BERING LAND BRIDGE CULTURAL RESOURCE STUDY

FINAL REPORT

submitted to

The Bureau of Land Management

Outer Continental Shelf Office

by

The University Museum

University of Alaska
Fairbanks, Alaska

In fulfillment of

Contract #08550-CT5-45

October 12, 1976

TABLE OF CONTENTS

ILLUSTRATIONS

Illustrations (continued)

Illustrations (continued)

Illustrations (continued)

ACKNOWLEDGEMENTS

The researchers would like to thank Mr. William Civish, BLM-COAR for his cooperation and participation throughout the course of the Phase I research and his assistance on board the R/V ACONA. His cooperation greatly facilitated the execution of all phases of the research. The valuable Russian translations by Ms. Katherine Arndt contributed much new data which would otherwise not have been available to this study. Mr. David C. Plaskett provided valuable research assistance and is to be commended for his infinite patience in the preparation of the species distribution maps and other graphics. Mrs. Dixie Brown also provided research support and assisted in typing and proofreading the manuscript. We wish to express our thanks to Mr. Barry McWayne for the excellent photographic support he provided to the project.

We are also indebted to David M. Hopkins for stimulating conversations and several maps of the Beringian area which he made available to the project. Mr. Robert Spiess, Mr. Gary Freitag, Mr. Fred Short and Mr. Cary Brown provided valuable assistance in executing the marine archeological survey. We would also like to thank hr. Wayne Lewis and Mr. Alexi Prokopioff of the Aleut Corporation and the residents of St. George Island for permission to establish on-shore transmitters on the Island. We appreciate the assistance provided by Mr. Roger Gentry of the National Marine Fisheries for surface transportation on St. George Island. We would also like to thank the U.S. Fish and Wildlife Service for permission to conduct the terrestrial archeological survey of St. Matthew Island. We also express our appreciation to the many researchers too numerous to mention here who gave so freely of their time and shared their data. Special thanks are due to Cindy Lippincott whose" dedication to the project and typing the manuscript through its many revisions is warmly appreciated.

INTRODUCTION

The following report was produced by the University of Alaska Museum, Fairbanks, Alaska, under Contract #08550-CT5-45 with the Bureau of Land Management Outer Continental Shelf Office. The purpose of the research was to identify areas of high archeological probability on Alaska's outer continental shelf and to assess the feasibility of actually detecting submerged archeological sites. The study is to be used as a planning tool by the BLM-OCS office to assure the preservation and management of cultural resources on the outer continental shelf in relation to oil lease activities.

Phase I of the research was to focus on an interdisciplinary research approach of the critical problem of isolating regions of high archeological probability on the Bering and Chukchi outer continental shelves off Alaska's *coast.* Phases II and III of the project attempted to locate archeological sites of Pleistocene age in the Bering Sea.

The project's research team consisted of G.D. Sharma, physical oceanographer, Sam W. Stoker, marine mammologist, Russell D. Guthrie, vertebrate paleontologist, and E. James Dixon, Jr., archeologist and project coordinator. Temporal restraints were felt by all authors because of the necessity to complete the research prior to off-shore oil lease sales planned for 1976.

The following report represents the most detailed study of the Bering Land Bridge as it pertains to human utilization and the colonization of the New World. Each of the four Phase I reports represents a major research contribution in its own right, In the section on the paleogeography of Beringia, Sharma presents, by a series of "snapshots" through time, the most detailed reconstruction of the Wisconsin evolution of Beringia yet advanced. The sections by Stoker and Guthrie are both innovative for they develop the theory and method for mapping paleodistributions of two major species complexes, marine and terrestrial mammals, respectively. The final section by Dixon provides a treatment of the evidence favoring the probable human occupation of Beringia and man's penetration of the North American continent via that route. It also proposes a theory and method for predicting high probability areas for archeological site occurrence.

This study is also significant in that it practices what is so often stated as an ideal in archeological research, but which is so seldom implemented--a truly interdisciplinary approach applied to a specific research problem. It is perhaps this very strength of the research design which leads to some of its apparent weaknesses. All investigators have pushed the existing data to their limits {sometimes deliberately stretching them to the breaking point) while, at other times, they have remained conservative in dealing with specific aspects of their research. It is these divergent lines of data and reasoning which lead to what some may interpret as internal inconsistencies within the total report. However, if we had all agreed, there would be no questions and little need for undertaking such a project. Each author is solely responsible for his individual presentation, and many times sharp differences in interpretation could not be reconciled on the basis of available information. In such instances, each author has expressed in his manuscript what he believes to be 'the best interpretation of the data available to him. With this note, we will let the readers join in the discussion and formulate their own interpretations.

E. James Dixon, Jr.

University Museum
University of Alaska
Fairbanks, Alaska 99701

October 1976

GEOLOGY

G.D. Sharma

EVOLUTION: The early geologic evolution of Beringia is not well known. The earliest known Paleozoic features of the Chukchi Sea are the east-west oriented Colville Geosyncline in the north and the Kobuk trough in the south, separated by a geanticline. The eastern extension of this geanticline in Alaska is known as the Brooks Range. The entire region of Beringia during Paleozoic and Mesozoic eras remained as a geosyncline and was filled with marine sediments. At the close of the Mesozoic era the region *was* uplifted. The geologic events during the Tertiary have been described by Hopkins (1959). During the Tertiary, the emergent Chukchi Sea floor was intermittently submerged as a result of crustal warping.

The Paleozoic rocks surrounding the northern Bering Shelf, when extrapolated to subsurface, presumably form the basement rock of the Norton and Chirikov basins. Southwards, beneath the offshore region between the Yukon and Kuskokwim Rivers, the shelf is probably underlaid by the Mesozoic rocks of the Koyukuk Geosyncline (Gates and Gryc, 1963). Between the Kuskokwim River and Togiak Bay, the Kuskokwim Geosyncline probably extends offshore under the shelf. The Bristol Bay shelf appears to be the extension of the Alaska Range Geosyncline.

Seismic records obtained by Moore (1964) and Scholl et al. (1966, 1968) from the Bering Shelf indicate that the subsurface deposits can be divided into three general groups. The lowermost unit is an "Acoustic Basement" consisting of folded rock below a strongly reflecting horizon. The acoustic basement has been related to Precambrian and Paleozoic sedimentary and metamorphic rocks in the northern shelf, to Cretaceus and early Tertiary volcanic rocks in the central shelf, and finally, to Jurassic and Cretaceus flysch-type sediments in the south (Nelson et al., 1974).

Overlying the acoustic basement is a thick sequence of . gently deformed marine and non-marine sediments of middle to the late Tertiary. This sequence is termed main layered sequence, and reaches a thickness *of* over 3 km in the northeast-trending Bristol Basin near Kvichak Bay (Scholl et al, 1966).

During the Quaternary period, Beringia was intermittently invaded by sea and ice. The sea level fell as much as 100-150 m below its present level during the height of the glaciation, thus exposing millions of square kilometers of shelf to ice erosion. The warmer temperatures during interglacial stages, on the other hand, flooded Beringia to a depth such that the sea level at times stood at least 20 m above its present shoreline. The chronology and type localities of various marine advances and retreats on Beringia have been described in detail by Hopkins (1967; 1972), and is shown in Figs. 1-1 and 1-2.

HISTORY OF CHANGES OF THE COASTAL SYSTEMS: Hopkins {1967) described seven episodes of transgressions in the Chukchi and Bering Seas. At the climax of each transgression, the sea level rose to flood the Bering Strait, while during glacial periods the sea level fell to expose large areas of the shelf and restored land connection between Alaska

Fig. 1-1. QUATERNARY MARINE TRANSGRESSIONS RECORDED ON ALASKAN COASTS *

Transgression	Type Locality	Altitude of Shoreline	Climate as Compared with the Present	Archaeological m Radiometric Dating	Correlation: North America	Correlation: Europa
Krusensternian	Recent beach ridges at Cape Krusenstern	Within 2 meters of present sea level for deposits <4,000 yrs. old	Same	<5,000 yrs. at Cape Krusenstern; up to 10,000 yrs. for terraces along Gulf of Alaska coast	Late Wisconsin and Recent	Late Würm and Recent
Woronzofian	Bootlegger Cove Clay near Point Woronzof, Anchorage area (Miller and Dobrovolny, 1959)	Probably a few meters below present sea level	Writer colder Air colder	<48,000 yrs.; >25,000 yrs.	Middle Wisconsin interstade	Middle Würm interstade
Pelukian	Second Beachat Norm (Hopkins et al., 1960)	Two distinct high-sefl.level stands at +7-10 meters	Water warmer Air slightly warmer	Cu. 100,000 yrs.	Sangamon Interglaciation	Broerup Interstade (?) and Riss-Würm Interglaciation
Kotzebuan	Marine beds 1jclow Illinoian drift along eastern shore of Kotzebue Sound (McCulloch et al., 1965)	Probably cu. -1-20 meters	Water same Air unknown	170,000 yrs.; 175,000 yrs.	Pre-Illinoian interglaciation	Mindel-Riss Interglaciation
Einahnuhtan	Einahnuhto Bluffs, St. Pull Is. (Cox et al., 1966)	Probably err, +20 meters	Water same Air unknown	<300,000 yrs,; >100,000 yrs,		Pre-Mindel interglaciation
Anvilian	'1'bird Beach-Intermediate Beach at Nome (Hopkins et al., 1960)	Probably much higher titan Kotzebuan and Einahnuhtan: <-1-100 meters; >+ 20 meters	Water warmer Air warmer	Probably <1,900,000; >700,000	Middle Pleistocene interglaciation	
Beringian	Submarine Beach at Nome (Hopkins, et al., 1960)	Two distinct episodes during which sea level was higher than nt present but probably lower than Anvilian sea level	Water much warmer Air much warmer	Last episode ca. 2,200,000 yrs. on St, George Is.	Late Pliocene and early Pleistocene	

* Directly from Hopkins (1967a:50-51).

Fig. 1-2: Sequence of Climatic Events in Beringia *

	ORTH AMERICA	ERINGIA			EUROPE
		ALASKA	CHUKOTKA	KAMCHATKA	
	HOLOCENE	Post-glacial thermal maximum in most of Beringia			HOLOCENE
		Early Holocene warming Northwestern Alaska			
10,000 years					
	WISCONSIN GLACIATION	Birch period in Seward Peninsula-Kotzebue Sound area -38 meter shore line Peak of last glaciation Minor marine transgression Glacial and climatic fluctuations during early part of last glaciation			WEICHSEL GLACIATION
	SANGAMON INTERGLACIATIC	ELUKIAN TRANSGRESSION AND LAST INTERGLACIATION	Valkatlen Suite & Koneraino Beds	Attarman Suite	EEM INTERGLACIATION
100,000 years	ILLINOIAN GLACIATION	PENULTIMATE GLACIATION KOTZEBUAN TRANSGRESSION	Kresta Suite	Ossor Suite	SAALE GLACIATION HOLSTEIN TRANSGRES SION
		EINAHNUHTAN TRANSGRESSION	Pinakul' Suite	Karagin Suite	
		ANVILIAN TRANSGRESSION		Tusatuvayam Suite	
1 million years					
	PLIOCENE	BERINGIAN TRANSGRESS ION		Ust-Limentevayam Suite	PLIOCENE
10 millio years					

'Directly from Hopkins (197.2:123).

and Siberia. The marine sediments of each transgression are separated by a subaerial environment of lowered sea level. The marine sediments identified in Alaska are of Beringian, Anvilian, Einahnuhtan, Kotzebuan, Pelukian, Woronzafian, and Krusensternian transgressions (Fig. 1-1).

BERINGIAN TRANSGRESS1ON: Though evidence, for glaciation in the Miocene has been reported by Plafker (1967), the glaciation and interglaciation cycles in Alaska started in the Tertiary. The earliest transgression in the Bering and Chukchi Seas occurred during the late Tertiary (Pliocene) and continued well into the early Quarternary. This transgression has been labeled as the Beringian Transgression, and the sediments deposited during this period have been dated about 2.1 million years B.P. This transgression was the result of continuing crustal warping, which submerged the Bering and Chukchi shelves, approximately in their present forms, about 3.5 million years ago.

The nature of the subaerial climate and landscape during the Beringian Transgression remains poorly known. Sediments deposited during this stage have been located near Nome, St. George Island and Kivalina. These deposits have been deformed by the crustal warping so that it is not possible to estimate precisely the rise in sea level. It appears, however, that sea level reached levels higher than present. The molluscan species found in Beringian beds near Nome also suggest that the Bering and Chukchi Seas were warmer than at present.

ANVILIAN TRANSGRESSION: This marine transgression was first designated by Hopkins (1965) and is based on the marine sequence deposited near

Nome. These deposits are distinctly different than both those of the preceding Beringian and following Einahnuhtan transgressions. The typical sediments deposited during the Anvilian Transgression are found on the coastal plain near Nome. These deposits contain marine fossils and have been exploited for their rich gold content. The sandy and gravelly beach and littoral sediments form a 2-3 meter thick discontinuous sheet. Transgressive sediments were also deposited during the Anvilian time along the Chukchi Sea coast and the Arctic Coast, including most of the Gubik Formation covering the Arctic coastal plain.

The Anvilian Transgression occurred between 700,000 and 1,800,000 years ago (Hopkins, 1967). The position of sea level during the transgression was probably about 20 m higher than present. The sea water temperature was moderate and water circulation on the shelf was similar to that of present, with northward flow through the Bering Strait.

EINAHNUHTAN-KOTZEBUAN TRANSGRESSIONS: In 1967, Hopkins identified two major transgressions between 100,000 - 300,000 and 1.70,000 - 175,000 years ago. Subsequent investigations and correlation revealed that these two transgressions occurred during a relatively short interval and, therefore, can be considered as one major transgression. This multiple transgression correlated well with the Termination 111 proposed by Broecker and van Donk (1970) which took place about 250,000 years ago.

The typical sediments deposited during the middle Quaternary sea level rise, the Einahnuhtan Transgression, are found in the Einahnuhto Bluffs on St. Paul Island, Pribilof Islands. The marine sequence consists of fossiliferous beach and littoral sediments. These sediments are overlain by basaltic lava flows and bedded tuffs, suggesting that at its near end the transgression was followed by volcanic eruptions on the island. In some sections of the bluffs, the Einahnuhtan marine sequence and the overlying volcanic beds are truncated by shelly gravels deposited during a later submergence. These sediments represent the Kotzebuan transgression and axe, in turn, overlain by a later volcanic sequence. Fortunately, the volcanic sediments provide excellent material for radiocarbon dating the glacial, and interglacial events of the Einahnuhtan-Kotzebuan stages. The best estimates of potassium-argon age determination for the lower lava flow is 320,000*70,000, and for the younger beds, 120,000*70,000 years B.P. {Hopkins, 1973).

The type locality for the sediments deposited during the Kotzebuan Transgression is the sea cliff facing Kotzebue Sound between latitudes 65°32′ N and 65°35′ N on the west shore of Baldwin Peninsula (Hopkins, 1965). The 100 m thick transgressive sequence consists of thick-bedded marine silty clay and deltaic thin-bedded peaty silt. Some nearshore well-sorted sand and beach gravel are also present. Farther north, the Einahnuhtan-Kotzebuan Transgression sediments are exposed along the Kukpowruk and Epizetka Rivers (McCulloch, 1967).

The Beringian Sea during the Einahnuhtan Transgression was slightly warmer than present and sea level stood approximately 20 m above present. The Kotzebuan Transgression was extensive and the sea level was probably slightly higher than during the Einahnuhtan

Transgression, though Hopkins (1973) postulated that the waters in Beringia were slightly warmer during the Einahnuhtan. The Kotzebuan Transgression was followed by the penultimate glaciation (Illinoian Glaciation).

ILLINOIAN GLACIATION: Sediments deposited during this glaciation are extensively exposed along the Chukchi shore and in the Bering Sea. The climate was severe and ice covered large continental regions. The Brooks Range was laden with snow and ice which formed large valley glaciers. Part of the lowlands were covered with large ice sheets reaching several hundred kilometers in length and width. Piedmont glaciers extended to within 15 km of the coast near Kivalina (McCulloch, 1967). Although most continental rivers (Kobuk and Noatak Rivers) were filled with valley glaciers, the ice probably did not extend seaward beyond the shoreline. The Hope Seavalley in the *southern* Chukchi Sea indicates subaerial erosion (Craeger and McManus, 1965) daring various glacial episodes.

The Seward and Chukotka Peninsulas were covered by ice caps, and glaciers extended onto the continental shelf. Glaciers from the Chukotka Peninsula flowed southward and extended as far as 100 km into the Chirikov Basin (Nelson and Hopkins, 1969; Grim and McManus, 1970; Kummer and Craeger, 1971). The Yukon and Kuskokwim lowlands probably remained ice-free. In southern Beringia the mountains and highlands were covered with snow, and the valleys were filled with interconnected glaciers and ice fields. The ice spilled over the low-land and spread onto the adjoining continental shelf. The extensive ice coverage in southern Beringia *was* due to moisture from the south and southwest, and to lowered snow line as a result of depressed summer temperatures.

At the height of the Illinoian glaciation, the shoreline receded seaward to the *-135* m isobath and exposed about 80% of the continental shelf. Some anomalous subbottom features at 2-5m along the -135 m isobath have been observed by ***Moore*** (1964). These highly reflective horizons were initially interpreted as lava flows by Moore (1964) . However, Hopkins (1973) has recently suggested that these reflective features may be high-angle buried sandy beaches formed during the Illinoian Glaciation at depths varying from -125 to -150 m isobaths. The overlying sediments, which vary from 2.5 m in thickness, represent detritus deposited during the Wisconsin Transgression, indicating that these beaches remained submerged during later regressions.

SANGAMON (PELUKIAN) TRANSGRESSION: Following the Illinoian glaciation, the climate became warmer, thus triggering a marine transgression which climaxed approximately 100,000 years ago (Hopkins, 1967). The Sangamon marine terraces and nearshore deposits are well preserved and are generally found landwards of the Holocene coastal deposits in areas which remained ice-free during Wisconsin glaciation. The Sangamon deposits suggest two episodes of transgression.s separated by a shoreline regression which lasted for several thousand years (Hopkins, 1973).

The records of the Sangamon Transgression are widely distributed as terraces, which are generally found at 5 to 10 m above the present sea level. Marine deposits associated with beach ridges at about 10 m above present sea level have been observed near Barrow (McCulloch, 1967). Southwards along the Chukchi coast, Sangamon transgression is commonly represented by narrow wave-cut terraces on the steep, rocky shores. Such terraces have been located near Cape Thompson and described by Sainsbury et *al. (1965).* An excellent stratigraphic sequence deposited during the Sangamon Transgression in Kotzebue Sound provides the best clues to the climate during that time. Sea level during the height of this transgression in this area was about 10 - 12 m higher than present sea level. Presence of ice wedge casts in Sangamon deposits suggest that the rise of' sea level was irregular and was interrupted by colder periods which promoted such ice wedge formation (McCulloch, 1967).

Evidence of the higher sea level during the Sangamon have been observed along the Lost River on the Seward Peninsula (Sainsbury, 1967), near Nome (Hopkins et *al., 1960},* and on the Pribilof Islands (Hopkins and Einarsson, 1966).

The major Sangamon deposits lie at about 6-12 m higher than present sea level. Because of the large variation in the present level of these deposits due to isostatic rebound, it is difficult to estimate precisely the maximum sea level rise during the Sangamon Transgression. It is, however, safe to suggest that at *the* peak of the transgression the sea level probably stood at 10 m above present. The nature of marine fauna suggests that the water of Beringia was slightly warmer than at present and that considerable Pacific water established a northward flow similar to the present circulation across the shelf.

WISCONSIN GLACIATION: The events occurring in Beringia between the Sangamon Transgression (approximately 70,000 years B.P.) and about 30,000 years ago are poorly documented and not well understood. The climate during this period was generally cold, though interspersed by a series of warming trends. In northern Alaska the Wisconsin Glaciation has been characterized by four stades recognized on the north side of the Brooks Range. The records of interstades during the Wisconsin, however, remain obscured. Evidence of a rise in sea level to within a few meters of present between 40,000 and 25,000 years ago is provided by the beach ridges near Point Barrow. Because the water in Beringia during interstades did not rise above the present sea level, the sediments deposited during these stages remain submerged except in areas of emergence, where these marine fossiliferous deposits have been exposed for study.

The lowering of sea level during the last glaciation caused the shoreline in Beringia to regress to the -90 to -100 m isobath, thus exposing the shelf to subaerial erosion. On the Chukchi shelf, the Hope Seavalley received the drainage of the westward flowing rivers. The valley extended westward and northward to enter the Arctic Ocean through Herald Submarine Canyon, northwest of Wrangell Island. Several deltaic deposits and extensive flats along the Hope Seavalley have been observed by Craeger and McManus (1967) and they postulated that these features developed as a result of irregular rise during Wisconsin Glaciation.

The drainage from the northeastern Chukchi shore was carried north and entered the Arctic Ocean through the Barrow Submarine Canyon.

Interestingly, the watershed divide between the Chukchi and Bering drainages was located along St. Lawrence Island rather than the Bering Strait. Therefore, part of the northern Bering Sea drainage flowed northward and carried into the Hope Seavalley.

On the Bering shelf, the Kvichak and Kuskokwim *Rivers* maintained a steady course, which is well illustrated by the inter- . connecting submerged river valleys. The course of the Yukon River is, however, difficult to follow. The contemporary shelf bathymetry suggests that the Yukon River, during the Wisconsin Glaciation, drained to the south and entered the Bering Sea through the Pribilof Submarine Canyon.

The fluctuations in sea level in Beringia during the Wisconsin glaciation are not adequately known. It is, however, well known that sea level underwent a major oscillation in other parts of the world during the peak glaciation. It appears that during the height of the last Wisconsin glaciation the shoreline in Beringia was about 100 m lower than present sea level.

MID-WISCONSIN TRANSGRESSION: The Mid-Wisconsin Transgression which flooded Beringia to about 15 m lower than present sea level occurred about 25,000 to 40,000 years ago (Hopkins, 19731- Evidence for this transgression is found along a beach ridge which lies about 2 km inland of the present coastline and 7 m above the present sea level. Plant fibers from the principal beach ridge and the organic material from the underlying littoral sandy silt provided the radiocarbon dates with a range of *25,000* to *40,000* years (Sellmann and Brown, in press].

The sea floor of Norton Sound consists of two topographic depressions, the major of which is a large east-west trending basin. This basin lies about 30 km south of Nome. Along the southern periphery of this basin *Moore* (1964) observed northward-dipping foreset beds on the sonoprobe records. These beds are overlain with 2-3 m of contemporary sediments and are located near the -20 m isobath. Southward of these foreset beds, Moore (1964) observed broad channels extending towards the present Yukon River mouth. The presence of the beds and the channel *on the* southern side of the basin were further confirmed by high-resolution seismic records obtained by C.H. Nelson (U.S. Geological Survey, Menlo Park, Calif.) in 1969. Because of the stratigraphy and the presence of channels, Moore (1964) concluded that these sediments were deposited as an earlier delta of the northward flowing Yukon River. Hopkins (1973) suggested that these deltaic sediments were probably deposited during the Mid-Wisconsin Transgression.

The Yukon River has a huge drainage area and therefore carried a significant amount of water and sediment. In spite of its size, it appears that the river has frequently changed its course during glacial and interglacial stages, and to locate precisely the course during each stage has been enigmatic. If it is presumed, as suggested by Hopkins (1973) , that the Yukon River indeed debouched into Norton Sound during the Mid-Wisconsin Transgression, then it is hard to explain why the river changed its course southward during the following episode. The buried channels and radioactive dates suggest that the Yukon River debouched north of Nunimak Island and drained westward at various points south of St. Lawrence Island between 15,000 and 20,000 years ago (Knebel and Craeger, 1973).

<u>LATE-WISCONSIN GLACIATION</u>: The extent of the last glaciation was much less severe than the preceding Mid-Wisconsin Glaciation due to the lack of moisture in northern Beringia (Hopkins, 1972). At the peak of the glaciation, about 20,000 years ago, the shoreline regressed seawards to about the -100 m isobath. The cold climate did not persist over an extended period and, therefore, there is little evidence from which to reconstruct the geography of Beringia during this period.

The glacial events during the Late Wisconsin have been well preserved in the Brooks Range and have been studied by Porter (1967) and Hamilton and Porter (1976). Four stades (substages of glacial advance) on the northern and southern sides of the Brooks Range have been recognized. In the central Brooks Range the last major glaciation of the Late Wisconsin has been termed the "Itkillik" (Hamilton and porter, 1976). The radiocarbon date determination of the material from various stades suggest that the glaciers in this region attained their maximum areal extent about 20,000 years ago and receded to their present stage between 11,000 and 6,000 years ago.

On the southern Bering shelf, the information concerning the extent of glaciation during the Late Wisconsin is not available. A few glaciers from the Kuskokwim Mountains and the Alaska Peninsula undoubtedly must have descended to the shelf. Relict glacial sediments on the southern shelf have not been discovered, however, indicating that these glaciers did not extend extensively seaward of the present strand line.

That part of the shelf exposed to subaerial erosion shows pronounced and numerous submerged river valleys and drainage systems. These submerged features suggest that the major drainage from the Alaska mainland was carried southward. The Yukon River probably skirted the eastern shores of Nunivak Island and into Pribilof Canyon. The Kuskokwim and Kvichak Rivers likewise drained to the south and southwest, respectively.

LATE-WISCONSIN TRANSGRESSION {HOLOCENE): At about *20,000* years ago a warming trend started and *sea* level began to rise. This trend corresponds to the global climate and sea level changes of Termination I, described by Broecker and van Donk (1970). The events and paleogeography during the Late Wisconsin Transgression are reconstructed primarily from the shelf topography, in particular the submerged river valleys, and from sedimentation rates and the scattered radioactive date determinations of core sediments. A variety of features of terrestrial origin occur offshore, including submerged beaches, beaches, bars, deltas, and other shore features.

Submerged river valleys are recognized world-wide. The submerged valleys of several of the best known rivers developed during the last glaciation and generally terminate between -70 m and -100 m. For example, (1) the submerged Hudson River valley is 140 km long and ends at -70m; (2) the ancestral Elbe River valley is 500 km long and ends at -80 m; (3) the Rhine River valley below sea level is *720* km long and ends at -90 m; (4) the Po River valley extends 250 km below the sea and terminates at -100 m; and finally, (5) on the Sunda Shelf, between Boreneo and the Malay Peninsula, a valley 1000 km long ends at -90 m. It is commonly accepted that these submerged valleys represent lowered sea level related to the last glacial age. The rising sea level caused by the change from glacial to interglacial climate conditions resulted in the drowning of river mouths and valleys. The changes in glacial regimen also resulted in changes of stream regimen. These changes are reflected in valley filling by slackened stream flow and valley erosion by accelerated stream flow.

A detailed study of the bathymetry of the Bering Shelf, using National Ocean Survey charts 1215 N-10, 1711N-17B, 1711N-18M, 1714-11B, 1714N-12B, 1814-10B and unpublished data of the University of Washington, reveals that the shelf consists of three broad benches (Figs. 1-3 and 1-4). The farthest offshore bench is located between the -80 m and -60 m isobaths, the mid-bench lies between the -50 m and -30 m isobaths, and the nearshore bench lies between the -20 m isobath and the tidal shoreline. Seawards, each bench has a narrow and relatively steeper frontal slope which occurs along the >80 m, -60 to -50 m, and -30 to -20 m isobaths respectively, The sediment characteristics (sediment mean size and sorting) along these steeper slopes is anomalous and quite distinctly different than those deposited on the benches. The topography and morphography of these features suggest that these steeper regions of the shelf are ancestral submerged shorelines. The shoreline at the height of the Late Wisconsin glaciation probably was located between the -100 and -120 m isobaths (Knebel, 1972).

The Bering Shelf is cut by numerous channels and river

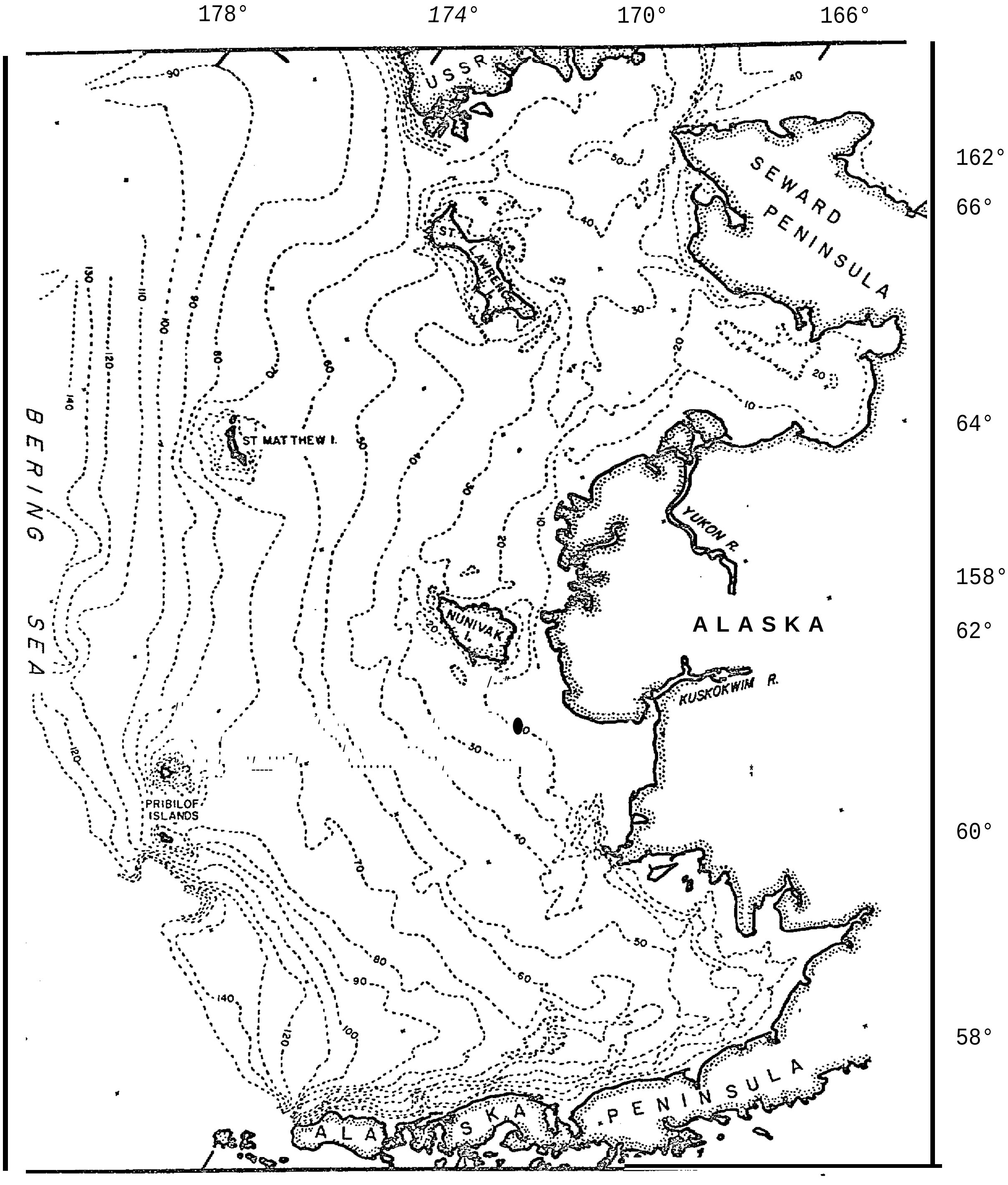


Fig. 1-3. Bathymetric map of the Bering Sea
Compiled by G.D. Sharma from National Ocean Survey charts 1215 N-10, 1711N-17B, 1711N-18M, 1714-11B, 1714N-12B, 1814-10B and unpublished data of the University of Washington.

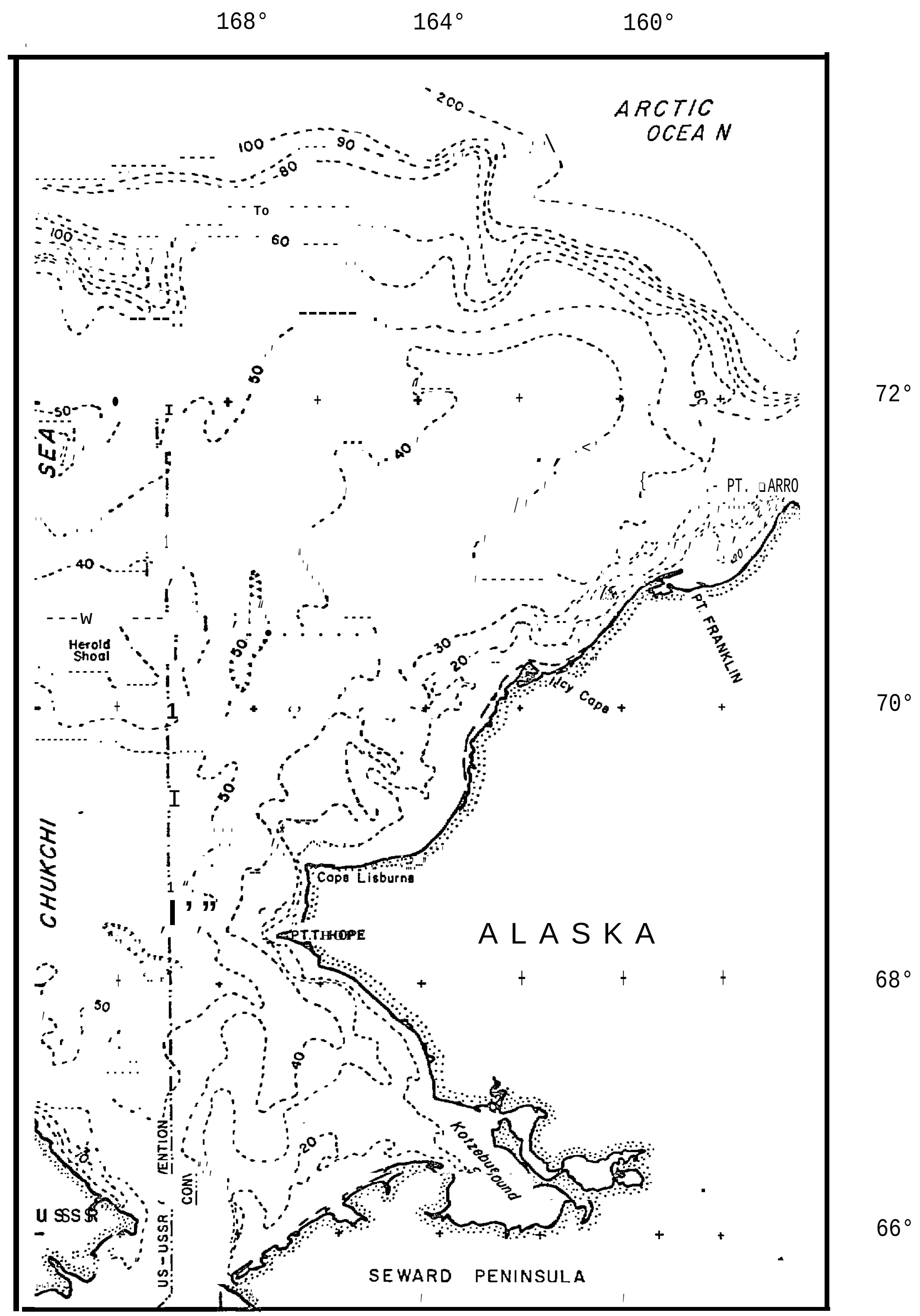


Fig. 1- 4. Bathymetric map of the Chukchi Sea
Compiled by G.D. Sharma from National Ocean Survey charts
1215 N-10, 1711N-17B, 1711N-18M, 1714 -11B, 1714N-12B,
1814-10B and unpublished data of the University of
Washington.

valleys, obviously the ancestral drainage systems of the major rivers from Alaska. The submerged channels of the southern shelf can be classified into "two categories: 1) channels which are continuous from the -90 m to -20 m isobaths, and 2) channels which are not continuous. The continuous channels are located in Bristol Bay and can be traced shoreward to the present drainage system of the Kvichak and Kuskokwim Rivers.

Two discontinuous but prominent channels east of the Pribilof Islands suggest a major river drainage from the north. It should be noted that, although the river valleys are quite prominent on the benches, they are conspicuously absent on the more steeply inclined forefront. Two prominent indentations in the -70 m isobath east of the Pribilof Islands, when traced shoreward, had no equally prominent indentations in the -40 m and -30 m isobaths, though the configuration of the -20 m isobath may connect the drowned river valley landward to an area north-east of Nunivak Island. It is suggested that these drowned valley features were formed by the ancestral Yukon River flow during various interglacial epochs. The locations and orientations of these drowned valleys suggest that the Yukon River, during the last Wisconsin glaciation (22,000 years B.P.), carried its discharge just south of the Pribilof Islands and debouched into the Bering Sea through the Pribilof Canyon (Fig. 1-5).

Evidence for northward migration of the Yukon River during the Late Wisconsin Transgression has been presented by Knebel and Craeger (1973). The northward shifting of the Yukon River drainage over

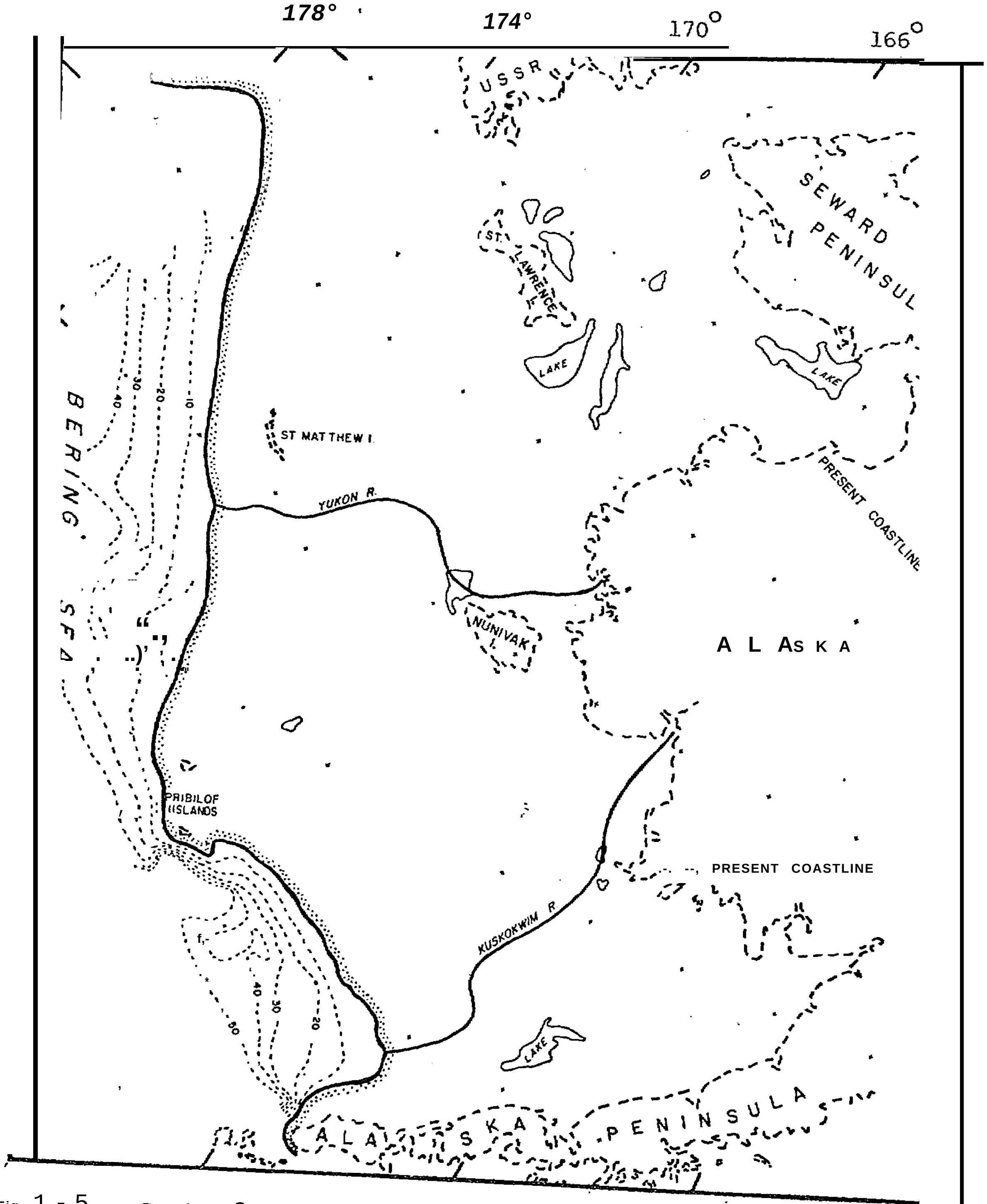


Fig. 1 - 5 . Bering Sea, Standstill I, 22,000 B.P.
Compiled by G.D. Sharma from National Ocean Survey charts 1215 N-10, 1711N-17B, 1711N-18M, 1714-11B, 1714N-12B, 1814-10B and unpublished data of the University of Washington.

the exposed shelf during the last transgression has been described by Hoare and Condon (1966, 1968) and Shepard and Wanless (1971). The bathymetry, buried channels, deltaic deposits, and radioactive dating determinations over the central Bering Shelf have been reported by Knebel and Craeger (1973) and they suggest that the Yukon River flowed between St. Lawrence and St. Matthew Islands between 11,000 and 16,000 years ago (Fig. **1-6).** Based on radioactive date determinations and forminiferal assemblages, the sea level during this period stood between -30 and –70 m.

During the early stages of the Late Wisconsin Transgression (12,000 - 20,000 years ago) , the sea level rose steadily from a low of about -70 m to -50 m. At this time the Bering Strait and the Strait of Anadyr were flooded, separating the Asian and American land masses. The opening of the Bering Strait permitted the flow of Pacific water into the Arctic Ocean. It is believed that this flow of water, although limited, must have significantly influenced the weather in the polar regions and thus somewhat stabilized the rapid warming trend. Therefore, the sea level may have risen slowly, thus forming a prominent shoreline between the -60 m and -50 m isobaths in the southern Bering Shelf.

Evidence for an abrupt expansion of dwarf birch over the Seward Peninsula-Kotzebue Sound region about 13,000 years ago has been observed by Hopkins (1972). A modest glacial retreat about 13,000 or 14,000 years ago was followed by an advance in Beringia (Porter, 1964b, 1967; Ferrians and Nichols, 1965). The major shoreline along the -60m and -50 m isobath was probably formed **14,000** to 13,000 years ago. Minor fluctuations continued during the period of 13,000 to 10,000 years ago.

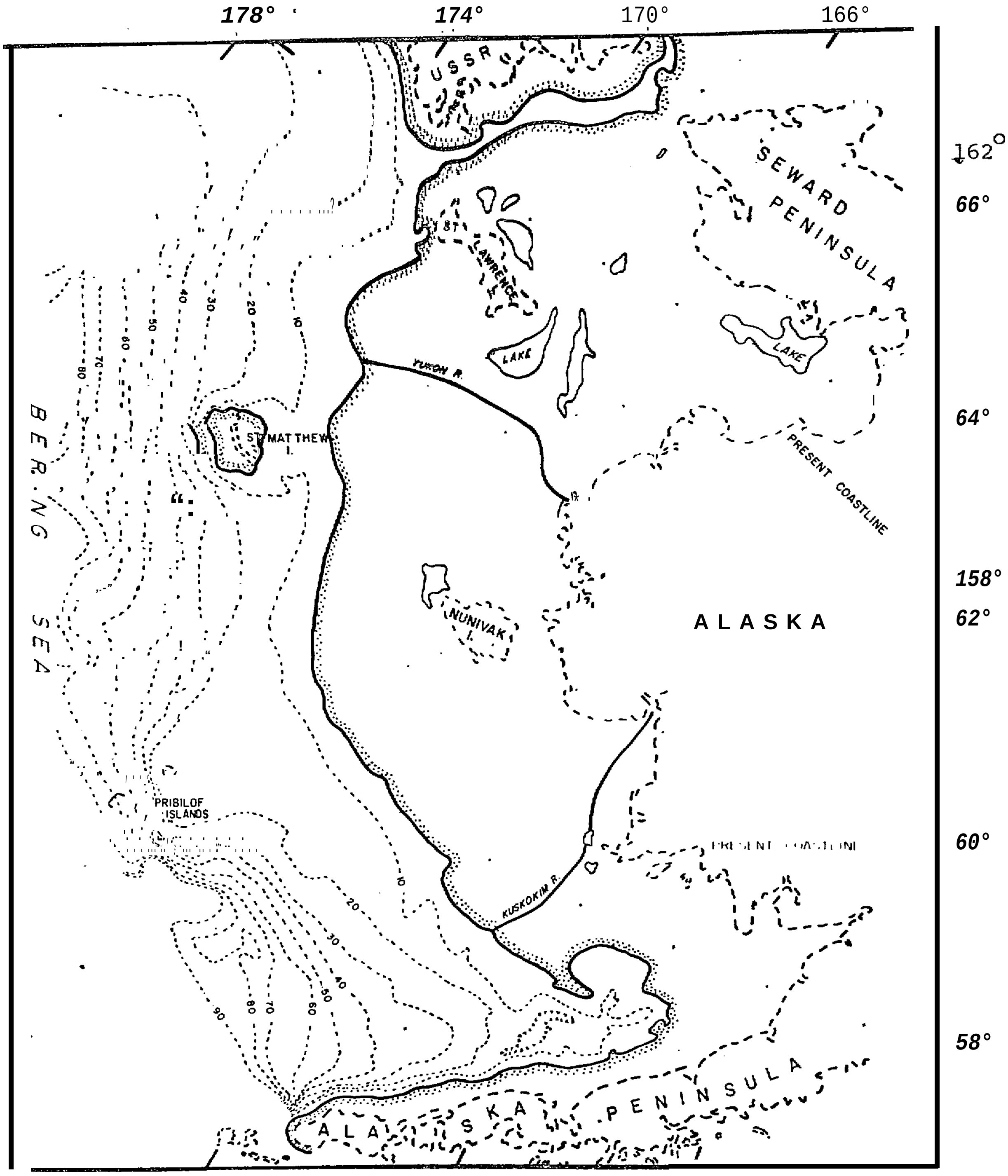


Fig. 1-6. Bering Sea, Standstill II, 16,000 B.P.
Compiled by G.D. Sharma from National Ocean Survey charts 1215 N-10, 1711N-17B, 1711N-18M, 1714-11B, 1714N-12B, 1814-10B and unpublished data of the University of Washington.

Sediments and fauna from deep-sea cores indicate that climate on a world-wide scale remained somewhat severe until an abrupt warming about 11,000 years ago (Broecker, 1966).

With a continued rise-in sea level, the shallow sill (-28 m) between St. Lawrence Island and the Alaska mainland (Sphanberg Strait) finally crested at about 10,000 years ago. At that time the Yukon River still drained south of St. Lawrence Island. With the opening of the Sphanberg Strait, the northward-flowing water set up a strong current along the mainland which diverted the Yukon River discharge into the Chukchi Sea through the Sphanberg Strait. It appears that this event coincided with a minor fluctuation of sea level. The slightly steeper slope between the -30 and -20 m isobaths suggests that sea level at that time either rose at a very slow rate or was stationary over a long period (Fig. 1-7).

After a minor interruption, the sea level again began to rise and attained its present level at about 6,000 years ago. The Yukon River flux was mostly diverted to the Chukchi Sea during this period and the river delta shifted northwards towards Norton Sound. The sea level changes, particularly during the Late Wisconsin Transgression, are not well reflected in the Chukchi Sea and are not well understood. Regional uplift during the Late Wisconsin has been observed along the Arctic Coastal Plains. Mid-Wisconsin beach ridges near Point Barrow have been uplifted to a magnitude of tens of meters. The rebound in this area further complicates the reconstruction of paleogeography in the Chukchi Sea. Submerged sedimentary records along the

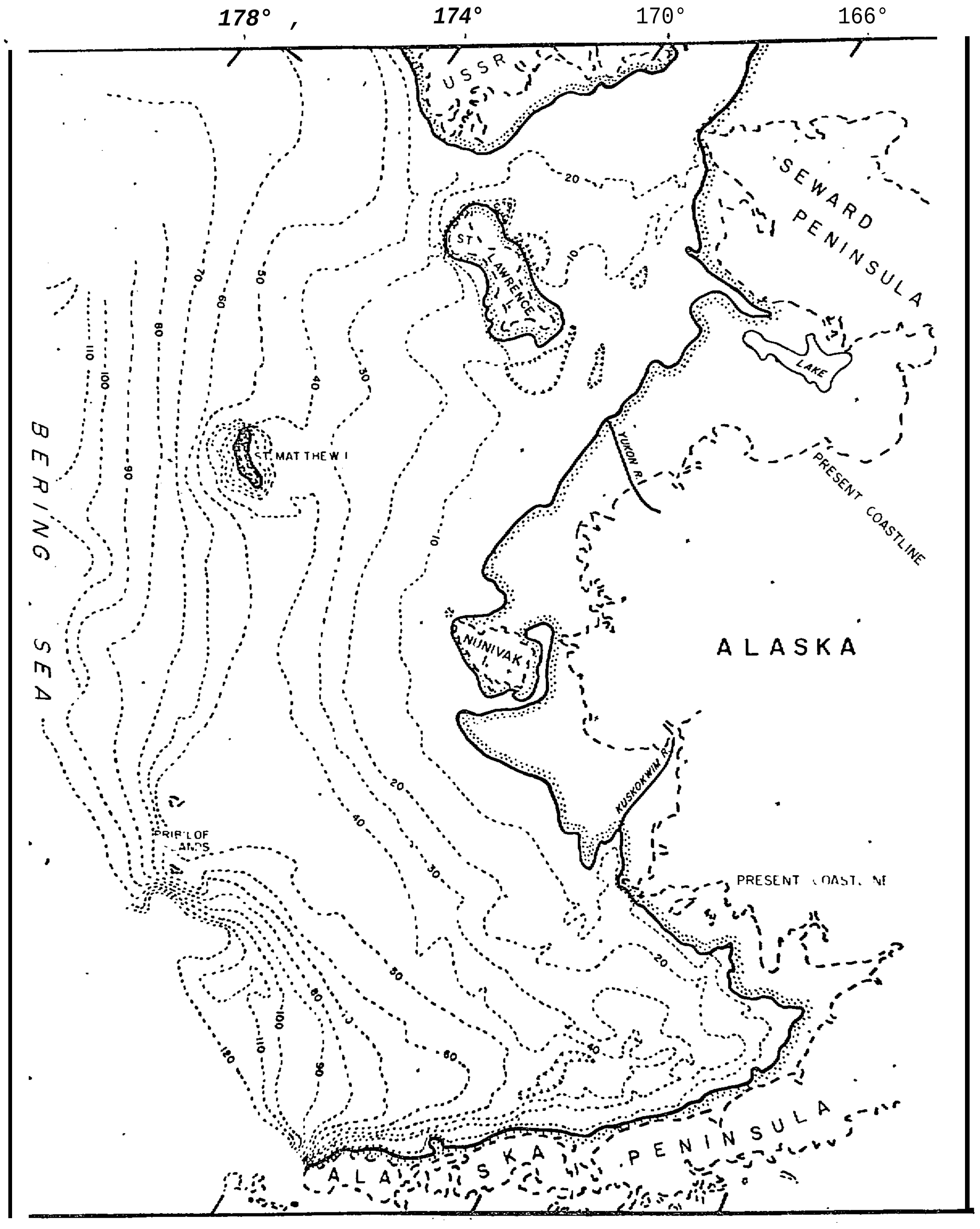


Fig. 1-7.. Bering Sea, Standstill III, 11,000 B.P.
Compiled by G.D. Sharma from National Ocean Survey charts 1215 N-10, 1711N-17B, 1711N-18M, 1714-11B, 1714N-12B, 1814-10B and unpublished data of the University of Washington.

eastern shore of the Chukchi Sea, and especially along the Hope Seavalley, however, provide some information about the sequence of events accompanying the last transgression.

The magnitude of seaward regression of shoreline during the last peak glaciation in the Chukchi Sea is not known. It is, however, postulated that the shoreline probably regressed 'co about –70 m. The ice began to advance about 22,000 years ago (Fig. 1-8) . According to Kind (1967), the last glaciation lasted until about 12,900 years ago. The marine sediments obtained from a long core from the southeastern Chukchi Sea and studied by Craeger and McManus (1965) indicate that between 14,000 and 18,000 years ago the sea level on the Chukchi Shelf stood between -55 m and -60 m (Fig. 1-9). These authors suggest that during this period the broad and flat shelf floor was traversed by river valleys. The core sediments indicated marine and deltaic sedimentation in that region.

Craeger and McManus ***(1967)*** further suggested that sea level in the Chukchi Sea began to rise about 15,000 years ago. The rise in sea level was briefly interrupted between 11,500 and 12,500 years ago and the sea level during that period reportedly stood at the –38 m isobath (Fig. 1-10). Colder climate during 11,000 - 10,000 years and 11,700 - 8,700 years has been reported by McCullogh (1967) and Kind ***(1967)*** respectively. Most investigators concur that from 8,.700 years ago a warming trend started and continued until present. Concurrent with the warming trend, the sea level in the Chukchi Sea rose steadily and culminated at about present level between 3,000 and 4,000 years ago.

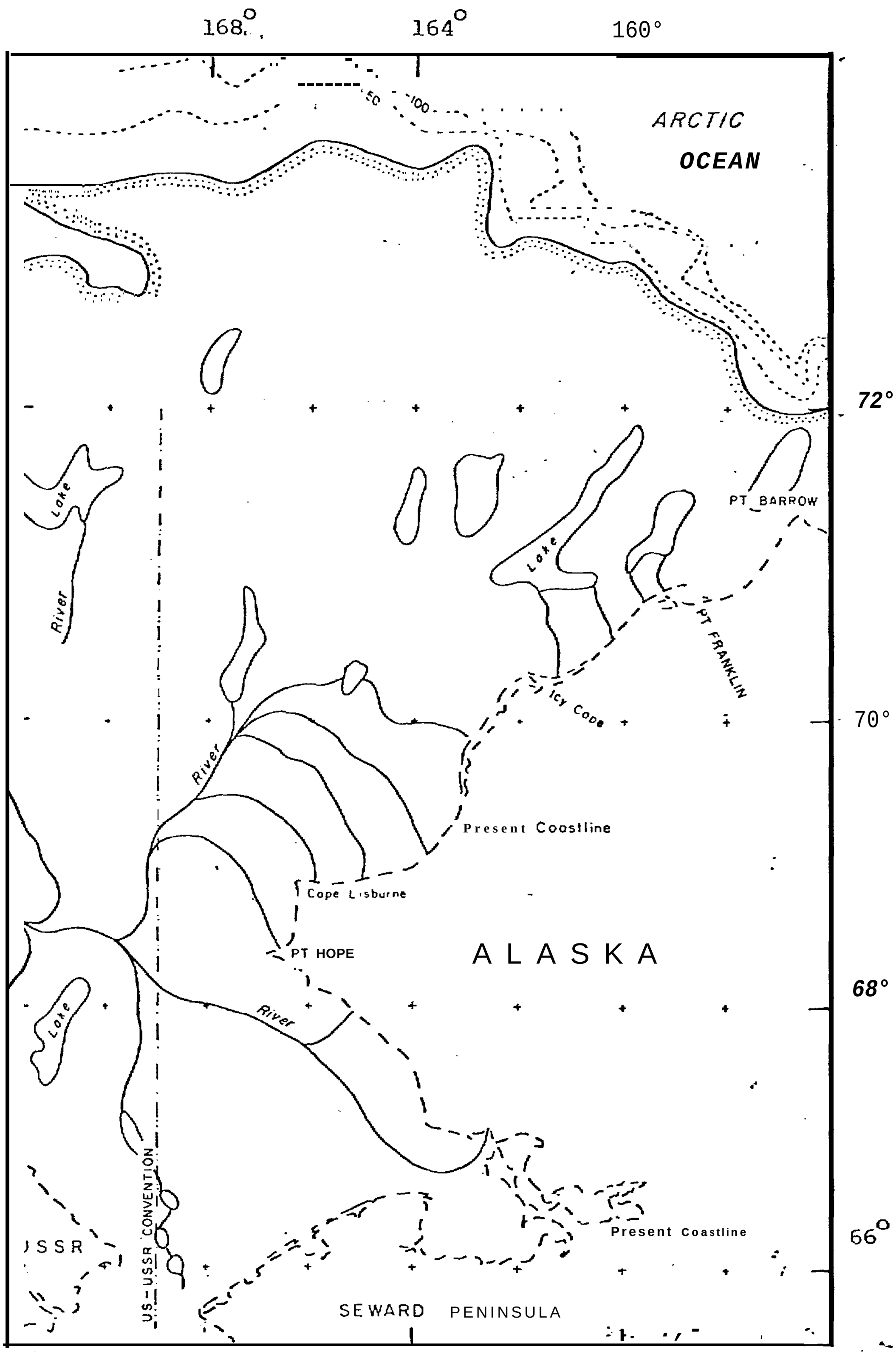


Fig. 1-8. Chukchi/Arctic coast, Standstill I, 22,000 B.P. Compiled by G. D. Sharma from National Ocean Surveycharts 121"5 N-10, 1711N-17B, 1711N-18M, 1714-11B, 1714N-12B, 1814-10B and unpublished data of the University of Washington.

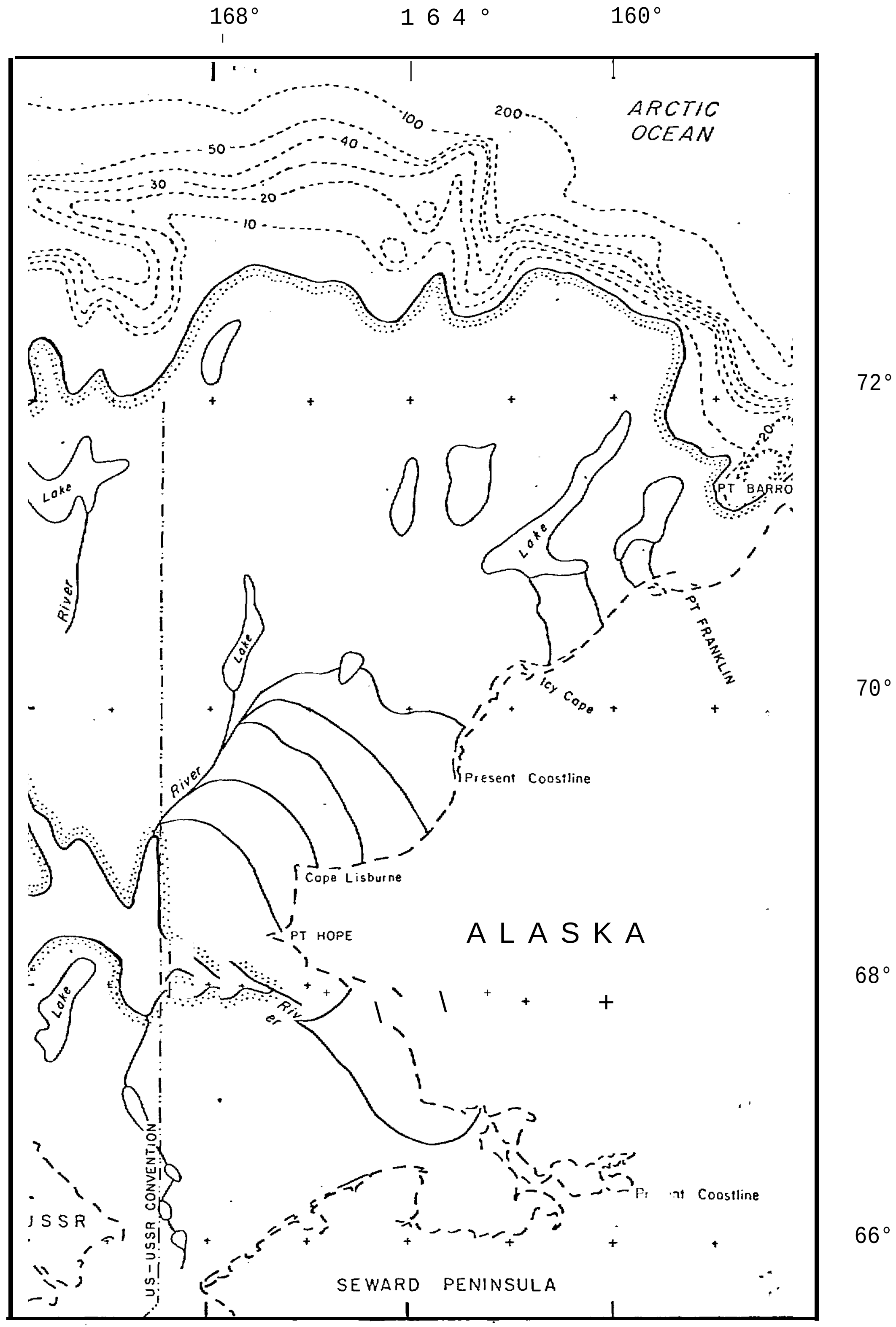


Fig. 1-9. Chukchi/Arctic coast, Standstill II, 1.6,000 B.P. Compiled by G.D. Sharma from National Ocean Survey charts 1215 N-10, 1711N-17B, 1711N-18M, 1714-11B, 1714N-12B, 1814-10B and unpublished data of the University of Washington.

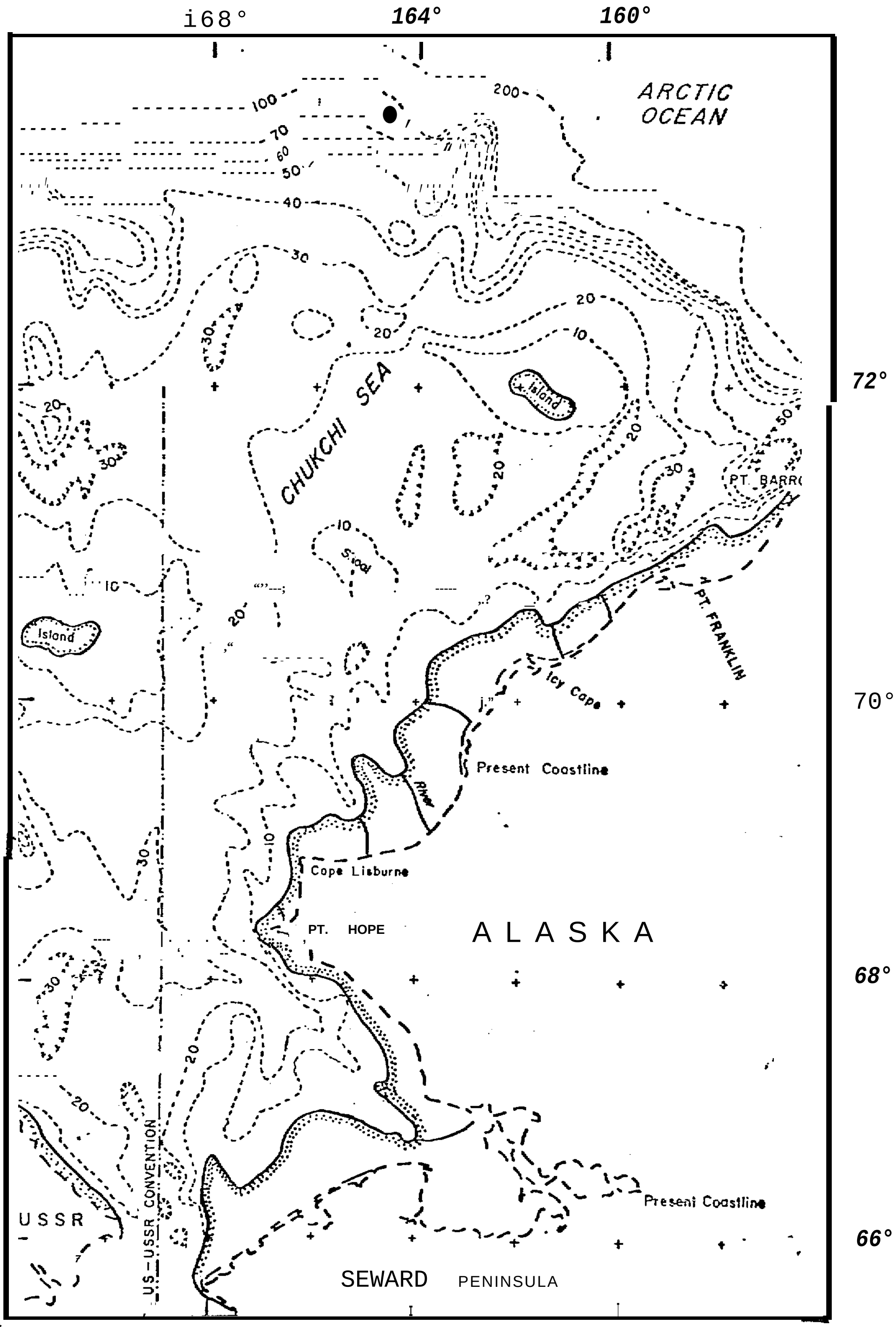


Fig. I-10. Chukchi, Standstill III, 11,000 B.P.. Compiled by G. D. Sharma from National Ocean Survey charts **1215 N-10,** 1711N-17B, 1711N-18M, 1714-11B, 1714N-12B, '1814-10B and unpublished data of the University of Washington.

CONTEMPORARY COAST: The present coastline in the Bering and Chukchi Seas is formed by subcontinental and peninsular land masses. Along its *southern* periphery, the Bering Sea is bounded by an active and young mountainous belt, which forms a rugged coastline. The insular coastline is also typically volcanic. A few of the mountainous ranges extend seawards, forming peninsulas and rugged *sea* coast. Diversity in physiography is characteristic throughout the coastline and, therefore, it is better to describe it regionally: the Bering Sea coast and the Chukchi Sea coast.

The major physiographic features along the Bering coast are the Alaska Peninsula to the south, the Kuskokwim Mountains north of Bristol Bay, a large and complex delta between the Kuskokwim Mountains and the Seward Peninsula, and the Seward and Chukotka Peninsulas feting the Bering Strait.

The Alaska Peninsula, to the south, rises gradually to an altitude of about 1,250 m. The peninsula is dotted with volcanic cones which rise to elevations between 1,500 and 3,000 m. Extensive glaciation occurs and is drained to the north and through the lowland by streams with braided channels. The lowlands contain numerous small and several large lakes, while the littoral zone generally consists of moraines and outwashes and is often covered with contemporary sand and silt.

Bristol Bay, to the northeast, is ***a large*** bight bordered by the Alaska Peninsula to the south and the Kuskokwim Mountains to the north. Its eastern and northeastern shores are bounded by the littoral lowlands. The northern region is dominated by the southeastern flank of the Kuskokwim Mountains, generally known as the Alklum Mountains. These steep and rugged mountains are heavily glaciated.

Alaska's two largest rivers, the Yukon and the Kuskokwim, form a huge delta. Between the Kuskokwim Mountains and the Seward Peninsula, the rivers have formed an extensive delta of sub-continental magnitude. This triangular-shaped delta is covered with marshland, lakes and ponds, and meandering streams. Presently, the Yukon River is actively prograding the delta in the central and northern Bering Sea. On the other hand, the Kuskokwim River flows south and forms a large estuary in Bristol Bay. The deltas of these two rivers are separated by a topographic high, part of which forms Nunivak and Nelson Islands.

The northern Bering Sea region is bordered by the Seward Peninsula to the north and the Norton Sound coastal. area to the east. The Seward Peninsula consists of broad, convex hills and uplands and the region is extensively glaciated. Drainage is provided mainly by two rivers; the Koyuk flows eastward and south into Norton Bay, and the Kuzitrin River flows westward into the Imuruk Basin-Port Clarence.

