OCS Study MMS 2007-004

Final Report

Review of Geological/Geophysical Data and Core Analysis to Determine Archaeological Potential of Buried Landforms, Beaufort Sea Shelf, Alaska

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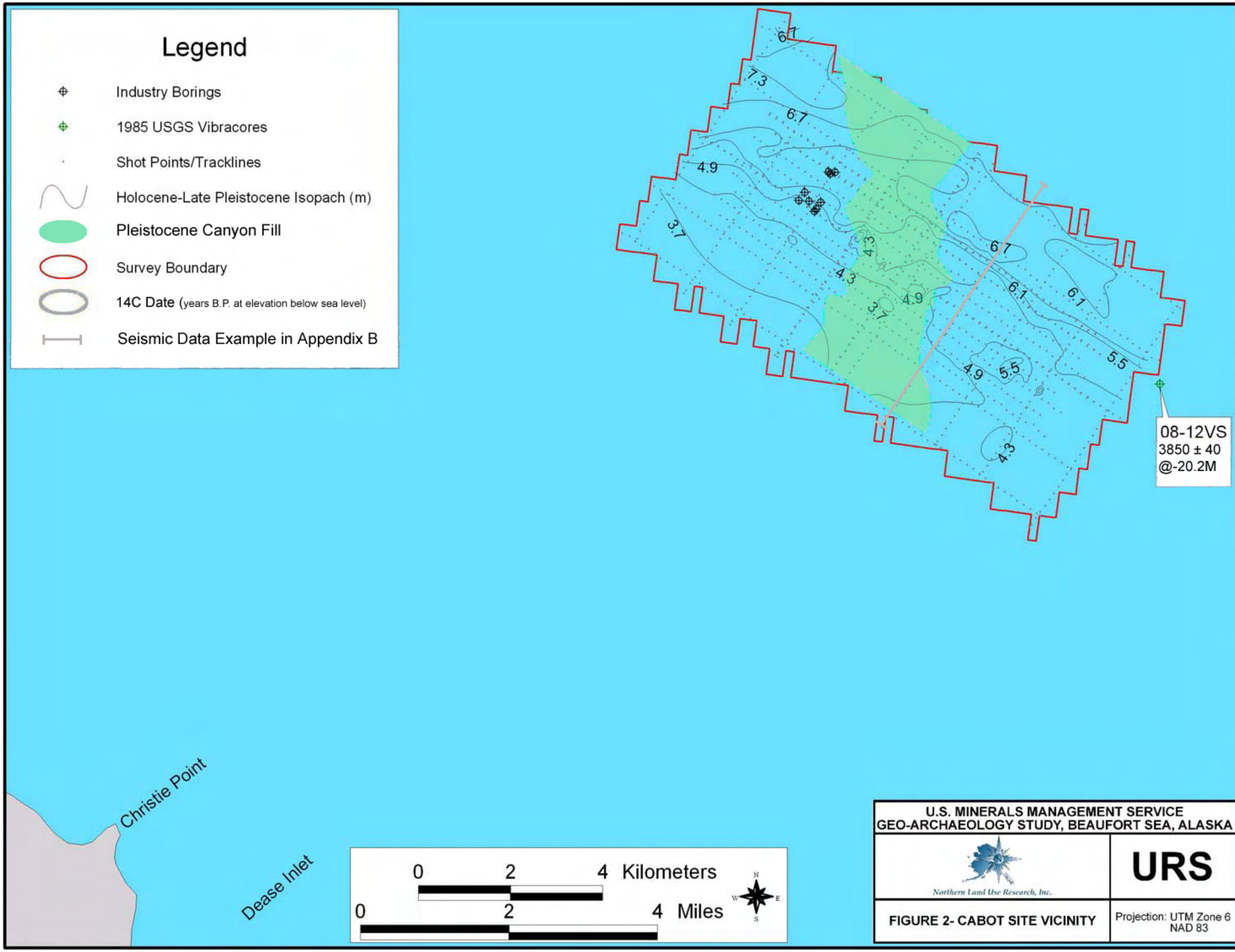

Legend
Industry Borings
1985 USGS Vibracores
Shot Points/Tracklines
Holocene-Late Pleistocene Isopach (m)
Pleistocene Canyon Fill
Survey Boundary
14C Date (years B.P. at elevation below sea level)
Seismic Data Example in Appendix B
6.7
7.3
6.7
4.9
3.7
4.3
4.3
3.7
4.9
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08-12VS
3850 ± 40
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0 2 4 Kilometers
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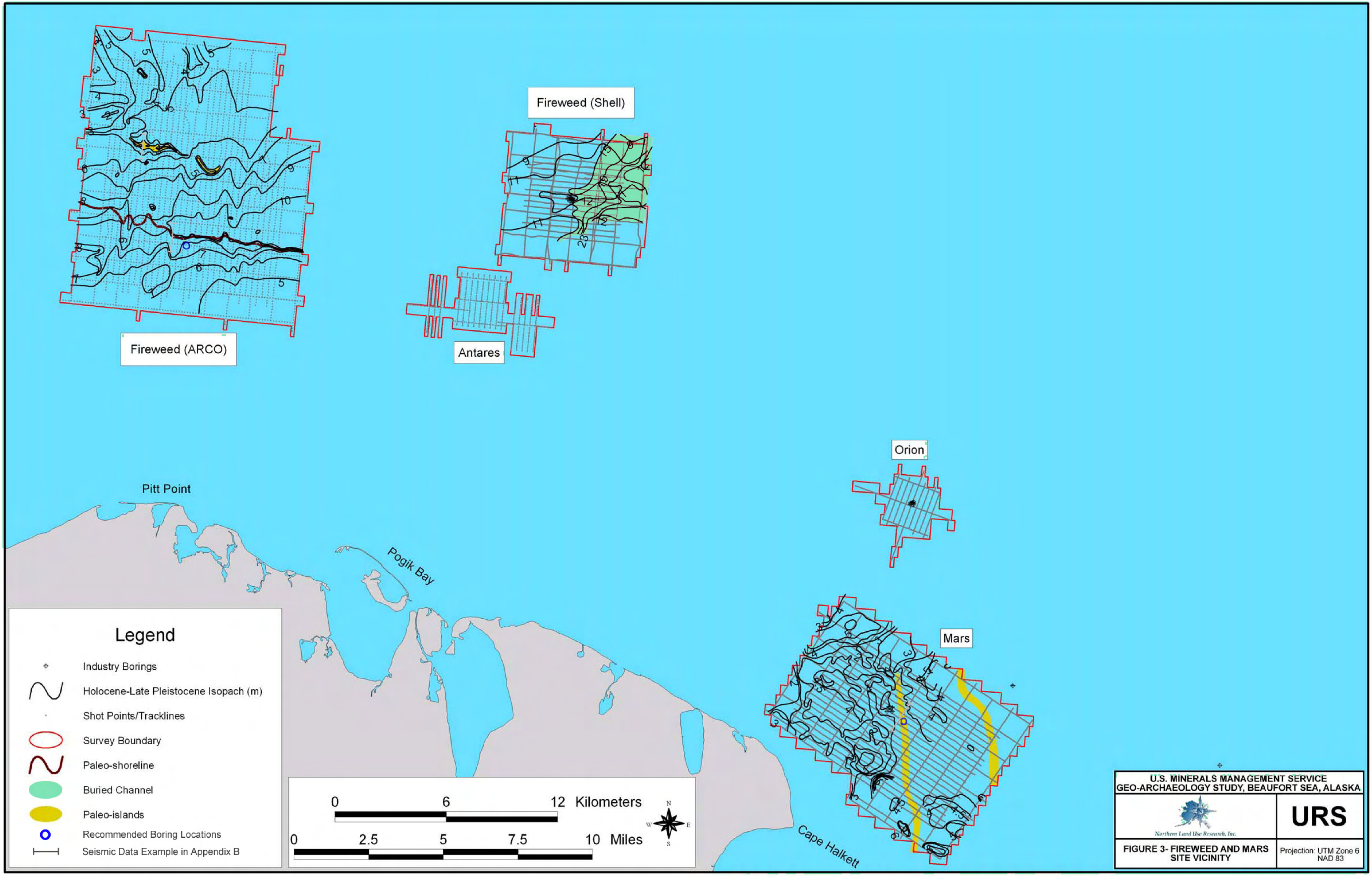
S
U.S. MINERALS MANAGEMENT SERVICE
GEO-ARCHAEOLOGY STUDY, BEAUFORT SEA, ALASKA
Northern Land Use Research, Inc.
URS
FIGURE 2- CABOT SITE VICINITY
Projection: UTM Zone 6
NAD 83



Fireweed (Shell)
Fireweed (ARCO)
Antares
Orion
Mars
Pitt Point
Pogik Bay
Cape Halkett
Legend
Industry Borings
Holocene-Late Pleistocene Isopach (m)
Shot Points/Tracklines
Survey Boundary
Paleo-shoreline
Buried Channel
Paleo-islands
Recommended Boring Locations
Seismic Data Example in Appendix B
0 6 12 Kilometers
0 2.5 5 7.5 10 Miles
U.S. MINERALS MANAGEMENT SERVICE
GEO-ARCHAEOLOGY STUDY, BEAUFORT SEA, ALASKA
URS
FIGURE 3- FIREWEED AND MARS SITE VICINITY
Projection: UTM Zone 6 NAD 83

3.2.4 Karluk

Karluk is located in the central part of the study area offshore of the Sagavanirktok River delta (Figure 1) in about 6 to 8 m of water depth. Holocene surficial deposits consisting of silty sand and sandy silt are interpreted to range from 0 to 4 m thick across the site. Beneath this layer lies a Pleistocene marine clay deposit extending to 10 to 18 m below the seafloor, which is underlain by a Pleistocene beach deposit consisting of dense gravel and sand (Harding Lawson Associates (HLA) 1988). A buried channel cut into the Pleistocene sediment was identified in the western part of the site trending north-northeasterly (Figure 4). The channel is filled with at least 3 m of organic-rich Holocene sediment. The base of the channel could not be determined from the seismic data. Bolder patch areas identified in the western part of the Karluk site are interpreted to be ice-rafted lag deposits formed by erosion of the boulder-rich glaciomarine Pleistocene Flaxman Formation during lower sea level stands (HLA 1988; Reimnitz and Ross 1979).

3.2.5 Liberty/Tern Island

The Liberty and Tern Island sites are located in the central part of the study area offshore of the Sagavanirktok River delta (Figure 1) in 1 to 7 m of water depth. The smaller Tern Island site overlaps the northeast corner of the Liberty site (Figure 4). Liberty consists of a proposed drilling site located about 9 km offshore in Foggy Island Bay, and proposed west and east pipeline routes extending to shore. Several types of paleolandforms have been identified at this site as described below. Examples of shallow seismic data and interpretive cross-sections depicting some of the features are provided in Appendix C.

Holocene sediments ranging from 0 to 2.6 m thick were mapped by Watson (1998b) in the eastern two-thirds of the main drilling site. These sediments form a wedge-shaped deposit, which thickens to the east and thins to the west where Pleistocene boulder patch deposits occur at the seafloor. The mapped Holocene deposits consist of unconsolidated sediments that are acoustically discrete from underlying sediment, and may include both marine and fluvial-deltaic sediments deposited in a flooded lagoon environment between the Sagavanirktok delta plain and the offshore McClure Islands (Watson 1998b). Holocene marine deposits were also identified by Watson (1998a and b) along the western pipeline route ranging from 0 to 1.8 m in thickness.

Along the western pipeline route, older deposits located beneath, and exposed at the seafloor between, the Holocene marine sediments were interpreted by Watson (1998a) and Marmaduke and Watson (1999) to be Pleistocene in age and to contain coarse material, peat layers, and small distributary channels (Appendix B). MMS (2000), in reviewing the latter report, suggests that there is a lack of evidence to support a Pleistocene age for these deposits and that some may be Holocene. The geophysical data indicate landforms that could represent a peat bog or lagoonal depression 3 to 4 m deep, with adjacent terrace-like features and relict island, that developed during a Holocene sea level stand about 6 m below present (MMS, 2000) (Appendix B). Geotechnical borings drilled along the pipeline routes by Duane Miller & Associates (DM&A) (1997, 1998) were reviewed in detail to identify potentially *in situ* peat deposits. The lateral extent of these deposits is depicted on Figure 4.

Figure 4A – Mukluk to Sandpiper Site Vicinity (in pocket)

Figure 4B – Northstar to Liberty Site Vicinity (in pocket)

The deposits are described on DM&A (1997, 1998) boring logs as organic silt, fibrous peat, or thin organic layers interbedded within silt. The deposits generally occur between 5 and 11 m below sea level, and range from several centimeters to as much as 2 m thick. Minor occurrences of organic lenses or bands thinner than this range were not included in the mapped areas. Based on the varying thicknesses and depths, the deposits may be discontinuous and interfingering.

A number of buried and near-surface distributary channels and channel fragments were identified at the Liberty site by Watson (1998a, 1998b) and Marmaduke and Watson (1999). These are interpreted to be distributary channels that formed as part of the Sagavanirktok delta front complex during a lower sea level stand. Channel fragments on the main Liberty site are depicted on Figure 4 grouped by age (Holocene or pre-Holocene) as interpreted by Watson (1998b). A number of distributary channel fragments were also identified along the western pipeline route incised into both Holocene and Pleistocene materials (Appendix C) (Watson 1998a). MMS (2000) suggests that the smaller channel fragments at Liberty could instead be strudel scour features. The largest of the buried channels, located in the northeast corner of the Liberty site, exhibits possible channel-edge features such as levees or overbank deposits (Appendix C) (Marmaduke and Watson (1999) ; MMS 2000).

Watson (1998b) describes an unusual buried landform in the northwest portion of the Liberty site. The northwest-trending structure consists of a depression-like feature described as a ravinement surface, which lies adjacent to a possible buried island or other geomorphic high (Appendix C). The feature, mapped in 5 subbottom profiles, is interpreted by Watson (1998) and Marmaduke and Watson (1999) to lie within Pleistocene deposits. They estimate it was an active drainage > 10,000 B.P. Marmaduke and Watson (1999) state that “a narrow terrace/floodplain may be preserved along the southern side of the deepest incision”, and conclude that “the eastern margin channel is the only readifiable terrestrial feature in the near surface sediments in the Liberty survey area. None of the sediments associated with the channel indicate preservation of landforms likely to contain archaeological remains of terrestrial origin (Marmaduke and Watson 1999).

3.2.6 Mars

The Mars site is located in the western part of the study area in 5 to 12 m of water. The thickness of surficial sediment at this site was originally mapped in milliseconds by Dames & Moore (1985c) and MMS (2002). These values were converted to meters using a nominal velocity of sound in sediment of 1,500 m/s. Holocene sediment is estimated to range from about 1 to 7 m thick across the site. Paleolandforms were not mapped in MMS (2002); however, Dames & Moore (1985c) note the presence of two sub-parallel narrow linear features, possibly relict coastal ridges or barrier islands, that are buried beneath less than 1 to 2 m of Holocene sediment (Figure 3, Appendix B). The features trend north-northwest roughly sub-parallel to the coastline rounding Cape Halkett.

3.2.7 McCovey

The McCovey site is located in the central part of the study area about 6 km offshore of Reindeer Island (Figure 4) in about 12 to 19 m of water depth. This site is not included in the MMS (2002) OCS database as it postdates that effort. Several paleolandforms mapped by Arctic Geoscience (2000b, 2000c) and Petrotechnical Resources of Alaska (PRA) (2002) were thus added to Figure 4.

About 2.5 to 7 m of Holocene surficial sediments were mapped across the site, underlain by predominantly stiff clay with lenses of sand and gravel interpreted to be Pleistocene (Arctic Geoscience, 2000b, 2000c). A shoal trending east-northeasterly rises in the center of the McCovey site about 3 m above the surrounding seafloor (Figure 4). Arctic Geoscience (2000b) suggests that the shoal may be a relict constructional barrier island. Based on boring log correlations, the surficial sediment unit in the shoal area consists of predominantly fine- to medium-grained sand. Two buried channels were also mapped in the central part of the site by PRA (2002). The northern of the two channels lies at a maximum depth of about 7 to 8 m below the seafloor in the shoal area, and is interpreted by both Arctic Geoscience (2000c) and PRA (2002) to be an old ice gouge filled with about 1 to 2 m of Holocene sediment. The channel southeast of the shoal lies at a maximum of 12 m below the seafloor, which places it within the interpreted Pleistocene section. A USGS seismic line that extends through the center of the McCovey site offers an additional perspective on the channel features (Section 3.7.3).

3.2.8 Mukluk

Mukluk is located in the western part of the study area offshore of the Colville River Delta. Paleolandforms were not mapped in MMS (2002); however, Dames & Moore (1983) notes the presence of a subtle, north-south trending, bathymetric high in the southwest quadrant of the site (Figure 4), which may be the result of erosion or deposition during lower sea level stands, such as a drowned coastal feature. Age dating conducted on four samples from a boring located about 0.5 km northeast of the feature indicate the presence of 1.5 m of surficial sand and silt dating from about 11,000 years B.P., underlain by several meters of clayey silt (Dames and Moore 1983). Shelly sand and peat layers representing possible beach and terrestrial deposits lie at a depth of 9.5 m below the seafloor (24 m bsl) in between two age dates of 14,580 and 27,450 years B.P. (see below in Section 3.4). Further discussion of these and other age dating results are presented in Section 3.4 and 4.2.

