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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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September 2005
Revised January 2007

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TABLE OF CONTENTS

ABSTRACT vi

1.0 INTRODUCTION 1

- 1.1 Background 1
- 1.2 Purpose and Scope 1
- 1.3 Cultural Background 2
  - 1.3.1 Geoarchaeological Setting 2
  - 1.3.2 Historic Context 4

2.0 METHODS 7

- 2.1 Industry Site Review and Screening 7
- 2.2 Review of Other Data 7
- 2.3 Core Search 8
- 2.4 Core Subsampling and Analysis 8
- 2.5 Geophysical Review for Data Gaps 9

3.0 RESULTS 10

- 3.1 Site Screening for Water Depth 10
- 3.2 Site Review for Paleolandforms 10
  - 3.2.1 Aurora 10
  - 3.2.2 Cabot 15
  - 3.2.3 Fireweed 15
  - 3.2.4 Karluk 19
  - 3.2.5 Liberty/Tern Island 19
  - 3.2.6 Mars 21
  - 3.2.7 McCovey 21
  - 3.2.8 Mukluk 22
  - 3.2.9 Northstar 22
  - 3.2.10 Phoenix 23
  - 3.2.11 Sandpiper 23
  - 3.2.12 Warthog 24
- 3.3 Core Contacts 26
  - 3.3.1 Industry 26
  - 3.3.2 U.S. Geological Survey 26
  - 3.3.3 Other 27
- 3.4 Compilation of Existing Age Dates 28
- 3.5 Subsampling and Age-Dating Program 28
- 3.6 Laboratory Results 33
- 3.7 Review of USGS Geophysical Data 37
  - 3.7.1 Colville Delta Area 37
  - 3.7.2 Northstar Area 37
  - 3.7.3 McCovey Area 38
  - 3.7.4 Saganavirktok Delta to Offshore of Barrier Islands 38
  - 3.7.5 Mikkelson Bay 39
  - 3.7.6 East of Mikkelson Bay 40

4.0 DISCUSSION 41

- 4.1 Geomorphic Trends Related to Landform Preservation 41
- 4.2 Beaufort Sea Radioarbon Database Interpretation 42

5.0 SUMMARY OF FINDINGS 43

6.0 RECOMMENDATIONS 44

6.1 Rationale for Paleolandform Selection 45
6.2 Seismic Data 45
6.3 Boring Locations 46
6.3.1 Industry Sites 46
6.3.2 Federal Lease Areas 47
6.3.3 Inshore of Barrier Islands 47
6.4 Stratigraphic and Laboratory Analyses 48
7.0 CONTACTS AND LITERATURE CITED 48

LIST OF TABLES

Table 1 - Summary of Core Search Results by Industry Site 11
Table 2 - Available Age Dates 29
Table 3 - ^{14}C Dating Program, USGS Vibracores 34

LIST OF FIGURES

Figure 1 – Site Location Map 16
Figure 2 – Cabot Site Vicinity 17
Figure 3 – Fireweed and Mars Site Vicinity 18
Figure 4A – Mukluk to Sandpiper Site Vicinity (in pocket) 20
Figure 4B – Northstar to Liberty Site Vicinity (in pocket) 20
Figure 5 - Warthog Site Vicinity 25

LIST OF APPENDICES

Appendix A Beaufort Sea Lease Sale Map, March 30, 2005
Appendix B Geophysical Data Examples from Selected Industry Sites: Aurora, Cabot, Fireweed-ARCO, Mars, Phoenix, Sandpiper, Warthog
Appendix C Liberty Site: Interpretive Pipeline Route Cross-Sections, Geophysical Data Examples, and Selected Boring Logs
Appendix D Northstar Site: Interpretive Cross-Section and Selected Boring Logs
Appendix E Beaufort Sea Radiocarbon Database and Implications for Paleogeography
Appendix F USGS Core Sampling Trip Report, December 2004
Appendix G Logs of USGS Vibracores Selected for Dating
Appendix H Laboratory Data
Appendix I Selected USGS 1979 Geophysical Data

ACRONYMS AND ABBREVIATIONS

AD	Anno Domini
AMS	accelerator mass spectrometry
ANIMEDA	Arctic Nearshore Impact Monitoring Development Area
ARCO	ARCO Exploration Company
ARLIS	Alaska Resources Library & Information Services
BC	Before Christ
B.P.	before present
BP	BP Exploration
bsl	below sea level
cal	calibrated
^{14}C	carbon 14, radiocarbon
CFC	Coastal Frontiers Corporation
cm	centimeter
CMG	Coastal & Marine Geology
Comap	Comap Geosurveys Inc.
CRREL	Cold Regions Research and Engineering Laboratory
DGGS	Division of Geologic and Geophysical Surveys
DM&A	Duane Miller & Associates
DOT&PF	Department of Transportation & Public Facilities
EBA	EBA Engineering, Inc.
ENSR	ENSR Consulting and Engineering
Fairweather E&P	Fairweather E&P Services, Inc.
GIS	Geographic Information System
HLA	Harding-Lawson Associates
Intec	Intec Engineering, Inc.
JPO	Joint Pipeline Office
km	kilometer
kyr	1,000 years
m	meter
MMS	Minerals Management Service
ms	millisecond
m/s	meters per second
bsl	below sea level
NGDC	National Geophysical Data Center
NLUR	Northern Land Use Research, Inc.
NLUR Team	NLUR, URS, and GeoArch Alaska
NOAA	National Oceanic and Atmospheric Administration
NTS	Northern Technical Services
OCS	Outer Continental Shelf
PRA	Petrotechnical Resources of Alaska
UAF	University of Alaska - Fairbanks
USACE	U.S. Army Corps of Engineers

URS	URS Corporation
USGS	U.S. Geological Survey
WCC	Woodward Clyde Consultants
yrs	years

ABSTRACT

This report presents the results of a study conducted by Northern Land Use Research, Inc., URS Corporation, and GeoArch Alaska to assess the existence and archaeological potential of submerged and buried terrestrial paleolandforms beneath the Beaufort Sea. It is based on a review of existing geological and archaeological information, geophysical data, and core analyses. The study area encompasses the inshore portion of the Beaufort Sea shelf offshore of northern Alaska, between Point Barrow and the Canadian border, and was conducted for the U.S. Department of the Interior Minerals Management Service under authority of Section 106 of the National Historic Preservation Act of 1966.

Past research in the Arctic suggests that relict terrestrial landforms such as stream terraces and coastal features dating from the last glacial advance and low sea level stands of Late Pleistocene-Holocene age are locations where preserved archaeological deposits could occur. Recent geophysical data from Outer Continental Shelf-lease areas in the Beaufort Sea indicate the potential presence of these types of relict landforms beneath the seafloor shoreward of approximately 20 meters (m) water depth, where shorefast ice in the winter tends to protect the seafloor from ice gouging. There has been insufficient data, however, to determine whether these landforms date from the last period of low sea level, or from an earlier Pleistocene low sea level.

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: (1) at the beginning of the Holocene, about 11,000 years ago, sea level was at or below about 50 m below modern sea level (bsl); (2) after 10,500 years B.P., sea level had risen to at least 50 m bsl and flooded the Bering Strait; (3) 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., (4) 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., and (5) 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.