The Nulato Hills border on eastern Norton Sound. To the south, the Sound is bordered by a small strip of coastal lowland and the Yukon River delta.

The tidal shoreline along the eastern Bering Sea is estimated at 2,900 km, which is about 4% of the tidal shoreline of Alaska.

In the Chukchi Sea, the coastline extends northeast from the

Bering Strait to Kotzebue Sound, then northwestwards from Kotzebue Sound to Point Hope and, finally, northeastwards from Point Hope to Point Barrow. Dominating major coastal physiography is the western flank of the Brooks Range, a major east-west mountainous range which cuts across northern Alaska. This range forms coastal promontories in the central Chukchi Sea. The eastern shoreline lies along the coastal plains which, for the most part, were until recently submerged." In some areas the coastal plain forms a narrow belt, while in other areas it extends deep into the hinterland.

The major indentation in the coast is the large, shallow embayment in the southeastern corner, Kotzebue Sound. The embayment receives the discharges of the Kobuk and Noatak Rivers, and is being rapidly filled with sediments.

Along the eastern nearshore zone in the Chukchi Sea, except between Cape Thompson and Cape Lisburne, which is bordered by sea cliffs, there are numerous coastal lagoons and barrier islands. These islands were formed by the longshore current which originates in the Bering Strait and hugs the Alaska mainland.

North of Point Hope, the coast is aligned along the structural lineaments. The coastline between Point Hope and Cape Lisburne is formed by the structural block of the Brooks Range with north-south lineaments, while the coastline between Point Lay and Point Barrow has three 90 km long linear coastal stretches which are successively offset to the east by approximately 25 km. Linear trends of the coast are apparently associated with the major 35° structural lineaments.

The coastal morphology in the northern Chukchi Sea is controlled by the prevailing winds and resulting wave influences, thus forming cape systems (Cape Lisburne, ICY Cape, point Franklin and Point Barrow). Northerly winds generate waves which dominate the shoreline northeast of each cape, whereas waves approaching from the southeast are generated by westerly winds, and these waves dominate the southwestern sections. The combined effect of these winds and waves results in a convergence of nearshore transport systems and resulting accretion of land at the capes or points and divergence in the central part of the system, where erosion of the shoreline is common.

ENVIRONMENTAL SETTING

INTRODUCTION : Beringia comprises an extremely large, shallow shelf which extends over different climatic and hydrographic regimes. It is, therefore, logical to describe the environmental setting in two sections: The Bering Shelf and the Chukchi Shelf.

The Bering Sea is a unique subarctic water body which lies between 52° - 66° N and 162° - 157° W. A relatively small sea (1% of world ocean), it contains approximately 3.7 x 10^6 km^3 of water. Its northern boundary is marked by a narrow (85 km?, shallow passage between Chukotka and Seward Peninsulas, the Bering Strait, which connects it to the Chukchi Sea and Arctic Ocean. In the south it is partly cut off from the Pacific Ocean by a 1,900 km long ridge and a chain of islands forming the Aleutians. Hydrography.tally, the sea is an immense bay in the northern part of the Pacific Basin, and exchanges water with the Pacific and Arctic Oceans. Geologically, it is a merging site for two gigantic structures: the Alaska Orocline in the east and the Chukotka Orocline in the west.

The sea covers an area of 2.25 -x 10^6 km^2 with an unusual bathymetry. More than half (53%) of the Bering Sea floor constitutes a gentle, uniformly sloped continental shelf and ***a very steeply*** inclined continental margin. Approximately 80% of the shallow shelf lies adjacent to Alaska and eastern Siberia. With the exception of several islands (Diomedes, St. Lawrence, St. Matthew, Nunivak, Pribilofs, Hagemeister, Round) , the shelf floor is featureless. The shelf displays *a* degree of leveling and slope uniformity that are extremely rare on other shelves of the world oceans.

The unusual features of the shelf are its width and the gradient. Compared to the world average shelf width of 65 km (Shepard, 1963], the Bering Shelf is about 500 km wide in the southeast and increases to over 800 km in the north. The average gradient of 0.24 m/km of the Bering Shelf is also markedly less than the average gradient of 1.7 m/km of the world shelves reported by Shepard (1963).

The Alaskan Chukchi Sea shelf lies between 65°40′ - 73°00′ N and 165°00′ - 171°00′ W and covers an area of about 580,000 km^2. To the south, the Chukchi Shelf is separated from the Bering Sea by the Bering Strait, and in the north it is bordered by an abrupt escarpment leading to the floor of the Arctic Ocean. The 200 m isobath is about 50 km offshore of Point Barrow. The Alaskan Chukchi Sea has an unusual shoreline--the entire coast consists of a narrow coastal plain, with the exception of a precipitous cliff near Cape Thompson. Because it is poorly drained, small streams and lakes are numerous. The shoreline is an almost continuous chain of barrier islands with lagoons.

BATHYMETRY: Regional bathymetry of the large Bering Shelf has been described by Gershanovich (1963), Grim and McManus (1970), Kummer and Craeger (1971), Sharma et al. (1972), Sharma (1972, 1974a, 1974b), Askren (1972), Knebel (1972), McManus et al. (19741. For the most part, the shelf is extremely flat with an average gradient of about O.Z/km (Fig. 1-3). The northern shelf displays several large depressions and banks. One elongated large and two circular small depressions are conspicuous in Norton Sound. The region between the Yukon River and St. Lawrence Island, Sphanberg Strait, has two linear depressions intervened by a northwest trending submarine ridge. TWO large banks, one south and the other northeast of St. Lawrence Island, are important features of the central shelf.

The Bristol Bay-Pribilof Islands region has the most salient bottom relief irregularities, including *a* distinct northeast trending trough along the Alaska Peninsula. The bottom topography in this region may be, in part, a result of structural features characteristic of the transition between the epicontinental shelf and the geosynclinal zone, and partly as a result of superimposition of *younger* Cenozoic rocks on older geological structures in this region.

Transitory bottom forms include channels, swales and ridges, and small, closed depressions. Channels are common in Kvichak and Kuskokwim Bays. Narrow troughs and ridges of about 10 m relief are the salient features of the shallow waters near the head of Bristol Bay. Northwards, near Nunivak Island, closed depressions and channels are conspicuous bathymetric features. A prominent channel lies east of Nunivak Island and extends northwards along the shoal adjacent to the Alaska mainland.

The Chukchi Shelf is monotonously flat and almost featureless. The average depth of this broad platform *is* about *50* m and the regional gradient ranges from about two minutes to an unmeasureably gentle slope (Craeger and McManus, 1966). The major topographic features of the Chukchi Shelf are Herald Shoal, Cape Prince of Wales Shoal, and Hope

Seavalley (Fig. 1-4). Herald Shoal lies on the central Chukchi Shelf and is less than 14 m deep. Another topographic high, Cape Prince of Wales Shoal, extends from the eastern margin of the *Bering* Shelf northward for about 130 km. The shoal is narrow and less than 10 m below sea level near the Bering Strait, but broadens rapidly northwards, attaining a width of approximately 50 km. The broad distal end of the shoal lies under 50 m of water. The prominent S-shaped, east-west oriented depression of Hope Seavalley lies south of Point Hope. This submarine valley originates in the vicinity of Kivalina and Cape Thompson and extends northwest and west. The deepest part of the shelf lies along Hope Seavalley. Farther north, a submarine valley extends southwest along the coast from Point Barrow for about 150 km (Carsola, 1954; Lepley, 1962). Most of the westward draining rivers were probably tributaries to these seavalleys. An extensive, relatively flat area at a depth of -54 to -58 m in the Hope Seavalley has been described as marine and deltaic deposits during the period of sea level standstill (Craeger and McManus, 1967).

The major features which were subaerial during lower *sea* level stands in the Chukchi Sea are the shallow sills. The sill between Herald Shoal and Cape Lisburne, which separates the southern Chukchi Sea from the Arctic Basin, is about 44 m below sea level. A shallow sill (47 m) to the west separates the Chukchi ***Sea*** from the East Siberian Sea. During low sea level stands, these sills must have emerged as large islands with prominent shorelines surrounding them.

HYDROLOGY AND HYDROGRAPHY: Most of the Bering Shelf lies in the subarctic latitudes, where cyclonic atmospheric circulation predominates. The annual weather patterns are largely controlled by the Honolulu, Arctic and Siberian Highs, and the Aleutian Low. During summer, the Honolulu High occupies the northern Pacific Ocean and its intensification generates southerly and southwesterly winds in the eastern Bering Sea. With the onset of winter, the summer Honolulu High moves to the southwest and is replaced by a large, intense Aleutian LOW. This shift permits the movement of the Arctic High farther southward and results in predominant northeasterly winds on the shelf. The seasonal winds significantly influence the currents on the shelf. The direction, intensity and duration of the winds influence the shelf water exchange between the Pacific Ocean to the south and the Arctic Ocean to the north.

The Bering Shelf lies in the paths of both extratropical cyclonic and Asiatic anticyclonic storms. The storms occur so frequently that sometimes several are present in the region. Frequent summer and winter storms intensify currents and sometimes reverse the general flow. Furthermore, these storms often destroy water stratification in shallow regions.

The shelf is influenced by the mild north Pacific Ocean and the Bering Sea maritime climate to the south and west respectively, as well as the cold continental subarctic climate to the east. The southern shelf is strongly affected by meteorological conditions prevailing along the Aleutians, and the climate is therefore milder than the one prevailing in the north. Cloudy skies, moderately heavy precipitation, and strong surface winds characterize the shelf weather. Average summer temperatures vary from 10° C. in Bristol Bay to about 8° C. in Norton Sound; the average winter minimum ranges from -14° to -18° C. (Environmental Data Service, 1968). The annual precipitation is 600 mm at the Pribilof Islands and 400 mm near the northwest tip of St. Lawrence Island.

Major rivers discharging fresh water and sediments into the eastern and northwestern shelf are: Yukon, Anadyr, Kuskokwim, Wood, Nuyakuk, Nushagak and Kvichak. Mean annual discharges of the Yukon, Anadyr, Kuskokwim, Nuyakuk and Wood Rivers have been described by Roden (1967). The high latitude drainage area which feeds these rivers has a typical unimodal discharge pattern, which reaches its peak in June. Ninety per cent of the annual flow occurs between the months of May and October, and approximately 60% of the mean annual discharge takes place during the months of June, July and August. According to Roden (1967), the total mean annual fresh water discharge into the Bering Sea exceeds the discharge into the Pacific Ocean of the combined states of California, Oregon and Washington. The significance of such a large discharge becomes even more important when it is considered that this discharge is added during a six-month period. Because of this large input of fresh water along the Alaska mainland, a distinct nearshore Alaskan Coastal Water is formed during the summer.

Waters of the Bering Shelf are complex and extremely dynamic. Large parts of the shelf can be regarded as an immense, shallow, high latitude estuary. The exceptional characteristics of the shelf waters during summer is their erratic variability. The waters of this immense subarctic shelf are continually influenced by the intrusions of Pacific and Arctic waters, river discharge, wind stress, and air temperature. The frequent brief, but violent storms, in particular, alter water density structure and cause upwelling and down-welling of large volumes of water. Because of the significant dominance of the relatively warm Pacific water intruding through the southern passes, and the influence of cold, polar waters from the Gulf of Anadyr and the Chukchi Sea in the north, the shelf waters can be broadly divided into two major hydrographic regimes: ‘1) The northern region between Bering Strait and St. Matthew Island is dominated during the summer by cold Gulf of Anadyr water and during the winter it is covered with sea ice; 2) The southern region between St. “Matthew Island and the Alaska Peninsula is mostly ice-free throughout the year, however, occasionally, the severe winter conditions may cause ice to form further south. The waters of both regions are continually modified near the surface by river discharge and at depth by shoreward movement of saline waters.

Ice conditions in the winter in the northern regime are *severe.* Observations recorded over 30 years (Climatological and Oceanographic Atlas for Mariners, Vol. II, North Pacific, 1961) indicate that generally the ice cover begins in November and reaches its maximum extent in March. The southward extension of sea ice on the Bering Shelf is highly dependent upon the atmospheric pressure systems and the prevailing winds (Konishi and Saito, 1974). During January through April, the ice in the region lying north of Nunivak Island covers between 80 - 90% of the sea surface. The ice begins to recede northward in May, and by early July the ice is generally beyond the Bering Strait.

Only fragmentary knowledge of movement of waters at surface and at depth on the Bering Shelf exists. Sparsity of direct current measurements in the region permits one to predict, with considerable uncertainties, only a generalized circulation pattern. The general circulation on the shelf and the basin has been described by Ratmanof - (1937); Barnes and Thompson (1938); Goodman et al. (1942); Saur et al. (1952); Saur et al. (1954); Dobrovol'skii and Arsen'ev {1959); Favorite and Pederson (1959); Favorite et al. (1961); Hebard (1961); Dodimead et al. (1963); Sharma et al. (1972); Favorite (1974).

The driving force for the water movements on the shelf is a combined effect of wind, tide and surface runoff. The tidal range on the shelf is moderately low and ranges from 2.4 m at the head of Bristol Bay in the south, to 0.6 m near the Seward Peninsula in the north. Winds and storms develop short-term local and regional circulation patterns. Current reversals in response to changes in the wind direction at many locations have been reported by the U.S. Coast and Geodetic Survey (1964).

Tidal current velocities of 50-100 cm/sec in the passes along the Aleutian chain have been reported by Lisitsyn (1966). The incoming tidal currents {175 cm/see) off Scotch Cap in Unimak Pass exceed the outgoing tidal currents (150 cm/see) by 25 cm/sec (U.S. National Ocean Survey, 1973b). The northward current through Unimak Pass may be considerably accelerated by the influence of an atmospheric depression north of the chain (U.S. National Ocean Survey, 1964).

Under such meterological conditions, the current velocity in the pass may exceed 300 cm/see, thus resulting in transfer of a large amount of Pacific water into the Bering Sea. Part of the water passing through Unimak Pass is deflected to the east and continues north of the Aleutian Peninsula, while the rest flows north along the outer shelf.

The tides in Bristol Bay are amplified near the head of . shallow embayments. Mean ranges at Cape Sarichef, Unimak Island, are 1.0 m; Port Moller, 2.3 m; Kvichak Bay, 4.6 m; Nushagak Bay, 4.7 m; Kuskokwim Bay, 4.1 m; Goodnews Bay, 1.9 m; and St. Paul Island (Pribilofs), 0.6 m (U.S. National Ocean Survey, 1973a). Hebard (1961) reported nearshore tidal currents of 40 - 85 cm/sec along the northern Alaska Peninsula and 50 - 75 cm/sec in central Bristol Bay.

In addition to the tidal influence, the semi-permanent currents form a counterclockwise circulation on the southern shelf. In Bristol Bay, the eastward moving water sets up a large counterclockwise gyre covering almost the entire southern shelf. Tine currents forming the gyre have been measured by Hebard (1961), and Natarov and Novikov (1970), who show them to vary seasonally and to be significantly influenced by changes in wind direction.

Farther north, the tidal currents are 40 cm/sec off the west coast of Nunivak Island, 40 cm/sec off Northeast Cape of St. Lawrence Island, and 50 cm/sec at Sledge Island, west of Nome. Near-bottom current speeds of 30-40 cm/sec on the northern Bering Shelf have been estimated by McManus and Smyth (1970). Surface and near-bottom currents of *15-72* cm/sec and 15-34 cm/sec respectively have been reported in the Bering Strait by Craeger and McManus (1967}.

The flow pattern of northward-moving Pacific water on the shelf is somewhat unclear. Many investigators have stipulated formation of various smaller gyres, particularly in the regions lying north and south of St. Lawrence Island. These gyres may be seasonal. Although the northward flow of water over the shelf and through the Bering Strait has been well asserted, no concerted attempts have been made to determine the intensity and the configuration of these currents or whether these currents prevail throughout the year. .

Oceanographic studies in the Chukchi Sea have been conducted by Saur et al. (1954), Aagaard (1964], Craeger and McManus (1966), Fleming and Heggarty {1966), Coachman and Aagaard (1966, 1974), and Ingham and Rutland (2972). Water characteristics of the Chukchi Sea are dominated by three factors: 1) winter *ice* cover, 2) influx of Bering Sea water, and 3) the coastal surface runoff. Most of the year, the waters of the Chukchi Sea are covered with winter ice and polar pack ice. The ice begins to form in early October and its southward growth proceeds rapidly. By later October or early November', ice clogs the Bering Strait. Break-up occurs about mid-June in the southern Chukchi Sea and ice begins to recede northward. The coastal regions are covered by shore-fast ice for ***about*** eight months. Generally, August and September are months with the least sea ice. The extent of open water along the Alaskan coast during summer months varies seasonally and is dependent upon wind field and winter ice cover. Easterly and southerly winds keep the ice at some distance from the coast.

The formation of yearly ice and extension of polar pack ice into the Chukchi Sea forms water masses typical of arctic regions. Its ice cover keeps the water temperature of the near-surface layers close to the freezing point for its salinity, and extrudes salt from the ice to underlying waters. Water masses formed as a result of the ice cover are continually modified by the inflow of Bering Sea water.

Coachman and Tripp (1970) reported a northward-flowing water through the Bering Strait of the order of 1×10^6 m^3/see, flowing under the impetus of a surface slope. The Bering Sea water transport through the Strait varies considerably and appears to be dependent on the wind regime. A variability of as much as a factor of 2 in transport may occur during one week (Coachman and Aagaard, 1974). These investigators also observed occasional net southward transport through the Bering Strait.

The amount of surface flow contributed by the adjacent Alaska mainland is low. Total river discharge to the Chukchi Sea is estimated at $2.5 \pm 1 \times 10^3$ m^3/sec. The average annual precipitation is approximately 100 nun. No measurements of evaporation in the Chukchi Sea have been reported. " Estimates of reported evaporation over the Arctic Basin range from 40 mm/year (Mosby, 1962) to 300 nun/year (Fletcher, 1966) .

The temperature and salinity measurements from the Chukchi Sea obtained by various investigators vary siqnificantly. It appears that water masses and properties change frequently and are readily affected by atmospheric conditions, Bering Sea water influx, the coastal runoff, and melting and formation of sea ice.

The water circulation in the eastern Chukchi Sea is dominated by the Bering Sea water influx, which sets an almost permanent northward current, and by the *local* wind regime. Near surface and bottom currents in the southeastern Chukchi Sea during August 1959 and 1960 have been described by Craeger (1963). Water currents in Bering Strait and NNE of Bering Strait during summers and winters have been obtained by Coachman and Tripp (1970), and Coachman" and Aagaard (1974}. The average current in the Bering Strait varied from 13-35 cm/see, and along the Alaskan coast ranged between 5-24 cm/sec (Craeger, 1963). These current measurements were fairly uniform throughout the water column. Data revealed *a* general northward flow from the Bering Strait which approximately paralleled the coast. Once past the Bering Strait, the water flows in a north and northeast setting. One northeast flow setting proceeds along the northern coast of the Seward Peninsula and, on arrival near the mouth of Kotzebue Sound, *is* defected towards , Point Hope. Near Point Hope it gains speed (50 cm/sec) and merges with the northward-flowing component. After leaving Point Hope, the combined current again bifurcates. A branch of the north flow continues west of Herald Shoal, while the main coastal branch flows north and *east* along the Alaskan coast and enters the Arctic Ocean near Point Barrow. Coachman and Aagaard (1974) reported that during July 1972 the northward transport through the Cape Lisburne section was $1.3 \times 10^6\ m^3$/see with approximately one-third moving northwest toward Herald Shoal and two-thirds moving northeast toward Point Barrow.

Currents, particularly the near-surface currents, in the northern Chukchi Sea are influenced more by regional winds than by northerly currents originating in the Bering Strait. The water movement in the nearshore region, especially during the open water months, appears to be predominantly controlled by atmospheric conditions, particularly wind stress and solar heating. Wind-driven currents cause variations in sea level far in excess of those produced by tides (up to 3 m). The sea level changes strongly influence the water mass properties in the nearshore areas and undermine the beach by subjecting it to wave action. The combined effect of wind and wave, then, sets up the local current system.

Deflection of currents by protruding land (capes and points] generally causes separation of current and formation of eddies past the cape. Evidence of an eddy northwest of Cape Prince of Wales has been reported by McManus and Craeger *(1963).* Formation of clockwise eddies in the regions of capes (Cape Lisburne, Icy Cape) have been observed by various investigators. South-flowing coastal currents between Icy Cape and Cape Lisburne were recorded by Fleming and Heggerty (1966). Similar currents accompanying northerly winds at Point Lay were observed by Wiseman et al. *(1973].* Periodically, the current system of these eddies is augmented by the prevailing wind.

SEDIMENTATION

The surficial sediments from the Bering Shelf consist of a varying mixture of clay, silt, sand, and gravel. Most of the Shelf is covered by either sand or silt. Gravel and clay components are generally absent or constitute a minor proportion of these sediments. The textural distribution of sediments on the Bering Shelf is complex because of the extremely variable and localized source input (rivers) and the variance in sediment transport energy (currents]. The distribution locally is *also* influenced by the action of wind, waves, tides, permanent water circulation, and ice. Regionally, semi-enclosed Bristol Bay and Norton Sound display sediment texture which is different from that observed on the open shelf. Local textural anomalies in nearshore zones may result from river detrius input and exposed relict glacial deposits.

The shelf deposits of Bristol Bay have been described in detail by Sharma (1972, 1974a, 1974b) and Sharma et al. (1972). These studies show that in Bristol *Bay* nearshore sediments consist of gravel and coarse sand, while a greater part of the central shelf is covered with fine and medium sands. Farther offshore the sediments become progressively finer. The floors of the shore indentations and some bays are covered with yellowish-brown clayey silt and clayey, *silty* sand, whereas the open shore is generally mantled with pebbley sediments. The sediment mean size decreases with increasing distance from shore and water depth. Sorting in sediments is related to sediment mean size; nearshore coarse sediments *are* extremely poorly sorted; medium and fine sands deposited on the mid-shelf are moderately well-sorted, and offshore, the sorting deteriorates with increasing silt and clay components. The medium and fine, moderately well-sorted sands on mid-shelf have nearly symmetrical size distribution, but progressively grade into strongly coarse-skewed sediments shoreward and strongly fine-skewed sediments towards the continental margin. Most sediments are leptokurtic to extremely leptokurtic.

Sediment cover of the shelf between Unimak Pass, Nunivak Island and St. Matthew Island has been described by Askren (1972). The triangular-shaped region consists of sand, silty sand, sandy silt, and sandy, clayey silt. The eastern shallow shelf, with a depth less than 60 m, is covered with sediments containing 75% or more sand. Westward, a narrow zone which lies between the -60 and -70 m isobaths consists of sediments with a varying mixture of sand and silt. The outer shelf, with depths greater than 75 m, is mantled with clayey silt and some sand. The sediment textural parameters *from* the intermediate zone (-60 to -75 m isobath) appear to be related to the ***water*** depth: the mean size, sorting and skewness isopleths, run almost parallel to the isobaths, particularly in the area just west and south of Nunivak Island. The shallow shelf sands are moderately well-sorted, but sorting deteriorates with increasing depth and increasing silt-clay fraction. Most sediments are finely to strongly finely skewed and show platykurtic to extremely leptokurtic size distribution.

The textural characteristics of sediments deposited on the shelf between St. Matthew and St. Lawrence Islands have been described by Knebel (1972]. He observed that sands are the most ubiquitous components in the sediments. The particle size distribution on the central Bering Shelf is, however, complex, and the sediment size grading with water depth is not obvious. The easternmost part, a narrow, elongated belt adjacent to the Alaska mainland, running parallel to the shore and shallower than the -10 m isobath, consists of silty sands. Shoreward of this belt the percentage of silt in sediments increases " rapidly. Offshore, however, the sand content in sediment increases and reaches a maximum (approximately 90%) between the -20 and -40 m isobaths. Sediments with a predominant sand fraction also cover a large shallow bank south of St. Lawrence Island. The shelf sediments, with a water depth of more than 40 m along the western periphery and southern region (north of St. Matthew Island), consist primarily of silt *with* minor components of sand and clay. Locally isolated patches of gravel and gravelly sediments *are* found in the nearshore regions east and northwest of St. Lawrence Island. In general, the gravel component in the sediments is insignificant and of limited lateral distribution. Mostly sand and silt components complement each other in the sediments.

The sediment mean size and isopleths in the nearshore region are parallel to the isobaths, but they show the usual sediment size-depth relationships: sediment grain size decreasing with decreasing water depth. This decrease in mean size is primarily due to an increase in the silt component brought by the Yukon River and other coastal streams. An increasing silt fraction also contributes to the poorer sorting in sediments. The sediment mean size distribution on the bank south of St. Lawrence Island, in general, conforms to the bathymetry, so that the sediment mean size decreases with increasing water depth. North of St. Matthew Island the region does not show any definitive textural distribution which could be related to either water depth or to the source.

The sediments on the central Bering Shelf are coarsely to very finely skewed and have platykurtic to extremely leptokurtic size distributions.

The northern Alaskan Bering Shelf is defined by the Bering Strait to the north and by a *46* m deep sill across Sphanberg Strait, between the Alaska mainland and St. Lawrence. This shallow shelf, with the exception of three passages, is surrounded by landmass. The eastern part of this shelf is a semi-enclosed, less than 30 m deep embayment, Norton Sound. The slightly deeper region (50 m) to the west and north of St. Lawrence Island, usually known as Chirikov Basin, has a complex bathymetry. The sediments from the Chirikov Basin and off-shore of Nome have been studied in detail by Craeger and McManus (1967), McManus et al. (1969), Venkatarathnam (1969), Nelson and Hopkins (1974), McManus et al. (1974), and Sharma (1974a, 1974b).

Sediments *on* the northern shelf consist of gravel, sand, and sandy and clayey silts. Gravel and *gravelly* sand occur in the passages (Bering, Anadyr and Sphanberg Straits). Gravel also lies along the coast between Nome and Bering Strait and along the northern coast of St. Lawrence Island. A narrow belt of gravel protrudes approximately 60 km northward from St. Lawrence Island (McManus et al., 1969). Because of the gravel's glacial origin, its distribution is complex (Nelson and

Hopkins, 1974; Sharma, 1974a, 1974b).

The Chirikov Basin, with the exception of a few small, anomalous areas, is covered with sand of very coarse to very fine size range. The sand component in sediments from this region mostly exceeds 75% (McManus et al., 1969). Eastward, a northwest oriented narrow belt extending from the Yukon River delta to Nome has low sand content.. In Norton Sound, the sediments are mostly very fine to medium sands. It is interesting to note that gravel complements sand in the Chirikov Basin while silt complements sand in Norton Sound, perhaps suggesting erosional and depositional environments respectively.

The shallow region (less than 10 m depth) along the Alaska mainland extending from Cape Romanzof to eastern Norton Sound is mantled with silt. The Yukon River silt also extends from its delta northwest towards Nome. Clay content in sediments is generally less than 10%, however, in some areas of Norton Sound, clay constitutes as much as 15% of the bulk sediments.

Sediments of the northern Bering Shelf are poorly to extremely poorly sorted with finely skewed to nearly symmetrical distribution, and vary from leptokurtic to extremely leptokurtic.

The Alaskan Chukchi Sea floor is mostly covered with gravel, sand and silt. Gravel occurs as long, narrow belts along the shore and as a few isolated patches in offshore regions. Gravel deposits also form benches along the sea cliffs and adjacent areas. Sand predominates in the nearshore areas and in the proximities of the major sediment input, while silts with clay are deposited offshore through settling. Clay content in sediments is minor and varies between 5 and 35%.

Sediment distribution in the southeastern Chukchi Sea has been described in detail by Craeger (1963). The results of sediment analysis of over 475 samples from the entire Chukchi Sea have been discussed by Craeger and McManus (1966), and McManus et al. (1969). These studies provided sediment description based on good station coverage.

Sediments in the Chukchi Sea grade offshore from sandy gravel to sandy, clayey silt. The Bering Strait, the southern proximity of the Chukchi Sea, is covered with sand and some patches of gravel. Northward and northeastward of the Strait, the sea floor is covered mostly with moderately to poorly sorted sand. The sand forms a north-south oriented lobate feature, the Cape Prince of Wales Shoal (McManus and Craeger, 1963). To the northeast, the sand extends to the north of Kotzebue Sound and continues northwest along the shore to Kivalina. A narrow belt of gravel covers the coast and nearshore area between Kivalina and Cape Lisburne. Between Cape Lisburne and Point Barrow, the entire nearshore area consists of sand with gravelly offshore bars separating numerous lagoons from open waters.

Coarse sediments with mostly sand and gravel are also often found on and around Herald Shoal in the central Chukchi Shelf. The northwest oriented shoal lies between Cape Lisburne and Wrangel Island at a depth of less than 40 m. Herald Shoal is bordered on the east and west by narrow channels mantled with clayey, silty sands.

Seaward, with the exception of a few irregularities, the sediments generally become progressively finer, consisting mostly of clayey, sandy silt. Sediments with a dominant silt fraction cover large offshore areas west of Point Hope and northwest of Point Barrow. At first glance, the distribution of sand, silt, and clay do not appear to be related to water depth, but a careful inspection reveals that sandy, clayey silts are mostly deposited in water with a depth of more than 50 m. In shallower regions, silty sand is commonly deposited.

Sorting of sediments is related mostly to the water energy. In areas of intense currents and wave action, the sands are moderately well-sorted, while in regions of relatively quieter environments, sands are poorly sorted. Gravelly deposits nearshore and on Herald Shoal are poorly and very poorly sorted. Sandy, clayey silts, also poorly sorted. are deposited offshore in relatively quiescent environments. The granulometric variables from over 400 bottom sediments were subjected to factor analysis to delineate the sedimentary environments in the Chukchi Sea by McManus et al. (1969). Three factors representing mud, sand and gravel provide some insight concerning processes of sedimentation on the Chukchi Shelf. These authors suggested that sand deposited along the northern shores of the Seward Peninsula is the result of wave-sorting, while sands deposited near the mouth of Kotzebue Sound are influenced by tidal currents. Sand transported by currents mantles the nearshore regions between Kotzebue Sound and Point Hope. The coarse sand and gravel observed along the northern shores of Cape Lisburne and offshore on and around Herald Shoal are considered as relict and residual sediments. Most of the offshore region is covered with modern silt and clayey silt. These fine sediments, according to McManus et al. (1969), are deposited through particle settling from the wash load of the shelf surface and bottom turbid waters.

ECOLOGICAL CONDITIONS AND MARINE MAMMAL DISTRIBUTIONS OF BERINGIA DURING THE LAST WISCONSIN SUBMERGENCE

Sam W. Stoker

INTRODUCTION : General Geography and Conditions

During, and as a result of, the climatic fluctuations known as the Pleistocene, the continental shelf of the Bering and Chukchi Seas has alternately been submergent as *a shallow ocean floor* and emergent as a flat, broad plain connecting Asia and North America. In this role it has provided a unique biological. gateway permitting periodic exchange and dispersal of terrestrial species between Asia and the Americas and, alternately, of marine species between the Arctic and the boreal Pacific. Conversely, the periodic closing of this gateway has brought about the genetic and environmental isolation necessary for adaptive diversification and the emergence of new forms, both terrestrial and marine.

At the height of the last Wisconsin glaciation, sufficient water was invested in continental glaciation to lower sea level by some 100 meters, thus exposing virtually the entire continental shelf of the Bering and Chukchi Seas as a flat, almost featureless plain extending from Siberia to Alaska and from the deep basin of the Bering Sea to the Arctic Ocean (Fig. 2-l). With the exception of a few river valleys and a few volcanic highlands (which exist today as islands--the Pribilofs, St. Matthew, Nunivak, St. Lawrence, King, the Diomedes), it was the flattest terrain on the face of the Earth.

The rivers that traversed this plain, though few, were impressive in magnitude--the Yukon, Kuskokwim, and Kobuk on the

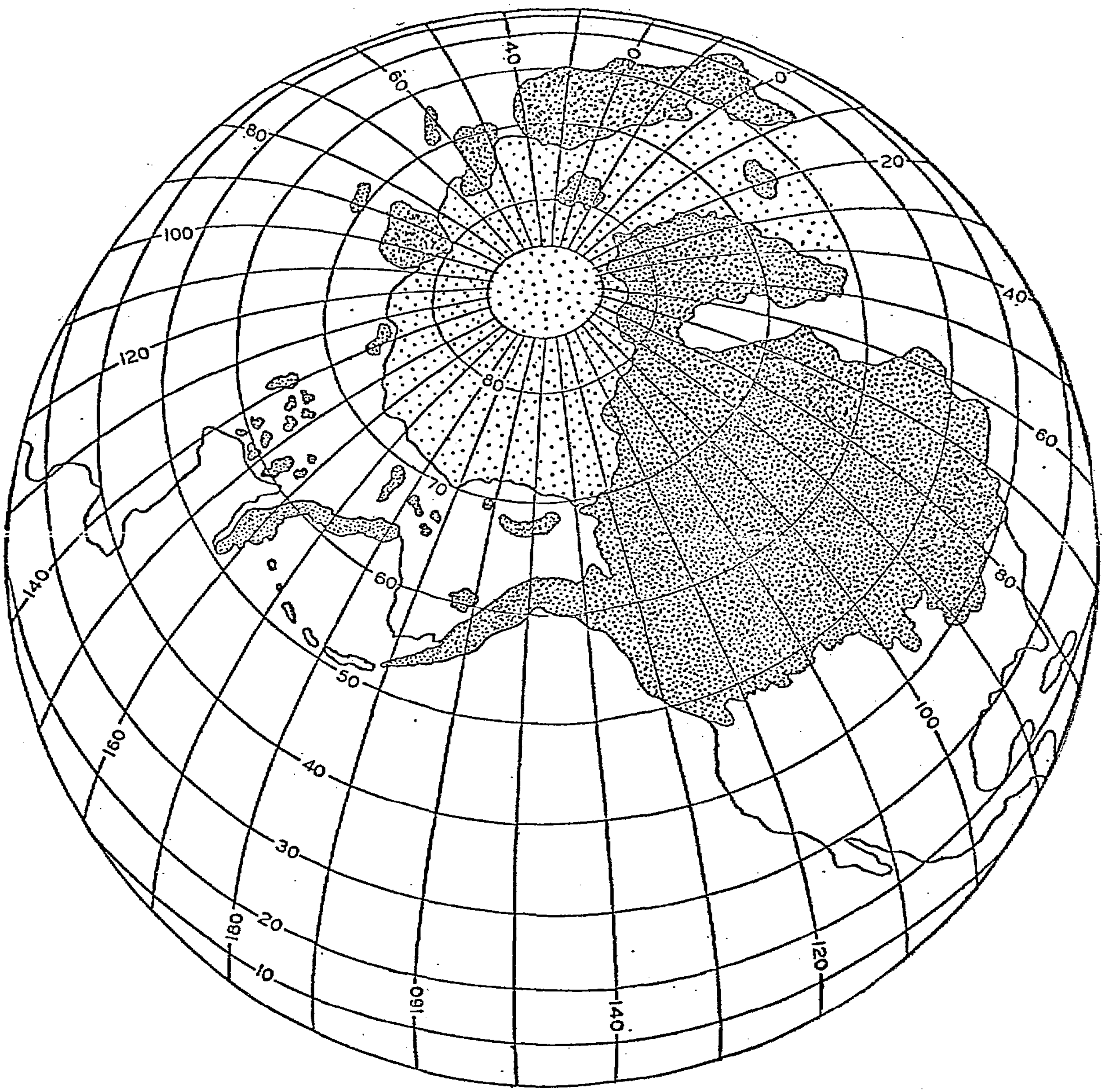
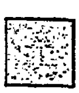
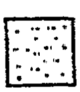


Fig. *2-1.* Circumpolar projection of the Northern Hemisphere during the height of the Late Wisconsin (ea. 18,000 B.P.). Alaska is geographically more a part of Asia than North America. From Flint, 1971 and Hopkins, 1973.

 continental ice

 possible ice cover on Arctic Ocean

American side, and the Anadyr on the *Asian.* The Yukon, Kuskokwim and Anadyr flowed generally southward, into the deep basin of the southern Bering Sea, while the Kobuk turned north to the Arctic. During the height of the glaciation it maY be presumed that the discharge of these rivers, particularly the Kobuk, was decreased. Conversely, during the onset of glacial wastage and ***resubmergence, their discharge*** was probably magnified. Given the terrain over which they crossed, it seems likely that these rivers followed a braided, meandering course not unlike that exhibited by the present Yukon where it crosses extensive flats. Undoubtedly they were choked and clouded with glacial silt.

Due to considerations which will be dealt with later, it seems probable that the terrestrial climate of this plain was severe. The winters were probably longer and colder than at present, at least during the early part of the transgression, and the summers were shorter and warmer (Hopkins; 1972). Precipitation, both rain and snow, was probably scantier and the winds more persistent and intense, in a region presently notorious for wind.

Along the southern margin of the land bridge lay the Bering Sea, shrunk at the height of the Wisconsin glaciation to its deep basin--roughly half its present areal extent--with its communication limited solely to the North Pacific through the deep passes of the Aleutian-Kommandorsky island chain. It was probably then, as now, a region rich in marine life, fed by nutrient-rich upwellings and supporting large populations of marine mammals, marine birds, marine and anadramous fish, and shellfish. For the most part, except for its river estuaries and such few sheltered embayments as are indicated by the present bathymetry and topography, its margin was probably an open, storm-swept coast of sand beaches and dunes in the summer and of strong winds and extensive shore-fast and pack ice in the winter time.

At the glacial maximum the Chukchi was dry over virtually its entire present extent, the northern shore of Beringia being the Arctic Ocean, the condition of which has occasioned much of the controversy pertaining to the mechanisms of ice ages in the *northern* latitudes. This problem will be discussed at some length.

WISCONSIN GLACIAL MECHANISMS AND EVENTS: For any discussion of Pleistocene events it becomes necessary at some point to touch at least cursorily upon the major theories of ice *age* causes and mechanisms. The "long range" or "remote" causes, or possible causes, of climatic oscillation and glaciation have little direct bearing on the regional questions considered here, and so will be dispensed *with* in summary fashion. The "short range" or regional mechanisms, particularly as involve the condition and role of the Arctic Ocean, will be considered in more detail.

The "long range" theories may be divided into terrestrial and extra-terrestrial, though there is some overlap. Extra-terrestrial theories consider temperature fluctuations at the earth's surface to be the principal mechanism behind the ice ages, and generally credit such fluctuations to either (1) varying solar output as a result of sunspots or solar storms, or (2) varying insolation values of the earth's upper atmosphere due to cloud cover or volcanic discharge. This second mechanism involves, of course, terrestrial events. The terrestrial long-range theories include (1) polar wandering, (2) disruption and instability of atmospheric circulation patterns as a result of mountain building and continental uplift, (3) increased albedo (reflectivity) at the earth's surface, (4) continental drift and concentration of land masses in the higher latitudes of the northern hemisphere, thereby restricting oceanic circulation, (5) impoundment of the Arctic Ocean due to continental drift, (6) any combination of the above. These mechanisms are reviewed by Flint (1971). All of these ***theories*** deal with global generalities, with explanations of why these climatic oscillations began in the first place and why they are apparently continuing.

The question of more immediate interest to this discussion is the role of the Arctic Ocean as a short-term mechanism in these fluctuations, for it is in this area that a controversy is encountered which has serious implications for the climatology and biology of the northern coast of Beringia. Ice age theorists seem to be divided rather sharply *into two* camps regarding the Arctic, one supporting the view that it was an open, unfrozen ocean, the other that it was ice-covered, at least to the extent to which it is today, throughout the Pleistocene.

The scheme of events and mechanisms presented here in explanation and tentative support of the open Arctic theory is a synthesis of previous investigations on the subject (Dorm and Ewing, 1966; Lamb, 197'1; Lamb and Woodroffe, 1970; Loeiue, 1971; Weyl, 1968; Dorm and Ewing, 1968; Olausson, 1972a; Flint, 1952).

According to this scheme, the initiation of glaciation would have been dictated by the temperature regime. A lowering of summer temperatures in continental high latitudes of only a few degrees centigrade would begin the accumulation of snow and ice for the simple reason that winter snowfall would exceed summer melt. The reasons for this temperature decline, though of interest in themselves, have little bearing on the progression of events once such accumulation is begun. It could be because of solar storms and varying solar output, increased insolation due to cloud cover or volcanic activity, increased continentality, disrupted atmospheric circulation and heat exchange, or increased albedo.

It doesn't much matter for the short-term view. Once such accumulation has begun, it provides its own increased albedo due to the greater reflectivity of snow and ice, thereby further depressing regional temperatures--a self-reinforcing effect. During this initial phase, the Arctic Ocean would probably be frozen, about as now, and sea level would be about as it presently stands. There would probably have been a relatively weak low pressure center over the central Arctic, and weakly cyclonic atmospheric and oceanic circulation with strong vertical stratification of the Arctic Ocean water due to salinity disconformity. Because of this dominating salinity structure, the Arctic would not react to surface temperatures as would a deep ocean,

e

by the sinking and mixing of cooled surface water with deeper, warmer water, but as would a shallow sea. Its surface water is of such low salinity that it can never achieve the density, through lowered temperature, sufficient to penetrate the halocline (salinity disconformity], and so freezes as sea ice. This is the condition seen today, during what may be the latter stages of an interglacial.

This low salinity surface water has, and probably would have had at that time, two major origins: (1) the direct terrestrial fresh-water input of major rivers such as the Colville and Mackenzie on the American side and numerous others on the Asian and European margin, and (2) the low-salinity input from the Bering Sea through Bering Strait. This low-salinity Bering Sea surface water is itself primarily a result of terrestrial input from the Yukon and Kuskokwim.

During this initial phase in the cycle of glaciation, the principal *source* of precipitation would probably be the North Atlantic with its northwest-trending warm Gulf Stream.

This accumulation of ice and snow acted, as noted previously, in a self-reinforcing manner. It served (1) to lower the albedo over the northern hemisphere, further depressing temperatures, and (2) to lower sea level around the world. Lowered temperatures would have resulted in decreased fresh-water discharge into the Arctic basin, weakening the salinity structure. At the same time, falling sea level would constrict and eventually cut off the low salinity flow from the Bering, further weakening the halocline which kept the Arctic a frozen ocean. Also during this phase, the increased continentality resulting from the partial exposure of the continental shelves "may have resulted in intensification of the Arctic high-pressure center, with resultant intensification of the cyclonic circulation of both sea and air (Lamb, 1971; Lamb and Woodroffe, 1970; Willett, 1950). Winds would have intensified over both the Arctic Ocean and the emerging land bridge, and would have shifted slightly to blow more northerly over the land, further depressing the summer temperature and accelerating glaciation in regions of sufficient precipitation. In addition, and this may be an important consideration, the intensified cyclonic marine circulation might have prompted an upwelling system within the deep Arctic basin, destroying completely the halocline and vertical salinity structure. There are indications that during this period the surface temperatures of the North Atlantic were depressed by *several* degrees, possibly as a result of increased exchange at that time with the colder Arctic waters (Ewing and Dorm, 1961).

With its insulating halocline destroyed by decreased low-salinity surface input and by cyclonic upwelling, conditions in the Arctic may have altered considerably to permit the Arctic Ocean to enter the picture in a major role. With its ice-covered surface layer in contact with the warmer, high-salinity deep water, and with Possibly increased exchange with the waters of the North Atlantic, rapid melting of the permanent ice pack would likely have ensued. This melting of the Arctic ice cover would not affect sea level as would the wasting of terrestrial ice. It would, however, open the Arctic as a major precipitation source *for* the growing continental glaciers. With its greater sea/air temperature gradient, the Arctic would provide a moisture source probably surpassing the original North Atlantic source, leading to rapid acceleration of continental glaciation and resultant acceleration of sea level lowering.

But because of this falling sea level, it may have been a self-limiting system, resulting in restricted exchange with the North Atlantic across the Greenland-Faroe sill. Once such exchange was sufficiently restricted, the Arctic would lose the ameliorating effect of the North Atlantic water and would become an essentially land-locked sea of curtailed circulation, subject once more to the growth of a permanent ice pack. This re-freezing would also be encouraged by continued temperature depression over the Arctic due to the growing ice masses around its margin and their albedo effect.

A rapid rise in North Atlantic temperatures about 11,000 years ago (Ewing and Dorm, 1961; Erickson et al., 1956) may indicate that such a restriction of interchange with the Arctic did take place, though this date seems rather late to fit with the calendar of events presented here. For this scheme, such restriction should have happened prior to 20,000 years ago. Also, as will be discussed later, there appears to have been a sudden overall warming trend about 11,000 years ago, which might be the reason for this rise in Atlantic temperature.

Whatever the events leading to this warming of the North Atlantic, it seems probable that by the glacial maximum the Arctic Ocean, if it was indeed open, would have been essentially the sole source of moisture sustaining continental glaciation, for during the period of intensive precipitation following the thawing of its ice cover, as outlined above, these glaciers would have expanded rapidly to "such an extent and thickness as *to* form a physical barrier to the moisture-laden Atlantic air. Now, with the Arctic re-freezing or refrozen, the glaciers' own size would very likely deny them a precipitation source for continued maintenance. By this time they would have expanded far enough southward so that, without continued massive precipitation, wastage would begin along the southern margins.

At the time of the glacial maximum, almost the entire shelf of the Bering and Chukchi Seas was exposed. As wastage and glacial retreat began, the sea again rose to recover this shelf until, about 15,000 years ago (Sharma, this report), the Bering Strait flooded to open communication once again between the Arctic Ocean and the Bering Sea. The resulting low-salinity input from the Bering (probably lower salinity than at present, due to increased river discharge fed from glacier melt) would have added its reinforcing effect to the freezing of the Arctic by setting up once again a permament halocline (Olausson, 1972b) .

There are several arguments in opposition to this scheme of events, and several obvious problems left unanswered. Why, for one, as the glaciers diminished following the re-freezing of the Arctic, lowering the barriers to the North Atlantic air, was this source not re-established for their maintenance? Perhaps the answer lies in warming global temperatures at this time. And why, once sea level had risen to once again open full communication between the North Atlantic and the Arctic, were not the same mechanisms envoked as previously to melt the re-formed Arctic ice? Perhaps because of increased fresh-water input into its margins from the retreating glaciers and from the Bering Sea; perhaps due to unaccounted for reasons.

In opposition to this scheme involving an Arctic Ocean fluctuating between a frozen and unfrozen condition is the view that the Arctic has been perpetually frozen throughout the Pleistocene and that the source of precipitation for glaciation lay in the North Atlantic throughout the sequence of events (Flint, 1952; Colinvaux, 1964b; Dillon, 1956; Lamb, 1974; Clark, 1971; Mercer, 1970; KarlStrom, 1966; Lamb, 1966).

There seem to be three principal arguments supporting this view: (1) oxygen isotope and micro-paleontological evidence that Arctic Ocean near-surface temperatures were never appreciably warmer than at present, (2) precipitation patterns as evidenced by extent of glaciation, and {3) the evolution in the Arctic during this period of animals, namely the polar bear, which are bound to an existence on the Arctic ice (Kurten, 1964). While these arguments cannot be discounted, neither do they seem conclusive.

As regards the evolution of the polar bear, *it is* not disputed that it probably did evolve in the Arctic during the Pleistocene, probably in response to conditions of sea ice. As we view the species now, it is bound quite strongly to sea ice and to another ice-oriented species, the ringed seal, for its major prey. This does not present a conclusive argument for a totally ice-bound Arctic, however, for the opposition view, as summarized earlier, does not maintain that the Arctic was entirely ice-free at any period, only that its deep central basin was. There certainly would have been seasonal, and probably permanent ice along the margins and in the shallow bordering seas such as the Beaufort, Kara, White, Barents, Chukchi, and East Siberian. Even as sea level fell during the glacials to shrink these seas, a considerable habitat of sea ice would have remained along their outer margins.

Also, the ringed seal, to which the polar bear is bound for food, appears to have existed south of the land bridge, in the Bering and Okhotsk Seas, during the Pleistocene glacials (Scheffer, 1967), where there was probably not permanent year-round ice, perhaps indicating that this species at least was not always as strongly ice-dependent as now seems the case.

The temperature arguments (Colinvaux, 1964b;Emiliani,1972; Lamb, *1974;* Hunkins, et al., 1971) are likewise not conclusive in themselves, for the thawing of the Arctic ice pack would not necessarily require warmer oceanic temperatures, only that the salinity structure be broken down to permit vertical mixing (Weyl, 1968; Olausson, 1972).

The remaining objection to an ice-free Arctic, that the lack of glaciation evidenced over northern Alaska and Siberia argues against an Arctic Ocean precipitation source (Lamb, 1966), is also open to dispute. These are for the most part flat, low-lying areas, presenting no physical or thermal barrier sufficient to induce the massive precipitation necessary for glaciation. Also, with tightened cyclonic circulation, winds off the open Arctic would likely have hugged more closely to the flat, featureless coast of Asia and Alaska, encountering no major barrier until they reached the continental glaciers of northeast Canada and Greenland.

A perhaps more serious objection to the view of the Arctic as ice-free is one fostered by lack of evidence. If the Arctic had been open, at least in its central basin, and subject to an upwelling system such as previously described, then it seems reasonable to assume that this region would have supported greatly increased marine productivity, at least on a seasonal basis. But there is no indication, from sediment cores, that this was so. Perhaps such evidence is there and has not been found; perhaps it is missing for reasons not understood; or perhaps it is absent because the Arctic *was,* after all, always a frozen sea.

Regardless of the mechanisms and sequence of events, however, and regardless of the condition of the Arctic Ocean, we do know that the glaciers grew and spread and that sea level fell in response to expose the shelf of the Bering and Chukchi Seas, and that subsequently these glaciers melted and returned their water to the rising sea, once more submerging Beringia.

DISTRIBUTION AND ECOLOGY OF MARINE FAUNA: For purposes of convenience and clarity, the marine biota of the southern, Bering Sea, margin of Beringia and that of the northern Chukchi/Arctic coast will be considered separately.

The Bering Sea

The complement of marine species which inhabited the Bering during the last Wisconsin transgression was probably not far different from that of today (Davies, 1958), with one major subtraction--the polar bear (*Ursis maritimus*)--and one major addition--the Steller sea cow (*Rhytina stelleri*). The marine mammal species probably consisted of the Pacific walrus, the bearded seal, ringed seal, harbor (spotted) seal, ribbon seal, Steller sea lion, northern fur seal, sea otter, Steller sea cow, beluga whale, harbor (common) porpoise, and other cetaceans large and small (Fig. 2-2). The relative and total *abundance* of these species would have fluctuated during this transgression as conditions changed, as will be discussed to some extent later on, but probably all of them were present throughout the period. In addition to the marine mammals, it seems almost certain that the other major species of marine and anadramous fish, shellfish, and marine birds currently found in the region (Rowland, 1973; Stoker, 1973; Neyman, 1960; Filatova and Barsanova, 1964; Andriyashey, 1964; Peterson, 1941) were present during that time. It is assumed that the needs and habits of these animals were about as they are today.

The species of greatest probable interest to early hunters would have been those which were gregarious and tied for existence closely to the land or to sea ice, such as the *walrus* and the otarid

Fig. *2-2:* MARINE SPECIES OF PROBABLE INTEREST TO EARLY MAN, WITH ECOLOGICAL AND BEHAVIORAL NOTATIONS.

SPECIES INHABITING THE BERING SEA:

Common Name	Latin Name	Ecological/Behavioral Type	Average Body Weight (kg.)
Marine mammals:			
Pacific walrus	*Odobenus rosmarus divergens*	Gregarious, ice or land dependent for hauling, depth limited	1,000
Northern fur seal	*Callorinus ursinus*	Rooking, gregarious, pelagic	*50*
Steller sea lion	*Eumetopias jubata*	Rooking, gregarious, pelagic	*400*
Bearded seal	*Erignathus barbatus*	Solitary, ice dependent, depth limited	*300*
Ringed seal	*Pusa hispida*	Solitary, shore-ice denning	*65*
Harbor seal	*Phoca vitulina*	Semi-gregarious, shore dependent, estuarine preference	*140*
Ribbon seal	*Histriophoca fasciata*	Solitary, pelagic	80
Steller sea cow	*Rhytina stelleri*	Semi-gregarious, shallow coastal	
Sea otter	*Enhydra lutris*	Semi-gregarious, coastal	**30**
Beluga whale	*Delphinapterus leucus*	Semi-gregarious, estuarine preference	*>1,000*
Gray whale	*Eschrichtius gibbosus*	Semi-gregarious, pelagic	*>1,000*
Bowhead whale	*Megaptera novaeangliae*	Solitary, ice preference	*>1,000*
Harbor porpoise	*Phocoena romerina*	Semi-gregarious, estuarine preference	<1,000

Fig.2-2 (continued) <u>SPECIES INHABITING THE BERING SEA</u>

Common Name	Latin Name	Ecological/Behavioral Type	Average Body Weight (kg.)
Fish:			
Marine Fish:			
Halibut	*Hippoglossus stenolepis*	Solitary, benthic	< 1
Flounder	several genera and species	Solitary, found nearshore	< 1
Sole	Several genera and species	Solitary, found nearshore	< 1
Sculpins	Several genera and species	Solitary, found	< 1
Cod	*Gaddus* species	Gregarious, pelagic	< 1
Herring	*Clupea pallasi*	Schooling, nearshore spawning	< 1
Capelin	*Mallotus villosus*	Schooling, shore spawning	< 1
Anadramous Fish:			
Salmon	*Oncorhynchus* species	Schooling, river/lake spawning	2
Whitefish	*Coregonus* species	River spawning	1
Sheefish	*Stenodus* species	River spawning	2
Char	*Salrelinus malma*	River/lake spawning	1
Invertebrates:			
Brachyuran crabs		All benthic, nearshore potential	< 1
Tanner crab	*Choanoecetes* species		

Fig. 2-2 (continued) SPECIES INHABITING THE BERING SEA

Common Name	Latin Name	Ecological/Behavioral Type	Average Body Weight (kg.)
Invertebrates:			
Brachyuran crabs (continued)		All benthic, nearshore potential	< 1
Spider crab	*Hyas* species		
Hairy crab	*Telmessus* species		
Anomuran crabs		All benthic, nearshore potential	< 1
King crab	*Paralithodes* species		
Hermit crab	*Pagurus* species		
Pandalid shrimp		All pelagic/benthic, nearshore potential	< 1
	Pandalus species		
	Spirontocaris species		
	Eualus species		
Crangonid shrimp		All benthic, nearshore potential	< 1
	Crago species		
	Argis species		
Bivalve mollusks		All benthic, intertidal or nearshore potential	< 1
	Mya species		
	Spisula species		
	Siliqua species		
	Clinocardium species		
	Serripes species		
	Macoma species		
	Liocyma species		
	Panomya species		
	Hiatella species		

Fig.2-2 (continued) SPECIES INHABITING THE BERING SEA

Common Name	Latin Name	Ecological/Behavioral Type	Average Body Weight (kg.)
Bivalve mollusks (continued)		All benthic, intertidal or nearshore potential	<1
	Tellina species		
	Venericardia species		
	Pecten species		
	Protothaca species		
	Saxidomus species		
	Pododesmus species		
	Mytilus species		
	Musculus species		
Cephalopod mollusks			
Octopus	*Octopus* species	Benthic, nearshore potential	<1
mollusks		All benthic, nearshore potential	<1
	Neptunea species		
	Buccinum species		
	Fusitriton species		
	Polinices species		
	Natica species		
	Colus species		
	Capulacmea species		
	Acmea species		
	Velutina species		
Echinoderms			
Sea urchins	*Strongylocentrotus* species	Intertidal or nearshore	<1
Sea cucumbers	Holothuridae	Benthic, nearshore potential	<1

Fig. *2-2* (continued) SPECIES INHABITING THE BERING SEA

Common Name	Latin Name	Ecological/Behavioral Type	Average Body Weight (kg.)
Miscellaneous Invertebrates	Tunicata	All intertidal or nearshore	< 1
	Echiurida		
	Sipunculida		
	Polychaeta		
	Amphipoda		
	Nemertinea		
Marine Rooking Birds:		2411 forming dense nesting rookeries	< 1
Murre	*Uris* species		
Kittiwake	*Rissa* species		
Auklet	*Aethia* species		
Puffin	*Fratercula* and *Lunda* species		
cormorant	*Phalacrocorax* species		
Gull	*Larus* species		
Guillemot	*Cepphus* species		

seals (Steller sea lion and northern fur seal), or which were large of body and easy prey, such as the Steller sea cow. With the possible exception of the beluga (white) whale and the harbor porpoise, which enter estuaries and river mouths in pursuit of salmon, the cetaceans would have been difficult to hunt and probably out of reach of man at this time. Beached whales, however, would have been a prize.

The walrus, a large, gregarious animal, is depth-limited due to its feeding habits and diving capability, and would probably have been restricted to waters of 50 meters or less in depth. Suitable habitat for this animal would have been severely restricted in the Bering at the height of the Wisconsin for this reason, expanding as the sea transgressed the shallow shelf. These animals also must haul out for extended periods on land or sea ice, and so are limited to nearshore regions or regions of winter or permanent ice, where they would be possible prey for man. Probable hauling grounds ashore would be rocky islands or headlands.

The otarid seals--the Steller sea lion and northern fur seal--though pelagic and unavailable for much of the year, form dense rookeries for pupping and breeding purposes in the summer, on rocky islands and isolated capes, at which time they would have been, and are, extremely vulnerable to man.

Of the phocid seals, the ribbon seal may be discounted as being of prime interest due to its pelagic habits and solitary nature, and relatively small body size (Fig. 2-2) . Bearded and ringed seals are also solitary, but are tied to a nearshore or sea ice existence, where they would have been accessible. The bearded seal would have been desirable due to its large size (Fig. 22) and the ringed seal vulnerable due to its habit of denning on the shore-fast ice to pup. The bearded seal, like the walrus, is depth-limited.

Harbor seals would probably have concentrated near river mouths, along the edge of seasonal ice (an area of enhanced productivity, from personal observation), or along glacier faces such as probably reached the sea from the Alaska Peninsula and in the Cape Newenham vicinity. Harbor seals are known to concentrate along such glacier fronts in south-central and south-eastern Alaska at present, perhaps in response to pandalid shrimp concentrations (personal observation). Ringed and bearded seals, and possibly walrus, might also have congregated for feeding purposes, or for hauling onto the ice, along such glacier fronts in the summer time. Harbor seals are also tied to the land or to sea ice for hauling and pupping, though they are not as gregarious as walrus and do not form the dense breeding rookeries typical of the otarid seals.

Walrus, phocid and otarid seals, cetaceans, fish, shellfish, and marine birds would all have tended to concentrate for feeding purposes in the vicinity or downcurrent of areas of intensified primary productivity such as upwelling or vertical mixing zones, or near river mouths. River mouths would have been host to summer spawning migrations of anadramous fish such as salmon, char, whitefish and sheefish, all of which would have provided in themselves an attraction to man as well as attracting marine mammal species--phocid seals, otarid seals, beluga whales, harbor porpoise--upon which he might have preyed.

In addition to river-spawning anadramous fish, there probably would have been dense spawning. runs of capelin onto the beaches, and of herring into certain areas. Marine fish, particularly halibut, flounder, cod, and sculpins, may have provided some further attraction to the coast, particularly in areas of increased productivity, as would shellfish such as crabs, clams, cockles, and urchins.

The Steller sea cow, a very large and vulnerable animal, would have been prime prey for early man. But it seems probable from its feeding habits, which require dense and extensive beds of the larger seaweeds, that the Beringian range of this species was limited to the remoter islands of the Aleutian-Kommandorsky Arc, inaccessible from land.

Marine bird species such as murres, puffins, auklets, gulls, cormorants, kittiwakes, and guillemots, which form dense nesting rookeries, would also have provided abundant seasonal sources of both meat and eggs. All of these species rook on nearshore cliffs, preferably adjacent to areas of high marine productivity.

In summary, it seems probable that throughout the last Wisconsin transgression the Bering Sea remained an area rich in marine coastal resources. The species composition and areal distribution of this resource, in terms of relative abundance, would have varied as the sea encroached over the shelf and as climate and conditions changed, but probably provided, during any given time, considerable attraction to early man over at least some portion of this coast.

The Chukchi and Arctic Coast

The northern margin of Beringia--the shore of the Chukchi Sea and the Arctic Ocean--was *almost* certainly a far less hospitable place than was the Bering, given even the best of possible conditions. ,

If the Arctic was ice-free in its central basin, as postulated earlier, it could, just possibly, have hosted a marine fauna including present North Atlantic-Greenland species such as the gray seal, hooded seal, harp seal, narwal, harbor seal, and Atlantic walrus in addition to currently present endemics--the bearded seal, ringed seal, polar bear, and beluga whale (Fig. *2-3).* There is no paleontological evidence in support of such a fauna, though this does not conclusively deny its possibility. If the Arctic were open in its central basin, it is probable that it was visited at least seasonally by Atlantic cetaceans, though they would likely have remained far from land due to the fringing ice. It is also possible, though improbable, that the Atlantic phocid seals might have utilized this ice edge. Even so, they would not likely have been readily accessible from the land. Atlantic walrus likewise might have frequented this ice edge, though this possibility is even more remote due ***to the*** depth limitation of these animals. More probably, even if open in its central region, the Arctic marine mammal fauna would have been limited, during the period of the land bridge, to the bearded seal, ringed seal, polar bear, and beluga whale.

If the Arctic was ice-covered during this period, as it

Fig. 2-3. SPECIES INHABITING THE CHUKCHI/ARCTIC

Common Name	Latin Name	Ecological/Behavioral Type	Average Body Weight (kg.)
Marine Mammals:			
Atlantic walrus (doubtful)	*Obobenus rosmarus rosmarus*	Gregarious, ice or land dependent for hauling, depth limited	1.000
Pacific walrus (only recently)	*Obobenus rosmarus divergens*	Gregarious, ice or land dependent for hauling, depth limited	1.000
Bearded seal	*Erignathus barbatus*	Solitary, ice dependent, depth limited	300

Fig. 2-3 continued) SPECIES INHABITING THE CHUKCHI/ARCTIC

mmo		Typ	Average Body
Marine mammals: (continued)			
Ringed seal	*Pusa hispida*	Solitary, shore-ice denning	65
Polar bear	*Ursus maritimus*	Solitary, shore denning, ice dependent	300
Harbor seal (only recently)	*Phoca vitulina*	Semi-gregarious, shore dependent, estuarine preference	140
Gray seal (doubtful	*Halichoerus*	Gregarious, shore or ice dependent	250
Hooded seal (doubtful)	*cristata*	Gregarious. ice dependent	250
Harp seal (doubtful)	*Pagophilus groenlandicus*	Semi-gregarious, ice dependent	200
Narwal (doubtful)	*Monodon monoceros*	Solitary, ice frequenting	> 1,000
Beluga whale	*Delphinapterus leucus*	Semi-gregarious, estuarine preference	> 1,000
Bowhead whale	*Megaptera*	Solitary, ice preference	> 1,000
Gray whale (only recently)	*Eschrichtius*	Semi-gregarious, pelagic	> 1,000

Fig. 2-3 (continued) SPECIES INHABITING THE CHUKCHI/ARCTIC

Common Name	Latin Name	Ecological/Behavioral Type	Average Body Weight (kg.)
Fish:			
Marine Fish:			
cod	*Gaddus* species	Gregarious, pelagic	< 1
Sculpins	Several genera and species	Solitary, found nearshore	< 1
Invertebrates:			
Anadramous Fish:			2
(same as for Bering, but probably not present until recently)			
Brachyuran crabs:			< 1
(same as for Bering, but probably with reduced abundance until recently)			
Anomuran crabs:			
Hermit crab	*Pagurus* species	Benthic, nearshore potential	< 1
Pandalid shrimps:			< 1
(same as for Bering, but probably with reduced abundance until recently)			
Crangonid shrimps:			< 1
(same as for Bering, but probably with reduced abundance until recently)			
Bivalve mollusks:		All benthic, intertidal or nearshore potential	< 1
Softshell clam	*Mya* species		
Cockle	*Clinocardium* species		
	Serripes species		

Fig. 2-3 (continued) SPECIES INHABITING THE CHUKCHI/ARCTIC

Common Name	Latin Name	Ecological/Behavioral Type	Average Body Weight (kg)
Gastropod mollusks:		All benthic, nearshore potential	< 1
Snails	*Neptunea* species *Buccinum* species *Polinices* species *Natica* species *Colus* species		
Miscellaneous Invertebrates: (Same as for Bering)		Same as for Bering	< 1
Marine Rooking Birds: (Same as for Bering, but probably with reduced abundance, possibly absent, until recently)			< 1

presently is, its fauna would certainly have been limited to these four marine mammal species. All of these species, with the possible exception of the beluga whale, which would not likely have been easy prey, are solitary in nature and would not have provided concentrations in terms of hunting resources.

Likewise, it seems unlikely that conditions would have favored nearshore concentrations of marine or anadramous fish, shell-fish, or marine birds, prior at least to the resubmergence of Bering Strait. The coast was probably frozen year-round, with extensive shore-fast ice and offshore pack ice, with few rivers to invite anadramous fish and few rooking sites suitable for marine birds.

Once Bering Strait flooded, faunal conditions in the Chukchi would have improved somewhat. The coast was probably ice-free on a seasonal basis by this time or shortly thereafter, with rivers providing spawning grounds for anadramous fish. Rooking birds would have occupied the nearshore cliffs of the Chukchi Sea, and the marine mammal complement would be swelled by seasonal migrations of walrus, harbor seals, gray whales, and bowhead whales from the Bering Sea.

Over most of the time span considered, however, it appears that the Arctic/Chukchi coast would have been much less attractive than the southern Bering coast. Probably, in fact, it was only marginally habitable, if that, prior to the opening of Bering Strait.

DISCUSSION OF ECOLOGICAL CONDITIONS AT MAJOR STANDSTILLS IN THE LAST TRANSGRESSION: During the last submergence of Beringia there appear to have been three major standstills--periods when sea level stabilized for long intervals in its encroaching rise. The *first of* these appears to have been about 22,000 years ago, the next 16,000 years ***ago,*** and the latest at 11,000 years ago (Sharma, this report). For these three intervals, the probable conditions of Beringia and its bordering *seas* will be discussed in as much detail as seems justifiable at the present time. All of these dates are tentative and very approximate. All coastline and bathymetric contour maps are taken from G.D. Sharma's maps as published in this paper.

Standstill I, 22,000 B.P.

During this period of stabilization the sea level stood some ***80 to 90*** meters lower than at present, exposing virtually all of the continental shelf of the Bering and Chukchi Seas (Fig. 2-4). The area thus exposed was a flat, monotonous plain for the most part, the only major features of relief being the river valleys of the Yukon, Kuskokwim, Anadyr, and Kobuk, and the scattered elevations of the present Pribilof, Nunivak, St. Matthew, St. Lawrence, King and Diomede Islands, whose towering cliffs must have been impressive landmarks on an otherwise featureless land. Massive glaciation characterized the Alaska Peninsula, though it probably did not extend out to sea or onto the plain, and there is evidence of extensive local glaciation in the Kuskokwim Mountains just *north* of present Bristol Bay (Porter, 1967). The geography of the region at this time was not greatly different than that of the glacial maximum, and it seems probable that ecological conditions and faunal distributions were equally similar.

