trimble 1981:312]	--	Organic carbon
Warthog 95M0001[2]	N.A.	20,200±1,070	[Beyond range of calibration]	Warthog BH-1-5-1	3.0-3.7	0.6	Organic fraction
Warthog[3] 95MOOO7	N.A.	20,480±870	[Beyond range of calibration]	Warthog BH-2-5-4	5.1-5.7	2.4-3.05	Organic fraction
Prudhoe Bay BP oil well	WSU-1426	25500±2000	[Beyond range of calibration]	BP oil well	122	122	Tamarack wood fragment
Mukluk N4	Beta-xxxx	27450±360	[Beyond range of calibration]	Geotech boring N	25.65	10.6-10.8	Organics in silt
Prudhoe Bay BP oil well	WSU-1428	29200±1000	[Beyond range of calibration	BP oil well	122	122	Tamarack wood fragment

[2] A split of this sample dated the carbonate fraction and yielded an age of 36,130+5880/3360 BP it is not included here, cf. Table 2.
[3] A split of this sample dated the carbonate fraction and yielded an age of 38,790 +/- 8700/4080; it is not included here, cf. Table 2.

Radiocarbon Sample ID	Laboratory Number	Conventional ^{14}C age (yrs BP)	Cal Age AD/BC	Vibracorer (V) or Borehole No.	Depth below sea level (m)	Depth below core top (m)	Material
Prudhoe Bay	USGS-210	34000±2100 [listed as >33900 in Robinson & Trimble 1981:312]	[Beyond range of calibration]	Borehole PB-3	46.5-47.1 [listed as 49 in Robinson and Trimble 1981:312]	40.9	Twigs, organics
Prudhoe Bay	USGS-249	42800±1440	[Beyond range of calibration]	Borehole PB-7	13.3-13.6	13.2	Twigs, organics

[In Bold: Samples obtained from archived cores, U.S. Geological Survey, Menlo Park, CA, collected by Dr. Owen K. Mason, 13 and 14 December 2004]. Vibracore series **V** derive from U.S. Geological Survey efforts in the 1970s. The date in italics lacks standard deviation and was not plotted (Figs. E-1 and E-2.). N.A. indicates that laboratory numbers were not available, Dr. Peter Barnes should be contacted for this information.

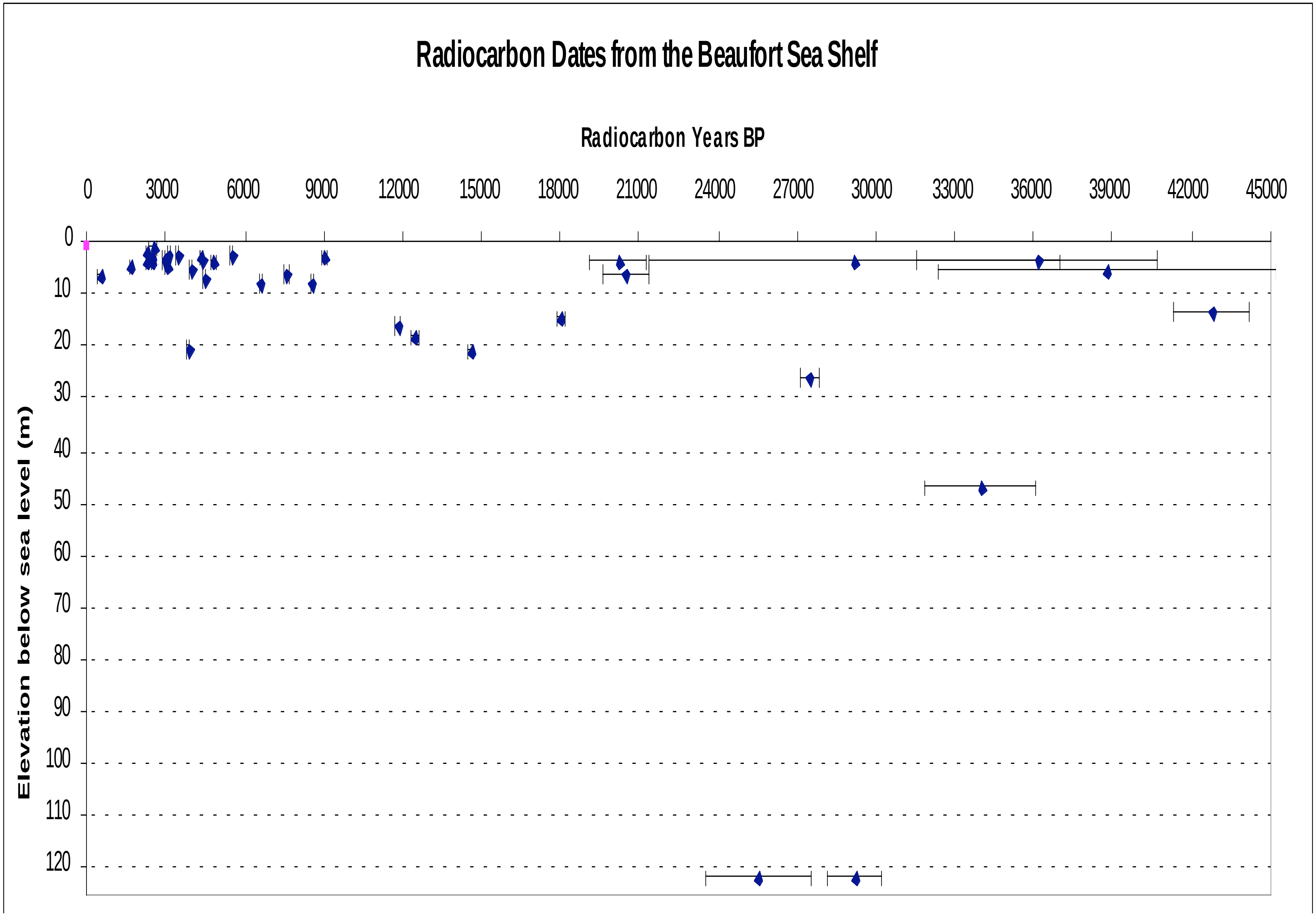


Figure E-1. Radiocarbon ages from the Beaufort Sea shelf from Pt. Barrow to the Canadian border -- less than 45,000 years old..

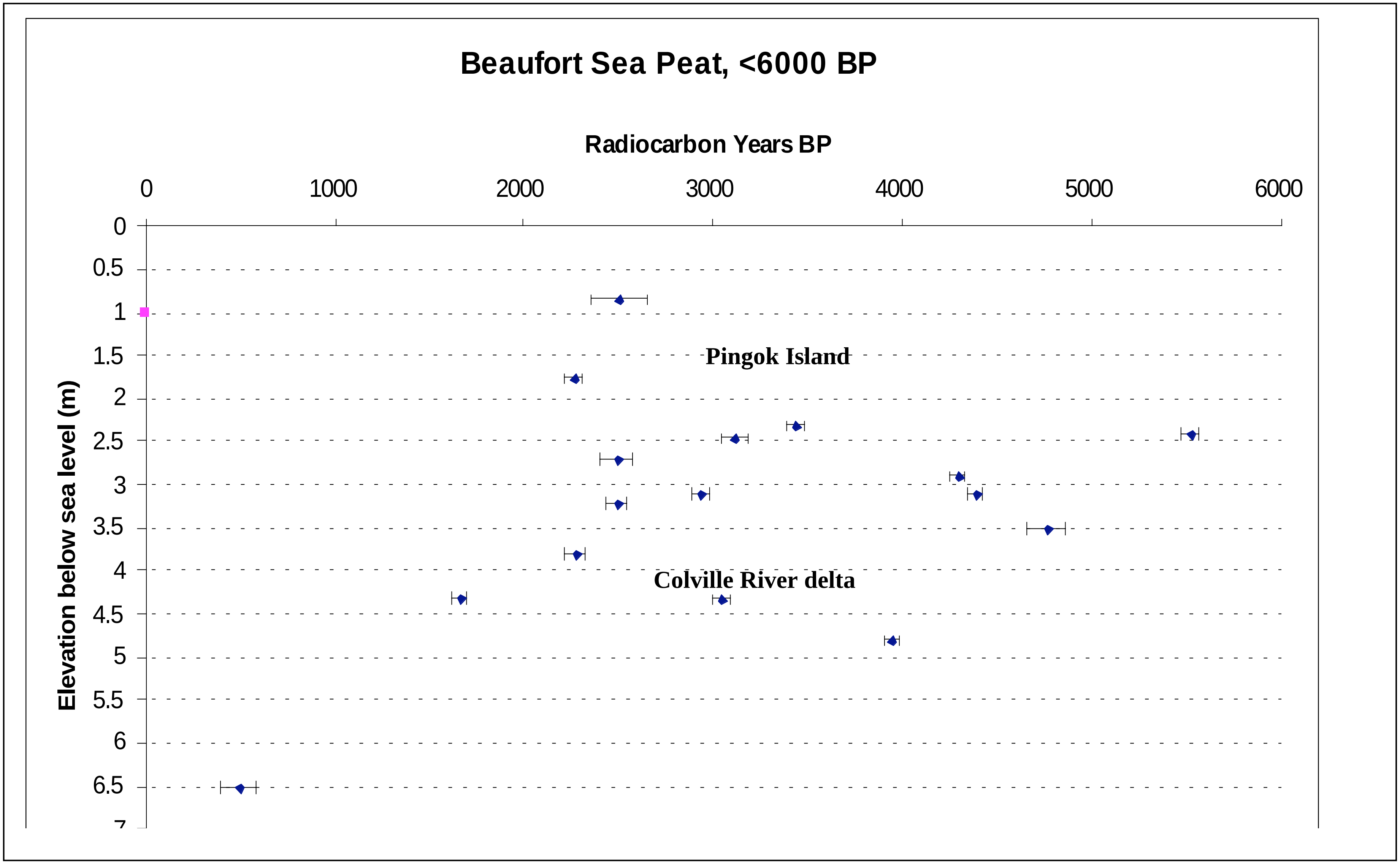


Figure E-2. Radiocarbon ages from the Beaufort Sea shelf -- fibrous peats, less than 6,000 years old.

APPENDIX F

USGS CORE SAMPLING TRIP REPORT,
DECEMBER 2004

APPENDIX F

Inspection and Sampling of Beaufort Sea Cores, archived by the U.S. Geological Survey in Menlo Park, California.

Trip Report by Owen K. Mason, Ph.D.

Monday, December 13, 2004
Red Cottage Inn
Menlo Park, CA

Arrived in Menlo Park, around 4 pm on Sunday afternoon, December 12, and checked into the Red Cottage Inn. I purchased various sundry items (Al foil, Ziplocs, packing material) from a local supermarket.

Arrived at 8.00 am at the office of Charles Steele within the USGS campus in Menlo Park. Mr. Steele produced a log of the archived core samples, listing the current warehouse provenience. Only four of the 20-odd cores were located in the inventory. Mr. Steele provided transportation to an aging warehouse (broken windows, tall grasses) several km from the USGS campus. Upon arrival at the unmanned and untidy facility, Mr. Steele related the unfortunate circumstances that resulted in the loss of 3/4ths of the cores: some years ago, an unsupervised drug-crazed employee decided to clean up the clutter and discard unneeded materials. The aftermath of this reorganization led to placing sample boxes on pallets wrapped in shrink-wrap. The warehouse interior had several rows of metal framing, divided into three shelves, each with pallets loaded with cardboard sample boxes, stacked four deep to a height of six or seven boxes (each pallet thus containing about 100 boxes of core samples). The samples were on several different pallets, up to 3 m above the floor, requiring a fork-lift operator to transfer the pallets—this meant a delay of several hours so that Mr. Steele could locate and assign someone to this task. In the meantime, Mr. Steele drove to the MARFAC building, the facility for cold core storage. Only the untouchable "archived" cores could be located and a call had to be made to supervisor Mike Torresan, who knew the location of the "working" cores.