3.2.9 Northstar

Northstar is located in the central part of the study area just west of Prudhoe Bay (Figure 1) in water depths ranging from 0 to 11 m. The site consists of an artificial island named Seal Island and pipeline routes to shore (Figure 4). Paleolandforms were not identified at this site by MMS (2002). Industry reports by Coastal Frontiers Corporation (CFC) (1996a, 1997, 1998, 1999) and Intec Engineering, Inc. (Intec) (1998a, 1998b, 1998c), and geotechnical borings drilled along the pipeline routes by DM&A (1995, 1996) were reviewed in detail to identify potential paleolandforms. DM&A (1996) identify the presence of about 5 to 11 m of Holocene sediments overlying a Pleistocene gravel surface along the main pipeline route (Appendix D). Coastal Frontiers Corporation (CFC) (1997) identified the presence of a shoal rising about 1 to 2 m above the ambient seafloor surface about 1.2 km offshore of the existing barrier islands. This feature could represent a relict barrier island.

Geotechnical borings indicate the presence of potentially *in situ* organic deposits described as organic silt, fibrous peat, or thin organic layers interbedded within silty sand (DM&A 1996). The lateral extent of these deposits is depicted on Figure 4. One area of peat was identified inshore of the barrier islands, and one about halfway between the barrier islands and Seal Island. Similar to Liberty, these deposits may have been formed in a peat bog or lagoonal depression during a lower sea level stand. The deposits inshore of the barrier islands occur between 2 and 7 m below sea level, and those offshore of the barrier islands between 7 and 13 m below sea level. The deposits generally range from several centimeters to as much as 1.2 m thick. Minor occurrences of organic lenses, bands, or blebs thinner than this range were not included in the mapped areas. Based on the varying thicknesses and depths, the deposits may be discontinuous and interfingering, rather than a continuous layer.

Subsurface geophysical data have not been conducted to date inshore of the barrier islands at the Northstar site. Sub-bottom data collected by CFC (1996b, 1997) offshore of the barrier islands were not interpreted or attached with the CFC reports, and were not available for review from MMS, JPO, or BP Exploration. A 1979 USGS seismic line that extends through the offshore portion of the Northstar pipeline route indicates a potential depressional landform corresponding to the peat in this area (Section 3.7.2).

3.2.10 Phoenix

The Phoenix site is located in the western part of the study area offshore of the Colville River Delta in 17 to 20 m of water depth. Appoximately 4 to 10 m of Holocene surficial deposits were mapped across the site by McClelland-EBA (1986). Paleolandforms were not identified for this site by either McClelland-EBA (1986) or MMS (2002). Mapped thicknesses of the uppermost sediment unit and high resolution geophysical data indicate the presence of several circular or elliptical-shaped depressions in the base of the unit in the northeast and southwest portions of the site (Figure 4, Appendix B). The depressions are up to 2 to 5 m deeper than the surrounding base of Holocene. McClelland-EBA (1986) suggests that these features correspond to permafrost irregularities based on borehole data at the central well site. It is also possible that they represent true geomorphic depressions such as paleo-lake basins.

3.2.11 Sandpiper

Sandpiper is located in the western part of the study area several kilometers northwest of Northstar in about 8 to 19 m of water depth. Several shore-parallel shoals, rising 1 to 3 m above the ambient seafloor surface, trend west-northwesterly across the southern half of the site (Figure 4) in water depths of about 9, 11, and 14 m. The most prominent of these extends through the approximate center of the site, and is referred to as Loon Shoal.

Holocene surficial sediment ranges from less than 1 m to 9 m thick across the site (Dames & Moore 1983c). The surficial deposits generally thicken towards the northwest, except where they thin across broad buried ridges that may represent subcrops of Pleistocene deposits near the seafloor surface and possible remnants of relict barrier islands. The buried ridges trend west-northwesterly subparallel to the coastline. Most are coincident with isopached Holocene thicknesses less than 1.5 m. Those in the south half of the site underlie existing shoals at the seafloor surface. Those in the north half of the site appear to be more broad and discontinuous, and have erosional surfaces, as compared to those in the southern half of the site. The most prominent of the buried ridges or relict islands lies beneath Loon Shoal in the center of the site (Appendix B). The elevations of the buried ridges fall into roughly three groupings that average about 15, 17, and 20 m bsl. Those beneath or adjacent to Loon Shoal comprise the 17 m bsl group.

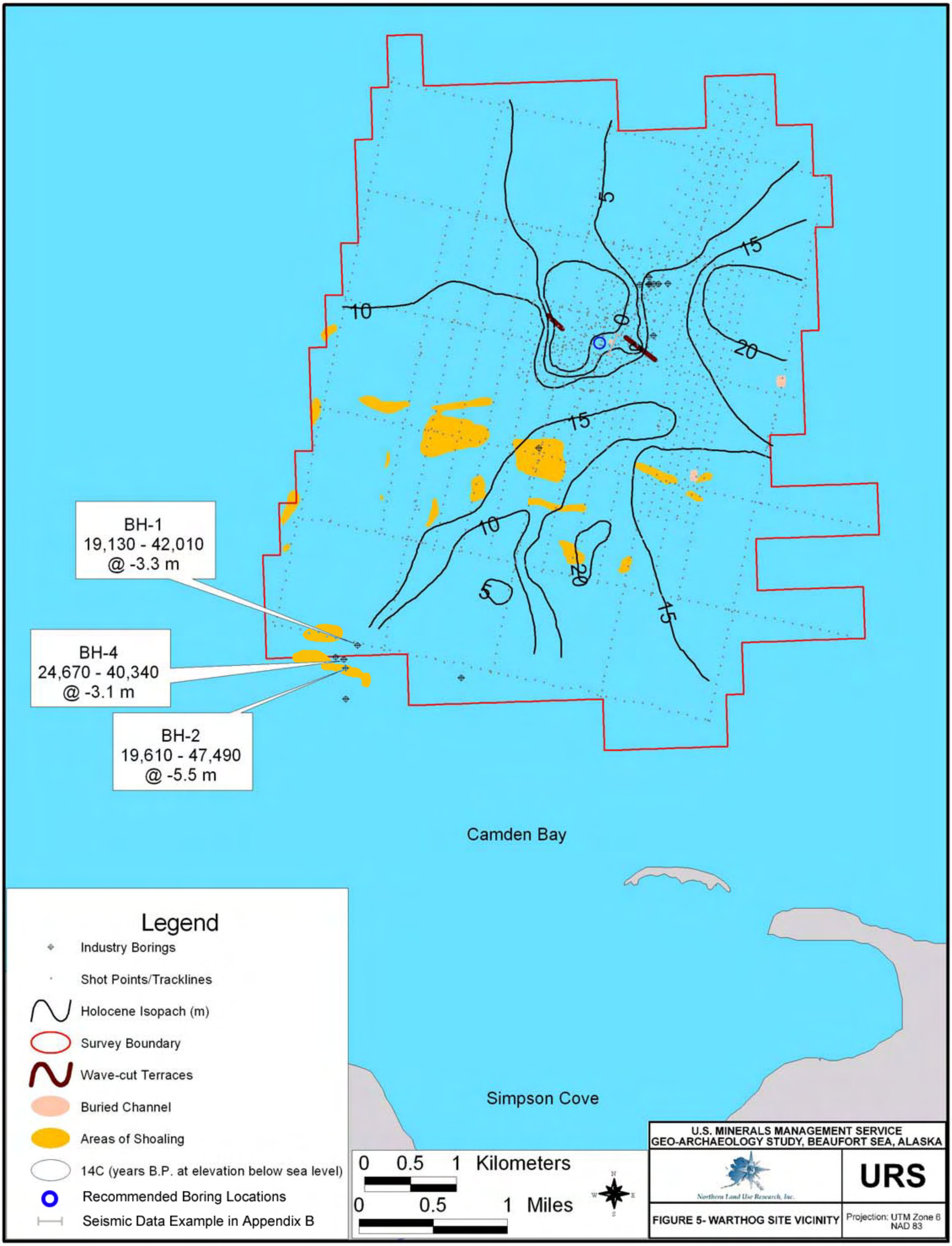
Dames & Moore (1983) identifies the presence of a large buried channel trending northeasterly across the northwestern one-third of the site. The northwest edge of the channel lies outside of the Sandpiper site boundaries. The channel fill is interpreted by Dames & Moore (1983c) to lie within the lower Pleistocene section, with the base of the channel possibly representing the Tertiary/Pleistocene contact at about 120 m below the seafloor.

3.2.12 Warthog

The Warthog site is located in Camden Bay in the eastern half of the study area (Figure 1). Water depths at this site range from 2 to 12 m. Fairweather E&P (1997a, 1997b) indicates that surficial unconsolidated sediment consisting of silt, clay, and sand ranges from less than 1 to 20 m in thickness across the site (Figure 5). The surficial unit thins in the center of the Warthog site where side-scan sonar data indicate the presence of a coarse-grained cobble and boulder deposit, which is likely a subcrop of relict Pleistocene material. Elsewhere, the base of the surficial unit corresponds to the top of a thick stiff clay in boreholes. The presence of permafrost in one borehole provides some evidence, although inconclusive, that discontinuous permafrost can be detected on the shallow seismic data and may cause the apparent lateral termination of deeper reflectors (Fairweather E& P 1997a). It is possible that this situation may give the misleading appearance of false paleolandforms, although no specific case is noted in the reports.

Buried channels were identified in three areas of the Warthog site extending to maximum depths of 9 to 25 m below the seafloor. Those mapped in the center of the site are incised into the older coarse-grained deposit. Choromanski et al. (1997) further identified the presence of possible channel-edge features such as levees and terraces associated with the buried channels in the center of the site (Appendix B). The channel-edge features lie at depths of about 5.5 to 6.1 m below the seafloor (about 16.1 to 16.8 m bsl). In addition, abrupt 1-m elevation changes on the fathometer records in this area indicate the possible presence of wave-cut terraces at the seafloor at elevations of about 10.7 to 11.0 m bsl that could represent lower sea level stands. These features could also be interpreted as subcrops of the more competent Pleistocene unit, tectonic features related to shallow faulting, or ice deformation (Choromanski et al. 1997).

Several areas of shoaling that may represent drowned barrier islands were observed on the bathymetric data where the seafloor locally rises about 1 to 2 m above the surrounding seafloor. The shoals comprise two broad bands which trend west-northwesterly, subparallel to existing barrier islands in Camden Bay. One of these areas, mapped by Fairweather E&P (1997a) and MMS (2002), extends through the southern half of the Warthog site in water depths of about 6 to 8 m, and is approximately 1 to 2 kilometers (km) wide (Figure 5).


BH-1
19,130 - 42,010
@ -3.3 m
BH-4
24,670 - 40,340
@ -3.1 m
BH-2
19,610 - 47,490
@ -5.5 m
5
10
15
20
Camden Bay
Simpson Cove
Legend
Industry Borings
Shot Points/Tracklines
Holocene Isopach (m)
Survey Boundary
Wave-cut Terraces
Buried Channel
Areas of Shoaling
14C (years B.P. at elevation below sea level)
Recommended Boring Locations
Seismic Data Example in Appendix B
0 0.5 1 Kilometers
0 0.5 1 Miles
U.S. MINERALS MANAGEMENT SERVICE
GEO-ARCHAEOLOGY STUDY, BEAUFORT SEA, ALASKA
Northern Land Use Research, Inc.
URS
FIGURE 5- WARTHOG SITE VICINITY
Projection: UTM Zone 6
NAD 83

A narrower band of shoals less than 1 km wide was mapped by Fairweather E&P (1997b) at a revised drilling location in the southwest corner of the site in 2 to 3 m of water depth. The shoaling features are coincident with a 2- to 3-m thick section of loose, fine- to medium-grained sand at the seafloor surface in geotechnical borings. The southern of the two shoal areas was documented to have migrated southwesterly over period of several years, which is consistent with barrier island migration and sediment dynamics in the Beaufort Sea (Fairweather E&P 1997b). Age dating conducted on samples from borings located in the southern of the two shoaling areas indicate age ranges in the late Pleistocene from shell and organic material within sand and silt deposits at elevations of 3.0 to 5.7 m bsl. The dates are inconsistent with the recent barrier island interpretation, and with the shallow geophysical data interpretation indicating about 10 to 15 m of Holocene material in this area (Figure 5). Bergman (1997) suggests that these deposits may contain reworked nonmarine lacustrine sediment or fluvio-deltaic sediment from nearby river systems. Further discussion of these and other age dating results are presented in Sections 3.4 and 4.2.

3.3 Core Contacts

The results of contacts made with various representatives of the oil industry, engineering consulting firms, USGS, and other sources, in an attempt to locate existing core material in storage, are summarized in Table 1 and described in the following sections. Contacts are included in the references in Section 7.0.

3.3.1 Industry

Industry sites in less than 20 m of water depth are listed in Table 1 in alphabetical order. Based on review of MMS (2002) and individual industry site reports (Section 3.2), sites with potential paleolandforms are indicated by a bold "yes" in the third column of Table 1. These sites were the focus of contacts made to oil industry representatives and engineering contractors to locate core material. Names of contacts made are listed in the central part of Table 1. No core material was identified from these contacts. Common responses to these inquiries indicated that core material generated during industry geotechnical investigations is kept in storage by the engineering contractor typically no longer than completion of laboratory analyses and reporting, and in rare cases up to one or two years beyond field work and reporting. Oil companies typically do not collect or store split samples of geotechnical core material (e.g., Croley 2004; Jones 2004).

3.3.2 U.S. Geological Survey

As indicated in Section 2.3, representatives of the USGS were contacted to identify pertinent Beaufort Sea vibracoring cruises, core storage status, and access procedures. In addition, the USGS CMG Program website was systematically reviewed to identify all Beaufort Sea/Arctic Ocean research cruises for which core material was collected. These cruises, conducted in 1976, 1977, 1979, and 1985, are listed in Table 1 alongside industry sites closest to their core locations. Individual USGS reports, available from ARLIS, were reviewed in detail to identify the locations of pertinent cores. The results of the USGS contacts and reviews are as follows:

- A number of vibracores from the 1976 and 1977 cruises (Barnes et al. 1979; USGS 2004b, 2004c) were collected in the central Beaufort Sea shelf between the Colville River delta and Foggy Island Bay, near the industry sites Phoenix, Sandpiper, Northstar, and Karluk (Figure 4). A limited amount of the core material from these cruises is available in bags and boxes in dry storage at the USGS in Menlo Park, California (Barnes 2004; Steele 2004).

- Vibracores from the 1979 cruise located near Liberty and McCovey are no longer available (Barnes 2004; Steele 2004).

- Geotechnical borings drilled by HLA (1979) for the USGS across the Beaufort Sea shelf between Gwydyr Bay and Flaxman Island, with boring locations near Northstar and Liberty, are not available in storage at either the USGS or CRREL (Fridell 2004).

- One USGS vibracore collected during their 1985 cruise (Miley and Barnes 1986; USGS 2004a) was located near the east edge of the Cabot site (Figure 2). This core is available in refrigerated storage at the USGS in Menlo Park, California (Frazee 2004). Other vibracores from this cruise were located in deeper water or in the Chukchi Sea.

3.3.3 Other

The results of contacts made to academia and government agencies other than the USGS yielded the following information:

- The State of Alaska DGGS core storage facility in Eagle River, Alaska is a repository primarily for oil company core material and cuttings from deep formations encountered in oil and gas wells, not shallow geotechnical or vibracore material (Reeder 2004). Oil and gas wells are typically not mudlogged or cored until well below the seafloor and surface casing depths.

- MMS indicated that USGS core material from the 1979 Beaufort Sea geotechnical investigation (HLA 1979) may be stored at CRREL in Hanover, New Hampshire. As indicated above (Section 3.3.2), these cores could not be located (Fridell 2004).

- Neither the MMS or JPO have long-term core storage requirements or require oil companies to provide split samples of offshore geotechnical core material (Farley 2005; Prentiki 2003).

- The DOT&PF statewide materials laboratory in Anchorage, Alaska does not have any core material from the offshore North Slope area. Barber (2003) indicated that they collect geotechnical material primarily from onshore projects, and do not store materials after a structure is completed.

- No core material was listed in the NGDC's Index to Marine and Lacustrine Geological Samples database for the Beaufort Sea shelf using multiple search criteria such as latitude and longitude, water depths, ship names, and institutions (NGDC 2005a).

- Split samples of nearshore core material collected by the USGS and studied by Dr. Sathy Naidu at University of Alaska-Fairbanks in the 1980s (e.g., Naidu et al. 1984) is not available (Naidu 2001; 2004; Naidu, pers. comm. 2005).

- Sediment sampling conducted recently in lagoons of the central Beaufort Sea shelf as part of an Arctic Nearshore Impact Monitoring Development Area (ANIMEDA) study were collected from very shallow sediment up to a maximum of 24 centimeters (cm) below the seafloor (Prentiki 2003; Trefry 2003). Sedimentation rates based on ^{210}lead and ^{137}cesium activities indicate that most of the material was deposited within the last 100 years (Trefry et al. 2003). Because of their limited depth and age, this core material was not pursued for subsampling.

3.4 Compilation of Existing Age Dates

During review of various documents for this study, existing radiocarbon dates and microfossil data for the shallow Beaufort Sea shelf were compiled and reviewed in light of their stratigraphic context in preparation for evaluating rationale for additional age dating. The result of this compilation is presented in Table 2. Core locations with ^{14}C dates and elevations are plotted on Figures 2, 4, and 5. Along with the laboratory results of this study (Section 3.6), an interpretation of the age data and their significance to understanding sea level history in the Beaufort Sea is presented in Appendix E and summarized in Section 4.2.

As noted in the first column of the Table 2, the data were compiled from various sources, including the USGS, industry, and academia, as well as the results of this study. Some of the age dates from USGS vibracores collected in the 1970s had not been previously published. Permission to access these data was granted by Dr. Peter Barnes of the USGS (Barnes 2004), who arranged to have the unpublished data placed on the USGS' Infobank website (USGS 2004c). Reservations about the unpublished data, having to do primarily with stratigraphic ambiguities and potential reworking of shallow sediments through erosion and redeposition, were discussed with Dr. Barnes and included in the "comments" column of Table 2. These issues are further discussed in Appendix E and Section 4.2.