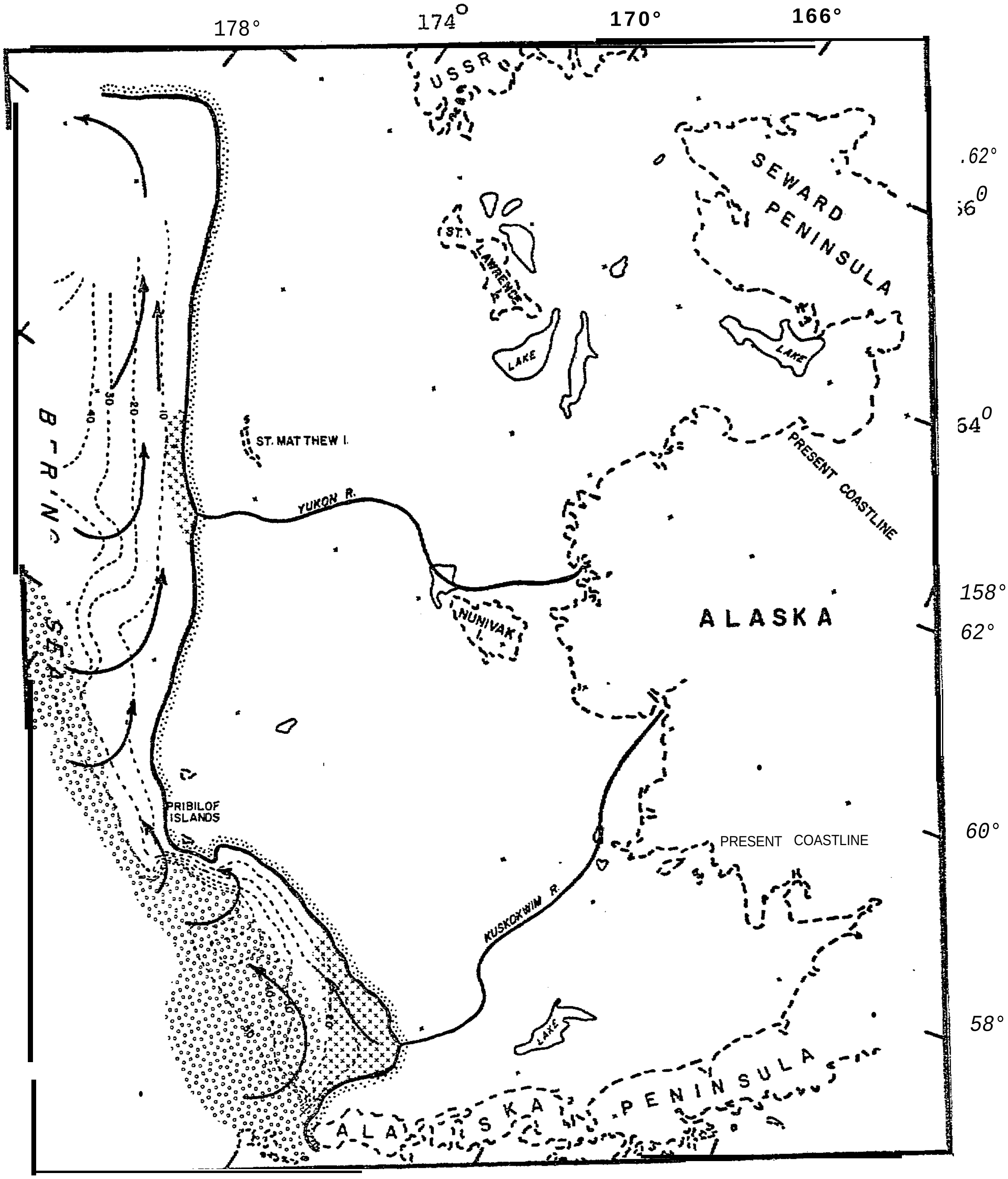


Fig. 24. Marine near-surface current structure, high productivity zones, and fresh water sources of the Bering Sea, Standstill I, 22,000 B.P.

Zones of marine upwelling and enhanced productivity

Regions of fresh water input

Except for the river valleys, and for areas such as the Alaska Peninsula whose mountains would have induced precipitation from the moist Pacific air, it was probably a *rather* arid and very windswept plain. There were no trees, other than perhaps willows in the river valleys, to break this wind out of the north and west, and little else to relieve the monotony of the endless steppe.

The weather was almost certain to have been severe. The effect of increased continentality resulting from the departure of the sea from this shelf would probably have promoted colder, drier winters and hotter, shorter summers than are presently seen on the adjoining land (Dillon, 1956; Hulten, 1963). Probably due to an intensified Arctic low pressure center (Lamb, 1971) , increased cyclonic circulation would have fostered stronger and more persistent winds, summer and winter, with a more northerly component. Unpleasant as they probably were, however, these winds may have had their value, keeping the vast plains swept free of snow for the large grazing mammals which frequented it and upon which early man likely depended for his prey.

From the evidence of the large herbivores which inhabited this region at this time--horse, bison and mammoth--and from the probable climatic conditions, it seems almost certain that the terrestrial environment during this interval was that of a cold grassland steppe.

Along this plain's southern margin was the Bering Sea, shrunk to little over half its present size and restricted to its deeper zones. It seems reasonable that the current structure might have been somewhat as depicted in Fig. 2-4 , with inflow through the deep passes along the eastern Aleutian Arc, fairly strong east-west currents nearshore, and outflow through the Kommandorsky or western Aleutian passes. There could have been cyclonic upwelling in the embayment along the Alaska Peninsula, and nearshore upwelling along the continental slope (Fig. 2-4).

There probably was increased summer discharge of fresh water from the large rivers entering the Bering and from the Alaska Peninsula, even during this interval of stabilization, as a result of glacial wastage. This fresh water input would have lowered the surface salinity of the Bering, encouraging winter ice formation and promoting coastal intensification of the current structure (R. Muench, University of Alaska, personal communication) . It is almost certain that the near-shore Bering was subject to seasonal shore-fast and pack ice extending to the continental slope, where upwelling water from the deep basin would have prevented its further expansion, as it does today. Due to the strong current and wind system, it was probably very rifted, active ice, desirable to marine mammal species such as inhabited the nearshore region year round.

As stated earlier, it seems reasonable to *assume* that all of the major marine species presently inhabiting the Bering were present at that time with the addition of the Steller sea cow and the subtraction of the polar bear. The extent of available habitat, and the resultant distribution and relative abundance of these species was probably, however, a good bit different from that seen today.

The walrus, due to its depth limitation, would have seen its range during this time shrunken to what was left of Bristol Bay, the embayment along the Kamchatka coast, a narrow band adjacent to the open shore connecting these embayments, and to the Sea of Okhotsk. Of these areas, the Sea of Okhotsk would probably have hosted the largest population, though a sizeable herd could have inhabited Bristol Bay, the Kamchatka embayment, and possibly even the intervening coast. During the winter these animals could have utilized all of the shallow areas where rifted ice for hauling was available, with concentrations along the ice edge (Fig. 2-6). During the presumably ice-free summer they would most likely have concentrated in the vicinity of the Pribilofs and along the Alaska Peninsula to take advantage of high-productivity feeding areas and hauling grounds (Fig. 2-5).

'rhe distribution of the Phocid seals of interest--harbor, ringed, and bearded--would probably have been not too dissimilar to 'chat of the walrus. During the winter the harbor seals would have concentrated along the ice edge, probably in the Pribilof region in particular (Fig. 2-6) . Bearded seals would likely have utilized all of the rifted ice over shallow feeding grounds during the winter, just as the walrus, with ice edge concentrations. Due to their habit of denning on the shore-fast ice, ringed seals would have been more numerous closer to the shore. It should be kept in mind, however, that both ringed and bearded seals are essentially solitary in nature, and would have

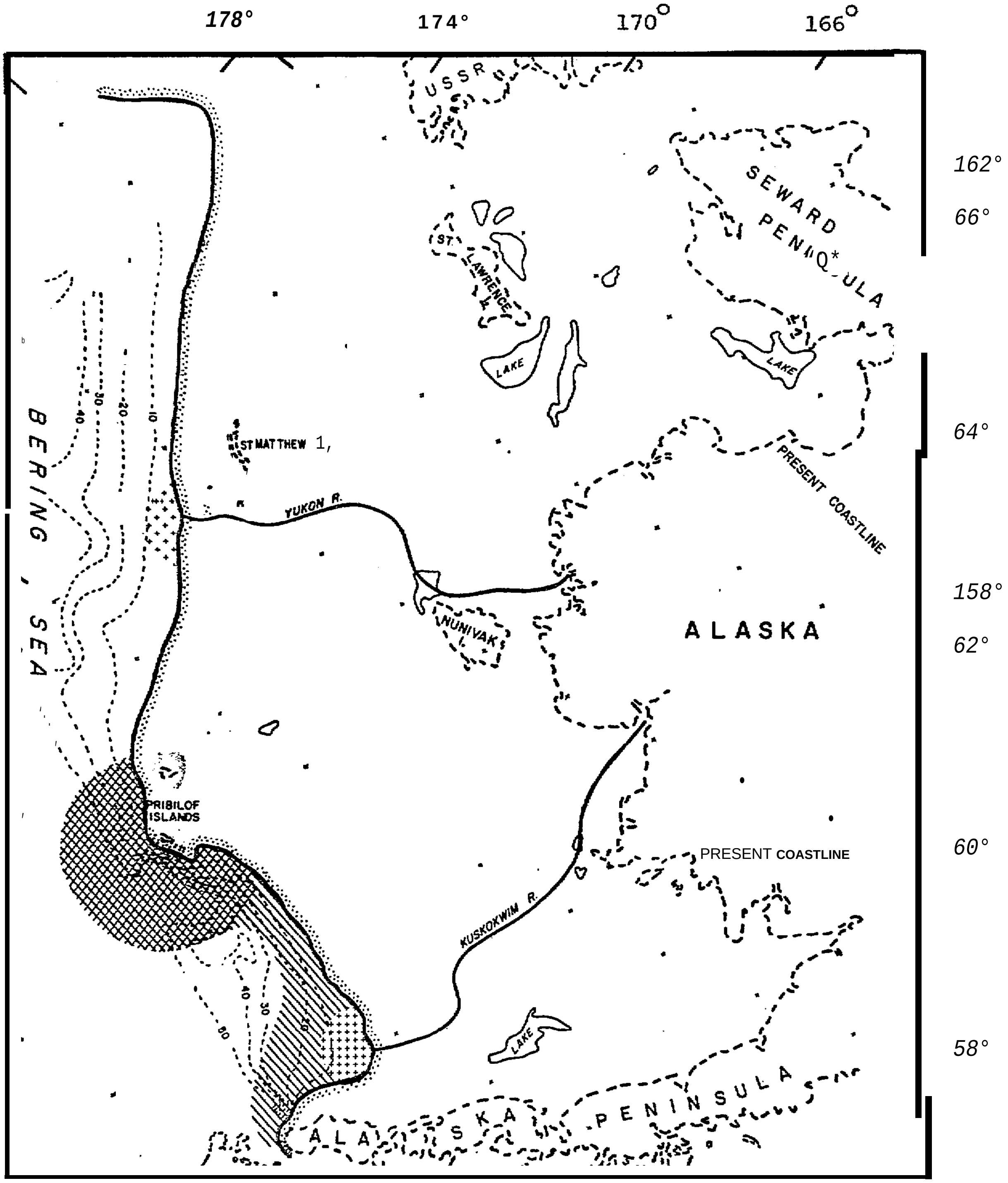


Fig. 2-5. Marine faunal concentration zones, summer, Bering Sea, Standstill I, 22,000 B.P.

Walrus and phocid seals

Walrus, phocid and otarid seals

Salmon complex

Marine rooking birds

provided minimal hunting concentrations. During the summer, it seems probable that harbor seals would have concentrated in the high-productivity Pribilof region and along the glacier fronts of the Alaska Peninsula. The Alaska Peninsula region may also have attracted a large portion of the bearded and ringed seal population during the summer (Fig. 2-5). Due to its pelagic habits, solitary nature, and relatively small body size, the other phocid inhabiting the Bering at this time, the ribbon seal, is considered to be of minimal interest. This species would probably have concentrated, with most of the other phocids and the walrus, along the ice edge in winter, and perhaps in the Pribilof and Alaska Peninsula region in the summer.

The otarid seals--sea lions and fur seals--would have been at sea and unavailable through the winter. During the summer, both these species would likely have formed dense rookeries in the Pribilof region, as would have the marine rooking birds (Fig. 2-5).

The estuaries and river mouths emptying into the Bering would have hosted *large summer* concentrations of anadramous fish and their predators, delineated as the "salmon complex" on Figs. 2-5 through 2-16.

Most of the Bering coast, particularly the central coast from the Pribilofs across to the Kamchatka embayment, would have been an open, windswept coast of sand beaches and dunes, probably wracked by frequent storms and subject to heavy surf--not overly hospitable for concentrations of marine mammals or of man. The Bristol Bay and

Pribilof Canyon regions, however, would have been somewhat sheltered from such open-ocean effects, would have been the most likely regions of upwelling, the recipients of rivers, and by all measures, the areas most probable of supporting increased marine productivity at all trophic levels, from phytoplankton to whales. The Pribilof region is of magnified interest in that it, of all the coastal areas of that or future periods, is the only one close enough to the continental slope upwelling zone to have remained essentially ice-free during the winter time. Combined with the enhanced productivity promoted by the upwelling out of Pribilof Canyon, this feature would have made the Pribilof region, particularly the vicinity of St. George Island, a very desirable location for marine-oriented human populations throughout the Year (Figs.2-4,2-5,2-6). During the summer there would probably have been concentrations of walrus, phocid and otarid seals, marine rooking birds, anadramous fish (salmon complex], marine fish, and cetaceans, drawn by the increased productivity of the upwelling zone, by streams which probably entered Pribilof Canyon, and by attractive hauling and rooking grounds. During the winter, the probable reduction or lack of extensive coastal ice would have permitted access to walrus, phocid seals, and possibly cetaceans.

The other likely region of marine faunal concentration during this period would have been the Alaska Peninsula (though probably glaciated and uninhabitable by man) and northeastern Bristol Bay, where increased productivity, river mouths, and possible hauling grounds would have provided attractions during the summer. During the winter,

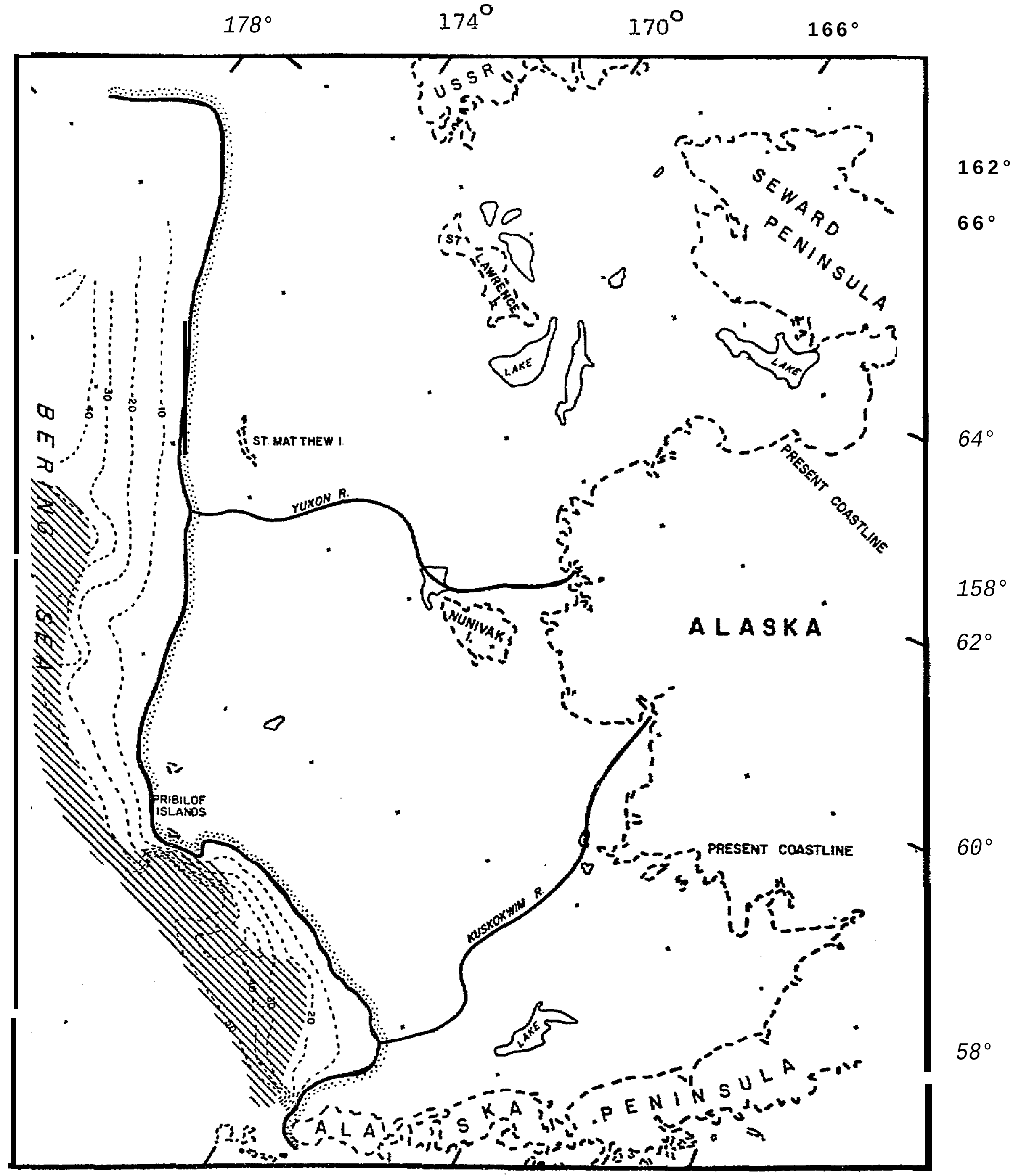
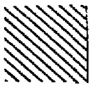


Fig. *2-6.* Marine faunal concentration zones, winter, Bering Sea, Standstill I, 22,000 B.P.



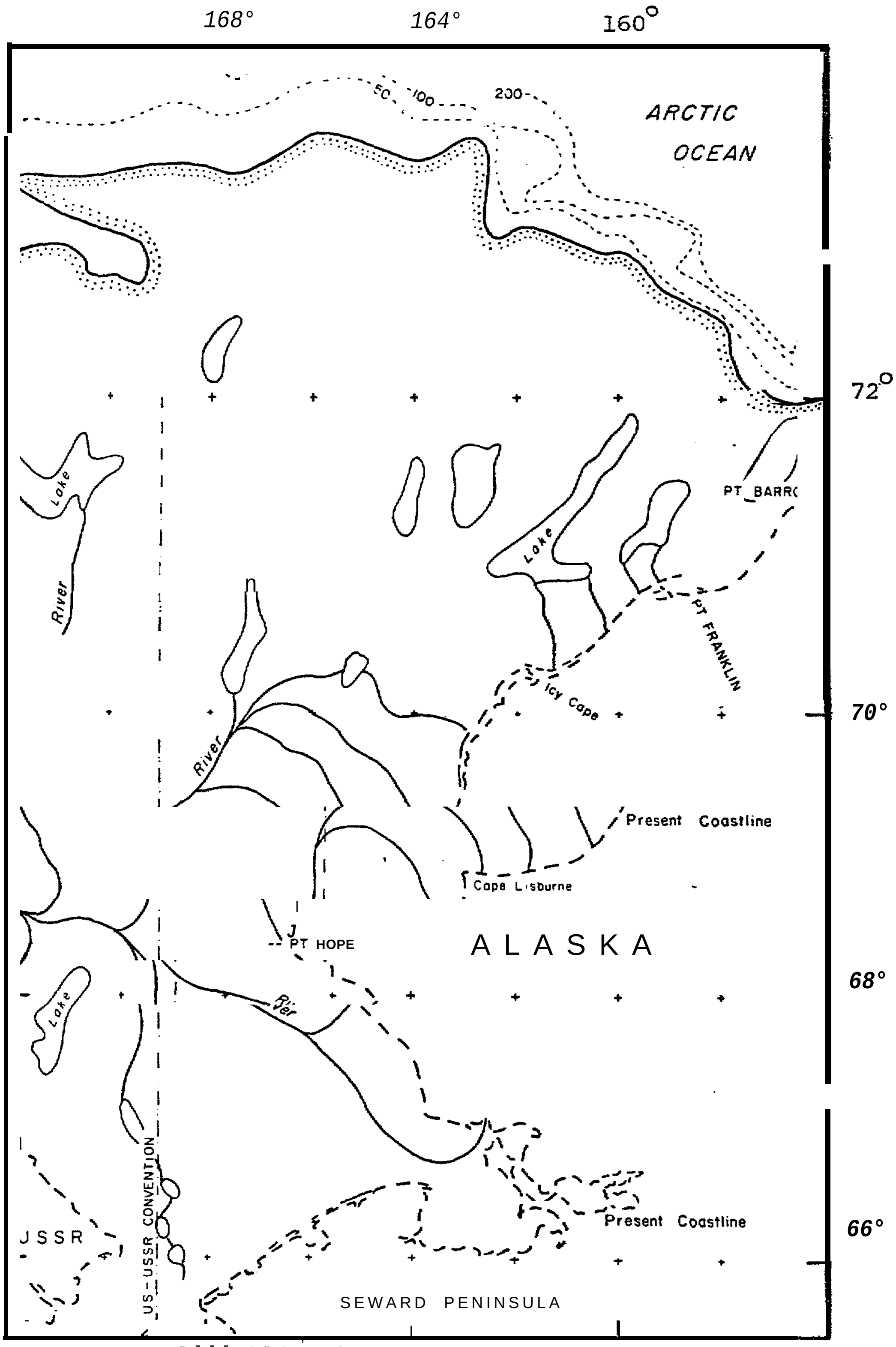
Walrus and phocid seals

this area would probably have been subject to extensive nearshore ice and not so desirable, though populations of walrus and phocid seals might have been accessible.

The northern border of Beringia during this interval was the edge of the Arctic Ocean, the Chukchi having been abandoned to its limits by the sea (Fig. 2-7). As discussed earlier, this ocean may have been ice-free in its central basin, though with extensive and heavy sea ice around its margins, or it may have been permanently frozen. In either event, it seems highly unlikely, given the information presently at hand, that this coast could have provided faunal concentrations which would have been attractive and accessible to early man.

Standstill II, 16,000 B.P.

The next major stabilization of sea level seems to have been about 16,000 years ago, when the shoreline was at the present 40 to 50 meter contour. By this time the Pribilofs and St. Matthew would have resumed their island status, the Beringian plain would have been shrunken greatly in extent, and the area of shallow sea would have expanded correspondingly (Fig. 2-8). The land was still a windswept plain of seasonal temperature extremes, though beginning to ameliorate in climate due to the encroaching marine influence and a lessening of the prevalent Arctic low (Lamb, 1971). The cyclonic atmospheric circulation would probably have lessened in intensity, with resultant reduction in wind strength. These winds by now would probably have begun to lose their northerly component also, shifting to blow more from the west.



'ig. 2- 7. Cln_Mc.hl/Arctic coast, Standstill I, 22,000 B.P.

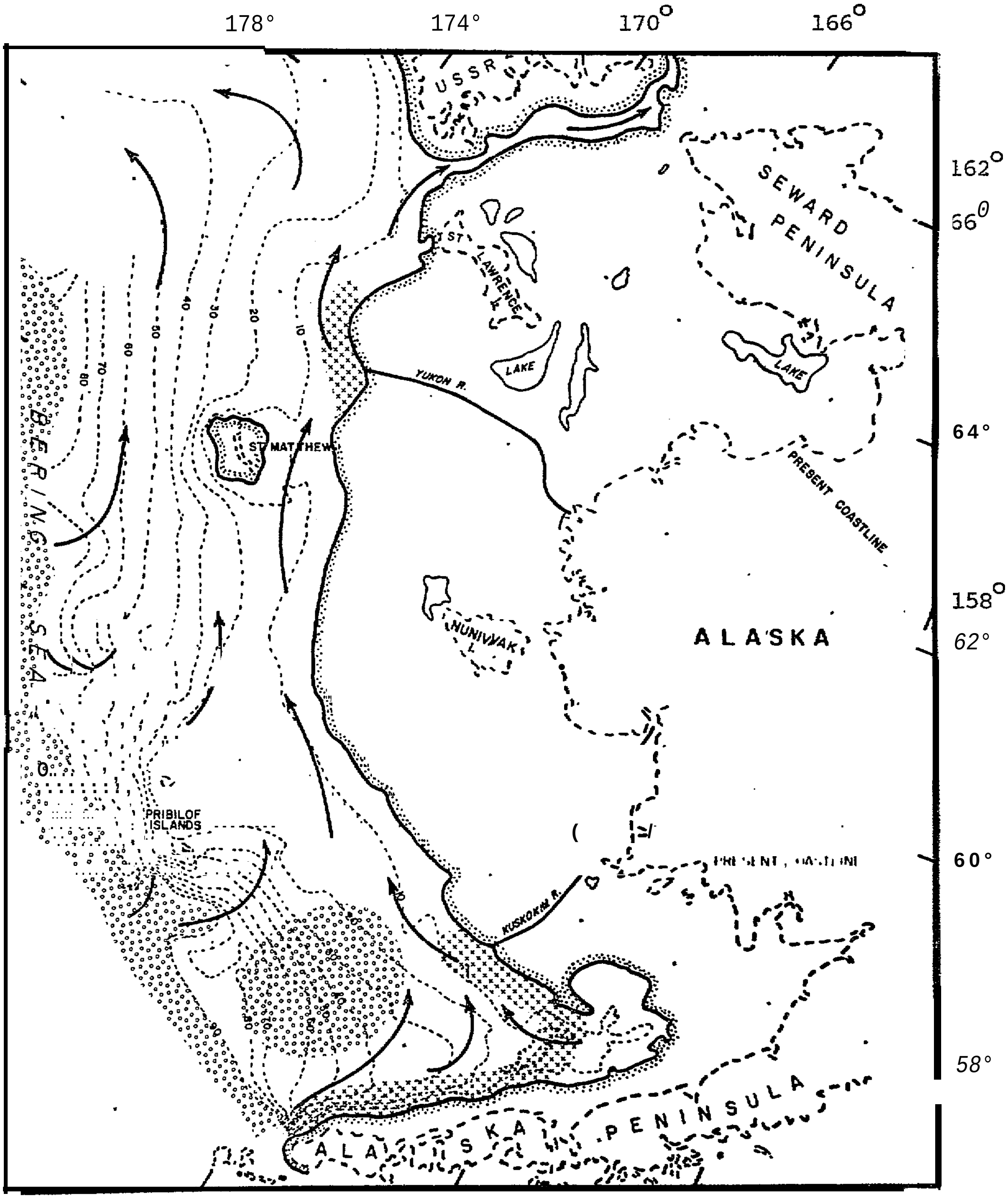


Fig. *2-8.* Marine near-surface current structure, high productivity zones, and fresh water sources of the Bering Sea, Standstill 11, 16,000 B.P.

Zones of marine upwelling and enhanced productivity

Regions of fresh water input

Precipitation may have also been increased over the land by this time as a result of the changing wind patterns and encroaching marine environment. The prevalent winds now would have been more off the expanded Bering Sea rather than from the arid northern plain, and thus were likely to have been warmer and more moisture-laden, providing rain and snow. This combined effect--increased precipitation and reduced wind to sweep away the winter snow--may have led to wetter ground conditions by this time, encouraging the development of shrub and muskeg tundra to the detriment of the grassland environment and its grazing herds. Other terrestrial herbivores, of course, would have been replacing these grazers.

The shallow zone of the Bering would have been greatly expanded by this time, providing habitat for increasing populations of such benthic-feeding marine mammal species as walrus, bearded seal, and ringed seal. Bristol Bay would be much more prominent by now, indented deeply at its head by the *estuaries* of the Kuskokwim and Kvichak Rivers, and would have provided favorable habitat for walrus, phocid *seals,* probably otarid seals, marine rooking birds, cetaceans, and marine and anadramous fish. It is possible that the Bering and Chukchi were re-connected at this time by a narrow strait west of St. Lawrence (Fig. 2-8), though there is some uncertainty regarding this reconstruction. At any rate, it seems unlikely that such a sinuous strait would have led to any great faunal exchange between these seas at this time or, conversely, that it would have constituted any great barrier to terrestrial exchange between Asia and America as yet.

The pattern of marine currents would probably have been about the same as during the previous standstill, though with decreased coastal intensification. The frequency and intensity of storms may have abated somewhat in keeping with the overall gentling of the wind regime. The continental slope upwelling zone would have been further offshore by now, and the cyclonic upwelling zone inside the tip of the Alaska Peninsula would have migrated deeper into Bristol Bay (Fig. 2-8). The glaciers of the Alaska Peninsula and of the Kuskokwim Mountains-Cape Newenham region, though retreating rapidly, would probably remain impressive in size and extent. The surface salinity of the Bering would be at least as low during this period as previously, promoting seasonal ice which would have extended to the continental slope.

This is a much vaster area than would have been subject to sea ice during the previous period, providing greatly expanded winter habitat for ice-seeking species such as walrus, ringed seals, bearded seals, beluga whales, and bowhead whales. These species may have occupied the entire continental shelf during the winter where ice conditions were favorable, with walrus, harbor seals, bearded seals, and ribbon seals tending to concentrate along the ice edge (Fig. 2-9) and ringed seals along the shore-fast ice. As previously, the Pribilofs, and possibly St. Matthew, would have been likely regions of winter concentrations of these mammals, though inaccessible now from land.

During the summer, walrus, otarid seals, phocid seals, and marine birds would probably have concentrated around the Pribilofs and St. Matthew for rooking, hauling, and feeding purposes (Fig. 2-10). Walrus and phocid

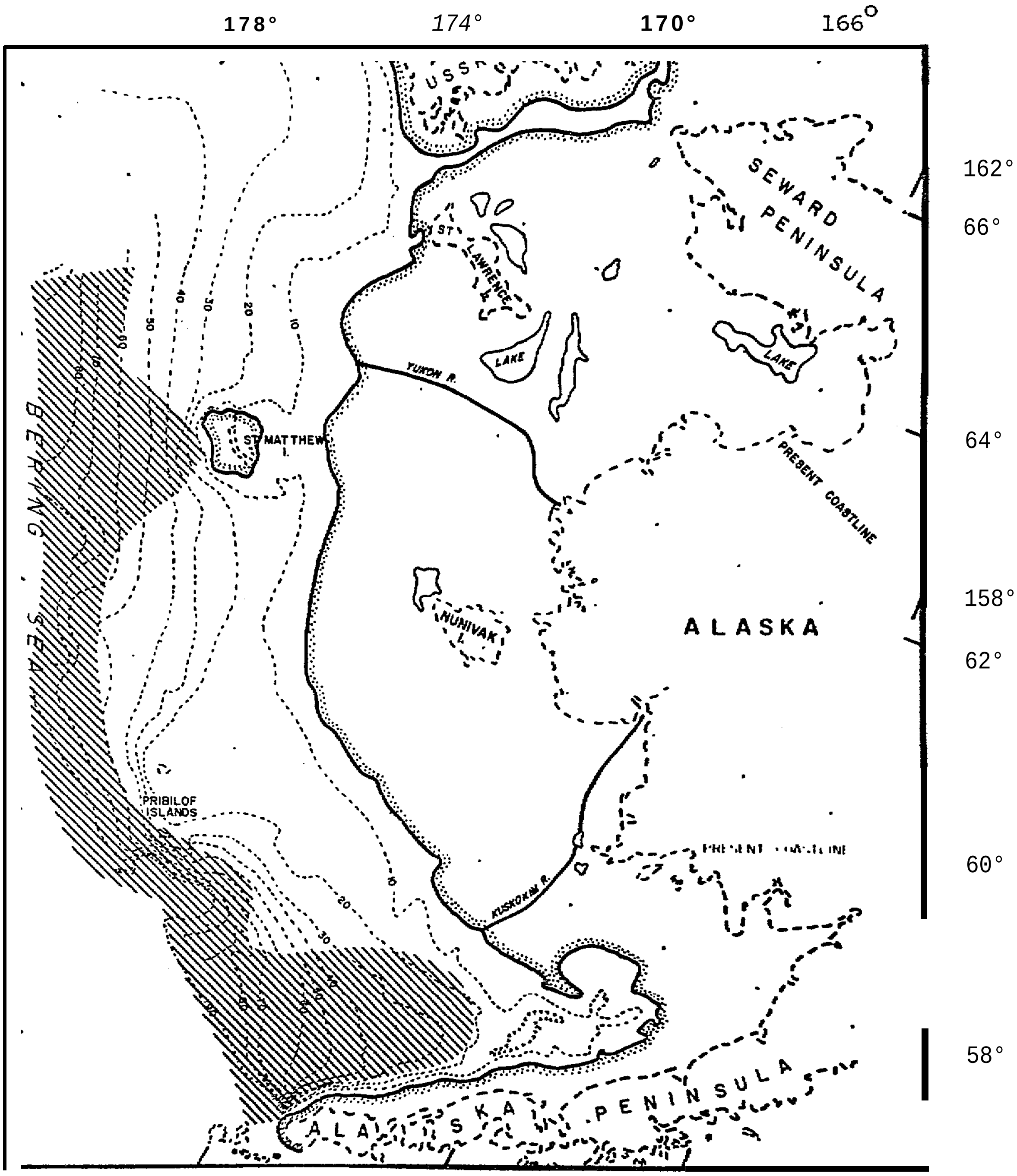


Fig. 2-9. Marine faunal concentration zones, winter, Bering Sea, Standstill II, 16,000 B.P.


Walrus and phocid seals

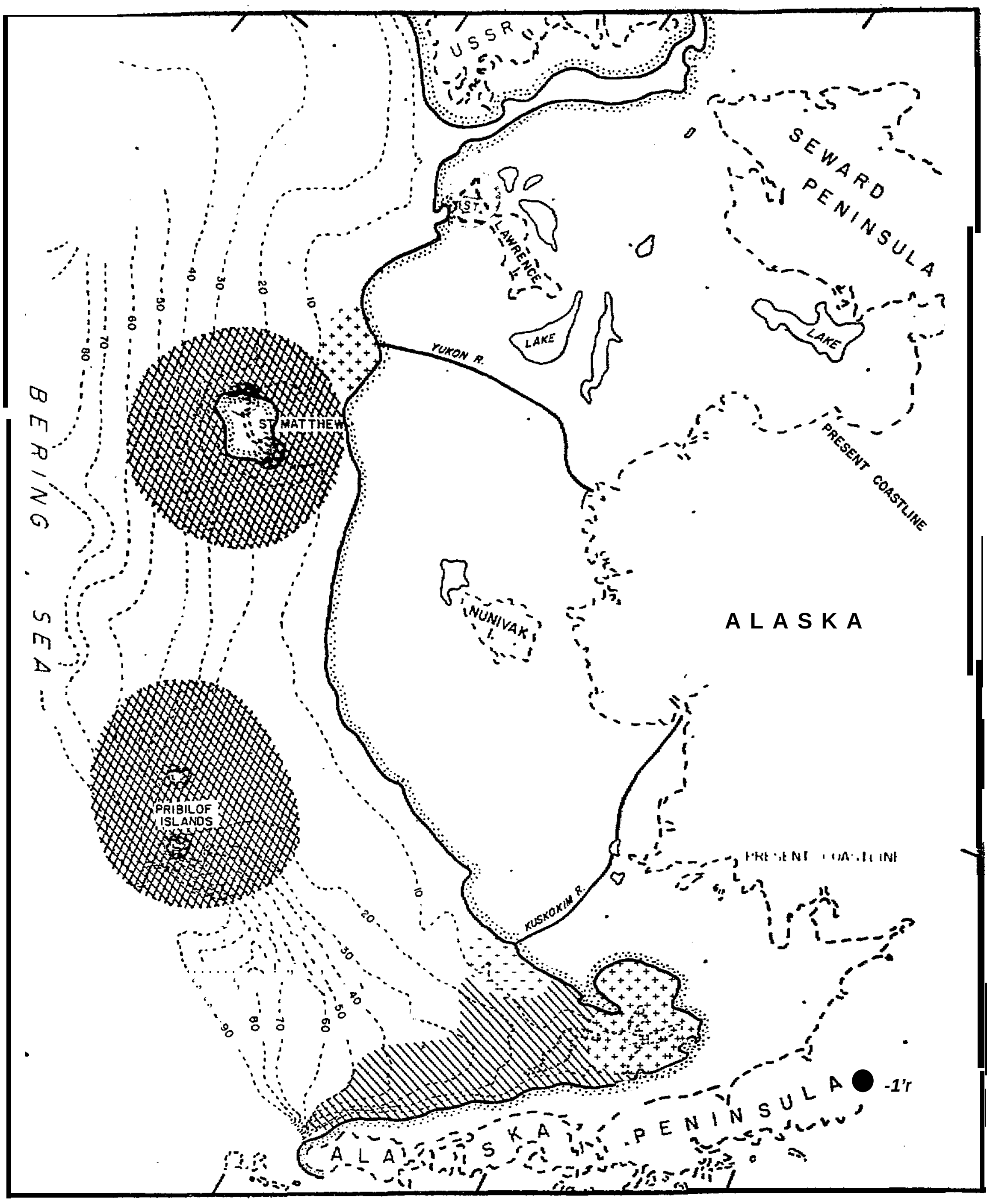
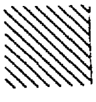
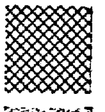
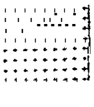


Fig. 2-10. Marine faunal concentration zones, summer, Bering Sea, Standstill II, 16,000 B.P.


Walrus and phocid seals


Walrus, phocid seals and otarid seals


Salmon complex


Marine rooking birds

seals would probably also have congregated during the summer, as previously, along the Alaska Peninsula and in Bristol Bay.

The areas of greatest probable interest to early man seeking marine food resources during this period would appear to be the northern side of Bristol Bay, particularly the Cape Newenham vicinity, and western St. Lawrence Island, still a part of the mainland at this time.

The river mouths of northern Bristol Bay would very probably have attracted spawning runs of anadramous fish along with their marine mammal predators--the phocid seals, otarid seals, and cetaceans--and this factor, in combination with the generally high primary productivity of the region, would have made them desirable locations.

The other area of high probability at this time, the western end of St. Lawrence, might have provided hauling grounds for walrus and would have been an ideal location for intercepting marine mammals passing through the strait into the Chukchi, for this strait was opened sufficiently to permit such communication.

During the winters, there would probably have been extensive shore-fast and pack ice over the shelf, with little or no open water accessible from shore. Winter hunting would have been limited to ringed and bearded seals, and possibly walrus, all of which would had to have been hunted from the ice.

The situation in the Chukchi/Arctic could not have been much improved by this time over that described for the preceding stand-still, and might, in fact, have worsened in that the central Arctic, if it had been open during the preceding interval, would very likely be re-frozen by this time or be deep in the process of becoming so. The Chukchi would have regained a considerable extent of its former shelf (Fig. 2-11), but it would as yet have been a very shallow sea of shoals and narrow channels, with restricted circulation. Almost certainly it would have been completely frozen most, if not all, of the year. The few species adapted to these conditions--the ringed seal, bearded seal, polar bear and beluga whale--would find themselves with expanded range, but probably would have occured nowhere in sufficient quantity to be very attractive as a food resource.

Once the Bering Strait was opened sufficiently to permit unrestricted communication there would have been seasonal migrations of walrus, harbor seals, gray whales, and bowhead whales, such as are seen today, following the pack ice back and forth from the Bering into the Chukchi. Such migration patterns did not evolve overnight, though, and certainly not before the strait was well open and the Chukchi had become more suitable for such animals, conditions which probably developed sometime between this and the next standstill.

Standstill 111, 11,000 B.P.

During this last major standstill, conditions of the Bering and Chukchi Seas were not greatly different from today. The climate, in

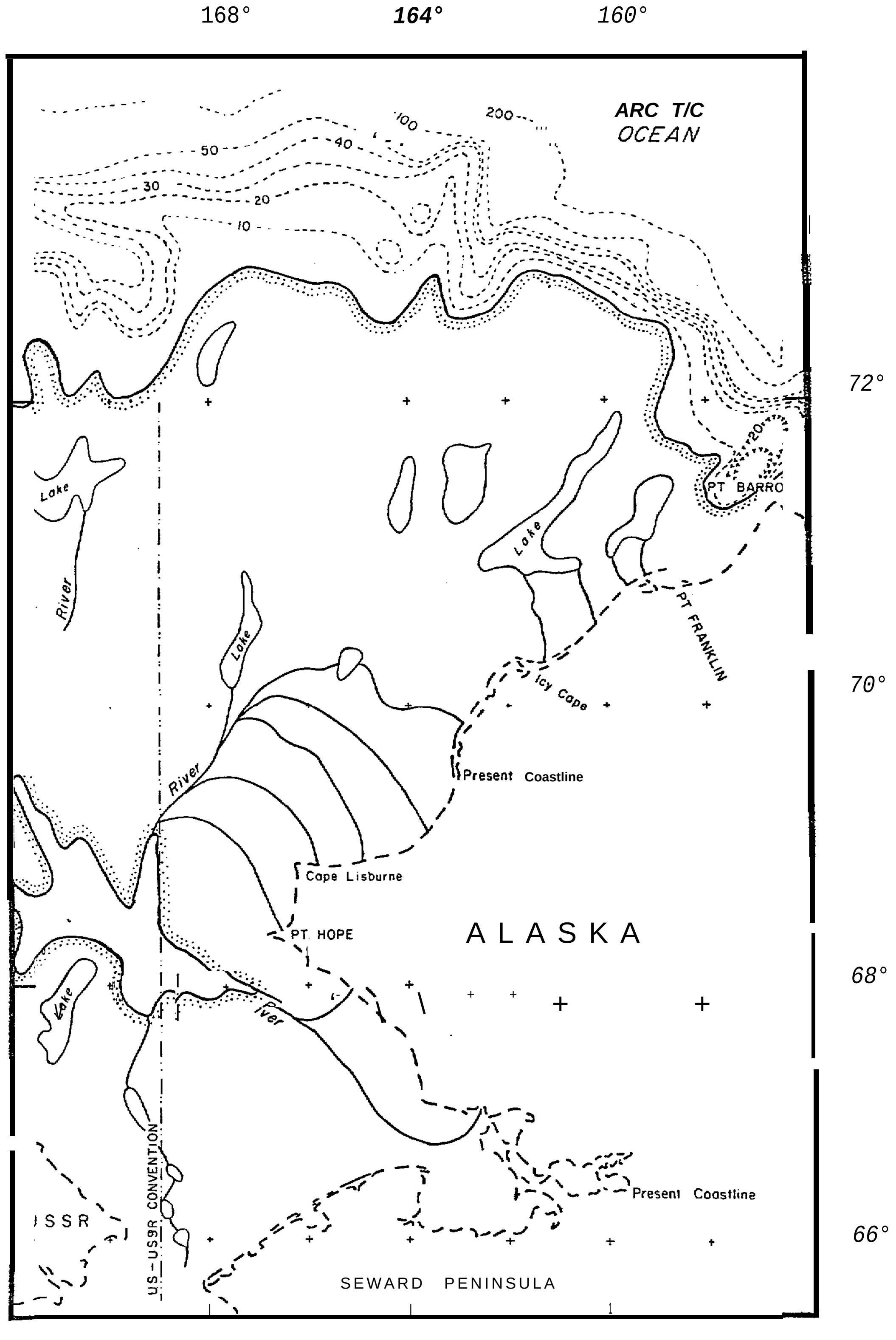


Fig. 2-11. Chukchi/Arctic coast, Standstill II, 16,000 B.P.

fact, may very well have been milder than today. A broad rim of land around the coast, including Kuskokwim Bay, Norton Sound, and Nunivak Island, would have still been connected to the mainland and not submerged. but all of the other islands would have been proper islands once more by this time, and most of the shelf would have been regained by the sea (Fig. 2-12). Terrestrial communication would have been severed between Asia and America and marine exchange would have been freely established once more between the Bering and Chukchi Seas.

On land, it is probable that the climate had altered significantly since the last standstill. Evidence such as floral distribution patterns of that period indicate that it *was* much milder than previously, and quite possibly warmer than at present (Black, 1966; Erickson et al., 1956; Broecker et al., 1960). The wind would probably have abated considerably and would have swung more to the west. Summers would probably have been slightly cooler and wetter and the winters warmer, with increased snowfall. Such conditions would probably have led, by this time, to almost total replacement of the dry grasslands of previous periods by a tundra vegetation, wet in summer and covered by deep snow in winter time. River valleys and waterways would have been densely grown with willow and alder, and it is highly likely that boreal spruce and birch forests crept onto the shelf of Beringia and spread north as far as the Mackenzie delta (Ritchie and Have, 1971; McCulloch and Hopkins, 1966). The discharge of rivers may have been much increased due to accelerated glacial melt. and was probably heavily laden with silt.

Marine circulation patterns would not likely have been greatly

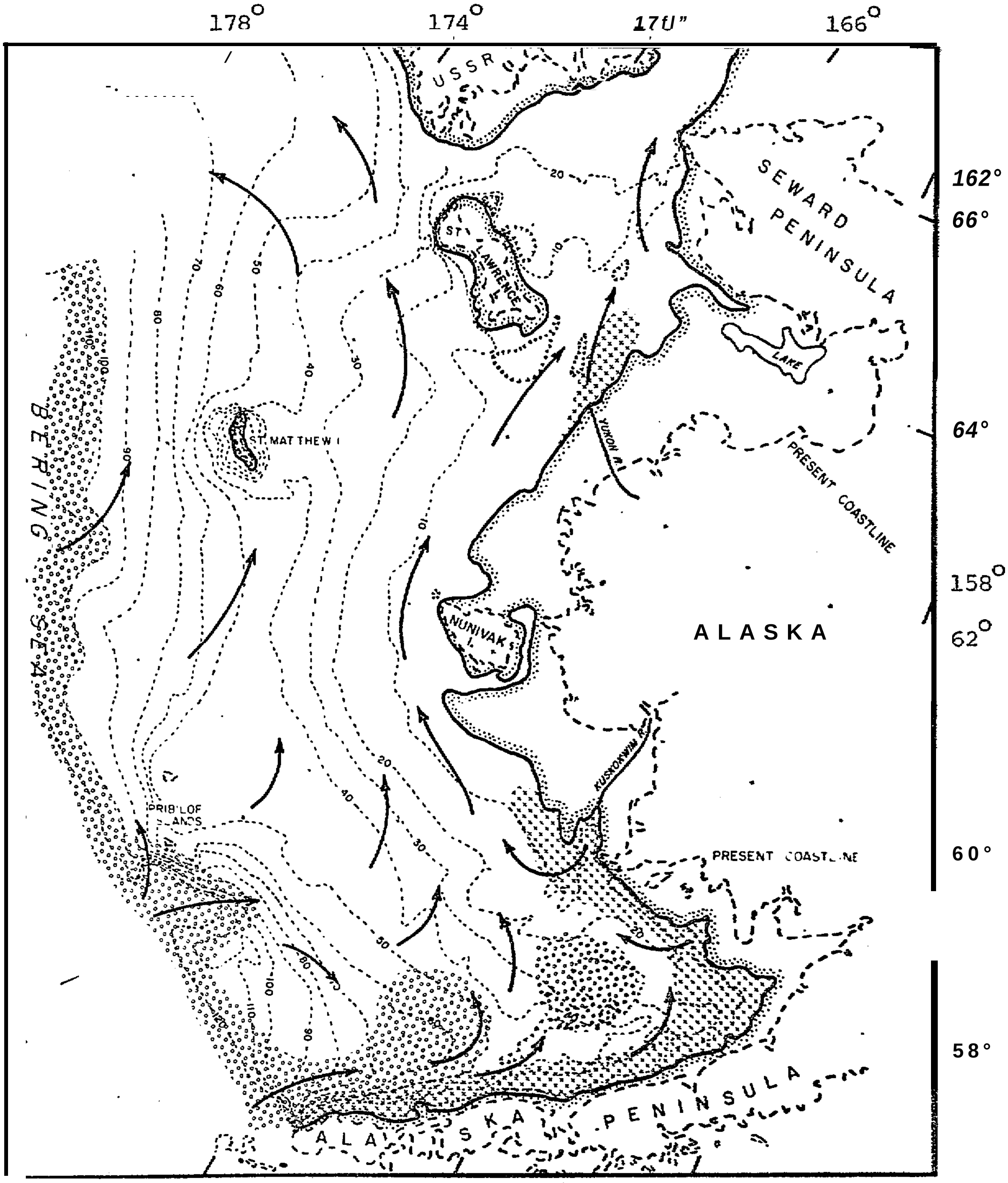


Fig. ***2-12.*** Marine near-surface current structure, high productivity zones, and fresh water sources of the Bering Sea, Standstill 111, 11,000 B.P.

Zones of marine upwelling and enhanced productivity

Regions of fresh water input

different from the present ones (Fig. 2-12), with Pacific water entering the Bering through the eastern Aleutian passes, drifting north and east across the shelf with part of it flowing north through Bering Strait into the Chukchi and part turning back south and recentering the Pacific through the western Aleutian and Kommandorsky passes (Avsen'ev, 1967). There would probably have been an upwelling zone along the continental slope, far now from the reach of land, and increased cyclonic upwelling in Bristol Bay. There may also have been turbulent mixing and areas of heightened primary productivity inside the Alaska Peninsula, north of St. Lawrence Island, and in Bering Strait. All of these would be *rich* marine areas, supporting large populations of fish, marine birds, shellfish, and marine mammals.

The situation regarding seasonal sea ice in the Bering during this period, along with its effect on marine mammal distributions, is difficult to assess. The warm, wet climate and accelerated glacial melt would tend to lower the surface salinity, promoting ice formation. But, the warmer winter temperatures might conversely have precluded such formation. It seems very possible, given the scanty information available, that seasonal pack and shore-fast ice might have been reduced in extent, thickness, and duration as compared to previous situations, possibly even as compared to the present. This condition might not have been agreeable to ice-seeking species such as the walrus, ringed seal, and bearded seal, and might have shifted their distributions further to the north. Correspondingly, the more pelagic species such as the otarid seals might have found their range expanded, perhaps to as far north as Bering Strait.

With communication fully established between the Bering and Chukchi now, the walrus would probably have established a pattern of seasonal migration back and forth between these seas following the edge of the pack ice, as is presently the case. In the winter they would probably have moved down into the Bering to wintering grounds along the edge of the pack ice and in the southern lee of St. Lawrence, (Fig. 2-13) where wind and currents keep the pack ice in an active, semi-open condition. In the summer they would probably have followed the ice edge back to its limits of retreat in the Chukchi Sea or along the edge of the Arctic Ocean (Fig. 2-16). It is possible that a year-round population might also have been established in the Cape Newenham region of northern Bristol Bay, where one exists today.

The other ice-seeking species--the ringed seal, bearded seal, beluga whale and bowhead whale--would have followed similar, though less well-defined seasonal patterns, probably always staying at or within the edge of the seasonal ice. Harbor seals would probably have penetrated into the southern Chukchi in the *ice-free summer* time, and polar bears would have been likely in the northern Bering now in winter time. In addition, the gray whale by now was probably taking advantage of the rich summer feeding in the northern Bering and southern Chukchi, as would have other cetacean species.

The otarid seals would almost certainly have utilized the Pribilofs for rooking grounds during this period, and very probably have frequented the Cape Newenham area, St. Matthew Island, western Nunivak, and possibly St. Lawrence and the islands of the Bering Strait

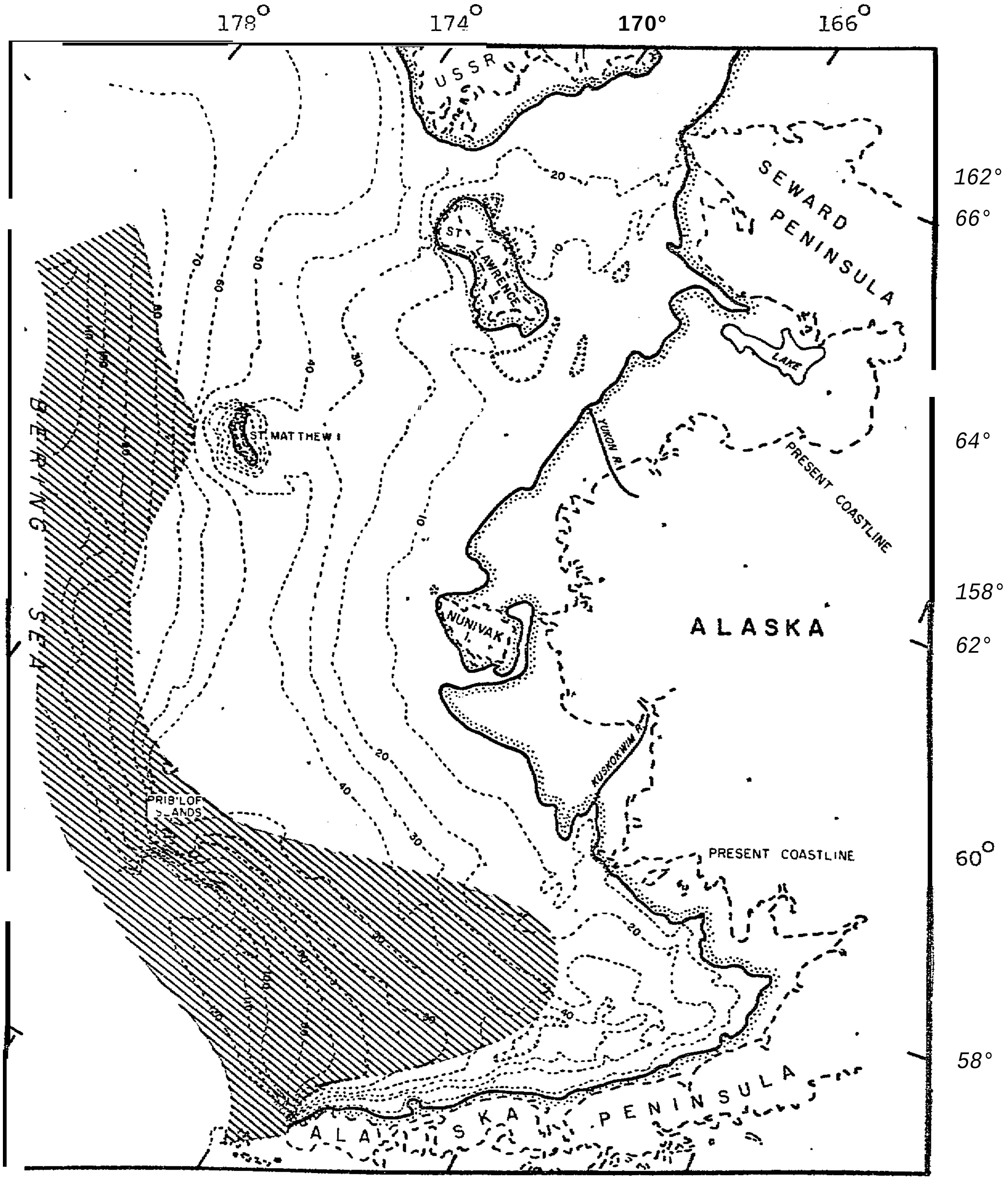


Fig. *2-13. Marine* faunal concentration zones, winter, Bering Sea, Standstill III, 11,000 B.P.

| Walrus | Walrus and phocid seals

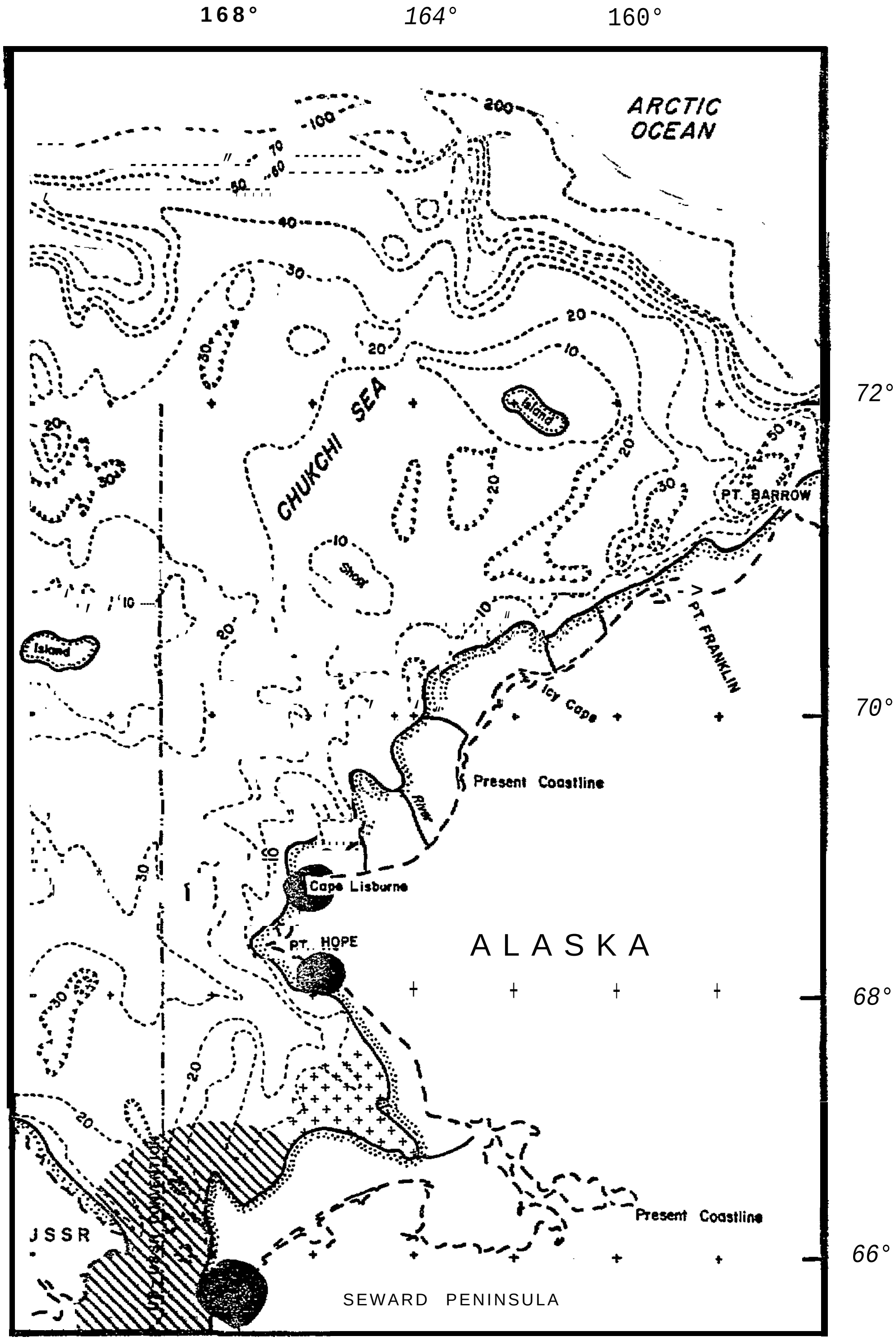


Fig. 2-16. Marine mammal concentration zones, summer, Chukchi-Arctic, Still stand III, 11,000 B.P.

Walrus	Walrus and phocid seals
Salmon complex	Marine rooking birds

for the same purpose. These same areas would have hosted rooking marine birds and would have provided summer hauling grounds for walrus and phocid seals (Fig. 2-14). Areas in the Bering which might have proved attractive to man during this period would have been the northern Bristol Bay and Cape Newenham region, for the same reasons as set forth for the previous standstill, western Nunivak, St. Lawrence Island, the islands of the Bering Strait vicinity, and the shores of Bering Strait itself. All of these localities would have supported marine bird rookeries, would have provided at least seasonal hauling grounds for walrus and phocid seals, might have supported otarid seal rookeries, and would have permitted interception of migrating marine mammals as they traded back and forth following the ice.

To the north, the Chukchi would have come to life again, at least on a seasonal basis. In the summer the walrus and other ice-associated species would have entered the Chukchi in pursuit of the retreating ice pack, vacating it in the fall as the ice moved south again.

The Chukchi would have regained most of its shelf by now (Fig. 2-15), though it was still a very shallow sea. It would very probably have been an extremely rich sea by now in its southern and central part, as is the case today. Then, as now, the currents from Bering Strait would have swept north across this shelf (Fig. 2-15), bringing with them much of the profits of the primary productivity of the north Bering Sea (Stoker, unpublished data).

The rivers entering the Chukchi, principally the Kobuk,

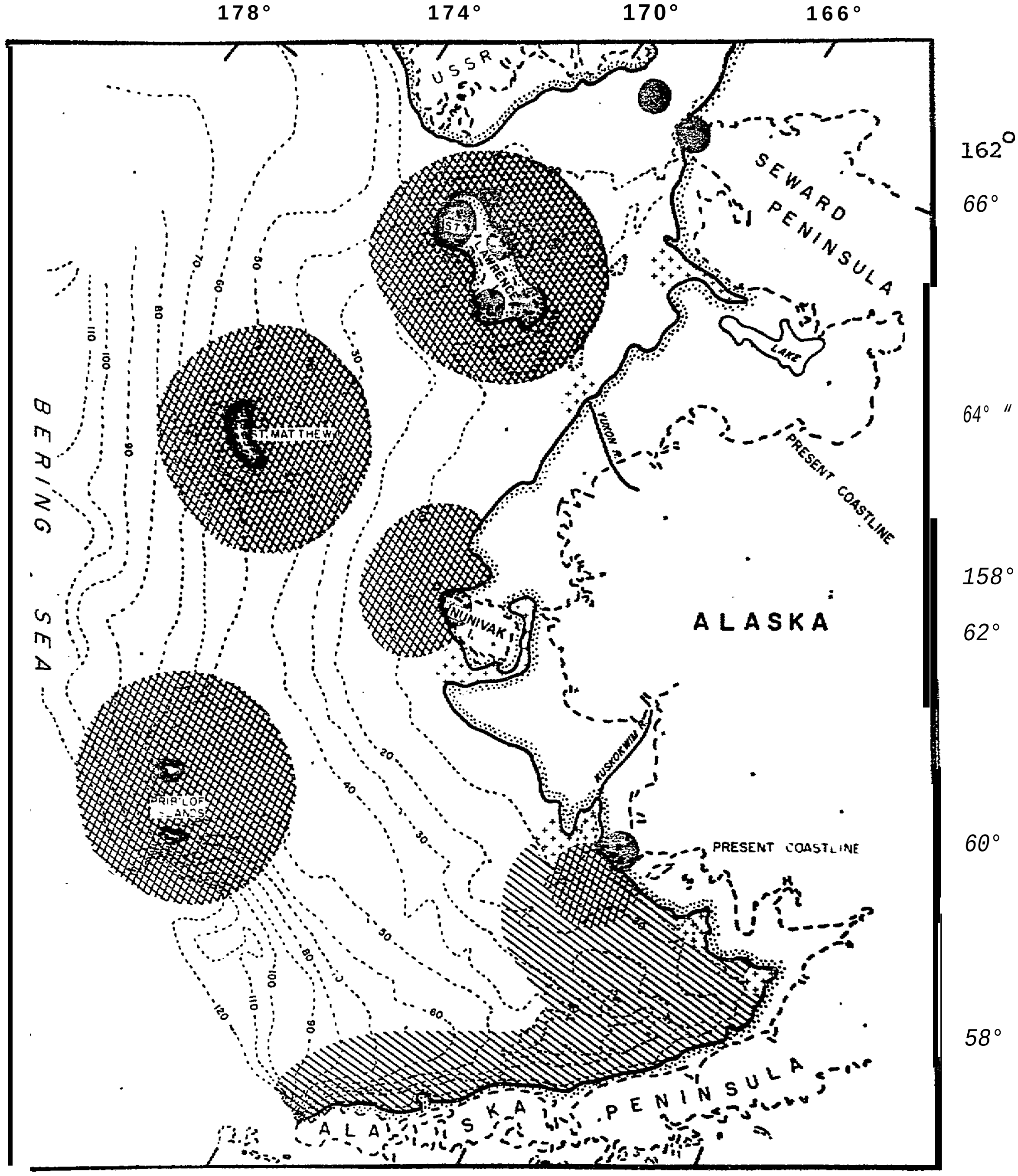


Fig. 2-14. Marine faunal concentration zones, summer, Bering Sea, Standstill III, 11,000 B.P.

Walrus

Walrus, phocid and otarid seals

Marine rooking birds

Walrus and phocid seals

Salmon complex

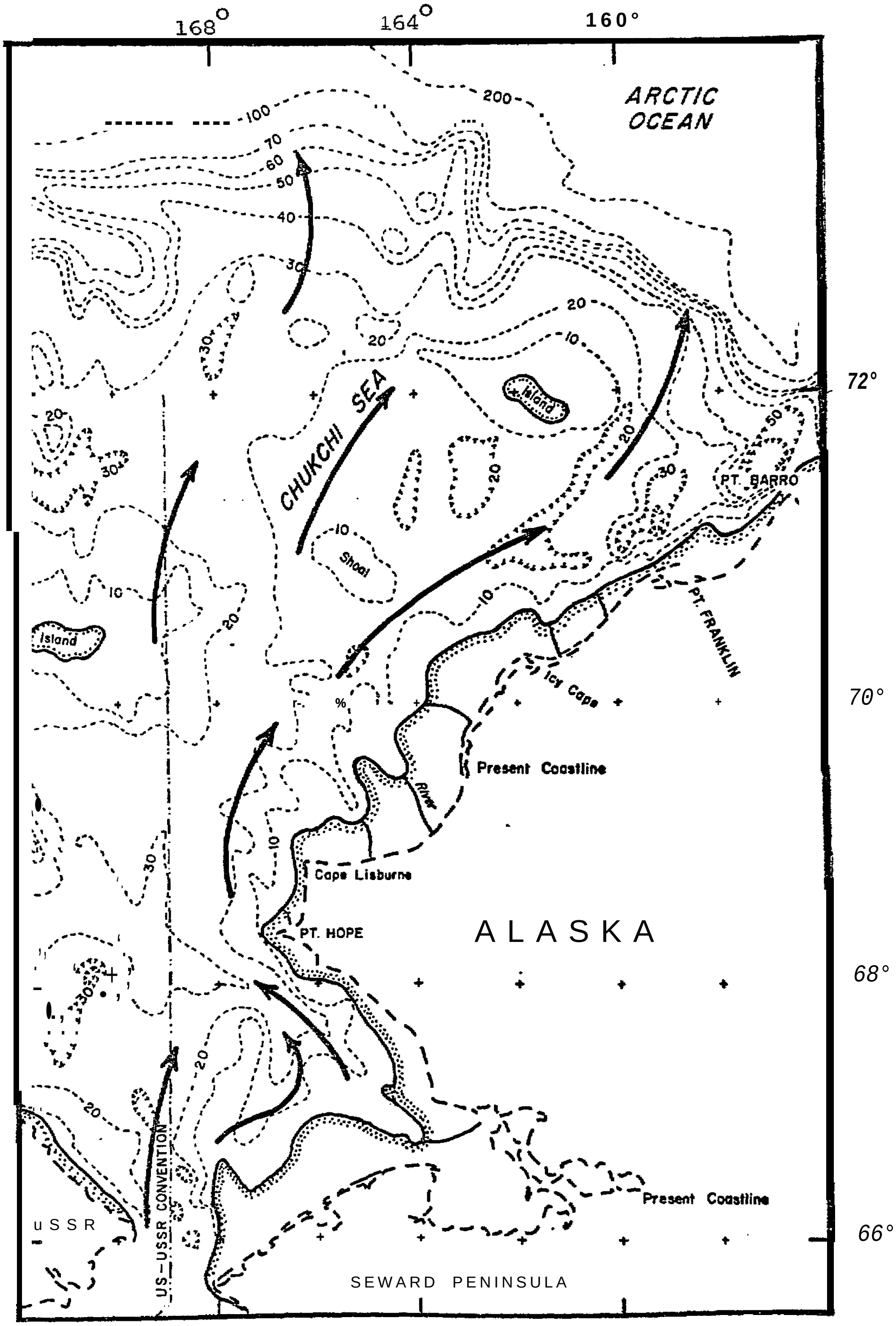


Fig. 2-15. Marine near-surface current structure, Chukchi Sea, Standstill 111, 11,000 B.P.

would probably have hosted anadramous fish migrations by this time, along with the associated retinue of predators (Fig. 2-16). Such river mouths would have been likely sites for early man as would capes projecting into migration routes of marine mammals. Such capes and nearshore cliffs would probably have supported marine bird rookeries as well.