Although there are a number of interpretative issues related to environment of deposition and recycled organic material, potential paleolandforms worthy of future consideration were identified at six industry sites. The analyses of radiocarbon dating conducted in this study indicated dates ranging from 8,600 to 1,600 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 comparison of data with available USGS geophysical data confirmed and expanded landform interpretations at industry sites, and identified additional landforms with possible preserved Early Holocene terrestrial features in the following areas: Colville River delta area, northwest of Reindeer Island, north of Cross Island, north of Narwhal Island, Mikkelson Bay, east of Stockton Islands, and north of Flaxman Island.

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 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 Chuckchi, 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.

Our recommendations focus on paleolandforms that are relatively clear based 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 areas include buried channels with possible channel-edge features, the landward side of buried paleo-shorelines, terraced sides of buried peat-bogs or lagoons, and buried relict islands of coastal ridges that may contain terrestrial material. We recommend that additional seismic data be collected across some areas of mapped peat to potentially define the lateral extent of paleolandforms related to these organic deposits. We recommend that USGS high resolution seismic data from the 1970s and 1980s, including missing lines from 1979, be systematically reviewed in areas less than 20 m water depth for evidence of paleolandforms before finalizing boring locations. Several borings are recommended at paleolandforms that exhibit the potential for possible Early Holocene terrestrial features. The boring recommendations are prioritized on the basis of data coverage and confidence level: (1) industry sites, (2) current federal lease areas, and (3) other nearshore locations not at industry sites or lease areas. Finally, we recommend that detailed stratigraphic evaluation of the continuous core material collected at the proposed 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.

1.0 INTRODUCTION

Presented in this report are the results of a study conducted by Northern Land Use Research, Inc. (NLUR), URS Corporation (URS), and GeoArch Alaska (hereafter referred to as the NLUR team) to assess the existence and archaeological potential of submerged and buried terrestrial paleolandforms beneath the Beaufort Sea. This study is based on a review of existing geologic and archaeological information, geophysical data, and core analysis. The study area encompasses the inshore portion of the Beaufort Sea shelf offshore of northern Alaska, between Point Barrow to the west and the Canadian border to the east (Figure 1). The study was conducted for the U.S. Department of the Interior Minerals Management Service (MMS) in accordance with MMS Solicitation No. 0103RP72892 dated August 25, 2003, NLUR team proposal dated September 11, 2003, and a document entitled *Modification Letter and Study Design* submitted by the NLUR team to MMS on December 30, 2003.

1.1 Background

The MMS is required under Section 106 of the National Historic Preservation Act of 1966 (as amended) to ensure that cultural resources are considered prior offshore development. As part of the section 106 process, historic properties are identified, evaluated for significance, and possibly mitigated prior to federally permitted or licensed actions that might otherwise adversely affect them, such as oil and gas exploration and development (see 36 CFR 800). MMS currently manages an archaeological resources program that requires review of geological and geophysical data within Outer Continental Shelf (OCS) lease areas to identify locations with the potential for prehistoric archaeological site deposits. Specific guidelines for marine archaeological survey are found in MMS Handbook for Archaeological Resource Protection (620.1-H) and Notice to Leasees 00-A03.

Past research in the Arctic suggests that relict terrestrial landforms such as stream terraces and coastal features dating from the last glacial advance and low sea level stands of Late Pleistocene-Holocene age (late Wisconsinan) are locations where preserved archaeological deposits could occur (Section 1.3). Recent geophysical data from OCS lease areas in the Beaufort Sea indicate the potential presence of these types of relict landforms beneath the seafloor shoreward of approximately 20 meters (m) water depth, where shorefast ice in the winter tends to protect the seafloor from ice gouging (MMS 2003a). There has been insufficient data, however, to determine whether these landforms date from the last period of low sea level, or from an earlier Pleistocene low sea level. If it can be shown that these features date earlier than late Wisconsinan time, MMS may not need to require prehistoric archaeological analyses and associated mitigation measures prior to permitting activities in certain areas of the Beaufort Sea.

1.2 Purpose and Scope

The overall goal of the project was to evaluate the prehistoric archaeological potential of the shallow Beaufort Sea shelf, through the identification of existing core material that could potentially represent relict terrestrial landforms from late Wisconsinan time. If available, a goal of the project is to locate suitable organic material and perform age dating analyses. The results of the project are intended to be used in the management of federal offshore oil and gas permitting activities, as well as in refining the current understanding of relative sea level history for the Beaufort Sea.

The scope of the project was based on *Section C - Description/Specifications/Work Statement* in the MMS (2003a) solicitation for this project; tasks listed in the NLUR team *Technical Proposal* of September 11, 2003; and clarifications discussed in a December 4, 2003 meeting between MMS and the NLUR team, which were documented in the NLUR (2003) *Modification Letter and Study Design*. Tasks completed during the study consist of the following:

- Detailed review of an MMS (2002) study entitled "Evaluation of Sub-Sea Physical Environmental Data for the Beaufort Sea OCS" and incorporation into a Geographic Information System (GIS) Database, for information related to previously identified paleolandforms in the vicinity of industry exploration sites in the study area.

- Review of other readily available and pertinent literature, maps, industry reports, core data, and geophysical results published by oil companies and their contractors, the U.S. Geological Survey (USGS), and academic organizations.

- Researching the potential existence of core material in storage through contacts at oil companies, engineering contractors, USGS, U.S. Army Corps of Engineers (USACE), Alaska Division of Geologic and Geophysical Surveys (DGGS), academia, and others.

- Correlation of existing cores to potential buried landforms identified during geological/geophysical data review.

- Examination and subsampling of available core material.

- Submittal of core material to a qualified laboratory for radiocarbon (^{14}C) dating.

- Review of geophysical data contained in industry geohazard reports, and selected USGS high resolution seismic data available from MMS, for the purpose of identifying data gaps in areas of potential paleolandforms. Based on NLUR (2003) and subsequent discussions with MMS, in an effort to focus the resources of this study, limited effort was expended on the identification of additional paleolandforms in between existing industry sites unless previously published, located within current federal lease sale areas, or located near identified core material in storage.

- Preparation of this report, presenting the results of the data review and core analyses, and recommendations for future study, including additional seismic data and core locations if necessary.

1.3 Cultural Background

1.3.1 Geoarchaeological Setting

The North Slope of Alaska was a near barren high arctic desert landscape during the late Wisconsinan last glacial advance of about 21,000 to 16,000 years before present (B.P.). A warming transition to the Holocene between 15,000 and 11,000 years B.P. caused a significant rise in sea level and increased moisture, that transformed the coastal plain and may have fostered human settlement (Hopkins et al. 1982; Mann et al. 2002). Pulses of higher productivity during this period were marked by the development of shrubby and tundra vegetation and complementary fauna (such as bison, horse, and mammoth) that may have served as a subsistence base for human hunters (Matheus et al. 2003). Additional moisture also resulted in increased slope erosion of unvegetated landscapes, the creation of outwash terraces, and peat development. Similar climatically driven landscapes are expected to have been present on the subaerially exposed continental shelf of the Beaufort Sea during this time period.

The possibility that archaeological sites remain intact on the continental shelf is based on the function of the Beringia subcontinent between Siberia and Alaska as a “land bridge” connection for migrating plants and animals during lower sea levels (Hopkins 1967; Hopkins et al. 1982; Dixon 1983, 1989). A number of archaeological surveys have documented human occupation in the Brooks Range uplands and Arctic foothills between 11,000 and 9,000 years B.P. (e.g., Reanier 1995; Kunz and Reanier 1995; Bever 2001). Comparatively few sites are known from the coastal lowlands, however, partly due to high rates of coastal erosion and retreat, barrier island migration, and the absence of spits and beach ridges. A small number of coastal archaeological sites that have been documented along river terraces, on top of pingos, and on barrier islands and low coastal dunes dating from 2,000 to 5,500 years B.P. (Lobdell 1980, 1985, 1986).