3.5 Subsampling and Age-Dating Program

Based on the results of the core search task, the subsampling program for this study focused on core materials available at the USGS in Menlo Park, California (Section 3.3.2). Boring logs by Barnes et al. (1979), Fishbein (1987), and USGS (2004a) were reviewed in detail for the potential presence of datable materials (organic material or terrestrial shells). Vibracores containing organic material are indicated on Figure 4 with a darker colored label than those with no organic material. *None of the vibracores with organic material were located directly over or immediately adjacent to identified paleolandforms.* The results of this review were compiled in order to provide prioritization for laboratory analysis based on material availability, and in the absence of close paleolandform correlation, stratigraphic rationale for age-dating. The results of this task are presented in Table 3, and were discussed with MMS in a meeting on November 24, 2004.

Table 2
Available Age Dates
Beaufort Sea Shelf, Alaska

Location[1]	Closest Industry Site[1]	Data Source	Boring or Vibracore Number	Depth below seafloor (m)	Water Depth (m)	Elevation (below sea level or ice surface)	Material Dated	^{14}C Date (years B.P.)	Micro-fossil Age (years B.P.)	Comments
Offshore Dease Inlet	Cabot	USGS (2004a), *this study*	8-12VS	2.15	18	-20.2	Shell within consolidated mud with sand-filled worm burrows.	3850±40	-	Upper 5.5 m estimated to be late Pleistocene/ Holocene by Fugro-McClelland (1990). Vibracore located ~5 km E of buried canyon.
Offshore of Colville River delta	South of Fur Seal and Mukluk	Barnes et al. (1979), *this study*	V-18	0.54	3.3	-3.8	Layers of coarse fibrous organic matter within silty clay.	2270±55	-	Location offshore of river delta suggests organic matter is detrital. No paleolandforms identified at Fur Seal. Vibracores are 20 km S/SE of Mukluk shoal.
				1.02		-4.3		3040±50	-	
				1.00-1.05				1660±40	-	
				1.45-1.50		-4.8		3940±40	-	
			V-23	1.30-1.33	1.0	-2.3	Organic-rich bedded clayey silt.	3430±45	-	
				1.40-1.45		-2.4 to -2.5	Organic laminae within sand and silt.	3110±70	-	
		Robinson and Trimble (1989)	V-56	1.20	22.5	-3.7	Fibrous organic matter, 5 cm thick layer.	2490±55	-	
			V-58	1.10	2.0	-3.1	Fibrous organic matter, 5 cm thick layer.	2930±50	-	
	Mukluk	Dames and Moore (1983)	Boring N	0.9-1.5	14.9	-15.8 to -16.4	Organic material in sandy silt.	11,810±120	-	Possible *in situ* peat at 9.5 m below top of core.
				2.3-2.4		-17.2 to -17.3		12,470±130	-	
				5.8-5.9		-20.7 to -20.8	Seams of fibrous organics in clayey silt.	14,580±130	-	
				10.7-10.8		-25.6 to -25.7	Laminated fibrous organics in silty clay.	27,450±360	-	
Simpson Lagoon to Kuparuk River delta	SE of Northstar	Barnes et al. (1979), USGS (2004c)	V-26	1.55	1.5	-3.1	Silty peat layer, 15 cm thick, with horizontal laminations and a few pebbles.	4385±35	-	Possible *in situ* peat.

Table 2
Available Age Dates
Beaufort Sea Shelf, Alaska

Location[1]	Closest Industry Site	Data Source	Boring or Vibracore Number	Depth below seafloor (m)	Water Depth (m)	Elevation (below sea level or ice surface)	Material Dated	^{14}C Date (years B.P.)	Micro-fossil Age (years B.P.)	Comments
Simpson Lagoon to Kuparuk River delta	SE of Northstar	Barnes et al. (1979), USGS (2004c)	V-27	0.42-0.49	1.3	-1.7 to -1.8	Well-preserved coarse fibrous organic matter interbedded with fine sand.	2260±50	-	Location offshore of Kuparuk River delta suggests organic interbeds are detrital.
				1.13-1.28		-2.4	Very organic-rich, finely laminated, cohesive sandy silt.	5520±45	-	
				1.64		-2.9	Horizontally laminated silty fibrous organic matter.	4295±40	-	
	W of Northstar		V-47	0.66-0.68	2.0	-2.7	Fresh-appearing, very fibrous organic peat.	2490±90	-	Possible *in situ* peat.
	SSW of Sandpiper		V-48	0.90-1.07	2.5	-3.4 to -3.6	2-4 cm thick fibrous peat with sticks, well-bedded and interbedded with thin mud and medium sand layers.	4760±100	-	Descriptions and locations within lagoon suggests possible *in situ* peat.
				1.61-1.71		-4.1 to -4.2	Almost pure peat mixed with small amounts of sandy silt.	10,320±?	-	
		Barnes et al. (1979), Naidu et al. (1984)	V-49	1.27-1.39	3.0	-4.3 to -4.4	10-cm thick, upward coarsening fibrous organic layer, well-laminated.	4500±?	-	
	Pingok I. WSW of Sandpiper	Naidu (1978)	Pi-5	-	-	-0.84	Peat	2500±105	-	Likely *in situ* peat.
Prudhoe Bay to Reindeer Island	SE of Northstar	McDougall et al. (1986)	PB-1	3.8	2.7	-6.5	Detrital peat within nearshore marine silt and clayey silt deposits.	490±90	-	
				6.3		-9.0	Sandy gravel; beach deposit.	-	<18,000	Interpreted base of Flandrian transgression.
	SW of McCovey		PB-2	1.4	11.8	-13.2	Interbedded fine sand and silt; inner neritic deposit.	-	<18,000	Interpreted base of Flandrian transgression.

Table 2
Available Age Dates
Beaufort Sea Shelf, Alaska

Location[1]	Closest Industry Site	Data Source	Boring or Vibracore Number	Depth below seafloor (m)	Water Depth (m)	Elevation (below sea level or ice surface)	Material Dated	^{14}C Date (years B.P.)	Micro-fossil Age (years B.P.)	Comments
Prudhoe Bay to Reindeer Island	SW of McCovey	McDougall et al. (1986)	PB-2	2.5	11.8	-14.3	Black organic silt laminations within dense stiff nearshore marine silt.	18,000 ±170	-	Interpreted to be younger organic material mixed with older Late Pleistocene (ca. 80,000 yrs. B.P.) marine sediment.
	SE of Northstar		PB-3	6.1	5.9	-12.0	Muddy gravel to Pebbly shelly sand; beach or lag deposit.	-	<18,000	Interpreted base of Flandrian transgression.
				40.9		-46.8	Detrital peat within alluvium consisting of coarse-grained sand and gravelly sand.	34,000 ±2100	-	Large date uncertainty suggests minimum age, unit beyond range of ^{14}C dating.
			PB-5	8.1	1.8	-9.9	Pebbly fine to medium sand with minute mollusk fragments; beach deposit.	-	<18,000	Interpreted base of Flandrian transgression.
			PB-6	0.9	1.8	-2.7	Detrital peat lens within nearshore marine deposits of interbedded sand and silty sand.	9020±90	-	
				4.0		-5.8	Clean, well-rounded gravel; beach deposit.	-	<18,000	Interpreted base of Flandrian transgression.
			PB-7	4.5	2.6	-7.1	Pebbly sand with numerous shell fragments, and a few twigs, bark shreds, and ventifacted pebbles; beach or lag deposit.	-	<18,000	Interpreted base of Flandrian transgression.
				10.6		-13.2	Plant fragments and wood chips within alluvial deposit of pebbly sand.	42,800 ± 1,440	-	Large date uncertainty suggests minimum age, unit beyond range of ^{14}C dating; dated material interpreted to be older Late Pleistocene (ca. 80,000 yrs. B.P.) based on stratigraphic position.

Table 2
Available Age Dates
Beaufort Sea Shelf, Alaska

Location[1]	Closest Industry Site	Data Source	Boring or Vibracore Number	Depth below seafloor (m)	Water Depth (m)	Elevation (below sea level or ice surface)	Material Dated	^{14}C Date (years B.P.)	Micro-fossil Age (years B.P.)	Comments
Prudhoe Bay to Reindeer Island	Between Northstar and McCovey	McDougall et al. (1986)	PB-8	6.0	7.0	-13.0	Silty clayey sand with shells and shell fragments, middle neritic marine deposit.	-	<18,000	Interpreted base of Flandrian transgression.
Offshore of Sag River delta	Karluk	Barnes et al. (1979); *this report*	V-9	0.40-0.45	6.5	-6.9	Shell fragments at base of sandy silt layer.	4450±40	-	
				1.35-1.40		-7.9	Shell fragment within muddy fine sand.	6590±40	-	Either material may have been reworked.
							Thin organic layer within muddy fine sand.	8560±40	-	
	NW of Liberty/ Karluk	Barnes et al. (1979), USGS (2004c)	V-29	0.23	5.5	-5.7	1 cm thick lens of fibrous organic matter within stiff clayey silt, faintly bedded to contorted.	7560±100	-	Location offshore of river delta suggests organic matter is detrital.
Camden Bay	Warthog	Bergman (1997)	BH-1	0.0-0.7	3.0	-3.0 to -3.7	Shell material in silty fine sand.	36,130 +5880/ -3360	-	Highly uncertain dates due to low observed ^{14}C activity. Geophysical data suggest Holocene sediment in this area. Dates likely represent reworked material.
							Organic material in silty fine sand.	20,200 ±1070	-	
			BH-2	2.4-3.0	2.7	-5.1 to -5.7	Shell material in sandy silt	38,700 +8700/ -4090	-	
							Organic material in sandy silt	20,480 ±870	-	
			BH-4	0.0-0.7	2.7	-2.7 to -3.4	Shell material in medium sand	29,170 +11,170/ -4500	-	

1 = Order of table listing is roughly west to east.
B.P. = before present
m = meters
bsl = below sea level
? = data not available
ca = circa
- = not analyzed

A visit was made to the USGS in Menlo Park, California on December 13 and 14, 2004 for the purpose of examining the core material and subsampling for ^{14}C analysis. Permission to access the core material was arranged through Mr. Clint Steele and Ms. Cathy Frazee of the USGS (Steele 2004; Frazee 2004). A trip report for the USGS subsampling visit is provided in Appendix F. During the visit, it was discovered that only five of the expected 34 vibracores from the 1970s were available, the rest having been discarded several years ago. Subsamples were extracted from five of the 1970s vibracores and from the one refrigerated vibracore collected in 1985. Remaining material for each core was left in storage at USGS. Subsamples were shipped to NLUR in Fairbanks, Alaska for review and selection of final material for dating (Table 3).

3.6 Laboratory Results

Subsamples from the USGS cores were selected for analysis of ^{14}C based on core availability and the rationale presented in Table 3. Six subsamples from three vibracores, V-9, V-18, and 8-12VS, were submitted to Beta Analytic Radiocarbon Dating Laboratory in Miami, Florida for ^{14}C dating by AMS methods. Logs of the three vibracores chosen for dating are presented in Appendix G. The laboratory data are presented in Appendix H. The results of the analyses are included in the age date compilation for the Beaufort Sea in Table 2 and Appendix E, and are described below. An interpretation of the data in the context of overall sea level history of the Beaufort Sea is presented in Appendix E and Section 4.2.

Vibracore V-9. This core (Barnes et al. 1979) is located in the approximate center of the Karluk site, Stefansson Sound, about 30 km east of Prudhoe Bay (Figure 4). As interpreted on the basis of seismic and geotechnical data by HLA (1988), Vibracore V-9 coincides with about 2 m of Holocene silty sand underlain by about 14 m of Pleistocene marine clay. The closest paleolandform to V-9 is a buried channel located about 0.5 km to the west, which was estimated by HLA (1988) to be filled with at least 3 m of organic-rich Holocene sediment (Section 3.2.4). The laboratory results indicate ages of 4,410 to 8,600 years B.P. at depths of 0.4 to 1.4 m below the seafloor (6.9 to 7.9 m bsl), which generally confirm the age of the surficial deposits as Holocene. Additional analysis in Appendix E suggests the material represents older eroded peat within younger Holocene marine sediment. Both plant and shell materials were dated from the 1.4-m depth, yielding dates that differed by about 2,300 years, the shell younger than the plant material. These data may indicate that either or both materials had been reworked prior to deposition, or that there is actually a 2,300-time span represented by the 5-cm sampling interval.

A small fragment of greenish gray chert was recovered while NLUR was sieving a sediment sample from core V-9. The sample was located 40-45 cm below the seafloor at a depth of –6.9 m. Although it is remotely possible the fragment is an artifact or ecofact, we interpret it as normally occurring chert. Neither a bulb of force nor energy ripples are evident on the ventral surface, two common hallmarks of human altered lithic flakes. The fragment is heavily polished on both surfaces from weathering, probably due to water rolling and sand abrasion. A sample of shell of probable marine origin associated with this lithic debris returned an age of 4,450±40 B.P. (Appendix H). Based on data we have collected elsewhere, this elevation appears low for this time period, if the enclosing sediments were to be of *in situ* terrestrial origin. This suggests both the shell and lithic fragment are retransported (cf. discussions in Leffingwell 1919; and discussions of boulder patches in Reimnitz and Ross 1979). As we discuss elsewhere (Appendix E:6-7), this entire core appears to be submarine in origin.

Table 3
^{14}C Dating Program, USGS Vibracores

Location[1]	Vibracore Number[2]	USGS Cruise	Description of Organic +/or Shell Material	Originally Proposed for Dating?	Rationale	Available at USGS December 2004?	Subsample Depth (cm below seafloor)	Subsample Material	Sample Number	Selected for Dating?
Offshore of Dease Inlet, near Cabot	8-12VS	D-1-85-AR	Dark organic silt layers 18-65cm. Random organic material 90-110cm. Organic silt layer within 110-190cm interval.	Yes	Upper 5.5m estimated to be Late Pleisocene-Holocene in age by Fugro-McClelland (1990).	Yes	100-105	Shell	MMS-04-04	Yes
Colville River Delta Area	V-17	K-1-76-AR	Dark band of fine-grained organic matter at 90cm.	No	Potential interpretive problems with location indicating possible redeposition at delta front.	No	-	-	-	-
	V-18		Coarse fibrous organic matter at 54 and 102cm. Organic-rich laminae above massive clay with abundant rootlets at 140-160cm.	Yes	Organics at 54 and 102cm already dated by Barnes et al. (1979). Fishbein (1987) suggests 140-160cm interval may be buried tidal marsh deposit - recommend for dating.	Yes	100-105	Plant	MMS-04-01	Yes
							145-150	Plant	MMS-04-02	Yes
	V-19		Interbedded organic and coal-rich laminae 50-70cm.	No	Potential sampling and interpretive problems with intermixed coal and organic material indicating possible redeposition at delta front.	No	-	-	-	-
	V-20		Interlaminated fine-grained coal-rich organic material noted throughout core.	No		No	-	-	-	-
	V-21		Interbedded coal particulate layers 0-45cm. Peat and wood stick previously removed by USGS (Barnes et al., 1979) for possible dating.	No		No	-	-	-	-
	V-22		Coal particle layers, some with other organic material, noted throughout core. Fishbein (1987) suggests layer of coal particles and fibrous organics at 50-60cm represents subaqueous distributary mouth bar.	No		No	-	-	-	-
	V-23		Thin organic layers noted throughout core. Abraded twigs and plant stems in organic interbeds 80-100cm (Fishbein, 1987).	No	Already dated by Barnes et al. (1979) (2 dates). Fishbein (1987) suggests delta front depositional environment.	No	-	-	-	-
	V-55	K-1-77-AR	Organic-rich layer 80-90cm within laminated silt and sand.	No	Potential interpretive problems with location indicating possible redeposition at delta front.	No	-	-	-	-
	V-56		Interbedded peat and mud at 116-143cm; includes fine to coarse, horizontally laminated organic matter with stems and sticks to 5 cm long.	Maybe	Although in delta front environment, unit appears to be possibly *in situ*. Fishbein (1987) suggests buried tidal marsh deposit at similar depth in V-18, already proposed for dating.	No	-	-	-	-
	V-57		Fibrous organic material and coal-rich lenses noted throughout.	No	Potential interpretive problems with intermixed coal and organic material indicating redeposition at delta front.	No	-	-	-	-
	V-58		Interbedded peat, mud, and sand at 86-118cm.	Maybe	Although in delta front environment, unit appears to be possibly *in situ*. Fishbein (1987) suggests buried tidal marsh deposit at similar depth in V-18, which is proposed for dating.	No	-	-	-	-
	V-59		Thin-bedded fibrous organic matter interbedded with silt and sand throughout core.	No	Potential interpretive problems with location at mouth of Colville River indicating possible redeposition at delta front.	No	-	-	-	-
	V-60		Organic-rich layers interbedded with sand and silt.	No		No	-	-	-	-
Oliktok Point	V-51		<1cm-thick lenses fibrous organic material at 8, 10, 45, and 162cm.	Maybe	Possible interpretive problems from Colville River redeposition. If submit for dating, 162cm layer is 1st choice.	No	-	-	-	-
Simpson Lagoon - Gwydyr Bay, inshore of barrier islands	V-47		Fresh-appearing very fibrous organic peat layer 67-69cm.	No	Already dated by Barnes (2004).	No	-	-	-	-