From 1300 to 1400 pm, I assessed the other Beaufort Sea cores, opening boxes in the rows of the warehouse in the dim light. Only five (V-1, V-4, V-9, V-12, V-18) of the 34 cores that we had expected were available—fortunately, three cores (V-1, 4 and 18) were in our highest priority for sampling; the other two were equivocal and were sampled as a back-up measure. My initial inspection and opening of a few sample bags led to the impression that the core samples offered little potential for organics—a consequence, it turned out, of the poor lighting. The annotation in Barnes et al. 1979 referred to subsampling by Dr. Naidu hints at the possibility that samples may remain with Dr. Barnes [Possibly significant, none of the cores sampled by Dr. Naidu were in storage, e,g,.the cores (V-47 to 50) from Simpson lagoon].

After a lunch break, we returned to the MARFAC storage laboratory and met Mr. Torresan at 14.30 pm. The core 08-12VS was laid in an adjoining laboratory room and I digitally photographed the relevant lower portion of the core, observing a fair amount of shell fragments in the lower 2 cm of a massive slightly oxidized sand. In spite of the absence of other datable substance, I extracted several shells from 215 cm below the core top (sample MMS-04-04), placing them in a glass vial provided by the Mr. Torresan.

December 15, 2004
Alaska Airlines,
en route to Anchorage,

On Tuesday December 14, 2004, I returned to the USGS campus and Mr. Steele drove me to the warehouse, and I commenced the inspection process, provided with a piece of cardboard to place atop the palletized sample boxes. I stood and opened each box, extracting the plastic sample fraction for each 5 cm level of each core. No better-lighted work space was apparently available, so that I had to open a nearby door and hold the sample to the light.

With sufficient light from the open door (fortunately it was a sunny California winter day), I was able to discern a fair amount of organics in most of the samples that were isolated prior to my visit. The results of the sampling are detailed in the attached table, 13 samples were extracted, from five cores (V-1, 4, 9, 12 and 18). In most cases, the amount of organics was low, in some cases a few pieces of shell or lenses of peat. None of the samples had the type of thick dense peat that might correspond to an *in situ* marsh or terrestrial peat. Organic material, either shell or plant macrofossil, were extracted from the sample bags by squeezers and placed within Aluminum foil within Ziploc bags, with provenience marked on each bag.

Sampling was completed by 11 am and I departed Menlo Park by 1 pm, after packaging the samples and sending to Fairbanks from the Fedex main office in Palo Alto, CA.

On the positive side, if all the cores had been available, the sampling effort would have involved several times more effort and expense. In terms of the equivocal context of the cores, this effort would likely not be justified. From the visit, my conclusion is that the material in the U.S. Geological Survey core warehouse likely will not prove of additional interest to researchers interested in past sea level or in chronologies of paleogeographic or environmental reconstruction.

Beaufort Sea Radiocarbon Samples obtained from archived cores,
U.S. Geological Survey, Menlo Park, CA.
[Researcher: Owen K. Mason, 13 and 14 December 2004].

Radiocarbon Sample ID	USGS Vibracore No.	Depth below core top (cm)	Material
MMS-04-01	V-18	100-105	Plant macrofossils
MMS-04-02	V-18	145-150	Plant macrofossils
MMS-04-03	V-4	70-75	Shell
MMS-04-04	08-12VS	215	Shell
MMS-04-05	V-9	40-45	Shell
MMS-04-06	V-9	55-60	Plant macrofossils
MMS-04-07	V-9	145-150	Plant macrofossils
MMS-04-08	V-9	135-140	Shell, Plant macros.
MMS-04-09	V-4	40-45	Shell, Plant macros.
MMS-04-10	V-4	25-30	Plant macrofossils
MMS-04-11	V-1	75-80	Plant macrofossils
MMS-04-12	V-1	45-50	Plant macrofossils
MMS-04-13	V-12	25-30	Plant macrofossils
MMS-04-14	V-12	110-115	Plant macrofossils

APPENDIX G

LOGS OF USGS VIBRACORES SELECTED FOR DATING

APPENDIX G

The following are included in this appendix:

- Logs of Vibracores V-9 and V-18 from Barnes et al. (1979);
- Description of Vibracore V-18 from Fishbein (1987); and
- Description of Vibracore 8-12VS from USGS (2004a).

Core V-9 (Barnes et al., 1979) Negative #Barnes-9

Two shells at surface, one live Astarte

Dark grey, medium sand, angular, structureless, with a few granules and a small pebble. Possibly some shell fragments. Becoming more muddy, with mud in little pockets.

Irregular contact, ill-defined

clay layer

Dark grey, sandy silt, irregular, horizontal banding

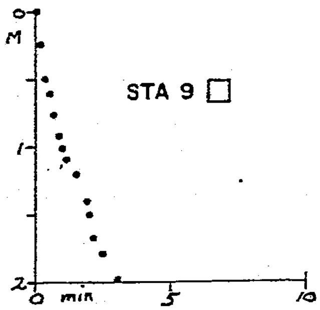
angular pebble

clay-rich

shell fragments

dark, organic rich, but fine grained layers

Horizontally banded clayey silt, banding mainly alternating dark grey/olive drab color in some areas mottled without bans. No shells, no pebbles.



clay layer

clean, light grey, fine sand layer

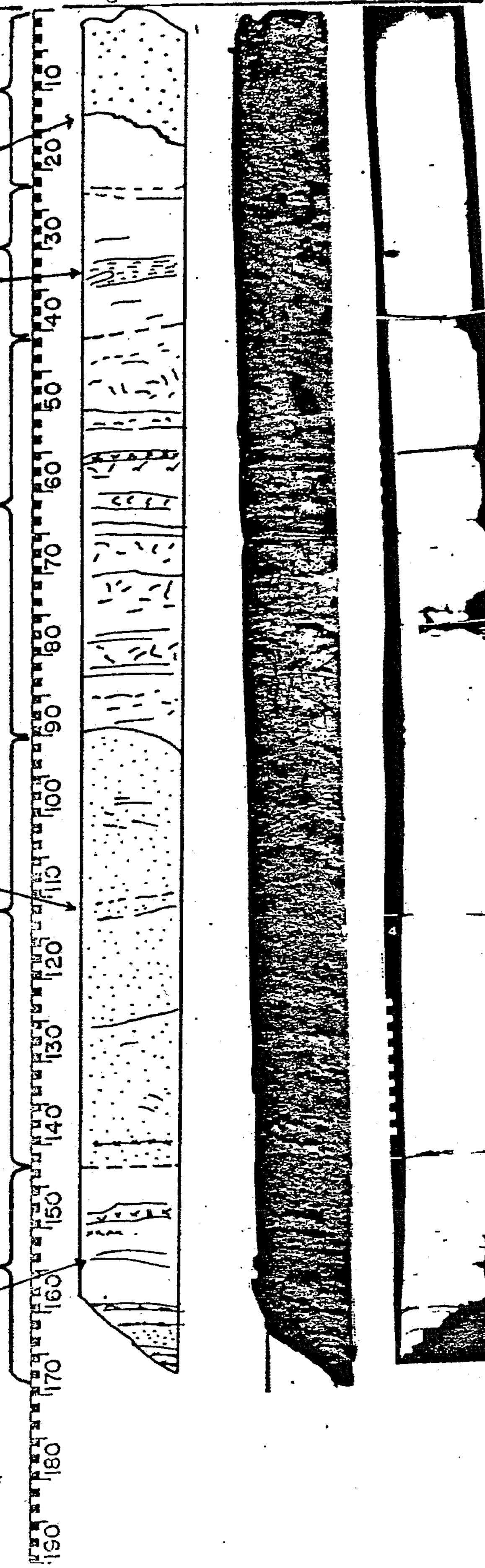
Dark grey, muddy fine sand, band: horizontal sometimes deformed by larger mud content gradually becoming less sandy--more muddy downward. Little to no structure from 130-140 cm. Shell fragment at 137 cm.

thin, fine organic layer

Dark grey, sandy, clayey silt, well bedded, bedding mostly defined by fine organic rich layers (crosses)

clean, light grey, fine sand

core catcher



Total core length: 169 cm; core catcher activated: some downslipping. Few angular pebbles as marked. Core not becoming much firmer toward bottom.

Core V-9 Depth 6.5 m 70°20.1'N, 147°31.1'W Remarks: Stefansson Sound south of Narwhal Island

Core V-18 (Barnes et al., 1979)

Negative #Barnes-18

Grey silty clay with interbedded lenses of oxidized medium to fine grained sand. Clay contains lenses of organic matter. Bedding plane lamination and fineing upwards in sands.

rey clayey silt, interlaminated with fine org. and coal

Silty clay, grey.

Dark grey, muddy fine sand rich in organic matter very coarse fibrous in lower part C^{14} subsample

Homogenous silty clay, grey 2270 + 55 y

Fine sand with some organic matter

Laminated sandy silt

Fibrous organic matter

ey, soft, silty clay, in upper part several laminae of ganic matter, shown dark in photos.

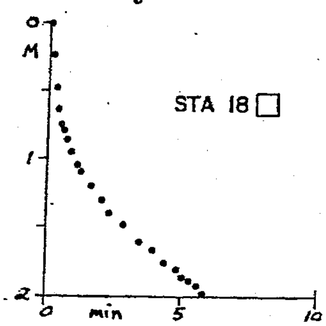
97-98 cm for C^{14} 3040 + 50 y.

Clean washed, coarse fibrous organic matter

Grey silty clay, soft, possibly horizontal banding in upper part.