Dixon et al. (1978) proposed the use of landforms such as topographic highs to enhance the possibility of finding terrestrial archaeological sites associated with mammal hunting (e.g., overlook and surround sites). Sites such as villages were likely to have been located on barrier islands, which are unlikely to be preserved due to rapid storm erosion and redeposition. The Holocene sea level transgression had various destructive effects on the coastal plain margin, producing rapid bluff erosion, catastrophic thaw lake drainage, ice gouge, and strudel scour. Along most reaches of the Beaufort Sea coast, submerged shorelines are not expected to be preserved due to bluff erosion. Reimnitz et al. (1988) have postulated that the Beaufort sea coast has been reduced by 7 – 27 km since 5,000 B.P. through themokarst collapse and thermal erosion. Although many Holocene sites may have been located on geomorphic features most susceptible to erosion such as barrier islands and coastal dunes, sites enclosed within alluvial terraces (e.g., Bowers 1982) may be comparatively better protected from shelf erosion processes.

The slope break at the outer edge of the continental shelf at about 100 m water depth is a useful marker for the lowest sea level stand of the last glacial advance about 18,000 years ago. Past efforts to establish rates of sea level rise during the Holocene for the Beaufort Sea (e.g., Dixon et al. 1978; Hopkins 1967; Mann et al. 2002) have been problematic due to extrapolations from areas with widely contrasting eustatic and isostatic conditions. Peat beds from 50 m below modern sea level (bsl) in the northern Chukchi Sea date to 11,000 years B.P. (Elias et al. 1992). Other data points from the Chukchi Sea have been derived from retransported peat, and are considered stratigraphically ambiguous. Possibly equivocal data points near Barrow indicate sea levels of about 12 m bsl at 7,000 to 6,000 years B.P., and 1.5 m bsl at 5,000 to 4,500 years B.P. (Jordan and Mason 1999; Mason and Jordan 2002). A number of sea level data points for the central Beaufort Sea shelf were compiled during this project from literature searches, USGS contacts, and laboratory analyses. These are presented and discussed in more detail in Sections 3.4, 4.2, and Appendix E.

1.3.2 Historic Context[1]

Given its large size, the prehistory of the North Slope terrestrial environment is poorly understood. Along the coast, sites predating the historic period (pre-1826) are rare. The resource base is severely compromised because much of the Beaufort Sea coast has been eroded, or is actively degrading, thereby damaging or altogether removing the important coastal element of the region's archaeology (Bowers et al. 2001). Nearly a half century ago, Giddings (1957) characterized the archaeology of the mid-Beaufort Sea region as "tenuous"; that description is still appropriate today. Although more than 1,200 prehistoric sites are known for the entire North Slope (Hall 1981:50; AHRS n.d.), only a handful of prehistoric sites are known for the coastal area adjacent to oil and gas exploration and development areas (e.g., Niglik, Thetis Island, Pingok Island, Putuligayuk River Delta Overlook, Central Creek Pingo, Kuparuk Pingo, TES-057, HAR-006) (Hall 1981; Lobdell 1986, 1995; Bowers 1991, 1992; Reanier 2003). Archaeological surveys were conducted east of Barrow from early in the 20th century (Jenness 1914; Hall 1987; Mathiassen 1930), though systematic surveys did not begin until the early 1950s (Irving 1952). With several notable exceptions, mainly in the Barrow area (e.g., Ford 1959; Stanford 1976), much of what we know about the area is derived from oil and gas related investigations (e.g., summary of USGS NPR-A program in Hall and Gal 1988; Davis et al. 1981; Reanier 2003; see also numerous references for Lobdell).

Paleoindian Tradition (c. 11,200 to 8,000 years ago)

The oldest well-documented sites in northern Alaska belong to what some archaeologists refer to as the Paleoindian Tradition, dating as old as 11,200 years and as recent as 8,000 years ago. The oldest sites in the Brooks Range region include the Tuluaq site (Rasic 2000) and the Mesa site (Kunz et al. 2003; Bever 2000; Kunz and Reanier 1994). The Mesa site was discovered as a result of oil and gas exploration activities in 1978 (Kunz and Reanier 1994, 1995). Information from this site, along with others such as the fluted point Putu, Lisburne, and Teshekpuk Lake sites (Alexander 1987; Bowers 1982; Davis et al. 1981) and other lanceolate point sites such as Bedwell and Hilltop (Bever 2000; Reanier 1995), has been construed to imply temporal and cultural connections with early sites in more temperate latitudes such as the Great Plains and the American Southwest (Kunz and Reanier 1995). Similarities exist in artifact forms (especially large projectile points, scrapers and spurred gravers), site settings, and implied subsistence patterns. Organic remains are not well preserved in these sites, forcing comparisons and interpretations to be made almost entirely from lithic artifacts.

American Paleoarctic Tradition (c. 10,000 to 7,000 years ago)

Appearing after and in some places contemporaneous with the Paleoindian Tradition is the so-called American Paleoarctic Tradition (Anderson 1970), generally thought to date in the North Slope-Brooks Range between about 10,000 and at least 7,000 years ago. Certain stone tool types, especially distinctive cores, blades, and burins found in American Paleoarctic sites are remarkably similar to stone technologies from Northeast Eurasia, suggesting cultural connections across the Bering Land Bridge (Nelson 1935, 1937; Rainey 1939). American Paleoarctic tool kits are generally thought to have been oriented toward the production of composite antler and stone projectiles, used to dispatch late Pleistocene-early Holocence fauna (Powers et al. 1983; West 1967). American Paleoarctic sites from the North Slope include the

[1] Much of the material for the cultural context section is from previous NLUR north slope reports (e.g., Potter et al. 2003).

Gallagher Flint Station (Dixon 1975; Bowers 1983; Ferguson 1997) and the Lisburne Site (Bowers 1982). The temporal distribution of the American Paleoarctic on the North Slope is somewhat open to question, however, with suggestions by some archaeologists that it persisted into the late Holocene (Ferguson 1997; Bowers 1999; see also Mason et al. 2001). Microblades are found in association with notched points at a few coastal sites such as Putuligayuk River Delta Overlook (Lobdell 1981).

Northern Archaic Tradition (c. 6,000 to 2,000 years ago)

Sometime between 5,000 and 6,000 years ago, side-notched projectile point forms begin to appear in northern Alaska archaeological assemblages, a hallmark of the Northern Archaic Tradition (Anderson 1968). The broad occurrence of this point type throughout interior and northern Alaska, along with distinctive scraping implements and other lithic tools, was originally suggested as a new boreal forest-oriented cultural tradition (Anderson 1988). Northern Archaic sites appear in upland tundra areas, such as Tuktu (Campbell 1962) and Kurupa Lake (Schoenberg 1985, 1995). The Northern Archaic is also represented on the coast of the North Slope at sites such as Kuparuk Pingo (Lobdell 1986) and the Putuligayuk River Delta Overlook site (Lobdell 1981).