In the winter the Chukchi was almost certainly ice-covered over its total extent, but the thickness and duration of this ice may not have been so great as at present due to the warmer climate. Winter populations of marine mammals would have been sparse over the Chukchi, consisting of scattered ringed seals, bearded seals, and polar bears.

SUMMARY: During the 11,000-year time span dealt with here, from 22,000 to 11,000 years ago, the Bering and Chukchi land mass underwent flooding and shrinkage from an area which included almost all of the continental shelf of these seas to one little larger than today. This period saw the exchange of terrestrial species between Asia and America and the subsequent exchange, once this bridge was breached again by the sea, of long-separated marine forms of the Bering-Pacific and the Arctic.

During this time the climate ameliorated from one of extremely cold, dry winters and short, hot summers, with severe winds from the north and west, to one of warmer, wetter winters and cooler, wetter summers, with decreased winds mostly out of the west. As a result, ... probably, of this climatic change, the terrestrial habitat altered from one of windswept dry grass plains to one of wet tundra and boreal forest,

with corresponding faunal replacement.

The conditions of the Bering Sea during this period were probably not vastly different from those of today, with seasonal shore-fast and pack ice extending to the continental slope and with areas of rich marine upwelling to support large populations of cetaceans phocid and otarid seals, walrus, marine birds, marine and anadramous fish, and shellfish. The relative composition and distribution of this fauna would have varied in response to changing conditions, certain species expanding or declining as their habitat expanded or shrank, but throughout the period it seems probable that sufficient habitats were available to maintain viable populations of all species.

The condition of the Chukchi/Arctic Ocean during this time could not have been nearly so hospitable. With the possible exception of the central Arctic basin, the Chukchi and nearshore Arctic were probably frozen for most, if not all, of the year, and supportive of only sparse and scattered marine resources. Only after the flooding of Bering Strait would the Chukchi seem to be a desirable area, at which time it would have been at least seasonally ice-free and the recipient of faunal migrations and primary productivity input from the Bering Sea.

For early man seeking marine food resources, the Bering coast would have been by far the most preferable environment throughout most, if not all, of the transgression. During the time when it was connected as part of the land bridge, the Pribilof region might have been a very desirable region, rich in marine life and probably ice-free virtually year-round. Other areas of attractiveness for man during this early period might have been the northern side of Bristol Bay and St. Matthew Island.

As the sea encroached, isolating St. Matthew and the Pribilofs, major interest might have shifted to northern Bristol Bay--to Cape Newenham and the inlets of the Kuskokwim and Kvichak Rivers--and to the western end of St. Lawrence Island from where marine mammal migrations might have been intercepted.

After the flooding of Bering Strait, likely areas would be the river mouths of northern Bristol Bay, particularly the Cape Newenham region, western Nunivak, St. Lawrence, the islands in the vicinity of Bering Strait and the shores of Bering Strait and Kotzebue Sound in the Chukchi Sea.

Fig. 2-17: MARINE SPECIES OR SPECIES GROUPS WHOSE DISTRIBUTION WAS CONSIDERED IN THE RANKING OF POSSIBLE HUMAN HABITATION SITES, IN DESCENDING ORDER OF IMPORTANCE, WITH ECOLOGICAL CONSIDERATIONS

Common Name	Latin Name	Areas of Probable Concentration
1) Salmon complex: (anadramous fish and associated marine mammal predators)		
Salmon	*Salmo* species	
Whitefish	*Coregonus* species	
Sheefish	*Stenodus* species	
Char	*Salrelinus* species	
Harbor seal	*Phoca vitulina*	River mouths and estuaries
Beluga whale.	*Delphinapterus leucus*	
Steller sea lion	*Eumetopias jubata*	
Northern fur seal	*Callorinus ursinus*	
Harbor porpoise	*Phocoena phocoena*	
2) Otarid seals:		Rooking grounds on rocky, isolated headlands or islands adjacent to productive marine zones
Northern fur seal	*Callorinus ursinus*	
Steller sea lion	*Eumetopias jubata*	
3) Walrus:	*Odobenus rosmarus*	Hauling grounds on islands or headlands. Areas of constricted migration pattern. Areas of feeding preference (shallow regions in zones of high marine productivity and adjacent to hauling grounds or ice in summer, areas of active, broken ice in winter.)
4) Phocid seals:		
Harbor seal	*Phoca vitulina*	Feeding concentrations in areas of enhanced marine productivity.
Ringed seal	Pusa *hispida*	Areas of shore-fast ice for denning.
Bearded seal	*Erignathus barbatus*	Shallow, highly productive areas with sea ice.

Fig. 2-17: MARINE SPECIES OR SPECIES GROUPS WHOSE DISTRIBUTION WAS CONSIDERED IN THE RANKING OF POSSIBLE HUMAN HABITATION SITES (continued):

Common Name	Latin Name	Areas of Probable Concentration
5) Marine Birds:		
Murre	*Uria* species	Dense nesting rookeries on cliffs or elevated headlands adjacent to productive marine zones.
Kittiwake	Rissa species	
Auklet	*Aethia* species	
Puffin	*Fratercula* and Lunda species	
Cormorant	*Phalacrocorax* species	
Gul 1	*Larus* species	
Guillemot	*Cepphus* species	

TERRESTRIAL VERTEBRATES AND THEIR EFFECT ON THE DISTRIBUTION OF HUMAN HABITATION SITES

JI'JTRODUCTION

During much of the Pleistocene the outer continental shelf between Alaska and northeastern Asia was a terrestrial environment inhabited by a now extinct fauna. Horse and mammoth bones have been found existing in terrestrial sites near the present shoreline and on some of the Bering Sea islands, and bones of large mammals have also been dredged from-the outer continental shelf itself.

The mammals which inhabited this area during the Late Wisconsin were what the Soviets have called the "mammoth fauna." It had many diverse components which varied in composition and proportion from area to area, but its major recognizable elements in the fossil record are mammoth, horse and bison.

These are the three species which predominate in the hunting campsite refuse and at kill sites of paleohunters in both North America and Eurasia. Although there are many unknowns about the exact nature of the hunting techniques of these early peoples, there are some pieces of information that can be compiled to aid us in establishing the more likely areas of large mammal concentration and, consequently, the concentration of paleo-campsites.

We know from modern analogs of hunting peoples that camp sites are positioned to best intercept seasonal movements of migratory large mammal species. An attempt will be made herein to portray the type of late Pleistocene landscape now submerged on the outer continental shelf, the distribution of its large mammal inhabitants, the chronology of the large mammal changes in that region, and develop the theory of the probable effect of the various topographic features on animal concentrations.

<u>THE LATE PLEISTOCENE LANDSCAPE OF THE OUTER CONTINENTAL SHELF:</u> Lately, much attention has been focused on the character of the Late Pleistocene vegetation patterns in the far north. The Wisconsin glaciation is our main concern, because the now submerged shelf became uninhabitable by terrestrial peoples after about 10,000 years B.P., and much earlier than the Wisconsin glaciation, it was probably too early for a mature human technology which could exploit it. The general conclusions are that it was a dry, herbaceous grassland, variously called steppe-tundra, loess-tundra, periglacial steppe, tundra-steppe, and several other synonyms. Its exact character and the climate which maintained it are somewhat controversial, although several elements are beginning to emerge: (1) It was drier, either from lack or precipitation, sublimation-evaporation by wind, or a deeper thaw-percolation zone than exists in tundra areas today. (2) The climate was more continental. (3) standing plant biomass must have been much less, but plant productivity may have been similar to present. (4) Because of this low plant biomass, the animals which exploited it were nomadic, or at least migratory. (5) They were a different kind of herbivore than those which utilize the far north today--they were grazers instead of browsers. (6) Because of topographic variations in plant maturity rate, these

grazers concentrated in certain predictable habitat types in different seasons. (7) Because of the seasonal boom-bust food economics of the super-nivian terrestrial vertebrates in the north, there were high quality summer resources available in relatively short periods, followed by a movement to more snow-free, sparse winter range. (8) It is probable that the herb-bunchgrass-*Artemesia* complex of plants served (in possibly unequal proportions, but the same species) as both summer high protein growth resource in the early growth stages, high carbohydrate fuel for winter fat reserves in the late summer, and low quality heat producing fuel for winter survival. (9) As far as we can tell from the pollen records, there were few woody plants available for browsers at the peak of the Wisconsin glaciation in the far north (Colinvaux, 1967a, 1967b). This lack of wood undoubtedly had an effect on the life-style of human inhabitants as well.

In conclusion, one could say that the climate during the terrestrial stage of the outer continental shelf was very severe, but food in the form of large terrestrial mammalian grazers existed in abundance locally and seasonally.

Much of the theory behind the paleoecology of the Pleistocene Arctic and Subarctic comes from western Eurasia and Alaska, although by extension, it applies to the Beringian area spanning the outer continental shelf between Alaska and Siberia. Hopkins (1972) has the only major review of this area. The status of Quaternary research in the Alaskan interior was reviewed by Pewe (1965) and Pewe et al. (1965).

Much of the palynological-paleontological studies have been for specific areas (eg., Sellman, 1967; Guthrie, 1968a, 1968b; Matthews, 1968, 1970, 1974a). In a recent paper, Ager (1975a] described several pollen profiles from central Alaska. Despite only a few carbon dates, the character of the Late Wisconsin to recent vegetational changes in this study and its chronology seems to have been well-documented in this study. At least, it is consistent with the bits of evidence we have from other sources.

Ager's lowermost pollen zone was produced by a steppe-tundra environment--high percentage of grass and wormwood, *Artemesia*. Pollen Zone 2 persisted from about 14,000 years ago until about 10,000 years ago. It is characterized by a reduction in the steppe element and an increase in the percentage of dwarf birch pollen. The changes, at least in the north shadow of the Alaska Range where these cores were taken, between Zones 1 and 2 appear to have been relatively abrupt. At about 10,000 years ago, the spruce invaded the Interior, producing Ager's Zone 3.

Although this chronology can be expected to vary from place to place, it probably represents a rough approximation of the general pattern of change. The dry steppe-tundra was replaced by tussock sedges and low shrubs, then the trees encroached into the better drained sites.

Exactly what this vegetational change means in terms of climatic change is uncertain. It is thought to mean (1) increasingly warmer conditions, and (2) an increase in moisture (probably summer moisture). But these are not necessarily linked to a shift toward more woody conditions. It could be due to a change in temperature regime--a shortened, warmer summer, a decrease in the summer thaw zone, increased winter snowcover, less wind, and several other factors or combinations of factors.

LARGE MAMMAL DISTRIBUTION ON THE OUTER CONTINENTAL SHELF: Because of the seasonal migratory movements of the different elements of the "mammoth fauna," they had a relatively high potential for colonizing large areas (zoogeographers characterize this as high-vagility). And, in fact, they are found very ubiquitously throughout the north. There are no areas in Alaska, which were not glaciated, that have not produced the "mammoth fauna" in abundance. Much the same is true for most of northern Eurasia.

There is an area in the far northeastern part of the Soviet Union which usually does not show on vertebrate locality maps as having produced fossils (Fig. 3-l). This may be more of an artifact due to lack of reconnaissance effort, or it, in fact, is deficient in vertebrate fossils. Interestingly enough, it is the area not inhabited by the wooly rhino--which apparently did not get into the outer continental shelf. Sher, working on the Upper Kolyma region in this general area of the Far East, has described mainly early Pleistocene sediments and associated fauna, much the same sort that have been found (Guthrie and Matthews, 1971) on the Seward Peninsula in Alaska. Judging from everything else we know of their distribution, it seems probable that the

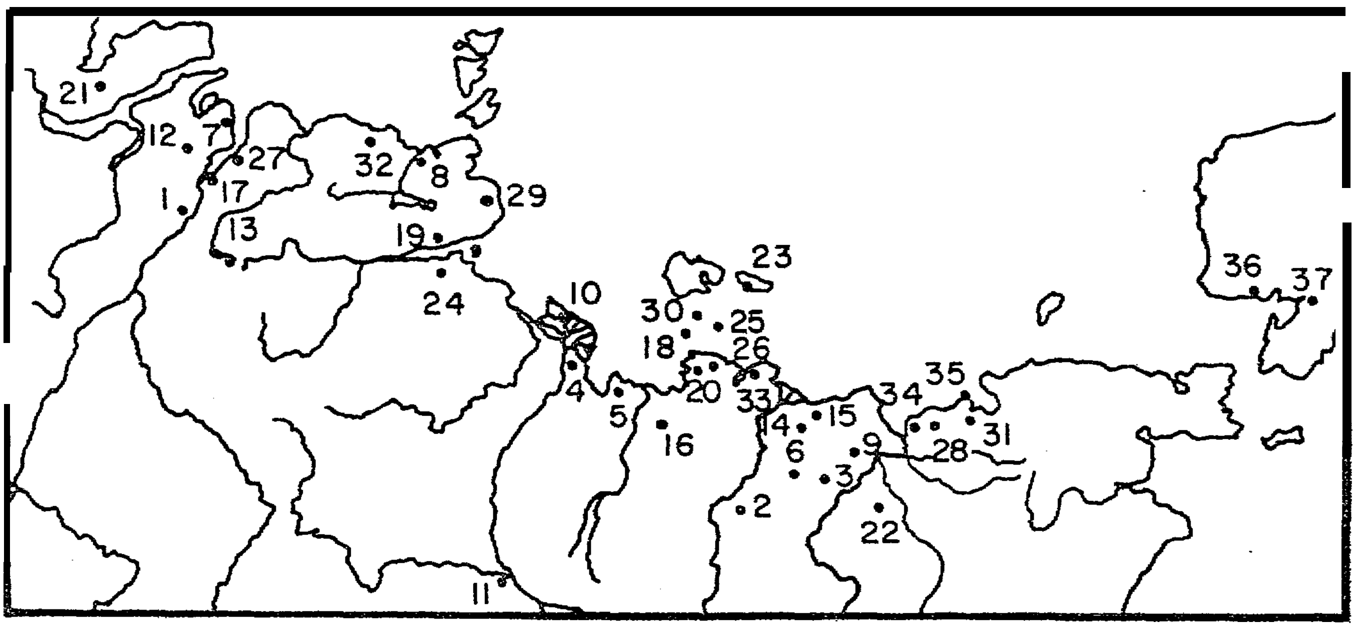


Fig. 3-1. Compilation of paleontological sites containing mammoth remains. The exact locality names are listed by number in Garrutt (1965).

"mammoth fauna" existed almost continuously from England, in the west, to the central Yukon Territory in Canada, in the east. The outer continental shelf does not appear to differ front other areas of slightly higher topographic relief to a degree significant enough to limit large mammal occupancy, nor, for that matter, "was it special enough in vegetational character which would, in turn, limit large mammal distribution. The difference in altitude between the Pribilof Islands to Fairbanks, Alaska (in the center of Alaska) is a mere 400 feet.

Distributional points of all the "mammoth fauna" except maybe wooly rhinos and camels are probably limited by more preservational and discoverability aspects than actual distribution. It is unknown why rhinos living in Siberia did not cross into Alaska, nor why camels living in Alaska did not cross into Siberia. It is unlikely, but it may be, that movement across the broad plains of the outer continental shelf required certain behavioral characteristics that these species did not have. The fact that rhinos did not get into far eastern Siberia may say something about the differences in climate of the eastern portion of the refugium, including eastern Siberia, Beringia and Alaska.

CHANGES IN LARGE MAMMAL COMMUNITY PROPORTIONS AND EXTINCTION PATTERNS: Given two propositions, (1) that the lives of early Paleolithic peoples centered around the distribution and kinds of large mammals, and (2) that this late Pleistocene community of large mammals underwent some drastic changes at or near the end of the Wisconsin glaciation, then one might suppose there were accompanying changes in human ecology as well. There were undoubtedly changes in the location of camp sites, hunting strategies, social structure and many other features which would affect the search for early man sites in the north.

There were two significant points about the chronological changes in the "mammoth fauna" that should be emphasized and these may, in fact, be related. The first is the change in the phylogenetic lines of species themselves; the second is an actual change in the community species composition. There are two major trends, one for each category. (1) As the Quarternary progressed, most northern species of large grazers and their carnivores became smaller in body size, sometimes depreciating by as much as 50%--something quite grossly noticeable. (2) At the end of the last glaciation, the large grazers began to become extinct with only a few remaining in relictual or very specialized habitats. In the fossil community these were replaced by browsers and their own predators, which were already in or near the north, but in limited habitats which existed during the Wisconsin. A more detailed discussion of these two major changes will be made under separate subheadings.

CHANGES IN SPECIES SIZE AND APPEARANCE THROUGH TIME AND ITS MEANING:

The exploitation of large mammal resources will depend, to some extent, on the nature of the resource itself. From a growing body of evidence (reviewed by Guthrie and Matthews, 1971), it appears that the development of the northern steppe and its faunas climaxed during the (Illinoian-Wisconsin or Riss-Wurm) last two glacial maxima. However, earlier Pleistocene floras and faunas contain nascent elements of this steppe assemblage. If we are to reconstruct human habitation potential in the New World Arctic, some review of these changes will be necessary.

The distinctive elements of the early Pleistocene faunas in Siberia, that is to say, the faunas through the Gunz or Kansan age, are easily identifiable. They consist of a simple-toothed mammoth, *Mammuthus trogontheri*, a large, robust horse, *Equus stenonius*, a moderately large, horned bison, Bison *schotensacki*, and a large, more primitive-toothed rhinoceros, Rhinoceros (Dicerorhinus) *mecki*. Many other faunal elements are present, but these are the most diagnostic and are the lines which later change so drastically to become index species for Pleistocene stratigraphers.

Entering into the Riss-Illinoian glaciation, the Arctic takes on its full steppe character and the species which are to persist until the late Wisconsin appear. They are *Mammuthus primagenius, Dicerorhinus antiquiatis,* Bison *priscus, Equus* sps., *Saiga tatanica*, and *Ovibos moschatus* and others. These differ from late Wisconsin faunas only by slight degrees. One of the major differences is in tooth complexity, and body and horn size.

The tooth complexity differences are undoubtedly a response to the newly expanded Arctic grassland habitat (Guthrie, 1968a, 1968b). Other evidence for this from rodents' change will be discussed later. The Siberian paleontologists (*eg.*, Garutt, 1965, 1966; Gromova, 1949; Popov, 1959) categorize the Paleolithic faunas into three main categories: early, transitional, and late forms.

<u>EARLY FORMS ASSOCIATED IN EUROPE WITH AURIGNACOID LITHIC TRADITIONS:</u>

A fairly primitive wooly mammoth of the *Archidiskodon* type with tooth ridges of the last molar ranging between 7 - 9 in <u>plate frequency</u> and an enamel thickness of 0.15 - 0.20 cm was present during this time as well as a quite long horned bison, sometimes referred to as Bison *priscus longicornis*. The horses were quite large, but declining in size. They were similar to the European *Equus stenonis-sussbornensis* types. The exact phylogeny of Pleistocene horses in the Arctic is somewhat controversial. This horse species is referred to as *Plesippus* verse by some Siberian authors. It is large with a moderately simple protocone. Other species include early moose (*Alces latifrons*), early musk oxen (*Praeovibos beringiensis*) , giant beaver (*Trogontherium* sp.) , and early forms of lion (*Felis speloea*), early rhinos (*Coelodonta* sp.) and the early, unusual ungulate *Soergalia* sp.

<u>TRANSITIONAL FORMS SOMETIMES ASSOCIATED IN EUROPE WITH SOLUTREAN TRADITIONS:</u>

These are between the early and late forms in degree of morphological change. Bison, horse, and mammoth phylogenetic gradients are discussed later in this section. Bones of the early *Ovibos, Rangifer, Ovis* and *Equus caballus* become common during this time.

<u>THE LATE FORMS ASSOCIATED IN EUROPE WITH MAGDALENIAN TRADITIONS:</u>

These include a smaller mammoth with quite complex teeth. Plate frequency is usually between 9 - 11 and enamel thickness is 0.10 - 0.15. The bison may have reduced only slightly in size, but considerably in horn dimension. This species is often referred to as *Bison priscus deminutus.* The horses are quite small, just over a meter at the shoulder.

Their species designation has been difficult to make and there may, in fact, be at least two sympatric species, although on ecological grounds it would seem unlikely. In sum, the major "trend was one of size reduction (Fig. 3-2).

In addition to the species mentioned as part of the "mammoth fauna", were wolves (*Canis*), Arctic foxes (*Alopex*), common foxes (*Vulpes*), wolverine (*Gulo*), weasels (*Mustela*), saiga antelope (*Saiga*), ground squirrels (*Citellus*), camels (*Camelops*), yaks (*Bos*), large bears (*Arctodus*), and other species depending on spatial or chronological setting.

The small Arvicoline rodents were also adapting to this newly expanded steppe environment. The major aspect of the change was increasing dental complexity which allowed a more efficient processing of the silicious sedges and grasses. The continuum of these changes for one genus, *Dicrostonyx,* of lemming are shown in Fig. 3-3. Other phylogenetic lines exhibit similar changes in a less drastic fashion.

In addition to telling a story of the changing vegetation and climate of the Arctic, these species of mice and lemmings also show rather closely the chronology of archeological sites, and are depended upon to a great extent by Eurasian zooarcheologists. Fossil small mammals are particularly valuable in sites which are out of the range of carbon dating or are lying in such a position that no physical geology (a terrace of similar age) may be used. This is likely to be the case on the knolls, ridges, and river courses of the now submerged outer

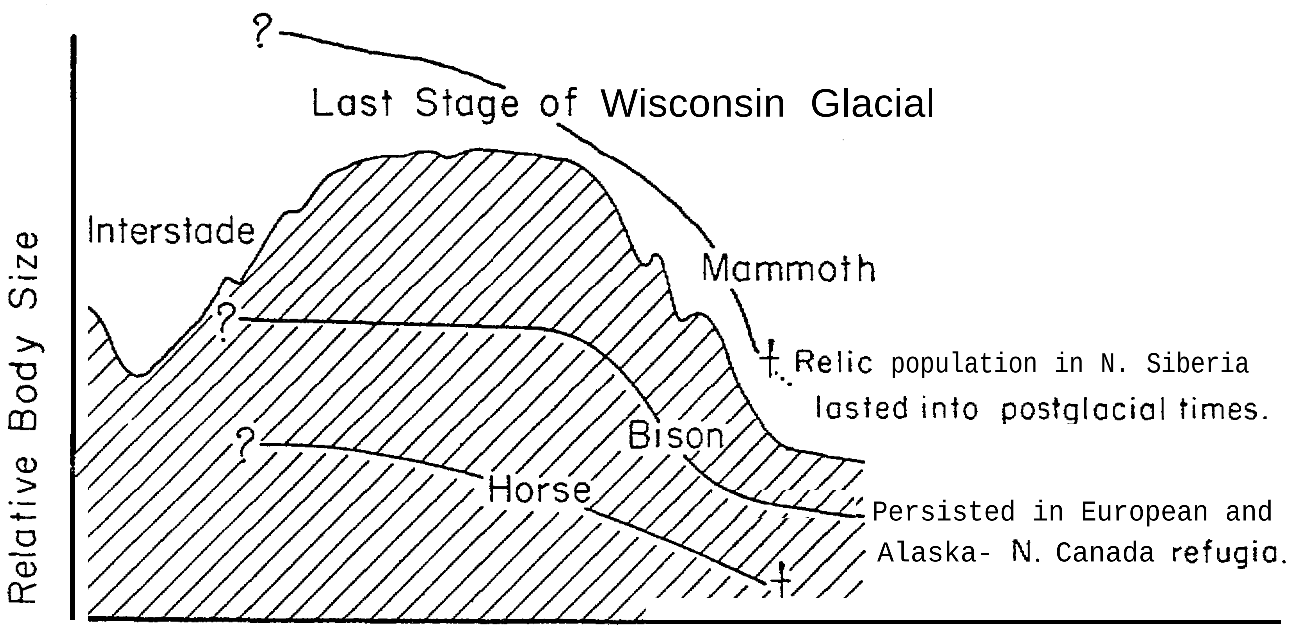


Fig. 3-2. The major trend among the three chief species of the "mammoth fauna" was a redaction in body size

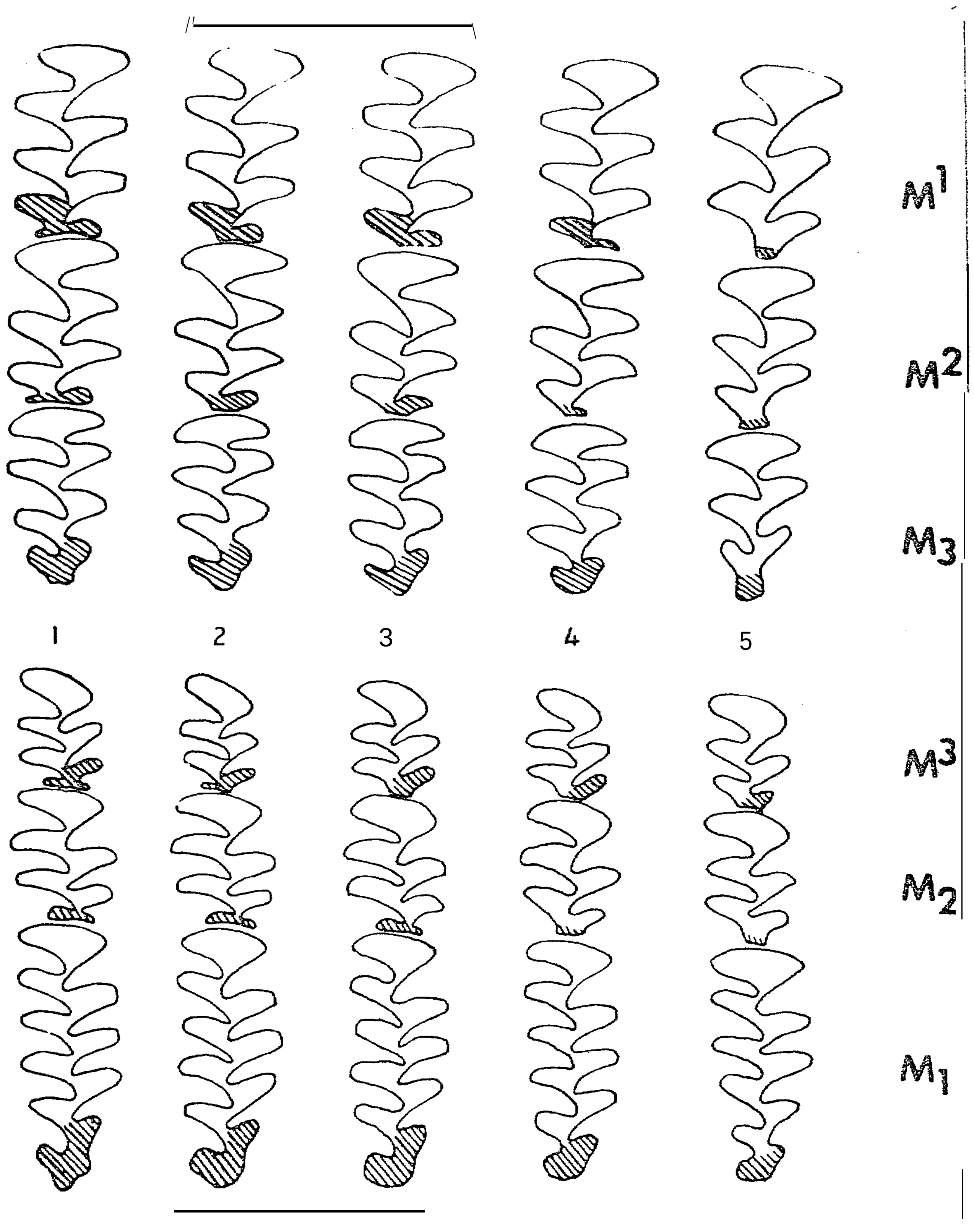


Fig. 3-3. Generalized molar patterns of *Predicrostonyx hopkinsi* and species of *Dicrostonyx*. 1 = *D. torquatus;* 2 = D. *henseli;* 3 = D. *hudsonius;* 4 = *D. simplicior;* and 5 *D.* hw~~nsi-

continental shelf--or, for that matter, throughout much of the present Arctic.

These tundra-steppe faunal elements did not all "become extinct at the end of the last glaciation, but continued to change physically by decreasing in size. The mammoth persisted in relict populations in far eastern Siberia (Vangenheim, 1961) , finally reduced to pygmean proportions. The exact terminal date of their extinction is unknown. Likewise, horses also perished quite late, but apparently became extinct before mammoth and bison. Bison, in fact, did not become extinct, but graded into modern bison through the transition from *Bison priscus longicornus* → *Bison priscus deminutus* → *Bison occidentalis* → *Bison* bison *athanascae* → *Bison* bison bison (Guthrie, 1970). This line of bison persisted in Alaska until historic times (Guthrie, unpublished data) Fig. 3-4 lists new radiocarbon dates run in an attempt to narrow extinction dates.

Near the end of the Wisconsin, accompanying the reduction of the steppeland environment, the shrub lands began to predominate in the low flats and the more mesic tundra in the highlands, then finally, the trees recolonized much of the low-lying areas. Throughout this transition, the caribou and moose, which were subelements of the steppelands, began to predominate at the expense of the grazers. This shift in resource character was felt throughout the peoples of the holarctic and serves as the major hiatus separating Paleolithic from mesolithic traditions in the Old World, as well as paleoindian from archaic traditions in the New World. Hunting techniques probably changed seasonal movement patterns, and many other revolutionary shifts probably occurred in human ecology. The bovid, probicidian and equid resource changed to a basically cervid-based resource. Although the exact chronology of these

	SAMPLE NUMBER	ELEMENT	SPECIES	LOCALITY	DATE B.P.
1	1-9420	metatarsal	horse	Fairbanks area	< 205*
2	1-9271	metatarsal	horse	Dominion Creek, Y.T.	16,270
3	I-9274	metatarsal	horse	Ikpikpuk River	20,810
4	I-9275	metatarsal	horse	Ikpikpuk River	32,270
5	1-9316	metatarsal	horse	Dominion Creek, Y.T.	14,990
6	1-9317	metatarsal	horse	Ikpikpuk River	30,200
7	I-9318	metatarsal	horse	Ikpikpuk River	23,910
8	1-9319	metatarsal	horse	Ikpikpuk River	<40,000
9	1-9320	metatarsal	horse	Ikpikpuk River	<40,000
10	1-9321	metatarsal	horse	Ikpikpuk River	23,920
11	1-9421	metacarpal	horse	Fairbanks area	195 *
12	I-9322	metacarpal	horse	Birch Creek	24,070
13	------	metacarpal	horse	------sample undatable@-	--------
14	1-9371	metacarpal	horse	Ikpikpuk River	19,250
15	I-9372	metatarsal	mountain sheep	Eva Creek	< 35,000
16	I-9373	tooth	mammoth	Ikpikpuk River	< 35,500
17	I-9422	mandible	horse	----	13,640
18	-------------------------sample uneatable @ -----------------				--------
19	I-9277	horn sheath	bison	near Anchorage	180
20	I-9273	horn sheath	bison	Tanana Bluffs	37,000

Fig. 3-4. Radiocarbon dates for Pleistocene fauna.
* . contaminated with varnish
@ = insufficient carbon

changes is not clear in Alaska because of the lack of archeological sites containing vertebrate material from the critical transitional periods; we do know the approximate dates so that sites with varying faunal midden assemblages can be located chronologically.

There are insufficient dates on mammoth and horse specimens to gain dependable information on the exact time of extinction. In southern Siberia the mammoth apparently became extinct earlier than the rhino, bison, or horse (Klein, 1973). Preliminary data from Alaska suggests the same pattern. (See Péwé (1975) for the most recent review of Alaskan radiocarbon dates.) The youngest dates for mammoth are 15,380 ± 300 (S 1453) and 17,695 ± 445 (S 1851). All the rest are older than 20,000 years B.P. Several dated younger than this have been found for both bison and horse (Guthrie, unpublished data). There are virtually no radiocarbon dates on horses in the far north, although several have been submitted (See Fig. 3-4 for new dates).

MAMMAL CONCENTRATION AREAS IN RELATION TO PALEOTOPOGRAPHY:

Large mammals do not exploit the landscape in a random fashion. Various areas are used differentially from season to season. Several factors control these uses: (1) plant quality as a result of vegetation type, (2) plant quality resulting from growth stage of the vegetation, (3) these two are often casually connected to the aspect of the terrain and the direction of the slope, (4) for some species, cover or escape terrain are of major importance, (5) also, the access to forage because of snow depth variations is a major limiting factor among present species, (6) forage condition is another key factor--areas which are browsed heavily on summer and autumn range are unlikely to serve as winter range,

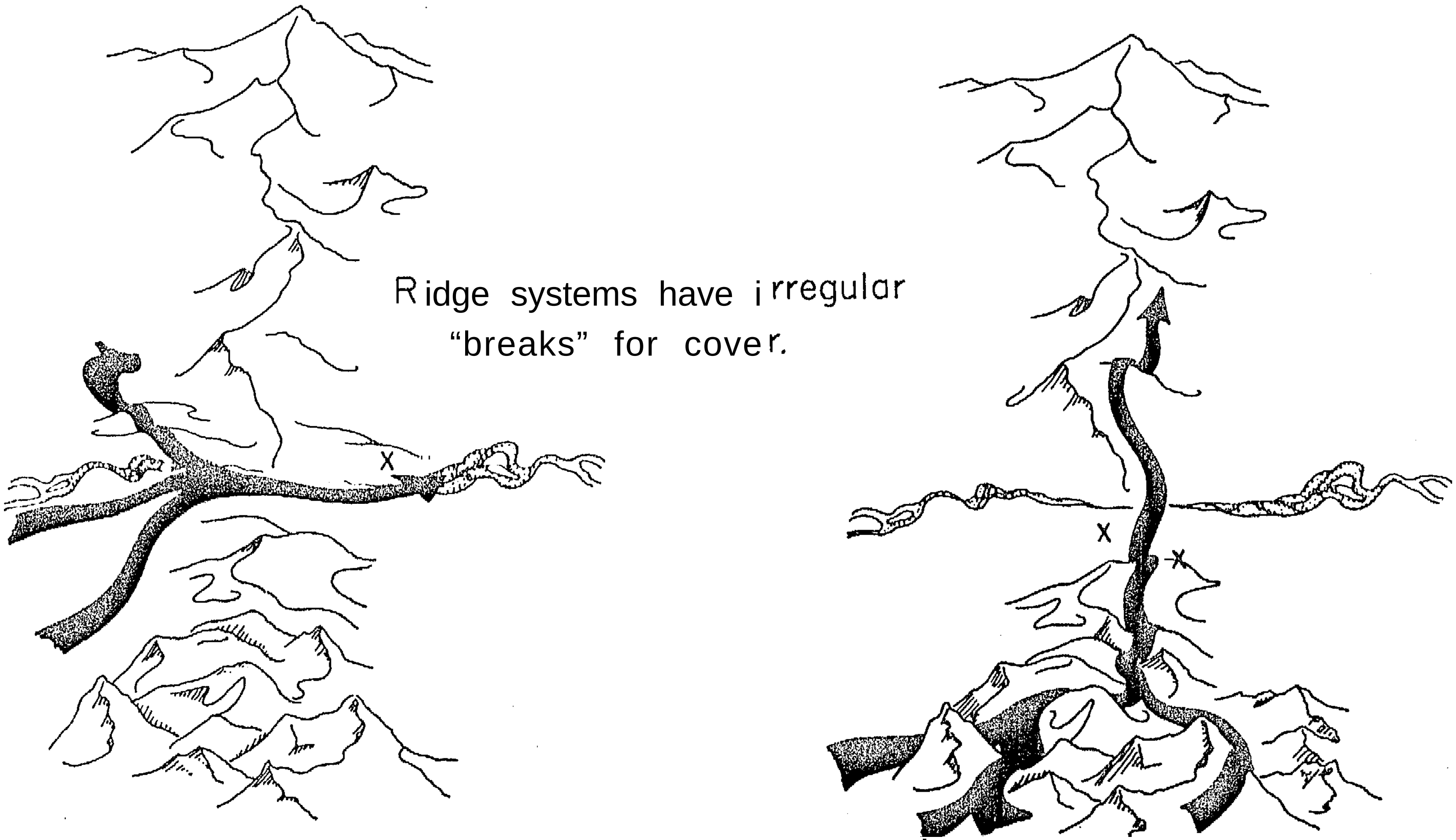
(7) the presence of insect pests plays some importance as does temperature in the form of inversion levels from valley floor to ridge top (which, in the north today, can vary 500), (8) wind is also a factor which can, at higher velocities, affect mammal range shift, and finally, (9) substrate form can also affect range use. Slopes too steep to climb and exploit and lowlands which are too boggy sometimes affect preferred areas.

For this study, there are several important considerations as to likely terrain:

1. Irregular, rolling terrain tends to provide a longer succession of richer plant growth stages than do the flat lowlands. This is particularly true of the south-facing slopes.
2. High country adjacent to catabatic wind activity reduces winter snow cover, allowing access to winter range. If it becomes traditional winter range, it is unlikely to receive intensive use as summer range.
3. Areas in which mountain ranges interfinger with other ranges usually concentrate large mammal movement from one system to the other, either to (a) use the high quality alpine vegetation, or (b) to exploit the more snow-free winter range (Fig. 3-5) .
4. Over long distance migration, the same is true, but for opposite reasons. Shorter distances or lower relief routes are used more often than others. This often means a movement through major "pass" systems or major gaps between mountain systems (Fig. 3-5) .
5. Because of its better footing and lack of relief, river valleys are frequent movement avenues for large mammals, both ungulates and

Fig. 3-5.

Bottleneck Prominences between Mountain Range Connections & Passes



Lowland habitat channels large mammal movement

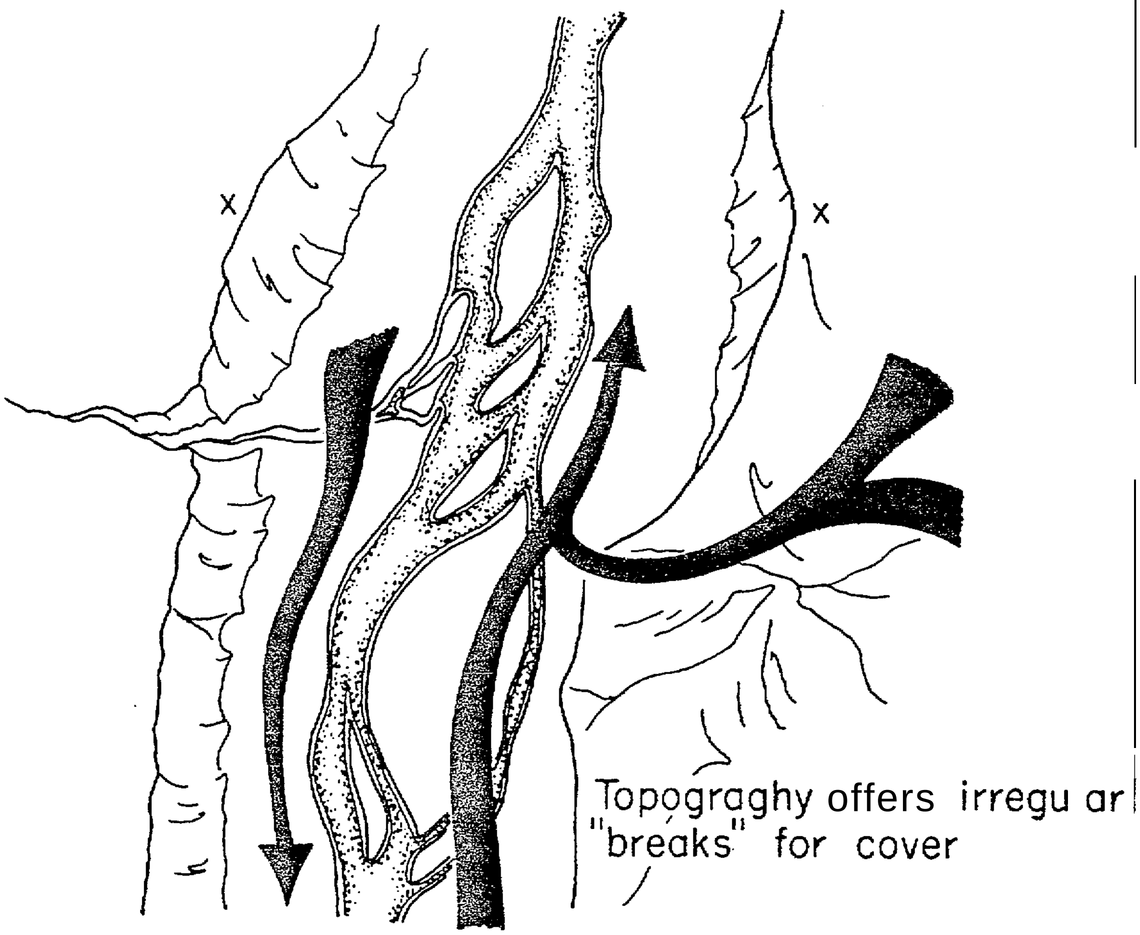
Upland habitat channels large mammal movement their predators. A wide river valley traveling over some distance, in either broken or open country, is a great concentration of large mammal movement, frequently on a seasonal basis. These are particularly conducive to mammal movement if the valleys are more deeply cut and the river is seasonally flushed, leaving a wide, gravel-barred valley with braided streams. And further, if the valley is deeply cut with large, prominent terraces, it is especially inviting to the location of human hunting camps (Fig. 3-6).

The bathymetric maps of the outer continental shelf (Figs. 3-8 thru 3-12) provide information as to the likely places one might find seasonal concentrations or migration paths. Even considering the destructive processes of inundation and the marine sediments changing the landscape, these older contours still must have some relationship to current bottom topography.

In the discussion and maps of terrestrial mammal resource concentration, however, several things must be kept in mind. There has been scouring of terrestrial sediments by marine currents, a layering of marine sediments over the terrestrial ones (Fig. 3-7) and, probably most important of all, a highly destructive process of beach migration inland as the continental shelf was reflooded at the end of the Wisconsin glaciation. This may have destroyed or redistributed many terrestrial deposits.

With this overall view, then, one can delineate several

Prom nences on River Terraces



Rive s are arterial highways for
arge mamma s.

Fig. 3-6.

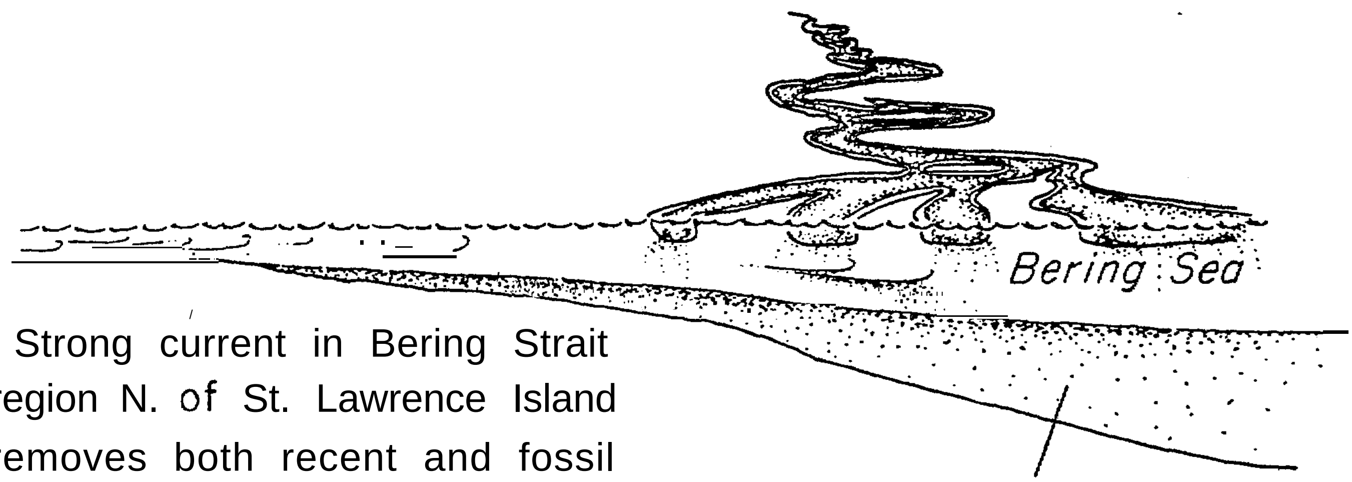

Yukon River dumps sediment onto southwestern portion of submerged shelf.
Bering Sea
Strong current in Bering Strait region N. of St. Lawrence Island removes both recent and fossil bottom sediments.
Potential terrestrial paleontological and archeological sites buried under thick marine sedimentary mantle.

Fig. 3-7.

important regions:

1. Spring ranges. After getting through the long Arctic winter on low-quality vegetation, ungulates are quick to establish traditional grazing areas where the topographic relief or some other feature produces the first growth of green plants in the springtime. These are known to be the lower portions of broadly south-facing slopes, which enhance the radiation level of the low sun angle (only around 35°, even during late spring in the far north). This new growth is exceptionally rich in protein, needed for the late-developing embryos and the lactating females, which fall into a negative nutritional balance throughout the winter.

In addition, spring was the rutting or musth season for many of the tundra-steppe ungulates. The ungulates which live in the north today have all summer to build their resources for the energetically expensive rut. Moose and caribou rut during October and sheep in late November and December. Equids, however, have an 11 - 12 month gestation period, which means that in order to have the parturitium time correspond with the early spring growth, rut would also occur in early spring. Likewise, the living proboscidians have gestation periods of around 22 months. So, mammoths also would have had their musth in the early spring. Bison rut in mid-summer, also requiring early nutritional resources. Among those non-territorial, social, nomadic ungulate species, there would, in all probability, have been violent rut battles, not only expensive to males, but also to females being herded and tended by the dominant males.

Because of the demands of the rut and the severe nutritional debts encountered during the winter, these species would have sought the earliest green growth on south-facing slopes, concentrating probably on the "banks" of what are now the Pribilofs, St. Matthew, St. Lawrence and Nunivak Islands.

2. Because river valleys are usually more open avenues of large mammal travel, these are also prime locations of large mammal concentration. Had the strong current and wave action of platform reflooding and subsequent sedimentary manteling not been so major, the river valleys would be even more prime sites for finding large mammal movement centers. Many of the old river channels are undoubtedly smoothed from their original relief. There are some deeper channels remaining in the Bristol Bay area and near Nunivak Island.

3. Lake shores do not usually concentrate large mammals unless they are on the route between important seasonal ranges. However, there is evidence that paleoindians did favor lake shores to some extent. For example, both Irving (1967), in the upper Old Crow River basin, Yukon Territories, and West (1974} in the Tangle Lakes region south of the Alaska Range in central Alaska have found important indications of lake margin use. As we know little of the breadth of early human economy in the Beringian area, it is possible that there were seasonally abundant resources available other than large mammals--fish, waterfowl, etc.--which may have attracted early hunters. Lakes are thus given a probability value slightly higher than the flat plains of the outer continental shelf.

4. Winter range, unlike summer range, is more difficult to pinpoint

precisely. Among modern species, it usually corresponds to areas (a) which are exposed, almost snow-free, or else protected from snow packing, and (b) areas which are not grazed much dining the summer, leaving standing dead and winter-green plant bases for winter reserves.

In the far north, autumn peak protein levels are found on north-facing slopes where plants in their early growth stages occur latest. While in these broadly north-facing areas, species tend to concentrate in windswept local areas for their main winter resources. However, among caribou and moose there is often a movement into woodland areas, where the lack of wind allows easy locomotion for moose, using supernivian twigs, and ease of cratering for caribou, using the subnivian lichen for winter maintenance. It is likely that neither of these strategies were used by the major steppe ungulates. Bison and horses in the north are known to concentrate where wind exposes vegetation.

The only obvious area for winter range during the glaciation was the potential north side of the Alaska Peninsula. It was a large valley with gradual north and south-facing slopes bordering the trough lying to the north of the peninsula. This broad valley may have supported substantial year-round populations as well. Unfortunately, the northernmost extent of the Alaska Peninsula glaciers is not well known. Also, this area may have produced an extremely heavy snowfall.

5. The area between the Seward Peninsula and the easternmost extension

of the Soviet Union, called the Bering Strait, may have been an important focus of large mammal movement. Animals changing ranges between uplands probably crossed this area seasonally as might have migrations from the Chukchi platform to the Bering platform. It is probably the most strategic site in which to catch the funneling of large mammal migrations. Unfortunately, it has experienced extensive scouring from the ocean currents.

RELEVANT ARCHEOLOGICAL RECORD OF LARGE MAMMAL RESOURCE USE IN THE FAR NORTH: A review of the literature of stratified camp sites containing middens shows that few have thus far been found in the far north of Asia and North America. Most of our knowledge of Paleoindian-Paleolithic hunting economies comes from farther south. Although the faunas were much the same (the steppe ungulates and their predators often, even to the species level), our knowledge of hunting in the north is somewhat inferential. Mammoth has been found in a site on the Ushki Peninsula and several sites in Central Siberia in the Lena drainage have produced extinct steppe faunas. In Alaska, only Trail Creek Caves on the Seward Peninsula and the Dry Creek site, a partially excavated site near Healy, Alaska, have produced Pleistocene large mammal bones *in situ.* These were predominantly bison and horse, two of the key elements of the “mammoth fauna”.

The best record comes from southern Siberia and Central Europe. Both illustrate considerable heterogeniety in species use and abundance (see Butzer, 1971, for a review].

Even during the early and mid-Paleolithic, the steppe fauna was represented in varying percentages. If any could be typical., the thoroughly excavated Lebenstedt site in northern Germany might serve as an example (Tode, 1954). It contained:

Wooly mammoth	14%
Bison	5%
Horse	5%
Wooly rhino	2%
Reindeer	72%

Upper Paleolithic northern European sites are diverse in faunal composition, but usually vary in percentages of the main steppe species. Some, like the famous Solutre in the Rhine Valley, are predominantly horse, while others show mainly reindeer or mammoth or a broad spectrum of prey species. Butzer (1971) has proposed a regional specialization specificity--reindeer in western Europe, mammoth in eastern-central Europe, reindeer and horse in Central Russia and bison in the southern Ukraine.

The sites of Molodora and Nezin Ukraine are especially rich in large mammal fossils. Klein (1973) contends that mammoth remains are the "hallmark" of early man sites in the northern Ukraine. Very few of these sites in Eurasia are "kill" sites. Judging from repeated analyses of the age structure of the prey assemblage, it appears that virtually all analysed camp sites were winter camps (Soergel, 1922; Butzer, 1971). Whether they were only seasonally occupied or the inhabitants lived on winter stores throughout the summer still remains a question.

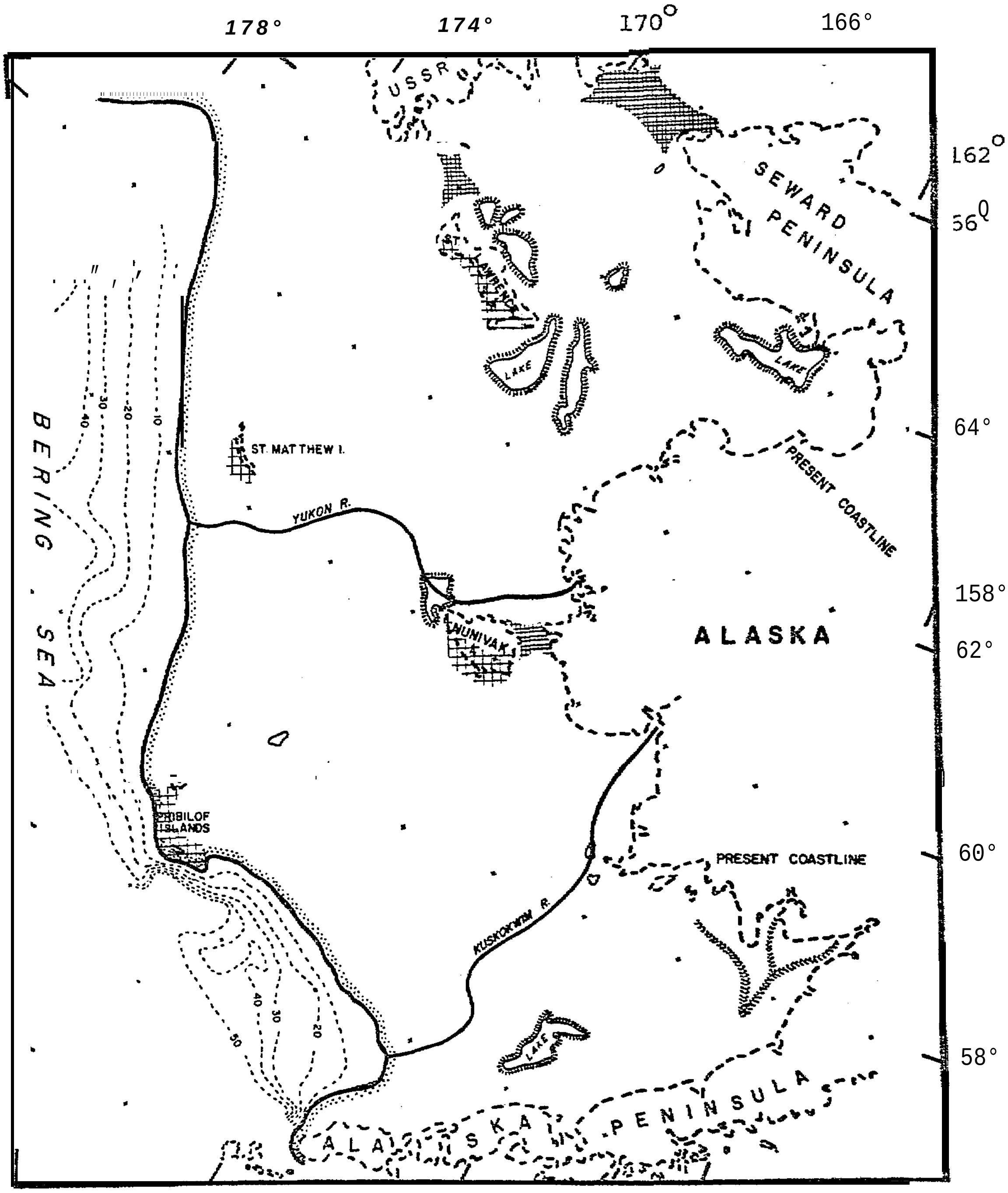


Fig. 3-8. Terrestrial mammal concentration zones, Bering Sea, Stillstand I, 22,000 B.P.

south slope areas, probably spring, early summer range concentration for grazing mammals

Probable migratory routes between areas of heterogeneous topographic relief

Probable lake and river margins providing access to summer aquatic resources and funneling large mammal movements along river valleys

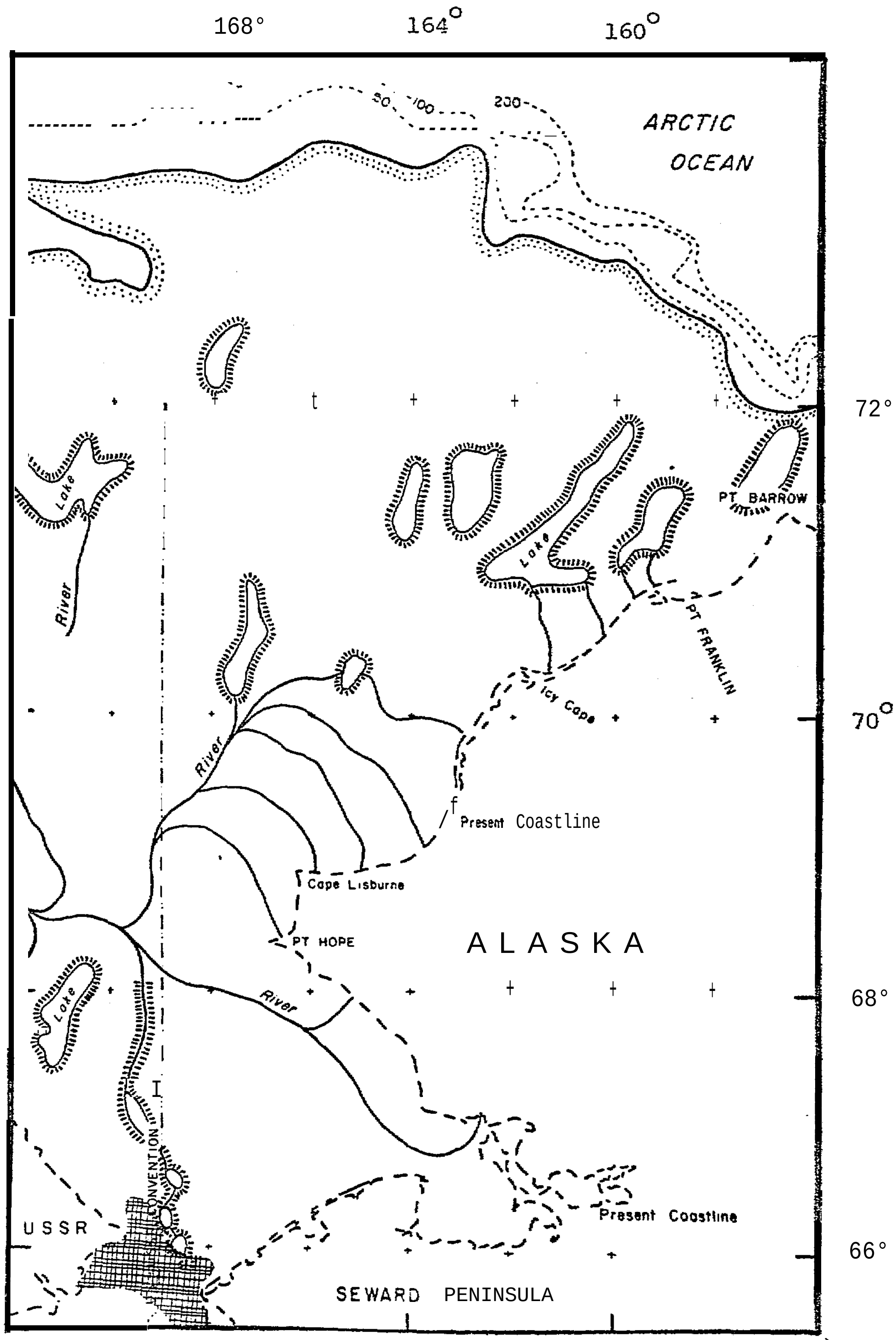


Fig. 3-9. Terrestrial mammal concentration zones, Chukchi Sea, Stillstand I, 22,000 B.P.

Probably migratory route between areas of heterogenous topographic relief

Probable lake and river margins providing access to summer aquatic resources and funneling large mammal movements along river valleys

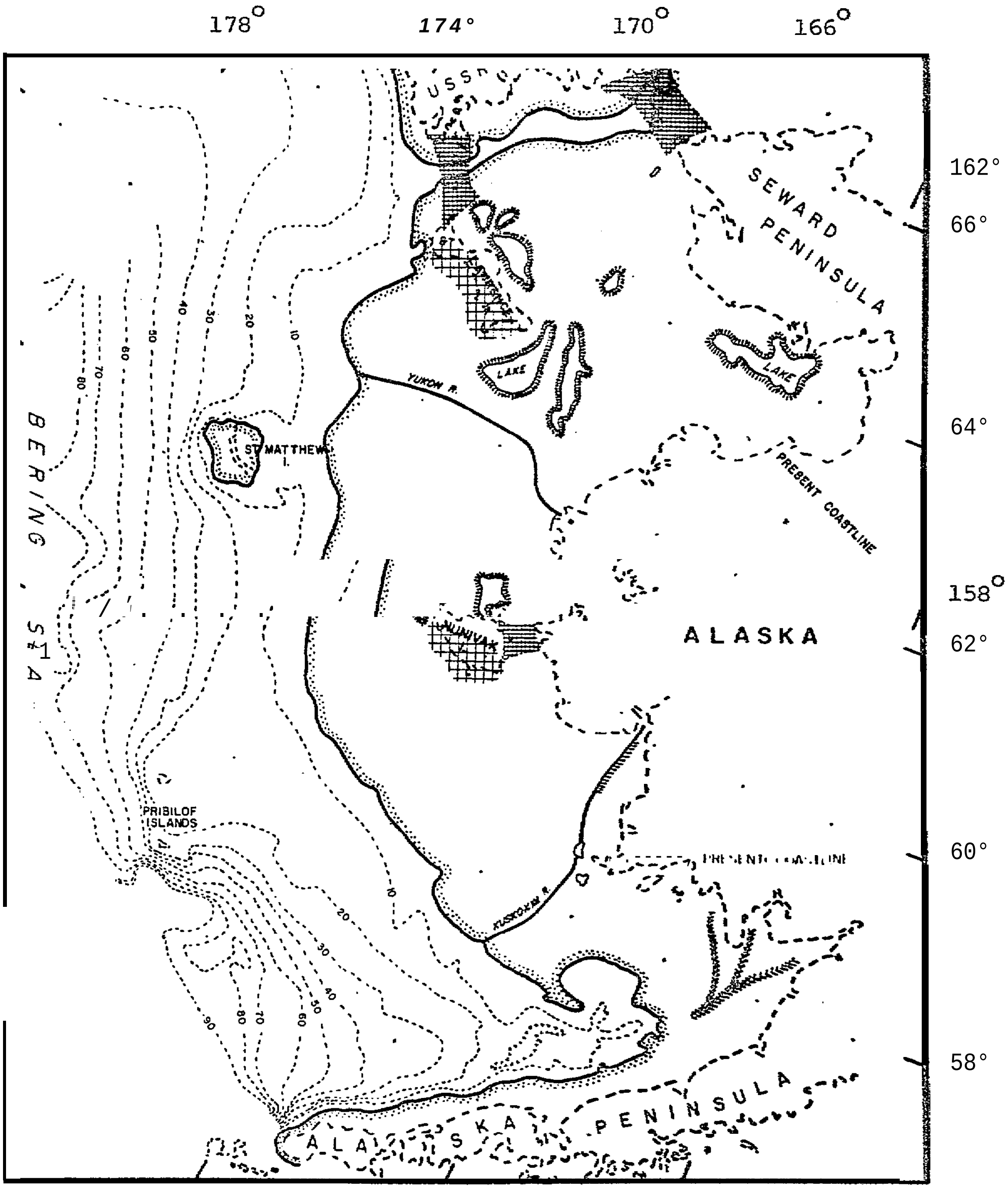


Fig. 3-10. Terrestrial mammal concentration zones, Bering Sea, Stillstand 11, 16,000 B.P.

South slope areas, probable spring-early summer range concentrations for grazing mammals

Probable lake and river margins providing access to summer aquatic resources and funneling large mammal movements along river valleys

Probable migratory routes between areas of heterogenous topographic relief

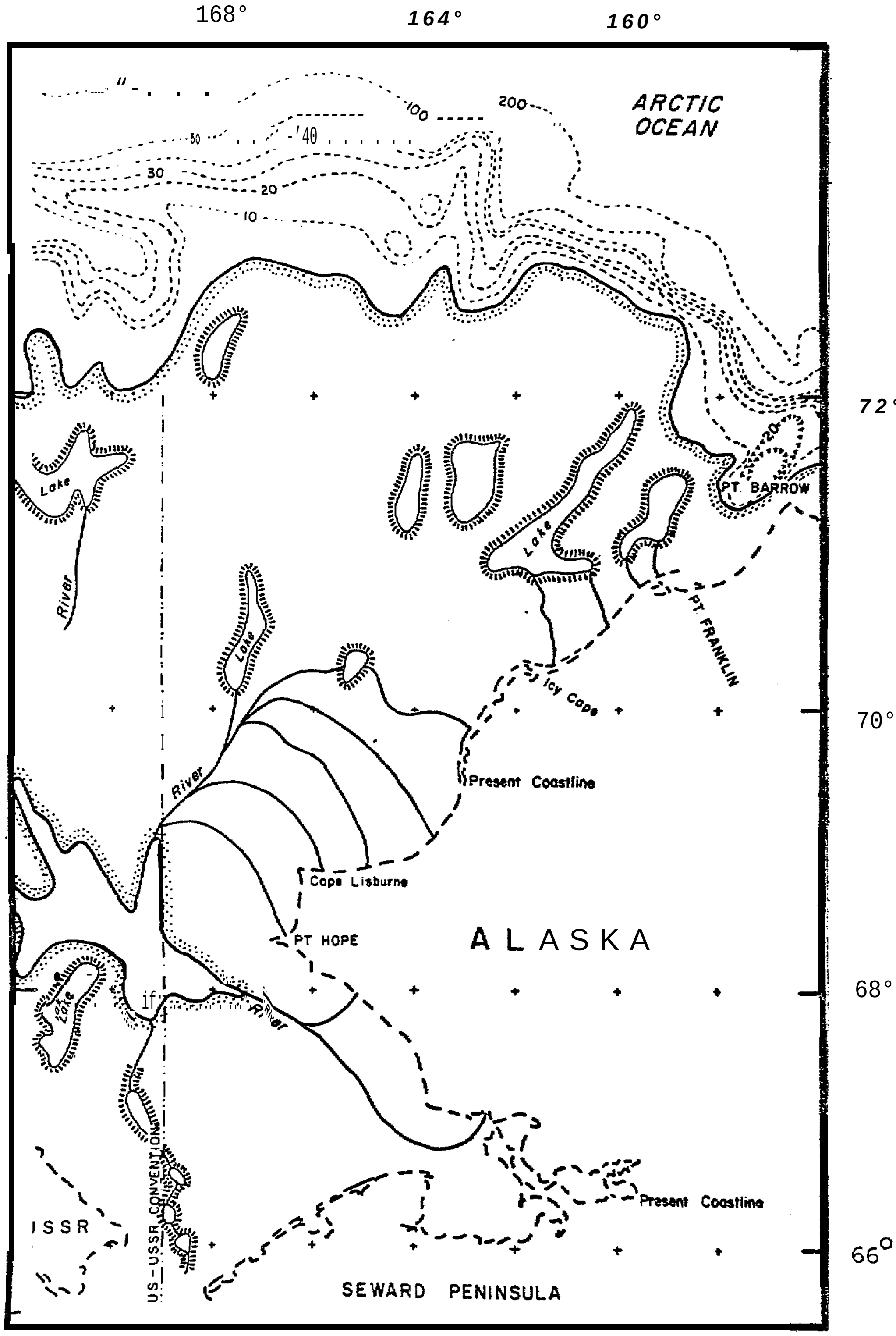


Fig. *3-11.* Terrestrial mammal concentration zones, Chukchi Sea, Stillstand II, 16,000 B.P.