Table 3
^{14}C Dating Program, USGS Vibracores

Location[1]	Vibracore Number[2]	USGS Cruise	Description of Organic +/or Shell Material	Originally Proposed for Dating?	Rationale	Available at USGS December 2004?	Subsample Depth (cm below seafloor)	Subsample Material	Sample Number	Selected for Dating?
Simpson Lagoon - Gwydyr Bay, inshore of barrier islands	V-48	K-1-77-AR	Interbedded fibrous organic matter (peat with sticks), clean medium sand, and thin mud layers at 95-110cm. Lemming turds and bluff microclams at 145cm. Peat (very fine fibrous organic material) mixed with small amounts of sandy silt containing micro-bivalves and vase-like seeds at 160-172cm.	Yes	Already dated by Barnes (2004) (2 dates). Redate material at 160-172cm for QC purposes. Original date of 10,320 yrs. b.p. had no sigma.	No	-	-	-	-
	V-49		Interbedded fibrous organic matter and sand 128-150cm.	Yes	Already dated by Naidu et al. (1984). Redate for QC purposes. Original date of 4,500 yrs. b.p. had no sigma.	No	-	-	-	-
	V-50		1cm-thick organic-rich mud layer at 20cm.	No	Other dated cores in area. Organic material is very close to seafloor.	No	-	-	-	-
Kuparuk River Delta area	V-27		Interbedded coarse fibrous organic matter throughout core.	No	Already dated by Barnes (2004) (3 dates).	No	-	-	-	-
Near Northstar pipeline inshore of barrier islands	V-28		Contorted pocket of sand mixed with fibrous organic matter 33-52cm.	Yes	Close to Northstar pipeline. Possible interpretive problems from sediment deformation and redeposition.	No	-	-	-	-
East of Northstar pipeline/ West Dock area	V-3	K-1-76-AR	<1cm-thick lens of organic material at 47cm. 2cm-thick black organic-rich fine sand with pebbles at 118cm.	No	Possible interpretive problem in deeper layer from redeposition.	No	-	-	-	-
	V-4		1-2cm thick organic lenses with clay at 28cm. Black organic lens within sandy mud at 39cm. Organic-rich muddy sand at 43-46cm. Shell fragments near base of core at 74cm.	Maybe	McDougall et al. (1986) dates in area are from deeper Pleistocene strata.	Yes	25-30	Plant	MMS-04-10	No
							40-45	Shell and Plant	MMS-04-09	No
							70-75	Shell	MMS-04-03	No
North of Reindeer Island, west of McCovey	V-7		Shell fragments and mud lumps above clear unconformity at 45cm. Sand in large vertical burrow below unconformity appears slightly oxidized.	Maybe	Oxidized remark may indicate subaerial exposure. Collect shell fragments at 45cm for identification and possible dating.	No	-	-	-	-
	V-43	K-1-77-AR	Snail within clean well-sorted fine sand at 123cm.	Maybe	Snail may indicate terrestrial environment. Collect for identification and possible dating.	No	-	-	-	-
Prudhoe Bay area	V-1	K-1-76-AR	1cm-thick organic bands at 47 and 77cm within silt/clay.	Maybe	Appear *in-situ*. Close to existing Barnes (2004) date in V-26.	Yes	45-50	Plant	MMS-04-12	No
							75-80	Plant	MMS-04-11	No
	V-2		Slight admixture of very fine organic substance in slightly oxidized medium sand at 110-153cm. Oxidation boundary noted at 72cm.	No	Organics within disturbed core section. Other McDougall et al. (1986) dates nearby.	No	-	-	-	-
	V-12		1cm-thick black organic-rich layer within silt/sand at 27cm; dark fine organics within silty clay at 110-115cm.	Maybe	Collect 2 subsamples. Possibly date deeper interval. McDougall et al. (1986) has nearby Holocene date.	Yes	25-30	Plant	MMS-0413	No
							110-115	Plant	MMS-0414	No
	V-25	K-1-77-AR	Fibrous organic matter at 17cm.	No	Core is close to V-1, already proposed for dating.	No	-	-	-	-
	V-26		Within 45-130cm interval: interlaminated sandy silt and fibrous organic layers up to 20cm thick. Silty peat with horizontal laminations and a few pebbles at 145-160cm.	Maybe	145-160cm interval already dated by Barnes (2004). Collect 2 subsamples to hold for possible QC dates.	No	-	-	-	-
Sag River Delta area	V-29		Lens of fibrous organic matter at 25cm.	Maybe	Already dated by Barnes (2004). Collect subsample for possible QC purposes.	No	-	-	-	-

Table 3
^{14}C Dating Program, USGS Vibracores

Location[1]	Vibracore Number[2]	USGS Cruise	Description of Organic +/or Shell Material	Originally Proposed for Dating?	Rationale	Available at USGS December 2004?	Subsample Depth (cm below seafloor)	Subsample Material	Sample Number	Selected for Dating?
Sag River Delta area	V-30	K-1-77-AR	1cm-thick fibrous organic layer at 48cm in sands with rip-up material. Interbedded organic-rich layers and silt 65-85cm. Disrupted organics mixed with silt 85-105cm. Interbedded fibrous organic matter and silt at 115cm. Sand with fibrous organics and mud balls 120-150cm.	No	Expect interpretive problems from redepositional delta front environment throughout.	No	-	-	-	-
	V-31		Thinly laminated silt and organic layers at 118-125cm. Small fragile snail noted within laminated fine sand and mud at 130cm. Other thin organic layers interbedded with sand and silt throughout core.	Yes	Possible freshwater shell (snail). Obtain date in Sag Delta area for constraints purposes, although possible interpretive problems due to redeposition in delta front environment.	No	-	-	-	-
North of Narwhal Island	V-35		Shell fragments and unbroken fragile shells within poorly sorted mixture of gravel to clay. Possible glacial outwash.	Maybe	Collect shells for identification and possible dating.	No	-	-	-	-
Karluk/ Boulder Patch area	V-9	K-1-76-AR	Shell fragments at 0-13, 41, and 137 cm. Dark organic-rich layer within banded clayey silt at 56cm. Thin fine organic layer within sand at 140cm. Fine organic-rich layers at 149-151cm within clayey silt.	Maybe	Expect mostly Pleistocene at surface in this area. Collect 2 subsamples for possible confirmation.	Yes	40-45	Shell	MMS-04-05	Yes
							55-60	Plant	MMS-04-06	No
							135-140	Shell and Plant	MMS-04-08	Yes
							145-150	Plant	MMS-04-07	No

Notes:
1. Locations listed roughly west to east.
2. Only cores with organic material or evidence of potential terrestrial shells listed.
- = Material not available.

Vibracore V-18. This core is located about 6 km offshore of the Colville River delta, and about 11 km southeast of Fur Seal (Figure 4). There are no paleolandforms mapped in this area. The laboratory data indicate Holocene ages of 1,620 to 3,980 years B.P. at depths of 1.0 to 1.5 m below the seafloor (4.3 to 4.8 m bsl). Fishbein (1987) describes environments of deposition for V-18 ranging from delta front in the upper part of the core to tidal marsh in the lower portion of the core (Appendix G). The shallower date (1,660±40 years B.P.) was obtained from a layer of "clean washed, coarse fibrous organic matter" within a silty clay between these two zones. Material from the shallow dated layer was also dated by Barnes et al. (1979) (3,040±40 years B.P.). The difference in dates could be due to different laboratory or sampling techniques, and/or to the material being detrital and having been redeposited into the delta front environment over a 1,600-year span. Fishbein (1987) notes that the lower of the two dated intervals (3,940±40 years B.P., this study) contains rootlets and plant stems possibly representative of a subaerially exposed tidal marsh environment, although correlations to regional data (Appendix E) suggest it may be from a deeper environment of deposition, such as a lagoon.

Vibracore 8-12VS. This core is located about 20 km offshore of Dease Inlet on the east edge of the Cabot site (Figure 2). The closest mapped paleolandform is a deeply buried Pleistocene canyon about 5 km to the west. The laboratory data indicate a Holocene age of 3,850±40 years B.P. for a shell collected at 2.15 m below the seafloor (20.2 m bsl). This date is generally consistent with a Holocene thickness of about 5 to 6 m in this area mapped from shallow seismic data by Fugro-McClelland (1990). The shell fragments were too fragmented for identification, but are thought to be of marine origin.

3.7 Review of USGS Geophysical Data

The results of the review of USGS high resolution seismic data from 1979, as well as the USGS eastern Beaufort Sea shelf interpretation from Wolf et al. (1985), are presented in the following sections, organized roughly west to east. Limitations on the availability and interpretation of the data are described in Section 2.5. Paleolandforms identified on the tracklines were mapped on Figure 4. Several examples of seismic data that intersect potential landforms are provided in Appendix I. Most potential landform features are subject to multiple interpretations. In many cases, potential landforms were only observed on one trackline; thus, their orientations are speculative and related to presumed geomorphic trends.

3.7.1 Colville Delta Area

The USGS seismic data in the lease area between Fur Seal and Thetis Island offshore of the Colville River delta were mostly of poor quality, possibly due to coarse Pleistocene material near the seafloor surface and/or water column anomalies. There is a faint expression of a possible buried ridge or shoal located about 6 km northwest of Thetis Island (Figure 4). A depression lies adjacent to the ridge on its landward side. Sediment is about 5 m thick on either side of the ridge, and less than 1 m thick over the ridge.

3.7.2 Northstar Area

A line crossing the Northstar pipeline area offshore of the barrier islands exhibits evidence of two shoals and a paleo-depression. The reflector at the base of the depression coincides with the 1.2 m-thick peat layer at 4 m below the seafloor in Boring TC-4 (Section 3.2.9, Appendices D and I), indicating the possibility that the reflector represents a paleo-lake basin or the terraced side of a channel. The northern of the two shoals lies near the southeast edge of the peat and appears to post-date the depression.

Northeast of the Northstar site and offshore of Reindeer Island lies as series of flat-bottomed depressions with terrace-like edge features that intersect one seismic line. They are interpreted to be one east-west trending linear feature that may represent a Holocene channel, lagoon, or lake basin. The base of the feature, which appears to be filled with Holocene marine sediment, lies at approximately 7 m below the seafloor at its west end and 11 m at its east end (about 20 to 24 m bsl). Its sides rise to about 4 m below the seafloor (Appendix I).

3.7.3 McCovey Area

Three buried channels or depressions were identified on the USGS line that extends through the McCovey site. These were interpreted on Figure 4 in conjunction with the PRA (2002) results (Section 3.2.7). The most prominent of the channels coincides with the feature described by Arctic Geoscience (2000c) and PRA (2002) as a possible ice gouge. The other two channels are relatively indistinct and were not interpreted as such by the previous authors. Both lie at similar depths to the Pleistocene channel interpreted by PRA (2002) just southeast of the shoal area. The easternmost channel on the USGS line is coincident with a possible fault zone or graben identified by PRA (2002), which could also be interpreted as an incised channel bank. The base of the westernmost channel is coincident with an "8-10 m gravel surface" described by PRA (2002), which could be an extension of the east channel. These channels appear to be filled mostly with material interpreted as Pleistocene by PRA (2002), but could also be interpreted as Holocene-filled on the basis of the USGS data.

Offshore of McCovey is evidence of a buried subtle ridge in the erosional surface at the base of the Holocene marine section. This feature is similar to those described to the west at the Sandpiper site (Section 3.2.11) that are interpreted to be possible remants of relict barrier islands. The thickness of sediment overlying the ridge is about 9 m.

3.7.4 Saganavirktok Delta to Offshore of Barrier Islands

The review of the 1979 USGS data in this area focused on federal lease blocks offshore of the barrier islands in less than 20 m of water depth. An area of constructional shoals lies at the seafloor on the northeast side of Cross Island (Figure 4). These shoals have about 5 m relief above an erosional reflector. The east end of the shoal area is interpreted to be a paleo-shoreline with about 2 m relief compared to the adjacent seafloor, which lies in a water depth of about 16 m.

Several features were mapped as Pleistocene channels within 4 km northeast of Cross Island. The age of the southern two of the channels, which extend to 5 to 11 m below the seafloor, is estimated to be Pleistocene based on a cross-cutting relationship with an overlying seaward-thickening Holocene marine wedge. The base of the northernmost channel in this area reaches a depth of at least 25 m below the seafloor, and its southern edge appears to be a possible fault. Parts of this feature are obscured by shallow gas anomalies. The largest of the channels is interpreted to extend southwesterly beneath the shoal area.

Its base lies about 16 m below the seafloor. This channel appears to contain both Pleistocene and Holocene channel deposits, and possible Holocene-aged terraced channel-edge features ranging from 2 to 8 m below the seafloor (about 20 to 25 m bsl) (Appendix I).

East of McCovey and about 7 km offshore of Cross Island lies a possible shoreline ridge at the seafloor in about 19 m of water depth. This feature, which exhibits about 2 to 3 m relief, may represent a relict island with an adjacent wave-cut terrace. Seaward of this feature are possible buried Holocene and Pleistocene channels (Appendix I). The base of the shallower channel lies at 6 to 9 m below the seafloor, and the deeper channel about 15 m below the seafloor.

Several features were mapped as Holocene channels about 5 and 6 km northwest and northeast of Narwhal Island. These were interpreted to be possible ice gouges based on their V-shaped sides. Alternatively, it is possible that former terrestrial ice wedges that melted during the last regression, and filled with sediment during sea level rise may have a similar appearance (Wolf et al. 1985). The base of these features ranges from 6 to 12 m below the seafloor.

The northernmost channel mapped about 8 km offshore of Narwhal Island in about 20 m water depth appears to be filled with both late Pleistocene and Holocene deposits, and exhibits evidence of potential channel-edge features (Appendix I). The base of the channel lies at a maximum of about 16 m below the seafloor (about 36 m bsl), while the channel-edge features vary between depths of 7 to 12 m below the seafloor (27 to 32 m bsl). South of the channel, the base of the surficial unit appears to rise to within 2 to 4 m of the seafloor surface over a feature that may represent a buried ridge or relict island. This channel may be part of a larger northeast-trending cut-and-fill sequence mapped by Wolf et al. (1985) that extends deeper into the Pleistocene (up to 100 m bsl) and is up to 4 km wide. Wolf et al. (1985) also describe two additional Pleistocene channels in deeper water to the northeast that extend to as much as 120 m bsl. The three channels mapped by Wolf et al. (1985) are truncated by a later Pleistocene erosional surface.

Wolf et al. (1985) interpret multiple continuous reflectors within the Pleistocene section offshore of the Saganavirktok River delta region as representing a repeated pattern of broad flood plains and embayments corresponding to the ancestral Saganavirktok fan-delta. The Pleistocene channels described above offshore of Cross and Narwhal Islands lie within this broad region. Inshore of the barrier islands, Wolf et al. (1985) mapped a wide swath of shallower cut-and-fill channels above about 15 m bsl, which may be late Pleistocene to Holocene in age. This swath ranges from 4 to 8 km wide, and extends northeasterly from the current coastline at the Saganavirktok delta front, across West Dock, and to the Dinkum Sands about half-way between Cross and Narwhal Islands. Individual channels within this swath were not mapped.

3.7.5 Mikkelson Bay

The 1979 USGS seismic data in Mikkelson Bay east of the Liberty site suggest the presence of a buried paleo-ridge and adjacent depression. The location lies in about 6 m of water depth. Appearing on only one seismic line, the feature is interpreted to be a possible paleo-shoreline or coastal bluff exhibiting roughly 5 m of relief (Appendix I). About 2 to 3 m of sediment overlies the crest of the feature. A strong reflector adjacent to the ridge, which may represent a Pleistocene erosional surface, lies at about 10 m below the seafloor. These thickness/depth estimates correspond well with units logged in USGS geotechnical boring #15 from the HLA (1979) investigation, which was located on the landward side of the presumed paleo-shoreline (Figure 4). This boring encountered about 3 m of interbedded sand and silt, with shell fragments and small twigs noted at about 2 m below the seafloor (about 8 m bsl); overlying black clayey silt with layers of organic silt to a depth of 10 m (16 m bsl). Gravel and sand, representing possible Pleistocene alluvial fan material, were encountered from 10 m to the total boring depth at 91 m. The presence of twigs and organic silt layers between 2 and 10 m below the seafloor maybe indicative of a terrestrial environment associated with this paleolandform.

3.7.6 East of Mikkelson Bay

The review of 1979 USGS data for this study in the area east of Mikkelson Bay focused on lease areas in less than 20 m of water depth, as well as selected areas inshore of barrier islands. Most of the lease blocks east of Mikkelson Bay are located in water depths greater than 20 m. No potential paleolandforms were identified in the shallower parts of these lease areas. The seismic data in these areas appeared relatively amorphous, with sections of rough seafloor and subsurface reflectors representing possible ice gouging or coarse material at or near the surface. Wolf et al. (1985) suggest that the acoustic transparency of the surficial unit offshore of the barrier islands in this region may be due to complete mechanical reworking by ice gouging.

The 1979 data inshore of the barrier islands were generally obscured by seafloor multiples and other interferences. Discontinuous areas of near-surface diffractions, that appear to mask otherwise horizontal strata, were interpreted to be possible bonded permafrost or lag deposits of coarse material from the Pleistocene Flaxman Formation that outcrops at the coast in this area (Wolf et al. 1985). Shoals at the seafloor were observed on the west side of Camden Bay just west of Konganovik Point. These are roughly in line with existing barrier islands that extend southeasterly from the Canning River delta area.

Although not in a federal lease area, a possible buried wave-cut terrace or shoreline bluff was noted about 0.8 km offshore of Flaxman Island beneath about 6 m of surficial sediment. In addition, Wolf et al. (1985) note the presence of a possible relict barrier island shoal at the seafloor about 9 km offshore of the Brownlow Point spit.