Arctic Small Tool Tradition (c. 4500 years ago to 1050 years ago [A.D. 900])

Following the Northern Archaic Tradition, beginning roughly 4500 years ago is a prehistoric culture known as the Arctic Small Tool Tradition (ASTt), first defined at Punyik Point (Brooks Range) by Irving (1964) and later expanded to include sites from the Canadian Arctic and Greenland. The original Arctic Small Tool Tradition definition has been expanded by Anderson to include later cultures such as Choris, Norton, and Ipiutak, extending the ASTt time period to about A.D. 900 (Anderson 1988). While these cultures were defined in part on the presence/absence of pottery, ASTt lithic assemblages are very similar, characterized by small, finely flaked sideblades and endblades, burins struck on bifaces, and flake knives (c.f., Larsen and Rainey 1948). Some sites, particularly those of the so-called Denbigh Flint Complex, have yielded microblades and microblade cores (Giddings 1964; Irving 1964). This dramatic change in stone tool technology from the earlier Northern Archaic may mark the introduction of the bow and arrow and is interpreted by many archaeologists as representing the direct ancestral lineage to modern Eskimo people on the North Slope (Giddings 1968; Irving 1964; Dumond 1987). However, the nature of the continuity and cultural relationship between late ASTt Ipiutak and ancestral Iñupiat people has not been clearly established (c.f., Gerlach and Hall 1988; Gerlach and Mason 1992).

ASTt sites on the North Slope include Putuligayuk River Delta Overlook and Central Creek Pingo (Lobdell 1981, 1995), Walakpa (Stanford 1976), the Mosquito Lake Site, (Kunz 1977; Wenzel 1998), and Gallagher Flint Station (Dixon 1975; Bowers 1983). In some areas of the Arctic Foothills and Brooks Range, ASTt sites are relatively common, for example, at Franklin Bluffs (Solecki et al. 1973) and the Tukuto Lake Site (Croxton and Sikurok) (Gerlach 1989; Gerlach and Hall 1988).

Late Prehistoric Eskimo (c. A.D. 500 to 1826)

By the middle of the First Millenium A.D., parts of Northern Alaska were occupied by the Birnirk culture (Ford 1959; Stanford 1976), the ancestors of the widespread Thule culture that is in turn a precursor to the present day Iñupiat. Interior sites, such as villages at Tukuto Lake (Hall 1976a) were occupied somewhat later, by c. 1300 A.D. Subsistence was broad-based, with both interior and coastal resources emphasized. Along the Arctic coast, whaling became increasingly important, an activity that continues to this day. Late prehistoric coastal material culture shows, among other traits, a well-developed and complex technology based on harpooning whales from skin boats. Thule and Late Prehistoric Eskimo sites on the Arctic Coast include Thetis Island and Pingok Island sites (Irving 1952; Bowers 1991, 1992), and the Nuvuk, Walakpa, and Utqiavik Sites around Barrow (Ford 1959; Stanford 1976; Dekin et al. 1981). Important sites were documented on Barter Island by Jenness (1914), Mathiassen (1930), and Hall (1987). The preservation of the archaeological record improves for Late Prehistoric/Early Historic times, as documented by numerous TLUI sites throughout the region (North Slope Borough 1996; see also Hoffman et al. 1988).

Historic Period (A.D. 1826 to present)

Historical documentation of Alaska's North Slope began with the writings associated with the Franklin Expedition (Beechey 1831) . From that time period to present, the Iñupiat residents of the region have undergone numerous social and economic changes in response to availability of new material goods, effects of missionaries, whalers, traders, disease, alcohol, the military, and oil and gas development.

Major changes to Iñupiat society took place with the advent of commercial whaling in the 1850s, activities which reached their peak in the 1880s and lasted until about 1910 (Bockstoce 1986). The economy of the area became increasingly cash based, although traditional subsistence activities were never abandoned. Traditional commerce, such as the trade fairs at Niglik on the Colville Delta, continued throughout the 19th and early 20th centuries (Steffanson 1913; Hoffman et al. 1988). However, with cash and wage labor opportunities came relocation of many people towards the coast; by 1920 the last of the Nunamiut (inland Eskimo) had left the Brooks Range (Gubser 1965). In the larger settlements such as Barrow (Utqiavik) and Point Hope (Tigara) were schools and stores, which further consolidated native populations. With the collapse of commercial whaling and a coincidental crash in the caribou herds in the interior, local cash economies faltered, resulting in, among other effects, government support for new enterprises such as reindeer herding and fur trapping (Spencer 1959).

During the early 20th century, the commercial fur trade, largely focused on the Arctic fox, became an important economic activity across much of the North Slope. Numerous historic sites dot the landscape which relate to the fur trade period such as Niglik and Qulvi on the Colville Delta (Hoffman et al. 1988), Milne Point and Pingok Island (Lobdell 1980), and Heald Point, located at the mouth of the Sagavanirktok River (Lobdell 1989). Sites from this time period include sod house ruins, ice cellars, trading posts, and graves. With the collapse in fur prices in the 1930s, commercial trapping could no longer sustain large groups in certain parts of the traditional Iñupiat homeland, so many people were forced to relocate to Barrow and other regional centers. In 1938, a few people returned to the then-nearly-vacant Brooks Range; by 1959, they had resettled in Anaktuvuk Pass (Gubser 1965; Wooley and Hess 1999).

People from the lower Colville area (Kukpikmiut) moved to Barrow in the 1940s so children could attend a Bureau of Indian Affairs school. Many of these Iñupiat hunters had continued to use the lower Colville River area since the 1940s for subsistence purposes (Hoffman et al. 1988). In 1973, following the passage of the 1971 Alaska Native Claims Settlement Act, 27 families from Barrow re-established the village of Nuiqsut near areas of previous traditional use (Hoffman et al. 1988).

During the Second World War, Iñupiat people formed local battallions for homeland defense (Wooley and Martz 1995) and enlisted in the military. After World War II, two important activities took place that had major effects on Iñupiat society on the North Slope. The first of these was exploration of the National Petroleum Reserve in Alaska, formerly known as Naval Petroleum Reserve No. Four or PET-4. This led to a number of construction projects and exploration activities, some of which provided wage employment to local residents. At about the same time, the Distant Early Warning System, or DEW line, was built by the U.S. military as part of a North American Cold War defense system (Denfield 1994). A more recent historical event that had a dramatic effect on the Inuipat people specifically, and Alaskans in general, has been the discovery of oil at Prudhoe Bay in 1968 (Wooley 1999). This event began the sequence of events that led up to settlement of Native Land Claims and to the authorization and construction of Trans Alaska Pipeline System in 1974, ushering in an important new era of Alaskan history.

2.0 METHODS

2.1 Industry Site Review and Screening

The initial stage of the project included a detailed review of the MMS (2002, 2003) documents and associated GIS database containing a compilation of geophysical and geotechnical survey data from 28 industry exploration sites in the Beaufort Sea. In accordance with the December 4, 2003 kick-off meeting and NLUR (2003) letter, the sites were initially screened to identify those located in less than 20 m water depth, due to the high concentration of ice gouges further offshore precluding most landform and prehistoric site preservation. The resulting industry sites are listed in Table 1 and discussed in Sections 3.1 and 3.2.

For industry sites in less than 20 m water depth, selected GIS data layers were compiled and reviewed to further focus the study on sites at which paleolandforms had been previously identified and mapped. GIS data for one industry site, McCovey (Arctic Geoscience 2002a; Petrotechnical Resources of Alaska (PRA) 2002) were provided separately by MMS and added to the data compilation/screening effort. GIS layers compiled and reviewed for this task included Holocene and pre-Holocene sediment thicknesses, boring locations, geophysical survey tracklines, and data related to possible terrestrial landforms such as buried channels, erosional cutouts, paleo-shorelines, shoals/drowned islands, and wave-cut terraces. This effort was supplemented by a review of: (1) summary geologic interpretations for each site contained in MMS (2002); (2) individual site geohazard and geotechnical reports available in-house, from MMS, from the State of Alaska Joint Pipeline Office (JPO), and through Alaska Resources Library & Information Services (ARLIS); and (3) MMS written comments of archaeological surveys conducted for several of the sites (Liberty, Warthog, McCovey). Potential paleolandforms identified during review of these documents that were not in the original MMS (2002) OCS compilation were mapped by the NLUR team and added to the in-house GIS database.