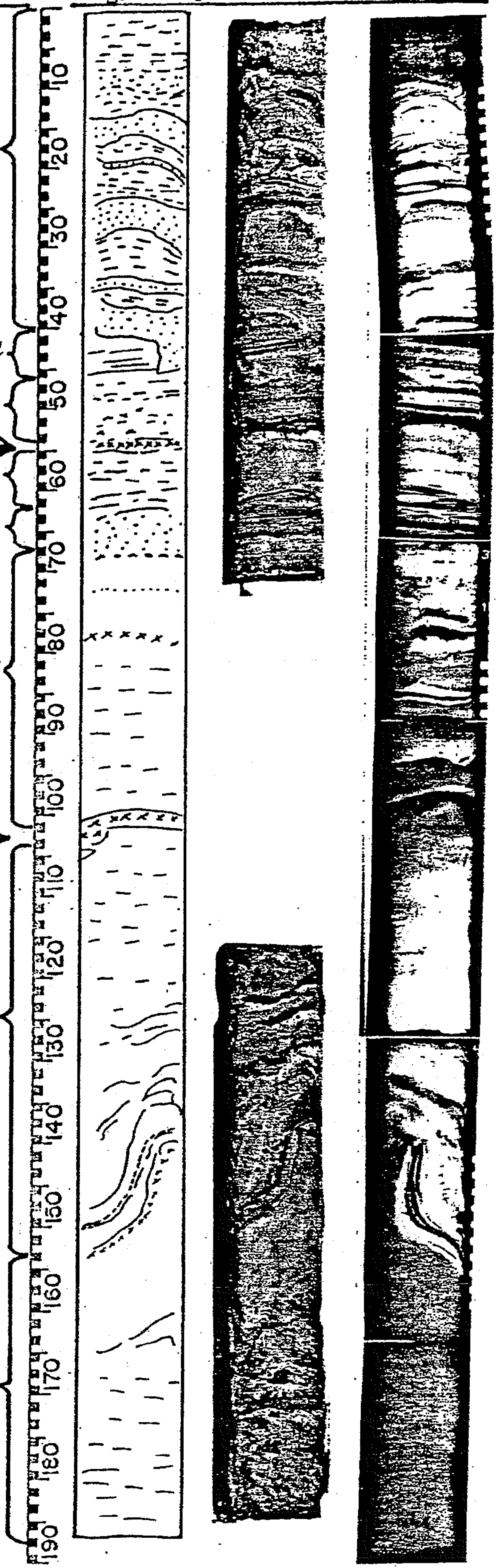
In lower part, large wave structure marked by more clayey layers and lamina rich in organics.

Ice disturbance



Light grey, soft, homogenous slightly silty clay

Note: *Except for peat layers, entire core was easily cut with wire. No shells or pebbles on first cut face.*



Core V-18 Depth 3.3 m 70°33.2'N, 150°27.9'W Remarks: North of Colville delta from Fishbein (1987)

CORE V-18

Core V-18 was extracted from 3.3 m of water, approximately 9 km from shore. The upper portion of this core consists of horizontally laminated clay, sandy clay, and sand interbeds with high organic content (Figure 9a and b). Cross-laminated and ripple cross-laminated sands are abundant in this portion of the core as well as thin beds (2 cm or less) of organic detritus. Truncation of horizontal and cross-laminations is present resulting in small cut and fill structures. The thin horizontally laminated clay and cross laminated sand interbeds and high organic content in this portion of the core may be indicative of the delta front depositional environment (Figure 9b, arrow 1) (Tucker, 1981; Reineck and Singh, 1980; Reading, 1986).

The lower portion of this core is composed of massive clay and sandy clay beds with few sand and organic interbeds. The lower 50 cm of the core shows extreme deformation of a sandy unit above a massive clay unit with abundant rootlets and plant stems (Figure 9b, arrow 2). The presence of the rootlets may indicate that this portion of the core was a mat of tundra vegetation that has subsequently been buried. However, because this part of the core is dominantly mud (approximately 85%), and a tundra mat would most likely contain a larger organic component (ie. >15% organics), this interpretation is improbable. The presence of rootlets in mud may indicate subaerial exposure (Reineck and Singh, 1980; Reading, 1986), and this portion of the core therefore may represent deposition in a tidal marsh environment (Figure 9b, arrow 3) (Reineck and Singh, 1980; Reading, 1986; Tucker, 1981).

Fishbein (1987)

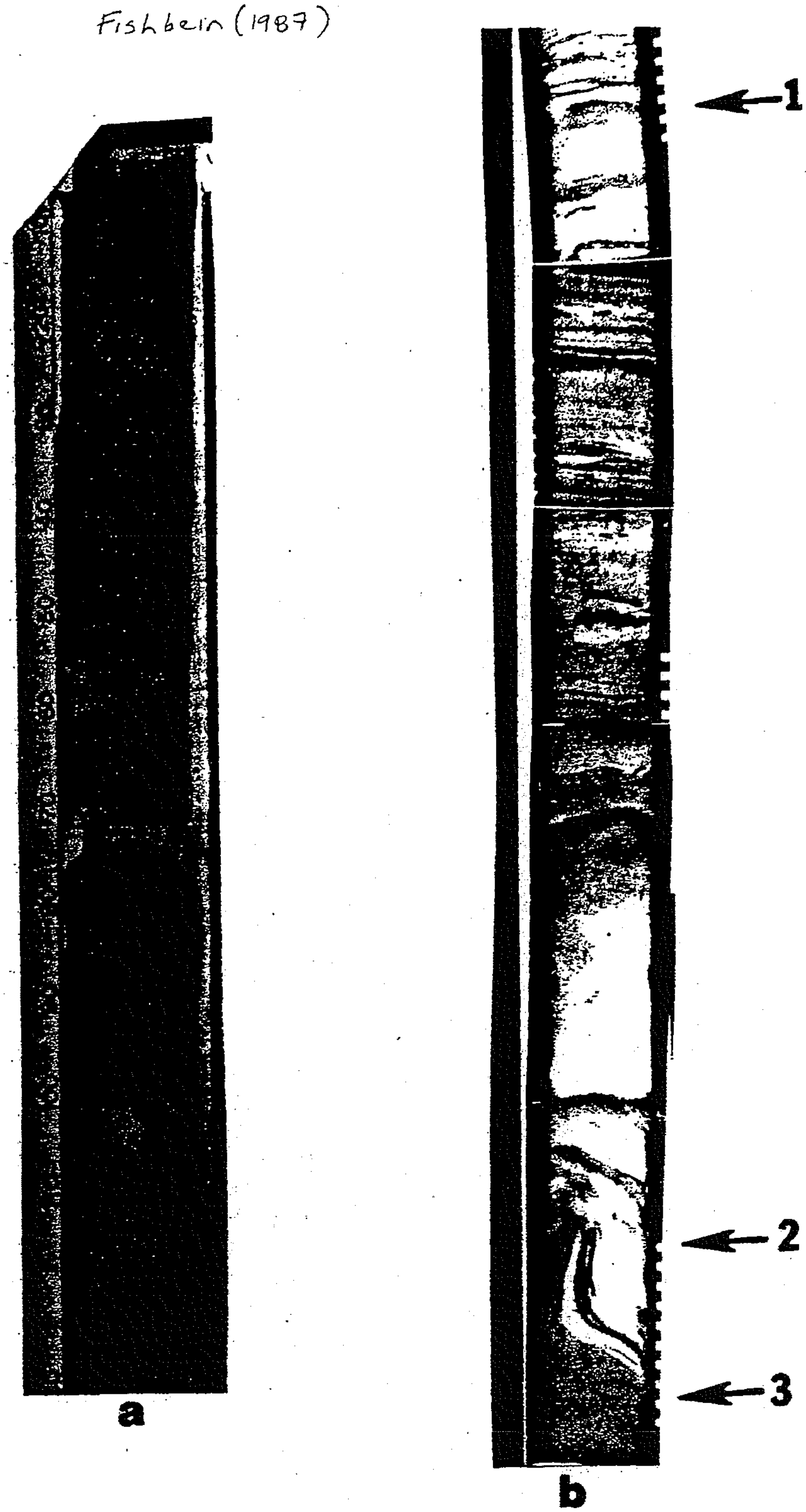
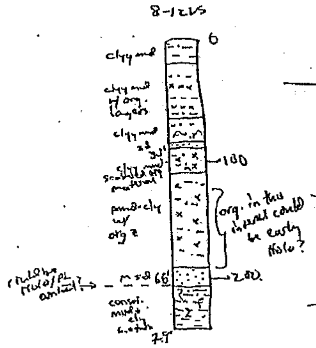


Figure 9a and b. A and b are peel and radiograph of core V-18. Arrow 1 points to horizontally laminated sands, silts, and clays of the delta front. Arrow 2 points to highly deformed bedding that may be a result of ice gouging. Arrow 3 points to clay with abundant rootlets that may represent a subaerially exposed marsh deposit. Scale is in cm.

Sample ID --- 08-12VS
Activity ID --- D-1-85-AR
Vessel --- Discoverer
Sampling Equipment --- vibrating core
Time --- 19852530000 (yyyydddhhmm)
Latitude --- 71.29167
Longitude --- -154.99833
Water Depth --- 18 (meters)
Core Length --- 242 (centimeters)
Core Diameter --- 0 (centimeters)
Comments ---

Subsample Purpose ---
Storage Method ---
Storage Location ---
Investigator(s) --- core described by M. Colgan, core recored by J. Miley
Comments ---
Subsample ID ---
Interval Top --- 0 (centimeters)
Interval Bottom --- 0 (centimeters)
Interval Age --- unknown
Primary Lithology ---
Secondary Lithology ---
Primary Texture ---
Secondary Texture ---
Other Components ---
Comments ---Description of Depostional Interval 0 cm to 18 cm
A.Color of unit: olive grey
B. Sediment texture: unconsolidated clayey - mud
C.Sedimentary structures: massive
D.Paleontologic obsevervation: none
E.Additional comments:



Description of Depostional Interval 18 cm to 65 cm
A.Color of unit: olive grey with grey mud
B. Sediment texture: consolidated clayey - mud with this layer of dark organic silt layers
C.Sedimentary structures: irregular spaced and unequal lamination of dark organic silt layers lower portion dark layer thicker and more numerous,some slight
D.Paleontologic obsevervation: none
E.Additional comments: dark layer decreasing upwards; 47 - 63 cm slight deformation zone

Description of Depostional Interval 65 cm to 85 cm
A.Color of unit: medium grey with olive grey
B. Sediment texture: consolidated clayey mud with scatter layer of darker silty layer
C.Sedimentary structures: thick,2cm layers of dark layer; around 70 cm, possible deformation; below 75 cm thin interbed of dark and light layer, some deforma
D.Paleontologic obsevervation: none
E.Additional comments: lower contact - silt lag deposit

Description of Depostional Interval 85 cm to 90 cm
A.Color of unit: medium grey with olive grey
B: Sediment texture: fine sand lag at base of unit; sands fine upwards
C.Sedimentary structures:
D.Paleontologic obsevervation:
E.Additional comments: sand over mud

Description of Depostional Interval 90 cm to 110 cm
A.Color of unit: olive grey
B. Sediment texture: clayey consolidated mud
C.Sedimentary structures: massive consolidated with random sites of organic material
D.Paleontologic obsevervation: none
E.Additional comments: found in both cores; increase in dark organic material below contact

Description of Depostional Interval 110 cm to 190 cm
A.Color of unit: dark olive grey with black layer
B. Sediment texture: mud - clay with organic silt layer
C.Sedimentary structures: sub parallel lamination at the two ends of the unit/the middle is marked by a zone of deformation

08-12vs (cont.)

D.Paleontologic obsevervation: scattered shell fragments of unknown origin
E.Additional comments: sharp lithology contact
Description of Depostional Interval 190 cm to 210 cm
A.Color of unit: olive green
B. Sediment texture: well sorted medium sands
C.Sedimentary structures: massive
D.Paleontologic obsevervation: shell fragments
E.Additional comments: sharp lithologic contact
Description of Depostional Interval 211 cm to 242 cm
A.Color of unit: light grey
B. Sediment texture: consolidated mud with sand filled worm tubes; 100% clay from 227 - 242 cm.
C.Sedimentary structures: massive
D.Paleontologic obsevervation: sand filled worm burrows; scattered shell fragments
E.Additional comments:bioturbation pebble at 560 cm

160? core only went to 242 cm

http://walrus.wr.usgs.gov/infobank/d/d185ar/samp/d-1-85-ar.cores.vibratingcore.08-12vs (USGS, 2004a)

APPENDIX H

LABORATORY DATA

FROM: Darden Hood, Director (mailto:mailto:dhood@radiocarbon.com)

(This is a copy of the letter being mailed. Invoices/receipts follow only by mail.)