Wolf et al. (1985) describe multiple continuous reflectors within the Pleistocene section, across the broad region from east Mikkelson Bay to the Canning River delta, as representing a repeated pattern of broad flood plains and embayments corresponding to the ancestral Canning River fan-delta complex. They note the presence of several buried channels in the following locations: in between the McClure and Stockton Islands, about 2 km offshore of the Stockton Islands, about 2 km east of the east end of the Stockton Islands, 4 km offshore of the Maguire Islands, and at the east end of Flaxman Island (none in lease areas). With one exception, these channels lie within the sequence of Pleistocene reflectors. At the channel location east of the Stockton Islands, the relief of the most recent erosional surface appears varied, suggesting incomplete planation prior to the latest transgression and possible buried landform preservation. Wolf et al. (1985) attribute the multiple sequences of cut-and-fill channels in this region to their possible confinement between barrier islands. They suggest that the eroding cores of the islands may represent remnant highs of a deltaic coast, which appear to have remained relatively stationary throughout several transgressions and regressions.

4.0 DISCUSSION

4.1 Geomorphic Trends Related to Landform Preservation

Several general patterns emerged, based on the review of industry and USGS data, as to Beaufort Sea shelf locations where late Pleistocene – early Holocene terrestrial landforms are more likely to be preserved. As described below, these include wide shelf areas inshore of the landfast ice zone, areas inshore of barrier islands, and areas in between major river systems.

MMS' previous experience in the Beaufort Sea indicates that geophysical data in water offshore of about the 20-m isobath appear heavily reworked and ice-gouged, likely precluding preservation of paleolandforms below this depth (Section 1.1). The width of the inshore Beaufort Sea shelf south of this isobath, that is more protected from present-day ice gouging by landfast ice in winter, ranges from 5 km east of the Aurora site, to as much as 55 km at Harrison Bay. Wolf et al. (1985) suggest that the Holocene basal surface offshore of the barrier islands in the eastern Beaufort Sea shelf, may be in part, a mechanically formed surface resulting from multiple overlapping ice gouges. Seismic data from several industry sites provide additional evidence. Buried linear ridges at Sandpiper, which may represent paleo-barrier islands (Section 3.2.11), appear to be more eroded and flat in the deeper northern half of the site (18 to 20 m bsl), as compared to the shallower southern half (15 to 17 m bsl) where they appear to have a more preserved constructional shape (Dames & Moore 1983). Buried channels at the Kuvlum, West Maktar, and Wild Weasel sites, located in water depths greater than 20 m, lie beneath a flat erosional surface at the base of the Holocene, which appears to have truncated any previously existing channel edge features (Deepsea Development Services 1993, 1994; Fugro-McClelland 1992). At the comparatively shallow Warthog site (2 to 12 m water depth), the low-angle slope of the inshore shelf combined with less exposure to ice gouging, may have contributed to the possible preservation of Holocene channel edge features (Choromanski et al. 1997).

Another likely cause of early Holocene erosive destruction were the major river systems crossing the Beaufort Sea shelf. During the last glacial maximum, rivers would have eroded to the lower base level of the current shelf edge (about 100 m bsl). Major braided fluvial and fan-delta systems, such as the Colville, Sagavanirktok, and Canning Rivers, drain enormous watersheds and would likely have cut wide swaths, precluding preservation of most channel-edge features in their immediate vicinity. Channels and fan lobes would have shifted back and forth many times in the development of these systems (Wolf et al., 1985), and strudel scour would have eroded nearshore sediment from the delta fronts. Most individual channels mapped offshore of the major rivers appear truncated by later erosional surfaces and do not exhibit potential channel edge features. In a study of the Canadian Beaufort Sea shelf, O'Conner (1982) divides the Canadian Beaufort Sea shelf into several physiographic provinces based on subsurface acoustic signatures; these include 20- to 100-km wide swaths of plains, plateaus, channels, and troughs that extend from the coastline out to the shelf edge, and are often extensions of major coastal systems such as the MacKenzie River delta. The large fan-delta complexes offshore of the Saganavirktok and Canning Rivers are similar in size and orientation to the Canadian shelf trough and channel provinces.

Areas inshore of barrier islands and in between the major river systems appear to be the most promising areas for possible early Holocene landform preservation. As indicated in Section 3.7.6, Wolf et al. (1985) attribute vertical sequences of multiple cut-and-fill channels in between barrier islands in the eastern Beaufort Sea shelf to their possible confinement between remnant coastal highs. The relative stability of such islands may have lead to inshore landform protection during the last sea level rise. Migrating constructional shoals would likely have provided less shelter from erosional forces. Two areas of the Beaufort Sea shelf that contain potential laterally continuous *in situ* peat deposits (near Northstar and Liberty) lie inshore of barrier islands and in between major deltas.

Based on a combination of the above geomorphic factors, areas that may be promising for preserved paleolandforms include (from west to east) inshore shelf segments near Elson Lagoon, Smith Bay, Cape Halkett, western Harrison Bay, Simpson Lagoon, east Gwydyr Bay, Prudhoe Bay, Foggy Island Bay, and and Mikkelson Bay. East of Mikkelson Bay, the inshore shelf narrows, suggesting more exposure to erosive forces. However, experience at Warthog suggests that inshore shelf areas in between major rivers, such as parts of Camden Bay, lagoons inshore of Barter Island, and between Martin Point and the Kongakut River, may also be promising for landform preservation.

4.2 Beaufort Sea Radioarbon Database Interpretation

The laboratory data collected during this study are evaluated in Appendix E in the context of previous dates collected in the Alaskan Beaufort Sea, as well as studies of sea level history in the Chukchi, Laptev, and Canadian Beaufort seas. Graphs of radiocarbon dates in relation to elevation below sea level are provided for the last 45,000 years and 6,000 years in Figures E-1 and E-2, respectively, with the dates on Figure E-2 representing only potentially *in situ* fibrous peats.

Beaufort sea dates from the late Pleistocene and early to middle Holocene range (about 40,000 to 6,000 years B.P.) are generally considered to be unreliable due to the mobility and likely redeposition of the dated materials. Dates from the mid to late Holocene (last 6,000 years) may be more useful due to the presence of potentially *in situ* peats in several of the cores. Based on regional correlations, dates from offshore of the Colville River delta are interpreted to be representative of a subsea delta front bench environment that suggest 2 m correction factor may be applicable. Age data collected during this study generally imply that older organics (up to 2,000 years older) were recycled in the upper 1 m of the sampled cores.

Several depositional processes are discussed in Appendix E that complicate the interpretation of the Beaufort Sea radiocarbon data. These include eroded river- or coastal-bluff detritus redeposited at delta fronts, marsh peat bodies recycled landward with rising sea levels, collapsed thaw lake banks recycled as marsh peat or lagoonal basin deposits, storm surges that lead to misinterpretation of beach ridge materials, and barrier island deposits that are particularly mobile. In addition, ice-related processes such as ice gouge, strudel scour, and melted ground-ice wedges may cause erosion and infilling that further complicate and potentially invert age dates beneath the shelf.

Although there are many interpretative problems related to environment of deposition and recycled organic material, the results of this study in the context of regional correlations generally point to the following Holocene paleo-sea levels and rates of sea level rise for the Alaskan Beaufort Sea shelf:

- At the beginning of the Holocene about 11,000 years ago, sea level was at or below about 50 m bsl. After 10,500 years B.P., sea level had risen to at least 50 m bsl and flooded the Bering Strait.

- Between 9,000 and 7,500 years B.P., sea level rose rapidly from about 44 m bsl to 18/16 m bsl, a rate of about 1.8 cm/yr.

- Sea level was about 12 m bsl by 6,000 years B.P. and reached near modern levels (within 2 m bsl) by 5,000 years B.P. The rates of sea level rise between 7,500 and 4,500 years B.P., at 0.3 to 0.6 cm/yr, were more than ten times the present rate of 0.3 mm/yr.

5.0 SUMMARY OF FINDINGS

The geologic and geophysical data reviews, core search results, and interpretation of radiocarbon data for this study yielded the following with respect to potential paleolandforms and age dates in the Beaufort Sea:

- Potential paleolandforms were identified at 13 industry sites. Those with possible preserved early Holocene[2] terrestrial features are itemized below.

    - Fireweed-ARCO: buried paleo-shoreline and buried paleo-islands
    - Liberty/Tern Island: peat in buried paleo-lake- or lagoon basin with terrace-edge features; narrow terrace/floodplain along incision
    - Mars: buried paleo-islands or coastal ridges
    - Northstar: peat in paleo-depressions
    - Sandpiper: buried paleo-islands
    - Warthog: channels with Holocene edge features

    Other landforms identified at the above sites, as well as landforms identified at the remaining sites (Aurora, Cabot, Fireweed-Shell, Karluk, McCovey, Mukluk, and Phoenix) were considered less likely to contain preserved early Holocene terrestrial material. These included seafloor shoals, Pleistocene channels, channels without Holocene channel-edge features, and unknown depressions that may be permafrost artifacts.

- The results of the core search revealed material in storage only at the USGS in Menlo Park, California from selected vibracores collected in the late 1970s and in 1985. No core material was found from industry, state, academia, or other sources.

- An onsite review of the available USGS cores in Menlo Park yielded subsamples from six vibracores. Subsamples from three of the cores (located next to the Cabot site, offshore of the Colville River delta, and at the Karluk site) were analyzed for radiocarbon dates. The analyses indicated dates ranging from 1,600 to 8,600 years B.P., confirming the Holocene age of sediment mapped from seismic data in these areas, although regional data imply that older Holocene organics (up to 2,000 years older) were recycled within younger Holocene deposits in the upper 1 m of the sampled cores.

- A review of USGS geophysical data was conducted to identify additional paleolandforms and data gaps in core material coverage. The review confirmed and expanded landform

[2] See discussion of late Pleistocene in preceding Section 4.2 and Appendix E.

interpretations at Northstar and McCovey, and identified additional landforms with possible preserved early Holocene terrestrial features in the following areas:

- Colville River delta area: buried paleo-ridge or island
- Northwest of Reindeer Island: buried channel or paleo-lake or lagoon basin with terrace edge features
- North of Cross Island: channel with Holocene edge features
- North of Narwhal Island: channel with Holocene edge features, buried paleo-island
- Mikkelson Bay: buried paleo-shoreline or coastal ridge
- East of Stockton Islands: channels with Holocene edge features
- North of Flaxman Island: buried paleo-shoreline or coastal bluff

Other landforms identified on the USGS seismic data were considered less likely to contain preserved early Holocene terrestrial material. These include shoals or shoreline ridges at the seafloor, a buried paleo-island ridge beneath an erosional surface, numerous Pleistocene channels, and filled ice gouges.

- General geomorphic patterns pointing to shelf locations where early Holocene terrestrial landforms are more likely to be preserved include wide shelf areas inshore of the landfast ice zone, areas inshore of barrier islands, and areas in between major river systems.

- The radiocarbon dates from this study were added to a compilation of all existing dates for the Beaufort Sea shelf, and interpreted in the context of regional data from the Chukchi, Laptev, and Canadian Beaufort Seas. Beaufort sea dates from the late Pleistocene and early to middle Holocene range were generally considered unreliable due to recycling of organics. Dates from the late Holocene (last 6,000 years) were considered more reliable due to the presence of potentially *in situ* peats.

- Many Beaufort Sea coast and shelf depositional processes complicate the interpretation of the radiocarbon data, such as river-eroded tundra redeposited at delta fronts, collapsed thaw lake banks recycled as lagoon peat, storm surges, and migrating barrier islands. In spite of these interpretive problems, regional correlations suggest the following Holocene paleo-sea levels for the Alaskan Beaufort Sea shelf: below or at 50 m bsl = 11,000 years B.P.; flooding of the Bering Strait after 10,500 years B.P.; rapid sea level rise from 44 to 18/16 m bsl = between 9,000 and 7,500 years B.P.; 12 m bsl by 6,000 years B.P.; and near modern levels (within 2 m bsl) by 5,000 years B.P.

6.0 RECOMMENDATIONS

Based on the review of industry site and USGS geophysical data, there are a number of locations in the nearshore Beaufort Sea shelf where paleolandforms potentially prospective of an early Holocene age have been identified, but data are either too sparse or conflicting to categorically determine their age. Although dating of these landforms could be fraught with depositional context issues similar to those described in Appendix E, previous dating studies did not specifically target paleolandforms using the selection criteria presented below (Section 6.1) or the specific sites described in Section 6.3, and additional dates could, at a minimum, constrain the landforms as Pleistocene or Holocene for the purposes of MMS' archaeological resources protection program. The following sections provide recommendations for additional seismic data and core locations that could help fill existing data gaps at identified paleolandforms.

6.1 Rationale for Paleolandform Selection

The recommendations focus on paleolandforms that are relatively clear on existing seismic data, are preserved beneath a protective sediment cover, may be terrestrial in nature, and are likely to be early Holocene in age. These include: (1) buried channels with possible channel-edge features, (2) the landward side of buried paleo-shorelines, (3) terraced sides of buried peat-bogs or lagoons, and (4) buried relict islands or coastal ridges that may contain terrestrial material. The recommendations do not focus on buried channels likely to be within a Pleistocene section, buried channels cut by an erosional surface at the top, lake or lagoon bottoms, shoals or wave-cut terraces at the seafloor surface, or buried barrier islands or sand bars that are likely to consist of reworked marine sand.

6.2 Seismic Data

Collection and review of shallow high resolution geophysical data is recommended as described below to further identify the extent of potential landforms related to subsurface peat deposits.

Liberty. One sub-bottom geophysical line was collected along the western pipeline route in the area of buried peat deposits. Only surface geophysics (fathometer, side-scan sonar) were run along most of the tracklines in this area. It is recommended that additional seismic data be collected in a grid pattern across the mapped peat area to potentially define the lateral extent of paleolandforms related to these organic deposits.

Northstar. There is no sub-bottom geophysical data coverage for the subsurface organic deposits mapped inshore of the barrier islands at the Northstar site. It is recommended that seismic data be collected in a grid pattern in this area.

A USGS seismic line extending northeasterly across the peat area offshore of the barrier islands yielded the shape of a prospective Holocene depression corresponding with peat in a geotechnical boring (Section 3.7.2, Appendix I). A single north-south seismic line collected by BP Exploration along the offshore pipeline route was not available for review during this study. It is recommended that an attempt be made to obtain and review additional USGS geophysical data from 1970 and 1972 that cross the area. If these data are unavailable or inconclusive, additional seismic data should be collected in a grid pattern across the area to potentially define paleolandforms related to the organic deposits.

Additional USGS Data Review. It is recommended that USGS high resolution seismic data from the 1970s and 1980s, including missing lines from 1979 (Section 2.5), be systematically reviewed in areas less than 20 m water depth for evidence of paleolandforms before finalizing boring locations. Obtaining and reviewing all previously collected USGS shallow seismic data was beyond the scope and resources of this study. The review method for the available 1979 data was potentially subject to missing feature details due screening and printing from microfiche, and was limited in locational accuracy due to the lack of published shotpoint maps. It is recommended that a request be made to USGS in Menlo Park, California to borrow original trackline charts and seismic data for copying prior to the review. The

NGDC also has some USGS high resolution seismic data available for purchase (years 1977 and 1978 only) (NGDC 1985, 2005b).

If, following the additional review of USGS seismic data, more landforms are identified, or the accuracy of the landforms identified on the 1979 data is still questionable, additional seismic data collection should be considered at specific sites prior to completing the recommended borings described in Sections 6.3.2 and 6.3.3.

6.3 Boring Locations

Several borings are recommended at paleolandforms that exhibit the potential for possible early Holocene terrestrial features (Section 6.1). The boring recommendations are prioritized on the basis of data coverage and confidence level as follows: (1) industry sites, (2) current federal lease areas, and (3) other nearshore locations not at industry sites or lease areas.

6.3.1 Industry Sites

Fireweed. One boring is recommended on the landward side of the mapped paleo-shoreline at the Fireweed-ARCO site (Section 3.2.3, Figure 3, Appendix B). Borings are not recommended on the buried sand bars as they are likely to contain mostly reworked marine sand.

Liberty. It is preliminarily recommended that two borings be drilled in the following areas of potential paleo-terraces adjacent to (1) the peat bog or lagoon feature along the west pipeline route and (2) the buried channel in the northeast corner of the site (Figure 4). The location of the recommended borings may be revised following collection and interpretation of seismic data described in Section 6.2.

> (1) This boring or borings could be located next to DM&A (1998) Boring D-9, which encountered 2 m of fibrous peat 1.1 to 3.0 m below mudline (6.1 to 7.9 m bsl). The boring should extend to a total depth of about 13 m to confirm the presence of presumably Pleistocene clay and gravel in nearby borings (e.g., Boring B-9). Logs of DM&A (1998) Borings B-9, D-9, and D-10 are provided in Appendix C.
>
> (2) This boring(s) should be located on the northeast side of the buried channel located in the northeast corner of the Liberty and Tern Island sites. This side of the channel appears to have multiple terrace-like features both within and at the base of the presumed Holocene unit between about 1 and 2.5 m below the seafloor (Appendix C). The boring should extend to a total depth of about 5 m to confirm the presence of presumably Pleistocene deposits below 2.5 m.

Mars. One boring is recommended on one of the two mapped linear features shown on Figure 3 and described in Section 3.2.6. The seismic data suggest that these may be relict coastal ridges with the potential to contain terrestrial material (Appendix B), rather than reworked barrier island deposits.

Northstar. Due to the lack of available seismic data coverage along the Northstar pipeline route, the geomorphic expression of the identified organic deposits is unknown. Thus, bog- or lagoon-edge features which could be prospective for preserved archaeological sites cannot be targeted. It is preliminarily recommended that two borings be drilled in the areas of thickest peat/organic silt occurrences, one located in each of the mapped areas inshore and offshore of the barrier islands (Figure 4). The location of the recommended borings may be revised following collection and interpretation of seismic data described in Section 6.2.