2.2 Review of Other Data

Data from other sources such as the USGS, USACE, DGGS, and academia were compiled and reviewed for information leading to the location of paleolandforms, existing core material, and/or age-dating results that may coincide with paleolandforms identified at industry sites. MMS provided a copy of a Beaufort Sea-wide geotechnical study conducted by the USGS and Harding-Lawson Associates (HLA 1979) for review. USGS' website for their Coastal & Marine Geology (CMG) Program (e.g., USGS 2004a) was systematically reviewed to identify all Beaufort Sea/Arctic Ocean cruises for which core material was collected.

2.3 Core Search

Contacts were made with representatives of the oil industry, government agencies, and academia in an effort to locate existing core material in storage:

- For industry sites with previously identified paleolandforms, oil industry representatives and/or engineering contractors were contacted for information on possible core material in storage.
- Dr. Julie Friddell of the USACE Cold Regions Research and Engineering Laboratory (CRREL) in Hanover, New Hampshire was contacted for information on possible cores in storage from the HLA (1979) investigation.
- The State of Alaska DGGS and Department of Transportation and Public Facilities (DOT&PF), were contacted for information on the DGGS core storage facility in Eagle River, Alaska and the DOT&PF statewide materials laboratory in Anchorage.
- Representatives from MMS and the State of Alaska Joint Pipeline Office (JPO) were contacted for information on possible core splits or storage requirements for offshore geotechnical borings.
- Dr. Julie Brigham-Grette at University of Massachusetts, Dr. Sathy Naidu at University of Alaska-Fairbanks, and Dr. John Trefry at Florida Institute of Technology were contacted for information on core material from nearshore shallow sediment studies conducted in the Chukchi Sea and in Beaufort Sea lagoons.
- Drs. Peter Barnes and Eric Reimnitz from the USGS in Menlo Park, California were contacted to discuss Beaufort Sea vibracore cruises from the 1970s, core storage status, age data, and data limitations.
- Representatives of USGS' core storage facilities in Menlo Park, California and the CMG Program website were contacted for information on accessing existing core materials in storage.
- The National Oceanic and Atmospheric Administration's (NOAA's) National Geophysical Data Center (NGDC) website was reviewed for information on the location of core materials listed with their Index to Marine and Lacustrine Geological Samples database.

The results of these contacts are organized by industry site in Table 1 and discussed in Section 3.3. Contacts made are included in the references in Section 7.0.

2.4 Core Subsampling and Analysis

Following the identification of potential core material in storage at the USGS in Menlo Park, California (Section 3.3.2), the NLUR team developed a proposed subsampling program for review by MMS, and applied for permission to USGS to access and subsample specific cores. A visit was made to USGS in December 2004 by Dr. Owen Mason of the NLUR team for the purpose of core material review and subsampling (Appendix F). Subsamples were delivered to NLUR in Fairbanks, Alaska for further review and selection for age-dating. There, they were cleaned, pretreated, and selected for further study by Peter Bowers and NLUR staff archaeologists. Six selected subsamples were submitted to Beta Analytic Radiocarbon Dating Laboratory in Miami, Florida for ^{14}C dating by accelerator mass spectrometry (AMS) methods. The rationale for the subsampling program and age-dating results are presented in Section 3.5.

2.5 Geophysical Review for Data Gaps

This task consisted of a review of industry and USGS high resolution seismic data for the purpose of identifying potential paleolandforms, and refining knowledge of previously identified landforms, in areas where core material does not exist. The review of industry data was conducted concurrently with the industry report screening effort described in Section 2.1. As described below, the review of raw USGS data was limited to tracklines available from one survey year (1979). A published USGS interpretation of multiple years of seismic data for the eastern Beaufort Sea shelf by Wolf et al. (1985) was also reviewed in detail in order to correlate previously identified potential paleolandforms to findings from the 1979 USGS data.

MMS provided a map of USGS geophysical survey tracklines in the Beaufort Sea for the years 1970 through 1985 in GIS format (Arctic Geoscience 1997) (Figure 4), as well as shallow high resolution geophysical data on microfiche for about half of the 1979 survey. A search was made for additional USGS data on microfiche at ARLIS library in Anchorage, Alaska. No additional data were found at ARLIS. Based on a review of published USGS maps for the 1979 cruise (Barnes et al. 1980), the missing trackline data are not necessarily concentrated in a certain area of the Beaufort Sea shelf.

A review of the available 1979 USGS data obtained from MMS was conducted using ARLIS' microfiche facilities. The review was prioritized to focus on: (1) evidence of potential paleolandforms in areas where existing core material was identified under Section 3.3, (2) evidence of potential paleolandforms within current lease sale areas (Appendix A) located in water depths less than 20 m, (3) refinement of landform morphology at industry sites with previously identified landforms, and (4) areas inshore of barrier islands where paleolandforms are more likely to be preserved. Prospective landform features viewed on microfiche were copied on 8-1/2 by 11-inch pages and returned to URS for compilation and further review.

The location of features identified on the USGS data depended on the spotty occurrence of shotpoint notations on the Barnes et al. (1980) maps. Individual shotpoint locations are not available on the Arctic Geoscience (1997) digitized trackline layers. Shotpoint notations in Barnes et al. (1980) are on the order of 1 to 6 km apart. Features identified in between these notations were located by interpolating between available shotpoints assuming an even shotpoint spacing. This assumption may be a cause of locational error in some of the identified landforms. In some areas, tracklines mapped by Arctic Geoscience (1997) did not match those of Barnes et al. (1980). In this event, landform locations were mapped using Barnes et al. (1980) maps.

There are no time scales marked on the USGS microfiche high resolution seismic data. Based on a single handwritten notation, it was assumed that the records represent a two-way travel time of 250 milliseconds (ms). Sediment thicknesses and depths were estimated using nominal velocity of sound in sediment of 1,500 meters per second (m/s). Sediment velocities ranging from about 1,450 to 1,800 m/s were used in the various industry and USGS documents reviewed for this study. The velocity of 1,500 m/s was used by many of the industry site reports from the 1980s. Water depths were estimated using a velocity of about 1,450 m/s (U.S. Navy 2005).

3.0 RESULTS

3.1 Site Screening for Water Depth

The results of screening of industry exploration sites for water depth are shown in Table 1. Those sites that are located partly or completely in water depths less than 20 m are listed in the far left column of Table 1. Industry sites which are located in water deeper than 20 m include: Belcher, Canvasback, Corona, Eric, Galahad, Hammerhead-631, Kuvlum/West Maktar, Thorgisl, and Wild Weasel (Figure 1). A review of several documents for these sites was conducted primarily to confirm bathymetry (e.g., Dames & Moore 1985a, 1985b; Deepsea Development Services 1993, 1994; Fugro-McClelland 1992). These sites were not considered further in this study due to the high concentration of ice gouging offshore of the zone of shorefast ice (Sections 1.1 and 2.1).