March 31, 2005

Mr. Peter Michael Bowers
Northern Land Use Research, Incorporated
P.O. Box 83990
Fairbanks, AK 99708
USA

RE: Radiocarbon Dating Results For Samples MMS0401, MMS0402, MMS0404, MMS0405, MMS0408-SHELL, MMS0408-WOOD

Dear Pete:

Enclosed are the radiocarbon dating results for six samples recently sent to us. They each provided plenty of carbon for accurate measurements and all the analyses went normally. As usual, the method of analysis is listed on the report with the results and calibration data is provided where applicable.

As always, no students or intern researchers who would necessarily be distracted with other obligations and priorities were used in the analyses. We analyzed them with the combined attention of our entire professional staff.

If you have specific questions about the analyses, please contact us. We are always available to answer your questions.

Thank you for prepaying the analyses. A receipt is enclosed. As always, if you have any questions or would like to discuss the results, don't hesitate to contact me.

Sincerely,

Darden Hood

Mr. Peter Michael Bowers — Report Date: 3/31/2005

Northern Land Use Research, Incorporated — Material Received: 2/28/2005

Sample Data	Measured Radiocarbon Age	13C/12C Ratio	Conventional Radiocarbon Age(*)
Beta - 202442	1710 +/- 40 BP	-27.8 o/oo	1660 +/- 40 BP

SAMPLE : MMS0401
ANALYSIS : AMS-Standard delivery
MATERIAL/PRETREATMENT : (wood): acid/alkali/acid
2 SIGMA CALIBRATION : Cal AD 260 to 290 (Cal BP 1690 to 1660) AND Cal AD 320 to 450 (Cal BP 1630 to 1500)

Beta - 202443	3980 +/- 40 BP	-27.5 o/oo	3940 +/- 40 BP

SAMPLE : MMS0402
ANALYSIS : AMS-Standard delivery
MATERIAL/PRETREATMENT : (wood): acid/alkali/acid
2 SIGMA CALIBRATION : Cal BC 2560 to 2520 (Cal BP 4510 to 4480) AND Cal BC 2500 to 2310 (Cal BP 4440 to 4260)

Beta - 202444	3460 +/- 40 BP	-1.0 o/oo	3850 +/- 40 BP

SAMPLE : MMS0404
ANALYSIS : AMS-Standard delivery
MATERIAL/PRETREATMENT : (shell): acid etch
2 SIGMA CALIBRATION : Cal BC 1950 to 1740 (Cal BP 3900 to 3690)

Beta - 202445	4160 +/- 40 BP	-7.2 o/oo	4450 +/- 40 BP

SAMPLE : MMS0405
ANALYSIS : AMS-Standard delivery
MATERIAL/PRETREATMENT : (shell): acid etch
2 SIGMA CALIBRATION : Cal BC 2830 to 2560 (Cal BP 4780 to 4510)

Beta - 202446	6290 +/- 40 BP	-7.0 o/oo	6590 +/- 40 BP

SAMPLE : MMS0408-SHELL
ANALYSIS : AMS-Standard delivery
MATERIAL/PRETREATMENT : (shell): acid etch
2 SIGMA CALIBRATION : Cal BC 5260 to 5050 (Cal BP 7210 to 7000)

Mr. Peter Michael Bowers | Report Date: 3/31/2005

Sample Data	Measured Radiocarbon Age	13C/12C Ratio	Conventional Radiocarbon Age(*)
Beta - 202447	8590 +/- 40 BP	-27.0 o/oo	8560 +/- 40 BP

SAMPLE : MMS0408-WOOD
ANALYSIS : AMS-Standard delivery
MATERIAL/PRETREATMENT : (wood): acid/alkali/acid
2 SIGMA CALIBRATION : Cal BC 7610 to 7550 (Cal BP 9560 to 9500)

CALIBRATION OF RADIOCARBON AGE TO CALENDAR YEARS

(Variables: C13/C12=-27.8:lab. mult=1)

Laboratory number: **Beta-202442**

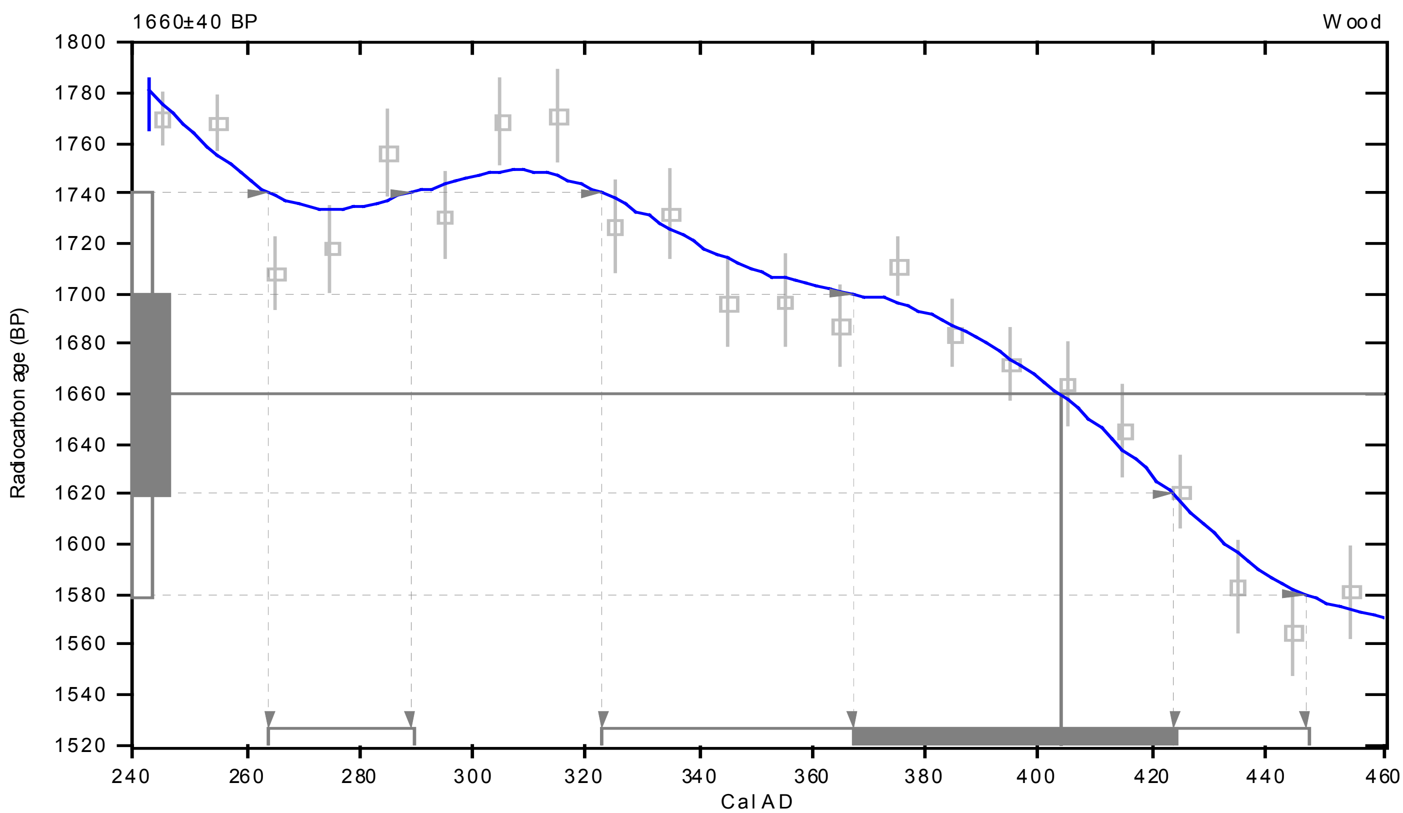
Conventional radiocarbon age: **1660±40 BP**

2 Sigma calibrated results: **Cal AD 260 to 290 (Cal BP 1690 to 1660) and**
(95% probability) **Cal AD 320 to 450 (Cal BP 1630 to 1500)**

Intercept data

Intercept of radiocarbon age with calibration curve: Cal AD 400 (Cal BP 1550)

1 Sigma calibrated result: Cal AD 370 to 420 (Cal BP 1580 to 1530)
(68% probability)



References:

Database used
INTCAL98
Calibration Database
Editorial Comment
Stuiver, M., van der Plicht, H., 1998, Radiocarbon 40(3), pxii-xiii
INTCAL98 Radiocarbon Age Calibration
Stuiver, M., et. al., 1998, Radiocarbon 40(3), p1041-1083
Mathematics
A Simplified Approach to Calibrating C14 Dates
Talma, A. S., Vogel, J. C., 1993, Radiocarbon 35(2), p317-322

Beta Analytic Radiocarbon Dating Laboratory

4985 S.W. 74th Court, Miami, Florida 33155 • Tel: (305)667-5167 • Fax: (305)663-0964 • E-Mail: beta@radiocarbon.com

CALIBRATION OF RADIOCARBON AGE TO CALENDAR YEARS

(Variables: C13/C12=-27.5:lab. mult=1)

Laboratory number: **Beta-202443**

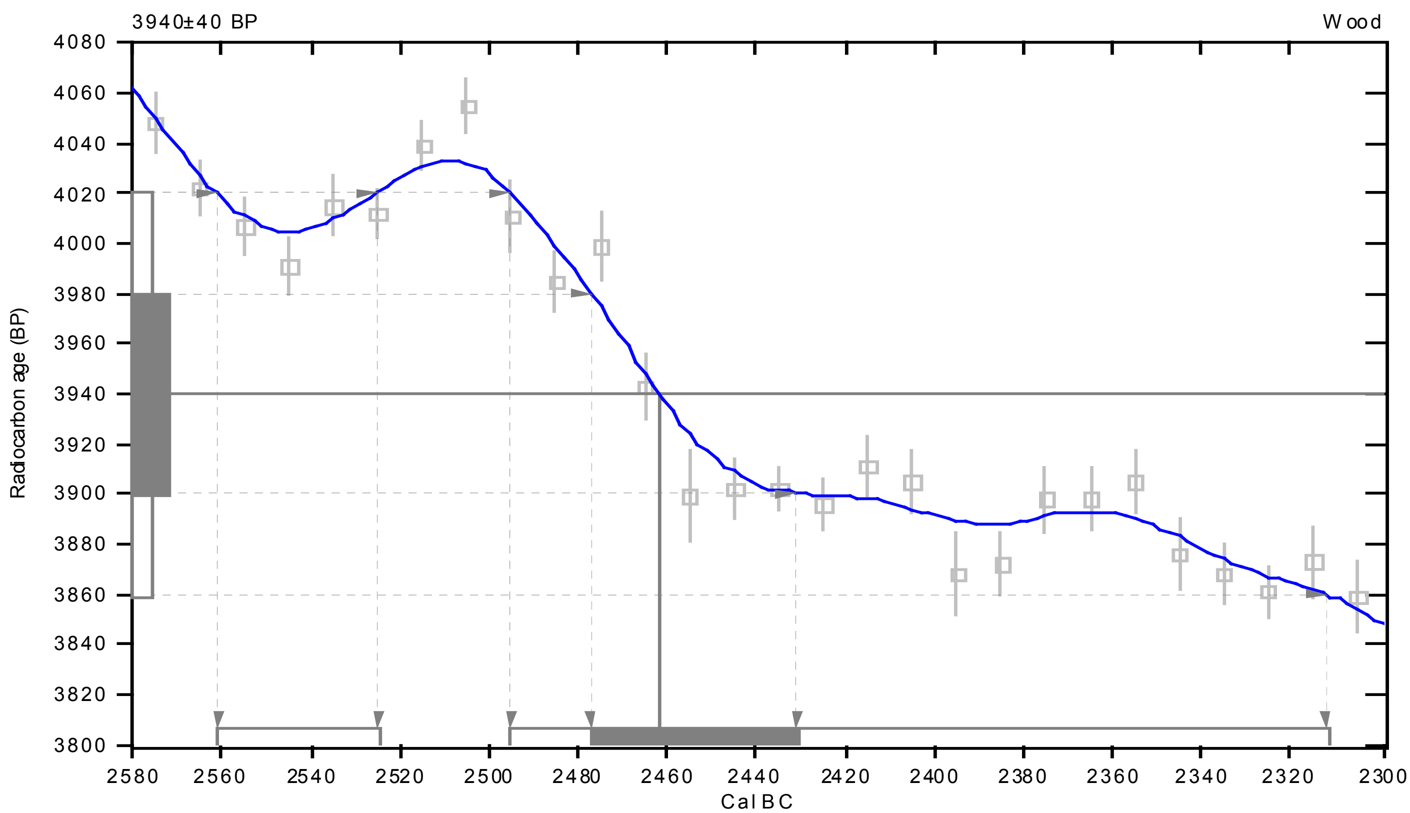
Conventional radiocarbon age: **3940±40 BP**