(1) The inshore boring could be located next to DM&A (1996) Boring PS-3, which encountered 1.2 m of organic silt 2.8 to 4.0 m below mudline (4.0 to 5.2 m bsl). The boring should extend to a total depth of about 7 m to confirm the presence of presumably Pleistocene gravel and sand encountered at about 5.8 m below mudline.

(2) The offshore boring could be located close to Boring TC-4, which encountered 1.2 m of fibrous peat 2.8 to 4.0 m below mudline (10.7 to 11.9 m bsl). The proposed boring should extend to a total depth of about 10 m to confirm the presence of presumably Pleistocene gravel and sand encountered in nearby borings (e.g., Boring TC-2).

Logs of DM&A (1996) Borings PC-3, TC-2, and TC-4 are provided in Appendix C.

Sandpiper. One boring is recommended on the buried relict island located beneath Loon Shoal in the center of the Sandpiper site (Figure 4, Section 3.2.11, Appendix B). Although likely to be constructed of primarily of reworked marine sand, this feature is the largest of the buried islands and ridges mapped across the Beaufort Sea shelf, and has more potential to contain terrestrial material than other such features.

Warthog. One boring is recommended on the side of one of the mapped channels in the center of the Warthog site (Figure 5, Section 3.2.12, Appendix B).

6.3.2 Federal Lease Areas

The following borings are recommended in or near the federal lease areas offshore of Reindeer, Cross, and Narwhal Islands.

(1) One boring along the south edge of the flat-bottomed paleo-depression offshore of Reindeer Island (Figure 4, Section 3.7.2).

(2) Three borings northeast of Cross and Narwhal Islands on the banks of buried late Pleistocene-Holocene channels that show potential channel-edge features within possible lower Holocene materials. These sites are located about 2-1/2 km northeast of Cross Island, about 7 km northeast of Cross Island, and about 9 km north of Narwhal Island (Figure 4, Section 3.7.4).

6.3.3 Inshore of Barrier Islands

One additional boring is recommended on the flank of the possible paleo-shoreline or ridge in Mikkelson Bay (Figure 4, Section 3.7.5).

6.4 Stratigraphic and Laboratory Analyses

It is recommended that detailed stratigraphic evaluation of the continuous core material collected at the recommended boring locations be conducted to identify sedimentary structures, facies relationships, environment of deposition, and potential *in situ* terrestrial material. Organic material or identifiable terrestrial shell material collected from potential *in situ* deposits should be subsampled and analyzed for ^{14}C by AMS methods. It is not recommended that potentially reworked organic material or marine shell material be analyzed. Micropaleontologic analysis of the core material should be considered to complement the environment of deposition and radiocarbon results.

7.0 CONTACTS AND LITERATURE CITED

Alaska Heritage Resources Survey (AHRS). n.d. Alaska Heritage Resources Survey files maintained by the Office of History and Archaeology, Department of Natural Resources, Anchorage.

Alexander, H.L. 1987. Putu: A fluted point site in Alaska. Simon Fraser Department of Archaeology, Publication No. 17. Burnaby, British Columbia: Simon Fraser University. 47 pp.

Anderson, D.D. 1968. A stone age campsite at the gateway to America. 1968. Sci. Amer. 218 (6):24-33.

Anderson, D.D. 1970. Microblade traditions in Northwestern Alaska. Arctic Anth. 7(2):2-16.

Anderson, D.D. 1988. Onion Portage: The archaeology of a stratified site from the Kobuk River, Northwest Alaska. Anth. Papers of the Univ. of Alaska 22(1-2). 163 pp.

Arctic Geoscience, Inc. 1997. U.S.G.S. geophysical trackline compilation. Prep. for BP Exploration, Alaska and U.S. Geological Survey. Project No. 96-0174. Map scale 1:750,000. Mar.7.

Arctic Geoscience, Inc. 2000a. Geotechnical and high resolution geophysical investigation site data report. Prep. for Phillips Alaska, Inc. June 9.

Arctic Geoscience, Inc. 2000b. Pre-historic archaeological assessment of the Phillips Alaska Inc.'s McCovey Prospect, Beaufort Sea, Alaska. Rept. prep. for Phillips Alaska Inc. Dec.

Arctic Geoscience, Inc. 2000c. Technical survey, Phillips Alaska, Inc.'s McCovey Prospect, Beaufort Sea, Alaska, Two Volumes. Nov.

Arctic Geoscience, Inc. 2001. Technical response, geohazards data presentation and transfer "supplement" to the technical addendum – Geohazards Survey. Prep. for Phillips Alaska, Inc. Jan. 4.

Barber, T., Alaska Department of Transportation & Public Facilities (DOT&PF), Statewide Materials Laboratory. 2003. Verbal communication, re: extent of sample coverage for North Slope; nothing available offshore. Sept. 4.

Barnes, P., U.S. Geological Survey, Menlo Park, CA. 2004. Verbal Communication, re: Subdivision and disposition of 1976-79 vibracores; 1976-77 cores stored in 10 cm sample bags; 1979 cores no longer available. Aug. 18.

Barnes P. and E. Reimnitz, U.S. Geological Survey, Menlo Park, CA. 2004. Verbal communication, re: USGS vibracore cruises in 1970s and limitation of data due to gouging and scour.

Barnes, P., E. Reimnitz, L. Toimil, D. Maurer, and D. McDowell. 1979. Core descriptions and preliminary observations of vibracores from the Alaskan Beaufort Sea Shelf. U.S. Geological Survey Open-File Report 79-351. 12 pp. plus appendix.

Barnes, P., E. Reimnitz, E. Kempema, P. Minkler and R. Ross. 1980. U.S.G.S. marine geologic studies in the Beaufort Sea, Alaska, 1979; Data Type, Location, and Records Obtained. U.S. Geological Survey Open-File Report 80-603. 4 pp., 3 plates.

Bauch, H.A., T. Mueller-Lupp, E. Taldenkova, R.F. Spielhagen, H. Kassens, P.M.Grootes, J.Thiede, J. Heinemeier and V.V. Petryashoy. 2001. Chronology of the Holocene transgression at the North Siberian margin. Global and Planetary Change 31:125-139.

Beechey, F.W. 1831. Narrative of a voyage to the Pacific and Bering's Strait, in the years 1825, 26, 27, 28. London, England: Henry Colburn and Richard Bentley. 2 vols. 742 pp.

Bever, M.R. 2000. Paleoindian lithic technology and landscape use in late Pleistocene Alaska: A study of the Mesa complex. Ph.D. Diss. Southern Methodist Univ., Dallas, Tex. 429 pp.

Bever, M.R. 2001. An overview of Alaskan late Pleistocene archaeology: historical themes and current perspectives. Jour. of World Prehis. 15:125-191.

Bergman, S. 1997. 14C ages of Warthog site survey seabed cores. Internal Memo, Atlantic Richfield Co., ARCO Exploration and Production Technology. Oct. 19. 3 pp.

Bicol, Arnel, geotechnical engineer with URS Corporation (formerly Dames & Moore), Los Angeles, California. 2005. Email communication, re: geotechnical core material from Mars or other D&M sites in Beaufort Sea not archived. May 11.

Bockstoce, J. 1986. Whales, ice and men: the history of whaling in the western arctic. Univer. of Wash. Press, Seattle, Wash. 400 pp.

Bowers, P.M. 1982. The Lisburne site: analysis and culture history of a multi-component lithic workshop in the Iteriak Valley, Arctic Foothills, Northern Alaska. Anth. Papers of the Univ. of Alaska 22(1-2):70-112.

Bowers, P.M. 1983. A status report on the Gallagher Flint Station National Historic Landmark. Unpl. MS. USDOI-Bureau of Land Management, Arctic Resource Area, Fairbanks, Alaska. 21 pp.

Bowers, P.M. 1991 Cultural resources assessment of proposed oil and gas exploration activities, Beaufort Sea, Northern Alaska. Technical Report 3. Northern Land Use Research, Inc., Fairbanks, Alaska. Report prepared for ENSR Consulting and Engineering, Anchorage, Alaska. 12 pp.

Bowers, P.M. 1992. 1992 archaeological survey of proposed oil and gas exploration activities, Beaufort Sea, Northern Alaska. Technical Report 15. Northern Land Use Research, Inc., Fairbanks, Alaska. Report prepared for ENSR Consulting and Engineering, Anchorage, Alaska. 8 pp.

Bowers, P.M. 1999 AMS dating of the area 22 American Paleoarctic tradition microblade component at the Lisburne site, arctic Alaska. Current Research in the Pleistocene 16:12-14.

Bowers, P.M., O.K. Mason and J.L. Cox. 2001. A preliminary review of cultural resource potential and proposed 2001 Beaufort Sea geophysical surveys. Northern Land Use Research, Inc., Fairbanks. Unpublished proprietary report prepared for North American Natural Gas Pipeline Group, Anchorage, Alaska. Mar. 20th.

Brigham-Grette, J. University of Massachusetts. 2004. Verbal communication, re: status of Chukchi Sea research and core storage possibilities. June.

Brown, J. and J.V. Sellmann. 1966. Radiocarbon dating of coastal peat, Barrow, Alaska. Sci. 153:299-300.

Campbell, J.M. 1962 Cultural succession at Anaktuvuk Pass, arctic Alaska, pp. 39-54. *In* J.M. Cambell. Prehistoric cultural relations between the arctic and temperatezones of North America. Technical Paper No.11. Montreal, Quebec: Arctic Institute of North America. 182 pp.

Campeau, S., A. Héquette and R. Pienitz 2000. Late Holocene diatom biostratigraphy and sea-level changes in the southeastern Beaufort Sea. Canad. Jour. of Earth Sci. 37:63-80.

Carter, L.D. 1981. A Pleistocene sand sea on the Alaskan Arctic Coastal Plain. Sci. 211:381-383.

Choromanski, D., D. Thurston, M. Hope and M. Stright. 1997. Archaeological assessment of Warthog Prospect, Camden Bay, Beaufort Sea, Alaska. Report prepared by MMS Archaeological Working Group and Chief Archeologist, MMS. Oct. 30. 7 pp.

Coastal Frontiers Corporation (CFC). 1996a. Northstar Development preliminary pipeline route survey, August 1995. Final Report prepared for BP Exploration (Alaska), Inc., Anchorage, Alaska. Ref. CFC-334-95. June.

CFC. 1996b. Northstar test trench geophysical profiling report. Report prepared for BP Exploration (Alaska), Inc., Anchorage, Alaska.

CFC. 1997. Northstar Development 1996 pipeline route survey. Final report prepared for BP Exploration (Alaska), Inc., Anchorage, Alaska. Ref. CFC-350-96. July 22.

CFC. 1998. Northstar Development 1997 pipeline route survey. Final report prepared for BP Exploration (Alaska), Inc., Anchorage, Alaska. Ref. CFC-364-96. Oct.

CFC. 1999. Northstar Development 1998 pipeline route survey. Final report prepared for BP Exploration (Alaska), Inc., Anchorage, Alaska. Ref. CFC-419-98. June.

Comap Geosurveys, Inc. (Comap). 1985. Geological hazards survey, Fireweed Prospect, Harrison Bay, Beaufort Sea, Alaska, Covering Tracts 71-7, 71-11 and 71-12. Report prepared for ARCO Exploration Co., Anchorage, Alaska. Jan.

Croley, C., geotechnical engineer, MACTEC Engineering & Consulting, Inc. (formerly Harding Lawson Associates), Anchorage, AK. 2004. Verbal communication, re: Karluk, Tern Island, or other HLA sites' core material not saved; not standard oil company practice to save core material. Sept. 28.

Dames & Moore. 1983a. Potential geologic hazards and constraints, Fur Seal Island site, Block NR 5-4-370, Lease OCS Y-0353, Tract 71-220, Harrison Bay, Beaufort Sea, Alaska. Report prepared for Texaco USA. Nov. 28 pp.

Dames & Moore. 1983b. Potential geologic hazards and constraints, Mukluk Island site OCS Y-0334 Block NR5-4 280, Lease Sale OCS 4-0334, Harrison Bay, Beaufort Sea, Alaska. Report prepared for Sohio Alaska Petroleum Company. Apr. 25 pp.

Dames & Moore. 1983c. Potential geologic hazards and constraints, Sandpiper Island Exploration site, Block NR 6-3-424, Lease OCS Y-370, Tract 71-322. Report prepared for Shell Oil Company. D&M Job No. 0216-267-20. 26 pp. Dec.

Dames & Moore. 1984. Potential geologic hazards and constraints, prospect: Block NR 5-2-883/Vicinity Near Cape Halkett, Beaufort Sea, Alaska. Report prepared for Shell Western E & P, Inc., Anchorage, Alaska.

Dames & Moore. 1985a. Potential geologic hazards and constraints, prospect: Block NR-6-4-678 Vicinity, Camden Bay, Alaska. Report prepared for Union-Shell-Amoco Bidding Group. Apr.

Dames & Moore. 1985b. Potential geologic hazards and constraints, prospect: Block NR7-3-705/Vicinity, Camden Bay Area, Beaufort Sea, Alaska. Report prepared for Union-Shell-Amoco Bidding Group. Apr.

Dames & Moore. 1985c. OCS Mars Y-0302 potential geologic hazards and constraints Block NR5-4-140/ Vicinity near Cape Halkett, Beaufort Sea, Alaska. Report prepared for Amoco Production Company. Oct..

Davis, C., D. Linck, K. Schoenberg and H. Shields. 1981. Slogging, humping and mucking through the NPR-A: an archaeological interlude. Occasional paper No. 25. Fairbanks, Alaska: Anthropology and Historic Preservation, Cooperative Park Studies Unit, University of Alaska, Fairbanks. 5 vols. 329 pp.

Davis, R.A. 1994. Geology of Holocene barrier island systems. Berlin, Germany: Springer-Verlag.

Deepsea Development Services. 1993. Shallow hazards report, Kuvlum Prospect, Beaufort Sea, Alaska. Report prepared for ARCO Alaska, Inc., Anchorage, Alaska. Jan. 18. 73 pp.

Deepsea Development Services. 1994. Shallow hazards report, Wild Weasel Prospect, Beaufort Sea, Alaska. Report prepared for ARCO Alaska Inc., Anchorage, Alaska. January 20. 65 pp.

Dekin, A.A., R.R. Newell, E.S. Hall, Jr., L. Bower, J. Cargill, R. Gill, R. Holloway, D. Libbey, J. Lobdell, J. Lothrop, R. Miraglia, R. Reanier, G. Reynolds, T. Smith, B.L. Turcy, C.G. Turner, C. Utermohle and T. Webster. 1981. The Utkiavik Excavations, Volume 1. Barrow, Alaska: North Slope Borough Commission on Iñupiat History, Language and Culture. 579 pp.

Denfield, D.C. 1994. The Cold War in Alaska: a management plan for cultural resources, 1994-1999. Anchorage, Alaska : U.S. Army Corps of Engineers, Alaska District. 327 pp.

Devoy, R.J.N. 1987. Sea surface studies: a global view. London, England: Croom Helm.

Dinter, D.A, L.D. Carter and J. Brigham-Grette 1990. Late Cenozoic geologic evolution of the Alaskan North Slope and adjacent continental shelves. *In* A. Grantz, L. Johnson, and J.F. Sweeney, pp. 459-490. The geology of North America, vol. L, The Arctic Ocean region. Boulder, Colorado: Geological Society of America.

Dixon, E.J., Jr. 1975. The Gallagher Flint Station, an early man site on the North Slope, Arctic Alaska, and its role in relation to the Bering Land Bridge. Arctic Anth. 12(1):68-75.

Dixon, E.J., Jr. 1983. Pleistocene proboscidean fossils from the Alaska Outer Continental Shelf. Quat. Res. 20:113-119.

Dixon, E.J., Jr. 1989. Reassessing the occurrence and survival of submerged terrestrial archaeological sites on the Bering Continental Shelf, pp. 21-24. *In* J.B. Arnold. Underwater Archaeological Proceedings from the Society for Historical Archaeology Conference, Baltimore.

Dixon, E.J., Jr., G.D. Sharma and S.W. Stoker. 1978. Beaufort Sea cultural resources study, final report, vol. 1. University of Alaska Museum, Fairbanks, Alaska. Report prepared for the Bureau of Land Management, Alaska Outer Continental Shelf Office, Anchorage. Contract AA550-CT7-40. June.

Duane Miller & Associates (DM&A). Existing geotechnical data, Northstar Development, North Slope, Alaska. Report prepared for BP Exploration (Alaska), Inc., Anchorage, Alaska. DM&A Job No. 4119.13. Dec. 2. 10 pp.

DM&A. 1996. 1996 geotechnical investigation, Northstar Development, Beaufort Sea, Alaska. Report prepared for BP Exploration (Alaska), Inc., Anchorage, Alaska. May 31.

DM&A. 1997. 1997 geotechnical exploration Liberty Development Project, Foggy Island Bay, Alaska. Report prepared for BP Exploration (Alaska), Inc., Anchorage, Alaska. Sept. 10.

DM&A. 1998. 1998 geotechnical exploration Liberty Development, North Slope, Alaska. Report prepared for BP Exploration (Alaska), Inc., Anchorage, Alaska. July 6.

DM&A. 1999. 1999 geotechnical investigation Northstar Development, Beaufort Sea, Alaska. Report prepared for BP Exploration (Alaska), Inc., Anchorage, Alaska. Aug. 15.

Dumond, D.E. 1987. The Eskimos and Aleuts. Revised Edition. London, England: Thames and Hudson. 180 pp.

Dyke, A.S., J.E. Dale and R. McNeely 1996. Marine mollusks as indicators of environmental change in glaciated North America and Greenland during the last 18,000 years. Géographie physique et Quaternaire 50(2):125-184.