3.2 Site Review for Paleolandforms

For industry sites in less than 20 m water depth, MMS' (2002) GIS database and site-specific geohazard and geotechnical surveys were reviewed for evidence of paleolandforms. The results of these reviews are listed in Table 1. Sites with no evidence of paleolandforms following the reviews were not considered further in this study. These included Antares, Fur Seal, Hammerhead-624/625, and Orion. A list of documents reviewed for these sites is included on Table 1 and listed in Section 7.0.

Descriptions of industry sites in less than 20 m water depth that show evidence of paleolandforms are presented below in alphabetical order. These sites were the focus of industry contacts to locate core material in storage (Section 3.3). Paleolandforms for most of the sites are presented on Figures 2 through 5.

3.2.1 Aurora

Aurora is located at the far east end of the study area near Kaktovik (Figure 1). The south half of the site lies in water depths ranging from 11 to 20 m. The north half of the site reaches water depths of 32 m. Approximately 2 to 12 m of Holocene surficial deposits were mapped across the site by Pelagos (1987). Other than prograding deltaic deposits, discrete paleolandforms were not identified for this site by either Pelagos (1987) or MMS (2002). Mapped Holocene thicknesses and high resolution geophysical data, however, indicate the presence of several circular or elliptical-shaped depressions in the base of the Holocene reflector in the central and southwest portions of the site. The depressions are up to 4 to 6 m deeper than the surrounding base of Holocene. These may represent paleo-depressions such as lake basins or channel fragments, or the result of permafrost bonding. Relict permafrost may result in the appearance of discontinuous or irregular reflectors where good stratification may actually exist (Wolf et al. 1985). An example of the high resolution geophysical data from the site is provided in Appendix B.

Table 1
Summary of Core Search Results by Industry Site[1]

Industry Site[1]	Approx. Water Depths (m)	Paleolandforms Previously Identified in MMS (2002)		Industry Sources									Government/Academia Sources						
		Y/N	Type/ Description	Do Industry Core Locations Coincide with Paleo-landforms?	Estimated Holocene Thickness (m bsf)	Operator			Geophysical Contractor	Boring Contractor			Agency/ University Name	Study Name	Do Core Locations Coincide with Paleo-landforms?	Core Material Available?			
						Name	Core Material Available?		Name (Report Date)	Name (Report Date)	Core Material Available?					Y/N	Contact/ Reference	Estimated Depth Range of Early Holocene (m bsf)	Organic Material Available within Early Holocene Depths?
							Y/N	Contact/ Reference			Y/N	Contact/ Reference							
Antares	14-16	No	n/a	n/a	n/a (Pleistocene at surface)	Exxon	n/a	n/a	HLA (1983)	HLA (1983)	No	Croley (2004)	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Aurora (S½)	11-20+	**Yes[2]**	Possible paleochannel and lagoon/lake basin	Unknown	2-12 m	Tenneco	n/a	n/a	Pelagos (1987)	Unknown	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Cabot	15-19	**Yes**	Pleistocene submarine canyon or river channel	4 borings within canyon area; several adjacent to it.	3.7-6.7 m Late Pleistocene to Holocene	ARCO	No	Jones (2004)	Fugro-McClelland (1990), EBA (1991b)	EBA (1991a)	No	Jones (2004)	USGS	Cruise D-1-85-AR (USGS, 2004a; Miley and Barnes, 1986)	No. Closest core is 5 km east of paleo-canyon.	Yes	USGS (2004a); Frazee (2004)	<5 m	Yes
Fireweed	12-20+	**Yes**	Buried paleo-shoreline/ coastal bluff and sand bars/ paleo-islands at Fireweed-ARCO. Buried channel at Fireweed-Shell.	Fireweed-ARCO: boring WB-15 is closest to landward side of paleo-shoreline; none on paleo-islands. Fireweed-Shell: several borings on outside edge of channel.	Fireweed-ARCO: 3-10 m Fireweed-Shell: 7-12 m site-wide; 15-26 m including channel.	ARCO/ Shell	No	Gardner (2004)	Comap (1985), Dames & Moore (1984)	ENSR (1990)	No	Gardner (2004), Wolf (2004)	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Fur Seal	8-14	No	n/a	n/a	5-8 m	Texaco	n/a	n/a	Dames & Moore (1983a)	Dames & Moore (1983a), McClelland-EBA (1983), WCC (1983)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Hammerhead - 624 & 625 (SE corner)	17-20+	No	n/a	n/a	n/a	Union	n/a	n/a	NTS (1985)	NTS (1985)	No	Wolf (2004)	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Karluk	6-8	**Yes**	Buried channel with Pleistocene and Holocene fill	No	0-4 m	Chevron	No	Croley (2004)	HLA (1988)	HLA (1988)	No	Croley (2004)	USGS	Cruises K-1-76-AR and K-1-77-AR (Barnes et al., 1979; USGS, 2004b, 2004c)	Possibly. Closest boring is 0.5 km east of channel.	Yes	Steele (2004)	1-2 m	Yes

Table 1
Summary of Core Search Results by Industry Site[1]

Industry Site[1]	Approx. Water Depths (m)	Paleolandforms Previously Identified in MMS (2002)		Industry Sources									Government/Academia Sources						
		Y/N	Type/ Description	Do Industry Core Locations Coincide with Paleo-landforms?	Estimated Holocene Thickness (m bsf)	Operator			Geophysical Contractor	Boring Contractor			Agency/ University Name	Study Name	Do Core Locations Coincide with Paleo-landforms?	Core Material Available?			
						Name	Core Material Available?		Name (Report Date)	Name (Report Date)	Core Material Available?					Y/N	Contact/ Reference	Estimated Depth Range of Early Holocene (m bsf)	Organic Material Available within Early Holocene Depths?
							Y/N	Contact/ Reference			Y/N	Contact/ Reference							
Liberty/Tern Island	1-7	**Yes**	Paleo-terraces on sides of peat bog or lagoonal basin; paleo-river channels; drowned island.[4]	Yes. Boring D–12 on paleo-island; D-9 and D-15 on paleo-terraces of basin.	0-15 m; most areas <3 m except for paleochannels	BP/Shell	No	Jakubczak (2004)	Watson (1998a, 1998b); HLA (1981)	DM&A (1997, 1998); HLA (1981)	No	Miller (2003)	USGS	Cruises K-1-76-AR and K-1-77-AR (Barnes et al., 1979; USGS, 2004b, 2004c)	No	Yes	Steele (2004)	n/a	No (Barnes et al., 1979)
														Cruises K-1/2-79-AR (Barnes et al., 1980; USGS, 2004d)	Possibly	No	Barnes (2004); Steele (2004)	n/a	No
														Beaufort Sea Geotechnical Investigation (HLA, 1979)	No	No	Friddell (2004)	n/a	n/a
													UAF	Sediment coring programs, Beaufort Sea coast (e.g., Naidu et al., 1984)	Possibly	No	Naidu (2004)	n/a	n/a
Mars	5-12	**Yes[2]**	Buried linear features, possible relict barrier islands	No. Closest borings are 0.2 km west of paleo-island.	2-7 m site-wide; <1m-2m over linear features.	Amoco	No	Bicol (2005)	Dames & Moore (1985c)	Dames & Moore (1985c)	No	Bicol (2005)	n/a	n/a	n/a	n/a	n/a	n/a	n/a
McCovey	12-19	**Yes[3]**	Shoal/relict island, channel features	Yes. Borings on shoal and over one of two channels.	2.5-7 m	Phillips/ Encana	No	Shoemaker (2004)	Arctic Geoscience (2000a, 2000c, 2001), PRA (2002)	Arctic Geoscience (2002a)	No	Shoemaker (2004)	USGS	Cruises K-1-76-AR and K-1-77-AR (Barnes et al., 1979; USGS, 2004b, 2004c)	No. Closest core is 5 km west	Yes	Steele (2004)	1.3-1.7 m in closest core	No (Barnes et al., 1979)
														Cruises K-1/2-79-AR (Barnes et al., 1980; USGS, 2004d)	Possibly	No	Barnes (2004); Steele (2004)	n/a	No
Mukluk	13-16	**Yes[2]**	Subtle bathymetric high, 1 m relief; possible drowned coastal feature.	No	~3 m	Sohio	No	Croley (2004)	Dames & Moore (1983b)	Dames & Moore (1983b), HLA (1983c)	No	Croley (2004)	N/a	n/a	n/a	n/a	n/a	n/a	n/a