2 Sigma calibrated results: (95% probability) **Cal BC 2560 to 2520 (Cal BP 4510 to 4480) and Cal BC 2500 to 2310 (Cal BP 4440 to 4260)**

Intercept data

Intercept of radiocarbon age with calibration curve: Cal BC 2460 (Cal BP 4410)

1 Sigma calibrated result: (68% probability) Cal BC 2480 to 2430 (Cal BP 4430 to 4380)



References:

Database used
INTCAL98
Calibration Database
Editorial Comment
Stuiver, M., van der Plicht, H., 1998, Radiocarbon 40(3), pxii-xiii
INTCAL98 Radiocarbon Age Calibration
Stuiver, M., et. al., 1998, Radiocarbon 40(3), p1041-1083
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CALIBRATION OF RADIOCARBON AGE TO CALENDAR YEARS

(Variables: C13/C12=-1:Delta-R=0±0:Glob res=-200 to 500:lab. mult=1)

Laboratory number: **Beta-202444**

Conventional radiocarbon age: **3850±40 BP**

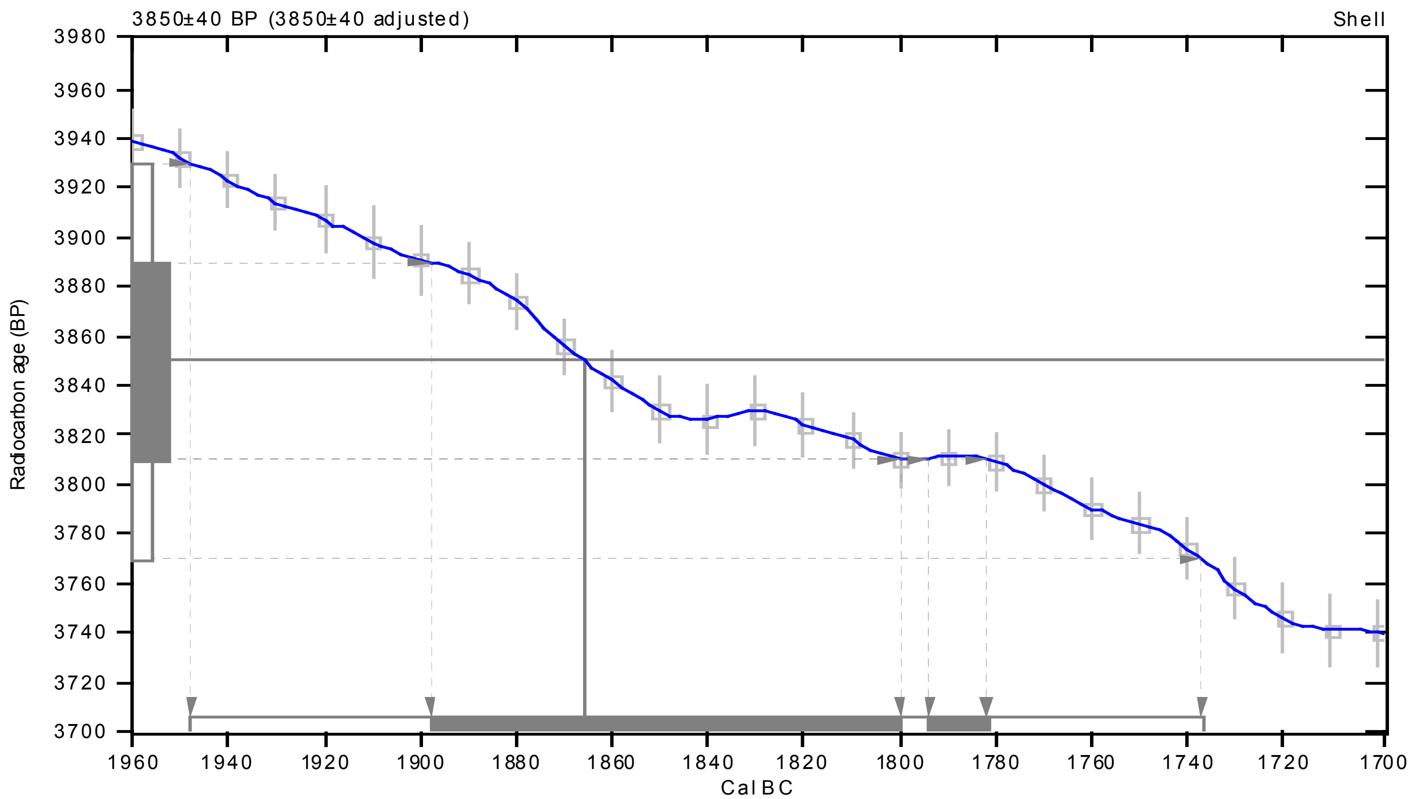
(local reservoir correction not applied)

2 Sigma calibrated result: **Cal BC 1950 to 1740 (Cal BP 3900 to 3690)**
(95% probability)

Intercept data

Intercept of radiocarbon age with calibration curve: Cal BC 1870 (Cal BP 3820)

1 Sigma calibrated results: Cal BC 1900 to 1800 (Cal BP 3850 to 3750) and
(68% probability) Cal BC 1790 to 1780 (Cal BP 3740 to 3730)



References:

Database used
MARINE98
Calibration Database
Editorial Comment
Stuiver, M., van der Plicht, H., 1998, Radiocarbon 40(3), pxii-xiii
INTCAL98 Radiocarbon Age Calibration
Stuiver, M., et. al., 1998, Radiocarbon 40(3), p1041-1083
Mathematics
A Simplified Approach to Calibrating C14 Dates
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CALIBRATION OF RADIOCARBON AGE TO CALENDAR YEARS

(Variables: C13/C12=-7.2:Delta-R=0±0:Glob res=-200 to 500:lab. mult=1)

Laboratory number: **Beta-202445**

Conventional radiocarbon age: **4450±40 BP**

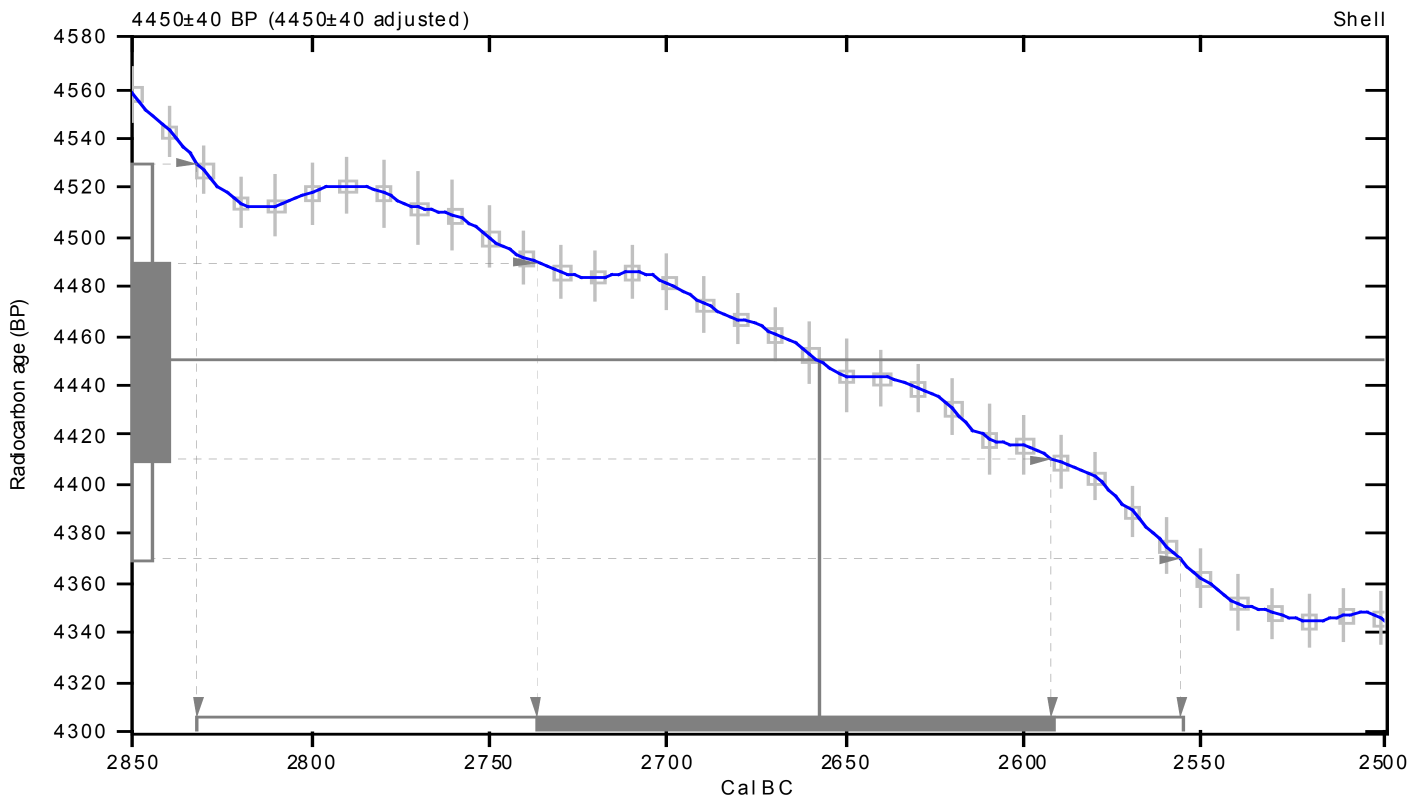
(local reservoir correction not applied)