 Probable lake and river margins providing access to summer aquatic resources and funneling large mammal movements along river valleys

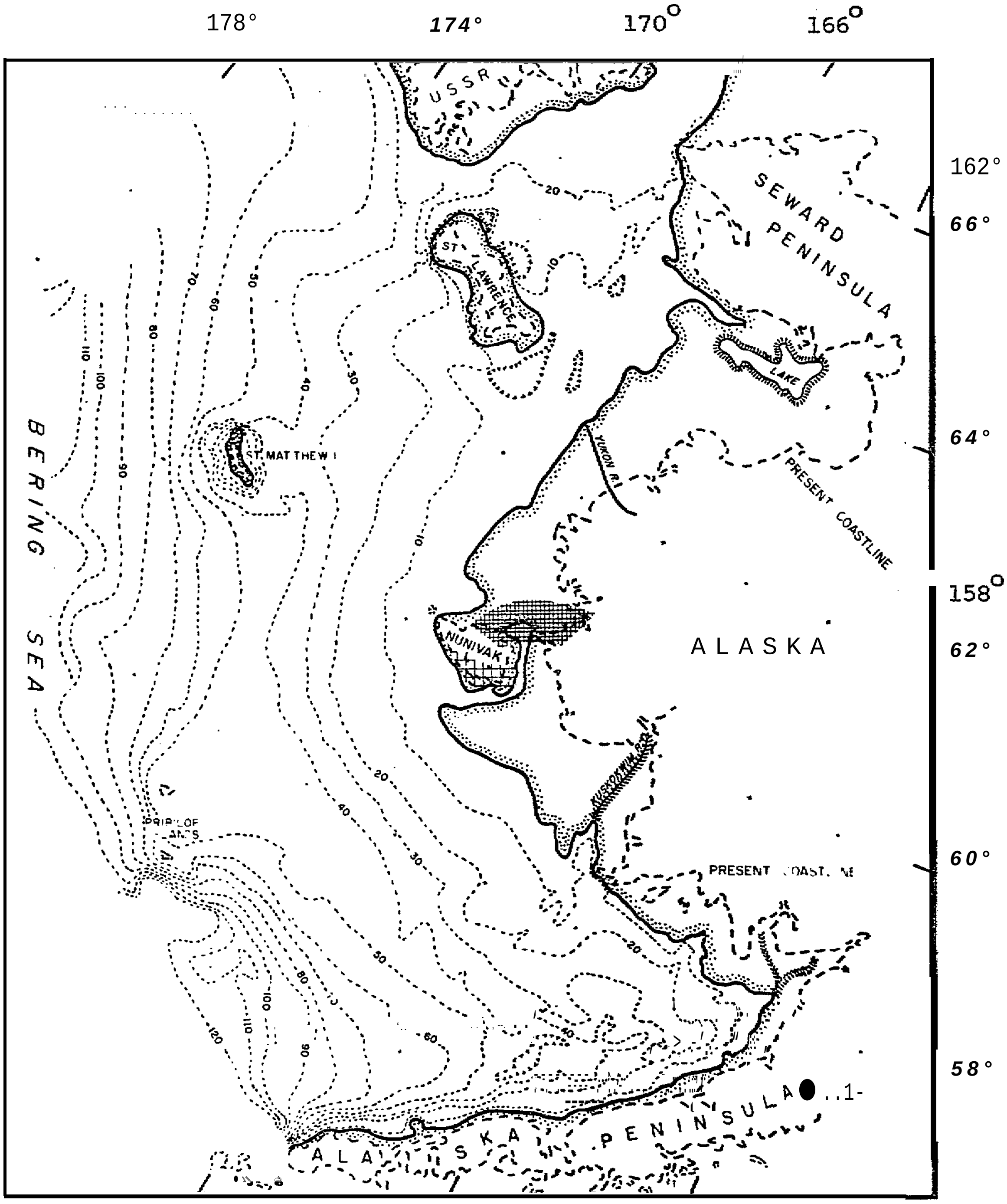


Fig. 3-12. Terrestrial mammal concentration zones, Bering Sea, Stillstand 111, 11,000 B.P.

South slope areas, probable spring-early summer range concentration for grazing mamma 1s

Probable migratory routes between areas of hetero-genous topographic relief

Probable lake and river marging pro-viding access to summer aquatic resources and funneling large mammal movements along river valleys

A SYNTHESIS OF CIRCUM-BERINGIAN PREHISTORY AND DELINEATION OF REGIONS OF HIGH ARCHEOLOGICAL SITE POTENTIAL

E. James Dixon, Jr.

The provocative concept of a land connection between North America and Asia has long captured the minds of Western scholars and explorers. (For a summary of the history of the "Beringian problem" in Western thought, see Hopkins, 1967b:1-6). However, it was not until 1937 that N.C. Nelson presented the first concrete archeological evidence demonstrating a strong technological similarity between artifacts of Mongolian origin and those from the Alaska Interior. Although Nelson did not attempt to ascribe an age to the specimens he was describing, it became apparent to most observers that the blade and core industry he was comparing demonstrated considerable antiquity.

During the nearly forty years which have followed Nelson's initial comparison, numerous hypotheses have been advanced. They have focused not only on the technological similarities between artifacts of Asian and Arctic North American origin, but also on the population of the New World from Asia via Alaska. However, most of these hypotheses are based on poorly dated archeological complexes and rely basically on typological comparisons between Alaska and the Old World. It has only been within approximately the last ten years that several significant archeological sites, dating to early Holocene or late Pleistocene times, have been reported in the arctic region of North America. These few sites have been subjected to absolute dating techniques and, for the first time, it is possible to gain an initial understanding of late Pleistocene-early Holocene prehistory in Arctic North America.

Although Pleistocene antiquity has been ascribed to numerous archeological sites in Arctic North America, surprisingly few have been verified through radiocarbon or geomorphic dating. In the interest of brevity, this presentation will deal only briefly with archeological complexes which investigators have "felt" represent Pleistocene occupations of Arctic North America, but which have not been subjected to absolute or relative dating techniques. The great majority of data presented will be from sites which have been subjected to comparatively sound dating methods.

MacNeish (1956) postulated an early archeological complex, which he called the British Mountain Complex. Since that time, geomorphological studies at the type site, known as the Engigstciak site, have demonstrated that stratigraphy at the site is unreliable as a relative dating technique due to solifluction. Most archeological scholars no longer believe that the British Mountain Complex exists. Campbell (1961) also theorized an early date for the Kogruk Complex, located at Anaktuvuk Pass in Alaska's Brooks Range. Once again, claims of great antiquity are based on typological considerations and, as yet, artifacts typologically similar to the Kogruk specimens have not been found in a datable context. Neither the British Mountain Complex nor the Kogruk Complex have been dated by absolute or relative dating methods, however, Campbell (1961:14) suggests the Kogruk site is probably no older than 10,000 B.P., based on deglaciation of the site area. It is apparent that both researchers felt the collections were of late Pleistocene age based upon topological arguments. Both sites remain undated.

J. Louis Giddings assumed an early age for the archeologic al specimens he recovered from the Palisades at Cape Krusenstern, based on weathering of some of the specimens. He labelled this assemblage Palisades 1. It is now apparent that the Palisades I artifacts belong to the Palisades II Complex, which is typified by notched points and falls into the general time framework of the Northern Archaic Tradition, ca. 2,600 - 4,000 B.C. (Anderson, 1968)

Thus, the 1950's and very early 1960's may be viewed as an era during which topological considerations, or '*general crudity" of the artifact assemblages were seen as a primary means of dating Arctic assemblages. However, in the mid- and late 1960's and early 1970's, a number of archeological sites have come to light which lend themselves well to radiocarbon dating.

During the Wisconsin glaciation in North America, which occurred between approximately 70,000 and 10,000 years ago, a land connection between Asia and North America emerged in the regions presently occupied by the Bering and parts of the Chukchi Seas. This land connection, commonly referred to as the Bering Land Bridge or Beringia, was formed as a result of a global transfer of ocean waters into glacial ice during the Pleistocene. Although marine transgressions and regressions have occurred numerous times in the region of the Bering Strait, only the last major glacial period, the Wisconsin Glaciation, is generally considered to be of relevance to the human population of the New World.

The Wisconsin is divided into two major periods: the Early and Late Wisconsin. The Early Wisconsin regression occurred sometime after 70,000 B.P. and probably lasted until sometime after approximately 35,000 years ago. During this time period the Bering Land Bridge was exposed, thus permitting a free flow of flora and fauna between Siberia and Alaska. The Mid-Wisconsin transgression probably peaked at roughly 25,000 years ago and Beringia was once again flooded. The Late Wisconsin regression occurred sometime before 20,000 years ago and was terminated by very late Wisconsin flooding of the Bering Land Bridge, approximately 14,000 or 16,000 years ago (Hopkins, 1972; Sharma, this report). Fig. 2-1 depicts a reconstruction of Arctic North America and eastern Siberia during the maximum extent of Late Wisconsin glaciation, approximately 18,000 years ago.

Most scholars feel that early hunting populations dispersed across Asia and into Alaska via the Bering Land Bridge during periods of marine regression. Evidence that Beringia supported Pleistocene fauna is available in the form of Pleistocene faunal remains secured directly from the outer continental shelf off the Alaskan mainland. Weniaminoff (1840:196, cited in Jochelson, 1925:114) reports the discovery of a mammoth tusk on St. Paul Island in 1836. Brown (1891:499) refers to the discovery of a mammoth tusk and tooth from St. Paul and St. George Islands respectively. However, he provides a cautionary note that these specimens may have been transported to the islands by recent inhabitants. In addition, Stein (1830:383, cited in Jochelson, 1925:114) indicates that both mammoth tusks and teeth were found on Unalaska Island in 1801.

Simultaneous with the marine regression in the Beringia area, the continental North American ice sheets (the Cordilleran and Laurentide) expanded and merged east of the Rocky Mountains in Canada and the extreme northern United States, thus blocking the movement of flora and fauna between the Arctic and more temperate regions of North America. It may be possible that a lag in the advance of glacial ice was sufficient to first expose the Bering Land Bridge before the continental ice blocked access from the ice-free regions of Arctic North America to the more southern regions of the continent.

Müller-Beck (1966; 1967) has theorized that what he terms a "Mousteroid" tradition entered the New World via the Bering Land Bridge from Asia sometime between about 26,000 to 28,000 years ago. He assumes that man was able to enter the ice-free areas of Arctic North America prior to the Mid-Wisconsin transgression and thus populate the more southern regions of the continent during the retreat of continental ice during the Mid-Wisconsin transgression. He speculates that the later

Llano tradition evolved independently south of the coalescent Late Wisconsin continental ice and represents a late manifestation of the "Mousteroid" tradition. He continued to postulate that a later "Aurignacoid" tradition reached North America during very late Wisconsin times. Although the terms "Mousteroid" and "Aurignacoid" are of doubtful utility in describing New World archeological assemblages for they imply European origins or relationships, Müller-Beck has devised a conceptual framework which is of utility in viewing the population of the New World.

The Trail Creek Caves, located on Alaska's Seward Peninsula, have yielded the earliest evidence of Alaska's occupation by early hunters. Larsen (1968) indicates that the stratigraphy at the caves is difficult to follow, and subsequent chronological interpretations "should be taken with reservation". It appears that the lowest level of Cave 9 yielded several bison calcanei and a horse scapula. The pattern of breakage of the bison bones suggests that they were broken by man. The level from which the bison bones were recovered has been dated by radiocarbon at roughly 13,000 to 15,000 years B.P. (Larsen, 1968). Stratigraphically above these faunal remains and an associated calcedony point were found antler projectile points and microblades. The microblades were used as insets in the bevel-based antler points, which date between 8,000 and 10,000 years ago (Larsen, 1968).

The Anangula site is located at the tip of the Alaska Peninsula on Anangula Island. Tectonic uplift has created a unique situation in that having been uplifted at a rate greater than the post-Wisconsin sea level rise, the archeological site has not been inundated by the sea. A mean date for the Anangula site has been derived by averaging four of seven radiocarbon dates, with their mean falling at 8,160 years B.P. (Laughlin, 1967:434). The Anangula assemblage consists of burins, house or tent depressions, pointed tools on blades and ridge flakes, stone vessels, rubbing stones, the use of red ochre, and both pumice and scoriaceous lava abraders (Laughlin, 1967). The presence of fragments of whale bone associated with hearths and the geographic location of the site indicate an economy adapted to marine mammal hunting during this time period. Laughlin feels that the site represents the earliest manifestation of Bering Sea Mongoloid culture in Arctic North America.

The Akmak assemblage from the Onion Portage site located on the Kobuk River has been radiocarbon dated at 9,570 ± 150 B.P. The Akmak assemblage is composed of recognized type cores (campus type or wedge shaped cores), burins, burin span artifacts, large biface knife blades, large flake unifaces, core bifaces, backed microblades and utilized flakes (Anderson, 1970:59-60). This site commands a panoramic view and is, today, an ideal location for hunting caribou. Stratigraphically above the Akmak assemblage at Onion Portage is Band Eight for which an occupation period between 8,000 and 8,500 years B.P. has been established based on five radiocarbon dates. Band Eight consists of backed microblades, camPus type microcore, burins, notched flake artifacts, elongate side scrapers and utilized flakes. Anderson feels that the Band Eight artifacts and the Akmak assemblage may be lumped into what he terms the American Paleoarctic Tradition. He believes that the American Paleoarctic Tradition is related to artifacts from Trail Creek Caves, dating approximately 7,000 B.C. In addition, Anderson sees a relationship to the Denali Complex of the Alaskan Interior.

Stanford (personal communication) has recovered an archeological assemblage from the Kahraok site which demonstrates topological similarity to the Akmak collection, and is probably of the same age.

The Denali Complex has been defined by Frederick Hadleigh-West (1967). West considered the following artifact types as the definitive characteristics of the Denali Complex: bifacial biconvex knives, end scrapers, large blades and blade-like flakes, prepared microblade cores, core tablets, microblades, burins, burin spalls, worked flakes and retouched flakes. Although the Denali Complex has not been subject to radiocarbon dating, topological comparisons between it and some Siberian assemblages led West (1967:378) to speculate that the Denali Complex was between 8,000 to 13,000 B.C. West (1974:224) has revised this assessment and currently estimates the age for the Denali Complex between approximately 8,000 and 10,000 years B.P. Holmes (1974) reviewed the Denali Complex and divided it into two major phases: an early phase and a late phase. Holmes feels that the early phase of the Denali Complex may be encompassed by the Akmak Assemblage, the lower levels at Dry Creek and possibly typologically related finds in the Alaskan Interior. Continuity between the two phases is implied, but as yet undemonstrated (Holmes, 1974:23).

The Chindadn assemblage, recovered from the lowest level at the Healy Lake site in Central Alaska, is characterized by thin, tri-angular projectile points, tear-drop shaped knives or projectile points, blade-like flakes, burins, and possible microblades. Eight radiocarbon samples from the Chindadn assemblage have yielded dates ranging between

8,000 and 10,500 years old. The period of occupation may extend as far back as 11,000 years (Cook, 1972, personal communication). Cook postulates that the Chindadn (meaning "ancestor" in Athabascan) assemblage represents the earliest manifestation of Athabascan culture in North America.

Locality I at the Gallagher Flint Station (Dixon, 1975), located in the arctic foothills of Alaska's Brooks Range, has been radiocarbon dated at 10,540 * 150 B.P. Locality I is characterized by percussion flaked cores and blades, platform flakes, bifacially retouched artifacts, and waste flakes. Burins and bifacially chipped artifacts are apparently lacking. Due to poor preservation of organic materials, all evidence of bone or other perishable materials is absent. Dixon believes the Locality I assemblage demonstrates technological similarities to material recovered from the Anangula site.

Ackerman (1974) describes a small artifact assemblage from Ground Hog Bay in Southeastern Alaska, not too far from the city of Juneau. Component III, recovered from Level 4 at this site, produced two obsidian biface fragments, a scraper and a few flakes. Two radiocarbon samples from the site bracket the date of this occupational period between approximately 9,000 and 10,000 years B.P. The small sample recovered from this occupational horizon makes it extremely difficult to assess possible relationships with other Arctic sites.

At the newly discovered Dry Creek site, located near the town of Healy, Alaska, adjacent to Mt. McKinley National. Park, fossil evidence of horse and bison have been discovered in unquestionable association with a Late Wisconsin occupational horizon (Powers et al., 1974). A maximum date for the occupation of this site is still somewhat in question, but initial radiocarbon determinations and detailed stratigraphic work at the site indicate the earliest period of occupation at approximately 11,000 B.P. A stratigraphic level, which has been dated to 10,690 ± 250 B.P. (S1 1561} contains wedge-shaped microblade cores, microblades, elongate bifaces, burins and burin spans, and blade-like flakes (Holmes, 1974).

There exists only one tantalizing bit of archeological data from the period prior to 20,000 years ago in the North American Arctic. Irving (1967) and Irving and Harington (1973) have described three bone artifacts, two of which have been manufactured from mammoth bones and one from caribou bone. These specimens have been sacrificed in part for radiocarbon dating and the resultant dates range between 25,000 and 30,000 years B.P.

Irving's finds are from the Old Crow Basin in the Northwest Territories of Canada, which was ice-free during Wisconsin times. Many analogous artifacts exist in the University of Alaska Museum's collections, which have been manufactured from bones of extinct fauna; however, it is difficult to state whether these artifacts were manufactured at the time the animals died or by later occupants of the area. In addition, Von Koenigswald (1975, personal communication) has suggested that many of these artifacts are, in reality, pseudo-artifacts and result from chewing on the bones by predators and ruminants. Some examples of these specimens are illustrated in Fig. 4-1.

The major source of contention regarding Irving's data is whether the artifacts were manufactured on fresh bone shortly after the death of the animal or whether they represent the later handiwork of more contemporary inhabitants of the Old Crow region. Especially questionable is the serrated edged flesher of caribou bone, dated ca. 27,000 years ago (GX-1640). This tool greatly resembles contemporary fleshers as used in Interior Alaska and northwestern Canada; modern examples are manufactured from metal files, trap springs, etc. Because these specimens have not been recovered *in situ*, their antiquity will remain in question.

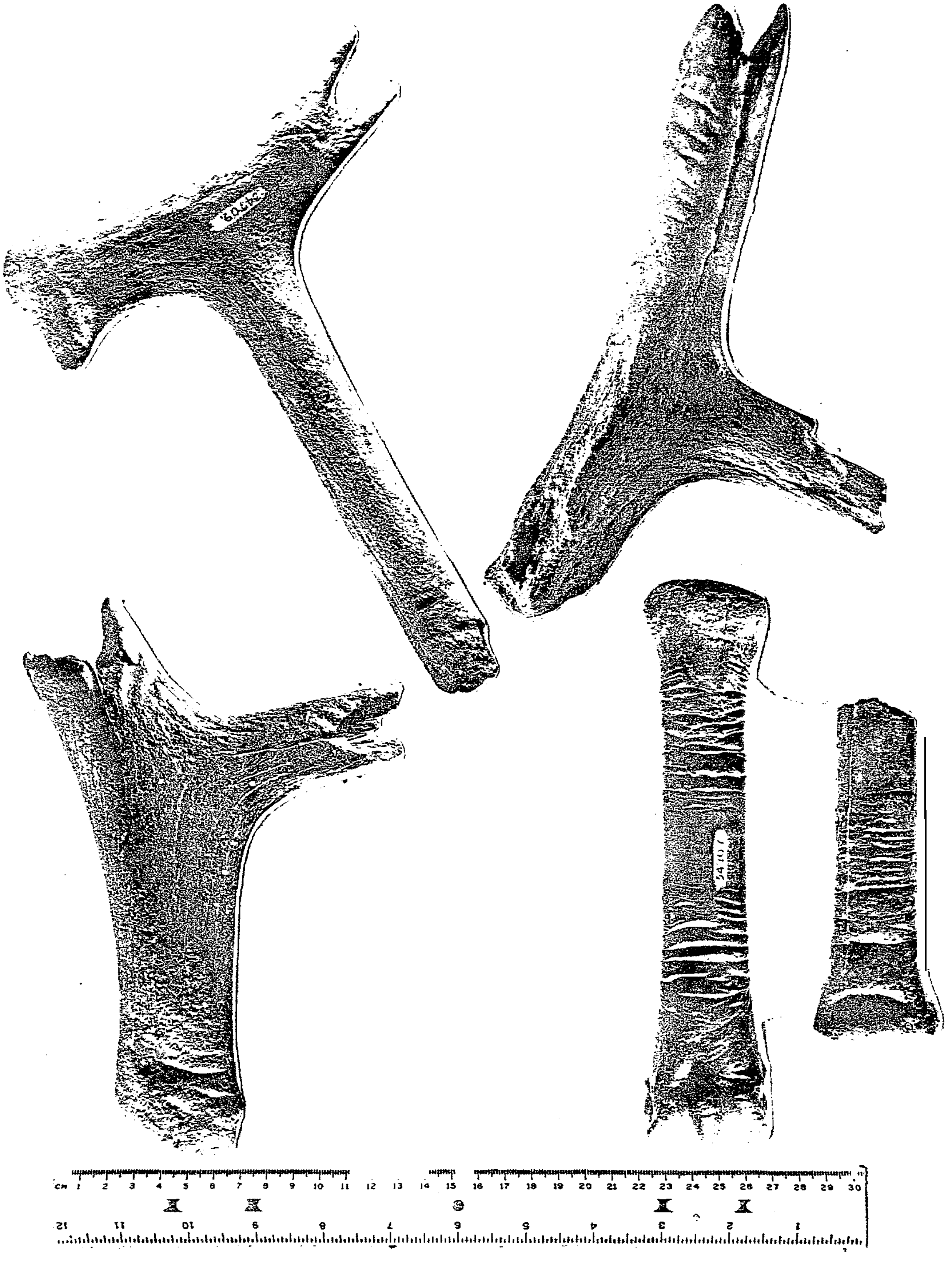


Fig. 4-1. Pseudo-artifacts from Pleistocene deposits near Fairbanks, Alaska

LATE PLEISTOCENE-EARLY HOLOCENE SETTLEMENT PATTERNS AND THE FLUTED POINT TRADITION IN ALASKA: This section considers the critical question of dating fluted points in Alaska. It specifically deals with the Late Pleistocene glacial sequence of the upper Sagavanirktok River valley, near the arctic flank of the Brooks Range, and two archeological sites from that region, the Gallagher Flint Station and the Putu site. Both these sites are significant to the fluted point problem. The Putu site is a fluted point site excavated by -Alexander in 1970 and 1973. Locality I at the Gallagher Flint Station is the earliest dated occupation of the Arctic slope yet discovered (Dixon, 1972, 1975). Locality I is characterized by a core and blade technology. No fluted points have been found at the Gallagher site. Both these archeological sites lie on Alaska's North Slope in the upper Sagavanirktok River valley, and are situated approximately 16 kilometers from each other.

Since the first reported discovery of fluted points in Alaska by Thompson (1948), additional finds have been reported throughout the state. Solecki (1951) reported specimens from the Kugururok River and since then Humphrey (1966), Clark (1972), and Alexander (1972) have all reported Clovis-like projectile paints in northern Alaska. An additional fluted point site was discovered in 1974 along the route of the trans-Alaska pipeline near Prospect Creek, south of the Brooks Range, and there are undoubtedly numerous others which have not come to the attention of archeologists. Hall (1959) suggests that two specimens have been discovered in the Bristol Bay region and another specimen was reportedly collected as a surface find near the Denali Highway in Interior

Alaska. It has become apparent in recent years that Clovis-like fluted points enjoy a wide geographic distribution throughout Alaska.

Basic ‘co every discussion of fluted points in Alaska is a postulated relationship with the Clovis tradition of the continental United States and southern Canada. It is difficult for most scholars to believe that such a highly specialized and unique method of point manufacture developed in Alaska independently of more southern regions of North America. Therefore, most researchers have assumed that somehow the finds in Alaska and those in the south are related.

There are two major schools of thought on the origin of fluted points. Haynes (1964, 1966, 1971), Humphrey (1966), and Martin (1973) interpret the existing data to indicate that a southern origin for this tradition is extremely unlikely. They propose that the fluted point tradition reached Canada and the southern United States from Asia via Alaska following partition of the merged Cordilleran and Laurentide ice sheets. Martin (1973) has theorized that northern hunters bearing the fluted point tradition are responsible for the rapid extinction of numerous species of Pleistocene mammals following partition of the continental ice.

An alternate hypothesis requires a south to north movement of the fluted point tradition, once again following partition of the continental ice (Krieger, 1954; Wendorf, 1966; Müller-Beck, 1967; Bryan, 1969). A major source of disagreement with the south to north hypothesis is that it requires the presence of man in southern North

America prior to the coalescence of the Cordilleran and Laurentide ice in Canada, probably sometime prior to 25,000 years ago. Although numerous sites have been nominated as candidates for occupation prior 'co 10,000 to 11,000 years B.C. (Bryan, 1969), none have been unquestionably accepted. However, recent discoveries at the Meadowcroft rock shelter in Pennsylvania (Anonymous, 1974:83-84) strongly indicate a period of occupation south of the Laurentide ice approximately 13,000 B.C.

There is agreement by all who have dealt with the problem that the definitive **answer** to these alternate hypotheses lies in dating both the partition of the continental ice and the fluted point tradition in Alaska. The Llano tradition has been well dated in the southwestern United States and also at Debert in central Nova Scotia (MacDonald 1968). An age ranging between 9,500 and 8,000 B.C. has been suggested for the fluted point tradition in the southwestern regions of the United States by Haynes (1964:1410). Because fluted points in Alaska have not yet been dated, the origin of this tradition has remained in dispute. A time slope between Alaska and the more southern areas of North America is critical to any argument. The presence or absence of the "ice-free corridor" is viewed by most researchers as the primary factor in controlling the dispersion of this point type.

During the initial phases of archeological research in the upper Sagavanirktok River valley, it was realized that the area demonstrated great potential for dating of the Itkillik glacial deposits, which are broadly equivalent to the Late Wisconsin drift of the standard North American glacial succession [Hamilton and Porter, 1976). By dating the various glacial units exposed in stratigraphic sections along the Sagavanirktok River and its tributaries, maximum limiting dates for human occupation of the region could be established. Radiocarbon dates on organic materials deposited above and below outwash, till, and other glacial sediments could establish minimum and maximum limiting dates for fluctuations of Itkillik-age glaciers in that region.

Three major interpretations are presented as a result of this research. First, a maximum limiting date for the Putu site has been established. Second, an ecological model is discussed which attempts to explain the juxtaposition of the Putu and Gallagher sites in the upper Sagavanirktok River valley. Finally, the model is expanded to propose an explanation for Holocene and Late Wisconsin settlement patterns. The model is offered as the primary mechanism by which the fluted point tradition was transmitted to Alaska and is placed within a testable framework.

FIELD RESEARCH IN THE SAGAVANIRKTOK RIVER VALLEY: Archeological field research in the upper Sagavanirktok River valley was initiated in 1970 as part of an archeological salvage program associated with the trans-Alaska pipeline. Both the Gallagher Flint Station and the Putu site were discovered in that year (Dixon, 1972, 1975; Alexander, 1972, 1974).

The Gallagher Flint Station is a multi-component site (Dixon, 1972). Spatially discrete clusters of artifacts demonstrating topological cohesiveness and radiocarbon dates from the hearths about which they were clustered have provided dating in the absence of well-defined stratigraphic levels. The earliest occupational area yet discovered at the Gallagher site is Locality I, which was radiocarbon dated at 8,590 ± 150 B.C. (S1-974) following the 1971 field season. An additional charcoal sample was secured from this same locality in 1974, but radiocarbon determinations are not yet available. The distinctive blade and core industry from Locality I, associated with a single radiocarbon date on charcoal, indicates a period of occupation between 8,000 and 9,000 radiocarbon years B.C.

Alexander discovered several fluted points at the Putu site, which is located approximately 16 kilometers south of the Gallagher site. Because fluted points are associated with extinct fauna in the "Lower 48," and radiocarbon determinations have verified their antiquity, the age of these points in Alaska has been assumed to be quite old, but until this time they had not been discovered in a datable context.

Glacial deposits of the Sagavanirktok River valley were mapped in 1972 by Thomas D. Hamilton (Hamilton, 1972). Hamilton subdivided Itkillik-age deposits into seven morainal belts which he considered to represent a major advance, major readvance, and five lesser readvances or stillstands of the Sagavanirktok Valley glacier (Fig. 4-2).

DATING: The extent of the Itkillik glaciation and subsequent sub-stades and standstills is illustrated in the map (Fig. 4-2) prepared by Hamilton (1975). A table (Fig. 4-3) lists all radiocarbon determinations in the Sagavanirktok River valley relevant to the problem under consideration. The location of the two late-Itkillik arch.eological sites, the

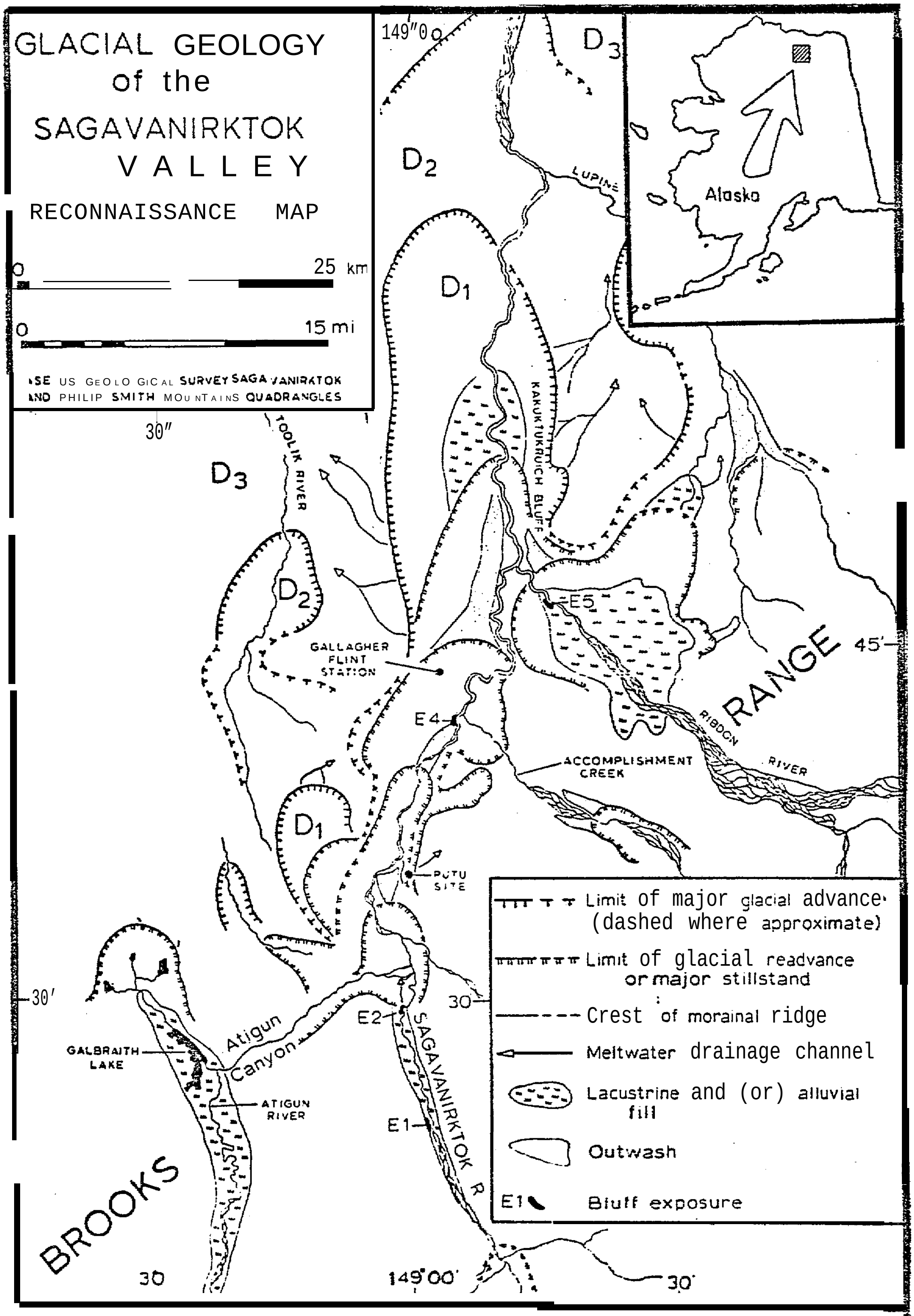


Fig. 4-2. Glacial geology of the Sagavanirktok Valley: reconnaissance map. Modified from Hamilton (1975).

TABLE OF RADIOCARBON DATES FROM

THE UPPER SAGAVANIRKTOK RIVER VALLEY

DATE	SAMPLE NUMBER	SUBSTANCE DATED	SIGNIFICANCE OF DATE	EXPOSURE DESIGNATION*
10,830 ± 440 B.C.	Au-72	Wood (willow?)	Minimum limiting age, Ribdon readvance	E-5
10,220 ± 270 B.C.	AU-71	Detrial wood fragments	Maximum limiting age, Accomplishment readvance	E-4
9,940 ± 200 B.C.	AU- 70	Woody shrubs (willow; dwarf birch?)	Approximate terminal date for al luviation behind Atigun moraine	E-2
9,810 ± 200 B. C..	AU-69	Willow	Contemporaneous alleviation behind Atigun moraine	E-1
8,590 ± 150 B.C.	S1-974	Charcoal	Occupation of Locality 1, Gallagher Flint Station	---
6,500 ± 130 B.C.	WSU-1318	"Soil"	Matrix associated with Putu site and limiting date for Accomplishment deglaciation	---
325 ± 110 B.C.	S1-1427	Grass	Terminal date for alleviation behind Atigun moraine	E-1
770 ± 45 A.D.	S1-1428	Willow	Eolian sand deposited behind Atigun moraine	E-1

*Keyed to Fig. 4-2

Fig. 4-3. Table of radiocarbon dates from the upper Sagavanirktok River valley

Gallagher Flint Station and the Putu site, have been added to the map to depict their location in relation to the glacial features.

The earliest period of occupation at the Gallagher Flint Station is between 8,000 and 9,000 radiocarbon years B.C., and is characterized by a core and blade technology. This earliest occupation, Locality I, indicates that its occupants probably did not use bifacially flaked projectile points. Among the thousands of pieces of lithic material recovered from this locality, only one small, crudely-flaked bifacial stone artifact has been recovered. This was discovered during the 1974 field season and, prior to that time, no bifacial material had been recovered in association with this occupational period. The hypothesis has been advanced (Dixon, 1972, 1975) that the hunting kit contained bone and antler projectile points, which have not been preserved. No burins or burin spans have been found in association with the earliest occupation at the site, although they are present in assemblages which have been radiocarbon dated to later periods of occupation.

Because less than 50 cm deposition has occurred at both the Gallagher and Putu sites, the possibility of cultural mixing should not be totally negated at either site. However, at both sites, isolation of these early occupations is possible due to the existing, albeit scant, vertical stratigraphy and the spatial distribution of the artifacts (Alexander, 1972; Dixon, 1975}. Although the Putu site has not been firmly dated, a radiocarbon determination of 6,500 ± 130 radiocarbon years B.C. (WSU-1318) has been obtained from what is apparently the loess matrix in which the artifacts were found. The fluted point locality at the Putu site also contains a well-developed burin technology, bifacially flaked knives, blades, and blade cores (Alexander, 1972, 1974).

It is apparent from examining the two assemblages that they are quite dissimilar. Fluted points, bifacial knives, and the pronounced burin technology are all absent from Locality I at the Gallagher Flint Station. In addition, the raw materials from which these assemblages were manufactured are strikingly different. The cores and blade at the Gallagher Locality I have been manufactured from calcareous mudstone, which grades into a coarse-grained grey-brown chert, while Putu artifacts are made from fine-grained cherts and one of the fluted points is obsidian.

Both sites appear to represent the same activity. BOth command panoramic views of the surrounding valley floor, locations extremely suitable for observing game movements within the valley. Such sites are commonly referred to as "look-outs" or "flint stations" in Alaskan archeology.

It is generally assumed by most prehistorians that such sites represent brief occupations by small groups of hunters waiting to intercept game which may be easily observed in the surrounding terrain. Consequently, attempting to explain the differences between the two assemblages on the basis of dissimilar functions proves extremely difficult, if not impossible.

Alexander (1972:9) cites Porter (1964a, 1964b) to demonstrate that the presence of obsidian at the Putu site suggests a late date because its source lies south of the Brooks Range which was "blocked by a tile high wedge of ice before 7,000 B.P." However, Alexander suggests that this date is entirely too extreme and that the site is probably older. Alexander's argument against such a date is persuasive, and Hamilton and Porter (1976) now consider that the main valleys and passes of the Brooks Range could have been deglaciated by 10,000 years ago.

Whether the radiocarbon date of 6,500 ± 130 B.C. actually dates the period of occupation at the Putu site is problematic; however, it does provide a minimum limiting age for the wastage of Itkillik ice in this area of the Sagavanirktok River valley (Hamilton, 1975:8). Hamilton (1975, personal communication) suggests that the kame upon which the Putu site lies is at or below the Itkillik II limit and can be no older than 11,000 B.C. Occupation of the kame consequently occurred after that time. Other lines of evidence suggest a period of occupation between 7,000 to 8,000 B.C.

Another radiocarbon date of 10,220 ± 270 B.C. discussed by Hamilton (1975:7) provides a maximum limiting date for the brief Accomplishment readvance, thus indicating that the glacial kame upon whit-n the Putu site is situated lay within a few hundred meters of the ice-choked valley until at least 9,500 years B.C. The limiting date for the Accomplishment readvance "was obtained on small detrial WOO d fragments which lay along bedding planes in the sandy alluvium about 3 m below the base of the outwash" (Hamilton, 1975:7). The outwash certainly dates the period of the Accomplishment readvance and consequently the sample should date a period before deglaciation. In other words, the radiocarbon date which established the maximum limiting date for the Accomplishment readvance is older than the advance itself and subsequent deglaciation must have occurred considerably later.

This limiting date for the Accomplishment readvance indicates that the region was not suitable for human occupation until sometime after 9,500 radiocarbon years B.C. This date, coupled with the date from the matrix from which the artifacts were recovered, and the fact that it is extremely unlikely that obsidian could have entered the region from south of the Brooks Range prior to 10,000 years ago, strongly suggests that the Putu site was not occupied prior to 9,000 to 10,000 radiocarbon years ago. When the entire suite of eight radiocarbon dates from the upper Sagavanirktok River valley are considered in total, they form a very cohesive picture of the glacial history of the region and it becomes increasingly difficult to ascribe an antiquity for the Putu site much beyond the 7,000 B.C. to 8,000 B.C radiocarbon year range suggested here.

The Putu kame is situated approximately eight km up-valley from the terminus of the Accomplishment readvance. It is difficult to envision the kame being an attractive hunting locale during Accomplishment times for it lay sandwiched between a steep mountain spur on one side and glacial ice on the other- Human occupation of the kame seems most feasible following deglaciation and vegetation of the valley floor. After deglaciation, the kame would command the valley below and prove a suitable locale from which to intercept large herbivores.

If we assume that this date for the Putu site is applicable to other flu-ted point sites in Alaska, it becomes reasonable to postulate that this tradition is older in the southern continental United States than it is in Alaska. A south to north time slope for the distribution of this point type in North America is strongly suggested. It seems highly unlikely that this point type was developed independently in Alaska and that there is no connection between fluted points in the "Lower 48" and Alaska. Although this is theoretically possible, it is extremely difficult to envision the independent development of such a unique method of point production prior to 8,000 B.C., a time at which the fluted point tradition is not present at the Gallagher Flint Station, the Akmak assemblage, the Chindadn Complex, the admittedly scanty archeological remains from Trail Creek Caves, nor the small sample recovered from the newly discovered site at Dry Creek. The striking differences between Locality I material from the Gallagher site and the Putu assemblage indicate two independent developmental histories. It would seem imperative that two such diverse technologies would have to develop in spatial and/or temporal isolation. The distance of 16 km between the two sites hardly provides spatial isolation and, consequently, temporal isolation seems to be the only viable conclusion.

Hopkins (1972) has indicated that land connections between Alaska and Siberia were severed for the last time approximately 14,000 years ago. Given the late date for the Putu site, it becomes quite evident that the point type could not have spread from Alaska to Siberia, for the flooded Bering Strait most probably blocked diffusion of this tradition to Asia. No fluted points have been discovered in Siberia and there is no evidence to support the possibility that the fluted point tradition has its origin in Asia and was transmitted across the Bering Strait prior to 12,000 B.C.

Six independent lines of evidence strongly indicate that fluted points are more recent in Alaska than in the lower states and Canada: (1) The glacial history of the Sagavanirktok River area indicates that the kame upon which the Putu site is located did not exist prior to 11,000 B.C.; (2) a reconstruction of the paleogeography of the area strongly implies that the kame would have remained unsuitable for human occupation until sometime after 9,500 B.C.; (3) artifacts assumed to represent an extremely different cultural tradition (Locality I at the Gallagher site) demonstrate that the region was occupied by another cultural group between 8,000 and 9,000 years B.C.; (4) the absence of fluted points in Siberia strongly supports a late date for this tradition in Alaska because land connections between Alaska and Siberia were severed approximately 12,000 years B.C.; (5) a radiocarbon date from the loess matrix from which the fluted points were recovered was 6,500 radiocarbon years B.C. and may indicate a late period of occupation; and (6) the presence of obsidian at the site implies that it was not occupied prior to 8,000 years B.C.

This late date in Alaska for the fluted point tradition is extremely critical to man's occupation of the New World and Beringia itself. It indicates that man must have penetrated the more southern regions of the North American continent prior to the coalescence of the Keewatin and Cordilleran ice sheets. It strongly supports the conclusion that human populations dispersed into North America via the Bering Land Bridge at a time prior to the merging of the continental ice. On the basis of the data already reviewed, it seems highly probable that the fluted point tradition developed in spatial isolation south of the continental ice and then transmitted to Alaska by peoples populating "new" territory recently vacated by the continental ice. If the tradition were older in Alaska than in southern areas of the continent, it could support the concept that the first population of North America may have occurred during very late Wisconsin times with fluted points constituting the first demonstrable evidence of man in the New World. However, this does not appear to be the case and the data strongly suggest human occupation of Beringia prior to the Late Wisconsin coalescence of the Laurentide and Cordilleran ice (prior to ca. 18,000 years ago}.

A PROPOSED MODEL: The Arctic's short summers and intense winters have made human reliance on floral resources in sufficient quantity to sustain human populations impossible, consequently a hunting or herding economy is essential to sustain human life in the Arctic. Because northern hunters have been forced to rely on animals as their major subsistence resource, the distribution of the Arctic's fauna has largely determined what locations could sustain aboriginal settlements. An extensive exploitation of Alaska's ecotones (Fig. 4-4) has characterized settlement patterns during Holocene times. This has occurred for two primary reasons: (1) Ecotones are characteristically areas of seasonal biomass concentration; and (2) ecotones are diverse in their faunal assemblage and permit alternate subsistence strategies.

To test the postulated ecotone settlement pattern model, the distribution of 4,028 Holocene-age archeological sites were plotted in relation to Alaska's major ecosystems. To achieve this result, a computer program was written to execute a least square polynomial fit to the third degree. The output of this program was a set of coefficients which could transform latitude and longitude to x and y coordinates for plotting site locations on a transparent overlay. An IBM 360/40 was used to produce a plot tape which was read by a NOVA 820. The NOVA was then used to drive a Calcomp ten inch drum plotter. The resulting "strips" were then overlaid on the Major Ecosystems of Alaska map and the composite is illustrated in Fig. 4-4. A striking visual correlation between site distribution and ecotones may be observed. With a fairly high degree of certainty, we may state that approximately 92% of Alaska's archeological sites occur no further than 1.25 miles from the ecotone as depicted in the Major Ecosystems of Alaska map.

Ecotones are taken here to mean those areas which are zones

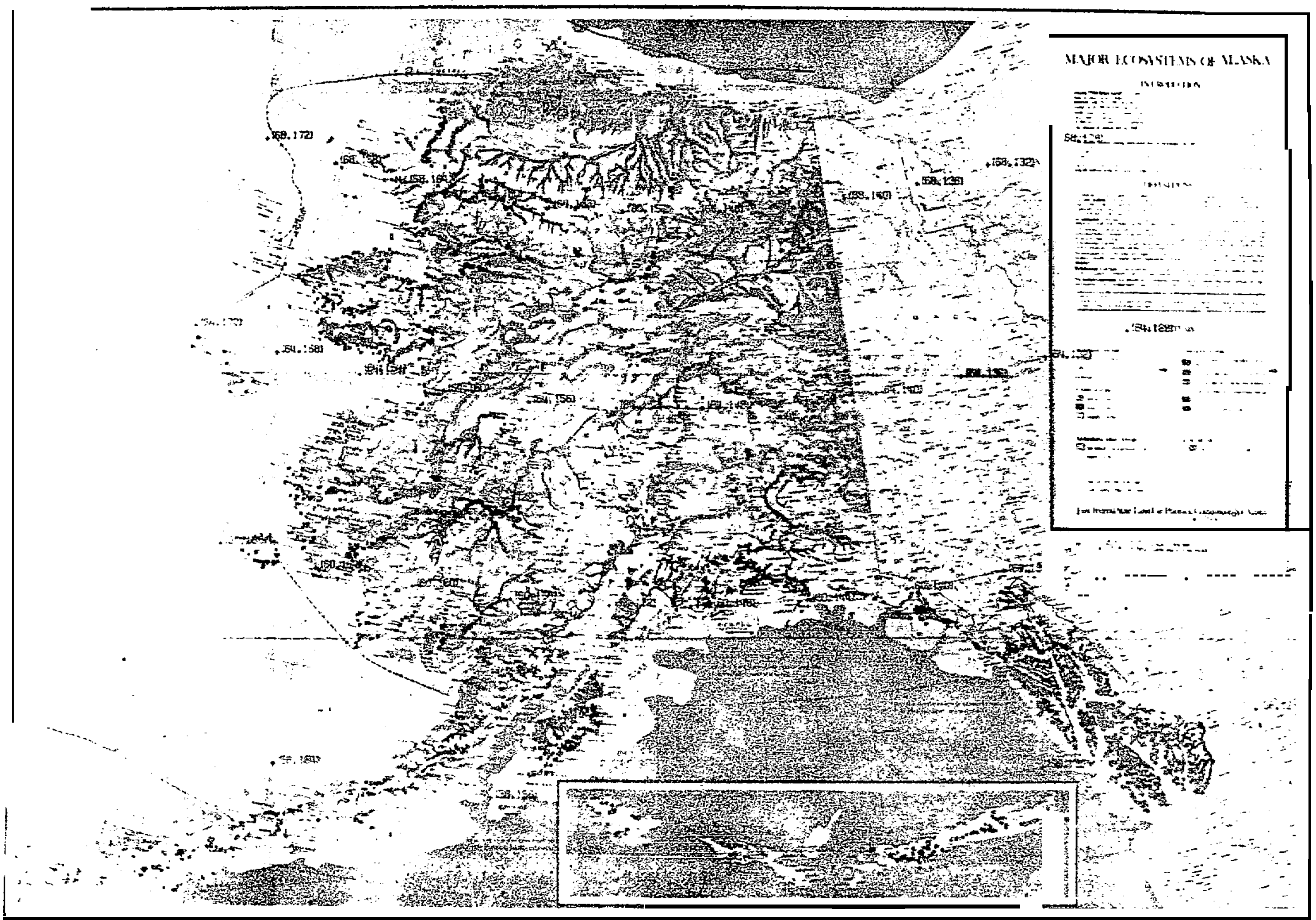


Fig. 4-4. A distribution of approximately 4,000 Holocene-age archeological sites in relation to Alaska's major ecosystems. Major ecosystems are in various grey tones; ecotones are areas of contact between grey zones; "X" depicts site locations.

of transition between two or more biomes. Migrating species, such as caribou, must pass through ecotones in moving between biomes. The diverse flora of ecotone areas seems to foster a rather diverse fauna. It is not the ecotones themselves that attract man, but their comparatively high biomass productivity.

A basic model is postulated for hunting economies. Human habitation sites will occur in greatest frequency where animal resources tend to concentrate. Environmental conditions provide important controls on vegetation and thereby the distribution of faunal resources. As environmental conditions change, so does faunal distribution. Man adjusts his settlement locations to optimize his faunal harvest. Settlements are seen to result from faunal harvests which exceed the immediate energy requirements of a population and an inability to transport large quantities of fresh meat.

Ecotones may be either static or dynamic. Static ecotones remain in the same location, whereas dynamic ecotones move. Dynamic ecotones provide a reliable dating technique if their movement can be traced through time. If the environment responsible for the distribution of fauna changes in a regular and predictable fashion, the distribution of fauna will do so as well. Hunters will find it essential to alter their settlement locations in order to remain within the region of greatest biomass productivity, and such regular and predictable shifts in the environment can be correlated with changing settlement patterns in the archeological record through horizontal. stratigraphy.

Giddings (1960) advanced the concept of "beach ridge dating." He correctly assumed that in areas where coastlines were extending further and further seaward by successive formation of new beach ridges, sea mammal hunters of Alaska's coast were drawn by this strong ecological force, proximity to the sea and its rich resources. Giddings (1957:17) later stated that "its main premise is that any people in this part of the world who live near a shoreline will prefer to camp on a sand or gravel beach from which they can most conveniently scan both land and sea." Thus, at Cape Krusenstern and the Choris Peninsula, he discovered that the age of former habitation sites varied directly with their distance from the present location of the sea.

Ecotones exist within the marine environment. For example, the ice edge on the Bering and Chukchi Seas, as it retreats northward in the spring, forms an area of contrasting temperatures, which is an area of extremely high primary productivity. Marine mammals are drawn to the highly productive ecotone and man, as predator, strategically situates himself on prominent spits, points and islands from which he may "ambush" this ecotone as it passes on its way northward.

Giddings' work represents an important innovation in Arctic archeology, for he developed a means of relative dating which incorporated environmental dynamics and did not rely on vertical stratigraphy. There would be no reason for Giddings' settlement pattern to work as a dating technique if it did not take into account the dynamics of a moving ecotone; that is, the beach edge which borders the marine aquatic and tundra biomes. Man found it advantageous to be situated in the ecotone and moved with it. Thus, Giddings assumed that although there were numerous older beach ridges suitable for camps, those which occupied the ecotone during any given time period would attract man. It is the movement of the ecotone which provided Giddings with the temporal dynamics of the rich archeological sequence at Cape Krusenstern.

Many of Alaska's ecotones have remained "static," that is, they have not moved throughout Holocene times. Therefore, Giddings dating technique is not applicable in many areas. Static ecotones result in a spatially diverse distribution of archeological sites within an ecotone. In the absence of a dynamic force to guide the residents of the region to specific settlement localities, such as proximity to the sea at Cape Krusenstern, various localities within the ecotone may prove equally suitable. This is not to say, however, that there do not exist specific localities within the ecotone which are more favorable than others. Such places do exist and are generally re-used.

HOLOCENE SETTLEMENT PATTERN OF THE ARCTIC SLOPE: The spatial distribution of scores of known archeological sites in the upper Sagavanirktok River valley indicates that the post-Itkillik, or Holocene, settlement pattern of this area reflects an intensive exploitation of the static ecotone bordering the north flank of the Brooks Range. The ecotone is bordered by the moist tundra biome stretching northward to the Arctic Ocean and the high alpine tundra of the Brooks Range. It is along this ecotone that the most diverse environment is apparent, and it is also where the greatest number of archeological sites have been found. The only other archeological "hot spot" found on the North Slope is the coastal area, and once again, an ecotone settlement pattern is reflected. The coastal region is the interface between the marine aquatic and tundra biomes. Archeological sites do occur in non-ecotone areas, but most of these represent briefly occupied camps resulting from transient stops along the Sagavanirktok River by travelers moving between ecotones. Thus, the river may be viewed as the major artery connecting the ecotones and is itself an ecotone, i.e., a fresh water aquatic system bordering a variety of terrestrial biomes.

The limits of the Itkillik ice along the north flank of the Brooks Range now roughly defines the ecotone. It is here that topographic features such as kames, moraines, and kettle lakes provide the setting for greatest exploitation of the region by man. Topographic relief provides many excellent lookouts for game animals such as caribou, bear and moose, and the well-drained gravel kames and moraines greatly reduce the difficulty of pedestrian travel in the boggy and tussock-ridden tundra. In addition, kames and moraines are the favored location for ground squirrel colonies, which represent important resources for both man and grizzly bears. The kettle lakes abound in arctic char, lake trout and grayling and offer a temporary resting place for migratory water fowl . The proximity of these glacial features to the Brooks Range also provides ready access to Dan sheep, which inhabit the high mountain peaks. In many circumstances, local topography provides excellent locations where migrating caribou may be ambushed. Hence, the extent of the Itkillik glacial advance roughly delineates the region of greatest post-Itkillik archeological potential on the North Slope. This ecotone settlement pattern represents the post-Itkillik human adaptation to the drastic changes which occurred in the biota during the transition between Itkillik and Holocene times.

LATE ITKILLIK SETTLEMENT PATTERNS: There are two archeological sites in the upper Sagavanirktok River valley which have been ascribed dates placing them in late Itkillik times. Consequently, the Holocene settlement pattern is not necessarily applicable in explaining their occurrence. These sites are Locality I at the Gallagher Flint Station and the Putu site. These two sites, and quite possibly others in Alaska, are seen to represent a transition between the Holocene ecotone settlement pattern and a drastically different one during Wisconsin times. It is suggested that the mechanism responsible for this transition is the replacement of an expansive tundra steppe by what are, today, recognized as Alaska's major ecosystems.

Guthrie (1968) has suggested that the major components of the now extinct Pleistocene mammalian fauna in Interior Alaska were horse, mammoth and bison. Because all of these species are primarily grazers, Guthrie presents a strong argument for a more steppe-like environment than exists today and his suggestion is supported by others [Hopkins, 1972; Matthews, 1974). A recent pollen core from Birch Lake in Alaska}s Interior (Ager, 1975, personal communication) further supports Guthrie's hypothesis of Alaska's vegetation during Late Wisconsin times. The Birch Lake core contains a three-zone pollen sequence encompassing the past 16,000 years. Zone I demonstrates the existence of a tundra-steppe until about 14,000 years ago. This was abruptly replaced by Zone 2, shrub tundra, which persisted until about 10,000 years ago. Zone 3 marks the invasion of spruce into the region approximately 10,000 years ago (Ager, 1975a:1-2).

Thus, several lines of evidence suggest a drastic change in the northern climate approximately 14,000 years ago: (1) This is a time at which the Pacific and Arctic Oceans are connected by Late Wisconsin eustatic sea level rise; (2) an abrupt change in the flora from tundra-steppe to shrub tundra occurs in Ager's pollen core; and (3) this is a period of rapid ice wastage at the end of Itkillik II time in the Brooks Range. The period from approximately 14,000 to approximately 10,000 years ago may be viewed as transitional between Wisconsin and Holocene times. This period may be characterized by the dominance of a shrub tundra, minor readvances of glaciers in the Brooks Range, and a rapid decline in the numbers of Pleistocene grazers. After the transition was complete, pronounced glacial activity in the Brooks Range ceased. The major ecosystems characteristic of contemporary vegetation were established and most probably remnants of the once-abundant Pleistocene grazers became extinct. These environmental alterations may not have occurred simultaneously in all regions in Alaska.

Ager (1975, personal communication) has suggested that plants such as *Artemesia* and some grasses probably continued to persist in microhabitats such as dry, windswept outwash deposits in the vicinity of retreating glacier fronts. Ager feels that the sudden climatic change which occurred approximately 14,000 years ago forced the remaining

Pleistocene grazers into these microhabitats, where they could possibly have persisted for several thousand years after the abrupt climatic change eliminated the once expansive tundra-steppe. The fact that all Late Wisconsin archeological sites in Alaska occur in regions which are characterized by such soil disturbances strongly supports Ager's hypothesis. The upper Sagavanirktok River valley most probably represents such a microenvironment and Pleistocene faunal remains are commonly found behind the limits of the Ribdon (Itkillik II) readvance.

Grasses are colonizing species and are a primary constituent of plant communities in areas where disturbance, such as forest fire or high winds have either destroyed a climax community or cause persistent soil movement and redeposition. Viereck (1966) has documented plant succession in a recently deglaciated area of Alaska’s Mt. McKinley National Park. What Viereck refers to as the “Meadow Stage” consists of “extensive areas of grass meadow interspersed with small clumps of willow and other shrubs” (Viereck, 1966:187). Viereck's “Meadow Stage” may well correlate with Ager's "refugium" concept.

As the successive glacial stades of the Itkillik glaciation in the Sagavanirktok River valley underwent mass wastage, their drift sheets were vegetated. There should be little doubt that these drift sheets were first colonized by grasses and other opportunistic plants. The presence of woody shrubs is indicated by the macro-fossils used in dating the glacial sequence. This microenvironment moved further and further towards the Brooks Range with each successive wastage of the stades of the Itkillik and most probably represented one of the few remaining refugiums for the then endangered grazing species such as horse, bison and mammoth. Increased pressure may have been placed upon such species to occupy this niche in the face of an overall disappearance of the once expansive tundra-steppe.

There is no direct evidence for the association of Pleistocene fauna such as horse, bison or mammoth with either Locality I at the Gallagher Flint Station or the fluted point locality at the Putu site, for no faunal material has been preserved in association with these early assemblages. It is, however, a major presumption of this presentation that a predator/prey relationship existed between the inhabitants of these early sites and the extinct mammalian grazers. There are only two reported Wisconsin age archeological sites in Alaska in which faunal remains have been preserved, and they demonstrate conclusively that a predator/prey relationship did exist between these extinct species and the Late Wisconsin man. At the newly discovered Dry Creek site in Alaskars Interior, fossil evidence of horse and bison have been discovered in unquestionable association with a Late Wisconsin occupational horizon (Powers et al., 1974), and Larsen (1968) has described the presence of bison and horse remains in association with the occupation at Trail Creek Caves on the Seward Peninsula. On the basis of the existing data, it is, therefore, reasonable to postulate that the early occupants of the upper Sagavanirktok River valley were hunters of the now extinct Pleistocene grazers.

The upper Sagavanirktok River valley, like numerous others on the North Slope, may be viewed as a micro-environment which gradually migrated south towards the Brooks Range with the successive stages of mass wastage during Itkillik times. This micro-environment may have persisted in the face of an overall transition in the biota from a tundra-steppe to what we now recognize as the moist tundra biome, and may have provided a refugium for the remnants of the once-abundant Pleistocene grazers. It is suggested that this moving micro-environment attracted Pleistocene grazers and these herbivores, in turn, attracted man. Thus, as the micro-environment moved south towards the Brooks Range, human predators did so as well in order to remain situated in a position of high biomass productivity. This situation presents striking similarities to Giddings' beach ridge dating with its dynamic ecotone.

The late Itkillik biota may, therefore, be seen as the driving force which provides temporal dynamics to the archeological record of the upper Sagavanirktok River valley during late Itkillik times. It is suggested that this moving micro-environment followed closely behind the retreating Itkillik ice, colonizing the newly created land forms, and that its continuance was probably fostered by a brief period of disturbance related to wastage following deglaciation. The retreat of this ecological niche toward the Brooks Range during late Itkillik times is offered as an explanation for the relative positions of the Gallagher Flint Station and the Putu site. It is suggested that the Putu site, which is closer to the Brooks Range, was occupied later than the Gallagher Locality I.

If we assume an adaptive hunting strategy based on the exploitation of grazing species during Itkillik times, it is reasonable to assume that adaptive strategies were different during Holocene times, due to the difference in the composition of the fauna. Archeological sites demonstrably older than late Itkillik times have not yet been discovered, possibly because the locations of modern ecotones have been the primary directive force in archeological survey.

When replacement of the tundra-steppe was complete at the end of Itkillik times, many of the areas which may once have been refugia became the location of modern ecotones. Thus, archeological sites like Locality I at the Gallagher Flint Station and the Putu site may be viewed as transitional between a once-common subsistence strategy based on hunting Pleistocene grazers and Holocene ecotone exploitation. If we assume the presence of an extensive grassland prior to late Itkillik times, we can then also assume an extensive distribution of the abundant Pleistocene grazers. This distribution would also reflect the distribution of man during this period and, consequently, the camps of these early hunters would not be expected to occur with regularity in the present day ecotones. Only the very late Itkillik settlements based on the exploitation of grazers have been found because remnants of these once-numerous animals were huddled close to the retreating Itkillik ice and feeding on the remnants of their once-extensive steppe-like habitat. If early early man is to be found in Alaska, survey strategies may have to concentrate on regions which were once the lush plains of the tundra-steppe.

<u>THE MODEL APPLIED TO THE DISTRIBUTION OF FLUTED POINTS:</u> It has been demonstrated that the kame upon which the Putu site is located was not

ice-free until sometime after 11,000 radiocarbon years B.C. Other lines of evidence strongly indicate that the occupation of the kame did not occur earlier than 7,000 to 8,000 years B.C. Assuming that the suggested date for the Putu site is roughly applicable to other fluted point sites in Alaska, it appears that this tradition is younger in Alaska than it is in the more southern regions of North America. Thus, a time slope for this technical tradition may be postulated with reasonable assurance.

The ecological model presented in this paper may explain the northward movement of the bearers of the fluted point tradition. Peoples south of the coalescent Laurentide and Cordilleran Wisconsin glacial ice developed the technique of manufacturing fluted points as an integrated part of their subsistence strategy based on predation of Late Wisconsin grazers, such as mammoth and bison. As the glacial ice of the Laurentide and Cordilleran retreated (Fig. 4-5), the newly exposed drift sheets were rapidly colonized by plant species which created a habitat suitable for Pleistocene grazers. Species such as horse, bison and mammoth filled this newly created niche. This response may have been accentuated by alterations in the biota south of the coalesced Laurentide and Cordilleran ice. Late Wisconsin hunters bearing the fluted point tradition were drawn northward with these species as their range extended in that direction. With final partition of the ice and subsequent vegetation, these hunters pursued this fauna into Alaska where remnant populations" still persisted in micro-environments such as the dry, windswept outwash deposits bordering the retreating glaciers. AS a result of this almost imperceptible northward movement, the fluted point tradition, as manifest

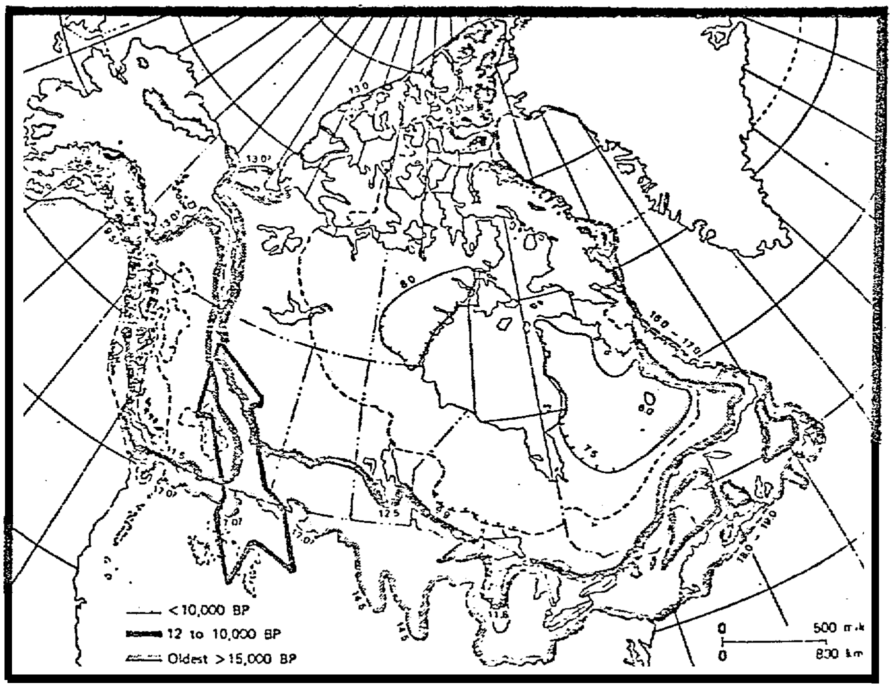


Fig. 4-5. Speculative model for the Late Wisconsin deglaciation of North America {directly from Flint, 1971:492). Arrow indicates the northward movement of the fluted point tradition, approximately 8,000 B.C.

at the Putu site, did not reach Alaska until very late Itkillik times. Under these circumstances, the model suggests that this technological tradition did not merely diffuse to Alaska, but a physical "migration" of individuals bearing a unique technology gradually moved from southern regions of North America northward.

The model which has been proposed can be tested. The postulated time slope can be verified or refuted by additional dating. Folsom-like sites must be discovered in the critical area of Canada which lies between Alaska and the continental United States, and in southern Canada. These sites must agree with the time slope and, in general, should demonstrate decreasing age northward. If the proposed model should withstand these tests, then such theories as that advanced by Martin (1973) which relies on a sudden burst of population from the north through the "ice-free corridor", cannot be entertained. That man may have contributed to the extinction of remnant populations of Pleistocene fauna is not unreasonable, but his role in Pleistocene extinctions must have been minor compared to that of climatic change and its accompanying alteration of the flora.

RECENT SIBERIAN DATA RELEVANT TO THE OCCUPATION OF BERINGIA: The first two sections have attempted to synthesize archeological data relevant to Late Pleistocene human occupation of Arctic North America. The data presented strongly supports a Wisconsin penetration of the North American continent by early man via the Bering Land Bridge. The age and diversity of these early archeological assemblages indicate that they represent later manifestations of earlier archeological traditions. These assemblages should be regarded as minimum dates for man's occupation of Arctic North America and this, in turn, supports an even earlier occupation of Beringia.

It is not the purpose of this presentation to provide a detailed synthesis of Siberian archeological data. However, it is important for this study to establish occupational horizons in Siberia which predate the Holocene inundation of the Bering Land Bridge. Arguments supporting the Wisconsin occupation of Beringia gain additional strength when the presence of man on the Asian side of the Land Bridge can be firmly established prior to the Holocene inundation of Beringia. A brief discussion of the Siberian Diuktai tradition is critical to this problem. As with the North American data, many Siberian sites have been ascribed Pleistocene antituity in the absence of radiometric or sound geomorphic dating. Again, in the interest of brevity, and to avoid confusion, only those sites which have been subjected to relatively sound dating techniques will be discussed in some detail.

The Diuktai culture represents the oldest yet discovered Siberian archeological tradition which demonstrates temporal, spatial and topological cohesiveness. Our knowledge of the Diuktai culture is attributable to the recent and rather spectacular work of IU. A.Mochanov of the Yakutsk Branch, Siberian Division of the Academy of Sciences of the U.S.S.R. This tradition derives its name from the type site, Diuktai Cave, located on the east bank of the Aldan River. Mochanov (Arndt, 1976:8, citing Mochanov, 1975) has recently divided the Diuktai culture into two major periods: Proto-Diuktai and Diuktai, but as yet no discussion of the type traits for Proto-Diuktai have appeared in print. However, as Arndt (1976:8) has aptly pointed out, continuity between Proto-Diuktai and Diuktai proper is implied. Undoubtedly this subdivision of Diuktai culture will require further clarification, however there are, at present, at least four archeological sites which have been placed within the Proto-Diuktai continuum by Mochanov. These are Ezhantsy, Ust'-Mil' II, Ikhine I and Ikhine II. Fig. 4-6 lists the spacial and chronological placement of these sites as well as fauna associated with each.

The artifact assemblage associated with the Proto-Diuktai culture will remain in doubt until the definitive traits are published. Artifacts present in the sites include chopper-like pebble cores, wedge-shaped cores (similar to multi-faceted burins) , Levallois (tortise) cores, bifacial blanks, a chisel-shaped tool, a "crude blade", waste flakes, and a fragment of worked mammoth bone (Arndt, 1976:11-15). The temporal placement for Proto-Diuktai culture apparently spans the period from approximately 35,000 B.P. to sometime before 20,000 B.P., for at Ikhine II, Mochanov (Arndt, 1976:15) classifies Horizon A, which he estimates to be between 24,000 and 20,000 B.P. as Diuktai, while Horizons B and C are classified as Proto-Diuktai.