EBA Engineering, Inc. (EBA). 1991a. ARCO Cabot No. 1 Prospect, geotechnical site investigation, vols. 1 through 3. Report prepared for ARCO Alaska, Inc., Anchorage, Alaska. EBA Job No. 0211-0196. June.

EBA. 1991b. ARCO Cabot No. 1 Prospect, high resolution geophysical review, shallow geohazards assessment. Report prepared for ARCO Alaska, Inc., Anchorage, Alaska. EBA Job No. 0218-0201. Aug.

EBA. 1996. 1996 geotechnical investigation Warthog Prospect, Beaufort Sea, Alaska. Report prepared for ARCO Alaska, Inc., Anchorage, Alaska. July 8.

ENSR Consulting and Engineering (ENSR). 1990. Fireweed Report of Geotechnical DataAcquisition and Analyses Document 0480-092-400. Rept. prep. for ARCO Alaska, Inc. September.

Elias, S.A., S.K. Short and R.L. Phillips. 1992. Paleoecology of late glacial peats from the Bering Land Bridge, Chukchi Sea. Quat. Res. 38:371-378.

Faas, R.W. 1964. A study of some late Pleistocene estuarine sediments near Barrow, Alaska. Unpub. Ph.D. Thesis. Dept. of Geo. Iowa State Univ. of Sci. and Tech. Ames, Iowa.

Faas, R.W. 1966. Paleoecology of an arctic estuary. Arctic 19: 343-348.

Fairweather E&P Services, Inc. (Fairweather). 1997a. Warthog No. 1, Camden Bay, Beaufort Sea, shallow hazard survey results. Report prepared for ARCO Alaska, Inc., Anchorage, Alaska.

Fairweather. 1997b. Final report, Warthog Prospect winter geotechnical and bathymetric programs. Report prepared for ARCO Alaska, Inc., Anchorage, Alaska. 10 pp.

Farley, Katy, State of Alaska Joint Pipeline Office (JPO). 2005. Verbal communication, re: no storage of core material from offshore geotechnical borings at JPO. May 20.

Ferguson, D. 1997. Gallagher Flint Station Locality 1: a reappraisal of a proposed late Pleistocene site in the Sagavanirktok River Valley, Arctic Alaska. Unpub. M.A. Thesis. Dept. of Anth. Univ. of Alaska, Fairbanks, Alaska.

Ford, J. 1959 Eskimo prehistory in the vicinity of Point Barrow, Alaska. Anth. Papers of the Amer. Mus. of Nat. His. 39. New Yory, New York: Amer. Mus. Of Nat. Hist.

Frazee, Cathy, refrigerated core curator, USGS, Menlo Park, California. 2004. Email and verbal communications, re: general core availability and access at USGS, and status of cores from 1985 USGS cruse. July 9 through Dec. 3.

Forbes-Kerslake, C., Technician, Alaska Testing Laboratories. Verbal Communication, re: Disposition and unavailability of McCovey core samples. July 29.

Friddell, Julie, Research Geophysicist, ERDC–Cold Regions Research and Engineering Laboratory (CRREL), U.S. Army Corps of Engineers, Hanover, New Hampshire. 2004. Email and verbal communications, re: no cores located from 1979 USGS/HLA study, and no cores from Alaska in general at CRREL in New Hampshire. Jan. 5 and Apr. 26.

Fugro-McClelland Marine Geosciences, Inc. 1990. Cabot Prospect high resolution geophysical survey and assessment of potential shallow drilling hazards, Dease Inlet (NR 5-1) Blocks 688/689 OCS-Y-0747/Y-0748, Beaufort Sea, Alaska. Report prepared for Exxon Company USA. Mar.

Fugro-McClelland Marine Geosciences, Inc. 1992. Shallow hazards report, Blocks 673 and 674, NR-6-4, Beaufort Sea, Alaska. Report prepared for BP Exploration. 14 pp.

Fujita, K., D.B. Cook, H.Hasegawa, D. Forsyth and R. Wetmiller 1990. Seismicity and focal mechanisms of the Arctic region and the North American plate boundary in Asia. *In* A. Grantz, L. Johnson, and J.F. Sweeney. The geology of North America, vol. L, the Arctic Ocean region, pp. 79-100. Boulder, Colo.: Geological Society of America.

Gardner, Robert, past president, Fairweather E&P Services, and former employee, Northern Technical Services/ENSR. 2004. Verbal communication, re: geotechnical coring investigations at Warthog and Fireweed, and lack of existing core material. Mar. 17.

Gerlach, S.C. 1989. Models of caribou exploitation, butchering, and processing at the Croxton Site, Tukuto Lake, Alaska. Ph.D. Diss. Brown University, Providence, Rhode Island.

Gerlach, S.C. and E.S. Hall, Jr. 1988. Later prehistory of Northern Alaska: the view from Tukuto Lake, pp. 107-135. *In* R.D. Shaw, R.K. Harrit and D.E. Dumond. The late orehistoric development of Alaska's Native people. Aurora Monograph Series 4. Anchorage, Alaska: Alaska Anthropological Association.

Gerlach, S.C. and O. K. Mason. 1992. Calibrated radiocarbon dates and cultural interaction in the western arctic. Arctic Anth. 29(1):54-81.

Giddings, J.L. 1957. The tenuous Beaufort Sea archaeology, pp. 94-99. *In* Proceedings of the Fifth Alaskan Science Conference. Fairbanks. Alaska.

Giddings, J.L. 1964. The archeology of Cape Denbigh. Providence, Rhode Island: Brown University Press. 331 pp.

Giddings, J.L. 1968. Ancient men of the arctic. London, England: Secker and Warburg. 442 pp.

Gubser, N. 1965. The Nunamiut Eskimos: hunters of caribou. New Haven, Conn.: Yale Univ. Press. 384 pp.

Hall, E.S., Jr. 1976. A preliminary analysis of house types at Tukuto Lake, Northern Alaska, pp. 98-134. *In* E. S. Hall, Jr. Contributions to Anthropology: The Interior Peoples of Northern Alaska. National Museum of Man Mercury Series, Archaeological Survey of Canada Paper No. 49. Ottawa, Ontario: Canadian Museum of Civilization, Ottawa.

Hall, E.S., Jr. 1981 Cultural resources in the mid-Beaufort Sea region, part II: cultural resource site potential. Hall and Associates, Brockport, New York. Report prepared for the North Slope Borough's Coastal Zone Management Plan. North Slope, Barrow, Alaska.

Hall, E.S., Jr. 1987. A land full of people, a long time ago: an analysis of three archaeological sites in the vicinity of Kaktovik, Northern Alaska. Technical Memorandum #24. Edwin S. Hall and Associates, Brockport, New York. 360 pp.

Hall, E.S., Jr. and R. Gal. 1988. The U.S. Geological Survey-Bureau of Land Management Cultural Resources Program in the National Petroleum Reserve in Alaska, 1977-1981, pp. 859-897. *In* G. Gyrc. Geology and exploration of the National Petroleum Reserve in Alaska, 1974 to 1982. U.S. Geo. Surv. Prof. Paper 1399. Washington D.C.: U.S. Govt. Print. Office.

Harding-Lawson Associates (HLA). 1979. USGS geotechnical onvestigation, Beaufort Sea - 1979. Report prepared for the U.S. Geological Survey Conservation Division, HLA Job No. 9619,005.08, Contract No. 14-08-0001-17718. July. 36 pp. plus app.

HLA. 1981. (Tern Island) Geotechnical investigation, Tract 42 Well Site. Report prepared for Shell Oil Company, Inc. Dec.

HLA. 1983a. Geophysical and geotechnical site evaluation of OCS Leases Y-0279 and Y-0280, Beaufort Sea, Alaska. Report prepared for Exxon Company USA, HLA Job No. 13167,001.01. July 5. 41 pp.

HLA. 1983b. Geotechnical investigation, Sand Piper Island, Beaufort Sea, Alaska. Report prepared for Shell Oil Company, HLA Job No. 9644,016.48. Nov. 22. 14 pp.

HLA. 1983c. Mukluk Island site investigation. Unpublished proprietary report prepared for Sohio Construction Co.

HLA. 1985. Geophysical and geotechnical site evaluation, OCS Lease Y-0804, Orion Prospect, Beaufort Sea, Alaska. Report prepared for Exxon Company USA, HLA Job No. 4167,107.09. July 15. 32 pp.

HLA. 1988. Geophysical and geotechnical site evaluation, Karluk Prospect, Beaufort Sea, Alaska. Report prepared for Chevron U.S.A. Inc., HLA Job No. 9611,282.08.

Hequette, A. and P.W. Barnes. 1990. Coastal retreat and shoreface profile variations in the Canadian Beaufort Sea. Marine Geo. 91:113-132.

Hill, P.R., A. Hequette and M. Ruz. 1993. Holocene sea level of the Canadian Beaufort shelf. Canad. Jour. of Ear. Sci. 30:103-108.

Hoffman, D., D. Libbey and G. Spearman. 1988. Nuiqsut: study of land use values through time. Revised edition. Anchorage, Alaska: North Slope Borough. 89 pp.

Hopkins, D.M. 1949. Thaw lakes and thaw sinks in the Imuruk lake area, Seward Peninsula, Alaska. The Jour. of Geo. 57(2):105-118.

Hopkins, D.M.. 1967. Quaternary marine transgressions in Alaska, pp. 47-90. I*n* D.M. Hopkins. The Bering Land Bridge. Menlo Park, Calif.: Stanford University Press.

Hopkins, D.M., J.V. Matthews, Jr., C.E. Schweger, S.B. Young and V. Stanley. 1982. Paleoecology of Beringia. New York, New York: Academic Press. 489 pp.

Hopkins, D.M. and J.G. Kidd. 1988. Thaw lake sedimentation and sedimentary environments, pp. 790-795. *In* K. Senneset. Permafrost: 5th International Conference, proceedings, vol. 1. Trondheim, Norway: Tapir Publ.

Hopkins, D.M. and R.W. Hartz. 1978. Coastal morphology, coastal erosion and barrier islands of the Beaufort Sea, Alaska. Open File Report 78-1063. Menlo Park, Calif.: U.S. Geological Survey.

Hopkins, D.M. and S.W. Robinson. 1981. Radiocarbon dates from the Beaufort and Chukchi Sea coasts, pp. B44-46. *In* K.M. Johnson and J.R. Williams. The United State Geological Survey in Alaska: Accomplishments during 1978. Arlington, Virg.: U.S. Geological Survey, Arlington, VA.

Hume, J.D. 1965. Sea-level changes during the last 2000 Years at Point Barrow, Alaska. Sci. 150:1165-1166.

Hume, J.D. and M. Schalk. 1967. Shoreline processes near Barrow, Alaska: a comparison of the normal and the catastrophic. Arctic 20:86-103.

Hunter, R.E. and T.E. Reiss. 1984. Inner shelf geology of southeastern Chukchi Sea, pp. 97-124. *In* Outer Continental Shelf Environmental Assessment Program, Final Reports of Principal Investigators 34, National Oceanic and Atmospheric Administration, Alaska office, Anchorage, Alaska.

Intec Engineering, Inc. (Intec). 1998a. Pipeline design basis, Northstar Development Project, detailed engineering. Report prepared for BP Exploration (Alaska), Inc., Anchorage, Alaska. Intec Project No. H-0660.03.Technical Note TN331, Rev. 1. May.

Intec. 1998b. Trench and pipe stability, Northstar Development Project, detailed engineering. Report prepared for BP Exploration (Alaska), Inc., Anchorage, Alaska. Intec Project No. H-0660.03. Technical Note 470, Rev. 1. May. 11 pp.

Intec. 1998c. Winter test trench summary, Northstar Development Project, detailed engineering. Report prepared for BP Exploration (Alaska), Inc., Anchorage, Alaska. Intec Project No. H-0660.03. Technical Note TN660, Rev. 2. May. 5 pp.

Irving, W.N. 1952. An archaeological reconnaissance of the Lower Colville River and Delta Regions: final report for submission to the Chief of Naval Research. University of Alaska, Fairbanks.

Irving, W.N. 1964. Punyik Point and the Arctic Small Tool tradition. Ph.D. Diss. Univ. of Wisconsin, Madison, Wisc. 433 pp.

Ito-Adler, J.P. and E.S. Hall, Jr. 1986. The ones that are dead, I can call their names: cultural resources sites documented by the Beaufort Sea Coastal Survey. Technical Memorandum #23. Edwin S. Hall and Associates, Brockport, New York. 55 pp.

Jablonski, N.G. 2002. The first Americans: the Pleistocene colonization of the New World. Memoirs of the California Academy of Sciences No. 27. Berkley, Calif.: Univ. of California Press. 331 pp.

Jacubczak, Ray, BP Exploration (Alaska). 2004, Verbal communication, re: unlikelihood of geotechnical core material storage by BP. Dec. 2.

Jenness, D. 1914. Archaeological notes on Eskimo ruins at Barter Island on the Arctic Coast of Alaska excavated by Diamond Jenness in 1914. Unpub. MS. # 779 on file in the Archaeological Survey of Canada, National Museum of Civilization, Ottawa. 56 pp.

Jones, K., geotechnical engineer, EBA Engineering Consultants, Ltd., Edmonton, Alberta. 2004. Verbal communication, re: Core material no longer available for Cabot or Warthog; client did not retain split samples. August 11.

Jordan , J.W. and O.K. Mason. 1999. A 5000 yr record of intertidal peat stratigraphy and sea level change from Northwest Alaska. Quat. Inter. 60:37-47.

Jorgenson, T., E.R. Pullman, T.M. Zimmer, Y.I. Shur, A. Stickney and S. Li. 1996. Geomorphology and hydrology of the Colville River Delta, Alaska. Alaska Biological Research, Fairbanks, Alaska. Fifth annual report prepared for Arco Alaska, Inc., Kuukpik Unit Owners, Anchorage, Alaska.

Jorgenson, T., Y.I Shur and H.J. Walker. 1998. Evolution of a permafrost-dominated landscape on the Colville River delta, northern Alaska, pp. 523-528. *In* A.G. Lewkowicz and M. Allard. Proceedings of the 7th International Conference on Permafrost, Yellowknife, N.W.T., Canada.

Kunz, M.L. 1977. Mosquito Lake site (PSM-049), pp. 747-982. *In* J.P. Cook. Pipeline Archeology, Final Report. Fairbanks, Alaska: Institute of Biology, University of Alaska.

Kunz, M.L., M. Bever and C. Adkins. 2003 The Mesa site: Paleoindians above the Arctic Circle. BLM-Alaska Open File Report 86. Anchorage, Alaska: Alaska State Office, Bureau of Land Management. 82 pp.

Kunz, M.L. and R.E. Reanier. 1994. Paleoindians in Beringia: evidence from Arctic Alaska. Sci. 263:660-662.

Kunz, M.L. and R.E. Reanier. 1995. The Mesa site: a Paleoindian hunting lookout in Arctic Alaska. Arctic Anth. 32(1): 5-30.

Larsen, H.E. and F.G. Rainey. 1948. Ipiutak and the Arctic Whale Hunting Culture. Anthropological Papers of the American Museum of Natural History, vol. 42. New York, New York: American Museum of Natural History.

Lobdell, J.E. 1980. Coastal and Barrier Island archaeological localities in the Beaufort Sea of Alaska. Lobdell and Associates, Inc., Albuquerque, New Mex. Report to the Environmental Conservation Dept., ARCO Alaska, Inc., Anchorage, Alaska. 45 pp.

Lobdell, J.E. 1981. The Putuligayuk River Delta Overlook site: fragile traces of ancient man at Prudhoe Bay, Beaufort Sea, Alaska. Lobdell and Associates, Inc., Albuquerque, New Mex. Unpub. report to the Environmental Conservation Dept., ARCO Alaska, Inc., Anchorage, Alaska.

Lobdell, J.E. 1985. The Putuligayuk River Delta Overlook site: fragile traces of ancient man at Prudhoe Bay, Beaufort Sea, Alaska. Second Edition. Univ. of Alaska Anchorage Comm. Coll., Anchorage, Alaska. Report to the Environmental Conservation Dept., ARCO Alaska, Inc., Anchorage, Alaska. 175 pp.

Lobdell, J.E. 1986. The Kuparuk Pingo site: a Northern Archaic camp of the Arctic Coastal Plain, North Alaska. Arctic 39(1):47-51.

Lobdell, J.E. 1989. The Heald Point site (49-XBP-006): a reassessment. Lobdell and Associates, Inc., Albuquerque, New Mex. Report prepared for BP Exploration (Alaska), Inc., Anchorage, Alaska.

Lobdell, J.E. 1995. North Alaska pingos: ephemeral refugia in prehistory. Arctic Anth. 32(1):62-81.

MacDonald, R.W., A.S. Naidu, and M.B. Yunker 2004. The Beaufort Sea: Distribution, sources, fluxes and burial rates of organic carbon. In The Organic Carbon Cycle in the Arctic Ocean, edited by Ruediger Stein, and Robie W. MacDonald, pp. 177-192, Springer Verlag, Berlin.

Mann, D.H., D.M. Peteet, R.E. Reanier and M.L. Kunz. 2002. Responses of an arctic landscape to late glacial and early Holocene climate changes: the importance of moisture. Quat. Sci. Rev. 21:997-1021.

Marmaduke, W. and W.D. Watson. 1998. Liberty, cultural resource assessment, Foggy Island Bay in Stefansson Sound, Alaska. Watson Company, Inc., Anchorage, Alaska. Report prepared for BP Exploration (Alaska), Inc., Anchorage.

Mason, O.K. and J.W. Jordan. 1993. Heigthened North Pacific storminess and synchronous erosion at northwest Alaskan beach ridge complexes. Quat. Res. 40:55-67.

Mason, O.K. and J.W. Jordan. 2002. Minimal late Holocene sea level rise in the Chukchi Sea: arctic insensitivity to global change. Global and Planetary Change 32(1):13-23.