2 Sigma calibrated result: (95% probability) **Cal BC 2830 to 2560 (Cal BP 4780 to 4510)**

Intercept data

Intercept of radiocarbon age with calibration curve: Cal BC 2660 (Cal BP 4610)

1 Sigma calibrated result: (68% probability) Cal BC 2740 to 2590 (Cal BP 4690 to 4540)



References:

Database used

MARINE98

Calibration Database

Editorial Comment

Stuiver, M., van der Plicht, H., 1998, Radiocarbon 40(3), pxii-xiii

INTCAL98 Radiocarbon Age Calibration

Stuiver, M., et. al., 1998, Radiocarbon 40(3), p1041-1083

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CALIBRATION OF RADIOCARBON AGE TO CALENDAR YEARS

(Variables: C13/C12=-7:Delta-R=0±0:Glob res=-200 to 500:lab. mult=1)

Laboratory number: Beta-202446

Conventional radiocarbon age: 6590±40 BP

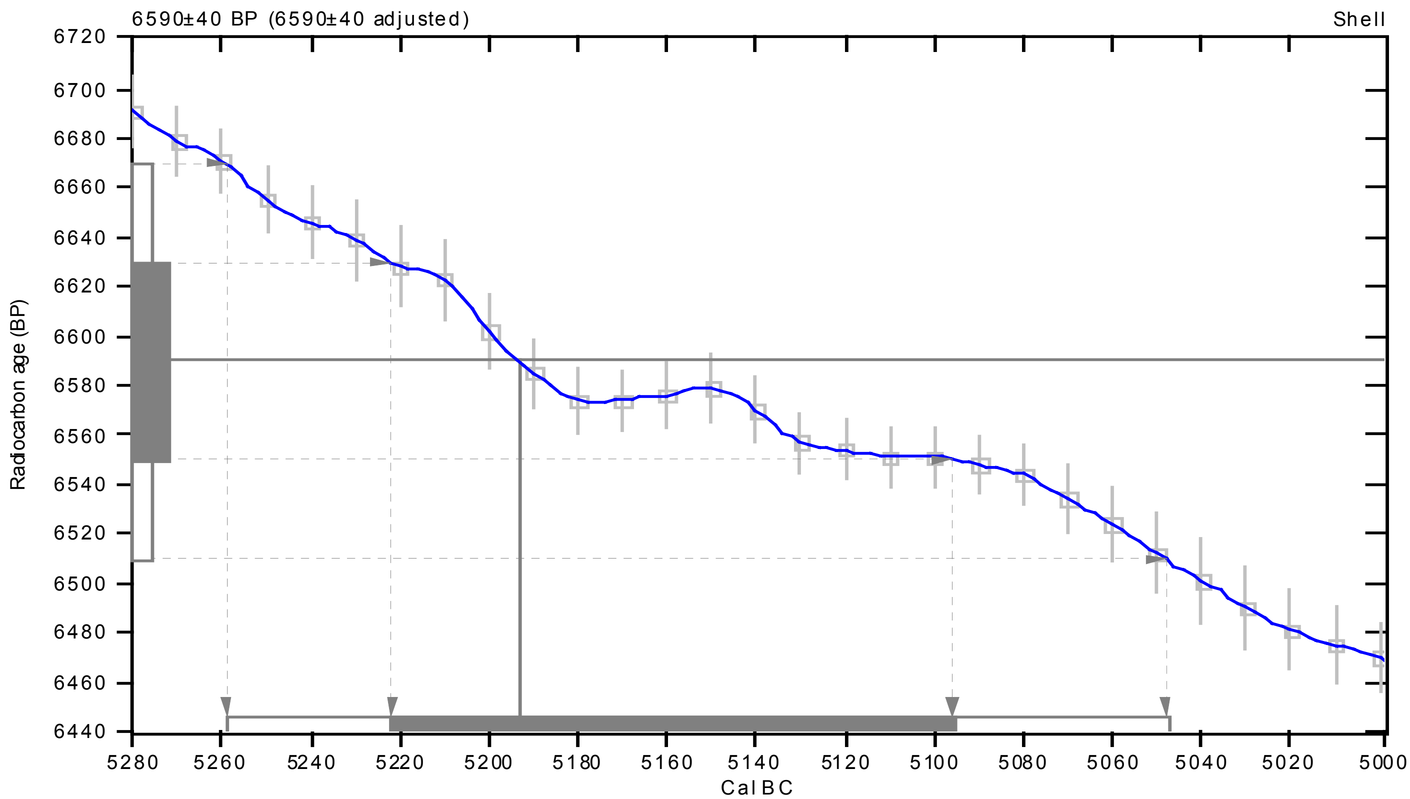
(local reservoir correction not applied)

2 Sigma calibrated result: Cal BC 5260 to 5050 (Cal BP 7210 to 7000)
(95% probability)

Intercept data

Intercept of radiocarbon age with calibration curve: Cal BC 5190 (Cal BP 7140)

1 Sigma calibrated result: Cal BC 5220 to 5100 (Cal BP 7170 to 7050)
(68% probability)



References:

Database used
MARINE98
Calibration Database
Editorial Comment
Stuiver, M., van der Plicht, H., 1998, Radiocarbon 40(3), pxii-xiii
INTCAL98 Radiocarbon Age Calibration
Stuiver, M., et. al., 1998, Radiocarbon 40(3), p1041-1083
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CALIBRATION OF RADIOCARBON AGE TO CALENDAR YEARS

(Variables: C13/C12=-27:lab. mult=1)

Laboratory number: **Beta-202447**

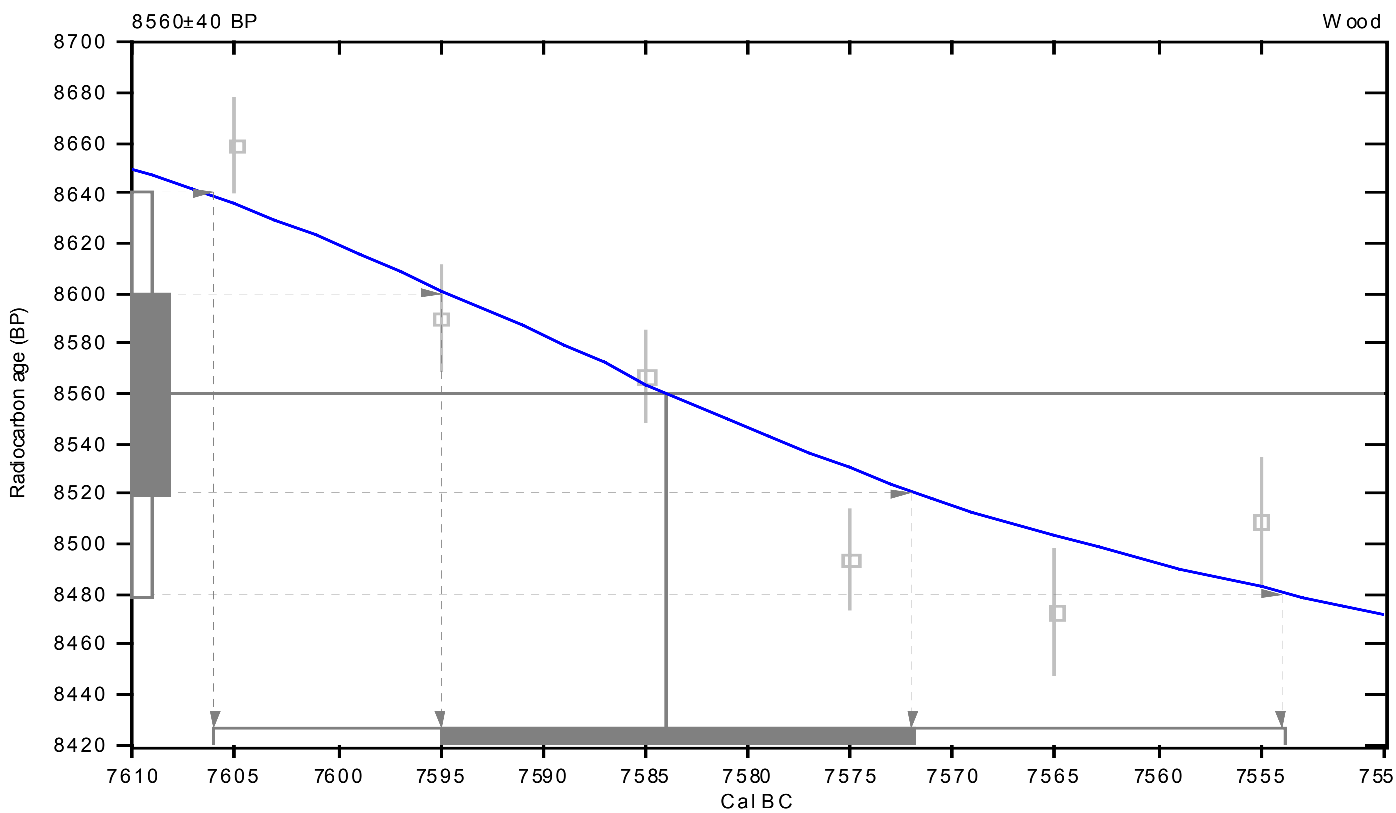
Conventional radiocarbon age: **8560±40 BP**

2 Sigma calibrated result: **Cal BC 7610 to 7550 (Cal BP 9560 to 9500)**
(95% probability)

Intercept data

Intercept of radiocarbon age
with calibration curve: Cal BC 7580 (Cal BP 9530)

1 Sigma calibrated result: Cal BC 7600 to 7570 (Cal BP 9540 to 9520)
(68% probability)



References:

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Calibration Database
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Stuiver, M., van der Plicht, H., 1998, Radiocarbon 40(3), pxii-xiii
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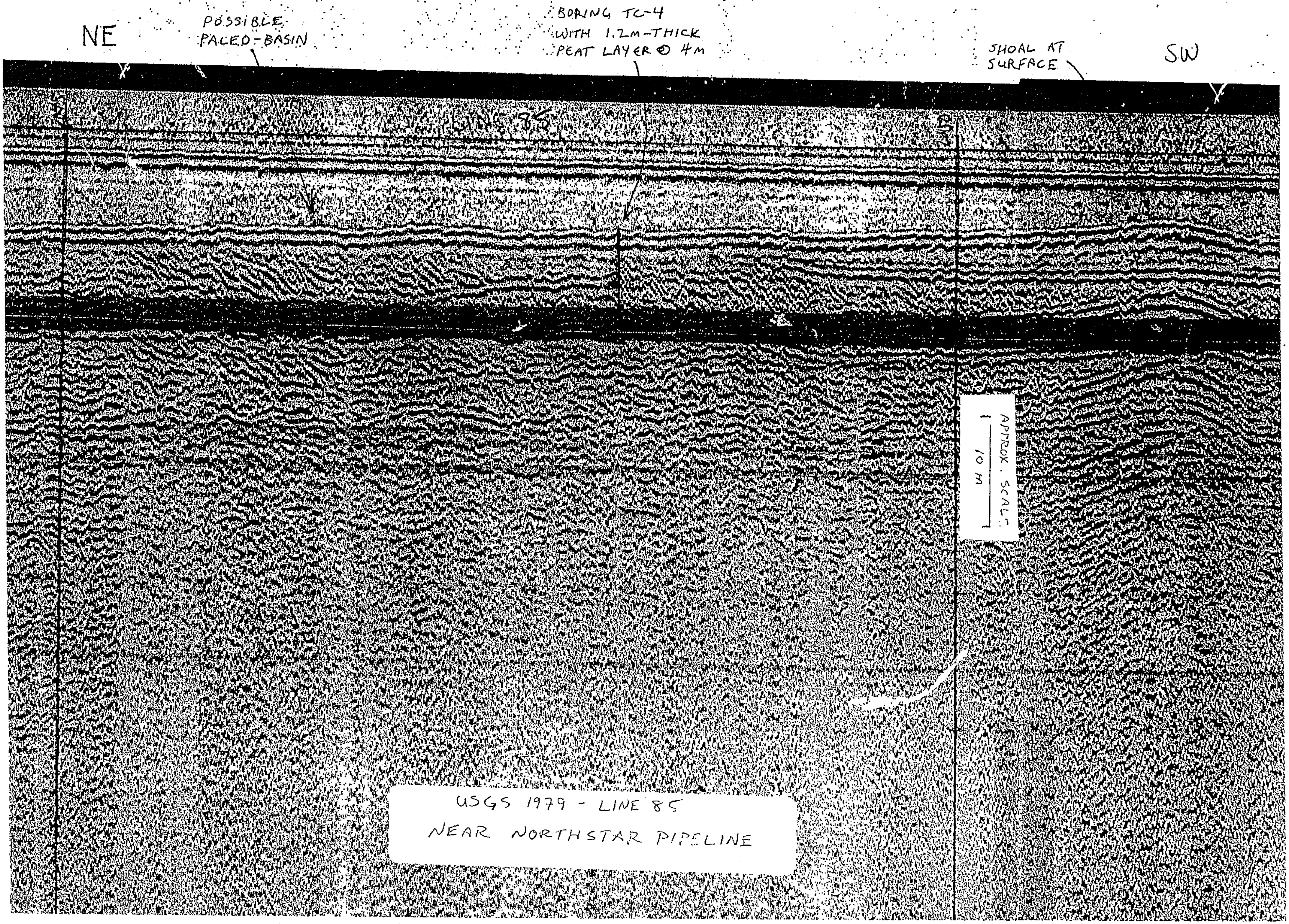
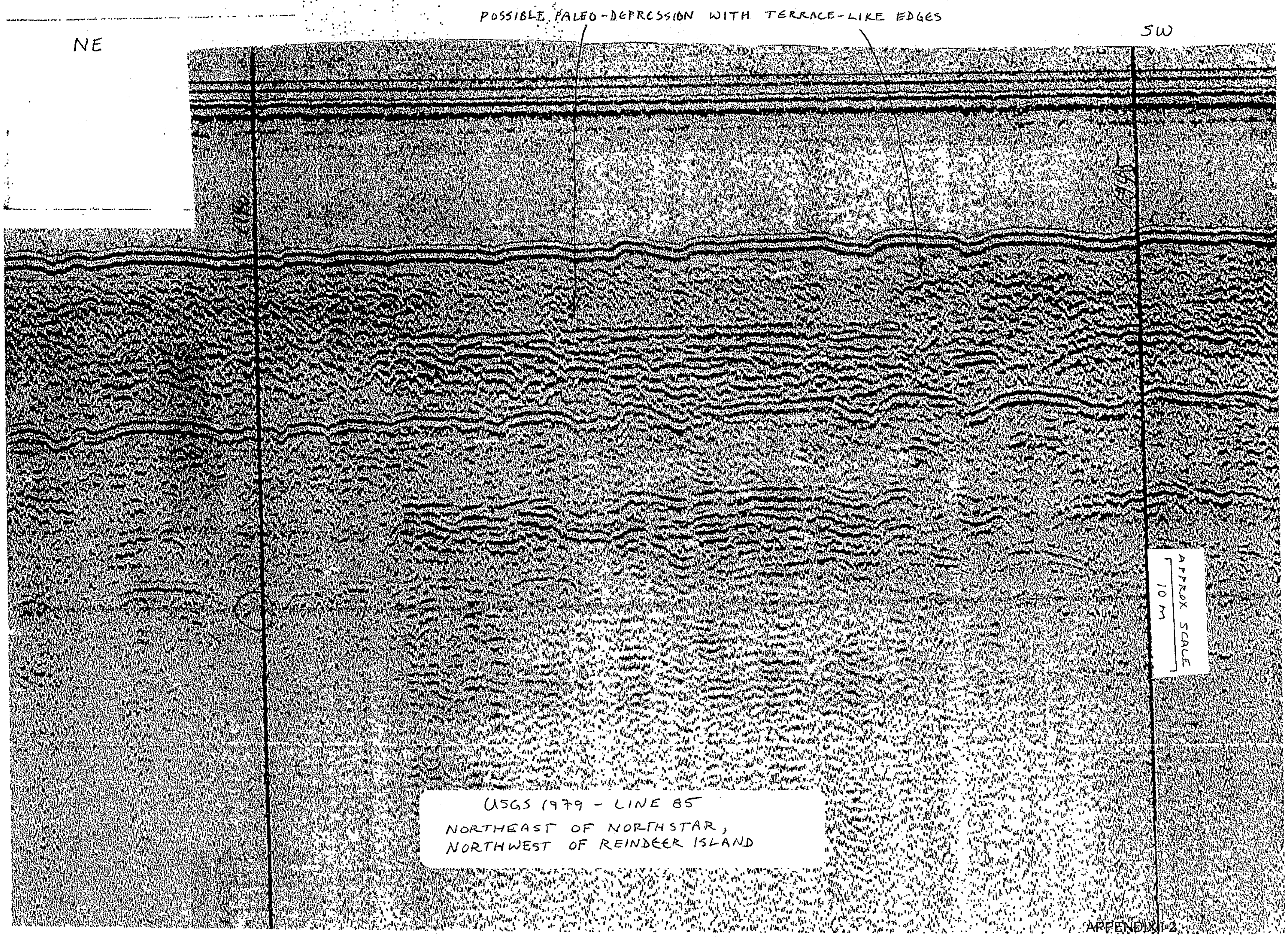
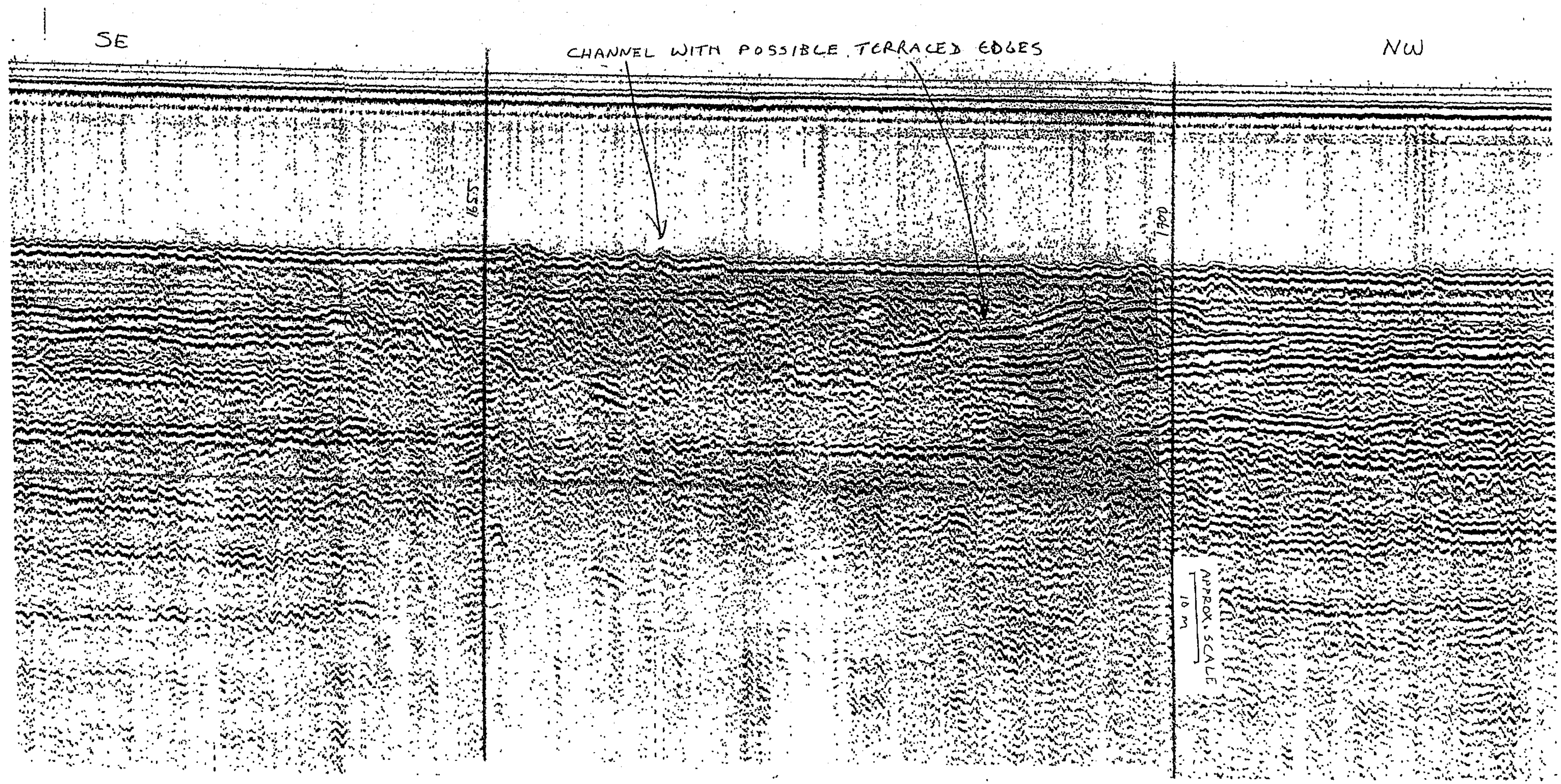
APPENDIX I

SELECTED USGS 1979 GEOPHYSICAL DATA


NE
POSSIBLE PALEO-BASIN
BORING TC-4 WITH 1.2m-THICK PEAT LAYER @ 4m
SHOAL AT SURFACE
SW
APPROX. SCALE
10 m
USGS 1979 - LINE 85
NEAR NORTHSTAR PIPELINE