In spite of the sketchy nature of the data relating to Proto-Diuktai, its significance is readily apparent. Most important is that Proto-Diuktai is firmly dated from at least three different sites, and is supported by a suite of at least eight radiocarbon dates which, in turn, support the geomorphic placement of additional horizons. At this

Fig. 4-6. PROTO-DIUKTAI - CHRONOLOGICAL PLACEMENT *

SITE	DATE	BASIS FOR DATE or C14 SAMPLE #	LOCATION	ASSOCIATED FAUNA
Ezhantsy	**35,000** B.P.?	geomorphological (3rd river terrace)	junction of the Aldan and Maia Rivers	*Mammathus primigenius* *Coelodonta antiquitatis* Bison *priscus* *Equus caballus*
Ust'-Mil II horizon C	**33,000** ± 500 B.P. **30,000** ± 500 B.P. 35,400 ± 600 B.P.	LE-1000 LE-1001 LE-954	**60 km** down-stream on the Aldan River from Diuktai Cave	*Mammathus primigenius* Bison *priscus* *Equus caballus*
horizon B	23,500 ± 500 B.P.	LE-999		
Ikhin I	34,000 to 31,000 B.P.	geomorphological (correlated with horizon C at Ikhin II	east bank of Aldan River, 284 km from its mouth	*Equus caballus* *Mammuthus primigenius* Bison *priscus deminutus* *Citellus undulatus fossilus*
Ikhin II horizon C	34,000 to 31,000 B.P.	geomorphological (stratigraphi-tally below horizon B)	"close to" Ikhin I	*Mammuthus primigenius* *Coelodonta antiquitatis* Bison *priscus* *Ovibos moschatus* *Equus caballus*
horizon B	31,200 ± 500 B.P. 30,200 ± 300 B.P. 24,600 ± 380 B.P. 24,330 ± 200 B.P.	GII?-1020 GIN-1019 IMSOAN-153 LE-1131		Same as horizon C with the notable addition of *Rangifer tarandus*

*Compiled from Arndt (1976:10-16) citing Mochanov (1973, 1975) and Mochanov and Fedoseeva (1968).

time there can be little doubt that man occupied Siberia's Aldan River valley by 35,000 B.P., a period well before the <u>Mid-Wisconsin</u> marine transgression on the Bering Land Bridge.

In addition, Proto-Diuktai conclusively demonstrates that man was sufficiently adapted to subsistence on Asia's tundra-steppe during <u>Early</u> Wisconsin times. Faunal remains indicate that subsistence was primarily based on predation of mammoth, horse and bison. It is firmly established that these species ranged over Beringia into Alaska and North America. There seems to be little reason to believe that human predators would not assume the same range as their prey. Although the Aldan River is considerably distant from the Bering Strait, the restrictions of Proto-Diuktai finds 'co the Aldan Valley more surely reflects the distribution of archeologists rather than the spatial distribution of Proto-Diuktai culture.

The second and later phase of the Diuktai tradition spans the time period from about 23,000 to 10,800 B.P. (Arndt, 1976:22) and is referred to simply as the Diuktai culture. Type traits for the Diuktai culture are (Arndt, 1976:22):

> . . small wedge-shaped cores; massive subprismatic cores made on pebbles; bifacially worked spear points and knives of willow leaf, subtriangular, and oval form; central, lateral, angle, and transverse burins; end scrapers and skreblos. There are also single specimins of subdiscoidal and tortise cores, spear points of mammoth tusk, and bone burnishers (Mochanov and Fedoseeva, 1975b:51).

A host of radiocarbon dates supports the Diuktai culture and are too numerous to list here. Faunal remains from the Diuktai sites indicate that subsistence emphasis remained on horse, mammoth and bison, although numerous small game species, waterfowl and fish are reported from the type site, Diuktai Cave (Powers, 1973:51).

The spatial distribution of Diuktai sites encompasses the Aldan, Olenek, Markha, Vitim, Maia, Indigirka, and Kukhtui Rivers and the Kamchatka Peninsula (Arndt, 1976:26, citing Mochanov, 1975:7). The site distributions may encompass the Kolyma River region as well, for Mochanov has attributed the Maiorych site to the Diuktai tradition (Powers, 1973:76-77). This wide geographic distribution for sites of the Diuktai tradition may be described as stretching from the Lena River basin to Kamchatka and from the Arctic Ocean to the Sea of Okhotsk. It seems probable that when archeological research is focused on the extreme Siberian northwest, the distribution will most probably extend to the western margins of the Bering Strait.

On the basis of Powers' valuable 1973 contribution and synthesis of Siberian literature, and particularly Arndt's recent synthesis of current archeological publications relating to the Aldan River area, it seems reasonable to postulate a penetration of Arctic North America via the Bering Land Bridge during Early Wisconsin times by early man bearing a Proto-Diuktai-related tool kit. Diuktai-related influences may have played an important role in North American Arctic prehistory during Late Wisconsin times. Very late manifestations of Diuktai-related traits may be manifest in the Chindadn complex from Healy Lake, the Akmak assemblage at Onion Portage, the earliest components at the Dry Creek site, and possibly the early phase of the Denali Complex.

EARLY MAN ARCHEOLOGY OF BERINGIA: Considerable speculation has traditionally focused on the potential of many islands in the Bering and Chukchi Seas to yield evidence of early population by man during Beringian times. It has long been realized that these islands once were prominent hills protruding from the relatively flat Beringian topography. However, surprisingly little non-coastal archeological field research has been executed on these islands.

Numerous reports deal with the coastal archeology of the islands in the Bering Sea. (See Jenness, 1929; Collins, 1937; Geist and Rainey, 3.936; Giddings, 1967; Ackerman, 1974; and Bandi, 1969.) In spite of this comparatively large body of literature dealing with the archeology of these islands, the most important being St. Lawrence, there is little reference to archeology in the interior portions of the islands. The coastal sites on these islands, especially St. Lawrence, offer extremely appealing ivory-rich midden deposits and these magnificent sites have captured the interest of virtually every archeologist who has attempted to survey them. Although these excavations have contributed greatly to Eskimo prehistory, they have had little bearing on the problem of human migration to the New World via the Bering Land Bridge during pre-Holocene times.

As a result of the post-Wisconsin eustatic sea level rise and subsequent stabilization of the Arctic coast, approximately 4,000 B.P., most sites located directly on the coast post-date that time period due to the marine orientation of their subsistence strategy. There is one notable exception to this general rule, however, and it is the Anangula site, located on Anangula Island. In this unique situation, tectonic uplift has occurred at a rate faster than that of sea level rise, resulting in the existence of a site predating 4,000 B.P. The physical location of the site strongly indicates a subsistence strategy involving marine predation.

There exists one notable exception to the coastal orientation of archeological survey among the islands of the Bering Sea. This is a survey executed by Alan L. Bryan, with the assistance of Robson Bonnichsen and Ross Thompson, during the late summer of 1966 (Bryan, n.d.). These men conducted a 15-day archeological survey of the Pribilof Islands, St. Paul and St. George. The original purpose of their Pribilof Survey was to attempt to locate archeological evidence dating to the period during which the islands were hills rising above the Bering plain (Bryan, n.d.:6). Although, once again, the survey efforts seem to have devoted considerable time to investigating coastal sites, Bryan reports having tested two lava tubes and one rock shelter on St. George Island. Unfortunately, "nothing of interest" was discovered at the cave sites and only "occasional disintegrated bone, charcoal flecks, and some water rolled pebbles amongst the sharp scoria" (Bryan, n.d.:5) were discovered at the rock shelter. However fruitless this short survey may have been in relation to the early man problem, it represents a pioneering effort in the search for human habitation of Beringia.

There exists one other important bit of data which may prove of profound significance in attempting to locate evidence of early man on Beringia. This find consists of what are believed to be artifacts dredged from the floor of the Bering Sea by David M. Hopkins, personal communication, 1976). The sample was recovered from a depth of 40 meters off the south shore of St. Lawrence Island. The "flakes" recovered are of fine-grained granite and it is apparent from the barnacle attachment that they have been removed from the parent core prior to their recovery by the dredge, i.e. , they are not artifacts manufactured from the dredging operation per se. Hopkins tentatively speculated that the 40 meter contour may have been innundated by 13,000 B.P. and, consequently, it is likely that if these specimens are truly the handiwork of early man, then they predate this time. The specimens are currently in the possession of John M. Campbell of the University of New Mexico, and he has been contacted in hopes that they may be made available for analysis in this project.

In summary, it can be readily noted that early man archeology on Beringia is in its infancy. This research has only been able to ferret out two possible attempts to isolate human habitation of Beringia during Wisconsin times. These are Bryan's survey of the Pribilof Islands and Hopkins' alert observation of possible artifacts on the Bering Sea floor. Consequently, this research represents the first concentrated inter-disciplinary research project to attempt to locate pre-Holocene age terrestrial habitation sites on the floors of the Bering and Chukchi Seas. From a purely anthropological point of view, human population dispersal into North America via the Bering Land Bridge is a hypothesis which is currently accepted as the prime mechanism for the human population of both the North and South American continents. Although there exists considerable data and even more arguments in support of this hypothesis, the concept is nevertheless a hypothesis and will remain so until firmly dated archeological remains dating to Pleistocene times are recovered from Beringia proper, i.e., either the ocean floor or the islands.

In conclusion, four lines of archeological evidence strongly support human occupation of Beringia: (1) The diversity of a number of Alaskan archeological sites dating to Late Wisconsin times suggests that they represent later manifestations of earlier traditions; (2) the late date for the fluted point tradition in Alaska indicates that man penetrated regions south of the coalescent Cordilleran and Laurentide ice prior to merging during Late Wisconsin times; (3} the Proto-Diuktai tradition is manifest in Siberia at a time suitable to permit an Early Wisconsin occupation of Beringia and Alaska and a Mid-Wisconsin penetration of the more southern regions of North America; and (4) so little work has actually been done relating to early man archeology of Beringia, that the lack of early man sites from the region does not reflect a lack of occupation.

THE THEORY AND METHOD OF ARCHEOLOGICAL SITE PREDICTION

The previous sections have discussed demonstrating the logical basis for the occupation of Beringia by early man. As ordered in the preceding text, these factors are: (1) The paleogeographic reconstruction depicts a terrestrial environment of sufficient size and diversity 'co support human occupation; (2) the reconstruction of probable marine mammal habitat indicates that these species were available and abundant for human predation; (3) the postulated distribution for terrestrial mammals indicates that these species were concentrated in patterns which made them vulnerable to human predators; and (4) man was present in the circum-Beringian region at a time suitable for the occupation of the Land Bridge proper, and thus indicating a sufficient degree of adaptation to the tundra-steppe to enable occupation of the Bering and Chukchi outer continental shelves.

A basic assumption for the model used for predicting archeological site locations in the Beringian region is" that human survival was predicated on a hunting economy. This assumption is based on anthropological literature which suggests: (1) during Beringian times hunting and gathering was the only economy being practiced in the chronology of evolution of human societies; (2) northern climatological and biological factors suggest hunting was more viable than gathering; and (3) the ethnographic and archeological literature does not substantiate any other types of economies in the northern prehistory of this area.

Anthropologists have long focused much attention on hunting and gathering societies in the belief that the development of contemporary social institutions and the ordering and structure of modern societies has derived its institutions from adaptive social forms developed during man's long development in the hunting and gathering "stage" of human evolution. Murdock (1968) has demonstrated the rather drastic decline of the number of humans engaged in hunting and gathering activities as their basic economic pursuit on a global scale during the past 10,000 years. At the beginning of Holocene times, virtually the Earth's entire human population relied on hunting and gathering as their economic mainstay. Hunting and gathering has declined, until today, only a few isolated pockets continue this life style in what are marginal habitats unsuitable for other economic pursuits.

Lee and DeVore (1968:11) have attempted to delineate the major traits of hunting and gathering societies.

> We make two basic assumptions about hunters and gatherers: 1) they live in small groups and 2) they move around a lot. Each local group is associated with a geographical range but these groups do not function as closed social systems. Probably from reciprocal visiting and marriage alliances, so that the basic hunting society consisted of a series of local "bands" which were part of a larger breeding and linguistic community. The economic system is based on several core features including a home base or camp, a division of labor--with males hunting and females gathering--and most important, a pattern of sharing out the collected food resources.

A universal aspect of these societies is that all must maintain a territory, or range, from which the essential resources to sustain life are derived. Within each territory or range, natural resources are not distributed uniformly, and certain resource concentrations play a more important or dominant role in subsistence activities than others.

The severe arctic and subarctic winters and short, cool summers have greatly reduced the potential for gathering plant products in the north. With the exception of berry products, and a few nonfaunal utilitarian resources such as birchbark, certain grasses, etc., gathering has been extremely limited in subsistence activities of northern peoples. Even today, with modern farming techniques, the development of hardier grains, and fertilizers, direct reliance on vegital products for human subsistence is, at best, a very tenuous enterprise.

The essential key to human survival in the north is faunal resources. Northern animal species are the Arctic's most efficient machines for converting and storing solar energy into usable protein and carbohydrates suitable for human consumption. These animal species are adapted to northern vegetation and are able to convert plant energy into body tissue and of storing the summer peak in the energy budget in the form of fats. Man's utilization of energy is consequently directed to predation of these animal species rather than to the flora itself. There exist two possible methods by which man may harvest this energy. 'These are herding or predation.

There exists no archeological nor echographic data (prior to the introduction of reindeer herding in Alaska in the early 1900's) for herding economies in Arctic North America. One possible exception to this was Giddings' (1957) suggestion of the possibility of reindeer herding during Choris times based on the comparatively small size of the caribou bones recovered from the Choris t-ype site. However, Giddings later withdrew his hypothesis and considered the Choris finds indicative of caribou hunting. All archeological and ethnographic data to date confirms human predation of animal species as the primary subsistence mechanism for the North American Arctic.

SETTLEMENT PATTERNS: Because human predation on animal populations is the primary subsistence activity for human populations, the distribution of fauna commands the dominant role in determining settlement locales. Chang(1962:29) defines settlement as " . ..any form of human occupation of any size over a particular locale for any length of time with the purpose of dwelling or ecological exploitation." Chang's definition is accepted as the definition of settlement as applied in this study. These locales may vary greatly in terms of specific function and duration of occupation and both these factors may be considered dependent upon faunal resources.

Anthropological investigators have long recognized the importance that the distribution of fauna has had upon the distribution of settlement locales of northern hunters. Boas (1964:11), in his monograph on the Central Eskimo, which resulted from his field work in Canada from 1883-1884, readily realized the role of natural resources in determining settlement pattern. He wrote,

> All depends upon the distribution of food at the different seasons. The migrations or accessibility of the game compel the natives to move their habitations from time to time, and hence the distribution of villages depends, to a great extent, upon that of the animals which supply them with food.

Since Boas' classic monograph, virtually all anthropological literature dealing with northern peoples has, in some fashion, dealt with the important role played by faunal composition and distribution in the lives of northern peoples.

When reviewing the literature dealing with subsistence activities of northern hunters, three major faunal resource categories emerge. These are (1) terrestrial mammals, (2) marine mammals, and (3) fresh water aquatic resources (waterfowl and fish). 'The importance of these three species complexes is that all, at some time in their annual cycle, form seasonal aggregates. There exists a host of ethnographic literature which describes methods by which man has preyed upon these aggregates, however, it is the surpluses which result from the harvest of the aggregates and the locations of these concentrations which enable human settlements and determine their locale.

Chang (1962:28-29), in analyzing settlement patterns for northern hunters-fishers, has observed:

> . . .the settlement patterns among hunter-fishers provide a wide range of varieties particularly suitable for micro-typological purposes. The circumpolar region further widens this range by means of marked seasonal fluctuations of climate and the resultant seasonal cycles of animal and plant life. Under such a natural environment, the impact of cultural ecology upon society is more plainly observable and is less complicated by historical factors than in other areas of the world.

Chang's observations are significant, for he accurately identifies the utility of extreme northern latitudes in concentrating faunal resources, or energy, in time and space. The phenomena of sharp energy peaks of short duration have had a profound effect on human population distribution. As briefly outlined earlier in this section (p. 151), settlement locales and the duration of occupation may be viewed as dependent on energy harvests. Chang (1962:30) has expressed this by stating that:

> It is evident that a circumpolar hunting-fishing group cannot subsist on the basis of a single kind of food resource all the year round at a single locale and has to move about among various locales according to the seasonal climatic fluctuations. Such movements of settlements usually are made among a network of locales, with a central base where most of the members of the group gather together at a particular season of the year and a varying number of scattered camps occupied by large or small branches of the group in particular seasons, engaging in various and specific kinds of subsistence activities.

Campbell (1968) has advanced an excellent typology of settlements for the Nunamiut. He has delineated six different types of settlement, ranging from his Type I settlement, which served as the central camp to which all members of the band identified themselves, to Type VI settlements, which consisted of brief, overnight stops while traveling.

Watanabe (1968:69), speaking of northern food gatherers, has delineated a universal pattern which he believes is common to all northern hunters. This is a "settled life in winter." Helm (1969:213) states that, ". . .we may predicate that in hunting-gathering band societies the directives underlying settlement patterns are based on the exploitative pattern, the exploitative pattern being the total set of activities in the acquisition of life's goods through the application of technology upon environment." In discussing Northern Athabascan peoples, McKennan (1969:100) states, "The primary ecological basis for these Alaskan bands was the dependence of native technology on geography." McKennan (1969) analyzed the ecological basis for northern Athabascan band composition and delineated two major technological devices which served to bind a regional band together; they were the fish wier and the caribou fence. McKennan felt that because they were both collective efforts 'chat required the cooperation of fairly large groups of people for their construction and maintenance, they tended to focus the population in specific geographic locales and provide band identity. In addition, it can be readily realized that these human aggregates could only form by anticipating the occurrence of biomass peaks in time and space, and that they could only persist through the process of securing a net energy budget which exceeded the immediate energy requirements of the population.

In short, biomass "peaks concentrated the human population, which through collective efforts,were able to maximize the faunal harvest. Thus , the subsistence strategy resulted in predictable settlement locales which coincided with the occurrence of biomass peaks, which were restricted to specific geographic locations and specific points in time. Within the limits of aboriginal technology, a collective effort could greatly increase the energy yield on a per capita basis. By this method, Interior aboriginal populations were focused into primary settlements.

Such primary subsistence locales may be considered to be the hub of the aboriginal territory. Thus, the primary focus in the aboriginal effective environment may be viewed as faunal resources. Satellite settlements result from specific resource exploitation of the effective environment around the primary energy yield locales. These sites are generally task-specific, i.e., quarry sites, feather collecting, egg collecting, etc. The territory may be defined as the resource range of the population. When energy expended exceeds the energy return, it may be viewed as the limiting factor in defining territorial area and configuration. Territorial range can be expanded by various weight reduction techniques, such as drying and boning meat (well documented in McKennan, 1965:30, 95; 1959:32; Wentworth, 1956:561-2, 564-7; Giddings, 1952:42-3; 1961:129; and Petitot, 1971:114; and numerous other sources). Transportation devices such as sleds and boats are also important energy savers and may increase territorial range considerably.

Because there exists no firm data relating to the time when marine mammal exploitation became a viable subsistence strategy in the circum-Beringian area, we have assumed, for the sake of this study, that it is a definite possibility throughout the Wisconsin history of Beringia. By using Anangula as a minimum limiting date for the demonstration of this form of subsistence orientation, we may state with some certainty that it was a viable economic base prior to ca. 8,000 to 8,500 B.P. The lack of data prior to the occupation of Anangula is attributable to eustatic sea level rise, which most probably has inundated archeological sites located along what were former coasts. As unlikely as it may seem, marine mammal predation may have been an early Wisconsin human subsistence strategy, and consequently, we have considered it a possibility in this study, rather than risk omitting what may be an extremely important, although undocumented, area of fo-rmer human habitat.

THE METHOD OF SITE PREDICTION: This study has demonstrated that early human habitation of Beringia is highly probable that any inhabitants would have been reliant on a hunting economy, and that settlement locales of hunters are based upon resource distribution. It is possible through paleogeographic and paleoenvironmental reconstruction to delineate paleo-resource distribution. It then follows that it should be possible to delineate paleo-settlement distribution. This basic axiom serves as the mechanism by which probability ranking for archeological site occurrence is postulated for Beringia. The ranking system which follows expresses probability of site occurrence as high, medium, and low for the Beringian area.

In an effort to rank specific areas in relation to one another for this vast region, in terms of probable biomass productivity, the entire region was divided into a series of 69 cells. In the interest of uniformity, standard U.S.G.C. quadrangles were considered the basic spatial unit, or cell. Using the maps prepared by the project's physical oceanographer, both the marine mammologist and vertebrate paleontologist ascribed values to every quadrangle under consideration. These values represent a qualitative statement as to the total biomass resource of any particular quarrangle during the most productive period during the time period under consideration, i.e., from the early Wisconsin to the end of the sea level rise during Holocene times. A summer and winter value was ascribed to each quadrangle for each major (terrestrial/marine) series complex, because obvious differences in species distribution and availability are dependent on seasonal factors.

It is granted that this exercise is qualitative and subjective, however, it is nevertheless repeatable. The overall distribution of species is ultimately dependent on physical factors which control their distribution. There is no need to reiterate these factors, for they are dealt with in greater detail in the previous sections- However, other researchers using this same data would, in all likelihood, rank these same areas in a similar fashion. The real differences between rankings by different investigators may be considered to be more a reflection of the actual ranking system employed rather than the the relative value of one area to that of another. In short, although the system developed here is subjective, it is based on physical evidence and should be repeatable by different investigators regardless of the artificial ranking system chosen for analysis.

The ranking system implemented here is a simple scale from one to ten, one representing the lowest possible estimate of resource availability, and ten being the highest evaluation. It was felt that no quadrangle could be ranked as zero, for each in its turn occupied a coastal position during some period of marine transgression and most certainly each has at some time in the past supported some terrestrial mammal population. Thus, all quadrangles demonstrate some potential for past exploitation of their faunal resources by man, and consequently, there is some, albeit low in many cases, probability of human occupation of any given region. An example of the ranking technique is depicted below, using the quadrangle presently occupied by St. Matthew Island:

	Smer Value	Winter Value
Marine Mammal	07	01
Terrestrial Mammal	06	06
	13 x	07 = 91 (ascribed quadrangle value)

This basic table illustrates the method by which the values were ascribed to each quadrangle. The total summer resource value was tabulated to quantitatively assess the total biomass resource available during that season during the period of peak productivity for any particular quadrangle throughout the time period under consideration. The same technique was applied to the winter values. Finally, in an effort to skew the product of these two totals in favor of those with higher values, the totals were multiplied. The value totals were multiplied because it was felt that this best expressed the possibility for faunal surpluses which were most likely to result in primary settlements. In other words, by multiplying the summer and winter value totals, quadrangles with the greatest year round potential for sustaining hunting human populations would be favored in the ranking system. This method enables a subjective ranking of each quadrangle in relation to all others and through qualitatively quantifying each region under consideration, it becomes possible to assess each region with greater objectivity, which, in turn, enables probability ranking.

If the reader has cause to question the value ascribed to any individual quadrangle, he need merely to turn to the appropriate section on marine or terrestrial species distribution and consult the appropriate maps. The species distribution maps should provide essential data relating to the value expressed. Relevant sedimentation data is to be found in the section dealing with paleogeography.

Human settlement is dependent on energy surplus, i.e., a harvest which exceeds the basic energy requirements of the population. The values expressed for the biomass resources for each individual quadrangle are thus directly transferable to the potential, or probability, of human habitation locales. Thus, the higher the value, the greater the possibility of energy surplus and the higher the probability of human occupation. The carrying capacity for any given region is governed by the minimum harvestable resources at any given point in time. Consequently, if surpluses are not stored during periods when food is abundant to carry the population through periods of marginal productivity, the population will find it difficult to sustain itself and famine may result. Thus , the less the carrying capacity, the fewer or smaller should be the settlements. The greater the carrying capacity, the greater the population density. The values may be considered statements of the peak carrying capacity for any given quadrangle.

The one universal in northern hunting cultures seems to be the presence of some form of winter settlement. Such camps may be expected in regions of high productivity which would enable surplus energy storage to sustain a winter settlement with the energy stores being supplemented by harvest of species in winter range and local small game resources. Generally winter settlements require substantial modification of the natural environment for the construction of some form of winter shelter. It seems most probable that such sites will be the easiest to detect using the geophysical instruments available for the study. It is also most likely that comparatively large winter settlements may be located in such areas where the greatest possibility to store energy exists, i.e., the regions ascribed the highest values in this study.

STUDY RESULTS

Fig. 4-7 depicts the series of U.S.G.S. quadrangles for the entire region under consideration, the Bering and Chukchi continental shelves from the International Date Line to the Alaskan coast. If the . date line crossed any portion of any quadrangle, it was considered as part of the total sample in the ranking system. The total population of U.S.G.S. quadrangles were placed in a row and column matrix for the purpose of organizing the data for analysis. University of Alaska Computer Center personnel assisted project researchers by writing a program to compute the values of each quadrangle and then print out this data in the row and column matrix. The values derived for each quadrangle are also depicted in Fig. 4-7, along with the range of sediment depth. Additional computer programs were generated to statistically analyze the sample in an effort to establish objective ranking through clustering the valued for the total sample. The values range from 2 to 154.

Fig. 4-8 is a bar graph depicting the absolute frequency for each value computed from the qualitative ranking system. Fig. 4-9 is a frequency polygon and normalized curve for the same data. Three major breaks in the distribution of the values may be observed from these distributions. The largest cluster of values ranges between 2 and 16, at which point there exists a significant break between 16 and 21. This distribution has been considered as values of comparatively low probability. Medium range probability values range between 21 'and 36, and high values between 40 and 154. These value clusters are depicted in Fig. 4-10, in which three different symbols depict the three different value ranges. From the distributions of the quadrangle values depicted in the graphs,

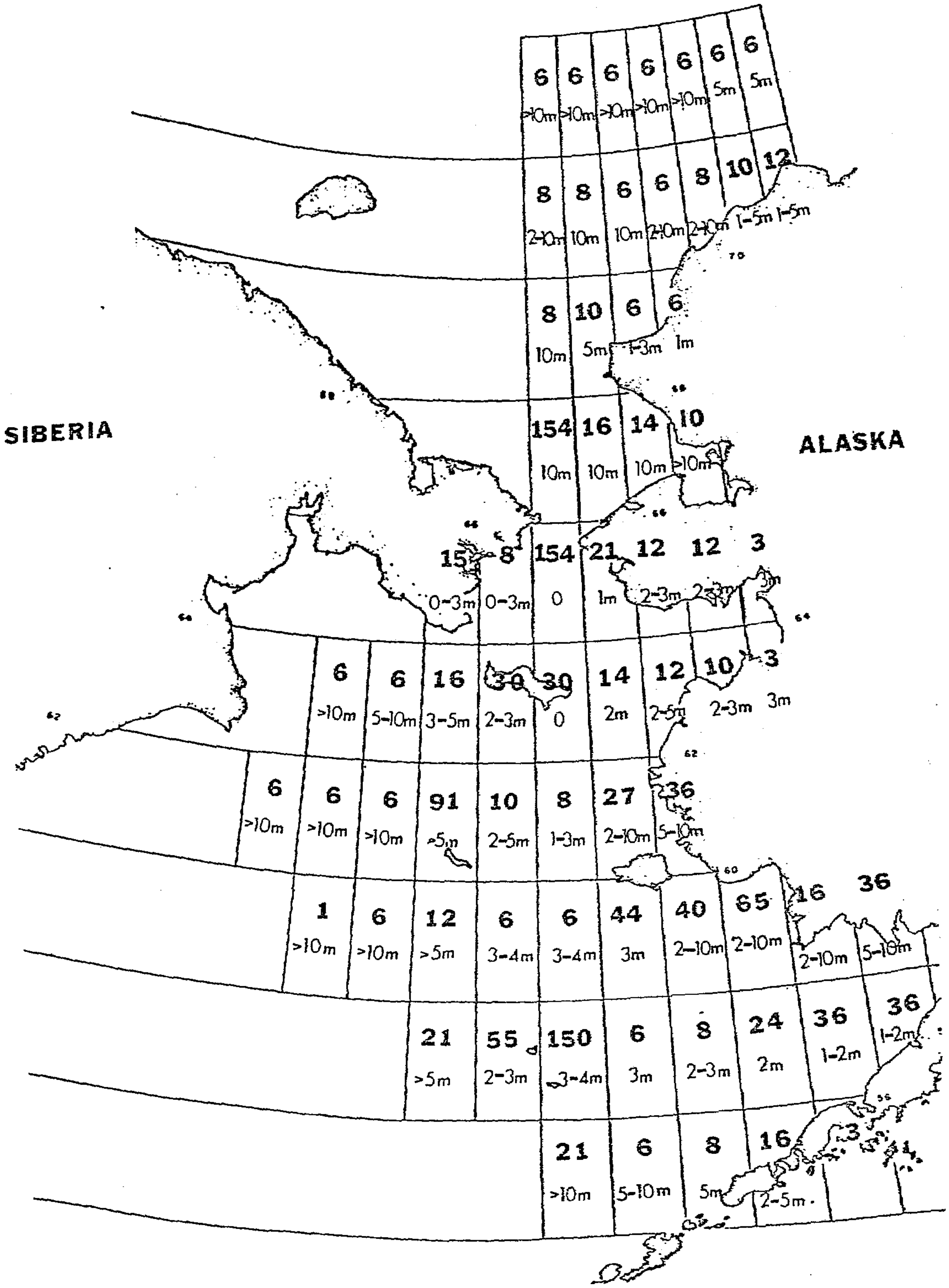


Fig. 4.7. Ascribed quadrangle values and sediment thickness in meters

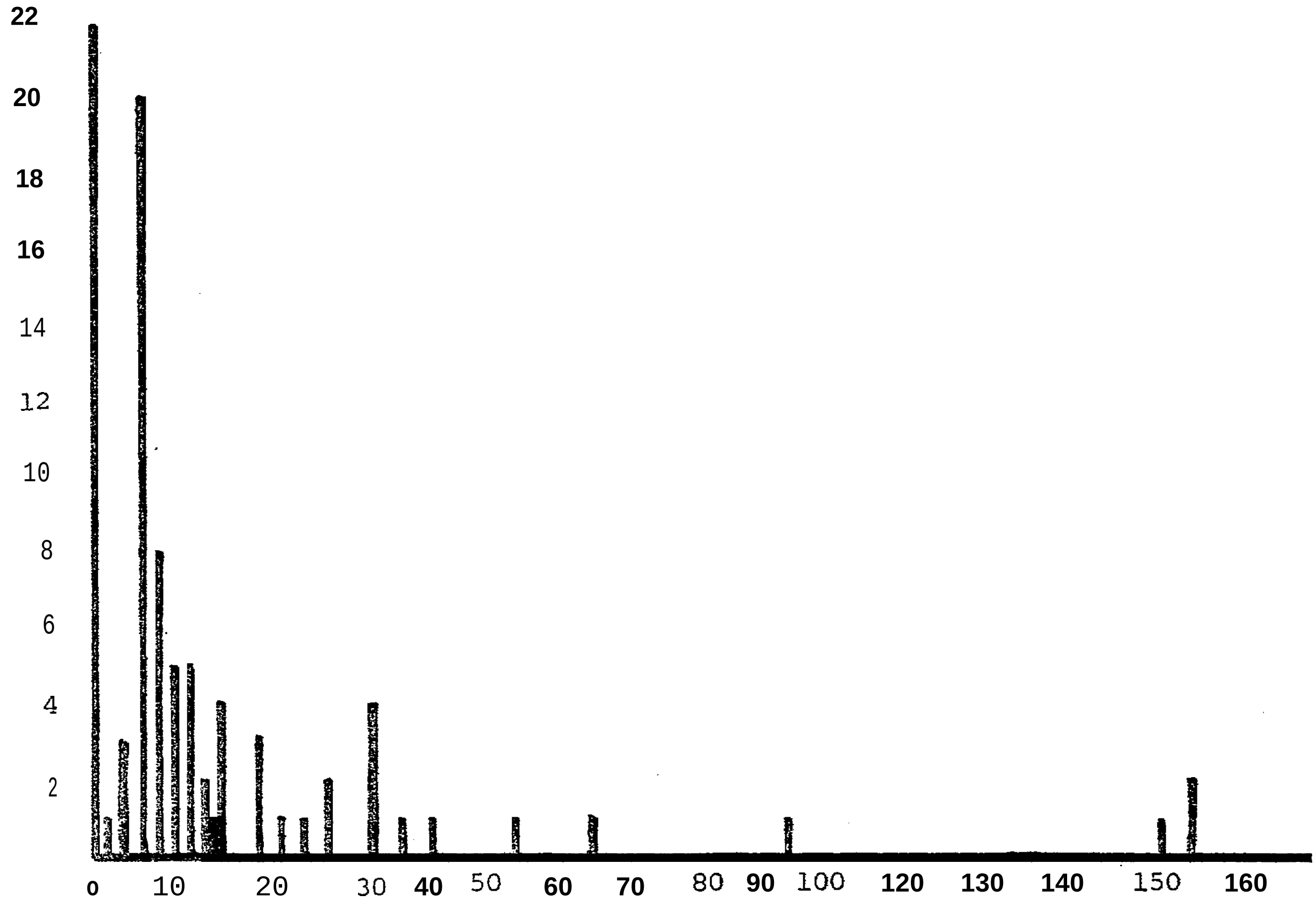


Fig. 4-8. Bar graph of probability values for U.S.G.S. quadrangles on the Bering and Chukchi outer continental shelves

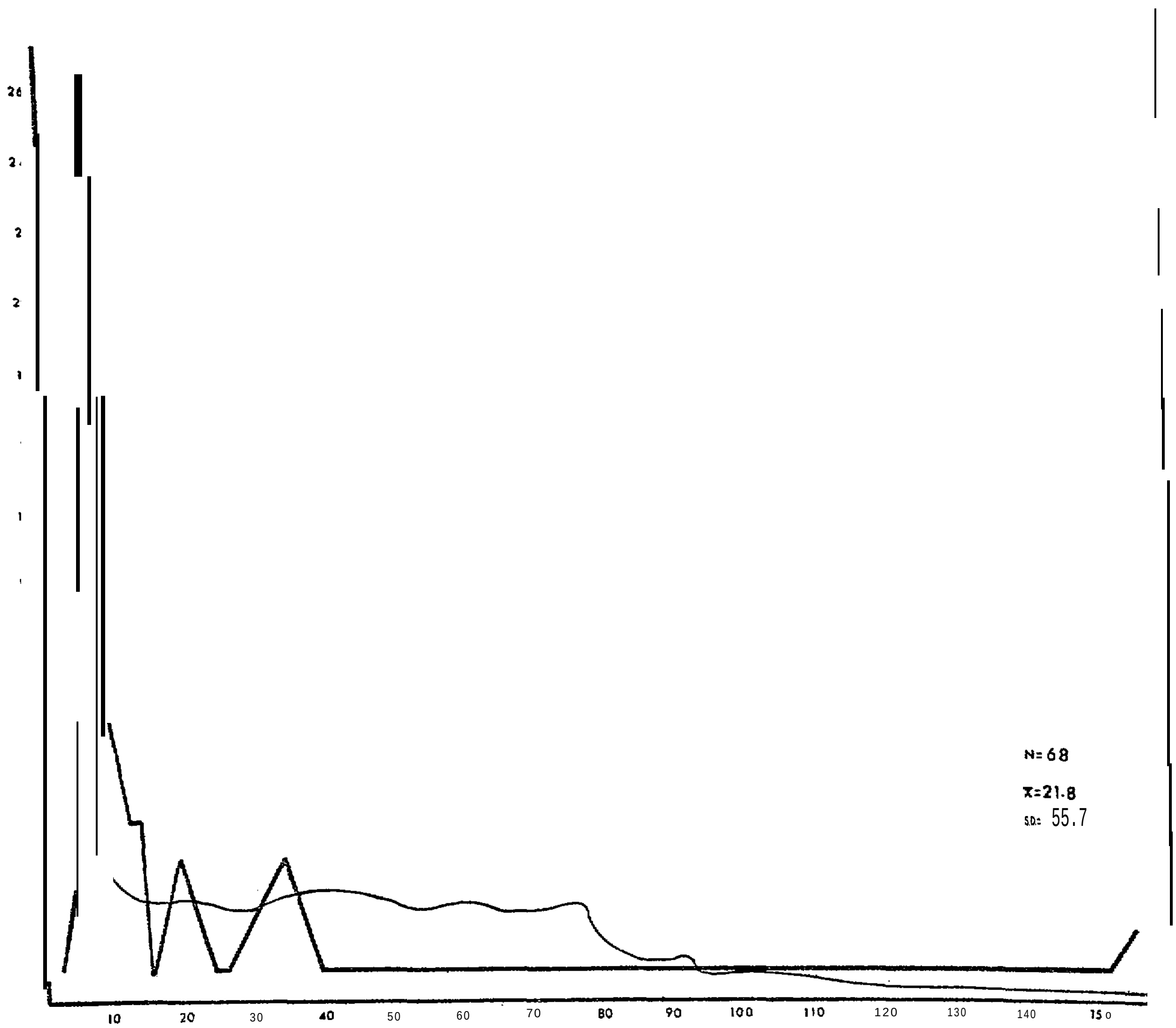


Fig . **4-9.** Frequency polygon and normalized curve of probability ranking for U.S.G.S. quadrangles on the Bering and Chukchi outer continental shelves.

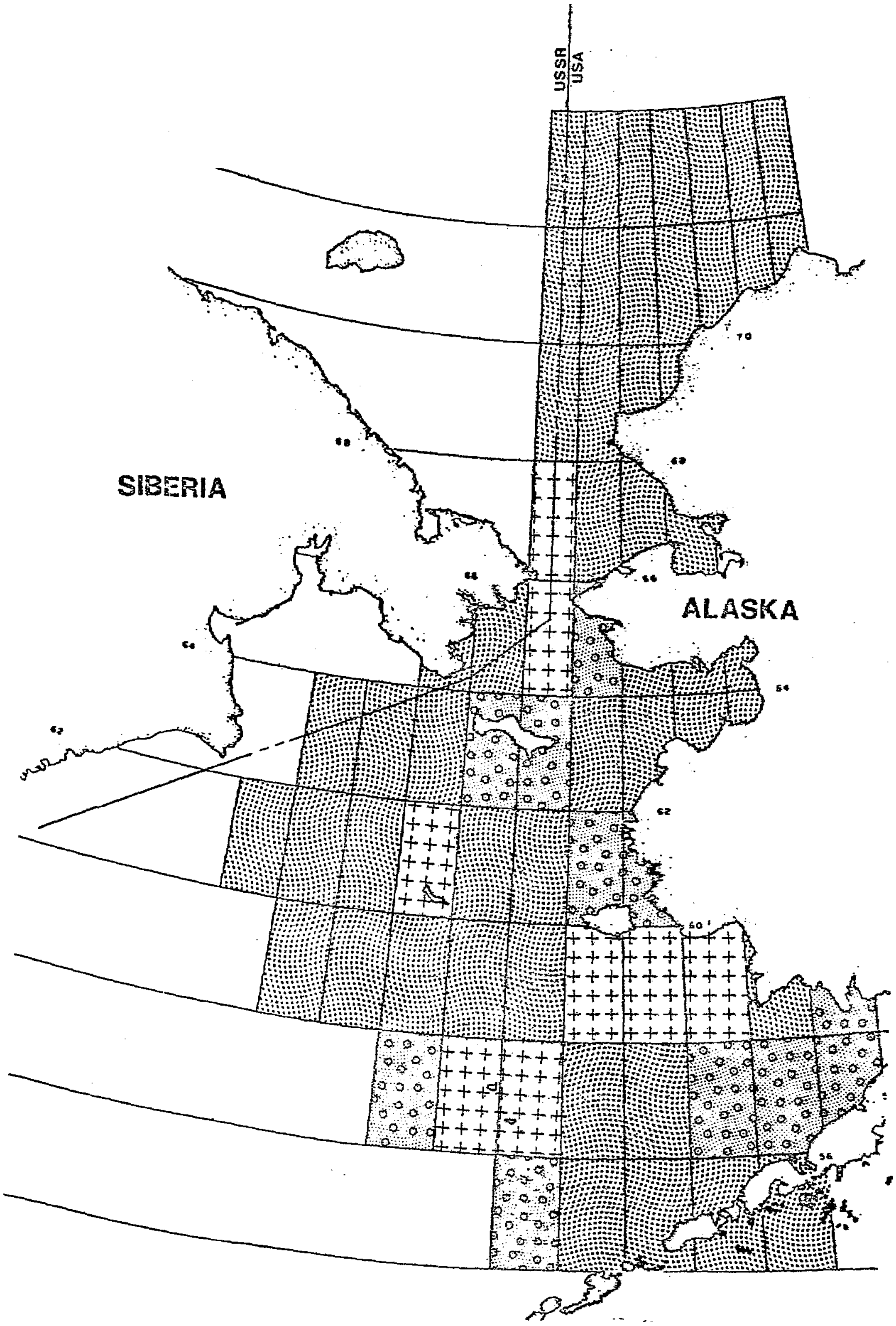


Fig. 4-10. High, medium and low probability quadrangles on the Bering and Chukchi outer continental shelves.

++++++ = high probability quadrangles

○○○○ = medium probability quadrangles

= low probability quadrangles

50 quadrangles have been classified as being of low probability, eleven fall within the medium range, and eight quadrangles are considered to be of high archeological potential,

In keeping with the University's contract with the Bureau of Land Management's Outer Continental Shelf Office, the physical oceanographer has prepared maps on a scale of 1:250,000 for six of the high probability areas. Two high probability areas have not been mapped in the area of the Bering Strait, for current scouring has resulted in severe erosion of this region. Because high probability locales are restricted to portions of the high probability quadrangles, maps were only generated for those specific areas. These maps are to be found in Appendix I

INTRODUCTION TO PHASES II and III

The Phase I report has discussed the data and reasoning indicating human population of the Bering Land Bridge. It further defines regions likely to have supported human populations in the past. Phases II and III were designed to verify the Phase I study, by actually attempting to locate archeological sites dating to Beringian times in high probability areas on the outer continental shelf. Two independent tests were devised. One (Phase II) consisted of a marine archeological survey from the University of Alaska's research vessel, the R.V. ACONA, in an area adjacent to the Pribilof Islands. The second test (Phase III) consisted of a terrestrial archeological survey of St. Matthew Island in the Bering "Sea. Both tests failed to discover archeological sites dating to Beringian times, but, as will be discussed in more detail in these sections, neither test can be considered adequate for a variety of reasons. Following the description and data presentation for the marine archeological survey, conclusions and recommendations for cultural resource surveys on the outer continental shelf relating to oil lease and drilling operations are presented.

PHASE II -- SHIP CRUISE REPORT

Sam W. Stoker

1: Resume of field operations as performed, 28 May - 10 June 1976

Activities directly involved with commencement of at-sea operations began 28 May with the departure for Anchorage of Mr. Stoker, chief scientist for shipboard operations. Upon arrival in Anchorage, Mr. Stoker took receipt of air freight sent from Fairbanks and of leased equipment (magnetometer probe and cable and Decca Trisponder navigation system}. Further equipment and supplies necessary to the operation were purchased in Anchorage, and arrangements were confirmed for the charter of a DC-3 aircraft for transport of gear and personnel from Anchorage to Dutch Harbor. Charter arrangements were conducted through Sea Airmotive, Inc., Anchorage, Alaska. On the evening of 28 May, Mr. Frietag and Dr. Sharma returned to Anchorage from Seattle, Washington, where they had attended instruction in the use of the side-scanning sonar to be used on this project. They had arranged for lease of this instrument in Seattle, and had air-freighted same to Anchorage, where it was received by Mr. Freitag. Mr. Stoker and Mr. Freitag remained in Anchorage overnight, while Dr. Sharma returned to Fairbanks.

On the morning of 29 May the remainder of the scientific party arrived in Anchorage from Fairbanks, and were joined at the airport by Stoker and Freitag, and by Civish and Brown of BLM, for departure to Dutch Harbor. The charter departed at 11:00 a.m., encountered mechanical difficulties, and returned to Anchorage at 2:00 p.m. All personnel were obliged to stay overnight in Anchorage while the plane was repaired.

On 30 May the charter departed at 9:00 a.m. with all personnel and equipment, arriving in Dutch Harbor at 1:30 p.m. Equipment end personnel were lightered to the R/V Acona from the airport that afternoon, but departure of the ship was delayed until the following morning due to inclement weather. The ship sailed from Dutch Harbor for St. George Island in the Pribilofs, at 10:00 a.m. on 31 May. Moderate to rough seas were encountered enroute, with winds from the south and southeast.

On 1 June the ship arrived at St. George and dropped anchor at approximately 8:00 a.m. in North Anchorage, in the lee of the island near the village of St. George. Mr. Stoker and Mr. Dixon went ashore by skiff to confirm permission from the village to undertake onshore operations and to arrange for shore transportation and assistance through Mr. Roger Gentry, N.M.F.S. Stoker and Dixon returned to the ship at 10:00 a.m. At 1:30 p.m. Stoker, Dixon, Short, and Brown went ashore again to establish radio navigation stations necessary to execution of the site survey as required by U.S.G.S. Operating Order 75-3.

Originally, the intention had been to survey the area to the east of St. George for selection of the required one square mile quadrant, the consensus being that this area was extremely favorable for human habitation sites prior to the last Wisconsin submergence. Due to deteriorating weather and sea conditions, however, it was decided that this original plan would have to be abandoned and that the survey would have to be conducted to the north of St. George, close inshore in the island's lee, in order to ensure fulfillment of the contract as specified. Strong winds and heavy seas from the south and southeast and forecasts for an extended period of the same, made it seem unlikely that operations could be conducted anywhere but in the island's lee within the time alloted. This decision was later justified by continued inclement weather.

Due to this change in operating plans, the two shore navigation stations now had to be established on the island's north shore rather than on the east as originally planned. U.S. Coast and Geodetic survey markers are located on this shore (U.S. Department of Commerce Provisional Chart #8995), and it was hoped that the radio navigation stations could be established on these markers for purposes of horizontal control. upon inspection of the terrain, however, it was apparent that this was in no way a feasible undertaking given the means and time available. Survey markers are in inaccessible locations distant from any road or trail systems, so that to set up stations on them would have required the expenditure of far more time and effort than was possible to allot. Consequently, the two shore stations were established on high ground near the ends of the trail systems to the east and west of the village of St. George (Fig. 5-3) so as to be visible from shipboard. These stations 'were not located on permanent geophysical markers; 'however, it was felt that the sacrifice of absolute horizontal control for the sake of fulfillment of the majority of the contract specifications was justified under these conditions. In any case, relative horizontal precision was maintained throughout the survey so that, if required, any desired point on the survey track could be relocated with reference to these stations.

After the two shore stations were set up, Stoker and Dixon returned to the ship at 4:30 p.m., leaving Brown and Short ashore to ensure the continued operation of the transmitters. The ship then weighed anchor and steamed offshore to test the radio reception from the shore navigation stations, which was excellent, and to rig and test the sonar, sub-bottom profiler, and magnetometer prior to selection of a survey site. After some operational difficulties, such as are generally encountered when using new techniques and equipment under such conditions, it was ascertained that all systems were operational and satisfactory. This rigging and testing took most of the night.

The following morning, 2 June, an area just north of St. George was selected for the one square mile survey site (Fig. 5-3] and a format was calculated for navigating the survey tracts as prescribed in the contract operating order (Appendix 1) . Since there was no absolute horizontal control of the two shore stations, relative control was achieved by measuring, with a sextant, the angle between the ship and both stations, which were line of sight from the ship. The point at which this angle was measured was then assumed as the southeast corner of the quadrant to be surveyed. Distances, in meters, which should be recieved on the ship from both stations in order to maintain the prescribed tracks were then calculated at 150 meter intervals and courses plotted to conform to these calculations. Though feasible to do, this method of rectilinear navigating proved very cumbersome and should be improved upon. More will be said about this matter later, in the recommendations section of the final report.

Once these navigational calculations were made and courses established, the acutal survey of the quadranti began at 1:00 p.m. As prescribed, parallel tracks were run at 150 meter intervals, with tracks at right angles to these through the center and along both -margins, and with two diagonals through the center (Figs. 5-1 & 5-2). For expedience and coordination of data, all three insturments were operated simultaneously along these tracks, the sonar and magnetometer by means of towed fish and the sub-bottom profiler from a fixed side-mount on the ship. Though problems and shortcomings were encountered in the operation of the sonar and sub-bottom profiler, which will be dealt with in the recommendations section, it is strongly felt that such simultaneous return from the various instruments employed greatly enhances interpretation of results. Despite minor difficulties it is believed that satisfactory results were obtained and that such surveys are very feasible, though modifications in gear and procedure might ease operational difficulties and enhance results. Suggestions for such modifications will be made in the final report.

The entire survey of this one-square mile tract required about nine hours steaming at the ship's minimum constant forward speed of 4 knots. Increased winds and seas from the south and southwest hampered efforts to some degree. At 10:00 p.m. the survey was completed, and the shore stations and personnel were returned aboard by 1:00 a.m. on 3 June.

Shortly after noon on 3 June the ship weighed anchor again from North Anchorage and steamed to the east of St. George Island where a brief reconnaissance of the area first selected as the survey site was attempted, the weather having abated somewhat for the interim. No shore survey stations were available for this reconnaissance? and since LORAN-C navigation was proving unreliable due to atmospheric effects,

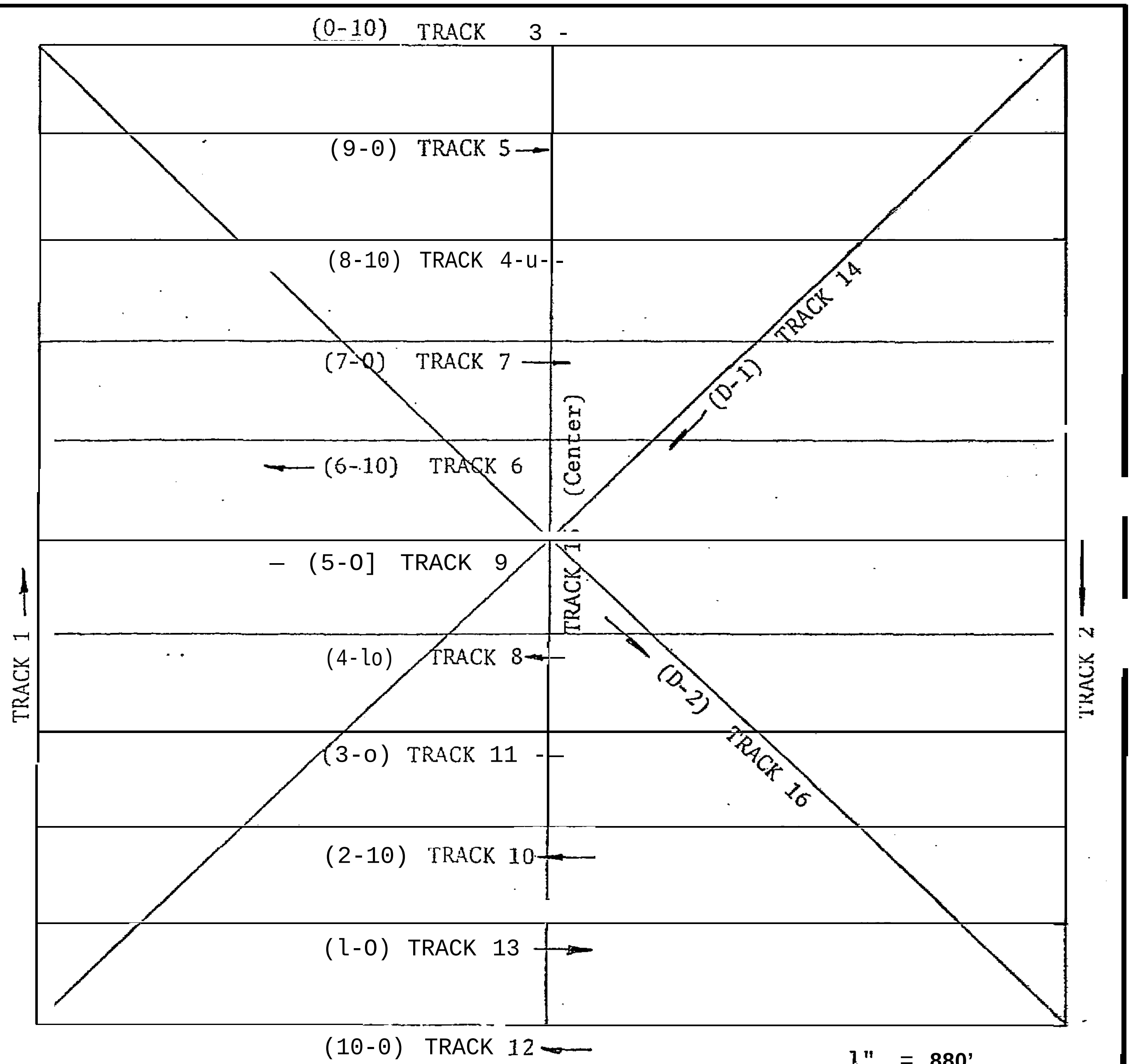


Fig.5-1. Square Mile Quadrant and Survey Tracks.

Survey tracks numbered according to sequence run. Vertical course 332°, horizontal course 242°. Courses referenced to True North.

	130	B1	132	B3	B4	135	B6	B7	B8	B9	B10	B11
A0	5631,226S	**5633,2419**	5639,2569	5649,2719	5663,2869	5681,3019	‘5702,3169	5728,3319	5757,3469	5791,3619	5827,3769	5868,3919
A1	5781,2274	5783,2424	5789,2573	5798,2723	5812,2873	5829,3023	5851,3173	5876,3322	5904,3472	5937,3622	5972, 3772	6012,3922
A2	5931,2289	5933,2438	**5939,2586**	**5948,2736**	5961,2885	5978,3034	5999,3183	6023,3333	6051, 3482	6083,3631	6118,3781	6156, 3930
A3	6081,2313	6083,2461	6088,2608	**6098,2756**	6111,2904	6127,3052	6147,3201	6171,3349	6198, 3498	6229,3647	6263,3796	6301, 3945
A4	6231,2347	6233,2492	6238,2638	**6247,2784**	**6260,2931**	6276,3078	6296,**3225**	6319,3373	6345,3521	6376,3668	6409, 3816	6446,3965
A5	6381,2390	**6383,2533**	**6388,2676**	6397,2821	6409,2965	6425,3111	6444,3257	**6467,3403**	**6493,3549**	**6522,3696**	**6555,3843**	**6591,3990**
A6	6531,2441	**6533,2581**	**6538,2722**	6546,2864	**6559,3007**	**6574,3150**	6593,3294	**6615,3439**	6640,3584	**6669,3729**	**6701,3875**	6736,4021
A7	**6681,2500**	**6683,2637**	**6688,2775**	**6696,2915**	**6708, 3055’**	**6723,3196**	**6741,3338**	**6763,3481**	**6788,3624**	**6816,3768**	**6847**, 3913	6882,4057
A8	**6831,2567**	**6833,2700**	6838,2835	6846,2972	**6857,3110**	**(6872,3249**	**6890,3389**	**6911,3529**	**6936,3671/**	**6963,3813**	**6994,3955**	**7027,4099**
A9	6931,2640	**6983,2770**	6987,2902	6995,3036	7007,3171	7021,3307	7039,3445	7060,3583	7083,3722	7110,N363	7140,4003	7173,4145
A10	**7131,2720**	**7133,2846**	7137,2975	7145,3105	7156,3237	7170,3371	7188,3506	7208,3642	7231,3779	7258,3918	7287,4057	7319,4196
A11	7281,2806	7283,2928	7287,3053	7295,3180	7306,3310	7320,3440	7336,3$73	7356,3707	7379,3841	7405,3977	7434,4114	7466,4252

Fig. **5-2.** Distance (meters) from shore control stations at navigation checkpoints along survey tracks. First distance in each pair is from westernmost station. Checkpoint B0 is initial reading. Line B0 - B11 is Track 1.

absolute horizontal control was not possible. One long track was run using sonar, magnetometer, and sub-bottom profiler along a submarine rise extending to the east of the island, from depths of 10 to 50 fathoms. Though results were inconclusive, it appears that this area may indeed be of prime interest for the location of submerged human habitation sites. By evening the weather was worsening once more and, given the time restraints placed on the ship, it was decided to break off further work and sail for Dutch Harbor.

The ship arrived in Dutch Harbor at 7:00 a.m. on 5 June after a very rough passage with seas to 30 feet out of the southeast. BLM personnel and all of the scientific party, with the exception of Stoker, disembarked at Dutch Harbor for return by air to Fairbanks. Mr. Stoker remained aboard for the return to Seward in order to see to the return of supplies and equipment.

The ship arrived in Seward at 11:00 a.m. on 8 June, after a smooth passage from Dutch Harbor. The following morning, 9 June, all equipment and supplies related to this project were off-loaded. Gear and equipment to be returned to Fairbanks was transported from Seward by Institute of Marine Science vehicle. The leased equipment (sonar, magnetometer probe and cable, survey system) was trucked by hr. Stoker to Anchorage, from where it was returned air freight to points of origin. Mr. Stoker overnighted in Anchorage, returning to Fairbanks by air on 10 June.

Sam W. Stoker Chief Scientist

28 May	To Anchorage (with excess baggage) 7 am, Alaska Fit. 092 Pick up additional equipment and supplies. Meet Freitag (reservations at Anchorage Westward) 272-7411
29 May	Charter DC-3 Anchorage to Dutch Harbor Sea Airmotive Anchorage 277-0522
29 May - 10 June	R.V. Acona - University of Alaska (IMS Research Vessel) - TO SEWARD Radio Phone: Call Seward IMS Station (Dolly Deiter) 224-5261 or Marine Operator (Nome) RCA or Coast Guard (in case o-f dire emergency)
10 June - 14 June	Return from Seward to Fairbanks via Anchorage on University truck

James Dixon Archeologist

29 May To Anchorage (7 am)
Alaska Fit. 092

Charter DC-3 Anchorage to Dutch Harbor

Sea Airmotive
Anchorage
277-0522

29 May -
7 June R.V. Acona - University of Alaska (Inst. of Marine Science]
Research Vessel

Radio Phone:
Call Seward IMS station (Dolly Deiter)
224-5261

or Marine Operator (Nome) RCA

or Coast Guard (in case of dire emergency)

7 June Dutch Harbor to Anchorage via

Winship Air 'Service charter
Volpar Turboliner 600 WA

7 June -
9 June Anchorage Westward Hotel 272-7411

9 June Return to Fairbanks

G. J). Sharma Geologist

*

25 May To Seattle to pick up equipment

28 May Return to Fairbanks

29 May To Anchorage (7 am)
Alaska Fit. 092

charter DC-3 Anchorage to Dutch Harbor

Sea Arimotive
Anchorage
277-0522

29 May -
7 June R.V. Acona - University of Alaska (IMS Research Vessel]

Radio Phone:

Call Seward IMS Station (Dolly Deiter)
224-5261

or Marine Operator (Nome) RCA

or Coast Guard (in case of dire emergency)

7 June Dutch Harbor to Anchorage

Winship Air Service charter
Volpar Turboliner 600 WA

Open return to Fairbanks

Robert Spies   Electronics Technician

29 May   To Anchorage 7 am
Alaska Fit. 092

DC-3 Charter Anchorage to Dutch Harbor

Sea Airmotive
Anchorage
277-0522

29 May -
7 June   R.V. Acona - University of Alaska IMS Research Vessel

Radio Phone:

Call Seward IMS Station (Dolly Deiter)
224-5261

or Marine Operator (Nome) RCA

or Coast Guard (in case of dire emergency)

7 June   From Dutch Harbor to Fairbanks via Anchorage

Winship Air Service charter
Volpar Turboliner 600 WA

Open return to Fairbanks

Gary Freitag Research Assistant

25 May Fairbanks to Seattle to pick up equipment

28 May To Anchorage with 200 lbs. excess baggage (equip.}

Meets Stoker in Anchorage
Reservations at Anchorage Westward for 3 for 2 days
272-7411

29 May Charter DC-3 Anchorage to Dutch Harbor

Sea Airmotive
Anchorage
277-0522

29 May -
7 June R.V. Acona - University of Alaska (IMS Research Vessel)

Radio Phone:

Call Seward IMS Station (Dolly Deiter)
224-5261

or Marine Operator (Nome) RCA

or Coast Guard (in case of dire emergency)

7 June Dutch Harbor to Anchorage

Winship Air Service charter
Volpar Turboliner 600 WA

Open return to Fairbanks

MARINE ARCHEOLOGICAL SURVEY

E. James Dixon, Jr.

The marine archeological survey was executed by a University of Alaska research team onboard the R.V. Acona, the University of Alaska's research vessel, during the period of May 30 to June 5, 1976. A high probability area south of the Pribilof Islands was selected as the target area for the marine archeological survey. Unfortunately, adverse weather conditions made an examination of this area impossible. Consequently, an area on the northeast side of St. George Island was selected in order to permit use of the geophysical instruments essential for the survey, i.e., sub-bottom profiler, side-scan sonar, and magnetometer. A more complete description of the logistics and personnel activities may be found in Stoker's ship cruise report.

The marine archeological survey is an extension of the Phase I research. Together they provide four "levels" of spatial analysis: continental, regional, sectional and high probability loci. These types of spatial analysis are defined as follows:

Continental -- consists of a reconstruction of the paleogeography of Beringia (the outer continental shelf stretching between Asia and North America, presently the floors of the Bering and Chukchi Seas) and adjacent terrestrial areas.

Regional -- an analysis of specific areas within Beringia, including probable seasonal distributional patterns of terrestrial and marine mammal populations. Maps generated for these areas, at a scale of 1:250,000 are analogous--but not idential to--U.S.G.S. quadrangles.

Sectional -- A one square mile area equivalent to (but not the same as) a U.S.G.S. Section.

High probability loci -- locations within the one square mile area suitable for the location of former human habitation sites.

Thus, Phase I may be viewed as a combination of both continental and regional spatial analysis, and Phase II as a combination of both sectional and high probability loci. In short, Phase I tells us on a continental basis what regions are more likely to contain prehistoric archeological remains and Phase II tells us what specific locales, within a one square mile survey area, are most likely to contain evidence of former human habitation and land use.

Fig. 5-3 depicts the location of the marine archeological survey executed by the University Museum research team. Strong winds and heavy seas from the south and southeast made it impossible to conduct the survey on the south side of the Island, for comparatively calm conditions are essential for proper operation of all of the geophysical instruments utilized in the survey. Once it was realized that it would be impossible to execute the survey on the south side of St. George Island as was originally planned, a field decision had to be made either to select an area on the lee, i.e. north, side of the island or to abandon the survey. Recognizing that this was not a high probability area, the decision was made to survey the north side of the Island. Thus the model was tested for a medium probability area. In addition, the geophysical instruments employed were tested for their feasibility in detecting submerged archeological sites on the outer continental shelf under sub-arctic conditions.

Through inspection of bathymetric charts, a prominent submerged feature was identified. At some time in the past, this geologic

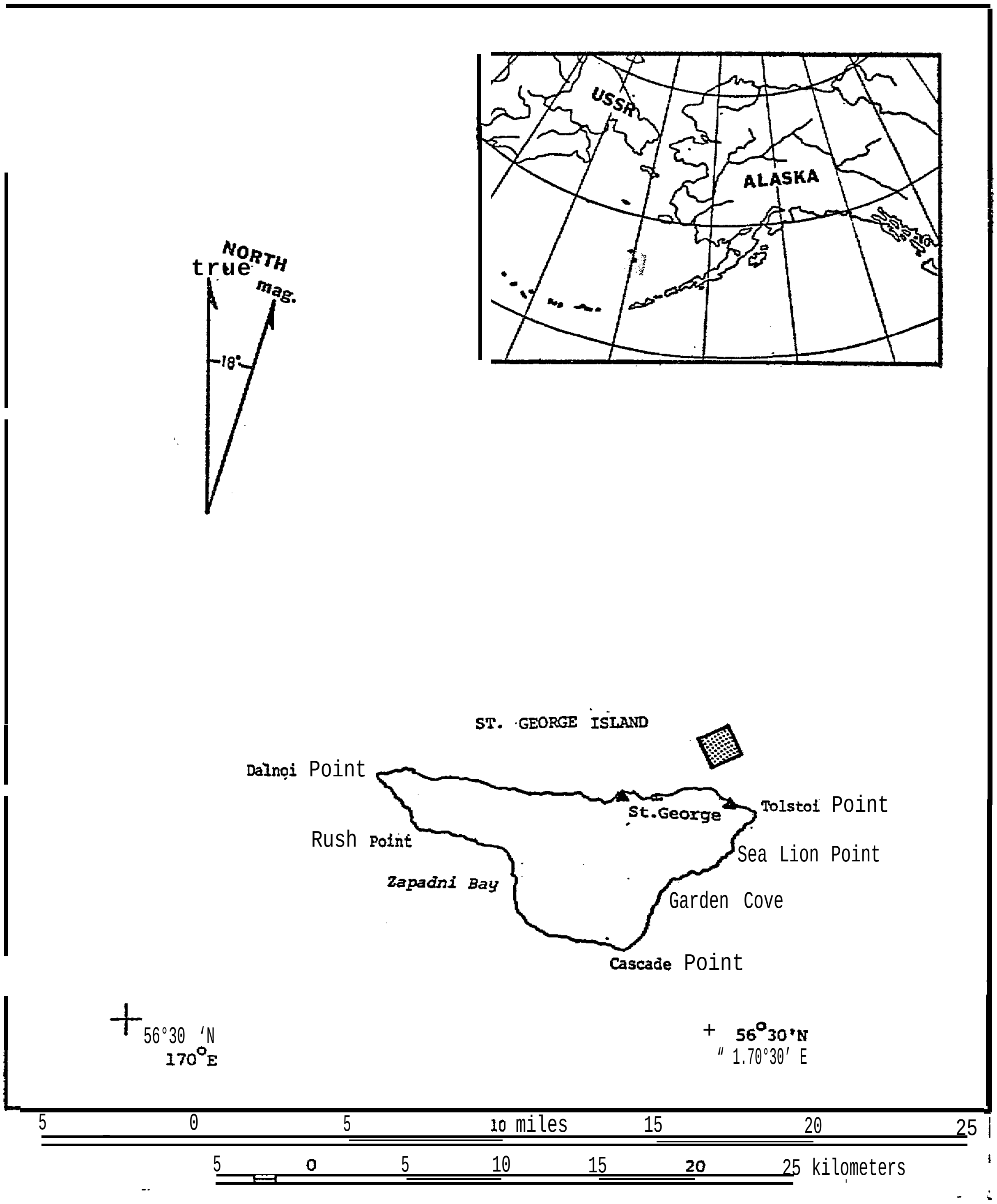


Fig. 5-3. St. George Island and survey site location (▩). Survey site one square mile. Shore stations indicated by triangles.

feature was a point jutting northeastward from St. George Island during a period of sea level rise. According to the reconstruction in the Phase I report, this area was not inundated until sometime after 22,000 B.P. and was probably completely submerged by 16,000 B.P. A one square mile area encompassing this prominent feature was selected for the marine archeological survey.