Mason, O.K., P.M. Bowers, and D.M. Hopkins. 2001. The early Holocene Milankovitch thermal maximum and humans: adverse conditions for the Denali complex of eastern Beringia. Quat. Sci. Rev. 20:525-548.

Matheus, P., M.L. Kunz and R. Dale Guthrie. 2003. Using frequency distributions of radiocarbon dates to detect relative changes in Pleistocene mammal populations – a test case from Northern Alaska. Paper presented at the 3rd International Mammoth Conference, White Horse, Yukon Territories, Canada.

Mathiassen, T. 1930. Archaeological collections from the Western Eskimos. Report of the Fifth Thule Expedition 1921-24, Vol. X. No. 1. Gyldendalske Boghandel, Nordisk Forlag, Copenhagen.

McClelland-EBA, Inc. 1983. Geotechnical investigation, Site 1, Block 370, Tract 71-220/Y-353, Harrison Bay, Alaska. Report prepared for Texaco, Inc. 29 p. Aug.

McClelland-EBA, Inc. 1986. High resolution geophysical survey and assessment of potential shallow drilling hazards, Phoenix Prospect, Harrison Bay Area (NR 5-4) Diapir Field, OCS Lease Sales 71 and 87, Beaufort Sea, Alaska. Report prepared for Tenneco Oil Company. Feb. 10 p.

McDougall, K., E. Brouwers and P. Smith. 1986. Micropaleontology and sedimentology of the PB Borehole Series Prudhoe Bay, Alaska. USGS Bulletin 1598. U.S. Geological Survey. 50 pp.

McManus, D.A. and J.S. Creager. 1984. Sea-level data for parts of the Bering-Chukchi shelves of Beringia from 19,000 to 10,000 ^{14}C yr B.P. Quat. Res. 21:317-325.

Miley, J.M. and P.W. Barnes. 1986. 1985 field studies, Beaufort and Chukchi Seas, conducted from the NOAA ship Discover. Open-File Report 86-202. U.S. Geological Survey. 57 p., 5 plates.

Miller, Duane, P.E., owner, Duane Miller & Associates. 2003. Verbal communication, re: Liberty and Northstar core material no longer in storage at Duane Miller & Associates, and typical one-year time period of core storage. Dec. 5.

Mineral Management Service (MMS), U.S. Department of the Interior, Alaska Outer Continental Shelf (OCS) Region. 2000. Letter to BP Exploration (Alaska), Inc., Re: Liberty Cultural Resources Report. 2 p. with encl. Aug. 31.

MMS. 2001. Letter to Phillips Alaska, Inc., Reference: Archaeological Report and Assessment for the McCovey Exploration Project OCS-Y 1577, Beaufort Sea, Alaska.

MMS. 2002. Evaluation of sub-sea physical environmental data for the Beaufort Sea OCS and incorporation into a Geographic Information System (GIS) database. User Manual and CD. OCS Study MMS 2002-017.

MMS. 2003a. Solicitation No. 0103RP72892, Subject: Determining the archaeological potential of buried terrestrial landforms in the Beaufort Sea: Review of existing geologic and geophysical data and analysis of existing cores. Aug. 25.

MMS. 2003b. Updated CD from OCS Study MMS 2002-017, with additional boring data added. Dec. 16.

Moore, G.W. 1960. Recent eustatic sea-level fluctuations recorded by Arctic beach ridges. *In* U.S. Geological Survey Research 1960, United States Geological Survey Professional Paper 40: b335-b337.

Murton, J.B. 1996. Thermokarst-lake-basin sediments, Tuktoyaktuk coastlands, Western Arctic Canada. Sedimentology 43:737-760.

Naidu, A.S. 1978. Sediment characteristics, stability, and origin of the barrier-lagoon complex, north Arctic Alaska. *In* Environment Assessment of the Alaskan Continental Shelf, volume X, Transport, Annual Report for Contract #03-05-022-56, pp. 628-686, National Oceanic and Atmospheric Adminstration. Boulder, Colorado: U.S. Department of Commerce.

Naidu, A.S., Institute of Marine Science, University of Alaska – Fairbanks (UAF). 2004. Verbal communication, re: past sediment coring investigations at UAF and unavailability of core material. March 12.

Naidu, A.S., T. Mowatt, S.E. Rawlinson and H.V. Wiess. 1984. Sediment characteristics of the lagoons of the Alaskan Beaufort Sea Coast, and evolution of Simpson Lagoon, pp.275-292. *In* P.W. Barnes, D.M. Schell and E. Reimnitz. The Alaskan Beaufort Sea Coast: Ecosystems, and Environments. Orlando, Flor.: Academic Press, Inc.

Naidu, A.S., J.J. Goering, J.J. Kelley, and M.I. Venkatesan. 2001. Historical changes in trace metals and hydrocarbons in the inner shelf sediments, Beaufort Sea: Prior and subsequent to petroleum-related industrial developments. OCS Study MMS 2001-061. University of Alaska Coastal Marine Institute, Fairbanks.

National Geophysical Data Center (NGDC), National Oceanic and Atmospheric Administration (NOAA). 1985. Seismic Reflection Data Announcement 85-MGG-03, High Resolution Seismic Reflection Data, Beaufort and Chukchi Seas-Alaskan OCS. USGS Open File Reports 82-33 & 81-34. www.ngdc.noaa.gov/mgg/fliers/85-MGG-03.

NGDC, NOAA. 2005a. Index to Marine and Lacustrine Geological Samples. Online database: www.ngdc.noaa.gov/mgg/curator/curator.html. Revised February 25.

NGDC, NOAA. 2005b. Marine Seismic Data Products. www.ngdc.noaa.gov/mgg/announcements/seismicdata.html. Revised March 31.

Nelson, C.H. and J.S. Creager. 1977. Displacement of Yukon-derived sediment from Bering Sea to Chukchi Sea during Holocene time. Geo. 5:141-146.

Nelson, C.H. 1982. Late Pleistocene-Holocene transgressive sedimentation in deltaic and non-deltaic areas of the northeastern Bering epicontinental shelf. Geologie en Mijnbouw 61(1):5-18.

Nelson, C.H., W.R. Dupré, M.E. Field and J.D. Howard. 1982. Variations in sand body types on the eastern Bering Sea, epicontinental shelf. Geologie en Mijnbouw 61(1):37-48.

Nelson, N.C. 1935. Early migrations of man to North America. Nat. Hist. 35:356.

Nelson, N.C. 1937. Notes on cultural relations between Asia and America. Amer. Antiq. 2(4):267-272.

Nelson, R.E., L. D. Carter and S.W. Robinson. 1988. Anomalous radiocarbon ages from a Holocene detrital organic lens in Alaska and their implications for radiocarbon dating and paleoenvironmental reconstructions in the Arctic. Quat. Res. 29(1):66-71.

Nittrouer, C.A. 1981. Sedimentary dynamics of continental shelves. Developments in Sedimentology, No. 32. Amsterdam: Elsevier Sci. Publ, Co. 449 pp.

North Slope Borough. 1996. The traditional land use inventory. North Slope Borough Commission on Iñupiat History, Language, and Culture, Barrow, Alaska.

Northern Land Use Research, Inc. (NLUR). 2003. Modification letter and study design, MMS Solicitation No. 0103RP72892, Review of Geological/Geophysical Data and Core Analyses, for Determining Archaeological Potential of Buried Landforms, Beaufort Sea, Alaska. 4 pp. Dec. 30.

Northern Technical Services (NTS). 1985. Hammerhead (624 & 625) Data Report NR 6-4 Federal OCS Lease Blocks, Beaufort Sea, Alaska OCSY 0849 & 0850. Report prepared for Union Oil Company of California. Feb.

O'Connor, M.J. 1982. Physiographic regions of the southern Beaufort Sea Shelf. Unpublished report by M.J. O'Connor Associates, Calgary, Alberta, for the Geological Survey of Canada, Dartmouth, Nova Scotia.

Pelagos Corporation. 1987. Aurora Prospect shallow hazards survey, OCS Y-0943, Block 890 (NR 7-3). Report prepared for Tenneco Oil Company. Sept. 14 pp.

Petrotechnical Resources of Alaska (PRA). 2002. Shallow geohazard investigation for McCovey Prospect, OCS Beaufort Sea, Alaska. Report prepared for EnCana Corp. Aug. 1. 15 pp.

Potter, B.A., P.M. Bowers, P.J. Kriz and J.D. Reuther. 2003. Cultural resources survey in NPR-A and Colville delta, 2003, Alaska. Technical Report 208. Northern Land Use Research, Inc., Fairbanks, Alaska. Report prepared for ConocoPhillips Alaska, Inc., Anchorage, Alaska. 72 pp.

Powers, W.R., R.D. Guthrie and J.F. Hoffecker. 1983 Dry Creek: archaeology and palaeoecology of a late Pleistocene Alaskan hunting camp. Draft report prepared for the National Park Service, Anchorage. 461 pp.

Prentiki, Dick, Minerals Management Service (MMS), Anchorage, Alaska. 2003. Verbal communication, re: ANIMEDA study information and MMS core splits and storage requirements for geotechnical borings; no splits or storage requirements by MMS. Sept. 8.

Rainey, F. 1939. Archaeology in Central Alaska. Anthropological Papers of the American Museum of Natural History 36(4):351-405.

Rasic, J.T. 2000. Prehistoric lithic technology at the Tuluaq Hill Site, Northwest Alaska. Unpublished M.A. Thesis. Dept. of Anth., Washington State University, Pullman, Wash.

Reanier, R.E. 1995. The antiquity of Paleoindian materials in Northern Alaska. Arctic Anth. 32(1):31-50.

Reanier, R.E. 2003. Archaeological and cultural resources reconnaissance in the ConocoPhillips Alaska Exploration Area, National Petroleum Reserve, Alaska, for the Year 2002. Reanier and Associates, Inc., Seattle, Wash. Report prepared for ConocoPhillips (Alaska), Inc., Anchorage, Alaska.

Reeder, J., Alaska Division of Geological and Geophysical Surveys (DGGS), Eagle River core storage facility. 2004. Verbal communication, re: extent and depth of core collection; most material from deep oil/gas exploration wells. Mar. 5.

Reimnitz, E., P. Barnes, and D. Maurer. 1979. U.S.G.S. Marine Geological Studies in the Beaufort Sea, Alaska, 1976; Data Type, Location, and Records Obtained. U.S. Geological Survey Open-File Report 79-766. 3 pp., 4 plates.

Reimnitz, E., and R. Ross. 1979. Lag deposits of boulders in Steffansson Sound, Beaufort Sea, Alaska. Open-File report 79-1205. U.S. Geological Survey.

Robinson, S.W. and D.A. Trimble. 1981. US Geological Survey, Menlo Park, California, radiocarbon measurements, II. Radiocarbon 23(2):305-321.

Robinson, S.W. and D.A. Trimble. 1989. US Geological Survey, Menlo Park, California, radiocarbon measurements, IV Radiocarbon 31(1): 69-84.

Ruz, M., A. Héquette and P.R. Hill. 1992. A model of coastal evolution in a transgressed thermokarst topography, Canadian Beaufort Sea. Marine Geo. 106:251-278.

Schoenberg, K.M. 1985. The archaeology of Kurupa Lake. Research/Resources Management Report AR-10. National Park Service, Regional Office, Anchorage.

Schoenberg, K.M. 1995. The Post-Paleoarctic Interval in the Central Brooks Range. Arctic Anth. 32(1):51-62.

Sharma, G.D. 1978. Geology, sea level history and bathymetric features of the Beaufort sea continental shelf, pp. I-1 to I-13. *In* E. James Dixon, G.D. Sharma and Sam W. Stoker. Beaufort Sea Cultural Resource Study, Final Report, vol. 1. University of Alaska Museum, Fairbanks. Report prepared for the Bureau of Land Management, Alaska Outer Continental Shelf Office, Anchorage, Alaska.

Shennan, I. 1987. Global analysis and correlation of sea level data, pp. 198-230. *In* R.J.N. Devoy. Sea surface studies: a global view. London, England: Croom Helm.

Shennan, I. and B.P. Horton. 2002. Holocene land and sea-level changes in Great Britain. Jour. of Quat. Sci. 17:511-526.

Sheppard, J.C. and R.M. Chatters. 1976. Washington State University Natural Radiocarbon Measurements II. Radiocarbon 18(1):140-149.

Shoemaker, B., engineer, Duane Miller & Associates, former engineer with Arctic Geoscience. 2004. Verbal communication, re: Disposition of McCovey cores; Arctic Geoscience no longer in business.

Solecki, R.S., B. Salwen and J. Jacobson. 1973. Archaeological reconnaissances north of the Brooks Range in Northern Alaska. Occasional Papers No. 1. Calgary, Alberta: Department of Archaeology, University of Calgary.

Spencer, R.F. 1959. The North American Eskimo: a study in ecology and society. Bureau of American Ethnology, Bulletin 171. Washington, D.C.: U.S. Government Printing Office.

Stanford, D.J. 1976. The Walakpa Site, Alaska: its place in the Birknirk and Thule cultures. Smithsonian Contributions to Anthropology 20. Washington, D.C.: Smithsonian Institution.

Steele, W.C., Infobank manager, USGS Coastal & Marine Geology Program, Menlo Park, CA. 2004. Verbal communication, re: Disposition of 1976-79 cores; boxes of samples from 1976-77 cores on pallets in USGS rock warehouse in Menlo Park; Deer Creek, CA core storage facility with 1979 cores closed in 1995. Aug. 10-18.

Stefansson, V. 1913. My life with the Eskimo. New York, New York: The MacMillan Company.

Stein, R. and R.W. MacDonald 2004. Organic carbon budget: Arctic Ocean vs. global ocean, pp. 315-322. *In* R.Stein, and R.W. MacDonald. The Organic Carbon Cycle in the Arctic Ocean. Berlin, Germany: Springer Verlag.

Trefry, J., Florida Institute of Technology. 2003. Verbal communication, re: near-surface core material and lead-cesium age-dating within last 100 years, Arctic Nearshore Impacts Monitoring Development Area (ANIMIDA) program. Sept. 8.

Trefry, J.H., R.D. Rember, R.P. Trocine and J.S. Brown. 2003. Pre-print. In Press. Trace metals in sediments near offshore oil exploration and production sites in the Alaskan Arctic. Environmental Geology. July 23. 34 p.

U.S. Geological Survey (USGS). 2004a. USGS CMG D-1-85-AR Metadata and Samples.http://walrus.wr.usgs.gov/infobank/d/d185ar. Accessed July 30.

U.S. Geological Survey (USGS). 2004b. USGS CMG K-1-76-AR Metadata and Samples. http://walrus.wr.usgs.gov/infobank/k/k176ar. Accessed July 2 and Nov. 2.

U.S. Geological Survey (USGS). 2004c. USGS CMG K-1-77-AR Metadata and Samples. http://walrus.wr.usgs.gov/infobank/k/k177ar. Accessed July 2 and Nov. 2.

U.S. Geological Survey (USGS). 2004d. USGS CMG K-1-79-AR and K-2-79-AR Metadata and Samples. http://walrus.wr.usgs.gov/infobank/k/k179ar. and http://walrus.wr.usgs.gov/infobank/k/k279ar Accessed July 2.

U.S. Navy. 2005. Seawater, Sound & Ice, website at http://pao.cnmoc.navy.mil/pao/Educate/OceanTalk2/indexseawater.htm

van de Plassche, O. 1982. Compaction and other sources of error in obtaining sea-level data: Some results and consequences. Eiszeitalter uber Gegenwart 30:171-181.

van de Plassche, O. 1986. Sea-level research: a manual for the collection and evaluation of data. Norwich, United Kingdom: GeoBooks.

Watson Company. 1998a. Final Report, Liberty Pipeline Route Survey, Foggy Island Bay in Stefansson Sound, Alaska, Report WPR, vol. 1. Report prepared for BP Exploration (Alaska), Inc., Anchorage, Alaska. April.

Watson Company. 1998b. Liberty High Resolution Geophysical Survey, Foggy Island Bay in Stefansson Sound, Alaska, Final Report, vol. 1. Report prepared for BP Exploration (Alaska), Inc., Anchorage, Alaska. Feb. with Nov. Addendum.

Wenzel, K.E. 1998. What put the small in the Arctic Small Tool tradition: raw material constraints on lithic technology at the Mosquito Lake site, Alaska. Unpub. M.A. Thesis. Dept. of Anth. Eastern New Mexico Univ., Portales, New Mex.

West, F.H. 1967. The Donnelly Ridge site and the definition of an early core and blade complex in Central Alaska. Amer. Antiq. 32(3):360-382.

Wolf, Janet, employee, ENSR, Anchorage, Alaska. 2004. Verbal communication, re: Beaufort Sea core material no longer exists for Fireweed or NTS sites. Mar. 22.

Wolf, S., E. Reimnitz, and P. Barnes. 1985. Pleistocene and Holocene seismic stratigraphy between the Canning River and Prudhoe Bay, Beaufort Sea Alaska. Open-File Report 85-549. U.S. Geological Survey.

Woodward Clyde Consultants (WCC). 1983. Soil characterization, Fur Seal Prospect, Gravel Island, Beaufort Sea, Alaska. Report preared. for Texaco USA. Nov. 16 pp.

Wooley, C.B. 1999. Prudhoe Bay Oil Field Discovery Well site. National Register Nomination, on file at Alaska State Office of History and Archaeology, Anchorage, Alaska.

Wooley, C.B. and B. Hess. 1999. Anaktuvuk Pass: images of Iñupiat mountain life. Report prepared for the North Slope Borough and National Park Service, Anchorage, Alaska.

Wooley, C.B. and M. Martz. 1995. ATG: Alaska's patriotic militia. Alaska Geographic Magazine 22(4).