Table 1
Summary of Core Search Results by Industry Site[1]

Industry Site[1]	Approx. Water Depths (m)	Paleolandforms Previously Identified in MMS (2002)		Industry Sources									Government/Academia Sources						
		Y/N	Type/ Description	Do Industry Core Locations Coincide with Paleo-landforms?	Estimated Holocene Thickness (m bsf)	Operator			Geophysical Contractor	Boring Contractor			Agency/ University Name	Study Name	Do Core Locations Coincide with Paleo-landforms?	Core Material Available?			
						Name	Core Material Available?		Name (Report Date)	Name (Report Date)	Core Material Available?					Y/N	Contact/ Reference	Estimated Depth Range of Early Holocene (m bsf)	Organic Material Available within Early Holocene Depths?
							Y/N	Contact/ Reference			Y/N	Contact/ Reference							
Northstar	0-11	**Yes[2]**	Buried peat deposits, and shoal/relict island	Possible in-situ peat inshore of barrier islands in borings B-16, TC-21, and PS-3, -4, and -6; and offshore of barrier islands in borings TC-4, and SI-5A, -6, and -7. No borings on shoal.	5-11 m	BP	No	DM&A (1996, 1999)	CFC (1996a, 1996b, 1997)	DM&A (1996, 1999)	No	Miller (2003)	USGS	Cruises K-1-76-AR and K-1-77-AR (Barnes et al., 1979; USGS, 2004b, 2004c)	Possibly. Vibracore V-28 adjacent to buried peat area, but core depth (1.5m bsf) may be too shallow to correlate to potential bog deposits at 2-4m bsf.	Yes	Steele (2004)	>1.65 m bsf based on nearby V-27 dates.	Probably not. V-28 contains scattered fibrous organics, likely detrital, within highly contorted muddy sand, which correlates to dates <5,500 yrs.b.p. in nearby V-27.
														Beaufort Sea Geotechnical Investigation (HLA, 1979)	No	No	Friddell (2004)	n/a	n/a
													UAF	Sediment coring programs, Beaufort Sea coast (e.g., Naidu et al., 1984)	Possibly	No	Naidu (2004)	n/a	n/a
Orion	14-16	No	n/a	n/a	n/a	Exxon	n/a	n/a	HLA (1985)	HLA (1985)	n/a	n/a	USGS	n/a	n/a	n/a	n/a	n/a	n/a
Phoenix	17-20	**Yes[2]**	Buried circular and elliptical depressions; possible relict permafrost features.	No	4-10 m	Tenneco	n/a	n/a	McClelland-EBA (1986)	Unknown	n/a	n/a	USGS	Cruise K-1-76-AR (Barnes et al., 1979; USGS, 2004b)	No	Yes	Steele (2004)	n/a	No (Barnes et al., 1979)
Sandpiper	8-19	**Yes**	Buried relict islands; buried Pleistocene channel	No. Closest boring located in between buried ridges.	<1-9 m	Shell	No	Croley (2004)	Dames & Moore (1983c)	HLA (1983b)	No	Croley (2004)	USGS	Cruises K-1-76-AR and K-1-77-AR (Barnes et al., 1979; USGS, 2004b, 2004c)	Possibly. Closest core is lies on north flank of Loon Shoal.	Yes	Steele (2004)	4-6 m	No (Barnes et al., 1979)

Table 1
Summary of Core Search Results by Industry Site[1]

Industry Site[1]	Approx. Water Depths (m)	Paleolandforms Previously Identified in MMS (2002)		Industry Sources									Government/Academia Sources						
						Operator			Geophysical Contractor	Boring Contractor						Core Material Available?			
							Core Material Available?				Core Material Available?								
		Y/N	Type/ Description	Do Industry Core Locations Coincide with Paleo-landforms?	Estimated Holocene Thickness (m bsf)	Name	Y/N	Contact/ Reference	Name (Report Date)	Name (Report Date)	Y/N	Contact/ Reference	Agency/ University Name	Study Name	Do Core Locations Coincide with Paleo-landforms?	Y/N	Contact/ Reference	Estimated Depth Range of Early Holocene (m bsf)	Organic Material Available within Early Holocene Depths?
Warthog	2-12	**Yes**	Buried channels with possible channel-edge features; areas of shoaling 1-2 m above surrounding seafloor - possible drowned barrier islands; possible wave-cut terraces in seafloor.	None adjacent to channel features. Several borings in shoaling areas.	0-20m overall; 3 m over potential channel-edge features; Pleistocene boulder patches near surface in between channels.	ARCO	No	Jones (2004)	Fairweather E&P (1997a)	EBA (1996); Fairweather E&P (1997b)	No	Gardner (1990); Jones (2004)	n/a	n/a	n/a	n/a	n/a	n/a	n/a

Notes:
1. Includes sites in <20m water depth only. Specific areas within sites that are <20m are shown in ().
2. Paleolandforms not identified in MMS (2002); however, evidence of paleolandforms in other documents (see text, Section 3.2).
3. McCovey not included in MMS (2002). Information is from PRA (2002) and MMS (2001).
4. Paleolandforms identified by industry contractors, as well as MMS (2000).

bsf = below seafloor
CFC = Coastal Frontiers Corporation
DM&A = Duane Miller & Associates
EBA = EBA Engineering, Inc.
HLA = Harding Lawson Associates
km = kilometers
m = meters
n/a = not applicable; no paleolandforms identified; boring contractor unknown; no government/academia core studies in vicinity.
NTS = Northern Technical Services
PRA = Petrotechnical Resources of Alaska
UAF = University of Alaska – Fairbanks
USACE = U.S. Army Corps of Engineers
USGS = U.S. Geological Survey
WCC = Woodward Clyde Consultants