There are several reasons why this area was not expected to reveal archeological sites. Quite probably the economic focus for any human population occupying this area would be marine subsistence. However, our preliminary analysis strongly indicated that adjacent areas to the south during this time period would have been far more favorable locales for this subsistence pursuit and would have tended to draw local populations in that direction. Furthermore, as stated earlier in Phase I, there is no direct evidence to support marine-oriented subsistence strategies in the North American Arctic prior to the occupation of the Anangula site, ca. 8,160 B.P. According to Guthrie (this report) there is little" indication that the north side of St. George Island would hold any great potential for funneling terrestrial mammal populations into specific locales suitable for ambush, although he has defined the southern slopes of the island and the adjacent continental shelf as probable areas of spring and early summer range concentration for grazing mammals. Phase I developed the hypothesis that submerged archeological sites on the outer continental shelf which are most likely to be detected are winter settlements which would have required a substantial alteration of the natural environment. These settlements require autumn surplus in the net energy harvest which could be supplemented through winter harvests of other species. The survey area does not meet these requirements. Thus, a medium to low probability area was tested. According to our ranking system, it would not be likely that an archeological site would be detected in such an area. None were found.

The marine archeological survey of a one square mile area (the equivalent of a standard lease block} was executed utilizing a hull-mounted sub-bottom profiler (Raytheon, portable survey system, Model RTT-1000 A), Klein side-scan sonar (dual channel recorder, Model 401 with Model 402 towfish), and Raytheon transducer (Model TC-7), and proton magnetometer (Geometries, Airborne Model G 803). In addition, on-shore radio navigation stations were established at prominent locations on St. George Island to achieve navigational accuracy required (± 50 ft.) to meet contractual requirements. A Decca Trisponder (range 100 m to 80 km, range accuracy ±3 m when maintaining an angle of 30° or greater) was utilized.

With the navigational aids previously described, the survey was executed aboard R/V ACONA at its minimum constant forward speed (4 knots) by running parallel tracks at 150 m intervals across the survey area. All three instruments were run simultaneously during the survey, and the scales of both the sub-bottom profile and the side scan chart recorders were set to 1.5 in. per minute so that the data strips would be compatible and thus facilitate the analysis. 150 m intervals for each run were more than adequate to provide overlap between successive runs and complete side scan coverage of the entire survey area was achieved.

During the course of the survey each instrument was visually monitored and no anomolies which could not be attributed to natural agents were noted at that time. If any such anomolies had been noted during the course of the survey, the researchers would have considered coring the anomoly or taking a grab sample. Following the survey, the chart records were transported to the University of Alaska Museum where the final analysis was conducted. Each individual chart strip was examined more thoroughly upon return to the University and no anomolies were noted in any of the records.

The sub-bottom profile records clearly indicate that the ocean floor in the survey area consists of fairly reflective deposits. Penetration into the sediment was minimal, thus indicating *reflective* materials. A closer examination of the side-scan records depicts a prominent land form which has been interpreted as a lava flow. *This* interpretation is consistent with the known geologic history of the Pribilof area. The lava tongue flowed seaward from the island as is evident from the bathymetric map, Fig. 5-4 , of the survey area and it can readily be noted that elevation decreases seaward from the source of the flow. Stoker's analysis of the magnetometer data indicates that this flow may have occurred sometime prior to the Late Wisconsin sea level rise. Areas of relatively low relief appear to have been filled with sand as is evident in track record 14 from the side-scan sonar records. Sand ripples on the ocean floor can be noted in this record. Further supporting the deposition of sands in these areas of low relief is the poor penetration achieved by the sub-bottom profiler. In other areas of the Alaskan Shelf good penetration has been achieved sing this same sub-bottom profiler, where the sediment structure consists largely of silts and similar fine-

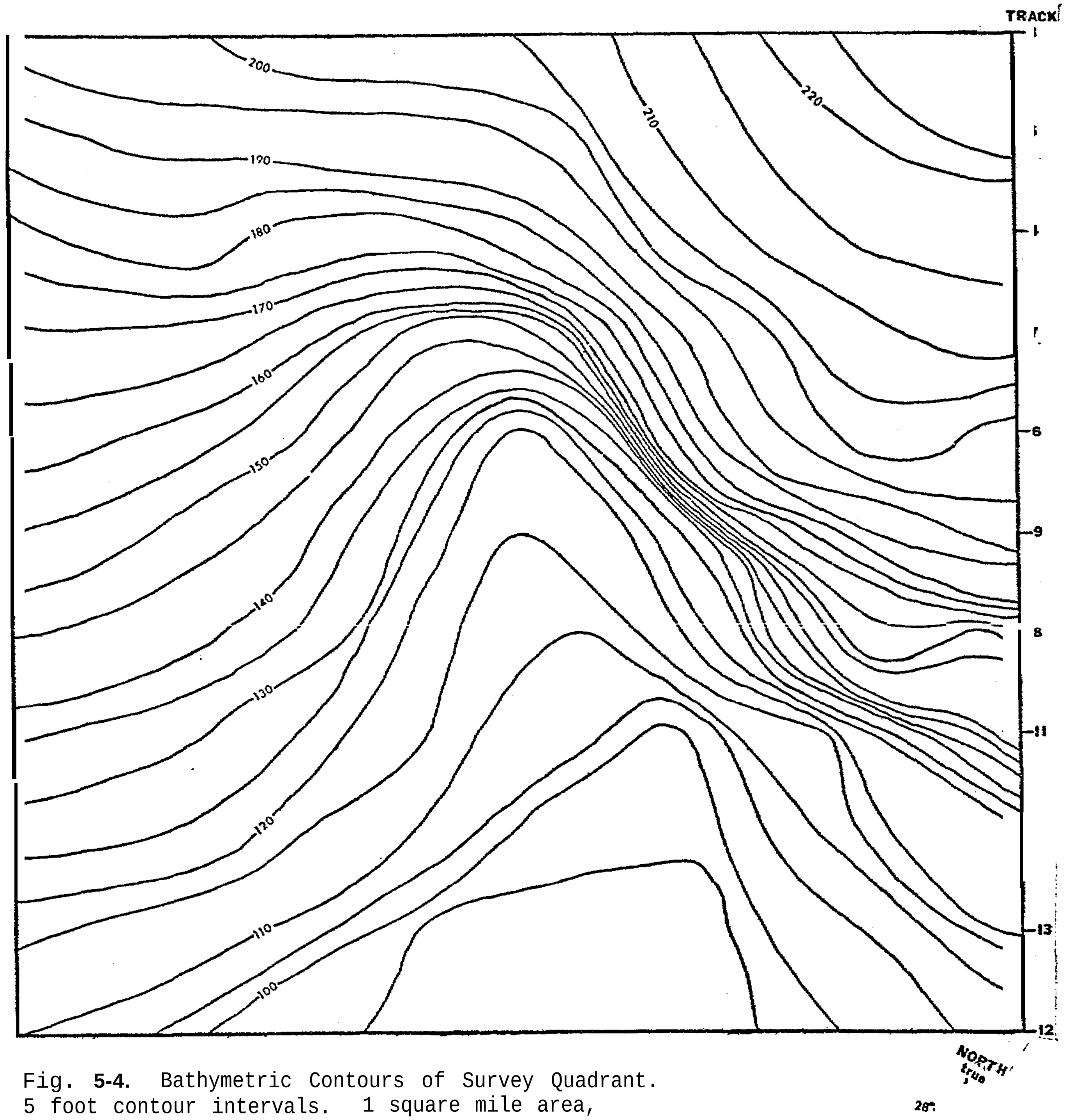


Fig. **5-4.** Bathymetric Contours of Survey Quadrant.
5 foot contour intervals. 1 square mile area,

grained material. The poor penetration realized from the sub-bottom profile records is attributed to surficial deposits, i.e., lava and sand. Fig. 5-5 shows the side-scan records which depict rock"outcrops" with intervening areas being filled by what is here interpreted as sand. What are most probably sand ripples have been noted near the end of run 14, although reduction necessary to incorporate side-scan sonar records in this presentation would make them almost illegible.

Side-scan sonar records of the overlapping passes of the R/V ACONA were synthesized into a photo mosiac which delineates the major bottom features and visually portrays the general topography of the survey area. The photo mosaic facilitates interpretation on a sectional level. Coupled with the geologic history of the area, it aids in further delineation of high probability areas within the survey area and also articulates with the larger scale probability modeling of the outer continental shelf. Although the photo mosaic provides a useful tool at this level of analysis, it cannot be over-stressed that it is no substitute for the original records. However, it can provide a useful tool which permits one to focus special and thorough attention to analysis of chart records on specific high probability areas within a survey block.

As a supplemental aid for this level of interpretation, a topographic contour map (Fig. 5-4) has been prepared from the sub-bottom profile records. This map has been extremely useful in relating to phenomena such as comparatively stable beach lines during periods of sea level rise. Although sub-bottom profile data was used to generate the topographic map, a bathymetric sounder with chart recorder would a

b

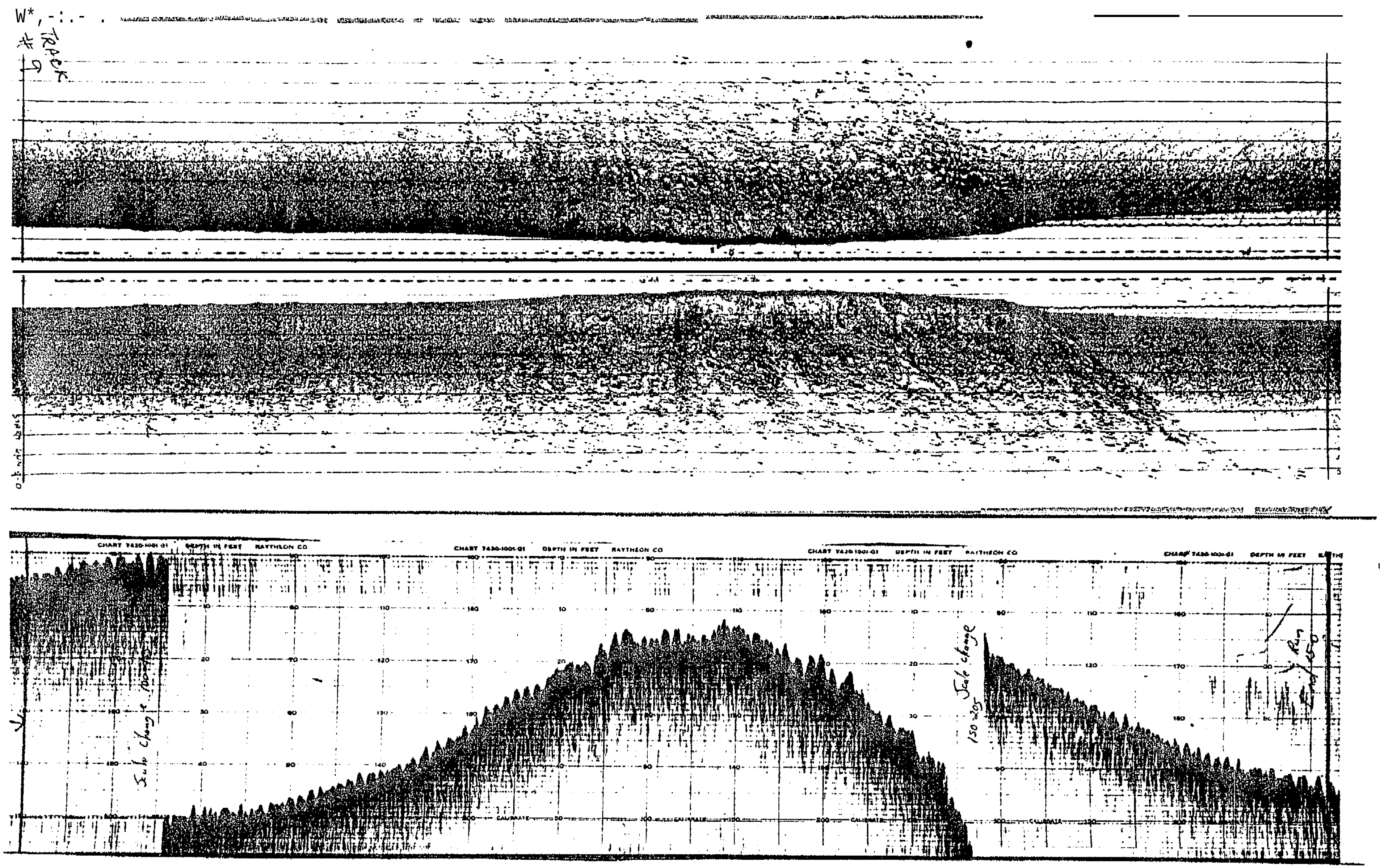


Fig. 5-5. Side-scan sonar (a) and sub-bottom profile (b) records - Track 9.

serve this purpose better. Our experience suggests that, if at all possible, the sub-bottom 'profiler should not be hull-mounted, for the rocking motion of the ship in response to wave action creates dips and peaks in the corresponding chart records.

The magnetometer records have also been contoured in a similar fashion to the sub-bottom profile records. This technique serves to lend interpretative strength at the section level of analysis by aiding in delineating geomorphic features such as lava flows, moraines quarried from igneous rock, winnowed sands, etc. The magnetometer may also assist in establishing minimum limiting dates for some geologic features through paleomagnetic dating. The effectiveness of magnetometer surveys in detecting historic site remains such as ship wrecks, in other study areas, has already been demonstrated.

Three analytical methods have been developed for sectional analysis: (1) photo mosaic of the side-scan sonar records, (2) contour map of the bathymetric data, and (3) contour map of the geomagnetic data. These three analytical tools facilitate analysis for locating high probability locales within the one square mile survey area. A cautionary note is warranted. These three analytical tools may be of little use in areas characterized by uniform topography, sediment structure, and little magnetic variation. In addition, it cannot be overstressed that none are a substitute for thorough examination of the original chart records in attempting to locate evidence of former human habitation.

The final analytical stage consisted of a detailed review of the chart records from all three instruments, which bore particular focus on loci within the survey area which demonstrated particular topographic characteristics which were considered of higher archeological site potential than other areas. Data quality was checked by comparing data from both the side-scan sonar and sub-bottom profiler to determine if specific features interpreted from the records could or could not be verified by the records of the other instruments. Through interplay and interpretation of these two instruments, with a constant eye on data quality, loci of higher probability than surrounding areas were thoroughly examined- No anomolies which could possibly be interpreted as evidence of former human habitation or ship *wrecks* were discovered.

MAGNETOMETER RESULTS

Sam W. Stoker

Upon completion of the magnetometer survey as described in the Resumé of Field Operations section of this report, the magnetometer chart graph was returned to Fairbanks for analysis. At the University of Alaska, Fairbanks, a grid was drafted representing the one square mile survey tract, with data points the equivalent of every .1 mile along each of the horizontal, vertical, and transverse survey lines. Values as interpreted from the magnetometer chart were then transferred to appropriate data points, and iso-magnetic contours drawn in with 100 gamma contour intervals (Fig.5-6). Contour lines are, of course, open to interpretation.

The results of this contouring indicate an alternating sequence of total field intensity high/low values aligning along the general N-S magnetic axis. As may be seen in Fig. 5-6, there is a high of 1600-1800 gammas in the southwest corner, followed by a low of 100 gammas in the center of the tract, followed by a succeeding high of 1600 gammas in the northeast corner. Apparently, the central low and northeast high reflect the structural bathymetry as evidenced in Fig. 5-6 , with magnetometer values being influenced both by the mass of the substrate formation and by the changing water depth. As is apparent from overlaying the magnetometer and bathymetric charts, the steep magnetic contours between the central low and northeast high line up approximately with bathymetric contours along the leading edge of the bathymetric formation.

Indications are that this bathymetric formation is an ancient lava flow of reverse polarity, probably exceeding 300,000 years in age

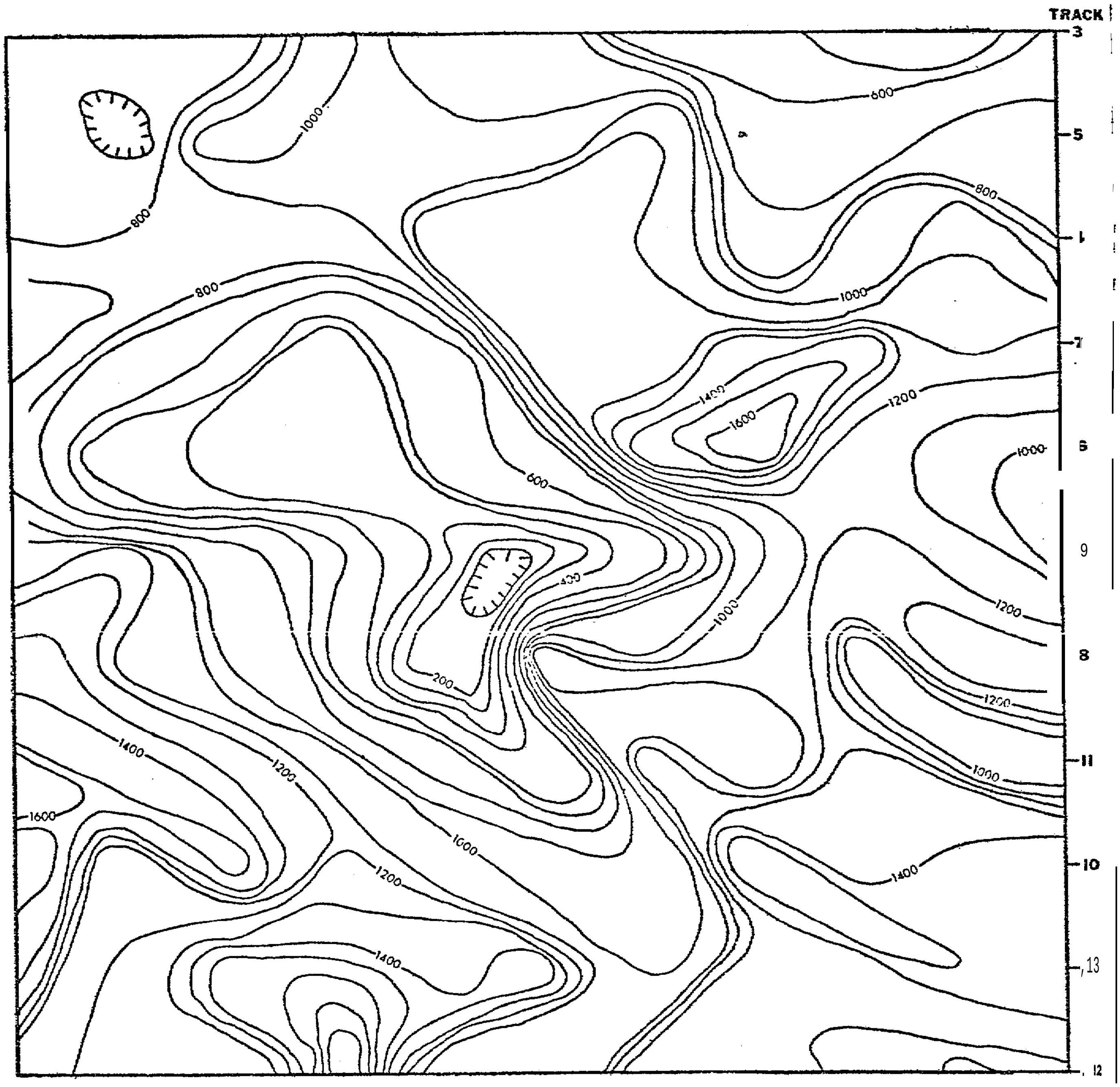
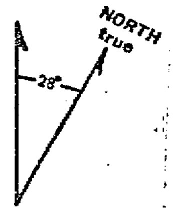


Fig. 5-6. Total Field Intensity Geomagnetic Contours-. 100 Gamma contour interval. 1 square mile area.



(personal communication with Dr. David Stone, Geophysical Institute, University of Alaska). The high in the southwest corner of the quadrant is partly a reflection of the shallowing depth, although it may also indicate a successive lava flow near the edge of the survey grid in that corner.

No magnetic anomalies appeared which might indicate sunken ships or other historic cultural resources.

RECOMMENDATIONS FOR PROCEDURE AND EQUIPMENT TO BE EMPLOYED

Based on the experience gained through this survey it seems justifiable to say that, with some modifications, investigations of this type are feasible to perform in the Bering and Chukchi Seas and possess potential for positive results in the area of marine survey archeology. Recommendations for modifications in procedure and equipment apply to navigation requirements, sub-bottom profiler usage, side-scanning sonar methods, and magnetometer usage. Each of these topics will be discussed separately.

(1) Navigation

No presently established system of navigation covering the Bering Sea, much less the Chukchi, permits the accuracy necessary for surveys of this type. In the Bering Sea, Loran-C coverage is available over all of the continental shelf, but permits accuracy, in general, of no better than one-half mile. Satellite navigation is also available, but permits accuracy of only one-quarter mile, with fixes every 90 minutes. In the Chukchi Sea, only satellite navigation is available. For surveys requiring greater accuracy, such as the type under discussion here, some alternate system using shore-based transmitting stations is essential. Sufficient accuracy can be obtained through multiple fixes with the satellite navigator, but such a procedure would be so cumbersome and time-consuming as to be almost out of the question.

The system used for this surrey, Decca Trisponder, permitted 3 meter accuracy at a range of up to 80 km, and was found to be convenient to use and highly satisfactory in all respects. For much of the Bering/ Chukchi shelf, however, this range would not be sufficient, necessitating a more powerful system such as the Decca Hi-Fix/6, with a range of 300 km. Even this range, in some areas, would not be sufficient. Cost of equipment and effort of installation increases greatly with output power demanded.

Also, for most of the coastal area and islands in the Bering/ Chukchi there are not sufficient geophysical markers for convenient location of these transmitters. In such cases, it would seem reasonable to sacrifice absolute accuracy for relative accuracy, to establish the transmitters on relocatable monuments set up for that purpose even though such monuments may not be referenced to geophysical markers of known absolute position. This practice was undertaken for the study just completed, the feeling being that what is required for surveys of this nature is an ability to relocate any specific bottom feature, not absolute positioning. However, if this method is adopted, description of the location of shore stations should accompany the survey report. In addition, the location of shore stations should be marked in the field with an appropriate reference point such as a metal survey marker.

It may be that absolutely rectangular survey grids are not the most efficient method of conducting the field surveys. When positioning by means of shore-based transmitters, it is often more efficient to hold the survey course at a constant distance from one of the transmitters. This would result in curved tracts, the degree of curvature dependent on the distance from one of the transmitters, but would result in no sacrifice of accuracy or coverage providing the spacing of each tract is close enough to ensure overlapping side-scan coverage. such procedure would have the advantage of dispensing with complicated course and distance calculations and would greatly simplify procedure in general, particularly when operating off temporary monuments of uncertain absolute position. However, this technique could make analysis of the records more difficult. For example, a curved track would create greater side-scan coverage on the outside of each track than on the inside. Also, it would not provide the reverse image of the same object(s) recorded on the next consecutive survey track. Generation of such analytical aids as contour maps and photo mosaics could prove extremely time-consuming. If this survey technique were employed, it might greatly facilitate field survey, but on the other hand could greatly complicate analysis of the records.

(2) Sub-Bottom Profiler

Several problems and shortcomings were encountered with the acoustic sub-bottom profiler used in this survey, some of which were due to the type of instrument and mounting used and some of which were due to substrate encountered.

The instrument used for this survey was of relatively low power and was side-mounted on the ship. Due to the rolling motion of the ship, this side-mounting practice was Discovered to be a disadvantage, resulting in oscillations on the graph corresponding to the ship's motion. This does not seriously impair results, but it is an inconvenience. It is recommended, therefore, that future operations be conducted with the transducer mounted on the keel to minimize the ship's motion effect or, better yet, towed astern. In addition, the substrate encountered (probably coarse sand) was of such reflectivity as to prevent desirable acoustic penetration. An instrument of increased power might overcome this problem, though it is recognized that acoustic penetration difficulties are encountered over much of the Bering Shelf (personal communication with Hans Nelson, U.S.G.S., Menlo Park, California] . This instrument has performed quite capably in areas of less reflective substrate.

Sharma (personal communication) has indicated that possibly 90% of the floors of the Bering and Chukchi Seas are covered by sand, thus posing the problem that highly reflective sediments will be encountered in most marine archeological surveys on the outer continental shelf. Consequently, penetration by most commercial instruments will be poor. Sharma has further indicated, however, that some private companies have developed instruments of higher resolution capable of penetrating sand and defining subsurface anomalous sand bodies. We are aware that the technology employed in marine archeological surveys is in its infancy and rapid developments are taking place which will, in the near future, greatly increase the capability of these geophysical instruments. Consequently, the industry should demonstrate "state of the art" capability in conducting marine archeological surveys, for rapid technological change will soon make the specific instruments used in 'ibis study obsolete.

(3) Side-scanning Sonar

The sonar performed very well after some initial difficulties. The main problem encountered was keeping the fish depressed and at constant distance from the bottom at minimum ship's forward speed of four knots. For surveys of this nature, particularly when conducted over uneven bottom, it would be very desirable to use a sonar fish which has constant depth monitoring and control.

(4) Chart Speed

It is recommended that the chart speed of both the side-scan and sub-bottom profile chart recorders have identical settings. This greatly facilitates analysis, for it negates the need to convert one record to be compatible with the other. A chart speed of 1.5 inches per minute was used for this survey and was found to be quite adequate.

(5) Magnetometer

The only recommendation regarding the magnetometer applies to its usage. It is felt that submerged aboriginal sites in this area would not provide any magnetic anomaly sufficient to register on the instrument. However, the magnetometer has demonstrated its usefulness in other study areas (the Gulf of Mexico) by detecting comparatively recent historic cultural resources, i.e., shipwrecks. For this reason alone, the magnetometer should be retained as an integral part of marine archeological surveys. As has been demonstrated in 'this report, it may also be useful in paleogeographic reconstruction and paleomagnetic dating.

General Comments

When conducting surveys such as that just completed, using magnetometer, side-scanning sonar, and sub-bottom profiler, it is recommended that all instruments be operated simultaneously along the survey tracts for purposes of correlation of results. Ships utilized should have towing and rigging capabilities compatible to such activities.

It should be kept in mind when working at sea in the Bering/ Chukchi that this is an area notorious for bad weather, poor visibility , strong winds and currents, and sudden storms, all of which serve to decrease efficiency complicate navigational difficulties, and increase the amount of time necessary to accomplish desired objectives. Any ship used in this area should be of sufficient size and capability to withstand predictable storms, should be highly maneuverable in order to accomplish the required navigational feats, and should be capable of maintaining herself at sea for extended periods. All of the continental shelf on the Bering and Chukchi is subject, in addition, to seasonal pack ice and is unworkable by all but ice-reinforced vessels from October through early June.

Appendix II (Recommended minimum Survey Requirements to Protect Cultural Resources on the Alaska OCS) represents a modified and slightly altered document drafted by the National Park Service (after receiving input from representatives of private industry, BLM OCS officials, and members of the Society of Professional Archeologists) during a week long meeting held in Austin, Texas, during the summer of 1976. It represents professional consensus as to what levels of data quality and professional standards are necessary to insure that marine archeological surveys, analysis, and report generation are meaningful endeavors which achieve the objectives expressed in regulations which require them.

Cultural resource survey stipulations become meaningless if the quality of the data secured from the survey is so poor that accurate interpretation is impossible. If the professional standards of the archeologist analyzing the records are so low that the presence of anomalies are overlooked, the survey effort is wasted. In addition; there exists an inherent danger in the analysis of marine archeological survey data that the archeologist responsible for analysis may, in a desire to avoid conflict or through fear of the loss of future “business”, may be inclined to ignore possible anomalies or poor data quality. It is conceivable that, if archeologists analyzing chart records are paid on a fixed fee basis, they may tend to hurry through analysis in an effort to increase their income with less expenditure of time. Although we are not aware that this has occurred in the past, it is quite possible that as the tempo of OCS development increases this problem may become very real. Hence, it is appropriate and timely that regulations similar to those outlined in Appendix II be implemented for marine archeological surveys.

Areas Recommended for Survey

The discovery of any submerged aboriginal archeological site on the Alaskan outer continental shelf would be a breakthrough of **profound** scientific significance. Such a discovery would require a rethinking of the prehistory of North America and could quite possibly necessitate a restructuring of global prehistory, depending on the age and location of the discovery. There can be little question that such significant cultural resources should be preserved for professional scientific investigation. Marine archeological surveys are feasible for the Alaskan outer continental shelf.

Based on the experience of this study, the attempt to document Pleistocene-age archeological sites on the outer continental shelf is an extremely difficult and time-consuming task. The effort, danger and expense required to undertake such surveys are considerable. To initiate a marine archeological survey in every lease area in the Bering and Chukchi Seas is unrealistic, for in most areas the probability of encountering submerged archeological sites is extremely low. However, there are a few areas of extremely high probability which warrant the effort required of a marine survey and it is recommended that marine archeological surveys be conducted in high probability areas on the outer continental shelf. High probability area maps are included in the Appendix.

TERRESTRIAL ARC-GEOLOGICAL SURVEY OF ST. MATTHEW ISLAND

E. James Dixon, Jr.

An archeological survey of St. Matthew Island was executed July 23 through July 31, 1976. The Island was selected as a test area based on a number of considerations. The St. Matthew area had received a very high probability rating during the Phase I analysis. In addition, according to what little historical information is available for the Island, it has received little human activity during historic times. It was felt that this fact would greatly enhance our ability to detect early man sites, for archeological remains from later periods would be minimal--thus not masking earlier cultural remains. At the time of Russian contact, the Island was uninhabited. Finally, it was felt that because no archeological survey of St. Matthew had ever been conducted, any discoveries on the Island would, in themselves, provide a significant contribution to the scientific community.

On July 18 the field party attempted to reach the Island in a Super-Widgeon, a twin-engine amphibious aircraft, but heavy fog did not permit a landing. Although Pinnacle Island was sighted through the fog, St. Matthew itself remained obscured. The aircraft remained in the vicinity of the island for approximately one hour hoping to find a hole in the fog and achieve a landing. Anxiety over the fuel supply as well as the gnawing fear that much of St. Matthew's coastline consisted of thousand-foot cliffs rising directly out of the ocean, resulted in a unamious decision to return to Nunivak Island and wait for a change in weather conditions. The field party was weathered in on Nunivak Island between July 18 and July 23.

The second attempt to reach the Island on July 23 was successful and the Super-Widgeon set down on Big Lake, located on the east central side of the Island, and a base camp was established near its margin. The field party divided into three separate survey groups. Guthrie and Morris surveyed an area north of the base camp, while Stoker surveyed to the south. Bacon and Dixon surveyed the large central valley which dissected the Island from east to west. All parties departed the base camp on the morning of July 24 with the understanding that such areas as natural lookouts, possible interception locations which might have been advantageous in hunting terrestrial animals, caves, rock shelters, lithic outcrops suitable for tool manufacture, and natural exposures such as stream or beach cuts and blowouts were to be given special attention. It was felt that habitation sites situated along the coast would postdate sea level stabilization and thus be too recent to be applicable to the test which the survey area was designed to fulfill. However, it was also recognized that marine erosion of Quaternary sediments along the coast might provide natural exposures suitable to our survey interests.

Stoker's and Guthrie's reports precedeand there is no need to reiterate information included therein. Figures 6-1 and 6-2 depict the survey route selected by Dixon, Bacon and Stoker as best as is possible at a scale of 1:250,000, which is the only map scale available for the Island. Figure 6-3 illustrates the test pit locations.

Survey conditions were poor for, comparatively speaking, the

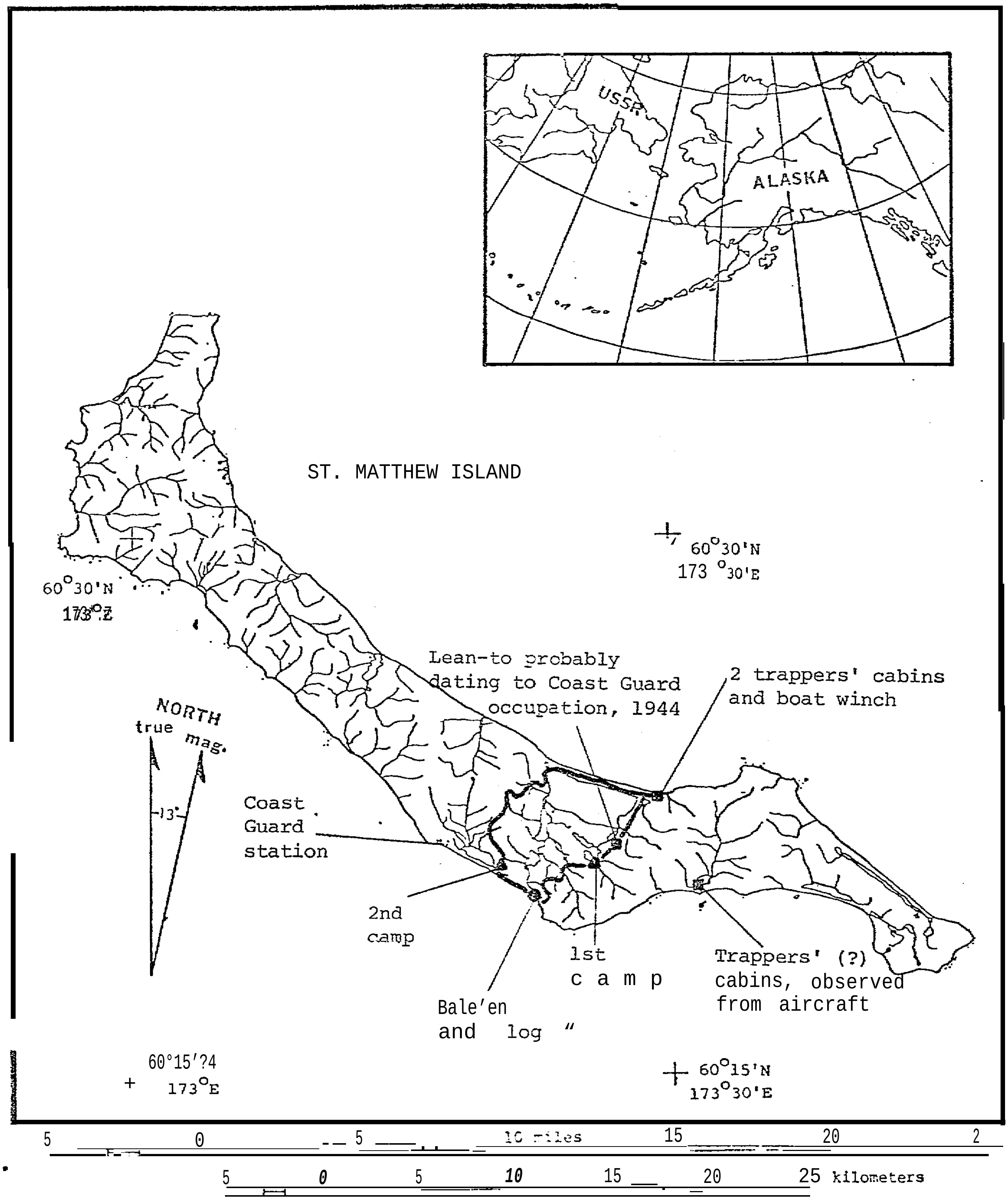


Fig. 6-1. Dixon and Bacon Survey Route Map depicting camps and historic site locations.

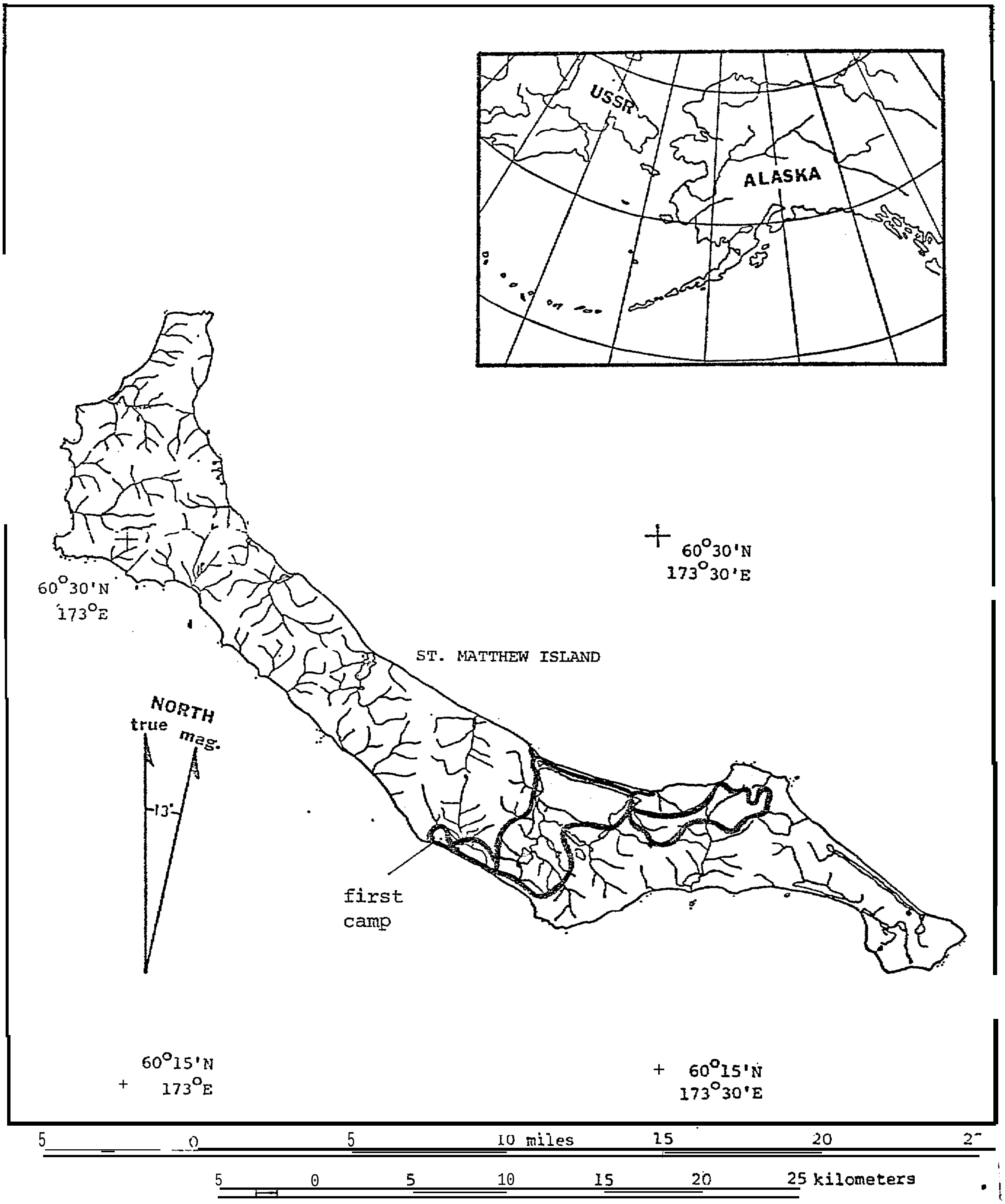


Fig. 6-2. Stoker Survey Route Map.

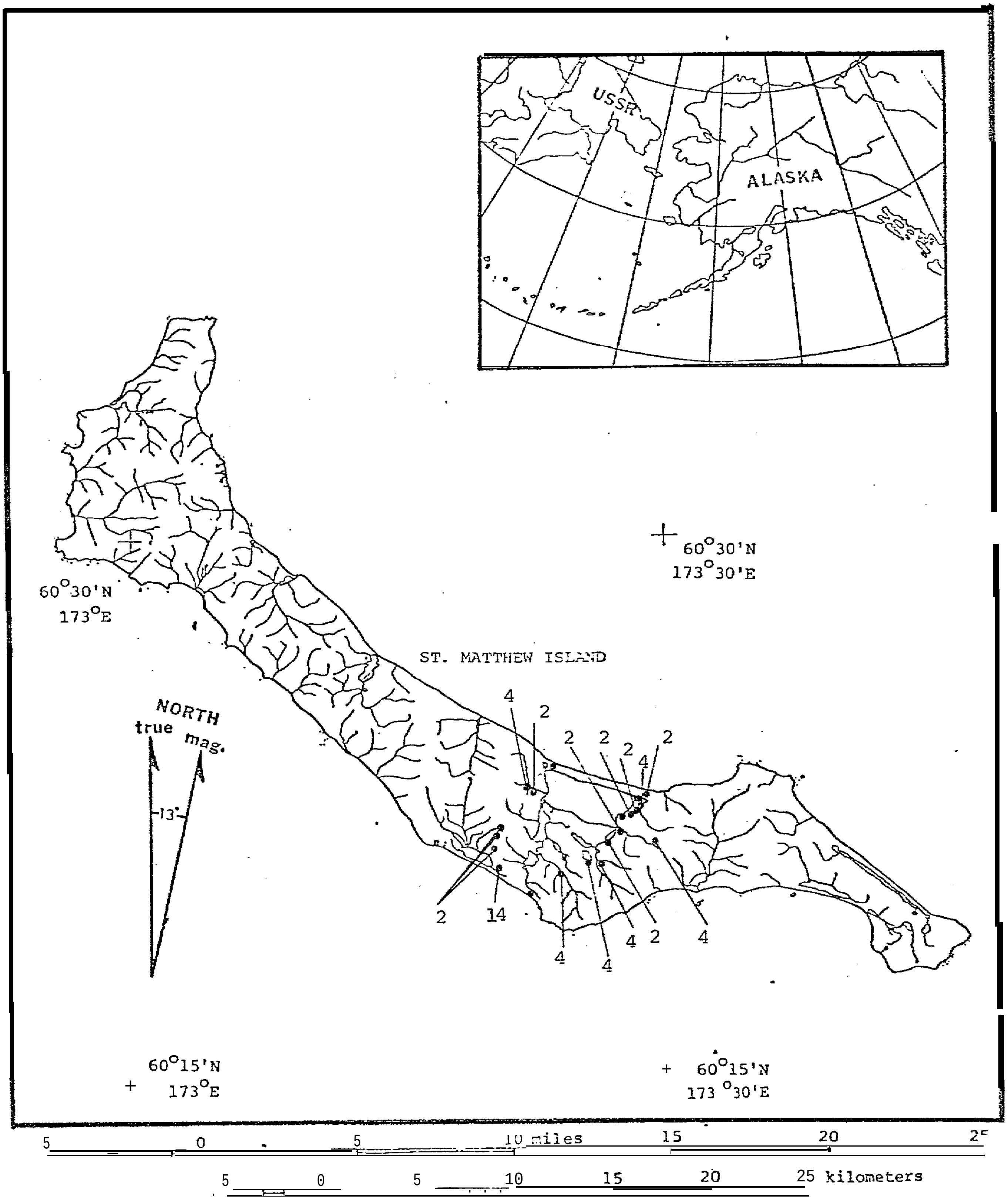


Fig. 6-3. Location of 'Test Excavations.

• = test excavation

↘4 = number of test excavations at a given location

Island in general lacks Pleistocene deposits suitable for archeological preservation. Although the larger valleys have accumulated Quarternary deposits, most elevated areas consist of pavements of frost-spalled rock. Attempting to locate stone artifacts in this extensive jumble is not only a frustrating, but futile experience. Natural agents have produced literally millions of "naturefacts", many of which bear an uncanny resemblance to tool forms characteristic of known late Wisconsin archeological assemblages, such as blades and flake cores. However, the context of the St. Matthew specimens most surely indicates that they cannot be attributed to former human occupation of the Island. It was impossible to ascertain prior to the archeological survey, due to the paucity of information relating to the Island, that the depositional situation would not be conducive to preservation and detection of archeological remains.

The lack of deposition in the elevated areas of the Island produces an environment which is not conducive to the preservation of organic remains. The numerous reindeer skeletons which litter the Island and represent a crash in their population which occurred during the winter of 1963-1964 (Klein, 1968:353) are in an advanced state of decay and clearly indicate the poor preservation of surface organic remains.

The survey method consisted of a foot traverse along the margins of the large central valley cutting directly across the Island. This valley was selected because it was felt that during Pleistocene times it formed a large central valley cutting through a steep series of mountains rising out of the comparatively flat surrounding plain. Such an ecological situation would most probably have funneled large mammal movements through it, thus presenting suitable ambush situations for early man. In addition, according to Patton et al. (1976:69) (Fig. 6-4 },

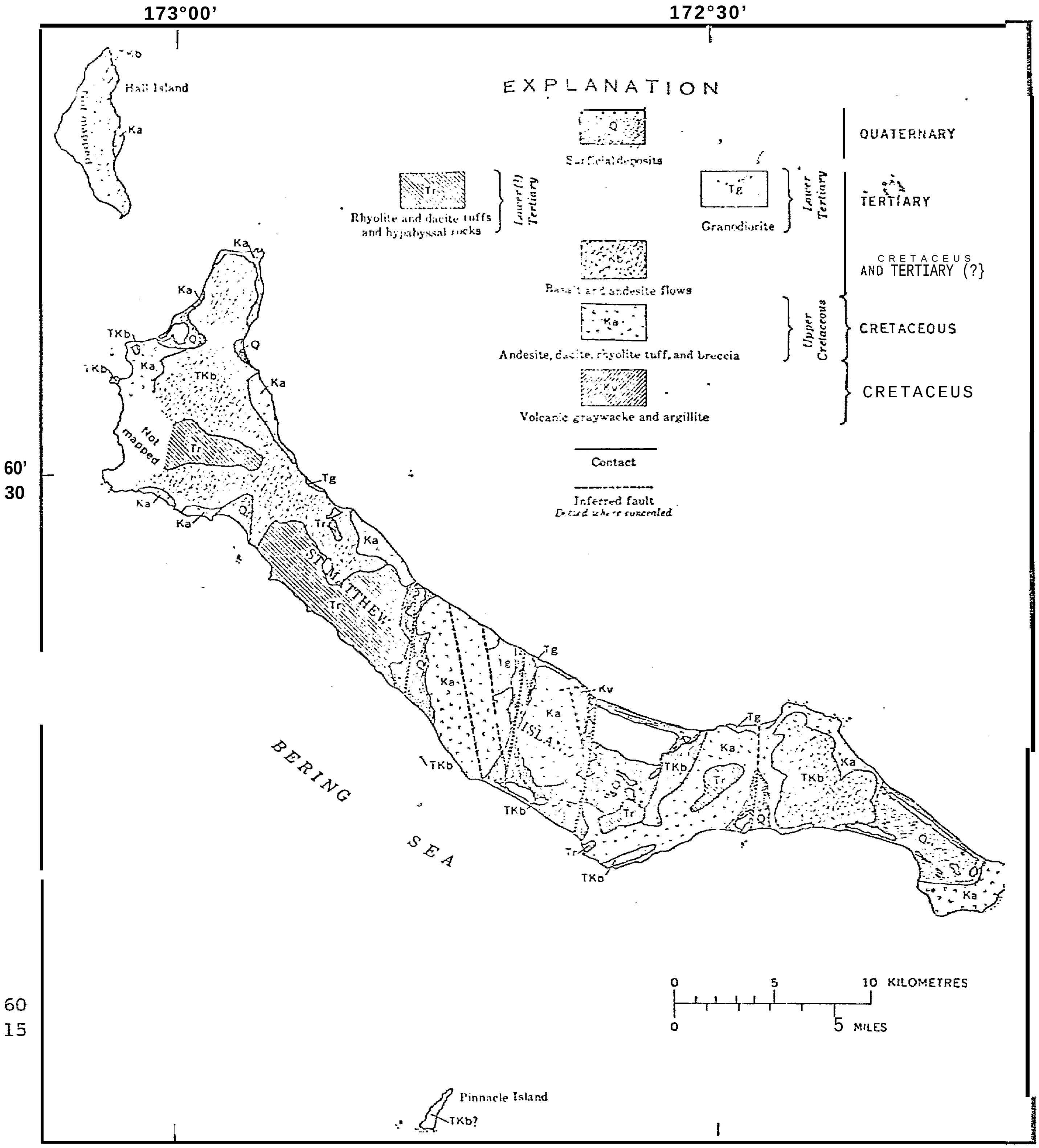


Fig. 6-4. Directly from Patton, Lanphere, Miller & Scott, 1976:69.

the valley has been filled with Quarternary deposits, thus offering some possibility for organic preservation so noticeably lacking in adjacent areas of higher elevation.

Food, fuel, camping gear and excavation equipment were back-packed. All test excavations were troweled until either bedrock, ground water or permafrost made further excavation impossible. All test pits were backfilled following excavation. Although one historic site, the remains of what appeared to have been a lean-to (Fig. 6-5) which probably dated to the 1944 U.S. Coast Guard occupation of the Island was discovered, all test excavations were negative and no evidence of prehistoric human occupation of the Island was discovered.

Of interest, however, was a ventifact layer which was found in several of the test excavations. The layer characteristically occurred between 30 to 50 cm below the surface and may indicate a period when the Island was subject to a prolonged period of subareal erosion. Loess deposition was negligible, thus possibly indicating that during Pleistocene times St. Matthew Island was not situated close to a source area, such as an outwash plain, from which wind-blown silts could have been derived.

The survey proceeded along the south flank of the valley and test pits were excavated (Fig. 6-6) at prominent overlooks and near the margins of bedrock outcrops. The survey of the south side of the valley was terminated at Sugarloaf Mountain where the valley meets the ocean. The beach erosional face was then inspected for possible evidence of human occupation and Pleistocene fossils. In addition, stream cuts through the eroding eastern beach were inspected. One possible archeological site was discovered along the southern end of the beach near Sugarloaf Mountain. This find consisted of a log protruding from the cutbank which

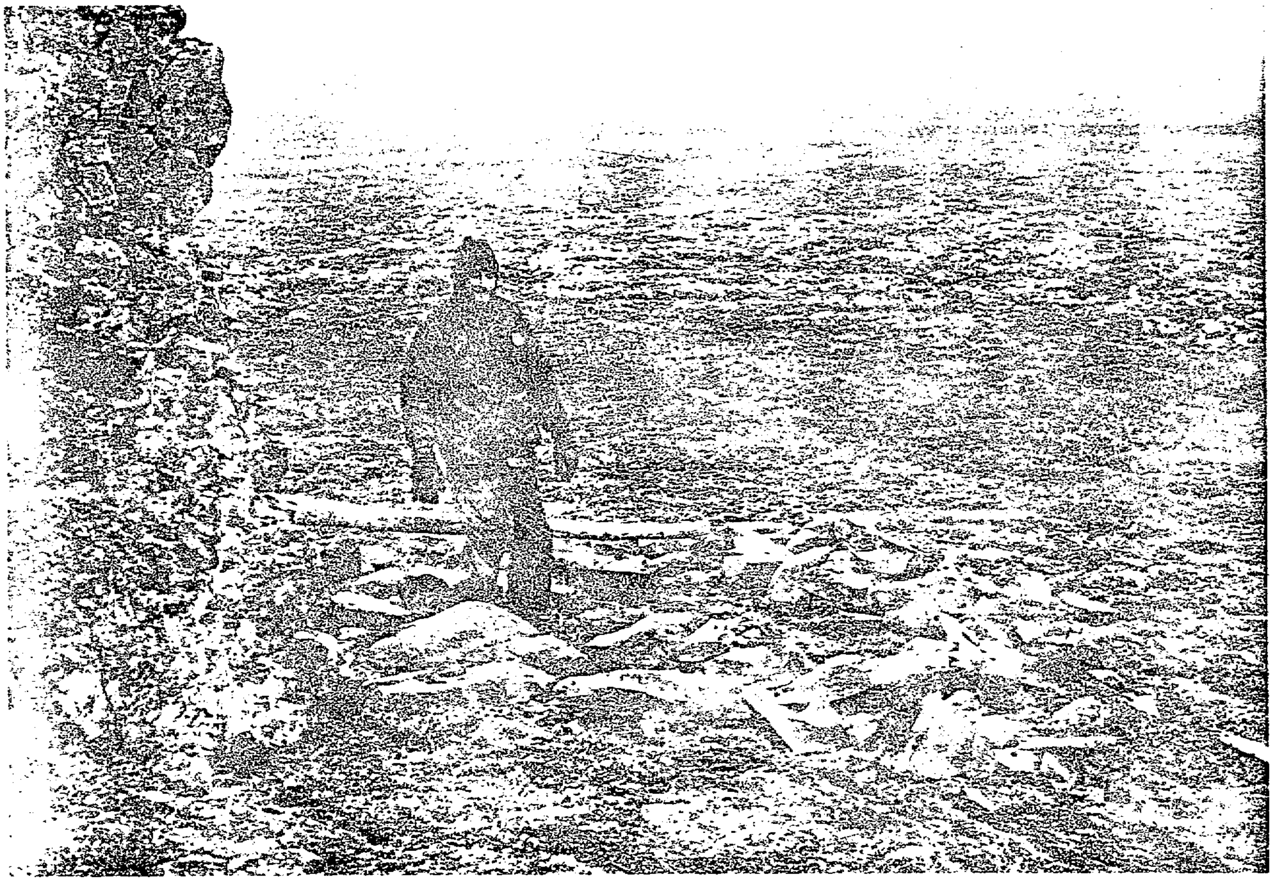


Fig. **6-5.** Remains of a lean-to, probably dating to U.S. Coast Guard occupation, 1944.

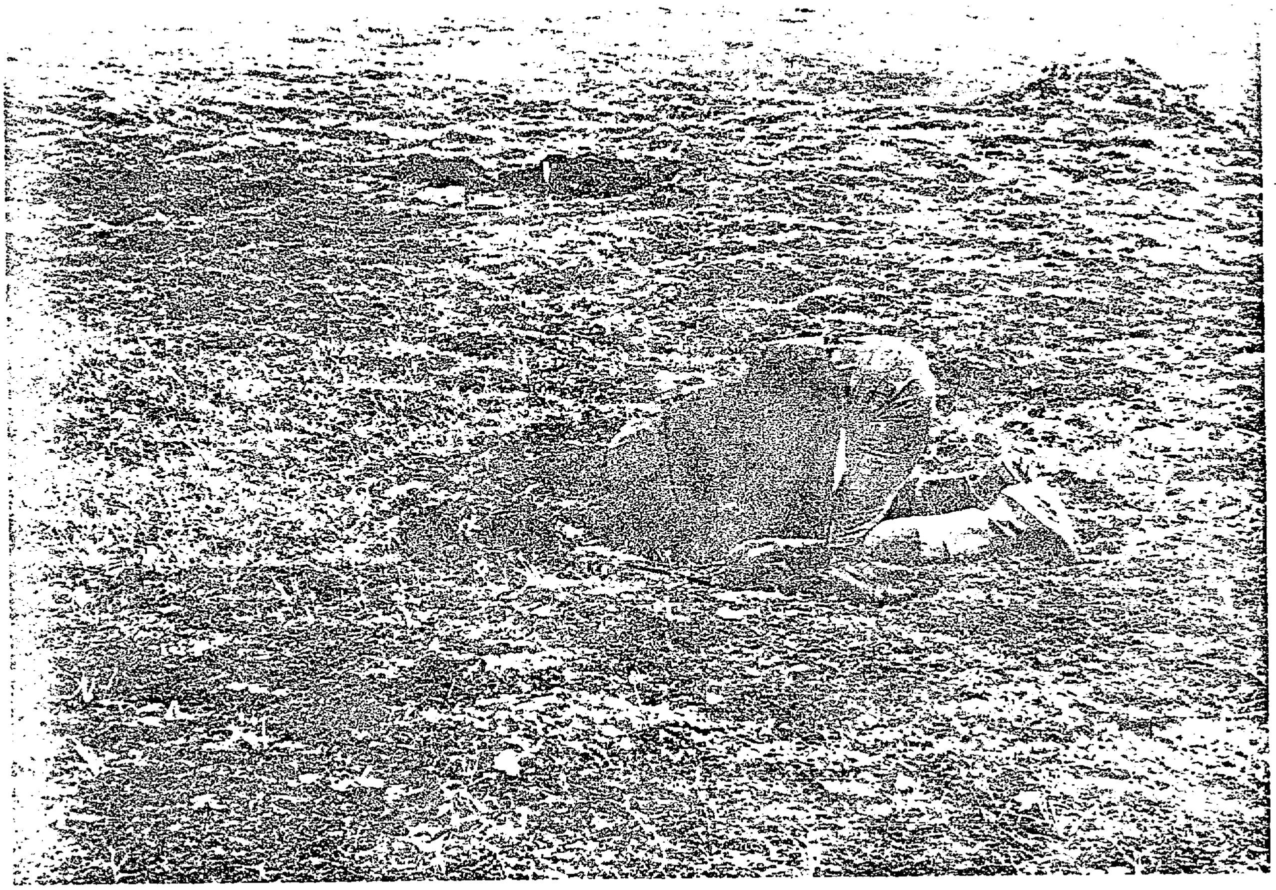


Fig. 6-6. Test pit excavation, interior St. Matthew Island.

had a piece of baleen lying directly on its upper surface. Bedding above the log in the exposed section indicated that the specimen was no doubt *in situ* and had remained so for some time. Test excavations were attempted, but the frozen bank made penetration of more than a few centimeters impossible. The surrounding area was examined for artifacts which may have been dislodged from the bank through wave erosion, however, a large snow/ice lens directly seaward from the exposure greatly reduced the area available for examination. The log demonstrated no evidence, such as adze marks, of having been culturally modified. A sample of the baleen was collected. It is impossible to ascertain whether this uncanny association represented evidence of human occupation of the Island, or was a rather fortuitous and somewhat unlikely natural depositional situation. This "site" is depicted in Figs. 6-7 and 6-8. Whatever the case, the site most probably dates to sometime after approximately 4,000 B.P. when sea level reached its present height and consequently contributes little to demonstrating Pleistocene occupation of the Island.

The survey proceeded from this location along the entire length of the beach northward to a large lagoon adjacent to the abandoned U.S. Coast Guard station. The deposits exposed in the beach cut appeared to become more contemporary along the northern portion of the exposure.

The survey of the valley was concluded by traversing the southern flank of an adjacent valley, once again testing in areas of high probability. The survey team then crossed back into the main valley near Big Lake and returned to the base camp via the adjacent series of beach ridges on the north shore. Because July 27 had been established as the time at which the air charter **was** to initiate attempts to reach the Island

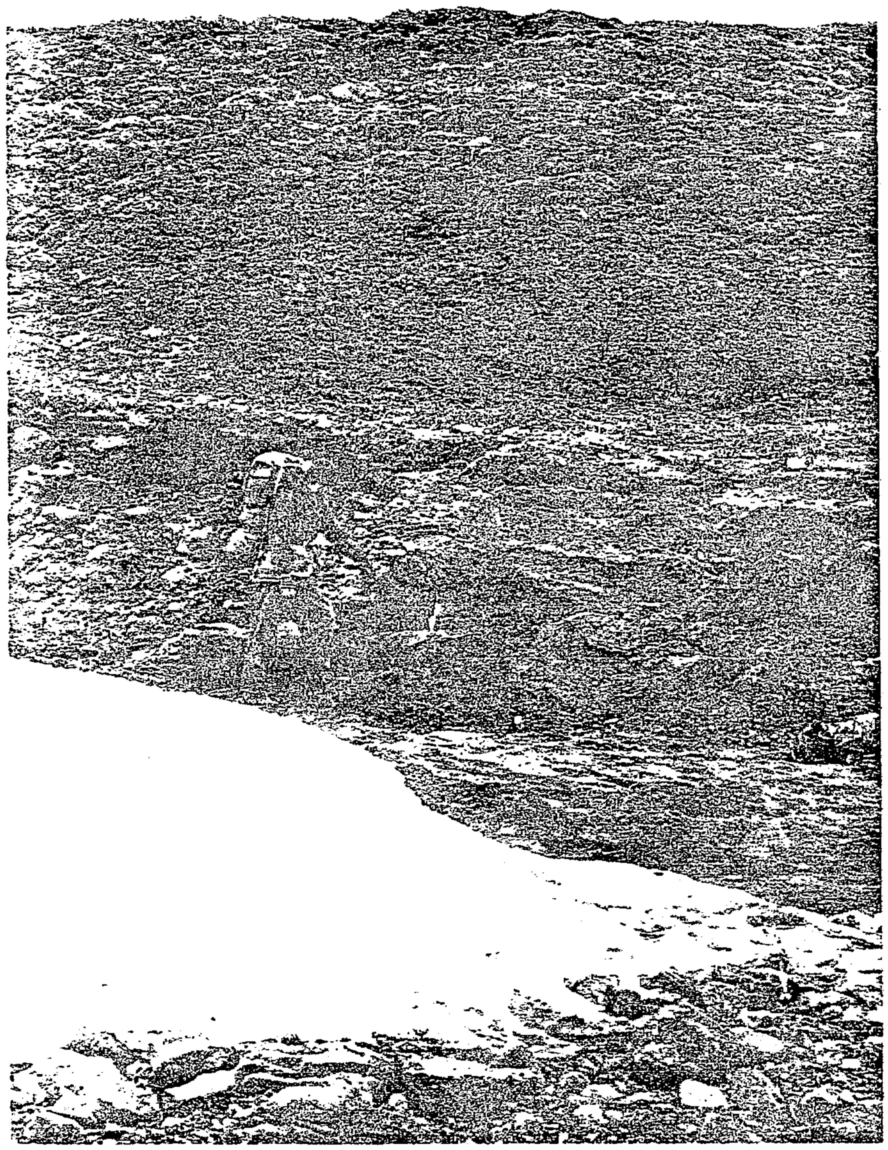


Fig. 6-7. Log and Baleen exposed by beach erosion.

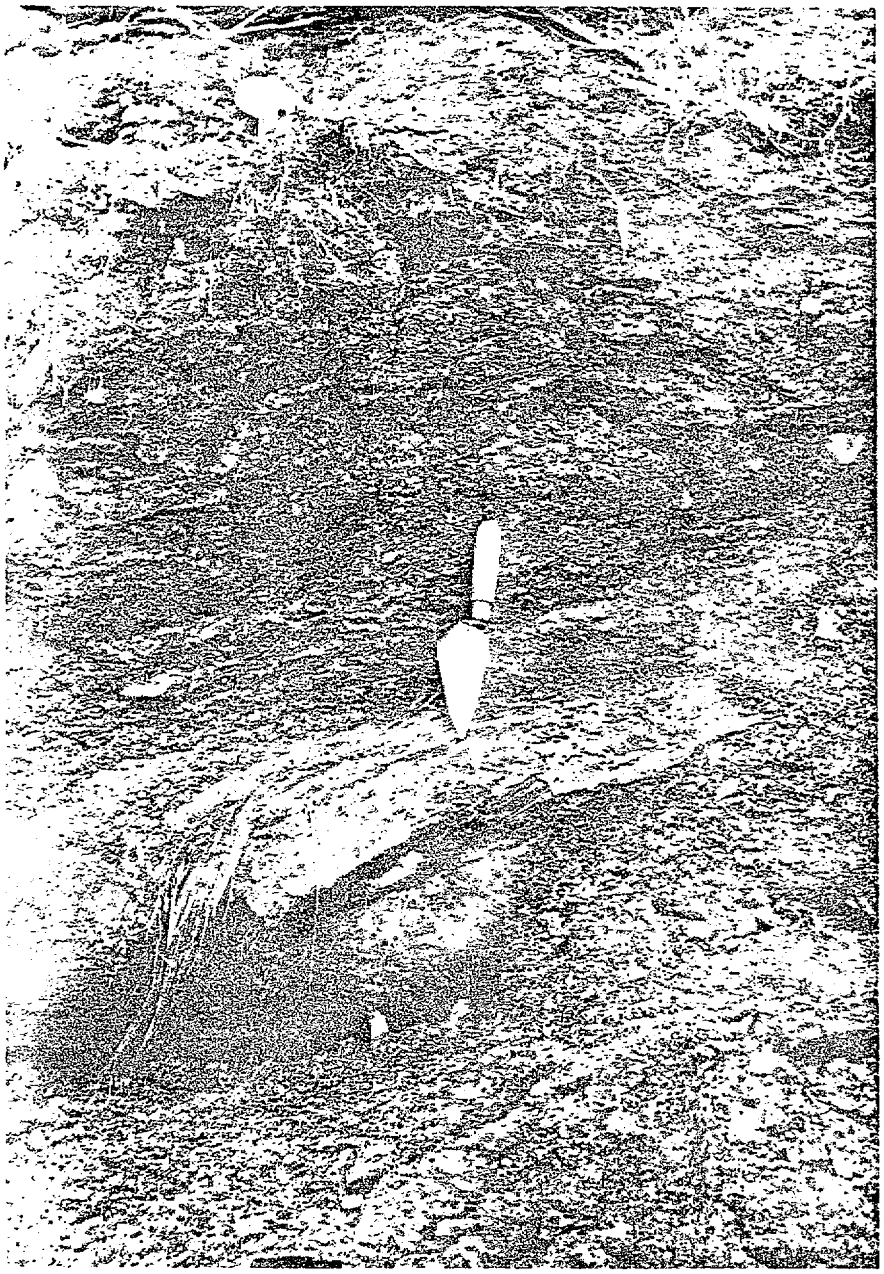


Fig. 6-8. Close-up of log and baleen *in situ*.

and evacuate the project personnel, we were restricted during the remaining days to conducting testing" near the base camp, for it was imperative that the crew not be scattered if the aircraft should arrive. During this three-day period, additional test excavations were conducted with negative results. Two historic semi-subterranean "trappers' cabins" were noted along the extreme southern extremity of the beach ridge sequence adjacent to Big Lake. Nearby the remains of a handmade boat winch were located on the most recent beach ridge and were no doubt contemporaneous with the two collapsed and abandoned cabins. Although the beach ridge sequence was not surveyed, it is possible that this area could prove productive with the accompanying benefits of relative dating of the beach ridges. In addition, it was noted that the formation of these beach ridges has not always been consistent with the present pattern. The alignment of the beach ridges clearly indicates that they may provide a useful tool in paleoenvironmental interpretation.

The fact that the terrestrial archeological survey of St. Matthew Island did not produce evidence of human occupation of this high probability area during Pleistocene times is not accepted by this researcher as a definitive test of the Phase I probability modeling for the following' reasons: (1) Adverse weather conditions limited the survey duration to only three full days in one of the most promising areas of the island; (2) the depositional situation on the Island was not conducive to preservation of organic archeological remains, and (3) the huge areas of frost-spalled rock in areas above the valley floor made detection of lithic artifacts extremely difficult. In conclusion, it is impossible to state, on the basis of this survey, that the area was uninhabited during Pleistocene times.

One final note should be added to a summary of the archeology of St. Matthew Island. The University of Alaska Museum houses a collection of artifacts from the Island which were donated by Dr. Klein. This assemblage is either early historic or late prehistoric in age. Although no historic artifacts are in the collection, it does contain aboriginal ceramics which are easily recognized as very late Eskimo. It is quite possible that this collection may document- prehistoric occupation of the island, but the obviously recent age of the assemblage does nothing to support Pleistocene occupation of the island.

TERRESTRIAL ARCHEOLOGICAL SURVEY OF ST. MATTHEW ISLAND

Sam W. Stoker

Stoker's planned route to the south end of the Island and Cape Upright lay along the crests of the rather jumbled ridge and valley complex to the south of Big Lake to the extensive flats on the southern end of the Island, along the east shore of these flats to Cape Upright, back along the west shore of the Island to the central valley, where rendevous was planned with Dixon arid Bacon (Fig. 6-2). Progress was made along this route throughout the day of July 24th, though with seriously deteriorating weather conditions. By mid-afternoon winds had increased to 40 to 50 knots, still from the south and southwest, and fog had greatly increased in density. The resultant very limited visibility made it virtually impossible to maintain a selective route, and contributed much to the difficulty of efficient progress.