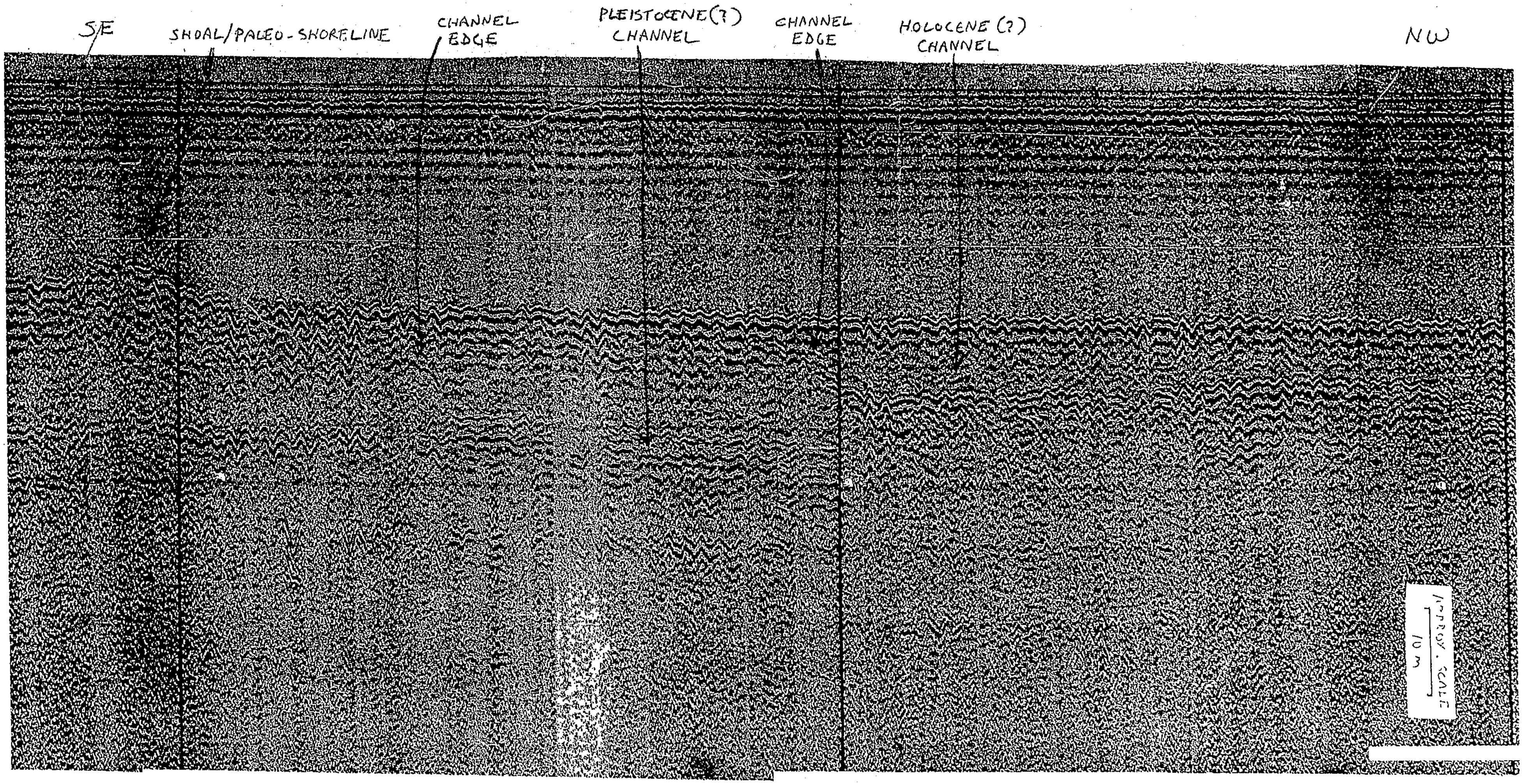
APPENDIX I-1


POSSIBLE PALEO-DEPRESSION WITH TERRACE-LIKE EDGES
NE
SW
APPROX SCALE
10 M
USGS 1979 - LINE 85
NORTHEAST OF NORTHSTAR,
NORTHWEST OF REINDEER ISLAND



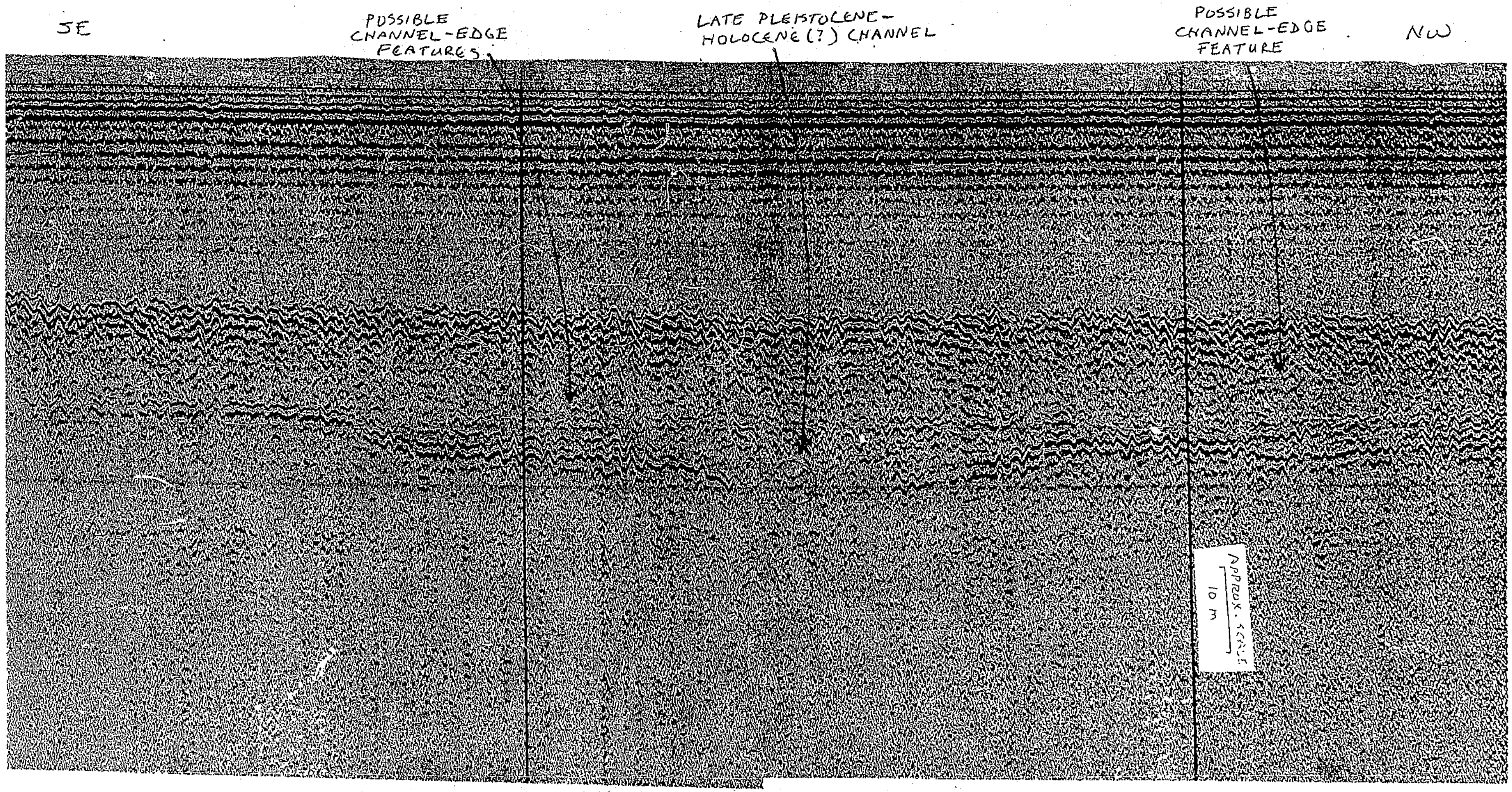
USGS 1979 - LINE 83

2-½ KM NORTHEAST OF CROSS ISLAND

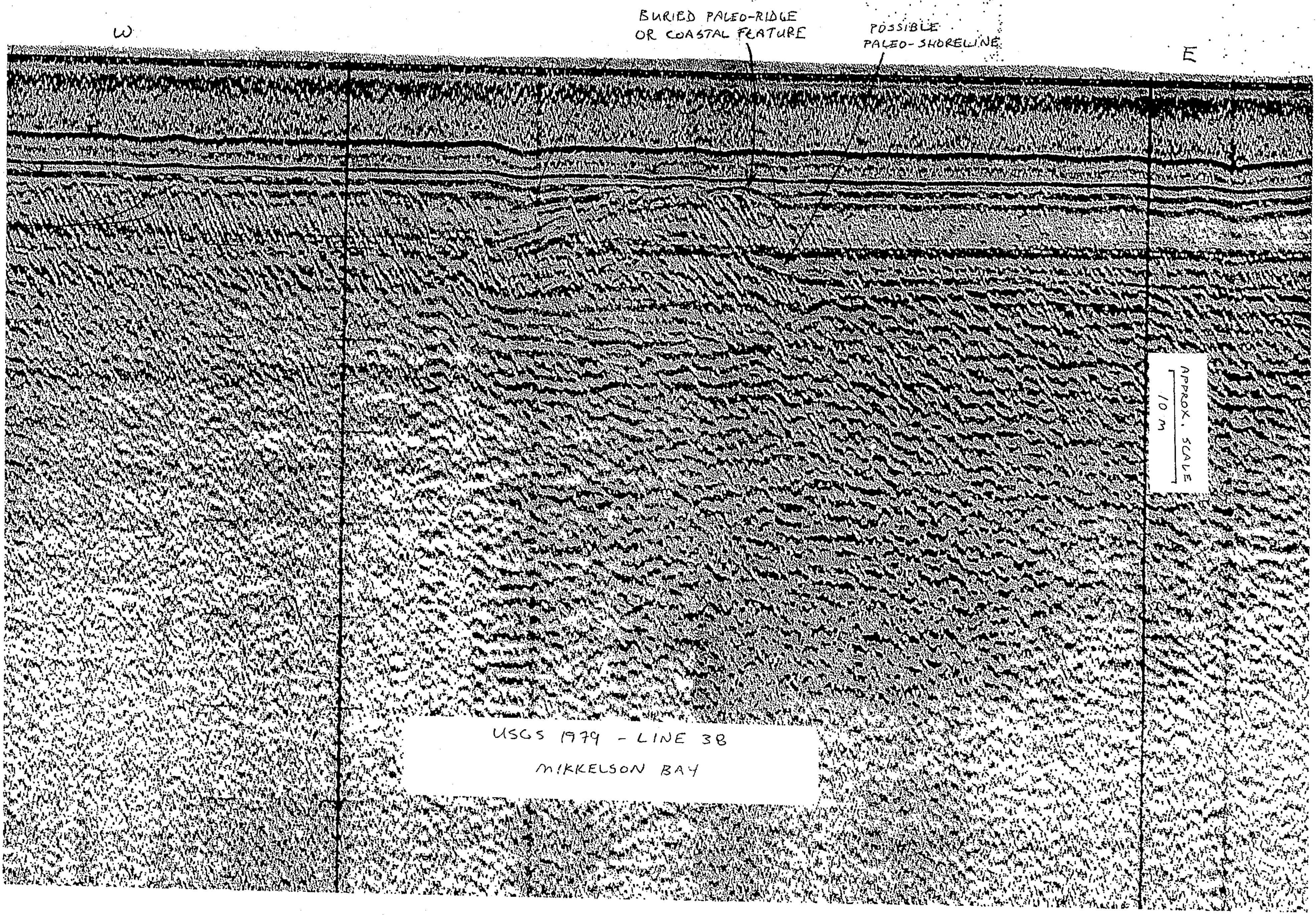


USGS 1979 - LINE 98

7 km NORTHEAST OF CROSS ISLAND



USGS 1979 - LINE 98
8 km NORTH OF NARWHAL ISLAND


W
BURIED PALEO-RIDGE
OR COASTAL FEATURE
POSSIBLE
PALEO-SHORELINE
E
APPROX. SCALE
10 m
USGS 1979 - LINE 3B
MIKKELSON BAY