3.2.2 Cabot

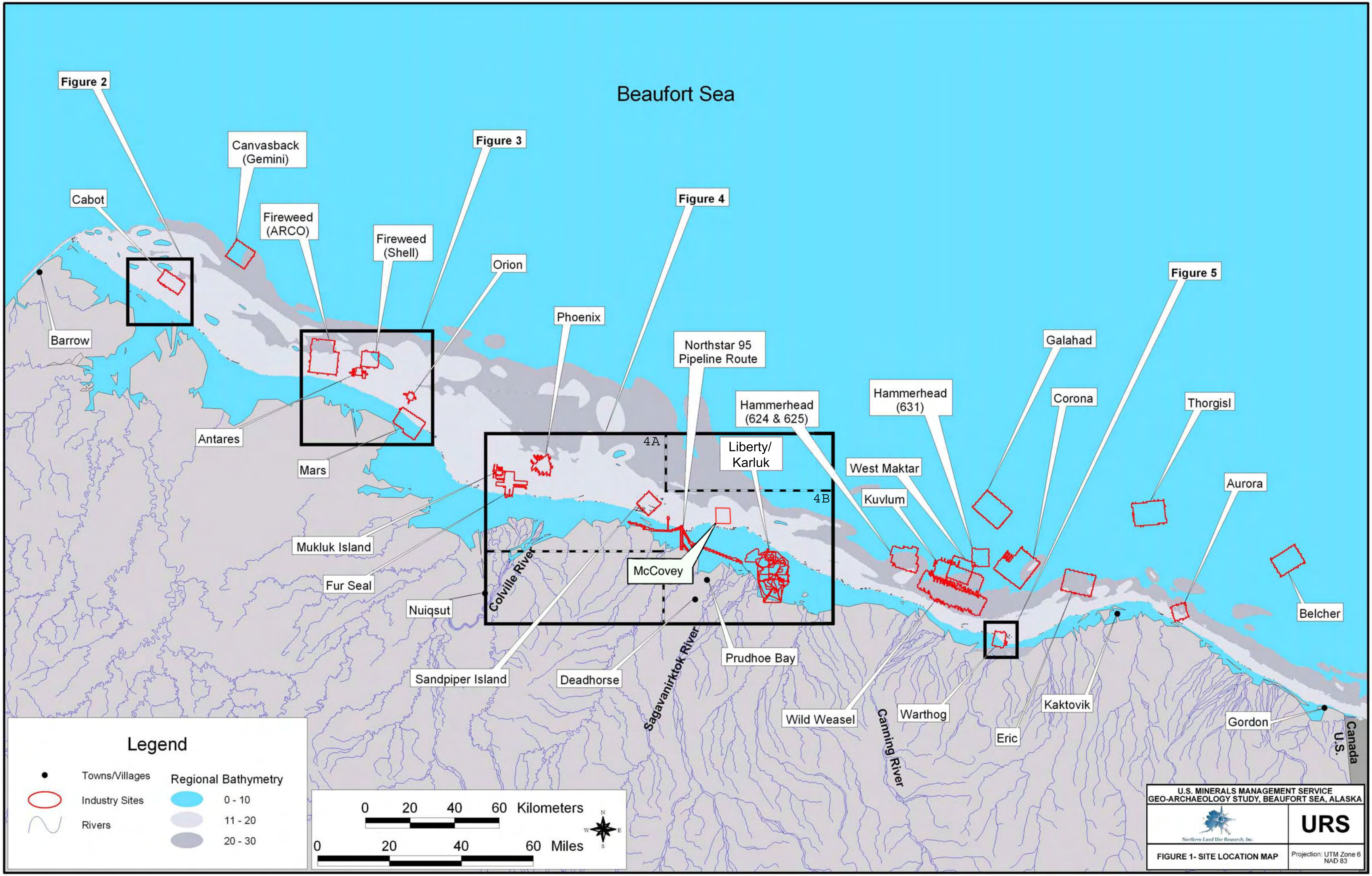
Cabot is the westernmost industry site in the study area, located offshore of Dease Inlet northeast of Barrow in 15 to 19 m of water depth. Late Pleistocene to Holocene surficial deposits are interpreted to range from about 4 to 7 m thick across the site. An erosional feature referred to as Simpson Canyon extends north-south through the site and underlies the mapped surfical unit (Figure 2, Appendix B). The canyon fill may also contain some late Pleistocene-Holocene deposits (MMS 2002). However, based on the depth of the base of the canyon, which is on the order of 600 m below sea level (Fugro-McClelland 1990), most canyon-fill deposits are likely to be of Pleistocene age and/or submarine origin. Paleolandforms were not identified in shallow surficial deposits at the Cabot site.

3.2.3 Fireweed

Fireweed-ARCO is the westernmost of two Fireweed sites located in the western part of the study area (Figure 1). Water depths at this site range from 12 to 25 m. Comap (1985) and MMS (2002) identify the presence of several paleolandform features that lie beneath Holocene surficial sediment ranging from 3 to 10 m in thickness. Comap (1985) suggests these features are formed on top of Pleistocene deposits that were subaerially exposed during the last low sea level stand. The most prominent feature is an east-west trending escarpment marked by up to 2 m of thickening of the overlying sediment from south to north (Figure 3, Appendix B). Comap (1985) interprets the escarpment to be a paleo-shoreline or coastal bluff that, in the underlying Pleistocene unit, marks the boundary between coarse coastal plain deposits to south and marine sediment to north. Landward of the escarpment, the interpreted Holocene/Pleistocene contact is both undulating and smooth, the high relief areas attributed to beach ridges, thaw lakes, and stream channels. Offshore of the escarpment lie two linear areas of Holocene thinning which are interpreted to be buried late Pleistocene sand bars or barrier island deposits (Appendix B).

Fireweed-Shell is the eastern of the two Fireweed sites (Figure 1), and is located in water depths ranging from 15 to 21 m. Dames & Moore (1984) and MMS (2002) identify the presence of a buried depression, channel, or shoreline beneath Holocene surficial sediment in the eastern half of the site. The west edge of the buried channel merges with the base of the overlying surficial sediment. The southern extent of the channel is unknown, as it is obscured on the seismic data by shallow gas. The thickness of the channel fill and overlying surficial sediment was originally mapped in milliseconds (ms) by Dames & Moore (1984) and MMS (2002). These values were converted to meters using a nominal velocity of sound in sediment of 1,500 m/s. The thickness of the surficial layer is estimated to range from approximately 7 to 12 m, while the total thickness in the channel fill area, including the overlying deposits, ranges from about 15 to 26 m. Dames & Moore (1984) suggest both units may be Holocene in age based on correlation to other studies in the area. However, the relatively flat, erosional-appearing nature of the contact at the base of the surficial unit suggests that the channel fill could be pre-Holocene.

There is some correlation between the reflector at the base of the surficial sediments and both permafrost and gravel occurrences in the Fireweed-Shell boreholes. The reflector appears to follow the gravel layer rather than permafrost as the permafrost dips slightly to the north in the boreholes (Dames & Moore 1984), favoring a geomorphic interpretation from the seismic data rather than permafrost occurrence.


Beaufort Sea
Figure 2
Figure 3
Figure 4
Figure 5
4A
4B
Canvasback (Gemini)
Cabot
Fireweed (ARCO)
Fireweed (Shell)
Orion
Phoenix
Northstar 95 Pipeline Route
Hammerhead (624 & 625)
Hammerhead (631)
Galahad
Corona
Thorgisl
Aurora
Belcher
Liberty/ Karluk
West Maktar
Kuvlum
McCovey
Barrow
Antares
Mars
Mukluk Island
Fur Seal
Nuiqsut
Colville River
Sandpiper Island
Deadhorse
Sagavanirktok River
Prudhoe Bay
Wild Weasel
Canning River
Warthog
Eric
Kaktovik
Gordon
Canada
U.S.
Legend
Towns/Villages
Industry Sites
Rivers
Regional Bathymetry
0 - 10
11 - 20
20 - 30
0 20 40 60 Kilometers
0 20 40 60 Miles
U.S. MINERALS MANAGEMENT SERVICE
GEO-ARCHAEOLOGY STUDY, BEAUFORT SEA, ALASKA
Northern Land Use Research, Inc.
URS
FIGURE 1- SITE LOCATION MAP
Projection: UTM Zone 6 NAD 83