By 4:00 p.m. the last ridge was attained before dropping down into the southern flats. Conditions by now were extreme, with winds estimated at 70 knots from the south and with very dense fog. In view of the wind conditions and the unsheltered nature of the southern flats, and due to limited visibility? which offered to make descent onto these flats very hazardous, it was decided to abandon the venture to Cape Upright and return to the relative shelter of the central valley. After some travail and meandering in the fog, the south slope of this central valley was reached about 7:30 p.m. The wind was decreased to 20 to 30 knots here, and the fog thinned to permit relatively good visibility (greater than 100 feet). The main camp on Big Lake was regained by 9:30 p.m.

The terrain along the route covered (Fig. 6-2) consisted, with the exception of the first and last few miles along the valley floor, of a confusing (in the fog) ridge and stream valley system. The ridge crests were primarily of bare, broken scree. The hillsides were of similar broken scree, extensive steep talus slopes, and unstable areas of loose mud and rock. The stream valleys, those which were blundered inadvertently into, were marshy grass interspersed with patches of muskeg swamp . No caves or rock shelters were found, nor hopeful natural exposures. Visibility at all times was extremely limited, usually to under 50 feet.

On the north-facing southern side of the central valley several interesting disruptions of the normal contour of the slope, consisting of shallow depressions, were observed and investigated, and four shallow test pits dug. It was concluded that these apparent anomalies were, however, natural results of frost and ground water action.

On the morning of the 25th, Stoker departed the main camp again, this time following the beach line north to the north side of Big Lake and thence west along the lake margin to the western side of the island. Weather on this day was much improved, with winds 10 to 15 knots from the south, intermittent fog above 100 feet, and occasional glimpses of the sun.

Several likely-looking locations were observed along the foothills near the north margin of the lake, from where game herds might have been intercepted, but no evidence of occupation was discovered. Four more test pits were dug in apparent anomalies such as had been investigated the day before but they, as the previous ones, were determined ‘co be the result of natural soil mechanisms.

From the northwest corner of Big Lake, Stoker skirted the north side of the adjacent smaller lake, crossed the flats to the western beach and followed this beach line north to the abandoned Coast Guard station in the foothills northwest of the central valley. The western beach line provided a cutbank of up to several meters in height, but no evidence of human occupation or animal remains were observed in this exposure.

Camp was made the night of the 25th-26th in the abandoned Coast Guard station. A blown-down wooden cross was found on a bluff abvove the Coast Guard station, apparently a grave marker, with the inscription "Etiuri". Weathering had obliterated other writing on the marker.

The morning of the 26th Stoker retraced his previous evening's route back south along the western beach, met with Dixon and Bacon at their night's camp in the northwest corner of the central valley (Fig. 6-1) and proceeded from there back south along the beach to the foothills and thence along the southern side of the central valley to the main camp. Several likely-looking areas were investigated, but no evidence of human occupation was discovered save for the remains of an apparent trapping camp of relatively recent age (Fig. 6-5) . The main camp was regained that night by Stoker, Dixon and Bacon, by separate routes. The weather on that day was good, with light winds and intermittent sun.

Terrain along this two-day route consisted of gentle hills covered by the ubiquitous loose scree, flat grasslands varying from semi-dry to marshy, arid areas of muskeg swamp. Several small streams were crossed in the central valley, none providing cutbanks of any lasting interest.

The only other excursion of any length undertaken by Stoker was on the **29th,** when an attempt was made to locate possible outcrops of workable lithic material (jasper and agate). Pebbles of this material were commonly seen on the eastern beach. Cliffs and rock outcrops on both the northern and southern ends of the beach were investigated, and it was concluded that such material, the jasper and agate, at least, probably did not occur in concentrated deposits but was eroding out more' or less at random from pockets in the country rock of the cliff faces.

No live marine mammals were observed on the beaches or at sea along these routes, though poor visibility made observations difficult and often impossible. Several skulls and assorted bones of large baleen whales were encountered on both the eastern and western beaches of the central valley. All were badly weathered, indicating exposure for at least several years. Weathered bones of one walrus (*Odobenus rosmarus divergeins*) were found on the southeast beach of the central valley, and relatively fresh bones of another on the northeast beach.

A SURVEY FOR FOSSIL TERRESTRIAL MAMMALS ON ST. MATTHEW ISLAND

by Russell D. Guthrie

Being the major interruption of the now submerged plain between St.Lawrence Island to the north and the Pribiloff Islands to the south, St.Matthew Island is a likely focal point for investigations of Pleistocene mammals in Beringia. Because it was a series of low mountains on a monotonous prairie it would very likely have been an area well used by large mammals. There are a number of aspects which suggest this. Ungulates often seek topographic relief, because of the variation in plant maturity - also to escape insects, and to use as a visually obvious traditional breeding or calving ground. It would have served as a major hibernation location for bears and a summer denning ground for lions and wolves.

As there had never been a paleontological search for fossil mammals on St.Matthew, prospects seemed likely that there would be suitable deposits. Our survey turned up neither suitable sedimentary deposits nor Pleistocene remains of mammals.

There was only a very thin mantle of silt, usually forming a matrix for angualr gravel which had been plucked from the underlying bedrock by frost action. Very little bedding was present, because of the seasonal frost churning of the silt and gravel. A number of streams were checked for possible erosion cutbanks and no likely ones were found. Unlike the continental area of Northwestern Alaska there were no seacliffs of Pleistocene sediments. The sea cliffs were all rocks of volcanic origin.

Literally thousands of bones were examined scattered in the gullies and along the beaches; however, these all were either reindeer (Rangifer tarandus) or sea mammals. During World War II the navy released a small herd of reindeer on the island. The herd expanded to 6,000 animals and crashed (Klein, 1973). Their bones, in various degree of decay, litter the island. Likewise, over the years carcasses of dead floating sea mammals have washed onto the beaches and decomposed leaving their bones scattered along the sand-gravel beaches.

The Island is mountainous. Not only the tundra vegetation cover but the general preponderance of boulder pavements and bedrock features near the surface and the virtual absence of eolian deposits on the island suggest the possibility that the rivers fanning out across the outer continental shelf were well enclosed with banks and not braided in a long broad delta which would have been a source of loess deposits throughout the area.

AREA SURVEYED

On its northeast side the Island has three major lakes separated from the sea only by a stern beach ridge of gravel. These cut-off lagoons mark the outer margins of the area which we surveyed - essentially the central two-thirds of the island. Both sides of the island within this segment were walked, as were several of the interior drainages. A team of two backpacked their camp over this area for a period of four days and then worked out of base camp on Big Lake for three more days.

RECENT MAMMALS OBSERVED

There was a population high of the island's only small mammal., _Microtus abbreviates._ These voles were almost everywhere in great numbers. They occupied virtually all habitats. While hiking around the siland their singing vocalizations were constantly in the background. As many as thirty animals were seen at one time.

White foxes (_Alopex lagopus_) were also common, probably as a result of the large numbers of voles. Two phases are present on the island - whites and blues. In summer coat the whites are a dirty brown trimmed in light buff. The summer coat of the blue phase is a dark grey. The frequency of the phases on the island is probably close to 50:50 - our counts were 16:14 whites to blues. Several dens were seen. All had pups. We counted six pups at one den. The pups were quite small weighing about 3 pounds. They could be run down and caught they were so young. This is well behind Arctic fox development described for other areas.

Whales, probably gray whales (_Eschrichtius glaucus_), were seen feeding off the coast of the middle lake and eight seals (probably harbor seals, _Phoca vitulina,_ were seen along the south central shore of the island.

Klein (1973) proposed that there were only cow reindeer remaining on the island in 1966. We did not get to the eastern end of the island which he described as summer range. However, we did see numerous tracks and faeces and observed five bull reindeer over the ridge east of Big Lake. Undoubtedly there were males remaining in 1966. The herd seems not to have increased greatly due to the almost total annihilation of lichens from the earlier population peak in the 1960's. Lichens normally form the bulk of reindeer winter diet. The reindeer do, however, seem to be surviving at the level of a few dozen. The bulls were healthy and fat - just as large as Klein had pictured before the crash. The antler development was enormous also, suggesting a healthy population.

BIRDS OBSERVED

Klein (19S9) gives a complete list of the birds on the island. We observed all the birds seen by his survey except the redpoll, Pacific fulmar, and whistler swans and black footed albatross. Beals (1944) describes several other birds on the island. We saw all of these except for Golden plover, snowy owl, red-breasted meganser, and rosy finches. In addition to their lists we observed semipalinated plover and the continental snow bunting.

Klein (1959) lists the number of bird species. Although we did not attempt actual counts we did notice marked qualitative changes from the proportions that he observed. I doubt if these are because the survey could have taken different routes. The differences are these:

1. He observed only a few McKay's snow buntings while we saw thousands.
2. He found fewer Aleutian sandpipers than red-backed sandpipers, we found the reverse.
3. He found tufted puffins more common than horned puffins, while we saw thousands of horned puffins but only a few tufted puffins.
4. We found more glaucous gulls than did Klein.
5. We found more ruddy turnstones than did Klein.
6. All three species of jaeger were very abundant with long-tailed jaegers most common.
7. Eiders were more rare than what he observed.

An explanation for some of these differences must relate in a primary arid possibly secondary way to the vole cycle. Klein's visits occurred during a low in their cycle and ours during a high. The large numbers of jaegers and glaucous gulls can be accounted for directly on the basis of the food source. The summer of 1976 coincides with a vole-lemming high across northern and western Alaska. These 4-year cycles result in a sympathetic cycle of avian mouse predators. Most of these avian predators are migrants and probably there is a spill over into northern islands from the mainland. The vole cycle on St.Matthew may be an artifact of the microtine cycle on the mainland.

The increased numbers of voles probably changes the habit for birds and most surely the presence of the avian predators, from the lemming population high, have a differential effect on various species of birds.

It looked to us as if there were the continental snow buntings in addition to McKay's snow bunting. The latter was subordinate to the former on the beaches.

The genetic-specific names for the bird species mentioned in this section appear in Klein (1959).

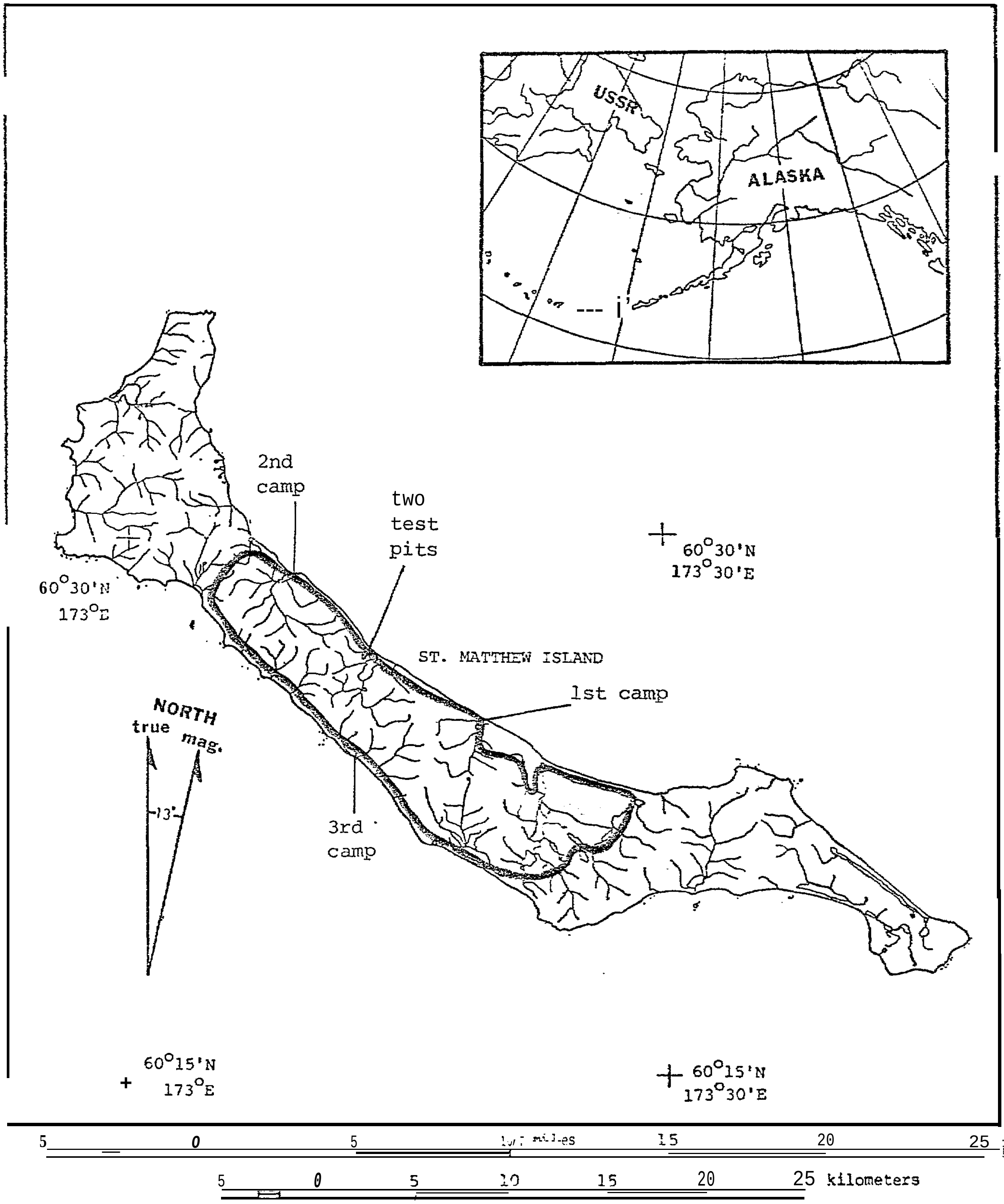


Fig. 6-9. Guthrie Survey Route Map.

BIBLIOGRAPHY

AAGAARD, K.

1964 "Features of the Physical Oceanography of the Chukchi Sea" Unpublished Master's thesis, University of Washington, Seattle. 28 p.

ACKERMAN, R. E.

1974 "Post Pleistocene Cultural Adaptations in the Northern Northwest Coast" *International Concerence* on *the Prehistory and Paleoecology of* Western *North* American *Arctic and* Subarctic. S. Raymond and P. Schledermann (eds.) University of Calgary Archeological Assoc. Calgary, Alberta, Canada. pp. 1-20.

AGER, T. A.

1975a "Late Quaternary Environmental History of the Tanana Valley, Alaska" Ph.D. Dissertation abstract. Ohio State University.

1975b "Late Quaternary Environmental History of the Tanana Valley, Alaska" Institute of Polar *Studies, Report No.* 54. 117 pp.

ALEXANDER, H. L.

1972 "The Association of Aurignacoid Elements with Fluted Point Complexes in North America." Unpublished paper. Simon Fraser University. Vancouver, B. C., Canada.

1974 "The Association of Aurignacoid Elements with Fluted Point Complexes in North America. *International* Conference on *the Prehistory and Paleoecology* of Western *North American Arctic* and *Subarctic.* S. Raymond and P. Schledermann (eds.). University of Calgary Archeological Assoc. Calgary, Alberta, Canada. pp. 21-32.

ANDERSON, D. D.

1968 "A Stone Age Campsite at the Gateway to America." Scientific *American* 218 (6):24-33.

1970 "Akmak: An Early Archeological Assemblage from Onion Portage, Northwest Alaska" *Acta Arctica* Fast. XVI. Copenhagen. 80 p.

ANDRIYASHEY, A.P.

1964 "Fishes of the Northern Seas of the USSR." *Keys to the Fauna of the USSR No.* 53 (Israel Program for Scientific translation. 1964) p 617.

ANONYMOUS

1974 "Earliest Evidence of Human Habitation in Eastern u.s." *Intellect* 103:83-84.

ARNDT, K.

1976 "The Pleistocene/Holocene Transition in the Aldan River Valley." Unpublished data.

ASKREN, D.

1972 "Holocene Stratigraphic Framework - Southern Bering Sea Continental Shelf." Unpublished Master's thesis. University of Washington, Seattle, Washington.

AVSEN'EV, V.S.

1967 *Currents* and *Water Masses of the Bering* Sea. Ixd. Nanka, Moscow. (Nat. Mar. Fish. Svv. N.W. Fish Center, Seattle, Washington. Translation, 1968) 135 p.

BANDI, H.-J.

1969 "Eskimo Prehistory" *Studies of Northern* Peoples, *No.* 2 Edward H. Hosley (cd.) University of Alaska Press. College.

BARNES, C. A. and T. G. THOMPSON

1938 "Physical and Chemical Investigations in Bering Sea and Portions of the North Pacific ocean.'" *Oceanog Vol.3* (2)35-72.

BEALS, F.

1944 Field Diary, June 30-August 20. U.S. Fish and Wildlife Service. Unpublished? and filed at Kodiak and Juneau, Alaska.

BLACK, R.F.

1966 "Geologic History, Late Pleistocene to Recent History of Bering Sea - Alaska Coast and Man." *Arctic* Anthropology *3*(2):7-22.

BOAS, F.

1964 The Central Eskimo. University of Nebraska Press, Lincoln, Nebraska.

BROECKER, W.S.

1966 "Absolute Dating and the Astronomic Theory of Glaciation." Science, *151*:299-304.

BROECKER, W.S., M. EWING and B.C. HEERZEN

1960 "Evidence for an Abrupt Change in Climate Close to 11,000 Years Ago." American *Journal* of Science, *258*:429-448.

BROECKER, W.S. and J. VAN DONK

1970 "Insolation Changes, Ice Volumes and the O^{18} Records in Deep-Sea Cores." Reviews *of* Geophysics and Spare Physics, *8*:169-198.

BROWN, STANLEY

1891 "Account on the Pribilof Islands.'! *Bulletin* of *the* Geological Society of America, *3*:496-501.

BRYAN, A.L.

1969 "Early Man in American and Late Pleistocene Chronology of Western Canada and Alaska." Current Anthropology, *10*(4):339-365.

n.d. "An Archeological Reconnaissance of the Pribilof Islands."

BUTZER, K.W.

1971a Environment and Archeology, Aldine, Chicago-

1971b "The Lower Omo Basin: Geology, Fauna and Hominids of Plio-Pleistocene Formations." *Naturwissenschaften,* *58*:7-16.

CAMPBELL, J.M.

1961 "The Kogruk Complex of Anaktuvuk Pass, Alaska." Anthropologic, N.S., *3*(1) :3-20-

1968 "Territoriality Among Ancient Hunters: Interpretations from Ethnography and Nature." Anthropological Archeology in *the* Americas, pp 1-21.

CARSOLA, A.J.

1954 "Submarine Canyons on the North Slope." Geology, *62*(6):605-610.

CHANG, K.

1962 "A Typology of Settlement and Community Patterns in some Circumpolar Societies" *Arctic Anthropology* 1 (2):28-41.

CLARK, D. L.

1971 "The Arctic Ocean Ice Cover and its Late Cenozoic History." *American Geological Society*, 82 3313-3323.

CLARK, D. W.

1972 "Archeology of the Batza Tena Obsidian Source, West-Central Alaska." *Anthropological* Papers *of* the University *of Alaska*. 15 (2):1-21.

COACHMAN, L.K. and K. AAGAARD

1966 "On the Water Exchange Through Bering Strait." *Liminological* Oceanography *Vol. II* p. 44-49.

1974 "Physical Oceanography of Arctic and Subarctic Seas." Marine *Geology* and Oceanography of the *Arctic Seas*. Yvonne Herman, (cd.) Springer-Verlag. New York p. 1-73.

COACHMAN, L. K. and R. B. TRIPP

1970 "Currents North of Bering Strait in Winter." *Liminological Oceanography* Vol. *15* p. 625-632.

COLLINS, H. B.

1937 "Archeology of St. Lawrence Island, Alaska" *Smithsonian Institution* Miscellaneous *Collection* 96 (1):1-431.

COLINVAUX, P. A.

1964a "The Environment of the Bering Land Bridge." *Ecological* Monographs, 34 p. 297-329.

1964b "Origin of Ice Ages: Pollen Evidence from Arctic Alaska." *Science, 145* p. 707-708.

1967a "Quarternary vegetational History of Arctic Alaska." *The Bering* Land *Bridge* D.M. Hopkins (cd.) Stanford University Press. p. 207-231. -

1967b "Bering Land Bridge: Evidence of Spruce in Late Wisconsin Times." *Science* Vol. 156, no. 3773 p. 380-383.

CRAEGER, J. S.

1963 "Sedimentation in a High Energy, Embayed, Continental Shelf Environment." *Journal Sedimentation and Petrology, 33.* (4):815-830.

CRAEGER, J. S. and D. A. MCMANUS

1965 "Pleistocene Drainage Patterns on the Floor of the Chukchi Sea." *Marine Geology, 3.* p. 279-290.

1966 "Geology of the Southeastern Chukchi Sea." *Environment of the Cape Thompson Region, Alaska.* N. J. Wilimovsky (cd.). US. Atomic Energy Commission. p. 755-786.

1967 "Geology of the Floor of the Bering and Chukchi Seas - American Studies." *The Bering Land Bridge* D.M. Hopkins (cd.). Stanford University Press. p. 7-31.

DAVIES, J.L.

1958 "Pleistocene Geography and the Distribution of Northern Pinnipeds." *Ecology,* 39. p. 97-113.

DILLON, L. S.

1956 "Wisconsin Climate and Life Zones in North America." Science, *123.* p. 167-176.

DIXON, E. J. , JR.

1972 "The Gallagher Flint Station, an Early Man Site on the North Slope, Arctic Alaska." Unpublished M.A. Thesis. University of Alaska.

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 Anthropology* 12. (1):68-75.

DOBROVOL'SKII , A. D. and V. S. ARSEN'EV

1959 "The Bering Sea Currents." *Problemy* SeVera, *Vol.* 3 p. 3-9.

DODIMEAD, A. J., F. FAVORITE and T. HIRANO

1963 "Salmon of the North Pacific Ocean, Part II: Review of Oceanography of the Subarctic Pacific Region." *International North Pacific Fisheries Commission Bulletin No. 13.* pp. 1-11; 177-187.

DOWN, W. L. and M. EWING

1966 "A Theory of Ice Ages III." *Science 152*. pp. 1706-1712.

1968 "The Theory of an Ice-free Arctic Ocean." Causes of *Climatic Change*. J. M. Mitchell (cd.) American Met. Sot.

EMILIANI, CESARE

1972 "Quaternary Paleotemperatures and the Duration of High Temperature Intervals." *Science 178*. pp. 398-401.

ERICKSON, D. B., W. S. BROECKER, J. L. KULP and G.WOLLIN

1956 "Late Pleistocene Climates and Deep-sea Sediments." *Science* 124. {3218)385-389.

EWING, M. and W. L. DONN

1961 "Pleistocene Climatic Changes." *Geology* of *the Arctic* Toronto University of Toronto Press. pp 931-941.

FAVORITE, F.

1974 "Flow into the Bering Sea Through Aleutian Island Passes." *Oceanography of the Bering Sea; Proceedings of an Internation Symposium.* Intitute of Marine Science University of Alaska, Fairbanks , Alaska.

FAVORITE, F. and G. PEDERSON

1959 "Bristol Bay Oceanography. August-September 1938." *U. S. Fish and Wildlife Service, Special Scientific Report - Fisheries, No. 311*.

FAVORITE, F, J. W. SCHANTZ and C. R. HEBARD

1961 "Oceanographic Observations in Bristol Bay and the Bering Sea, 1939-41. *U.S. Fish and* Wildlife Service. Special Scientific *Report - Fisheries, No. 381*.

FERRIANS, O.F. and D. R. NICHOLS

1965 "Copper River Basin." *Central* and *South Central Alaska: Guidebook.* Pewe, T. L. (cd.) (For Field Conference F: International Quarternary Assoc., 7th Congr. Boulder, Colorado. 141 p.

FILATOVA, Z. A. and N. G. BARSANOVA

1964 "Communities of Benthic Fauna in the Western Bering Sea." *Trudy.* Institute Okeanolagii 69:6-97.

FLEMING, R. H. and D. E. HEGGARTY

1966 "Physical and Chemical Oceanography of the South-eastern Chukchi Sea." *Environment of the Cape Thompson Region, Alaska* N. J. Wilimovsky, (ed.) U.S. Atomic Energy Commission. pp. 697-754.

FLETCHER, J. O.

1966 "The Arctic Heat Budget and Atmospheric Circulation." *Proceedings of the Symposium on the Arctic Heat Budget and Atmospheric Circulation, Lake Arrowhead, California Jan. 31 - Feb. 4, 1966.* The Rand Corp. Memoir RM-5233-NSF'. pp. 25-43.

FLINT, R. F.

1952 "Ice Age in the North American Arctic." *Arctic.* 5(3):135-152.

1971 Glacial and *Quarternary Geology.* John Wiley & Sons, Inc. New York, London, Sydney, Toronto.

GARUTT, V. E.

1965 "Iskopaemye slony Sibiri. (Fossil elephants of Siberia)." *Antropogenovyi Perioda v Arktike i Subarktike.* (k VII sessii INQUA,) Trudy Nauchno-Issledovatel'skogo Instituta Geologii Arktiki, tom. 143. Izdatel'stvo "Nedra," Moscow. pp. 106-130. Translation by "K. Arndt.

GARUTT, V. E. and K. B. IUR'EV

1966 "Mumifitsirovannye ostatki dikoi loshadi iz vechnoi merzloty basseina r. Indigirki (The Mumified Remains of a Wild Horse from the Permafrost of the Basin of the Indigirka River)." *Akademiia Nauk. Komissiia po izucheniiu chetvertichnogo perioda. Biulleten', no. 31.* Translation K. Arndt.

GATES, G. D. and GEORGE GRYC

1963 "Structure and Tectonic History of Alaska." *Backbone of the Americas; American Assoc. Petroleum Geologists Memoir 2.* O. E. Childs and B. W. Beebe (eds.) pp. 264-277.

GEIST, OTTO and F. G. RAINEY

1936 "Archeological Excavations at Kukulik, St. Lawrence Island." *Vol.* 11 *of the* Miscellaneous *Publications of the University of Alaska.*

GERSHANOVICH, D. E.

1963 "Bottom Relief of the Main Fishing Grounds (Shelf and Continental Slope) and Some Aspects of the geomorphology of the Bering Sea." *Soviet Fisheries Investigations in the Northeast Pacific. Part I.* P. A. Moiseev (cd.) Translation Israel Program for Scientific Translations, Jerusalem, 1968, pp. 9-78.

GIDDINGS, J. LOUIS

1952 *The Arctic Woodland Culture of the Kobuk River.* Museum Monographs, University of Pennsylvania Museum, Philadelphia.

1957 "Round Houses in the Western Arctic." American *Antiquity, 23(2).* Salt Lake City.

1960 "First Traces of Man in the Arctic." *Natural History, November.* pp. 10-19.

1961 "Kobuk River People." *University of Alaska Studies of Northern Peoples, No.* 1.

1967 *Ancient Men of the Arctic.* Seeker & Warburg, London.

GITERMAN, R.E.

1973 "Vegetation of Pleistocene Cold Epochs of the Kolyma Lowland in Connection with the Problem of Landscapes of Polar Beringia." *In* R.E. Giterman *et al.* (eds.), *The Bering Land Bridge and its Role for the History of Holarctic Floras and Faunas in the Late Cenozoic.* Academy of Sciences of U.S.S.R., Far-Eastern Scientific Centre, Khabarovsk, pp. 65-68.

GOODMAN, J.R., J.H. LINCOLN, T.G. THOMPSON and F.A. ZENSLER

1942 Physical and Chemical Investigations: Bering Sea, Bering Strait, Chukchi Sea, during the Summers of 1937 and 1938, *University of Washington Publications in Oceanography, 3*(4):105-169.

GRIM, M.S. and D.A. McMANUS

1970 "A Shallow Seismic-profiling Survey of the Northern Bering Sea." *Marine Geology, 8*:293-320.

GROMOVA, VERA

1949 "Istoriia loshadei (roda *Equus*) v Starom svete. Chast' I: Obzor i opisanie form [The history of horses (genus *Equus*) in the Old World. Part I: A Survey and Description of Forms)." Akademiia nauk SSSR. Paleontologicheskii institut. *Trudy, tom XVII,* vypusk 1. Moscow-Leningrad. Translation by K. Arndt.

GUTHRIE, RUSSELL D.

1968a "Paleoecology of the Large Mammal Community in Interior Alaska during the Late Pleistocene." *The American Midland Naturalist, 79*(2):346-363.

1968b "Paleoecology of a Late Pleistocene Small Mammal Community from Interior Alaska." *Arctic, 21:*223-244.

1970 "Poison Evolution and Zoogeography in North America during the Pleistocene." *Quarterly Review of Biology, 45*:1-15.

GUTHRIE, RUSSELL D. and JOHN V. MATTHEWS, JR.

1971 "The Cape Deceit Fauna--Early Pleistocene Mammalian Assemblage from the Alaskan -Arctic. *Quaternary Research, 1:*474-510.

HADLEIGH-WEST, FREDERICK

see WEST, FREDERICK HADLEIGH

HALL, E.S., JR.

1959 Comment in A.L. Bryan, "Early Man in America and the Late Pleistocene Chronology of Western Canada and Alaska." *Current Anthropology, 10*(4):352-353.

HAMILTON, THOMAS D.

1972 "Itkillik Glaciation of the Sagavanirktok Valley, Alaska." Unpublished manuscript. Geology Department, University of Alaska.

1975 "Itkillik Glaciation of the Sagavanirktok Valley, Alaska." Unpublished report. U.S. Geological Survey, Menlo Park, California.

HAMILTON, THOMAS D. and S.C. PORTER

1976 "Itkillik Glaciation in the Brooks Range, Northern Alaska." *Quaternary Research, 5:*471-497.

HAYNES, C. VANCE, JR.

1964 "Fluted Projectile Points: Their Age and Dispersion." *Science 145:* 1408-1413.

1966 "Elephant Hutning in North America." *Scientific American 214* (5): 104-112.

1971 "Time, Environment and Early Man." *Arctic Anthropology* 8 (2): 3-14.

HEBARD, J. F.

1961 "Currents in Southeastern Bering Sea." *International North Pacific Fisheries Commission. BuZZ. 5,* pp. 9-16.

HELM, JUNE

1969 "Remarks on Methodology of Band Composition Analysis." Contributions *to Anthropology: Band Societies.* David Damas (cd.) National Museums of Canada Bulletin 228, Anthropology Series 84: pp 212-217.

HOARE, J. M. and W. H. CONDON

1966 U.S. Geological Survey Misc. Geol. Investigation Map I-469.

1968 U.S. Geological Survey Misc. Geol. Investigation Map I-523.

HOLMES, CHARLES E.

1974 "New Evidence for a Late Pleistocene Culture in Central Alaska: Preliminary Investigations at Dry Creek." Paper presented at the 7th Annual Meeting of the Canadian Archaeological Association at Whitehorse, Yukon during March 1974.

HOPKINS, D. M.

1959 "Cenozoic History of the Bering Land Bridge." Science 129: 1519-1528.

1965 "Quaternary Marine Transgression in Alaska." Anthropogene Period in the Arctic and Subarctic: Nauchno-Issled. Inst. Geol. Asktiki. *Trudy Vol. 143* pp. 131-154. In Russian; translation available from American Geol. Inst.

HOPKINS, D. M. (continued)

1967a "Quarternary Marine Transgressions in Alaska." *The Bering Land Bridge* D. M. Hopkins (cd.) Stanford University Press, Stanford, Calif. pp. 47-90

1967b "Introduction" The *Bering Land Bridge*. D. M. Hopkins, (cd.) Stanford University Press, Stanford, Calif. pp. 1-6.

1967c "The Cenozoic History of Beringia: A Synthesis." *The Bering Land Bridge*. Stanford University, Stanford, Calif. pp. 451-484.

1972 "The Paleogeography and Climatic History of Beringia during Late Cenozoic Time." *Inter-Nord 12:* 121-150.

1973 "Sea Level History in Beringia during the Past 250,000 Years." *Quaternary Research 3:* 520-54 0.

HOPKINS, D. M. and THOMAS EINARSSON

1966 "Pleistocene Glaciation on St. George Island, Pribilof Islands. *Science 152:* 343-345.

HOPKINS, D. M., F. S. MACNEIL and ESTELLA B. LEOPOLD

1960 "The Coastal Plain at Nome, Alaska - A Late Cenozoic Type Section for the Bering Strait Region." *Report 21st* International *Geological Congress* ('Copenhagen) pt. 4, pp. 46-57.

HULTEN, E.

1963 "The Distribution Conditions of the Flora of Beringia." *Pacific Basin Biogeography: Symposia Papers Presented at the 10th Pacific Science Congress at Honolulu*, 1961. J. L. Gressitt (cd.] Bishop Museum Press. Honolulu.

HUMPHREY, ROBERT L.

1966 "The Prehistory of the Utukok River Region Arctic Alaska: Early Fluted Point Tradition with Old World Relationships." *Current Anthropology* 7 (5): 586-588.

HUNKINS, K., A. W. H. BE, N. D. OPDYKE and G. MATHIEW

1971 "The Late Cenozoic History of the Arctic Ocean." *The Late Cenozoic Glacial Ages*. K. K. Turekian (cd.] Yale University Press pp. 213-237.

INGHAM, M. C. and B. A. RUTLAND

1972 "Physical Oceanography of the Eastern Chukchi Sea off Cape Lisburne - Icy Cape." *WEBSEC-70, An Ecological Survey in the Eastern Chukchi Sea, Sept.- Oct. 1970. M. C. Ingham et al (eds.. U.S. Coast Guard Ocean. Rept. #50 CG 373-50.* pp. 1-86.

IRVING, W.N.
1967 "Upper Pleistocene Archeology in Old Crow Flats, Yukon Territory." *Arctic* Circular, *17*(2):18-19.

IRVING, W.N. and C.R. HARINGTON
1973 "Upper Pleistocene Radiocarbon-dated Artifacts from the Northern Yukon." Science, *179*(4071):335-340.

JENNESS, DIAMOND
1929 "Little Diomede Island, Bering Strait." Geographical Review, *19*(1). New York.

JOCHELSON, WALDEMAR
1925 Archeological Investigations in the Aleutian Islands. Carnegie Institution of Washington, Washington, October 1925.

KARLSTROM, T.N.V.
1966 "Quaternary Glacial Records of the N. Pacific Region and World-Wide Climatic Changes." Pleistocene and *Post*-Pleistocene *Climatic* Variations in the Pacific Area: *A* Symposium. D.T. Blumenstock (ed.), Bishop Museum Press, Honolulu.

KIND, N.V.
1967 "Radiocarbon Chronology in Siberia." The Bering *Land* Bridge. D.M. Hopkins (cd.]. Stanford University *Press*, Stanford, California. pp. 172-192.

KLEIN, DAVID R.
1959 *St. Matthew* Island Reindeer Range *Study*. U.S. Fish and Wildlife Service Report No. 43. 48 p.

1968 "The Introduction, Increase and Crash of Reindeer on St. Matthew Island." The Journal of Wildlife Management, *32*(2):350-367.

1973 "Alaska's St. Matthew Island." Soertrykk av POLARBOKEN, pp. 33-52.

KLEIN, R.G.
1973 Ice-Age Hunters of *the Ukraine*. University of Chicago Press, Chicago. 140 pp.

KNEBEL, H.J.
1972 "Holocene Sedimentary Framework of the East-central Bering Sea Continental Shelf." Ph.D. Thesis, University of Washington. 186 pp.

KNEBEL, H.J. and J.S. CRAEGER
1973 "Yukon River: Evidence for Extensive Migration During the Holocene Transgression." Science *179:*1230-1232.

KONISHI, R. and M. SAITO
1974 "The Relationship Between Ice and Weather Conditions in the Eastern Bering Sea." Oceanography of *the* Bering Sea, Proceedings of an International Symposium. D.W. Hood and E.J. Kelly (eds.), Institute of Marine Science, University of Alaska, Fairbanks, Alaska.

KRIEGER, ALEX

1954 A Comment on "Fluted Point Relationships" by John Witthoft. *American Antiquity 19:* 273-275.

KUMMER, J. T. and J.S. CRAEGER

1971 "Marine Geology and Cenozoic History of the Gulf of Anadyr." *Marine Geology Vol.10* pp. 257-280.

KURTEN, B.

1964 "The Evolution of the Polar Bear." *Ursus Maritimus Phipps. Acts Zoologica Fennica* (108):1-30.

LAMB, H. H.

1966 *The Changing Climate.* London, Methuen 236 pp.

1971 "Climates and Circulation Regions Developed Over the Northern Hemisphere During and Since the Last Ice Age." *Paleogr., Paleoclimatal, Paleoecological Vol. 10:* pp125-62.

1974 "Atmospheric Circulation During the Onset and Maximum Development of the Wisconsin/Wurm Ice Age." Marine Geology and *Oceanography of the Arctic Seas.* Yvonne Herman (cd.) Springer-Verlag New York pp. 349-358.

LAMB, H. H. and A. WOODROFFE

1970 "Atmospheric Circulation During the Last Ice Age." *Quaternary Research 1* (1): 29-58.

LARSEN, HELGE

1968 "Trail Creek, Final Report on the Excavation of Two Caves on Seward Peninsula, Alaska" *Acta Arctica Fasc. XV.* Copenhagen.

LAUGHLIN, W. S.

1967 "Human Migration and Permanent Occupation in the Bering Sea Area." *The Bering Land Bridge.* D. M. Hopkins. Stanford University Press, Stanford, Calif. pp. 409-450.

LEE, RICHARD B. and IRVEN DEVORE

1968 "Problems in the Study of Hunters and Gatherers." *Man the Hunter.* R. B. Lee and I. DeVore (eds.) Aldine Publishing Co., Chicago. pp. 3-12.

LEPLEY, L. K.

1962 *Submarine Topography of -the Head of Barrow Canyon*, DeepSea Research (Great Britian) 9:214-217.

LISITSYN, A. P.

1966 *Recent Sediment in the Bering Sea* Israel Program Sci. Translation. Jerusalem. Washington, D. C., U.S. Department of Commerce, National Science Foundation p. 614.

LOEIUE, F.

1971 "Considerations on the Origin of the Quarternary. Ice Sheets of North America." *Arctic Alpine Research 3* (4):331-344.

MACDONALD, GEORGE F.

1968 "Debert, a PaleO-Indian Site in Central Nova Scotia." *Anthropology Papers*. National Museum of Canada. 16

MCCULLOCH , D. S.

1967 "Quaternary Geology Of the Alaskan Shore of Chukchi Sea." The *Bering Land Bridge* D. M. Hopkins (cd.) Stanford University Press, Stanford, California pp. 91-120.

MCCULLOCH , D. and HOPKINS, D. M.

1966 "Evidence for an Early Recent Warm Interval in Northwest Alaska." Geological *Society America Bulletin #77:* pp. 1089-1108.

MCKENNAN, ROBERT A.

1959 "The Upper Tanana Indians." *Yale* University *Publications in Anthropology No. 55* Yale University Press.

1969 "Athapaskan Groupings in Central Alaska." *Contributions to Anthropology: Band Societies.* David Damas (cd.) National Museums of Canada Bulletin 228, Anthropological Series 84: 93-115.

MCMANUS, D. A. and J. S. CRAEGER

1963 "Physical and Sedimentary Environments on a Large Spit-Like Shoal-" *Journal of Geology 71:*498-512.

MCMANUS, D.A., J. C. KELLEY, and J.S. CREAGER

1969 "Continental Shelf Sedimentation in an Arctic Environment." *Geological Society America Bulletin Vol. 80* pp.1961-1984.

MCMANUS, D. A. and C. S. SMYTH

1970 "Turbid Bottom Water on the Continental Shelf of the Northern Bering Sea." *Journal Sedimentary Petrology Vol.* 40 pp. 869-873.

MCMANUS, D. A., KOLLA, VENKATARATHNAM, D. M. HOPKINS, C.H. NELSON

1974 "Yukon River Sediment on the Northern Most Bering Sea Shelf." *Journal Sedimentary Petrology Vol. 44* pp. 1052-1060.

MACNEISH, RICHARD S.

1956 "The Engigstciak Site on the Yukon Arctic Coast." *Anthropological Papers of the University of Alaska* 4 (2): 91-112.

MARTIN, PAUL S.

1973 "The Discovery of America." *Science 179:* 969-974.

MASON, R. J.

1958 "Late Pleistocene Geochronology and the Paleo Indian Penetration into the Lower Michigan Peninsula." *University of Michigan Museum of Anthropology, Anthropological Papers 11.*

1962 "The Paleo-Indian Tradition in Eastern North America. *Current Anthropology 3:* 227-278.

MATTHEWS, J. V., JR.

1968 "A Paleoenvironmental Analysis of Three Late Pleistocene Coleopterous Assemblages from Fairbanks, Alaska" *Quaestiones Entomologicae 4:* 202-224.

1970 "Quaternary Environmental History of Interior Alaska: Pollen Samples from Organic Colluvium and Peats." *Arctic and Alpine Research* 2(4):241-251.

1974a "Wisconsin Environment of Interior Alaska: Pollen and Macrofossil Analysis of a 27 Meter Core from the Isabella Basin (Fairbanks, Alaska)" *Canadian Journal of Earth Science 11* (6): 828-841.

MATTHEWS, J. V., JR.

1974b "Quarternary Environments at Cape Deceit (Seward Peninsula, Alaska)." Geological Society of America Bulletin No. *85*:1353-1384.

MERCER, J.H.

1970 "A Former Ice Sheet in the Arctic Ocean." *Paleogeogr., Paleoclimate, Paleoecol.*, 8"19-27.

MOCHANOV, IU. A.

1973 "Severo-Vostochnaia Aziia v IX-V tysiacheletiiakh do n.e. (Sumnaginskaia kul'tura) (Northeast Asia in the 9th - 5th millenia BC (the Sumnagin culture)." In: *Problemy arkheologii Urala* i *Sibiri*. Izdatel'stvo "Nauka," Moscow. pp 29-43. Translation by K. Arndt.

1975 "Stratigrafiia i absoliut aia khronologiia paleolita Severo-Vostochnoi Azii (PO dannym rabot 1963-1973 gg.) (The stratigraphy and absolute chronology of the Paleolithic of Northeastern Asia (according to data from the work of 1963-1973)}." In: *IAkutiia ee* sosedi v *drevnosti*. Izdanie IAkutskogo filiala SO AN SSSR, Yakutia. pp. 9-30. Translation by K. Arndt.

MOCHANOV, IU.A. and S.A. FEDOSEEVA

1968 "Paleoliticheskaia stoianka Ikhine v IAkutii (The Paleolithic site Ikhine in Yakutia)." *Sovetskaia arkheologiia,* no. 4:244-248. Translation by K. Arndy.

1975 "Periodizatsiia i absoliutnaia khronologiia arkheologicheskikh pamiarnikov IAkutii (The periodization and absolute chronology of the archeological sites of Yakutia) ." In: *Sootnoshenie drevnykh kul'tur Sibiri* s *kul'turami sopredel'nykh terrirorii (Sbornik nauchnykh trudov)*. Novosibirsk. pp. 51-59. Translation by K. Arndt.

MOORE, D.G.

1964 "Acoustic Reflections Reconnaissance of Continental Shelves--Eastern Bering and Chukchi Seas." *Papers* in Marine *Geology,* R.L. Miller (cd.), Shepard Commerative Volume, McMillan, New York. pp. 319-362.

MOSBY, H.

1962 "Water, Salt and Heat Balance of the North Polar Sea and of the Norwegian Sea." Geophysical *Publication, 24*(11):289-313.

MÜLLER-BECK, HANS-JÜRGEN

1966 "Paleohunters in America: Origins and Diffusion." Science, 152(3726):1191-1210.

1967 "Migrations of Hunters on the Land Bridge in the Upper Pleistocene." *In: The Bering* Land Bridge, D.M. Hopkins (cd.), Stanford University Press, Stanford, California. pp. 373-408.

MURDOCK, GEORGE PETER

1968 "The Current Status of the World's Hunting and Gathering Peoples." Man *the Hunter*. R.B. Lee and I. DeVore (eds.) Aldine-Atherton, Chicago.

NATAROV, V.A. and N.P. NOVIKOV

1970 "Oceanographic Conditions in the Southeastern Bering Sea and Certain Features of the Distribution of Halibut." *Soviet Fisheries Investigations in the* Northeastern Pacific, P.A. Moiseev (cd.). Part V, pp 292-303. Translated from the Russian by Israel Project in Scientific Translation, Jerusalem, 1972. U.S. Dept. of Commerce, Washington, D.C.

NELSON, C.H. and D.M. HOPKINS

1969 "Sedimentary Processes and Distribution of Particulate Gold in Northern Bering Sea." U.S. Geological *Survey* Professional Paper, *689*:27.

NELSON, C.H., D.M. **HOPKINS** and D.W. SCHOLL

1974 "Tectonic Silting and Cenozoic Sedimentary History of the Bering Sea." In: Oceanography of the *Bering* Sea, Proceedings of an International *Symposium*. D.W. Hood and E.J. Kelly (eds.), Institute of Marine Science, University of Alaska, Fairbanks, Alaska.

NELSON, N.C.

1937 "Notes *on* Cultural Relations between *Asia* and America." *American Antiquity 4*:267-272.

OLAUSSON

1972a "The Role of the Arctic Ocean during Cool CLimatic Periods." Y. Vasari, H. Hyrarinen and S. Hicks (eds.) *Climatic* Changes in *Arctic Areas during the* Last *Ten-thousand* Years.

1972b "Oceanographic Aspects of the Pleistocene of the Arctic Ocean." *Inter-Nord, 12*:151-171.

PATTON, W.W., JR., M.A. LANPHERE, T.P. MILLER and R.A. SCOTT

1976 "Age and Tectonic Significance of Volcanic Rocks on St. Matthew Island, Bering Sea, Alaska." Journal Research *of the* U.S. Geological *Survey*, 4(1):67-73.

PETERSON, R.T.

1941 Field Guide to Western Birds. Houghton Mifflin, 366 pp.

PETITOT, EMILE

1971 The *Amerindians* of *the Canadian* North-West *in* the 19th Century, as seen *by Emile Petitot. Vol. II:* The *Loucheux* Indians. Northern Science Research Group, Department of Indian Affairs & Northern Development, Ottawa.

PÉWÉ, T.L.

1975 Quaternary Geology of Alaska. U.S. Geological Survey Professional Paper 835.

PÉWÉ, T'. L.

1965 "Resume of the Quarternary Geology of the Middle Tanana River Valley." *In* C.B. Schultz and H.T.U. Smith, (eds.), Guidebook *for Central* and *South Central* Alaska. (Field Conference F). INQUA VIIth Conference, Nebraska Academy of Sciences, Lincoln. pp. 1-64.

Phi, T.L. , D.M. **HOPKINS** and J.L. GIDDINGS

1965 "The Quarternary Geology and Archeology of Alaska." N.H.F.. Wright, Jr. amd D.G. Frey (eds.) , *The Quaternary of* the U.S., Princeton University Press, Princeton.

PLAFKER, **GEORGE**

1967 Geologic Map of the Gulf of Alaska. U.S. Geological Survey Miscellaneous Geological Individual Map 1-484, Scale 1:500,000.

POPOV, A.I.

1959 "Taimyrskii mamont i problems sokhraneniia ostatkov" mamont fauny v chetvertichnukh otlozheniiakh Sibiri (The Taimyr mammoth and the Problem of the Preservation of the Remains of the Mammoth Fauna in Quarternary Deposits of Siberia)." *In: Lednikovvi period na territorii Evropeiskoi chasti* SSSR i *Sibiri*. Isdatel'stvo Moskovskogo Universiteta. Moscow. pp. 259-275. Translation by K. Arndt.

PORTER, S. C.

1964a "Antiquity of Man at Anaktukvuk Pass, Alaska. *American Antiquity, 29:*493-496.

1964b "Late Pleistocene Glacial Chronology of North Central Brooks Range, Alaska. *American Journal* of *Science, 262:*446-460.

1967 "Glaciation of Chagvan Bay Area, Southwestern Alaska. Arctic, *20(4)* :227-246.

POWERS , WILLIAM ROGER

1973 "Paleolithic Man in Northeast Asia. *Arctic Anthropology, 10*(2). University of Wisconsin Press.

POWERS , WILLIAM ROGER, R.D. GUTHRIE and T.D. '**HAMILTON**

1974 "Archeology and Paleoecology of the Dry Creek Site, Central Alaska." Research Proposal submitted to the National Science Foundation.

QUIMBY, G-I.

1958 "Fluted Points and Geochronology of the Lake Michigan Basin." American Antiquity, *23*:247-254.

RATMANOF, G.E.

1937 *Explorations of* the Seas of Russia. Publications of the Hydrological Institute, Leningrad, No. 25, p. 175.

REPENNING, C. A., D.M. HOPKINS and M. RUBIN

1964 "Tundra Rodents in a Late Pleistocene Fauna from the Tofty Placer District, Central Alaska." Arctic, *17: 177-197.*

RITCHIE, J.C. and F.K. HAVE

1971 "Late Quaternary Vegetation and Climate near the Arctic Tree Line of N.W. North America. *Quarternary Research, 1*(3):331-342.

RITCHIE, W.A.

1957 Traces *of* Early Man in the Northeast. New *York* State Museum and Science Service Bulletin 358.

RODEN, G.I.

1967 "On River Discharge into the Northeastern Pacific Ocean and the Bering Sea." *Journal* of Geophysical Research, *72:*5613-5629.

ROWLAND, R.W.

1973 "The Benthis Fauna of the Northern Bering Sea." Ph.D. dissertation, University of California at Davis.

SAINSBURY, C.L.

1967 "Quarternary Geology of Western Seward Peninsula, Alaska." *In:* The Bering *Land* Bridge, D.M. Hopkins, (cd.), Stanford University Press, Stanford, California, pp. 121-143.

SAINSBURY, C.L. and R. KACHADOORIAN, R.H. CAMPBELL AND D.W. SCHOLL

1965 "Marine Platform of Probable Sagamon Age, and Associated Terrace Deposits, Cape Thompson, Northwestern Alaska. Arctic, *18*:230-245.

SAUR, J. F., R.M. LESSER, A.J. CARSOLA, and W.M. CAMERON

1952 "Oceanographic Cruise to the Bering and Chukchi Seas, Summer 1949. Part 3. Physical Observations and Sound Velocity in the Deep Bering Sea." U.S. *Navy* Electronics Lab Report 298, San Diego, California. p. 38.

SAUR, J. F., J.P. TULLY and E.C. LA FOND

1954 "Oceanographic Cruise to the Bering and Chukchi Seas, Summer 1949. Part 4. Physical Oceanographic Studies. U.S. Navy Electronics *Lab Report* 416. p. 31.

SCHEFFER, V.B.

1967 "Marine Mammals and History of Bering Strait." *In:* The Bering Land Bridge, D.M. Hopkins (ed.), Stanford University Press, Stanford, California.

SCHOLL, D.W., E.C. BUFFINGTON, and D.M. HOPKINS

1966 "Exposure of Basement Rock on the Continental Slope of Bering Sea." *Science, 153:*992-994.

1968 "Geologic History of the Continental Margin of North America in the Bering Sea." *Marine* Geology, *6:*297-330.

SELLMAN, P.V.

1967 "Geology of the USA CRREL Permafrost Tunnel, Fairbanks, Alaska." U.S. *Army* CRREL Technical *Report* 299, 22 pp.

SELLMAN, P.V. and J. BROWN

in press "Stratigraphy and Diagenesis of Perennially Frozen Sediments in the Barrow, Alaska Region," Proceedings of the Second International Permafrost Conference, Yakutsk, U.S.S.R. , July 1973.

SHARMA, G.D.

1972 "Graded Sedimentation on Bering Shelf." Proceedings *of* 24th International *Geological* Congress Sec. 8, Montreal, pp. 262-271.

1974a "Contemporary Depositional Environment of the Eastern Bering Sea. *In: Oceanography* of *the Bering* Sea, Proceedings of an international symposium. D.W. Hood and E.J. Kelley (eds.), Institute of Marine Science, University of Alaska, Fairbanks, Alaska. pp. 517-552.

1974b "Geological Oceanography of the Bering Shelf." In: *Arctic Geology and Oceanography,* Yvonne Herman (cd.), Chapter 5. Springer-Verlag, Inc., New York.

SHARMA, G. D., A.S. NAIDU, and D.W. HOOD

1972 "Bristol Bay: A Model Contemporary Graded Shelf." American Association of Petroleum Geologists Bulletin, *56*(1):2000-2012.

SHEPARD, F.P.

1963 Submarine Geology. Harper and Row, New York. 577 pp.

SHEPARD, F.P. and H.R. WANLESS

1971 Our Changing Coastlines. McGraw-Hill, New York, pp. 458-465.

SOERGEL, W.

1922 Die *Jagd der Vorzeit*. G. Fischer, Jena.

SOLECKI, R.S.

1951 "Notes on Two Archeological Discoveries in Alaska, 1950." *American* Antiquity, *17*:55-57.

STEIN, F.

1830 "On the Time of the Appearance of the Aleutian Islands." *Memiors* Mineralogical Society, *1*. St. Petersburg. In Russian.

STOKER, S.W.

1973 "Winter Studies of Under-Ice Benthos on the Continental Shelf of the Northeastern Bering Sea." Unpublished M.A. Thesis, University of Alaska.

THOMPSON, R.W.

1948 "Notes on the Archeology of the Utukok River, Northwestern Alaska." *Americna* Antiquity, *14*:62-65.

TODE, A.

1954 *Mammutjäger* vor *100,000 Jahren*. E. Appelhaus, Braunschweig.

U.S. COAST AND GEODETIC SURVEY

1964 "united States Coast Pilot 9, Alaska Cape Spencer to Beaufort Sea." 7th ed. Washington, D.C., U.S. Government printing Office, 348 pp.

U.S. DEPARTMENT OF COMMERCE

1968 "Climatology of the United States." Environmental Data Service, Nos. 60-49. Washington, D.C.

U.S. NATIONAL OCEAN SURVEY

1964 "United States Coast Pilot 9, Alaska Cape Spencer to Beaufort Sea." 7th cd., Washington, D.C., U.S. Government Printing Office, 348 pp.

1973a "Tide Tables 1974, West Coast of North and South America." U.S. Department of Commerce, Washington, D.C.

1973b "Tidal Current Tables, 1974. Pacific Coast of North America and Asia." U.S. Department of Commerce, Washington, D.C.

U.S. NAVAL **HYDROGRAPHIC OFFICE**

1961 "Climatological and Oceanographic Atlas for Mariners, Vol. II, North Pacific." Washington, D.C.

VANGENHEIM, E.A.

1957 "Novye dannye o chetvertichnoi faune mlekopitaiushchikh iuga Sibirskoi platformy (New data on the Quarternary mammalian fauna of the southern part of the Siberian Platform)." Medvezh. soveshchanie PO razrabotke unfitsirovannykh stratigrafishesykh skhem Sibiri. Trudy . Gostoptehizdat, Leningrad.

1961 "Paleontologicheskoe onosnovanie stratigrafii antropogenovykh otlozhenii severa Vostochnoi Sibiri (The paleontological basis of the stratigraphy of the Anthropogene deposits of northern Eastern Siberia) ." Akademiia nauk SSSR. Geologicheskii institut. Trudy, *vyp.* 48. Moscow. Translation by K. Arndt.

1967 "The Effect of the Bering Land Bridge on the Quarternary Mammalian Faunas of Siberia and North America." In: The Bering Land Bridge, D.M. Hopkins (cd.), Stanford University Press, Stanford, California. pp. 281-287.

VENKATARATHNAM, K.

1969 "Clastic Sediments of the Continental Shelf of the Northern Bering Sea." *U.S.* Geological Survey Open-File Report, p. 93

VIERECK, LESLIE A.

1966 "Plant Succession and Soil Development on Gravel Outwash of the Muldrow Glacier, Alaska." *Ecological* Monographs, *36*(3):181-199.

WATANABE, HITOSHI

1968 "subsistence and Ecology of Northern Food Gatherers with Special Reference to the Ainu." In: *Man* -the Hunter, R.B. Lee and I. DeVore (eds.). Aldine Publishing Co., Chicago.

WEYL

1968 "The Role of the Oceans in Climatic Change: A Theory of Ice Ages." Met. *Mong.,* American *Met.* Sot., *8:*39.

WENDORF, **F.**

1966 "Early Man in the New World: Problems of Migration." American Naturalist, *100*(912):253-270.

WENDORF, F. and JAMES J. HESTER

1962 "Early Man's Utilization of the Great Plains Environment ." American Antiquity, *28:*159-171.

WENIAMINOFF, J.

1840 *Notes On* the Islands of -the *Unalaska* District. Publ. at the expense of the Russian-America Company, in Russian. 3 volumes, St. Petersburg.

WENTWORTH, E.N.

1956 "Dried Meat--Early Man's Travel Ration." Annual **Report** to the Board of Regents, Smithsonian **Institution**, pp. 557-571.

WEST, FREDERICK HADLEIGH

1967 "The Donnelly Ridge Site and the Definition of an Early Core and Blade Complex in Central Alaska." American *Antiquity, 32*(3):360-382.

1974 "The Significance of Typologically Early Site Collections in the Tangle Lakes, Central Alaska: A Preliminary Consideration." In: *International* conference on the *Prehistory* and *Paleoecology* of *Western North American* Arctic and Subarctic. pp 217-238.

WILLETT, H.C.

1950 "The General Circulation at the Last (Würm) Glacial Maximum." *Geog. Annaler., 32*:179-187.

WISEMAN, W.J., JR., J.M. COLEMAN, A. GREGORY, S.A. HSU, A.D. SHORT, J.N. SUHAYDA, C.D. WALTERS, JR. and LD. WRIGHT

1973 "Alaskan Arctic Coastal Processes and Morphology." Louisiana State University, Coastal Studies Institute, Technical Report 149, p. 171.

APPENDIX II

MINIMUM SURVEY REQUIREMENTS TO PROTECT

CULTURAL RESOURCES ON THE ALASKA OCS

modified and adapted from

"MINIMUM SURVEY REQUIREMENTS TO PROTECT CULTURAL RESOURCES", NPS :1976

APPENDIX II

MINIMUM SURVEY REQUIREMENTS TO PROTECT CULTURAL RESOURCES ON THE ALASKA OCS

Several legal instruments bear upon the treatment of cultural resources on the Outer Continental Shelf (OCS). Those directly related to their protection are: The Antiquities Act of 1906, Historic Sites Act of 1935, National Historic Preservation Act of 1966, National Environmental Policy Act of 1969, Executive Order 11593, OCS Act of 1953 and 36 CFR 800. To satisfy these requirements, recent OCS leases include a stipulation concerning archeological and historic resource (cultural resources) surveys. Should such an archeological survey be required in the leased area, or area sought for permit, the following minimum survey requirements are recommended. It is recommended that full surveys shall be conducted on those areas of proposed bottom disturbance identified on the current Bureau of Land Management OCS office cultural resource map as being an area of high probability. If any cultural resource is discovered during the conduct of operations on any lease, these should be reported immediately to the U.S. Geological Survey (USGS) supervisor and every reasonable effort made to preserve and protect such resources from damage until the supervisor has given directions as to its disposition. Prior to drilling or coring operations or the installation of any structure or pipeline, the lessee should be required to conduct a (high resolution) remote sensing survey in the immediate area to determine the possible existence of cultural resources. These cultural resources may be indicated by geophysical anomaly records, historical records or the reconstruction of the total paleo-environmental setting which may be indicative of aboriginal sites. Evaluation and synthesis of data for probability of cultural resource existence should be performed by. persons qualified at least according to the standards for "marine survey archeologist" of the Society of Professional Archeologists. Such data and synthesis should be submitted for review to the **USGS** supervisor and the Manager, Bureau of Land Management OCS office. The following minimum equipment and operating standards (representative of the state of technological development) are recommended and in performing surveys. **As** new survey techniques, are developed, particularly for aboriginal sites, these should be incorporated into the field survey process on an as needed basis.

1. Magnetometer - Total field intensity instruments should be required. Sensors towing height should be less than 6 meters above the bottom wherever possible. Depth of sensor should be determined by sensing device using a single channel recorder. Sensitivity should be a minimum of ± 1 gamma. Noise level should not exceed ± 3 gammas. Interference (single spikes should be less than 5 spikes every 10 minutes. Dual scale continuous recording should **be** utilized with one scale at 100 gammas and the other at 10 or 1000 gammas. It is recommended that chart speed be, at a minimum, 4 inches per minute. The cycle rate should be 1 per second unless another rate is necessary to maintain the required sensitivity. Survey speed should be computed so as to obtain continuous coverage without the existence of magnetic voids between pulses. Cable length should be sufficient to place the sensor outside the survey vessel's gradient and within designated proximity to the bottom. Cable length and length of boat behind antenna should be recorded.

2. Dual Side Scan Sonar - One hundred percent coverage of the sea floor at a range scale width not exceeding 150 meters per side in the

proposed area is needed. Tow height above bottom should provide optimum seafloor detail. Vertical beam-width should be appropriate to the water depth and horizontal beam-width should provide optimum resolution. Tuning should be appropriate to enhance the return from smaller nearby objects and still retain acceptable returns from more distant targets.. Cross talk should be minimized to less than 20 percent comparative shading density on the opposite trace. Record annotation should be performed by the operator including noting the cable length and the presence of boats, buoys, debris, schools of fish, etc., which may appear as bottom features in the record. All anomalies should be cross-annotated with the other equipment being used. Sensor location relative to the navigation antenna should be recorded.

3. Sub-Bottom Profiler and Water Depth Recorder - For shallow penetration, the acoustic source should provide a pulse of an energy level and frequency so as to resolve targets on the order of one to two meters dimension occurring within the upper 15 meters of sediment. Tow speed and pulse timing should be computed so as to provide 100 percent along the survey track. Minimum recorder sizes should be adequate to provide full second or 1/2 second scale. An analog recorder should be used for bathymetry. Sensor location relative to the navigation antenna must be recorded.

Any equipment record containing noise sufficent to mask valid data should be the cause for the USGS supervisor to reject that data.

It is recommended that the use of optional tools and methods such as underwater TV, still or movie cameras, divers or submersibles, be encouraged in high probability areas where direct physical evidence or remote sensing data strongly indicate the presence of cultural resources. Any engineering cores containing Wisconsin or Recent sediments should be made available for the archeologist's inspection. These data should be evaluated for evidence of cultural resources, such as stratigraphic anomalies, charcoal flecks, bone fragments, or other detritus which may be attributable to former human occupation or land use of the survey area.

Navigation for the surveys should utilize a state of the art continuous navigation system with a mimimum accuracy of ± 15 meters within the survey area and shall have a navigation plot sufficient to maintain track spacing and locate anomalies. Positioning points should be shown on all records (A C) and tied in with the same time clock. Point spacing should be at a maximum of 150 meters.

The survey should be run along parallel primary lines spaced 75 meters in protected bays and inlets and 150 meters apart in more open waters with perpendicular tie lines spaced 330 meters apart in all cases. The magnetometer and sub-bottom profiler should be run on all lines. The side scan sonar may only be necessary on alternate primary lines and on all tie lines. The central tie line should be centered on the proposed drill or other operation's site. The grid pattern may be run parallel to bottom contours wherever this would be beneficial due to the existence of high relief bottom conditions. The choice of survey pattern should be explained within the body of the report. The area surveyed should include 125 percent of the area within which physical and/or long-term magnetic disturbance will occur. Physical disturbance should include, but not be limited to, the area within which drilling vessel anchors may be placed but may not include work boat anchors or similar minimal disturbances.

Future prospecting for cultural resources with a magnetometer may be precluded in areas within the OCS where development results in the accumulation of magnetic debris or the installation of cables, pipelines and other such sources of magnetic signals or perturbation of the natural magnetic field. Therefore, areas within such activities will result in a long-term impact should be surveyed. For pipelines and cables, the line spacing should include a line along the proposed center line with offset parallel lines at 75 meter spacing sufficient to enclose an area 125 percent of the area within which physical (barge of boat anchors) and/or long-term magnetic disturbance will occur.

The same grid spacing should apply whether the survey is done in conjunction with a point location or is done for an entire tract. To clear an entire tract, the area of a tract within its boundaries should be surveyed as well as that portion external to the tract but within which physical and/or magnetic disturbances, as defined above, will occur. A marine survey archeologist should not be required to be present on all survey activities. A remote sensing equipment operator must insure that the survey equipment is properly tuned and records are accurate, readable, and properly annotated. Annotation should be made at the beginning and end of lines showing anomalies or magnetic values. Annotation of records should include, at a minimum: (A) course changes, (B) known sources of anomalies, i.e. , well heads, known pipelines, changes in cable length, other boats in areas, sensor tow speeds, including both current and vessel components, should not exceed 6 knots Data gathered in high sea states may be unacceptable due to excessive noise, and (C) anomalies from other instruments. The records should be inspected by the marine survey archeologist along with the remote sensing equipment operator who should advise the marine survey archeologist as to record quality and anomaly occurrences. The marine survey archeologist should have the option to decline review of any or all survey producing data which are technically inadequate to enable a reasonable professional judgement concerning the presence or absence of cultural resources in the survey area. Some examples of inadequacy include, but are not limited to, poor record or data quality, inadequate coverage, improper tuning or sensor development, and unfavorable meteorologic oceanographic or magnetic conditions. The total data should be maintained by the lessee and should be available to Bureau of Land Management and U.S. Geological Survey upon request.

Survey Report

The archeological survey report should include evaluation of appropriate geological, geomorphic, historical, archeological and other environmental factors, in addition to data generated specifically by the field survey. At a minimum the report should include:

1. Description of tract surveyed to include tract number, OCS number, block number, geographic area, e.g., Mobile South No. 1 Area, and water depth.

2. Map (l″ = 2000″, or metric equivalent) of the lease block showing the area surveyed.

Navigation post plot map (l″ = 500′, or metric equivalent) of area surveyed showing track lines and shot points with UTM X and Y coordinates, latitude-longitude reference points, all located anomalies and all indicated paleo-environments possessing a high probability for cultural resource occurance.

3. A bathymetric map (1" = 500'. or metric equivalent) with vessel tract lines, or an overlay showing vessel tract lines. Contour interval shall be appropriate to adequately reflect bottom terrain conditions.

4. Classification of personnel and duties.

5. Survey instrumentation, procedures and logs.

6. Narrative of sea state over length of survey (to include boat size, meteorological conditions! neighboring vessels, and any changes in these).

7. In all cases where an anomaly is encountered, the original of all survey data for the line(s) indicating the anomaly should be submitted.

8. Archeological assessment. This should be a statement signed by the marine survey archeologist assessing the likelihood,? of cultural resources being present. This assessment shall include:

A. Lease history and background.

i. oil and gas or other developmental activity on or adjacent to the lease;

ii. known or suspected shipwrecks or aboriginal sites;

iii. geological and geomorphic setting as related to the identification of cultural resources; and

iv. projected late Pleistocene and Holocene adaptive patterns of human settlement drawn from adjacent land areas.

B. Discussion of method.

i. surveying problems in either method of instrumentation affecting the archeologist's opportunities to assess resources in the area surveyed;

ii. presentation of survey data relevant to identification of cultural resources; assumptions and rationale guiding analysis, i.e., the reasons for considering that certain data indicate either the presence or absence, as the case may be, of cultural sites. Anomalies should be considered to be of cultural significance unless unequivocal contrary evidence is present; and

iii. where additional survey, i.e. , photo, television, diver observation, etc. was, considered necessary, a general narrative summarizing this information shall be included.

C. Conclusions.

i. identification of or statement of potential for cultural resources in the survey area; and

ii. recommendations either for avoidance or for steps to be taken to further identify the nature of electronic or other anomalies.

9. Copies of the cultural resources report should be submitted to the appropriate offices of the U.S. Geological Survey and Outer Continental Shelf Office of the Bureau of Land Management.